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MDAC

Ford IBM RCA

SPACE STATION DATA SYSTEM ANALYSIS/ARCHITECTURE STUDY

Task 4 – System Definition Report

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MCDONNELL DOUGLAS
CORPORATION

SPACE STATION DATA SYSTEM ANALYSIS/ARCHITECTURE STUDY

Task 4 — System Definition Report

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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.

This report was prepared for the National Aeronautics and Space Administration Goddard Space Flight Center under Contract No. NAS5-28082

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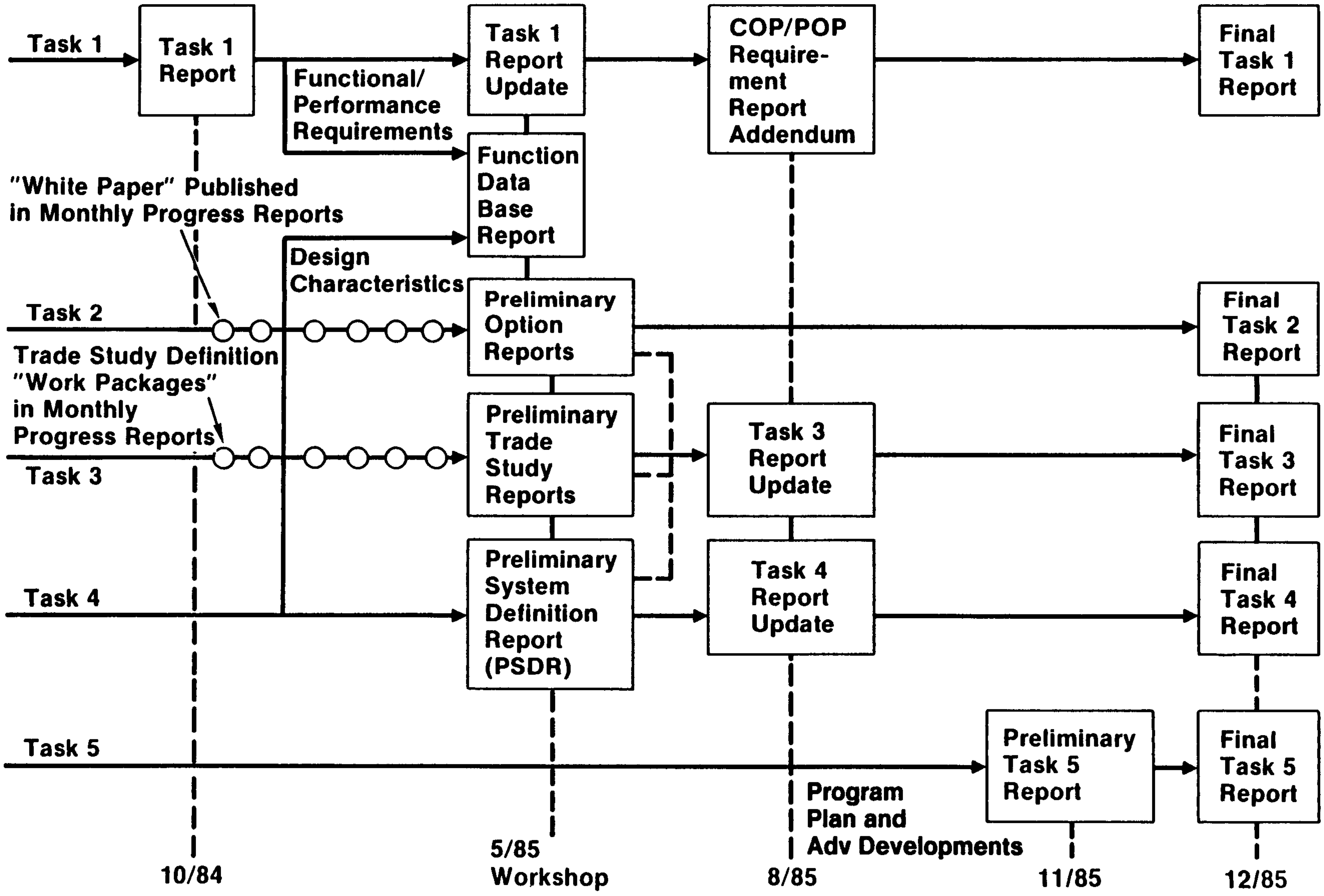
VHG598

SSDS A/A DOCUMENTATION SCHEDULE



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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-0	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 Múlti-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

SSDS SYSTEM DEFINITION REPORT

1.0 INTRODUCTION

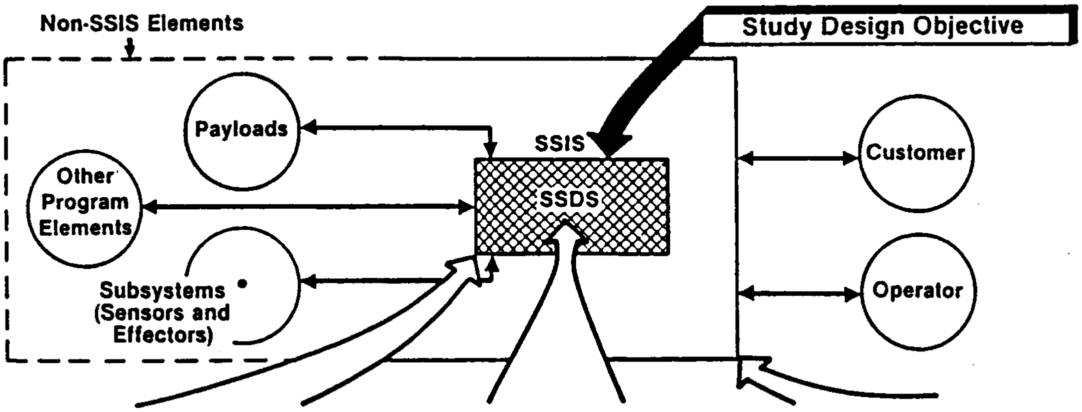
The McDonnell Douglas Astronautics Company has been engaged in a Space Station Data System Analysis/Architecture Study for the National Aeronautics and Space Administration, Goddard Space Flight Center. This study, which emphasizes a system engineering design for a complete, end-to-end system, is divided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

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

An update to the Task 1 report along with the revised appendix and the preliminary reports on tasks 2, 3 and 4, were submitted to NASA on 1 May 1985. As a result of the Review Item Descriptions (RIDs) from the NASA/Industry review of these reports, the SSDS Workshop Presentation and the continuing study efforts at MDAC, certain sections of Task 1 Appendix, Task 3 and Task 4 Reports have been updated and supplemented with additional data. In addition, several new trade studies (Task 3) have been completed. The updates and the newly completed trade studies form the package for this final submittal.

This volume contains updates to the Task 4 (System Definition) Report. The key task 1 products that form the basis for this definition report are summarized in Figure (1-1). A summary of documentation availability is summarized in Figure (1-2).

McDonnell Douglas was assisted in Task 1 by the Ford Aerospace and Communications Corporation, IBM Federal System Division and RCA.



- SSIS to SSDS Interfaces
  - Customer
  - Operator
  - Payloads
  - Subsystems Sensors/ Effectors
  - Institutional Services, Facilities and Functions
- SSDS Functional Requirements
  - Function List (Hierarchial and Data Flow Diagrams)
  - Function Data Sheets
  - Customer Requirements (Standard Services)
  - Supporting Analysis
- Key Performance Requirements
- Traceability Matrices
- End-To-End SSIS Concept
  - Functional Topology
  - Functional Architecture
- Operating Concept
  - Operator Perspective
  - Customer Perspective

Figure 1-1. Summary of Key Task 1 Products

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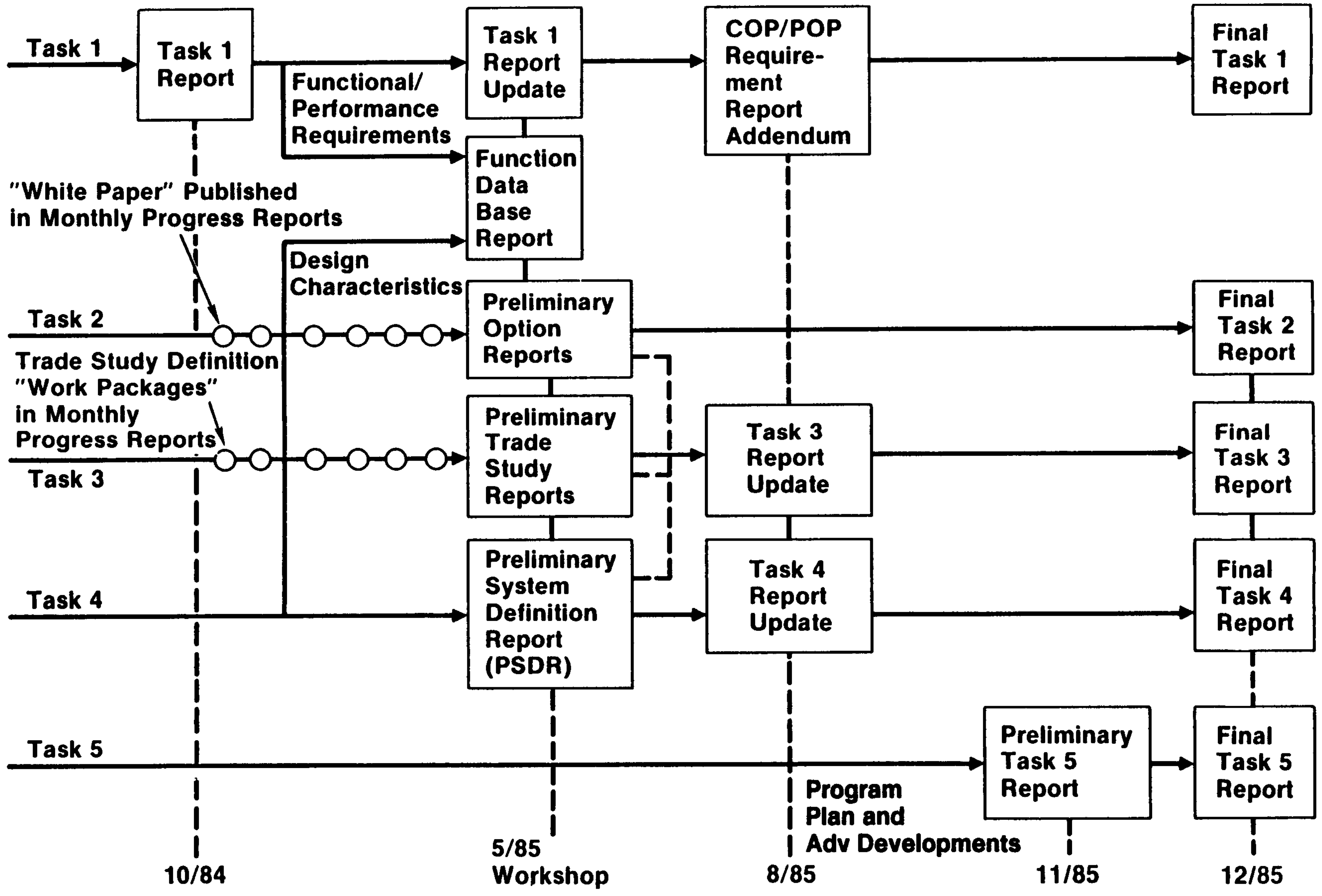


Figure 1-2. Task Documentation

2.0 SYSTEM DEFINITION APPROACH/METHODOLOGY

2.1 Objectives

System definition is the process of analyzing functional/performance requirements and deriving balanced architectural design concepts that can be evaluated in terms of their:

a. Ability to meet requirements,

b. Performance and growth potential,

c. Technical feasibility and risk, and

d. Cost-effectiveness.

This requires a systematic decomposition and refinement of design-to requirements such that a system design can be synthesized from the technology available in the appropriate time frame. This report is the primary product of this system definition process and describes the architectural framework to support the following objectives:

a. Identification of critical long-lead SSDS items.

b. Recommendations for technology development to enhance performance and/or cost-effectiveness.

c. Cost estimation.

d. Establish technical feasibility within performance envelopes and physical/environmental constraints.

e. Quantify those architecture design attributes that will support requirements iteration/refinement leading to a cost-effective balance between requirements and design.

2.2 Relationship To Other Tasks

System definition (Task 4) is the natural extension of requirment definition (Task 1) where design-to requirements and characteristics are derived from a baseline set of functional and performance requirements. This is a step-wise procedure that progressively leads to increased levels of design detail within the context of an evolving architecture. The baseline requirements data base developed by Task 1 is the primary input to this process and is the foundation on which architectural concepts are established. However, it is recognized that this is an iterative process where design attributes serve to measure the feasibility and cost-effectiveness of the requirements baseline. One of the key functions of system definition will be to clearly identify and examine those requirements that are significant cost or schedule drivers. The intent is to strive towards an implementable, cost-effective, acceptable risk design based on a balanced set of requirements.

As shown in figure 2.2-1, system definition is directly supported by options development (Task 2) and trade studies (Task 3). This is a highly integrated relationship with the system definition task providing the basic framework and identifying architectural needs that focus task 2/3 activities. Options development provides the information base for technology, design and programmatic alternatives that are required to support key design/programmatic decisions and/or trade studies. Based on evolving architectural needs and requirements, the options development task is a coarse filter that reduces all possible alternatives to a focused subset most likely to contribute to system definition. The selection of preferred options is accomplished within the system definition process either directly or via trade studies. Those design decisions that have significant architectural or cost implications and/or require detailed analysis and evaluation are subjected to trade studies within Task 3. Trade studies are performed within the context of system definition and provide a highly visible and systematic means of selecting preferred design/technology options. A further description of task 2 and 3 methodologies is included in their respective task reports.

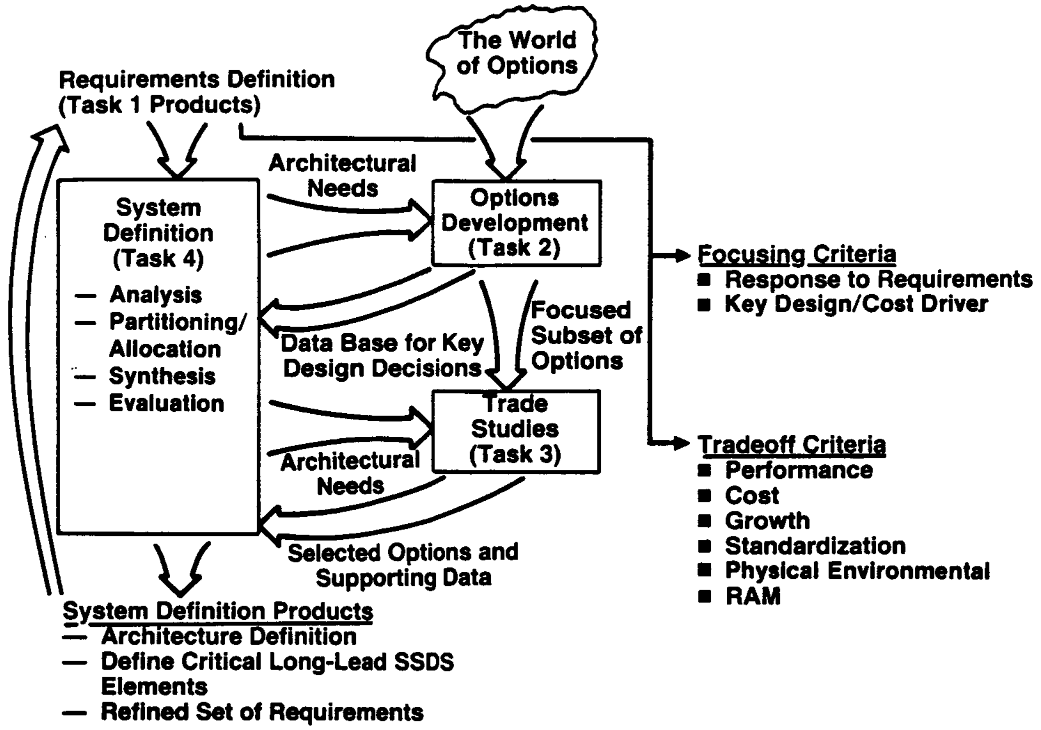


Figure 2.2-1. Supporting System Analysis Overview

2.3 Task Approach

The system definition task approach is illustrated in figure 2.3-1 and can be characterized as systematic and incremental in nature. This process is a controlled step-wise refinement with verification of viability before proceeding to the next step of design detail. Each step is defined as the (1) analyses/trades, (2) partitioning/ allocation, (3) design synthesis, and (4) design evaluation necessary to provide a stable framework for more detailed system definition. The products of each step include topology refinement, functional allocation, nodal characterization, and interconnection characteristics. The specific steps represent a systematic decomposition/refinement of requirements and characteristics and are defined as follows:

a. Space/Ground Allocation

b. Network Architecture

c. Local Area/Node Architecture

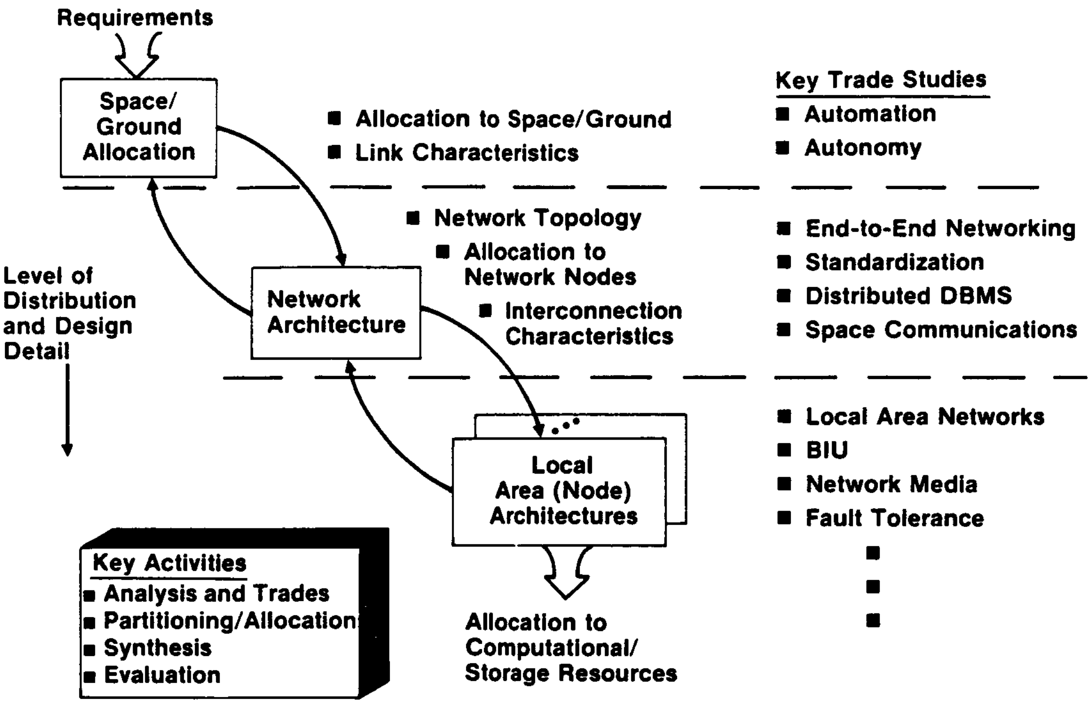


Figure 2.3-1. Incremental Design Approach

While design processes are generally iterative in nature, this approach attempts to constrain such iteration to successive steps thus allowing traceability of design and driving requirements.

The first step is the space/ground segment allocation that is supported by three major trade studies; (1|) space autonomy, (2) function automation, and (3) AI automation. Functions were allocated to space/ground segments based on an assessment of autonomy/ automation goals, cost, risk, and performance benefits. The function automation study identified the degree to which a function should be automated and the AI automation study considered the applicability of AI technology vs. conventional techniques. The product of this step is a preliminary space/ground allocation and the characterization of functions to be automated (either conventional or AI). These results will be re-examined to incorporate Advanced Technology Advisory Committee (ATAC) recommendations.

The second step is the definition of an SSDS Network architecture and is supported by a number of key trade studies. This step includes the definition of system network topology, the allocation of functions to network elements, and the characterization of elements and their interconnecting communication links. While the allocation of functions to logical elements and their assignment to physical locations is relatively straightforward for space elements, a wider range of alternatives is possible for ground elements. The system network topology trade study evaluated these alternatives and developed a "reference configuration" that is described in section 3. This study considered the technical/cost implications of communication data rates, data buffering, and ease of customer use. Alternatives were evaluated using simulation and modeling tools. This definition process resulted in some iteration with the space/ ground allocation step to reflect the additional insight gained from this level of end-to-end definition.

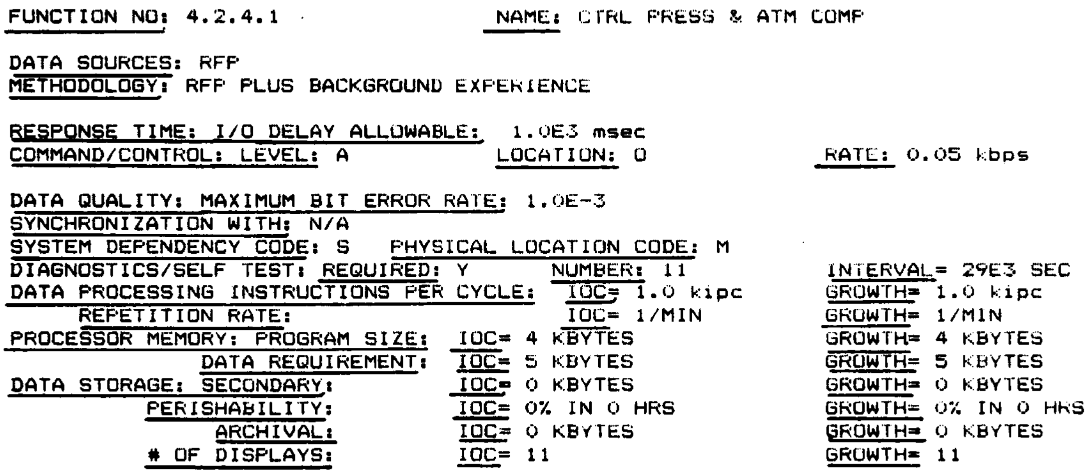
The third and final step is the definition and characterization of the localized architecture of each element defined by the network architecture. This is based on well defined interfaces between an element and other SSDS elements or SSDS external elements. These architectures are described for space elements in section 6 and ground elements in section 7. The level of definition provided varies greatly depending on the criticality and perceived cost implications. For example, the architecture of space elements will require significantly more design definition than some of the ground elements. Ground systems can use more commercial hardware and software products while onboard systems will tend to be more "customized" and will have to deal with additional requirements and physical constraints imposed by the environment.

The following sections describe the key activities performed during system definition.

2.3.1 Requirements Analyses

Requirements analyses are related activities that support the estimation of processing, storage and communication resource requirements within the context of a specific level of architecture definition. This includes the appropriate traffic analyses and the derivation of function design characteristics. These activities are supported by the refinement and expansion of the data flow diagrams initiated by Task 1 and the development of associated data dictionaries. This supporting material is included in Appendices D & E.

A key element of the design process is the transformation of functional and performance requirements into design characteristics that can be used to "size" the system. This generally requires making certain algorithmic assumptions about how a function will be implemented and the level of implied automation. Design characteristics include such essential information as instruction rates, timing, memory, sequencing, enablements, etc.. The set of design characteristics estimated for each function is shown in Figure 2.3-2. These design characteristics have been entered into our automated functions data base and a complete tabulation is included in Appendix G. The process of estimating these design characteristics is based on a number of available models including similar programs (Shuttle, Space Telescope, Spacelab, etc.), and related NASA studies as well as engineering judgements derived from team experience.



```
FUNCTION NO: 4.2.4.1                NAME: CTRL PRESS & ATM COMP

DATA SOURCES: RFP
METHODOLOGY: RFP PLUS BACKGROUND EXPERIENCE

RESPONSE TIME: I/O DELAY ALLOWABLE:  1.0E3 msec
COMMAND/CONTROL: LEVEL: A           LOCATION: O                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 INSTRUCTIONS 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
            # OF DISPLAYS:        IOC= 11                      GROWTH= 11
```

Figure 2.3-2. Design Characteristics Data Base Format

2.3.2 Partitioning/Allocation

Fundamental to the system definition effort is the partitioning and allocation process. This is the process of gradually dividing a complex problem (described by requirements) into logical groupings that can be allocated to physical locations and resources. Again, this is an incremental process consistent with the design approach previously described.

The end result is the allocation of functions and their associated requirements and design characteristics to realizable computational/storage resources. However, this process must consider many factors other than resource utilization that will directly contribute to system performance, cost-effectiveness (life-cycle), risk, maintainability, and growth potential. The primary criteria applied to the various steps of partitioning are identified in Table 2.3-1. The specific rationale applied to partitioning and allocation decisions will be described in subsequent sections of this report.

Table 2.3-1. Functional Partitioning Guidelines

Design Step	Specific Partitioning Criteria	Generic Criteria
1. Space/Ground Architecture	• See Autonomy/Automation Trade Study Criteria	• Autonomous, Stand-Alone Development • Minimize Interface Complexity • Measurable and Testable Interfaces • Time Phasing of Buildup to IOC • Data Base Access and Sharing • Response Time Requirments • Isolate Cooperative/Highly Dependent Functions • Facilitate Growth and Technology Insertion • Sequential Control Structures
2. Network Architecture	• Operational Concepts • NASA Organizational Structure • Institutional Resources	
3. Local Area Architecture	• Functional Criticality (Onboard) • Different Computational Structures • Equivalent Resource Characteristics • HW/SW Commonality • Technical Disciplines • Specialized Capabilities (I/O, AI Machine, FFT, Etc.)	

2.3.3 Design Synthesis

Design synthesis is the formulation of physical design structures that apply hardware resources (processors, storage, interconnections) and software techniques to the implementation of partitioned requirements. The alternative techniques and technologies that are applicable to these design structures were developed and characterized by Task 2 (options development). While partitioning strives to decompose a system into logical groupings, design synthesis tends to "recombine" these groupings within the context of a system design. The adequacy of design concepts (network topology, processor throughput, storage capacity, interconnection bandwidth) tend to constrain the way in which a system is partitioned and/or synthesized. Therefore, this activity must be highly interactive with the partitioning process to result in a design that is realizable as well as cost-effective and growth supporting. In a distributed environment (either geographically or locally), this interaction is extremely important since there are many potential advantages of system networking that can be exploited through proper partitioning. There are also potential disadvantages that must be identified and managed. These advantages/disadvantages will be quantified in subsequent sections of this report.

2.3.4 Design Evaluation

An essential element of system definition is the quantification of key design attributes that measure a system's ability to cost-effectively satisfy requirements. In a well-balanced design approach this includes cost estimation and risk assessment as well as performance measurement and the determination of physical characteristics. These programmatic concerns (cost and risk) are primary criteria for all trade studies and key design decisions. A credible design evaluation for a system as complex as the SSDS can often be greatly enhanced by the proper use of simulation and modeling techniques. Such techniques are only as good as the models employed but they can provide a level of insight that cannot be easily attained through analyses. This is especially true for distributed systems where relatively complex network interactions are important design attributes (buffer sizing, response times, resource utilization, interference effects, etc.) and are difficult to quantify. Due to modeling uncertainties that are prevalent at this stage of program development, such tools and techniques will not provide absolute "answers". Their real value is in providing a "relative" assessment of alternative concepts to support trade studies and key design decisions. Two primary levels of simulation have been developed to support SSDS design evaluation. This includes an end-to-end network simulation using the Data System Dynamic Simulation (DSDS) and several LAN simulations. These modeling capabilities and their assumptions are described in Appendix F.

2.4 Growth Accommodation

This Preliminary System Definition Report provides SSDS design concepts for an IOC space station. However, this should not imply that SSDS growth considerations have been ignored in the process. A primary goal of this study is to develop an IOC system definition that will cost-effectively grow to support anticipated future needs. In fact, the system definition process must include a "Design-To-Growth" (DTG) philosophy. This approach recognizes the basic uncertainties associated with future requirements (core/mission), projected technology capabilities, and the impact of significantly enhanced levels of autonomy/automation that are necessary to develop a credible "optimum" design. It also recognizes the inadequacy of merely relying on such broad concepts as modularity, standardization and extendability.

The DTG approach is based on two key principles: (1) maintain a "growth perspective", and (2) build growth considerations into all aspects of the design process. The "growth perspective" is established through the requirements definition (Task 1) and the options development (Task 2) activities. Requirements and design characteristics have been developed that reflect not only anticipated expansion of mission/core needs but also the transition to high levels of autonomy/automation during growth phases. In addition, a "growth scenario" was developed to establish design goals and objectives. The options development task has identified and characterized those technologies that could significantly influence future growth via technology insertion. This technology profile contributes to an SSDS growth path that is a balance of design extendability and technology infusion. The technology recommendations provided in section 9.0 are intended to enhance the SSDS growth scenario.

Growth considerations are integrated directly into the system definition process including all supporting activities. All trade studies (Task 3) will include growth (extendable design and technology insertion) as a key criteria that will be highly weighted. Trade study recommendations will include growth as well as IOC preferences. The system definition steps previously described in this section will also include the following DTG considerations.

1. Requirements Analysis - The derivation of function design characteristics and traffic analyses will consider the implications of enhanced autonomy/automation and increased mission/core requirements.

2. Partitioning/Allocation - Growth (design extendability and technology insertion) is a key partitioning criteria to be applied at all levels of system decomposition, from top-level architecture to processor/storage allocation. Specifically, this will include the accommodation of advanced automation that is likely to enhance station autonomy.

3. Design Synthesis - All key design decisions will consider the implications of growth. Design concepts will be formulated for a proposed growth scenario.

4. Design Evaluation - Proposed design solutions will be tested against growth scenarios that include technology profile accommodation as well as anticipated design extensions (i.e., added resources to a module, added modules to existing network, etc.).

Particular attention will be focused on ways in which advanced automation (AI technology) can be promoted by the IOC configuration and its growth capability. This will include the infusion of related technologies such as AI machines and knowledge data base storage.

2.5 Design Traceability

The merit of an architectural design can be measured by its ability to satisfy all system, functional and performance requirements in a cost-effective manner. To accomplish this requires that all key design decision can be traced to driving requirements and that all requirements can be clearly allocated to design components. This level of visibility is necessary not only for design evaluation, but also to identify sensitivities for potential requirements/design tradeoffs and to accommodate future requirement updates/modifications. The system definition described in this document includes the identification of driving requirements that directly influence a key design decision. In addition, many such decisions are supported by detailed trade studies and analyses. These trade studies include relevant requirements and derived design characteristics.

The primary means for establishing visible linkages between requirements and the design process is through functional allocation. This is supported by the SSDS Functionally Automated Database System (FADS) that provides the capability to extract functions, requirements, and design characteristics that are currently allocated to an SSDS entity (elements, facilities, modules, subsystems). This includes physical (i.e., module) as well as logical (i.e., subsystem) allocations. FADS will extract information based on functional allocation and generate a "minispec" as summarized in Figure 2.5-1. The current function allocation matrix for the SSDS is included in Appendix H. Summary reports can be generated for all onboard subsystems, for each SS module (or external entity), or for each element (DHC, POCC, RDC, etc.) of the SSDS. The mechanism for establishing functional allocation is extremely flexible and will easily accommodate changes as tradeoffs and design decisions mature. Since allocations may change during build-up and growth phases, this will also support the development of a function transition profile for growth considerations.

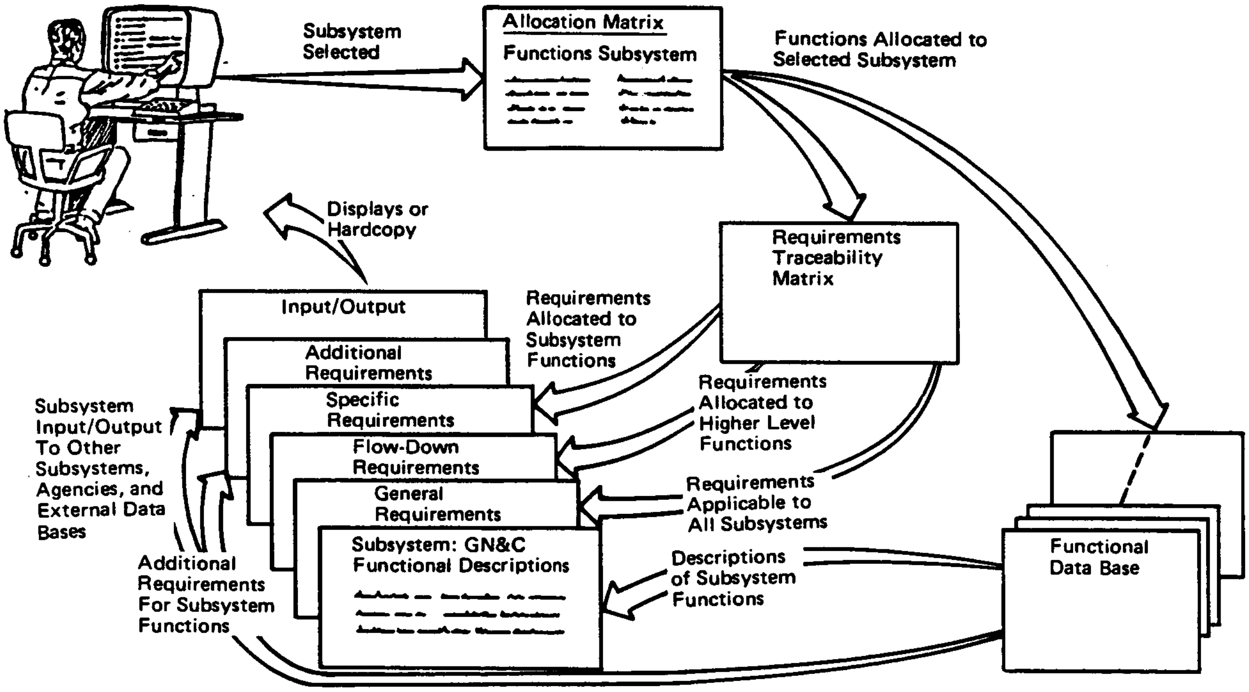


Figure 2.5-1. Automatic Subsystem Minispec Generation

2.6 Supporting Tools & Techniques

This section provides a summary description of key tools and techniques used to support the system definition. Where appropriate, references have been included for further description and/or supporting data.

a. FADS - The FADS is a relational database system that is organized by SSDS function and includes procedures for generating various types of reports. The database includes function descriptions, requirements and design characteristics. This database was initially established by Task 1 (requirements definition) and appended to the data base. Additional capabilities have been added to support the design process (i.e., extraction of information by logical/physical allocations) but have been kept separate to retain the functional integrity (no built-in design implications) of the data base and to facilitate changes in an evolving design process.

b. Data Flow Diagrams (DFD's) - DFD's were initially developed by Task 1 as a logical (nonphysical) model of the SSDS. They specify precisely "what" the system has to do, leaving the designer free to specify "how" it can be done. They also promote communications between requirements developers, the designers and the customers (NASA, etc.). The top-level DFD's developed by Task 1 have been refined and significantly expanded during the requirements analysis phase of system definition. The complete set of current DFD's is contained in Appendix D. Note that DFD elements are numbered to facilitate correlation with the function data base. DFD's provide the graphical model for the connectivity of functions documented by FADS.

c. Data Dictionaries - Data dictionaries provide additional DFD related documentation that make up a comprehensive "picture" of a functional system specification. They provide descriptive information related to data storage and support the formulation of database structures. This capability has been automated within FADS and a complete compilation is included in Appendix E.

d. Simulations/Models - Simulation and modeling tools have been used extensively to support tradeoff analyses and design evaluation. These capabilities are described in Appendix F.

3.0 SSDS TOP-LEVEL ARCHITECTURE OVERVIEW

The SSDS is the combination of hardware and software that provides data management services to Space Station subsystems and customers, both in orbit and on the ground. In general, the data management services provided by the SSDS are those that are needed by multiple subsystems or customers and do not include customer unique services. Typical data management services provided by the SSDS include data transport, data processing, data storage, and man-machine interfaces. Figure 3-1 is a conceptual representation of the SSDS within the wider scope of a Space Station Information System (SSIS), where the SSIS also includes customer- and subsystem-unique data services, sensors and effectors, and institutional (multi-program) services.

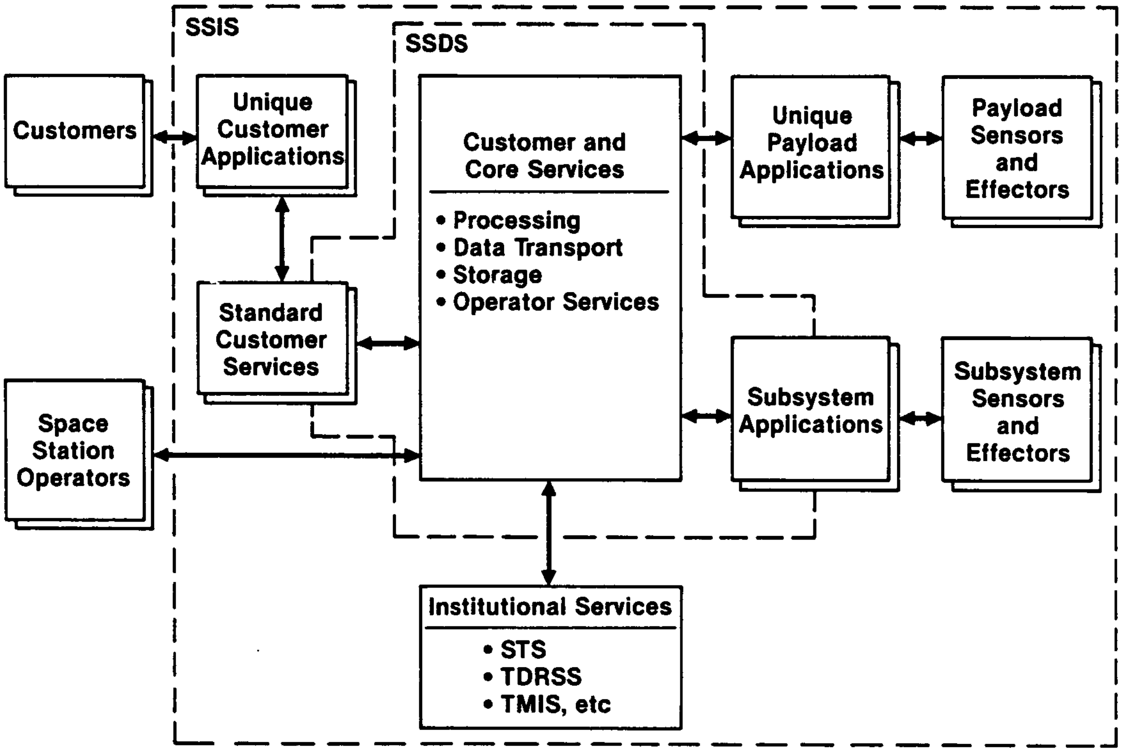


Figure 3-1. SSIS/SSDS Model

This section provides a top-level overview of the SSDS architecture that has been developed in the MDAC/FACC/IBM/RCA study. The architecture is defined in terms of (1) system-level design concepts and assumptions, (2) SSDS external interfaces, (3) identification and characterization of the elements of the SSDS, (4) functional allocation to elements, (5) SSDS topology/connectivity, and (6) an overview of SSDS operational concepts. An overview of key design drivers that have been identified is also included. The onboard and ground segments of the SSDS architecture are defined in considerable detail in sections 6 and 7, respectively. An end-to-end SSDS design perspective is presented in section 4.

3.1 System-Level Design Concepts and Guidelines

During the course of our study we have been guided by NASA's goals and objectives for the Space Station program. We have evaluated these goals and objectives with respect to their meaning to the SSDS and have derived a set of requirements, design concepts and guidelines that are appropriate to ensuring that the objectives are met. These concepts and guidelines have been used to influence the architecture selection and are recommended as design policy statements to be used in future Space Station data system design and development activities. The critical objectives and corresponding concepts/guidelines are described in the following paragraphs.

3.1.1 Autonomy/Automation

The SSDS architecture definition for IOC, as well as evolutionary growth, requires a comprehensive understanding of: (1) NASA goals and objectives for space station autonomy/automation, (2) the technology that can be applied to achieve these goals and objectives, (3) the specific application areas most appropriate for advanced automation, and (4) the implications that these decisions have on SSDS architectural design (Table 3-1 contains NASA-provided terminology related to this discussion).

NASA goals and objectives related to autonomy/automation were assumed to be those expressed in the recent Advanced Technology Advisory Committee (ATAC) reports. The stated goal is to "create and use a new generation of machine intelligence, robotics and automation" to maximize space station functional capability and to promote technology for potential terrestrial applications. Since advanced automation concepts are not well understood today (although

Table 3-1

AUTONOMY: The ability to function as an independent unit or element, over an extended period of time, performing a variety of actions necessary to achieve pre-designated objectives, while responding to stimuli produced by integrally-contained sensors.

AUTOMATION: The ability to carry out a pre-designated function or series of actions, after being initiated by an external stimulus, without the necessity of further human intervention.

ROBOTICS: The technology by which machines perform all aspects of an action, including sensing, analysis, planning, direction/control, and effecting/manipulation, with human supervision.

ARTIFICIAL INTELLIGENCE: A discipline which attempts to simulate or duplicate the efficient problem-solving capabilities of humans.

substantial progress is being made), the IOC capability should "be designed to capture as many advanced concepts that are necessary and available today while allowing for the hardware scars and the software hooks that will be needed to accept the developing technology". The report also identified specific objectives that included the extensive use of expert systems for all onboard subsystems. The goals and objectives for autonomy/automation will significantly influence the onboard SSDS architecture in the following key areas:

a. Partitioning/allocation of SSDS functions to promote NASA's IOC autonomy/automation goals.

b. Architecture to accommodate evolutionary growth.

c. Adequate onboard resources (processing, storage) to support advanced automation for IOC.

The final ATAC technical reports were not available in time to comprehensively factor into this document and the system definition presented here is based on internal trade studies. However, the influencing factors identified above have been addressed in the system definition process. The key difference is that onboard subsystem resources were "sized" based on conventional automation algorithms rather than ATAC recommended expert system implementation. These algorithmic characteristics are certainly better understood and more available. Sufficient resource margin has been provided in the conceptual design but the adequacy of these resources for broad application of expert systems, as recommended by the ATAC reports, will be investigated in future study activities.

Recognizing the influence that autonomy/automation concepts must have on the design process, several key trade studies were initiated early in the SSDS architecture study. These highly interrelated studies (illustrated in Figure 3-2) result in the following.

a. Function Automation – Determine degree of automation appropriate for all SSDS functions (IOC and growth).

b. Space Autonomy – Allocation of SSDS functions to space and/or ground (IOC and growth).

c. AI Automation – Given that a function is to be automated, determine if AI or conventional techniques should be applied (IOC and growth).

These trade studies are highly interactive and form the basis for many key design decisions. The preliminary results of these studies are provided in the Task 3 report. The degree of automation and the application of AI/conventional techniques are manifest in the function design characteristics. The allocation of functions to space/ground elements provides the basis for further partitioning/allocation.

The AI automation study focused primarily on the application of expert systems and did not address other areas such as robotics, etc. Expert system approaches were weighed against conventional approaches for the SSP in terms of cost, risk and required resources. It did not address the more global

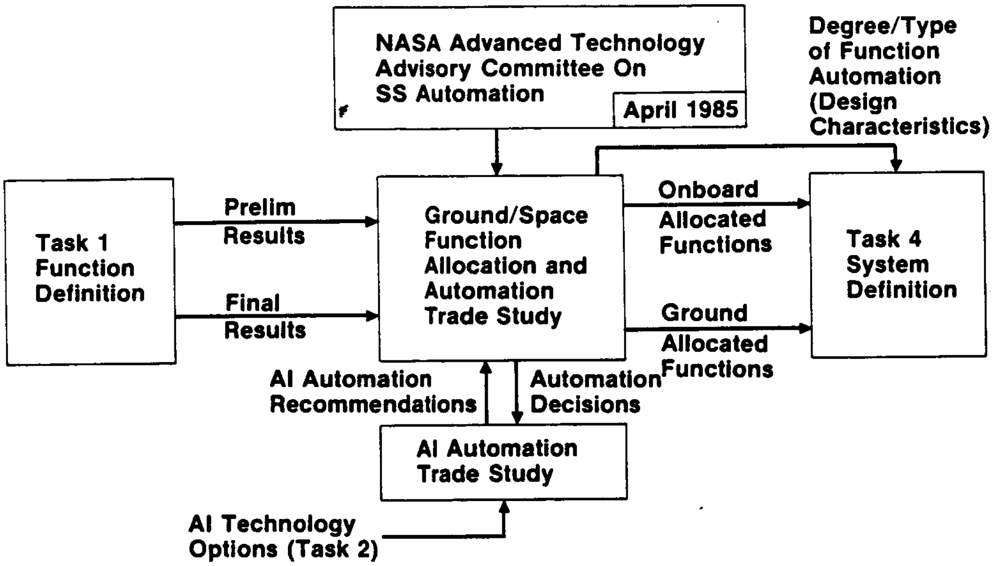


Figure 3-2. Autonomy/Automation Trade Study Interaction

goals of the ATAC associated with the development of a technology base for "terrestrial applications". The preliminary results of the trade study recommended functions as candidates for IOC and growth advanced automation. Some of these functions are in addition to those identified by ATAC and are of considerable magnitude and complexity (planning/scheduling). However, while technically challenging, their implementation would advance the general state-of-the-art for expert systems and potentially result in significant cost savings. We have focused on the planning/scheduling function because of the very large potential payoff in operational man-hour savings.

Subsystem autonomy onboard the Space Station is enabled and promoted by several features of the proposed onboard SSDS architecture including the following: (1) standard data processors (SDP's) that can be dedicated to subsystem application processing, (2) SDP operating systems that provide a set of easy-to-use and easy-to-understand services for subsystem applications software, (3) a primary data network (bus, NIU, NOS) that provides subsystems with a predictable, responsive, high-capacity data transport service, and (4) a set of DMS user support services such as data base maintenance and access, man-machine interface, caution and warning, and time management and reference signal distribution.

In summary, our preliminary architecture incorporates a high degree of space and subsystem autonomy, includes selected advanced automation features for IOC, and provides for the growth of automation throughout the Space Station lifetime. Additional study will assess the increased use of AI automation in the IOC system.

3.1.2 Standardization/Commonality

Standardization and commonality are consistently promoted as attributes that will help the Space Station program achieve its cost and productivity goals. The following definitions for these terms have been developed to guide our study.

> Standardization is the process of developing a uniform hardware, software, interface, or procedural approach and enforcing its use across a set of similar applications.
>
> Commonality is the property that two or more applications or systems have when they incorporate identical sub-elements (hardware or software units).

Standardization of hardware and software elements enables commonality between subsystems and systems. Commonality can be an important factor in controlling development costs in a large program by reducing or eliminating parallel development of similar items. Commonality can reduce operational costs by reducing the training and spare parts costs. Commonality can also improve system reliability and availability by allowing non-critical applications to serve as backup to critical units.

Standardization has additional benefits, including improved user familiarity, and more efficient and effective integration of new payloads and subsystems. The key to achieving these benefits is the selection of appropriate data communications standards. These standards define how a user will interface with the SSDS to take advantage of the SSDS services.

Data system communications standards are applicable in three major areas in the end-to-end architecture:

- Flight segment local area networks
- TDRSS uplink/downlink
- Terrestrial local area and wide area networks

Needs for customer/user transparency, efficient high speed protocol translation, and eventual migration of ground functions to the flight segment, dictate that these standards and related conventions be as compatible as possible across all three sets of network components. The proposed approach to achieving this is in an end-to-end architecture that is described in Section 4. The ISO/OSI reference model is utilized in this description.

The primary set of standards likely to be of use for lower-level ISO layer flight segment LAN standards are (1) the IEEE 802 family of protocols which include multiple physical link protocols united by a common logical link control protocol (IEEE 802.2) and (2) the emerging 100 Mbps ANSI X3T9.5 fiber optic physical and data link protocols. Although the collision sense and token ring protocols associated with IEEE 802 may not be appropriate under the constraints of bandwidth requirements for the SSDS, the use of the medium access and logical link control protocols are appropriate.

The TDRSS and direct user links essentially should be viewed as noisy links between the onboard and ground ISO/OSI networks. The selection of standards for these links is driven by the limitations of the underlying physical links. It is recommended that the current CCSDS standards be used for these links with the choices of the many various options supported within the CCSDS, and that uplink/downlink protocol conversion be supported as outlined in Section 4. The telemetry/telecommand standards should be adopted as SSDS standards. While customers may format the internal content of their data in any way they wish, the basic structures of the telemetry formats should be adhered to and the SSDS must certify that the payloads are in fact formatting the data properly. The SSDS may consider providing source code to do the formatting of the customer data. Core data should adhere to additional internal format standards for identification of measurement data as described in Section 7.

The need for a symmetric uplink/downlink capability is particularly important. This implies:

- providing all services (such as verified vs unverified delivery) in both directions

- using the same packet/frame format in each direction (currently the formats are different for the uplink/downlink)

- implementing an addressing scheme that can be used for either space or ground

In addition, the possibility of augmenting these telemetry/telecommand standards should be examined so that the following are customer selectable options:

- quality of transport service (bit error rate)
- delivery service (immediate delivery vs store & forward delivery)
- reliability services (verified vs unverified delivery)

The ground segment LAN's are likely to be significantly less uniform than the flight segment LAN's. The IEEE 802 family seems to provide the most straightforward set of solutions, since they provide a broad set of physical link layer solutions, and have been implemented on most major vendors' processors. Additional physical layer protocols (e.g., fiber optics protocols) can be provided for enhanced bandwidth, but maintaining the same data link layer protocols.

A leading candidate for a SSDS wide area standard for "low speed" data is the X.25 packet standard. Current commercial implementations of X.25 provide service at rates up to 56 kilobits per second. Although higher data rates are feasible, the bandwidth of X.25 is constrained by feasible switching rates, buffering requirements, and handshaking procedures. It is unlikely that rates over a megabit per second can be supported within the forseeable future. In addition, portions of the network (e.g., White Sands to Regional Data Center) may only require relatively static routing capabilities (permanent real or virtual circuit standards). For higher speed data, circuit switching standards or connectionless ("datagram") standards may be most appropriate. Another feasible alternative is to define multiple classes of X.25 services, removing elements of the X.25 protocol (e.g., dynamic routing or acknowledgement services) in order to achieve satisfactory performance for various data rates. The high rate experiments may or may not be sent in the form of telemetry packets and wide area standards for this data may be limited to transport standards.

For the ground segment it thus appears feasible to adopt an evolutionary approach to selection of standards, expanding the quality of services as packet switching technology improves. A distinction between high and low data rate services that is technology-dependent could be adopted; high data rates would simply be defined as those for which standard X.25 services could not be provided with off-the-shelf switching equipment. High data rate users would be limited to non-dynamic services although they would have access to low rate command and data transfer channels which would provide fully transparent packet network support. As switching technology improves (or as new high performance packet standards are introduced) further capabilities for high rate services could be introduced with the net effect of removing the distinctions between high rate and low rate services and standards.

The standards selected for direct interface to customers should be in conformance with the ISO/OSI model and should use commercially available standards if possible. Thus if NASA specific standards are used within the data distribution networks, the SSDS should support protocol conversion to commercial standards before delivery of data to customers.

These data communications standards are necessary in the Space Station program so that the user can effectively plan, develop, integrate, and utilize their Space Station experiment or application. A continuing, focused effort is needed to further define, publicize, explain, update, and maintain these standards.

There are several promising areas for commonality that have been identified, including data processing hardware, operating systems, programming language, user command and control language, and work station hardware. While it is recognized that growth versions of the SSP will certainly have to accommodate heterogenous data system elements, it is concluded that the IOC and growth planning for a large degree of standardization/commonality should be followed. This is particularly true for the SSP Subsystems. Rigid justification procedures for any waivers should be established. At this point in the development it is not likely that the "off-the-shelf" excuse can be made palatable. The need for subsystem development and testing independence will still allow the enforceability of standards/commonality especially at levels such as accepted data bus standards and processor Standard Instruction of Architectures (ISA's). Further discussion on selection and application of standards/commonality is included in Section 6 and 7. The results of applicable trade studies are in the Task 3 report.

3.1.3 Security/Privacy

Security and privacy are defined as follows:

> Security is the protection of SSDS resources, data, and information 1) from damage, 2) from disclosure to unauthorized individuals, and 3) against unauthorized modification.
>
> Privacy is the limitation of access to data or information to some level, short of a complete guarantee as implied by the term security.

A key design driver with respect to security/privacy implementation is an assessment of both the threats to security/privacy and the relative value of data, or loss if its privacy is violated.

The threat assessment involves evaluation of the likelihood of various types of security/privacy violation at each node and for each data type within the SSDS network. The threat categories include potential physical damage as well as logical penetration of implemented safeguards.

The value assessment is the association of a value to each type of data and information, or equivalent, and a loss value for breach of security/privacy for each data or information type. This assessment highlights those SSDS areas most in need of protection, thereby most impacting SSDS design features. The differing value of customer data suggests that differing levels of privacy protection will be implemented within the SSDS depending on data type and customer.

Detailed threat and data value assessments have not been performed. A NASA threat assessment is being performed under contract to Kennedy Space Center (KSC) and will be available in preliminary form for the Phase B contractors by the end of calendar year 1985. As the KSC threat assessment matures, and as the customer base solidifies and their data privacy requirements become known, possible security/privacy impacts on the SSDS design will need to be reassessed.

The following key policy statements define the basic framework for the security/privacy impacts on the present SSDS system design. Key policy issues are presented subsequently.

1. Different nodes and communication paths will require different levels of security/privacy. Protection of the Space Station base and platforms is accorded the highest priority with respect to secure commanding and operations, i.e., the highest levels of SSDS security required are for onboard resource control and operations authorizations. The ultimate control for onboard decisions is presumed to rest with the crew, with ground takeover possible if the crew become incapacitated.

2. The SSDS will assure privacy of data, audio, and video links, but not ultimate security of customer information.

3. The user is responsible for higher levels of information content protection. Encryption is one technique available to the user. The SSDS will facilitate user implementation of encryption by providing standard interfaces for encryption equipment.

4. No military security requirements are incorporated into the baseline design.

5. The key constraints which limit the amount of privacy/security provided as a standard service are life-cycle cost impacts, cost versus benefit of

protection by customer and data class, and potential system performance degradation.

6. International security/privacy requirements have been assumed to be contained within the spectrum of U.S. commercial and other user requirements.

Key Policy Issues

1. The role and extent of National Security Agency (NSA) versus NASA responsibility for communications system security needs to be determined.

2. The levels of personnel and physical security at each SSDS node needs to be established.

3. If NSA Trusted Computer System evaluated subsystems are required for the SSDS, the available computer system options will be significantly reduced.

4. NASA, NSA, ESA, etc., interagency coordination needs to be established in the area of security/privacy implementation.

5. The extent of NASA cooperation with NSA with respect to encryption chip technology utilization and dependence needs to be determined.

6. Upgradeability for possible future military requirements needs to be considered in the SSDS design.

3.1.4 Evolutionary Growth

One of the key requirements imposed on the SSDS is to provide sufficient growth capability to support the future needs of the program in a cost-effective manner. This includes growth in functional capability, available internal resources, and the ability to handle increased external interface demands. While applicable to both ground and space elements, the primary focus is on the more constrained environment of space where improvements and new capabilities may be accommodated by modification/replacement of existing modules or the addition of new ones. In any case, it must be recognized that future data system needs over the expected life-time of the space station cannot be accurately forecast and it will be difficult to determine "how much" growth potential is adequate. Therefore, SSDS architectural concepts need to consider multiple mechanisms for accommodating growth. The key growth objectives for the SSDS may be summarized as follows:

1. The SSDS should facilitate growth in data service requirements throughout the life of the Space Station.

2. The SSDS should facilitate the insertion of new technology.

3. The SSDS should support the evolution to higher levels of autonomy and automation.

The system developer's viewpoint of the space station evolutionary process is that phased development, new customers and improvement needs will result in data system requirements for more increased functional capability and/or resources. This section describes the concepts for extending the SSDS capability to meet these requirements. An alternative viewpoint from the customer perspective, however, is that "growth" can be measured in terms of increased information derived from mission data. This can, of course, have the same effect as the traditional viewpoint if the result is increased data rates requiring additional SSDS functional/resource capabilities. The "information content" of the mission data handled by the SSDS could also be improved through additional onboard payload data processing and/or data compression without necessarily increasing data rates. This could be particularly beneficial if applied to the high data rate missions. It is not likely that such payload unique functions would be included in the SSDS; however, they must be considered in a well-balanced, evolutionary process as a viable alternative to SSDS expansion.

The SSDS architecture concepts that we recommend to enhance growth capability are the following.

1. Partition systems, subsystems, and modules for maximum functional autonomy at each level. The critical partitioning task determines the degree of autonomy of each functional module, and hence, the ease by which it can be replaced or expanded for growth reasons without inter-related impacts on other elements.

2. A hierarchial organization of processing elements. This approach supports both vertical and horizontal expansion and allows functional autonomy.

3. Selection and enforcement of widely-accepted standards for interfaces, communication protocols, languages, etc. The standards that are selected must have widespread support and staying power in the commercial and/or DOD areas.

4. Extensive "hooks and handles" in the IOC hardware and software. Machine-readable test-points, status monitors, environmental monitors, and unit identifiers are examples of these "hooks and handles" that are needed to allow growth in automation. Machine-capable controls should be considered for all IOC manual control functions for the same reason.

5. Design features to promote increased information content of the data. For example, allowance for special purpose data processors, image data compression hardware and software, and robust general-purpose processing capability. (Programmatic features such as a user charge policy that provides a strong incentive for users to maximize the information content of their data should also be considered.)

6. Large capacity margins in the IOC SSDS backbone data networks. We recommend that the capacity of the IOC core data network and customer data network each exceed the expected IOC load by a factor of at least 150%

These concepts have been incorporated in the onboard SSDS architecture and, perhaps to a lesser extent, in the ground SSDS architecture since it does not have the same weight, power, volume, and accessibility constraints. The ground segment, however, must be uniquely responsive to increasing automation, to increasing autonomy of the space segment, and to changes in the communications infrastructure. Program operating costs associated with ground staffing will continue to be a concern. The ground segment must accommodate this drive toward lower staffing by supporting increased space autonomy and increased automation of ground functions. The concepts of modularity and use of widely-accepted standards are equally applicable to ground and space.

The ground segment will also need to adapt to changes in communications capabilities, such as TDRSS evolution or TDAS in the NASA world, and the rapidly changing commercial communication environment. Examples of the latter are more and new kinds of commercial communications satellite service, expanding commercial fiber optic networks, growing commercial digital services, and new standards such as Integrated Services Digital Network (ISDN). The ground segment needs to be capable of supporting Space Station data distribution in a way that allows the program to take advantage of the performance and cost benefits of these new commercial services.
The development of TDAS or a TDAS-like capability that allows direct broadcast of Space Station data to several regional sites will allow the ground SSDS data capture, sorting, and routing functions to be re-allocated. First-level sorting and routing would be moved from the Data Handling Center to the space segment. Data capture and the next level of sorting and routing would be distributed to the Level Zero Processing Centers. The IOC ground SSDS architecture allows this kind of function re-allocation and relocation.

3.1.5 Transparency. The SSDS should have the property that it appears to be "transparent" to a user; that is, the user should be able to communicate with his payload or subsystem via the SSDS such that the SSDS has minimal affect on the customer to payload interfaces. For example, when a customer connects his work station to his payload at his facility, the operation should be functionally identical to the on-orbit phase when the customer, at a work station at his facility, is interacting with his payload on orbit. Some implications of this objective on the SSDS are as follows:

- The SSDS should transport customer-generated commands and data to the payload with no format changes and with minimal delays and constraints. Any artifacts added by the data transport service must be removed prior to delivery to the payload.

- The SSDS should transport data packets or messages from the payload to the customer with no format changes and with minimal delays. Artifacts that are added by the data transport service, such as error correction coding, bit reversal, or packet sequence re-ordering, must be removed by the SSDS prior to delivery to the customer.

Several SSDS design concepts are suggested to promote the "transparency" of the system. These concepts include the following:

1. The use of packet formats with self-contained, autonomous packets created by the source (customer or payload).

2. The use of standard interface formats and protocols.

3. Minimization of command checking by the selection of a command management approach that allows most commands to pass through unchecked and applies the constraint/restriction checks to a small, pre-defined set of commands that have mode (resource) change requirements or hazard/safety potential.

4. Excluding from SSDS the need to merge payload data with data from other sources prior to delivery to the customer. This is possible if the external data is made available to the customer in a form and at a time that permits him to do the merging expeditiously (either onboard or on the ground).

5. The use of first-in, first-out or random access communication buffers to avoid data reversal.

6. Robust communication links to avoid or minimize delays due to bandwidth limits or link unavailability.

7. Real-time foward error correction coders and decoders to provide essentially error-free data communication.

8. A network operating system (NOS) for the onboard and ground LAN's and a wide-area network manager that provides a range of network services for the user in an invisible manner to the user. The network services include session control, network resource management, routing, synchronization, flow control, and error control. Section 4 describes the implementation of these services.

3.1.6 Telescience. Telescience is the capability for scientist/investigators to (1) control and monitor their space instrumentation from their institution and (2) to have access to data (bases) in many locations for analysis at their home institution. This concept involves near real time operability, transparency, data delivery and data base access across many differing logical interfaces. The system definition of Section 6.0 and Section 7.0 accommodates the Telescience concept as detailed in Section 4.0.

3.2 SSDS External Interfaces

This section describes the functional relationship between the SSDS and the key external elements that have direct interfaces with the SSDS. The concept of SSDS standard services is discussed and the primary SSDS standard services are described. A summary of the partitioning criteria that were used to do the interface functional partitioning is included.

3.2.1 Identification of Interfaces. Figure 3-1 showed that the SSDS has external interfaces with customers, payloads, subsystem sensors and effectors, space station operators, and institutional services. These interface categories are expanded in Table 3.2-1.

3.2.2 Functional Partitioning Guidelines. For the external interfaces, the functional partitioning is driven by the needs and constraints of the external element for the case where that element is external to the Space Station program. For instance, the SSDS must, for the most part, adapt to the existing capabilities, interfaces, and operational procedures for its

Table 3.2-1 SSDS External Interfaces

- Customers
    - Customers at customer facilities
    - Customers at POCC's
    - Customers at RDC's
    - Customers onboard the Space Station

- Payloads
    - On the Space Station
    - On the POP
    - On the COP

- Subsystem Sensors and Effectors
    - On the Space Station
    - On the POP
    - On the COP

- Space Station Operators
    - Onboard crew
    - At the SSOCC, POPOCC, or COPOCC

- Institutional Services, Facilities, and Functions
    - NSTS
    - NSTS Mission Control Center
    - TDRSS
    - Network Control Center
    - GPS
    - TMIS
    - NORAD

---

interfaces with institutional services such as TDRSS, GPS, and the NSTS. Customer and payload interfaces must be adaptable to a wide-range of needs, capabilities, and operational procedures. Space station operator interfaces are driven by productivity, flexibility, training, safety, and system security considerations. The subsystem sensor and effector interface is defined so that all data services that support sensors and effectors that are generally considered to be "general-purpose" data processing have been allocated to the SSDS and "special-purpose" processing or signal processing functions are allocated to the sensors and effectors side of the interface. This last guideline (for sensors and effectors) should not be taken as a recommended guideline for Space Station subsystem partitioning but is intended to provide a broadly-scoped definition of the SSDS. Table 3.2-2 summarizes these key partitioning considerations.

3.2.3 SSDS Standard Services. The SSDS provides a set of standard services for users (customers, operators, payloads, subsystems). The functional interface definition is based on the existence of these standard services. It must be recognized that, in general, the use of standard services by a Space Station customer is optional. The customer may select from the set of standard services, using the ones that meet his needs and providing alternative capabilities when he judges it necessary to achieve his objectives. In some instances, payloads will be required to use particular standard services to insure that the overall Space Station integrity can be maintained. For instance, a payload having a potentially hazardous command sequence will have its commands screened by the SSDS command processing service so that risk to Space Station systems and crew are minimized.

Table 3.2-3 provides a summary of SSDS standard services. The generic functional interfaces described in the next section assume maximum use of these services by SSDS users.

3.2.4 Functional SSDS External Interfaces. Figures 3-3 through 3-7 describe the major features of the functional interfaces between the SSDS and the major external element categories. The description identifies the key high-level functions assigned at each side of the interface and the types of data that must flow across the interface to support that functional

Table 3.2-2 Partitioning Guidelines for
SSDS External Interfaces

SSDS Interface Category	Functional Partitioning Considerations
• Customers and Payloads	• Customer/payload operational needs • Customer/payload data rates, quantities, types • Customer development and integration needs • Customer physical location • Degree of Transparency • Overall cost to SSP and customers
• Space Station Operators	• Operator productivity • Operator training and skill level • System safety and security • Overall cost to SSP
• Subsystem Sensors and Effectors	• Uniqueness or generality of data service needed • Overall cost to SSP
• Institutional Services and Facilities	• Established systems and procedures • Overall cost to NASA

allocation. Appendix C contains an expanded description of the functional SSDS external interfaces.

3.3 SSDS Element Identification and Characterization

The SSDS resides in a more global entity called the Space Station Information System (SSIS) which includes all of the end-to-end data services for Space Station customers and subsystems. To define the basic elements of the SSDS, we began with the basic set of Space Station Program Elements (SSPE's) identified by NASA, including the core manned station, co-orbiting platforms,

Table 3.2-3 SSDS Standard Services

Data Handling

- Capture raw data and process to level 0 (routine).
- Provide a quick-look capability for level 0 data.
- Process customer data to level 1A (customer option.)
- Provide data analysis utilities.
- Provide data processing hardware and operating systems to support subsystem applications.
- Provide short-term (customer delivery plans one week) archiving of level 0 and SSDS-produced level 1A customer data.
- Provide a two-year archive of engineering/ancillary data.
- Provide catalog, catalog query, inventory, and retrieval services for all archived data.
- Provide on-line storage for customer data for 12 hours.

Ancillary Data

- Collect, format, and process ancillary data (Space Station engineering and operations data).
- Provide on-board time management and time reference distribution.
- Provide electronic access to ancillary data.
- Provide customers a means to electronically access Space Station administrative, operations, and engineering data files.

Data Distribution

- Provide local (within a program element, e.g., Space Station) and wide-area data transport services to support distribution of mission, engineering, operations, command and control, and other types of data plus audio and video data.
- Provide distribution network control services.
- Provide a means for users to request communications services.

Table 3.2-3 (continued)

Command and Control

- Provide standard work stations for customer and operator control and monitor, both in space and on the ground.
- Provide command management to ensure that all payload and subsystem commands are compatible and safe.
- Provide a capability for real-time interaction between customer and payload, or between operator and subsystem.
- Provide onboard resources to support stored command sequences.

Operations Support

- Provide data base access and tools to support mission planning and scheduling.
- Support integrated operations planning, scheduling, and resource allocation.
- Provide users with visibility into future plans, schedules, and resource availability.
- Support fault detection, isolation, recovery, and repair for subsystems and payload.
- Monitor payload and subsystem usage of Space Station resources. Support appropriate responses to resource usage deviations.
- Provide resource utilization history reports.
- Provide payload and subsystem event history reports.

Testing, Simulation, and Training Support

- Provide hardware and software interface verification tools.
- Provide a remotely-accessible real-time simulation of SSDS software interfaces.
- Provide simulation and facilities to support customer and operator training.
- Provide tools to support development of software and procedures.

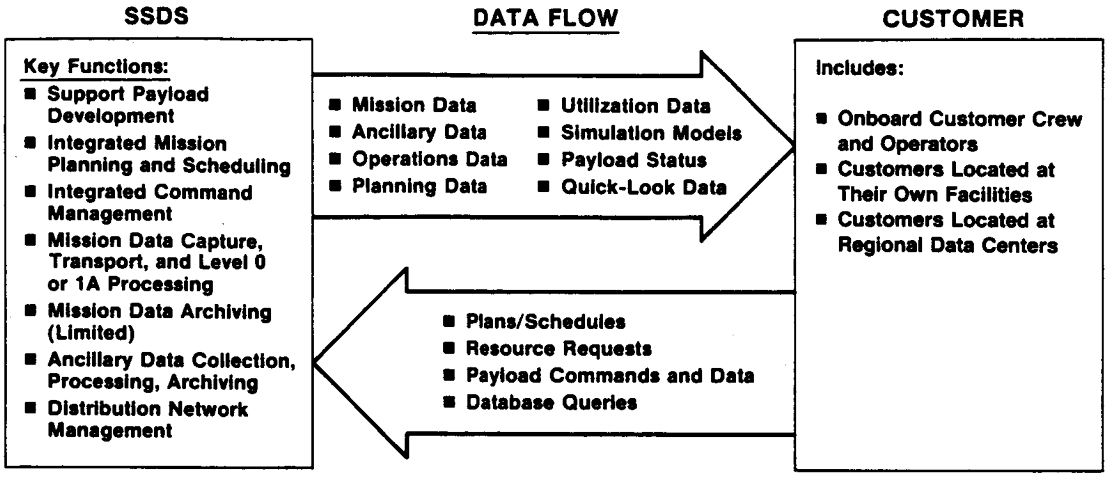


Figure 3-3. SSDS External Interface With Customers

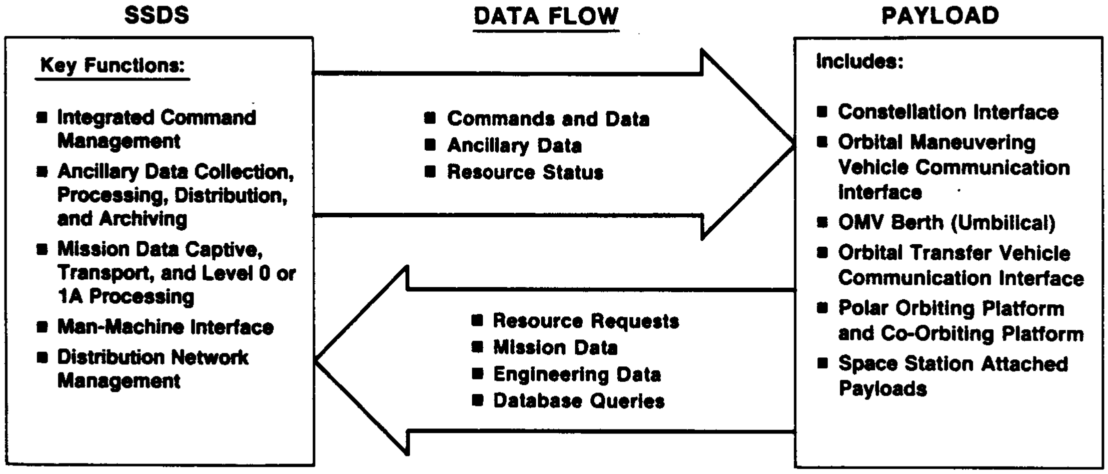


Figure 3-4. SSDS External Interface With Payloads

and polar-orbiting platforms. Operational analyses led to the identification of a complete set of elements that constituted the SSIS. This set of elements is shown in Table 3.3-1 and includes the basic ground system elements required for mission control and for customer data handling and delivery.

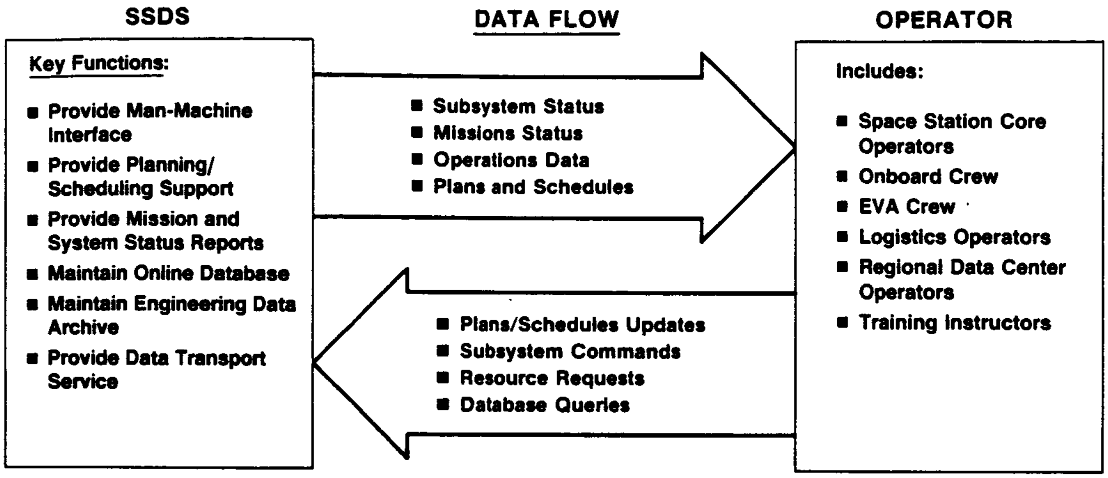


Figure 3-5. SSDS External Interface With Operators

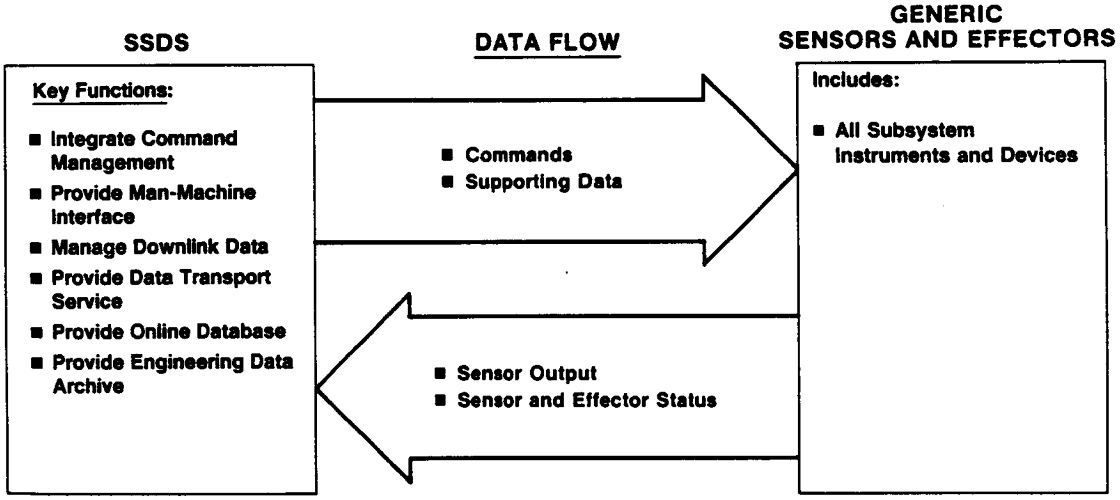


Figure 3-6. SSDS External Interface With Subsystem Sensors and Effectors

A set of criteria was developed to sort the SSIS elements into two categories; (1) within the SSDS and (2) external to the SSDS. These criteria are summarized as follows:

- Elements that provide data services for core subsystems or that provide "standard" (no cost) data services to customers are in the SSDS. Additional "standard" customers services, such as long-term archiving, will be available at additional costs. These additional services are not in the SSDS.

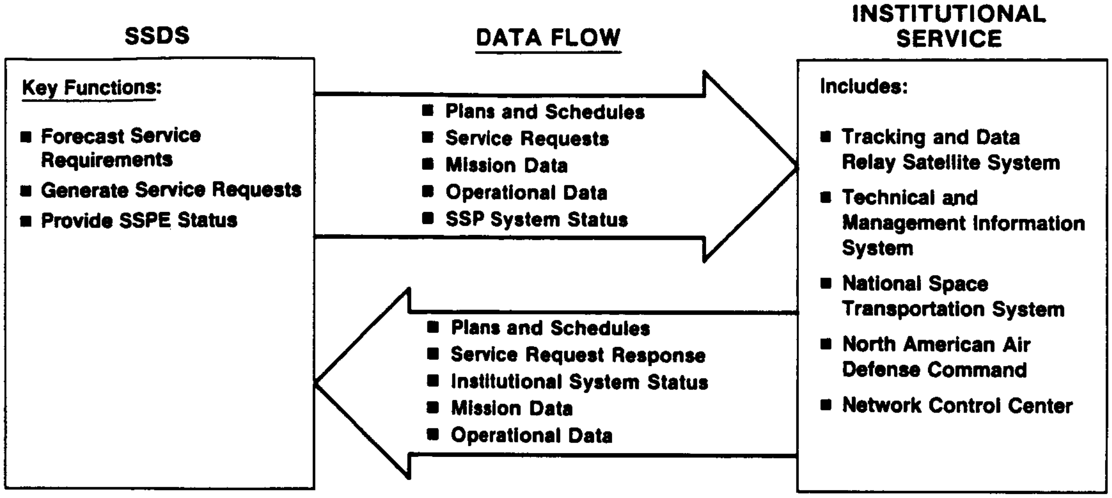


Figure 3-7. SSDS External Interface With Institutional Services

- Elements that provide data services that are unique to a particular customer or payload are not in the SSDS.

- Elements that are multi-program institutional services, such as TDRSS, are not in the SSDS.

Using these criteria, the SSDS elements were identified (Table 3.3-2). Each element and its general role in the SSDS is discussed below. For the purpose of developing a "strawman" system definition, locations have been assumed for these elements.

- The Space Station – The Space Station node serves as a communications concentration point for multiple payloads, core subsystems, and other identified elements. These include the OMV, OTV, free fliers; with options for STS and the COP. The Space Station receives data from the payloads and constellation elements, and relays the data to the gorund, together with core systems data. The Space Station routes the commands and data for payloads, core systems, and other SSPE's. The Space Station Network 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.

Table 3.3-1 SSIS Elements

Space Station (SS)
Polar Orbiting Platform(s) (POP)
Co-Orbiting Platform(s) (COP)
Data Handling Center (DHC)
Space Station Operations Control Center (SSOCC)
POP Operations Control Center (POPOCC)
COP Operations Control Center (COPOCC)
Payload Operations Control Center(s) (POCC)
Regional Data Center(s) (RDC)
Level 0 Processing Facility (LZPF)
Ground Services Center (GSC)
Engineering Data Center (EDC)
Development, Simulation, Integration, and Training (DSIT)
Global Positioning System (GPS)
Free-Flyer(s) (FF)
Tracking and Data Relay Satellite System (TDRSS)
Orbital Maneuvering Vehicle (OMV)
Orbit Transfer Vehicle (OTV)
Remote Customer Facilities
NSTS Orbiter
Deep Space Network (DSN)
Technical and Management Information System (TMIS)
Launch Integration Facilities
Contractor Facilities
Commercial and Institutional Communications Links

Real-time operations of the payloads require limited two-way data relay, including audio and video links.

- Polar Orbiting Platform(s) - The POP is a polar platform in sun-synchronous orbit which will be used primarily for earth and atmospheric observation. POP has no interaction with the Space Station on orbit, but will share some ground data handling facilities.

Table 3.3-2 SSDS Elements

Space Station (SS)
Polar Orbiting Platform(s) (POP)
Co-Orbiting Platform(s) (COP)
Data Handling Center (DHC)
Level 0 Processing Facilities (LZPF)
Space Station Operations Control Center (SSOCC)
POP Control Center (POPCC)
COP Control Center (COPCC)
Payload Operations Control Center(s) (POCC)
Engineering Data Center (EDC)
Development, Simulation, Integration, and Training (DSIT)
Ground Services Center (GSC)

The Space Station Network must support real-time transmission of operations data and commands for the POP payloads as well as near real-time transmission of quicklook science data and delayed transmission of stored commands and data. Based on the mission model, it is assumed that there will be two POP's at IOC, three at growth.

- Co-Orbiting Platform(s) - It is assumed that if the COP maintains continuous line-of-sight with the Space Station, the station can be used as a communications relay node. Options also exist for a direct COP to TDRSS link. It is assumed that the direct TDRSS link will be used if the COP is not in continuous line-of-sight with the Space Station. The space station network must support real-time transmission of operations data and commands for the COP payloads as well as near real-time transmission of quicklook science data and delayed transmission of stored commands and data.

- Data Handling Center - The Data Handling Center receives, buffers and retransmits uplink and downlink data. High speed downlink data is routed based on predetermined schedules, low speed downlink data is routed on the basis of information which is contained in the CCSDS telemetry packet header. The DHC is located at White Sands.

- Space Station Operations Control Center (SSOCC) – The SSOCC is responsible for ground support of the Space Station operations and control. The SSOCC is located at JSC.

- POP Operations Control Center (POPOCC) – The POP Operations Control Center is responsible for ground support of the platform operations and control. It is assumed that there will be one POPOCC for each POP. The POPOCC is located at GSFC.

- COP Operations Control Center (COPOCC) – The COP Operations Control Center is responsible for the ground support of the platform operations and control. The COPOCC is located at GSFC.

- Payload Operations Control Centers (POCC's) – The POCC's are responsible for the ground support of payload operations and control. This will include interactive real-time commanding and quick-look analysis of science data. The POCC's will receive a select subset of core ancillary data and will coordinate operations with the related Space Station or platform control center. It is assumed that there will be multiple POCC's. The POCCs are distributed among NASA centers, RDCs and customer sites.

- Level 0 Processing Facilities – Level 0 Processing Facilities (LZPFs) functions are standard interfaces (which are basically the same as for a POCC) and Level 0 Processing. High rate LZPFs are co-located with RDCs at GSFC, JPL, and LARC. A low rate LZPF is centralized at GSFC to serve the other RDCs and customers. High rate LZPFs are co-located with RDCs at GSFC, JPL and LARC. A low rate LZPF is centralized at GSFC.

- Ground Services Center – The Ground Srvices Center (GSC) provides communications and common resource coordination for the ground system. It serves to coordinate the scheduling of the communication and ground facility resources shared among the Space Station, COP, and POP operations control centers. These shared facilities include the Data Handing Center, and the Level 0 Processing Facilities. The GSC also collects status information from these facilities (outages, data quality monitoring, etc) and prepares reports of this information to both customers and the Global System Manager at the OCCs. The GSC also performs SSIS functions involving the collection of usage information from the ground elements used by customers and the processing of customer bills. The GSC is located at GSFC.

- Engineering Data Center - The Engineering Data Center provides archival storage of Space Station engineering data. This center will support program and customer requests for Space Station historical data. One Engineering Data Center is co-located with the SSOCC (at JSC) and a second EDC is co-located with the POP & COP OCCs at GSFC.

- Development. Simulation, Integration and Training - The DSIT will support 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. The SSE, a key part of this capability, is described in Section 8. The DSIT functions will be distributed throughout the ground system; elements of the DSIT will appear at each Control Center, LZPF, RDC and facilities that involve software development and simulations.

- Regional Data Centers - Regional Data Centers are SSIS elements that fall outside the SSDS boundaries, but their location affects the SSDS architecture. Their basic function, as assumed in this study, is the support of a single scientific discipline or group of related disciplines (at each RDC). The RDCs receive, analyze (processing above Level 0) and archive data from many sources, including space entities as well as non-space sources. It is assumed that the RDCs are mapped into the following disciplines:

RDC 1 - Astrophysics
RDC 2 - Solar
RDC 3 - Earth and Planetary
RDC 4 - Life Sciences
RDC 5 - Environmental
RDC 6 - Materials Processing

It is assumed that RDCs will be established at GSFC, JPL, LARC, JSC, MSFC and customer sites.

3.4 Functional Allocation to Elements

The requirements definition task of the SSDS study derived and validated an extensive set of functions that define the tasks that the SSDS needs to perform. The functions were identified by examination of mission requirements, operational scenarios, and subsystem interfaces, and by decomposition of high-level functions into lower and lower levels through structured systems analysis. The top two levels of the function set are shown in Figure 3-8. The complete set includes over 300 functions and is described in the task 1 report (requirements definition).

The implementation of the functions into an SSDS architecture was approached in an incremental manner as illustrated in Figure 3-9, with the first allocation defining the space versus ground functions, the next step allocating functions to elements (see paragraph 3.3), and finally, an allocation to SSDS nodes within the elements. The key trade studies that supported these allocation steps are shown in Figure 3-9. These trade study results are documented in the Task 3 report.

The space/ground function allocation is intimately related to the degree of space autonomy and to the degree of automation of in-space functions. The degree of automation, whether AI or conventional, has a strong bearing on the degree of space autonomy that is achievable since on-orbit crew time is a scarce resource. Consequently, there will be a strong motive to assign functions that cannot be readily automated to the ground segment.

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 PAYLOAD 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 3-8. Top Level SSDS Function Tree

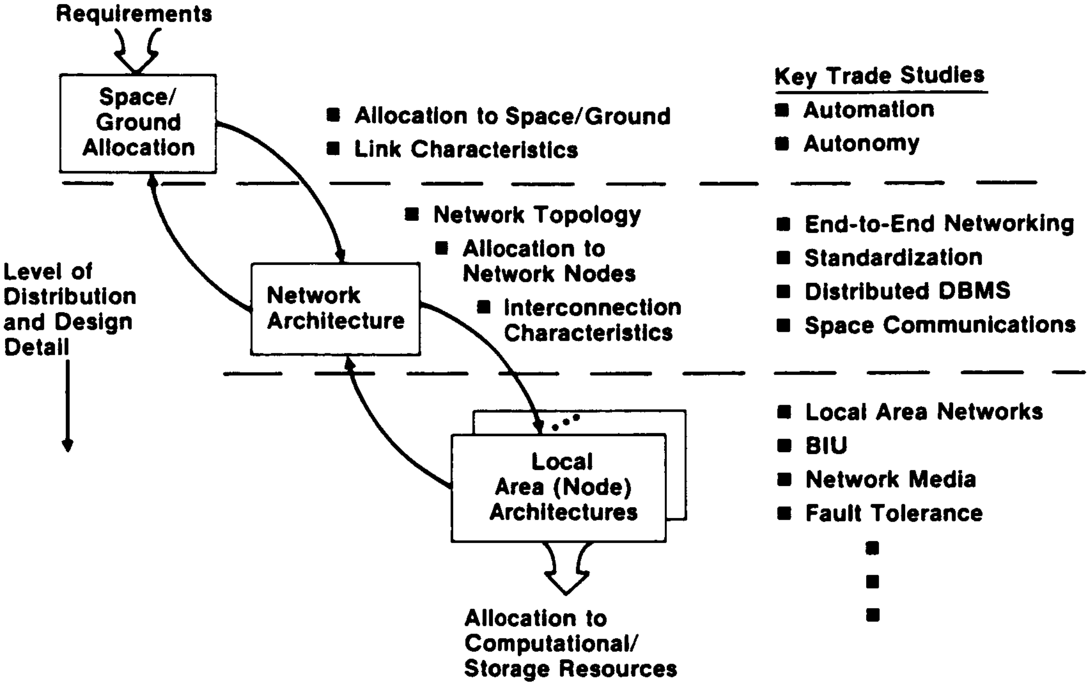


Figure 3-9. Incremental Design Approach

Our approach has been to (1) perform a space/ground function allocation based on a set of coordination criteria, (2) categorize each function implementation as automated, interactive, or manual based primarily on crew impact, response time requirements, and automation feasibility and cost. The ATAC draft report provided guidance for this decision. The Space Autonomy/Function Automation trade study in the Task 3 report shows the current allocation of functions to the space and ground segments and the level-of-automation category for each. Table 3.4-1 shows the criteria used in developing this allocation.

Within each of the two major SSDS segments (space and ground), functions have been allocated to the next lower level. Ground functions have been allocated to the various ground elements. The results of this allocation are discussed in Section 7. Onboard functions have been allocated to subsystems and modules. This allocation is discussed in Section 6. A current function allocation matrix is included in Appendix H.

The primary partitioning criteria that guided this network allocation process is shown in Table 3.4-2. The applicability of the criteria to ground element allocation and onboard subsystem allocations are identified. The resulting

Table 3.4-1
Criteria for Space/Ground Allocation
and Function Automation

Criteria	Comment
Criticality	What is the allowable restoration time for the function after a failure?
Impact	What is the potential impact of a failure of this function on crew, systems, or missions?
Co-location	Should the function be co-located with its input data source?
Space/Ground Link Availability	Is the availability/reliability of the communications link a determinant in the function location?
Function Autonomy	Does the function have significant I/O traffic with other functions?
Response Time	Is the communication delay significant to performance of the function?
Space/Ground Link Bandwidth	Is the finite TDRSS bandwidth a significant factor?

allocations need to be periodically reviewed and updated as the system definition progresses to account for changes in program priorities and goals and to incorporate the improved level of detail in the SSDS definition.

3.5 SSDS Topology/Connectivity

The topology of the SSDS defines the connections (data paths) between the elements of the SSDS. This section provides an overview of the top-level SSDS

Table 3.4-2

Partitioning Criteria

	Ground	Onboard
1. Partition so that stand-alone development of elements/subsystems is possible.	X	X
2. Partition to minimize interface complexity.	X	X
3. Partition so that interfaces are testable.	X	X
4. Partition so that critical and non-critical functions are separated.	X	X
5. Partition to support time-phased buildup to IOC.		X
6. Partition to efficiently use power, weight, volume, etc.		X
7. Partition so that response time requirements can be met.	X	X
8. Partition so that resources and data can be efficiently shared.	X	X
9. Partition to facilitate system growth and technology insertion.	X	X

end-to-end topology and of the Space Station onboard SSDS topology. The topology selection has been driven primarily by user data traffic needs and analysis and growth considerations but is also affected by institutional resources (e.g., TDRSS), and operational flexibility considerations. For instance, we have assumed that the Space Station will be capable of acting as a communication node for the COP to allow efficient use of TDRSS, but we have included in our topology a direct COP-to-TDRSS link for added operational flexibility and for contingency modes.

The elements of the SSDS were identified and discussed in paragraph 3.3. Figure 3-10 shows the top-level SSDS topology that interconnects these elements. In general, these connections are all duplex and are implemented in a range of capacities and forms to best match the system needs with capabilities. While the topology shows all space segment-to-ground segment traffic passing through TDRSS, a direct channel between a space element and a customer facility is not precluded (outside of SSDS). In addition, system failure tolerance needs may dictate a direct-to-ground link as a backup to TDRSS for operational, rather than mission-related, communications. Figure 3-10a illustrates the multiplicity of SSDS elements and identifies those data paths that are expected to be design drivers due to their traffic levels. Figure 3-10b describes the supporting data and assumptions used to derive these network data rate characteristics.

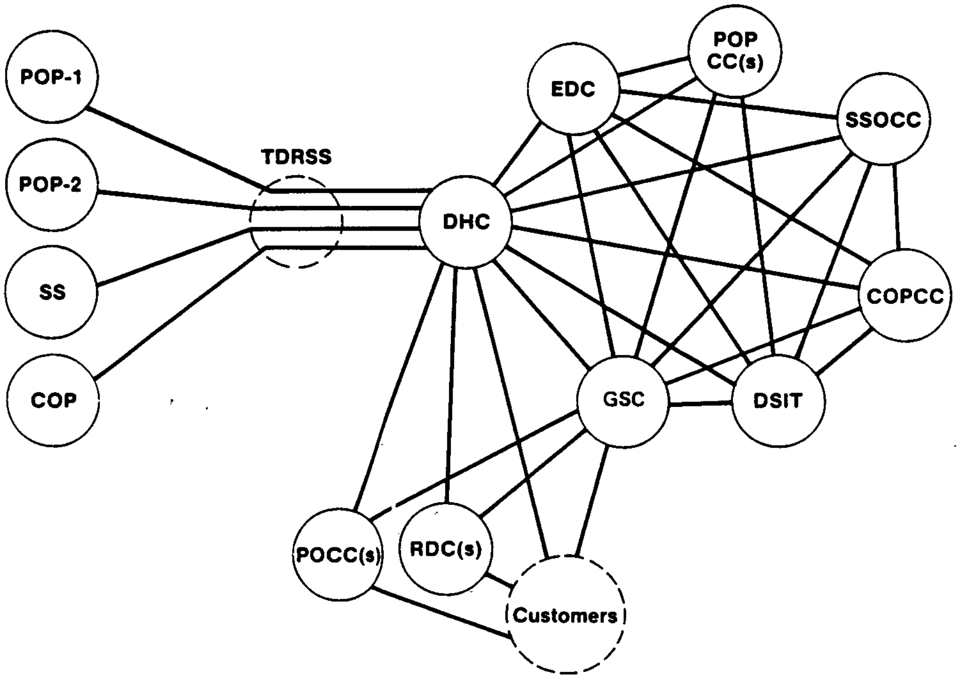


Figure 3-10. Overall SSDS Topology

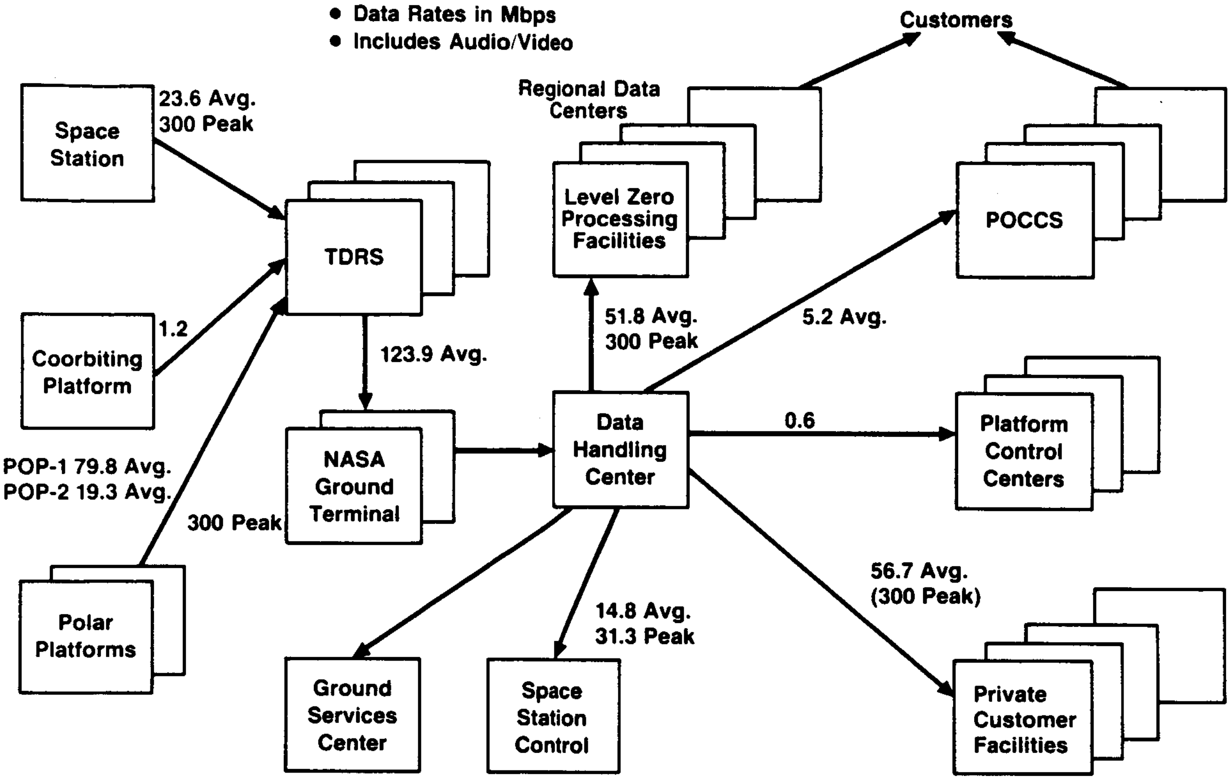


Figure 3-10a. SSIS Data Network Data Rates — IOC

— All Rates in Mbps —

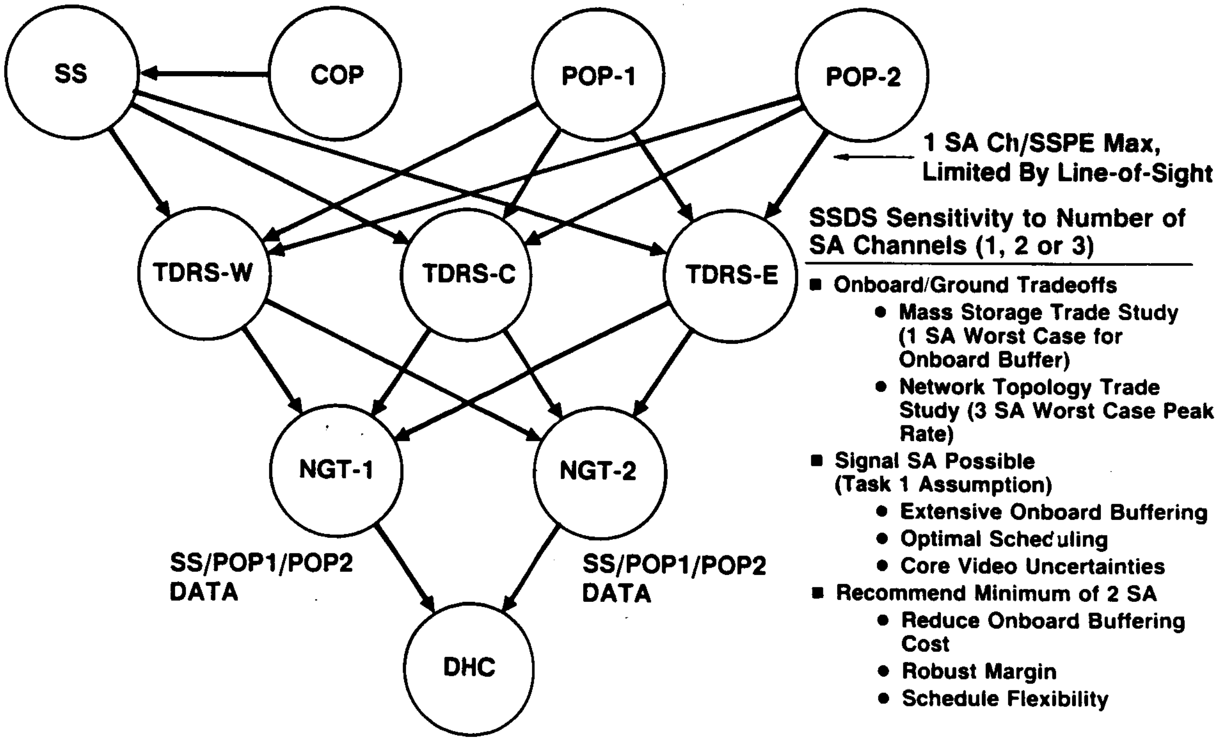
Data rate entry	Data rate	Source or makeup		Comments
Space Station peak	300	Remote Sensing Test		• Other Ku-band data recorded during operation
POP peak	300	SAR on POP-2		• Other data recorded or transmitted in S-band • POP-1 total is 393 Mbps, recording assumed for excess over Ku capacity • Record capability required for exclusion zone adequate to buffer POP-1 • Consider providing 600 Mbps capability to improve SAR resolution by buffering or use of both TDRS SA channels
Space Station average	23.6	Remote sensing test	- 2.5	
		Solar terrestrial obs.	- 2,5	• TDMX 2542 corrected to 10kbps
		Pinhole Occultor	- 0.875	• Payload video 38 hr/day lab coverage at 1 frame/sec, plus 7 hr/day at 4.5Mbps NTSC
		Misc payloads	- 0.475	
		Payload video	- 2.47	
		Core data	- 0.26	• 2 channels surveillance video at 4.5Mbps plus 6 hr/day at 22Mbps
		Core audio/video	- 14.5	
COP average	1.2	1Mbps payload, 0.2 core		
POP-1 average	79.8	Stereo I.S	- 54.2	• Duty cycles are expected to be reduced to less than half for high-rate missions
		High res I.S.	- 21.7	
		Misc	- 3.7	
		Core data	- 0.2	
POP-2 average	19.3	SAR	- 16.25	
		Misc	- 2.85	
		Core data	- 0.2	

Figure 3-10b. Supporting Data for SSIS Data Network Rates — IOC

The ground segment topology allows the Data Handling Center to sort and distribute downlink data directly to users and to collect uplink data from users for routing to space elements. Many element-to-element links are provided within the ground segment to handle not only mission data traffic but system management and administrative traffic.

Growth can be accommodated in the ground segment topology by virtue of the mesh-like connectivity. This allows routing flexibility as the data traffic increases. TDRSS enhancement (i.e., TDAS) that provide direct broadcast of space data to regional sites will be readily accommodated by this topology and by the distributed nature of the user data processing in the SSDS ground segment.

The single access channel connectivity is shown in Figure 3-11. This connectivity assumes that a second TDRSS ground terminal is available. Three TDR satellites are shown as an example of potential TDRSS space segment configurations. Either 1, 2, or 3 of these SA channels may be carrying SSDS



SSDS Sensitivity to Number of SA Channels (1, 2 or 3)

- Onboard/Ground Tradeoffs
  - Mass Storage Trade Study (1 SA Worst Case for Onboard Buffer)
  - Network Topology Trade Study (3 SA Worst Case Peak Rate)
- Signal SA Possible (Task 1 Assumption)
  - Extensive Onboard Buffering
  - Optimal Scheduling
  - Core Video Uncertainties
- Recommend Minimum of 2 SA
  - Reduce Onboard Buffering Cost
  - Robust Margin
  - Schedule Flexibility

Figure 3-11. SA Channel Connectivity

traffic at a given time, depending on the TDRSS SA allocation. We have assumed that either TDRSS ground terminal may be acquiring data from any TDR satellite and that, therefore, SSDS SA traffic can come to the DHC from either ground terminal.

The space station on-board SSDS segment Topology is shown in Figure 3-12. This topology, which is also applicable to the platforms, consists of a group

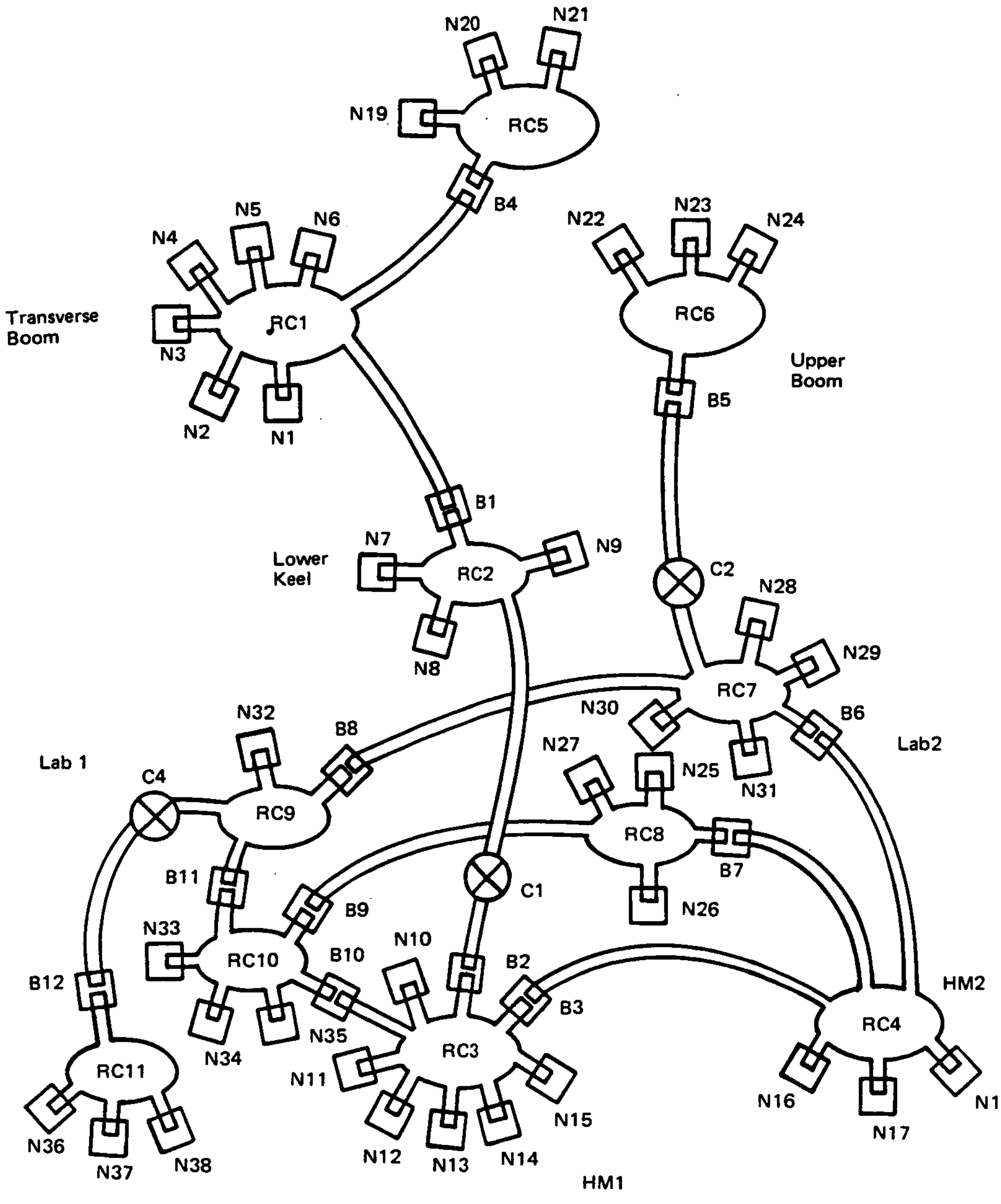


Figure 3-12. Network Topology

of interconnected, dual redundant, token-ring busses, with major partitions between payload (customer) networks and core networks.

A token ring will be needed in each module, at each end of the power tower configuration and on the solar array truss. It is desirable to separate the core data traffic from the payload traffic whose growth is difficult to predict. This will maximize the possibility of using the core network for a majority of subsystem data transmission (i.e., minimize dedicated subsystem local busses by providing a core network with predictable and acceptable transmission delays to sensors and effectors).

This configuration will provide:

1) Maintainability by allowing network repair and checkout at the concentrator.

2) Ease of connectivity during build-up.

3) Token ring allows for prioritization of token to support real-time control application.

4) Token ring performance is superior to CSMA/CD with high traffic loads (and superior to "voting arbitration" methods).

5) Emerging ANSI standards (X3T9.5) to promote growth for fiber optic media.

Safe haven requirements can be met by having separate token rings in each module. The onboard topology is discussed in more detail in Section 6. Detail on the ground network topology is in Section 7. Trade studies leading to the topology selections are documented in the Task 3 report.

3.6 SSDS Operational Concepts Overview

A key component of the SSDS architecture definition is a description of how the SSDS operates as viewed by the user. This section provides an overview of some of the key SSDS operational concepts, including mission planning and scheduling, payload control, customer data handling, and software development. More detail on these operational concepts, and discussion of additional concepts may be found in sections 4, 6, 7, and 8.

3.6.1 Mission planning and scheduling. The planning and scheduling process is illustrated in Figure 3-13. It begins with identification of significant milestones in the SSP, herein called Major Events. Major Events, by their nature, will have an impact on the entire scope of spacecraft and mission operations. These events include visits by the NSTS orbiter, changes of payload compliment, changes of spacecraft equipment, and, for the Space Station, major operations such as OMV and OTV launches and satellite servicing. The Major Events form a framework into which the normal operations of mission payloads and core systems must fit. Long term planning will be used to apportion operating time and critical resources among customer and space craft objectives. The major events and apportioned resources become the SSP Master Plan, which is developed and maintained by the SSDS.

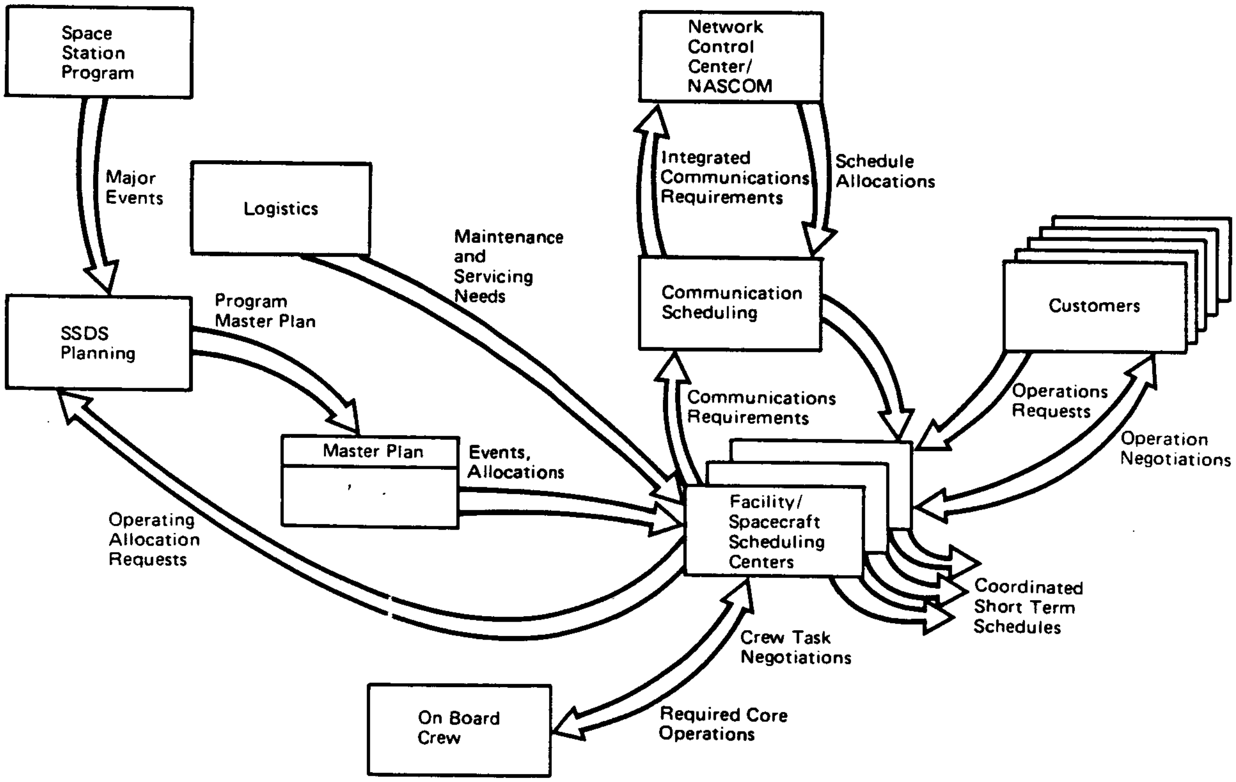


Figure 3-13. SSP Mission Planning and Scheduling

A Short Term Schedule is developed beginning approximately two weeks in advance of the time of actual operation. Specific customer mission requirements, payload and core system maintenance and servicing requirements, and major events are input, together with anticipated spacecraft capability. The scheduling function seeks an arrangement which maximizes the value of payload output within expected resource limitations. This process proceeds in two hierarchial steps:

1) Communication Link Scheduling – The TDRSS and Space Station Data network links are shared among the Space Station and platform systems. The first step is to schedule use of these links. To minimize onboard storage for the very high data rate missions, bent pipe relay is preferred. The polar platforms will not be able to utilize this communications mode in the zone of exclusion, but will still benefit from its use elsewhere by reducing onboard buffer requirements. Hence, priority allocations are made to the high rate missions, consistent with their desired operating times and availability of appropriate targets and data network links.

   The next priority is given to real time and quick look requirements for interactive control. Real time and quick look are distinguished by an identified need for communication between space and ground measured in seconds, as opposed to tens of minutes. The later should be accommodated in normal, bulk transmissions. Only data rates above the very low rates accommodatable within a TDRS MA channel are considered in this grouping.

   The final grouping includes bulk space–ground communication. The communications are coordinated with the NCC and NASCOM from a single point of contact within the SSDS.

2) Spacecraft and Facility Scheduling – With the communications schedule established as the only regularly occuring, program wide interaction among SSPEs, each facility and spacecraft can undertake its own internal scheduling. It is noted that coordinated operation of payloads between spacecraft may be required by customers. However, this operation should be accommodated in the communications schedule

and within the schedules of the individual spacecraft. The communications schedule provides for the primary coordinated activity among the SSPEs.

Developing the short term schedule is expected to involve interaction and negotiation among customers. This may be especially true for earth observations. The customers will select targets and instruments to be used, and the control center developing the schedule will be able to determine when the targets will be observable. The schedule function will attempt to balance resources available with observation opportunities to maximize the total value of payload output. Most of the Space Station payloads will be competing for electric power and crew time. The scheduler function will attempt to allocate these resources in a similar optimum manner.

A very valuable adjunct to preparing the short term schedule is a set of prestored templates of recurring operations. These templates cover at least the use profiles for power, crew time and communications. Other resources may be included if it is determined that these resources are important to scheduling. However, details of the process which do not affect resources are not included.

The templates for requested operations are assembled according to timing, crew preference, resource demand, and resource availability considerations. Negotiations among customers and operators are conducted to resolve difficulties, including potential problems of safety and interference among operations.

The scheduling and negotiation process is continued until a best obtainable schedule is developed. However, the schedule is held open until the last few hours (or less) to accommodate targets of opportunity and other unforseen events. The dynamic result is the short term schedule. It should be noted that these scheduling/negotiation functions are provided to the customer as an optional service to enhance the probability of having access to available resources at the time of need.

An Operating Events schedule is developed from the short term schedule, containing the actual commands required to implement the short term schedule. The origin of these commands and their management is discussed under Section 3.6.2.

3.6.2 Command management. The command management process and the planning and scheduling process are mutually complementary. Planning and scheduling provides for the efficient use of critical resources and reserves operating envelopes for the payload and core operations. Command management provides the commands to implement the operating schedule. Its objectives are to ensure that the Space Station system is responsive to user commands and to prevent damage to the Space Station systems and payloads and to prevent crew injury as a result of those commands. Our operational concept meets these objectives by incorporating the following features:

1. Payload and core system operations are classified by a joint NASA/customer review as:
    - Restricted – Those which pose a potential hazard to the Space Station or crew.
    - Constrained – Those which may interfere with other payloads or core systems.
    - Non–restricted – all others.
2. Commands implementing these operations assume the classification of the operation.
3. Non–restricted commands may be sent directly to any payloads or core subsystem (or originated by the payloads or subsystems). The SSDS responsibility will be limited to authenticating the sender and address.
4. Restricted and constrained commands must be determined by the SSDS to be executable at the time of execution. The SSDS may provide user

friendly aids to the customer and operator to assist in clearing commands determined to be not executable under conditions forecast at the planned time of execution.

5. The SSDS will not test the customers commands for implementability or potential damage to the payload. These responsibilities remain with the customer.

Figure 3-14 illustrates this command management concept. The SSDS is responsible for authentication of the customer or operator issuing a command and the payload or core system addressed. All non-restricted commands are, by definition, executable at any time. These are passed directly to their destination. Restricted and constrained commands are conditionally executable. When the planning and scheduling process has been used as an optional service to create the necessary conditions for a restricted or constrained command to be safely executed, the command is issued at its scheduled time. If these necessary conditions do not exist or are not forecast to exist at the scheduled time, the command is judged to be not executable. The scheduling process may be re-entered to determine whether the schedule can be altered to accommodate the command. If so, the schedule is changed and reissued and the command is reclassified to executable. The customer or operator issuing the command may be contacted to aid in accommodating the requested operation. If it is not possible to accommodate

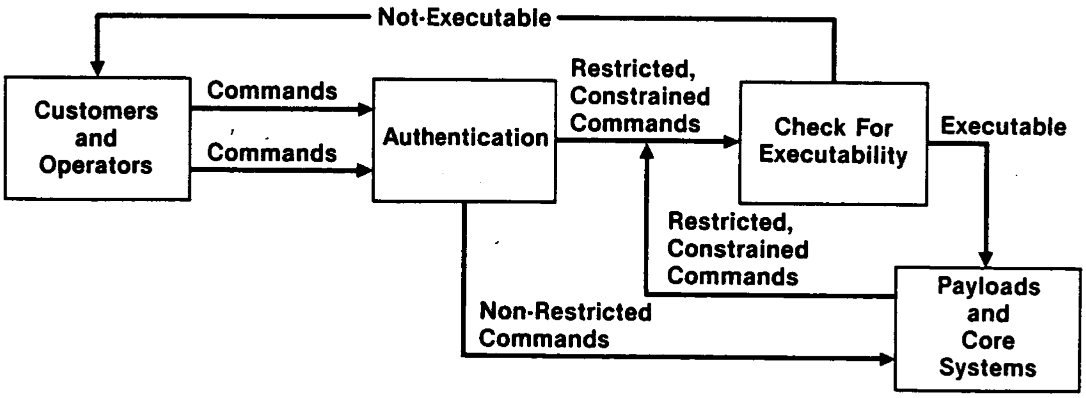


Figure 3-14. Command Management Concept

the command, the originator is notified and supplied the reasons for the command being not executable. The executability of these commands will be subject to resouce availability and constraint conditions at the time of execution. A "robust" SSDS design will help to maximize the probability of unscheduled command execution. However, it should be noted that some key resources are not contained within the SSDS (i.e. power, TDRSS, etc.).

3.6.3 Customer data handling. A primary responsibility of the SSDS toward Space Station customers is to provide a highly reliable, robust, transparent data transport service. The SSDS also provides data processing, data storage, and ancillary data services for customers. The architectural features that implement these services effectively and efficiently include the following:

- Standard data communication protocols and formats based on the ISO/OSI model and the CCSDS recommendations for payload and ancillary data formatting and transport.
- Onboard buffering of payload and ancillary data.
- Limited onboard mass data storage for payload data bases and software.
- Short-term ground storage of customer data to facilitate data delivery and assurance of satisfactory quality..
- Network control, data sorting, data routing, data time-ordering, and artifact removal services as necessary to make the overall data transport function transparent to customers.
- First-level sorting of customer data at White Sands for separate transmission to discipline-oriented RDC's.
- Ancillary data provided to the onboard payloads to allow merging with payload data at the source.
- Electronic access to an ancillary data base that will be maintained by SSDS at the EDC and spacecraft control locations..

- Customer data privacy and customer control of third-party access to customer data. The SSDS allows customer data encryption, as long as headers are readable, to permit the customer to provide his desired level of security.

Customer data processing (beyond the Level 0 processing described above) may be implemented in several ways. Onboard payload data processing may be done in a payload-provided processor or in an SSDS-provided standard data processor. In either case the processor has access, through a standard interface, to the onboard LAN's, the communication gateways, the onboard data base, and the onboard work stations. Ground data processing beyond Level 0 may be provided as a service by NASA (outside of SSDS) or may be done by the customer. The RDC's and POCC's will have data processing resources (CPU's, operating systems, peripherals, etc.) to support customer data processing.

The SSDS data archiving is limited to one week storage after receipt of verification of acceptable data quality from the customer. Long term archiving for up to two years is an SSIS service which may be negotiated with the customer. The archival services will generally not be extended to "bent pipe" relayed data, as the data capture function is bypassed at all intermediate nodes. If exceptions to this rule are to be negotiable, additional high rate equipment for data capture will be required.

The SSDS data transport service is symmetrical in the sense that commands may be sent from ground to space and from space to ground. Data may likewise be sent in either direction. For commands, the SSDS implements the CCSDS protocol that resends the command if a transmission error is detected.

3.6.4 SOFTWARE SUPPORT ENVIRONMENT (SSE)

The purpose of the SSE is to provide an environment to support the development of software for the Space Station. The SSE is a set of tools which are portable and will be made available for subsystem and payload developers. The tools included in the SSE will not dictate a specific methodology or set of procedures. The users will be able to define their procedures (within limits) and utilize subsets of the tools as required to support those procedures.

The primary goals of the SSE are to reduce the life cycle cost and insure the quality of all software produced for the Space Station. This includes core, payload, ground support, and SSE software. This will be accomplished by the achievement of the following subgoals:

1. Provide a stable, common base for the development of the software.

2. Provide integrated support of the entire software life cycle, from conceptual definition through delivery, including configuration management at all stages.

3. Provide easily attainable status at many levels by providing tools which facilitate definition, scheduling and tracking of intermediate milestones.

4. Provide state of the art tools for each task in the software life cycle to increase overall productivity.

5. Provide a common, convenient interface for each of the tools to avoid the necessity of learning multiple interfaces.

6. Provide an easy way to expand the tool set in order to add new tools.

7. Provide a method of maintaining multiple versions of all documentation such that it is available on-line or it can be printed.

8. Provide tools which support and encourage commonality and the reuse of existing components.

9. Provide sufficient flexibility within the configuration management and software engineering methodology support to make the SSE attractive to payload customers as well as satisfying the needs of core software developers.

10. Provide SSE capabilities such that support provided is independent of users physical location.

The types of software support by the SSE will include:

- Real Time Flight Software
- Ground Command and Control Software
- Ground Data Processing Software
- Support Software
- Integration and Test Software
- Emulation and Model Software
- Customer Application Software

The SSE will be used by development groups to generate software elements, and by the software integration site to combine the elements into integrated software loads. The support provided to each development user group will be identical. This support will be provided in a manner which will allow each group to develop their applications as autonomously as possible, but will encourage communications and software commonality among the groups. This is depicted in Figure 3-15. Each function in the figure is summarized in the following paragraphs and is described in more detail in paragraph 8.2. The support for the integration will consist of many of the same functions as provided for the development groups, but it will also include facilities to integrate the software produced by all and it will provide more extensive system/integration test facilities.

A set of tools will be provided by the SSE to support Configuration Control and to support management in user activities of planning and resource allocation. It is assumed that to maintain configuration control over the Space Station software, the project will utilize a series of NASA and contractor control boards (similar to what has been used in previous NASA projects) and an automated data base system for storing and enforcing decisions made by the boards.

Requirements Generation/Analysis, using tools provided by the SSE, provides a foundation for software by identifying interface details, providing descriptions of functions, determining design constraints, and defining software validation requirements. On a project as large and complex as Space

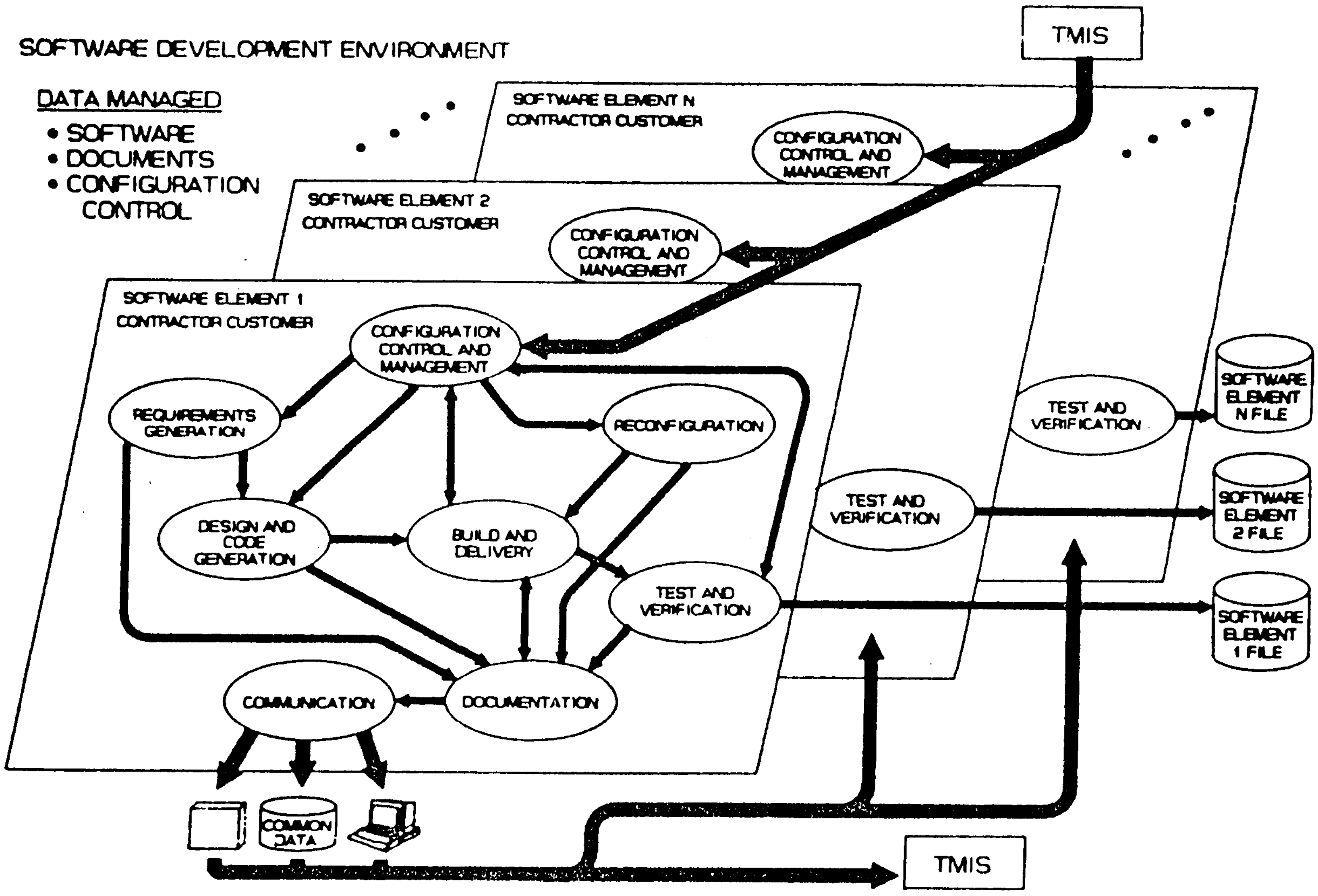


Figure 3-15. Services Provided by the SDE for the Development Function

Station, each of the afore mentioned are crucial to maintain communication between the requirements initiator and the software developer.

Design and code generation is the process by which programmers create new software and make changes to previously-created software. Because the process is a creative one, it tends to rely heavily on manual inputs made by skilled humans. In order to generate software for the Space Station in the most cost-effective manner, the SSE must provide tools to assist the human programmer in designing and coding in the most efficient and errorfree manner possible. See Figure 8.2-6 for a summary of the process.

The System Build and Integration function of the SSE provides the tools necessary for orderly and controlled collection and integration of software systems (and their associated documentation and data) by their developers and testers and for controlled delivery of those systems to their users.

Testing is the examination of program execution behavior. Testing of the Space Station software will be very important because of its life/mission critical nature. Facilities must be provided in the SSE for testing because of the inability to observe the software in actual use in a safe environment (i.e. on the ground). These test facilities should include a variety of tools that will support cost effective testing of the core, application software, and payload software.

The tools and capabilities provided for test and analysis represent the full spectrum of test facilities for the project. Subsets may be defined and used to support various levels such as unit testing, performance testing, and independent verification and validation.

The documentation function of the SSE will provide online documentation facilities to create a minimum paper environment with hard copying capability. This function will be used for viewing as well as creating the online documents. There will be a capability to assign access levels for security of nonpublic documents. Examples of document types are: requirements, user's guides, instruction manuals, test specifications, program test reports, software build reports, status reports, and working papers.

Working papers are lost, historically, in most long-lived projects as the designers move on to newer tasks. The documentation capabilities will support the archiving of background information, such as design rationale and justification, etc.

The communication function will provide the means to make the SSE appear as a single facility to each user, regardless of site location. It will enable a user to send and receive data, e.g., documents, messages, or software to other users or functions of the SSE. This function will field requests from other functions to transfer data between functions and to users.

The software on the Space Station will be required to interface with a vast number of hardware components (e.g. IMUs, rate gyros, etc.). During the life time of the station, it will be necessary to integrate, test, operate, and replace hardware components. Each component has specific characteristics which must be provided for within the software. Reconfiguration data is that set of data values required to tailor the application software and user interface language interface environments to be compatible with a specific hardware configuration. The process of managing the reconfiguration data and incorporating updates into the target system (e.g. onboard DMS, integration test sets) is called reconfiguration. The SSE must support this activity.

The SSE will provide the environment for development of the DMS. Once developed, the DMS will be made available in the SSE for application software/hardware development and verification. The On-board Data Management System will consist of the software and hardware to support crew control of the Space Station (SS) structure and other SS subsystems. These systems include a set if "core elements" such as housekeeping data (e.g., time), a data storage system, a Crew Interface system, a network for support of a distributed processing system, and an operating system which supports many core and payload systems. The software and hardware of the DMS will be configured into a network of Standard Data Processors (SDP's), Network Interface Units (NIU's), and data buses connecting sensors/effectors into a network(s).

The SSE can be made available to the customer community as an optional service. This will be a necessary service for any customer desiring to use an onboard SSDS-provided standard data processor that may be shared among customers. This greatly facilitates customer application, software build, integration and checkout. If a customer provides his own dedicated onboard processor , his use of the SSE will largely depend on his preferences for processor type, implementation language and existing development tools/facilities. Due to the diverse nature of the customer community and their available resources, it is unlikely that any concensus standardization will emerge in these areas. The SSE service will provide little utility for those customers, that do not adopt the level of commonality imposed by the SSE. However, for those customers that choose to use the common SSE, potential benefits include the development of a "reusable" software base that can be made available to new customers and the availability of a stable development environment.

3.7 Key Design Drivers

Several SSDS requirements or requirement categories have been identified as "drivers" in the sense that they have a particularly strong influence on the design and cost of the SSDS. The purpose of identifying these drivers is two-fold: (1) to allow a focus on the requirements so that they will be specified at an adequate but not excessive level, and (2) to allow a focus on particular design areas and techniques that might accommodate these requirements at lesser complexity and cost. The key design drivers are listed in Table 3.7-1 with the potential impacts of each driver.

All of the requirements must be implemented with a consideration of affordability - in both an initial and a life-cycle cost context. The identification of the key design drivers is intended to provide some cost leverage by indicating the areas of SSDS requirements and design which most significantly affect costs. They provide priorities for requirements analysis and review, design innovation, and advanced development.

Table 3.7-1 Key SSDS Design Drivers

Requirement	Potential Impacts
● High Mission Peak/Average Data Rates	● Communications Bandwidth/Buffering ● Processing Throughput ● Data Storage Capacity and I/O Rates
● Automation/Autonomy	● Software Development Costs ● Onboard Processing Capacity ● Flexibility/Adaptability of Onboard Design
● Geographic Distribution of Elements	● Extent of Communication Network ● Network Management Complexity ● Distribution of Processing and Data Base
● On-Orbit Integration	● Subsystem and Module Autonomy ● Ground Processing/Verification Capability
● Evolutionary Growth/Technology Accommodation	● Autonomy/modularity approach ● Selection of standards ● IOC Resource margins

4.0 END-TO-END SSDS DESIGN AND OPERATIONS PERSPECTIVE

By way of review, the approach used to develop the top-level architectural topology of the SSDS was to: 1) define data processing functions and resource requirements; 2) iteratively partition/subdivide the functions and allocate them to logical entities (nodes, elements, facilities, subsystems, ...), and 3) continue the process until all functions had been assigned to physical entities and a logical interconnection matrix had evolved. The results of this process were discussed in section 3.0 and lower-level definitions for space and ground elements are provided in sections 6.0 and 7.0, respectively.

This top-down approach leads to well-defined end products that can be characterized in terms of their resource and interface requirements (within the context of a total system architecture). However, it is equally important to ensure that the "modularization" of the SSDS is consistent with SSIS goals to retain an end-to-end design perspective. This requires the development of "unifying" design concepts across SSDS entities that facilitate the flow of data/commands between the onboard payloads/subsystems and the ground or space based users. This section will describe design concepts at a sufficient level of detail to identify key end-to-end implications for system definition. This will be accomplished within the framework shown in figure 4.0-1 and includes a description of (1) payload/subsystem/user operations scenarios, (2) standard SSDS interface services, and (3) data/command transport services. These three components will be discussed in subparagraphs 4.1, 4.2, and 4.3, respectively.

A key element of this description will be a relatively detailed examination of the appropriate use of standard communication protocols with an end-to-end perspective. The technique employed here includes the step-by-step tracing of information "threads" through the SSDS network. To accomplish this, design concepts will be introduced (based on the system definitions established in sections 6 & 7) that are necessary to provide a detailed understanding of how standard communications protocols can be effectively used.

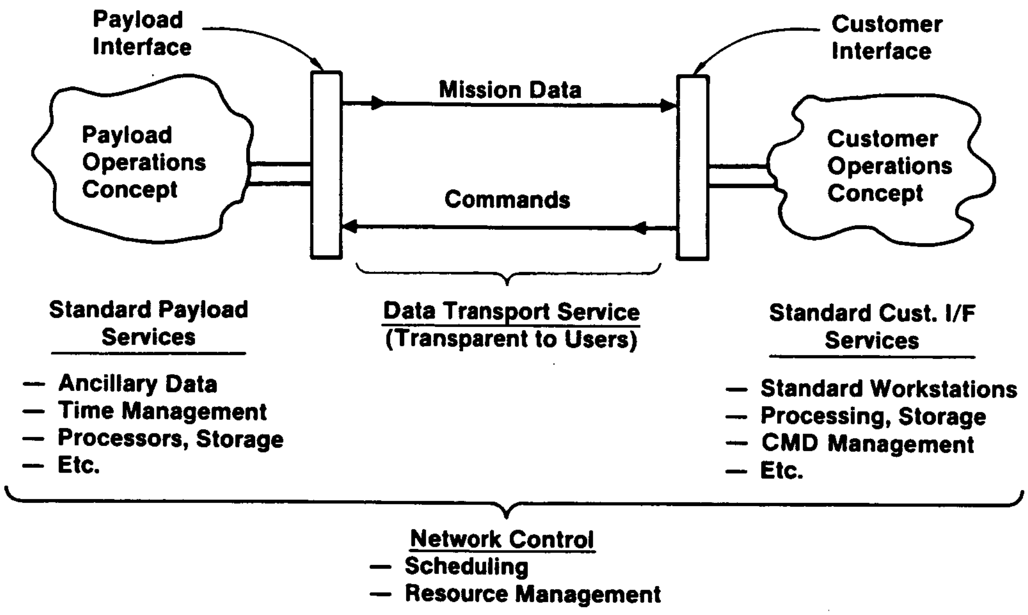


Figure 4.0-1. End-to-End Architecture (Experiments)

4.1 Payload/Subsystem User Operation Scenarios

4.1.1 Introduction

This section describes an end-to-end design perspective from the customer payload and subsystems operator points of view; it includes considerations of the various operational scenarios encountered by customers and operators of the SSDS, their interfaces and interactions with their payloads and subsystems, and the end-to-end data flow and routing associated with payload and subsystem operations. Data flow and routing that support these scenarios will be developed later in paragraph 4.3 in terms of a standards model that illustrates the protocols used on an end-to-end basis and the degree of standardization, compatibility, and commonality that should be realizable in the SSDS.

This section will discuss only a small subset, but an important one, of all the operational scenarios that could be expected to occur in the SSDS; this subset has been selected to show an in-depth understanding of the end-to-end protocol requirements. For a complete and comprehensive discussion on a more extensive set of scenarios, the reader is referred to the Task 1 report, Reference 1.

The contents of this section are applicable to the ground operations and the onboard operations for the Information and Data Management Systems (IDMS) on the Space Station (SS), Co-Orbiting Platform (COP), Polar Orbiting Platform (POP) and other SS Program Elements (SSPEs).

The design perspective discussed herein was developed using the criterion that if customer interfaces (onboard and ground, and in all planning, design, test and operation phases) are designed to be "friendly" and "easy to use" then broad acceptance of the SS Program by the commercial and scientific communities can be expected.

The end-to-end operations perspective encompasses the following physical nodal extremes: core subsystems and payload packages integrated via point-to-point links and the onboard local area networks (LANs) in the various SSPEs, space/ground communications and the use of special TDRSS uplink/downlink protocols, and the ground-to-ground world-wide area communications network. The wide area network includes the interconnection of subnetworks (e.g., ground based LANs in the various centers) via long haul satellite and terrestrial communication links. The wide area network has unique characteristics, as compared with public data networks, including:

- significant control by NASA,
- the use of high level coding such as Reed-Solomon to detect and correct errors,
- transport of both interactive and non-interactive messages,
- functions such as data capture which support recovery of lost application data,
- data encryption and customer payload security,
- customer data privacy,
- data that is transported through the network that can be interpreted as commands and, hence, must be checked, in some instances in realtime, for restrictions and constraints (station safety and

experiment cross-interference), and

- transport of critical data (with retransmission upon detection of non-correctable error) and non-critical data.

The SSDS provides data transport services for both real time and non-realtime messages, highly interactive (e.g., teleoperated) and non-interactive operations, high and low rate quick-look and production data, image and non-image data and in both realtime and (delayed) non-realtime, commercial quality imagery, low-resolution freeze-frame and high resolution TV, audio and teleconferencing among nodes in the SSDS. The SSIS extends the nodes to the customers facilities, and provides data transfer services among all nodes.

4.1.2 Customer Interface Definition and Interaction

The development/operation cycle of a payload includes the following phases: Feasibility analysis, mission planning, payload development, ground integration and verification testing, transportation to space, onboard integration and verification testing, payload operations (production, maintenance, etc.) and finally, transport back to earth.

In the feasibility analysis and planning stages, resource requirements, distribution of resources, cost of resources, and operational constraints must be established to determine the overall feasibility of a particular mission. Considerations here include the following:

1. Power Resources Allocation - The user power requirements must be known for long range planning and for near term operations control.

2. Timeline Constraints - Constraints associated with orbital position (earth viewing), daylight or darkness or any other timeline constraint must be integrated into the plan to develop realizable operational windows.

3. EVA Servicing - EVA is treated as a mission resource and, whether required on a one-time or periodic basis, must be established and factored into mission planning and crew timeline planning to determine resource requirements and availability.

4. Computing and Data Storage Resource Allocation - The data processing requirements for the experiment must be developed by the user and factored into his planning. Also any realtime constraints associated with realtime control (such as transport lag or jitter experienced through the SSDS network) will be provided to the user so that he can develop criteria for space/ground autonomy decisions. If the user intends to use SSDS hardware resources (processing, I/O, memory, workstation, ...) then these must be identified and integrated into the mission plan.

5. Crew Monitor and Control - If the payload operations are to be managed by the flight crew, the crew monitor and control requirements must be factored into crew mission timelines. In addition, crew training must be planned and integrated into mission preparation.

6. Software Development Resource Allocation - If the user wishes to use the SSE then he must estimate the resources required to develop the experiment applications software and these resources must be factored into programmatic decisions and long range planning.

7. Communication Link Resource Allocation - The user must estimate the full- and half-duplex communication resources required to control his payload and to transport his data from orbit to ground data handling facilities. This will allow for mission planning and assignment of communication network resources. These estimates, along with network communication scheduling constraints, must be planned and integrated into the mission plan.

8. Develop, Simulate, Integrate and Train (DSI&T) - The user must estimate the resources required in the DSI&T element. Key decisions here will affect how he intends to develop and integrate his payload (planned use of his facilities, SSDS-supplied interface simulators, DSI&T integration services, ...).

9. Standard Services - A key decision in the customers planning phase will be the selection of standard services provided by the SSIS (some

of which were discussed above, and all of which are discussed in paragraph 4.2).

As part of the planning and preliminary design activity the customer will have to perform automation and allocation trade studies analogous to those performed for non-payload functions (e.g., core subsystems). Issues to be resolved here are the following:

1. How should a payload's functions (e.g., data acquisition/processing/-compression, command/control, ...) be distributed between the customer's supplied payload package, onboard SSDS resources, ground SSDS facilities and resources, and the customers own ground facilities? How should ancillary data be acquired (onboard or ground)?

2. What degree of automation should the customer incorporate into his payload operations phases (quick look verification, production quality tests, machine diagnostics, ...)?

3. What development methodology should the customer employ so that he will have continuity through his proposal, development, fabrication, testing, integration, operations, data reduction, analysis, and archiving phases? For example, can the system be built so that a user can employ a single set of equipment and software to check his instruments before delivery, during integration, and periodically during operation? Can instrument calibration traceability be achieved?

4. For the various classes of payloads, what should the relative roles be for the scientist/astronauts, flight crews, mission controllers, instrument controllers, and the users during the operations phases? Who will have decision-making authority for different user-related activities and for different mission timelines?

For items 1 and 2 above, the methodology to be used that implements a procedure that leads to an "optimal" payload function allocation and automation realization is similar to the one used in the Task 3 Function Allocation and Automation trade study. The exception is that the procedure would be interactive between the customer and a customer information support function. Resource costs and constraints would be clearly identified in this interaction.

For item 4 above, the roles of crew personnel and their relative authority in making decisions relative to payload operation, is deferred to a future programmatic study.

4.1.3 Scheduling and Session Establishment

The customer is an individual or organization with an interest to place a payload/experiment in an SSPE and to use the standard communication and processing facilities, and other standard services provided by the SSIS. Onboard, the customer payload is supported by Space Station or platform facilities such as a pallet with power, active thermal control, communication interfaces, and if required, a pointing and tracking capability or a pressurized module. The customer provides an experiment compatible with the SSPEs electrical, mechanical, thermal, dynamic and other interfaces, as specified in the SSPE's Interface Control Drawing (ICD). On ground, the customer can conduct his payload operations from his own facility or from one contained within the SSIS.

The end-to-end architecture from the customer's point of view was shown in Figure 4.0-1. Standard onboard payload services and ground interface services are provided as shown in the figure and as further expanded later in paragraph 4.2. The data transport service presents a simple, easy-to-use, and transparent interface both onboard and onground (i.e., the real complexities of the command and data transport process are, in all cases, hidden from the customer).

The customer operations with his payload can be conducted onground from a Payload Operation Control Center (POCC), Regional Data Center (RDC) or in his own facility, or in space using an MPAC or his own custom workstation. This is depicted in Figure 4.1.3-1 which shows a payload connected to a local area network (LAN) via a standard network interface unit (NIU) and operations being conducted from onboard. This figure illustrates two standard options for interfacing a payload: one where the customer connects his payload using only a standard I/O interface (e.g., RS422, MIL-STD-1553, ...) and the other where he supplies all of the data processing equipment except for the network interface (an SS-supplied card-set) at the LAN medium.

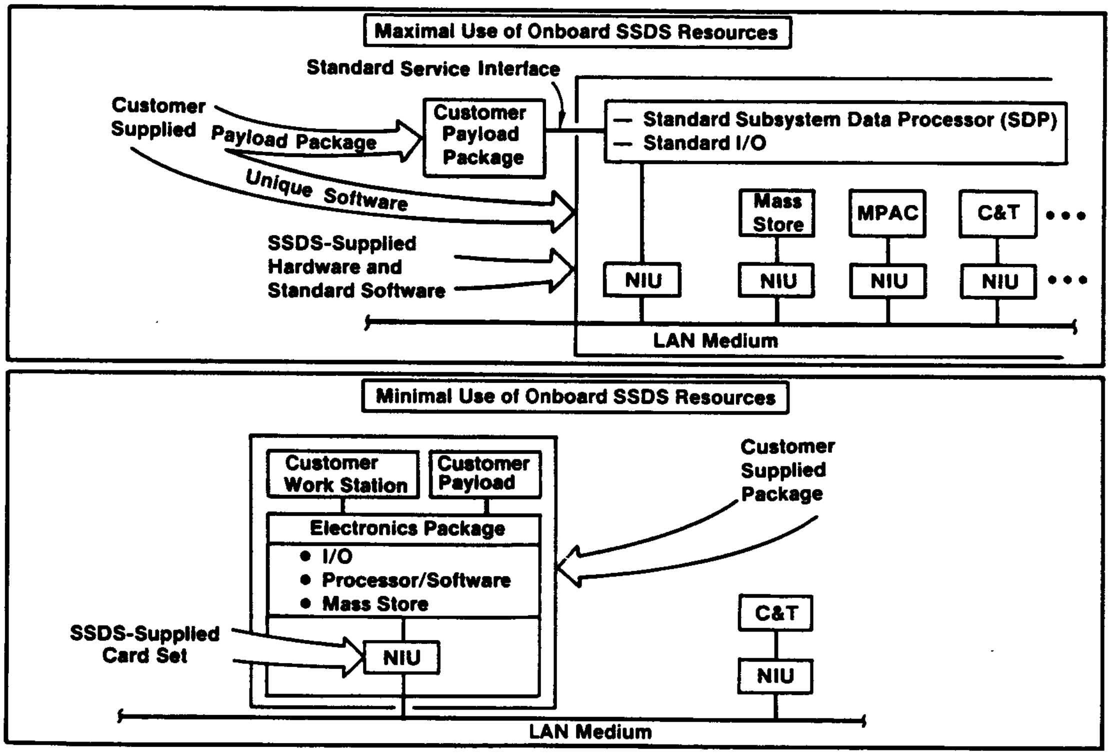


Figure 4.1.3-1. Customer Standard Onboard Interfaces

In either case, when the customer's payload is delivered to orbit, and is mechanically, thermally, and electrically integrated, communication with the payload can be initiated via the end-to-end data distribution system. Command control and sensor data are distributed using this system and data and program storage services are available from onboard mass storage devices (for proprietary and other reasons, the customer may elect to embed his program code in his package and make it non-accessible to the external world or he may elect to encrypt it and uplink it every time his payload is activated).

The customer will provide the application software to command and control his payload; this software can be divided into four components:

1. Onboard data processing
2. Onboard workstation processing
3. Ground data processing
4. Ground workstation processing

When the payload is active, the data processing software is resident in the customer's processors (1 and/or 3 above) and the workstation processing software is resident in the customer's workstations (2 and/or 4 above). When the experiment is inactive the customer's software may be stored on a mass storage device. Data processing deals with command processing, sequencing, data manipulation (e.g., transformation, filtering), status monitoring, and payload production and performance data acquisition associated with the experiment. Workstation processing includes graphics processing, display, command entry, and interactive processing to support the experiment for quick-look, production, diagnostic, and other operations phases.

If the customer uses standard services, including the SSE and a high order language (HOL), he will then develop application software which may utilize real-time statements and which must be compiled from HOL source statements into a machine load module. The customer, therefore, must be familiar with the software development language, including the real-time features of this language. Software development will generally be conducted on ground but onboard development/compilation is not excluded.

Payload Requests for Service

This subsection will discuss the operations associated with activating a payload and attaching it and its associated control centers, workstations, ..., to the SSDS Data Distribution Network. These discussions will be in terms of the data flow diagrams included in Appendix D. A brief discussion of these diagrams is presented here to show the flow of requests for service. Customer/operator requests for services or delivery of commands, are initiated in two places (see diagrams and locate blocks 0001); schedule requests (for future service or on-demand activation) go directly to Function 3.0, Schedule and Execute Operations. Payload and core commands (real and non-real time) pass through Function 2.0, Manage Customer/Operator Supplied Data for authentication (log-on, etc) checks, and for restricted/constrained tests and are then transported to Function 3.0 where they are scheduled for future execution (non-real time) or are sequenced for real time execution. Payload activation will be controlled by Function 3.4.1, Sequence Payload Operation, and network attachment will be implemented via Function 3.4.2, Sequence Core System Operation, whose command outputs are eventually passed to Function 4.2.5.1, Communication Network Control.

Payload sequencing operations (Function 3.4.1) involve functions like connection of the payload to the TCS, application of prime power, ..., and are not discussed any further in this section. The continuing discussion here will be directed towards the operations in Function 4.2.5.1, Communication Network Control, that attach the payload, the customer, and other entities onto the network and bind these entities into a SESSION.

Payload Session Services

Payload session services are one component of a set of services collectively called Network Management (see Figure 4.1.3-2, especially item number 1) that are distributed between the onboard SS function 4.2.5.1, Communication Network Control, and various ground element functions. These generic network management functions are further defined in Figure 4.1.3-3 which shows a function characterization and allocation. In this figure, functions 3 and 4 are self explanatory and are not involved in session establishment. Function 2 includes setting-up, maintaining, and disconnecting sessions, while Function 1 is the implementation of ISO/OSI layers 1-7 after a session is established.

For SSDS, connections are generally established between all the entities that are involved in command/data transactions between ground components and space payloads or core subsystems. The tenure of a session may be momentary or it may be permanent depending on the application. A session binds entities into a contract to provide resources and services for a data transaction operation. At session establishment time, protocols and other services to be

1. **Session services**
- Request to have sessions are received.
- The session requests are validated.
- Resources are allocated to sessions.
- Subchannels, table entries, session identifiers, etc., are assigned.
- The route for the session is selected. Alternative routes in case of failure may also be selected. (This is for systems without dynamic routing of packets.)
- The communicating parties are *bound* and their session initiated.
- When session is over, the communicating parties are *unbound* and their session terminated.
- When failures occur, session recovery is initiated.
- Accounting information is gathered for billing purposes.
- Requests for network sessions with devices of foreign architecture are handled.

2. **Handling of physical resources**
- A directory of physical resources is maintained (processors, terminals, cluster controllers, peripherals, channels, circuits, line groups, etc.)
- The management software permits these physical resources to be activated and deactivated.
- Dynamic reconfiguration may take place when failures occur.
- Recovery action may be initiated.
- Information is provided to the network operators to enable them to deal with the physical resources.
- Information is provided to the maintenance engineers about the physical resources.
- Resources are monitored for performance measurement.

3. **Maintenance**
- Terminal facilities are provided for maintenance engineers to access the network.
- Errors and failures are logged.
- Reports and analyses of the errors and failures are done and made available at the engineer terminals
- Problems are automatically reported to a network operator.
- Diagnostics and confidence tests are run, possibly triggered automatically, possibly by an operator or engineer.
- Decisions to take down network components or circuits are made, based on the severity or frequency of errors.

4. **Security**
- A surveillance log is maintained of all security procedural violations.
- The surveillance log is analyzed for the security officer, highlighting occurrences needing immediate attention.
- Triggering of alarms on detection of certain types of procedural violations.
- Files of passwords, cryptography keys, or other security information are securely managed.
- Terminals are provided for security officer functions.

5. **Administration**
- Terminals are provided for network operators.
- The operators can display details of the network and its various resources.
- The operator can start and stop the network.
- An operator can activate and deactivate network components.
- An operator can start and stop application programs.
- An operator can reconfigure the network dynamically (i.e., without shutting it down).
- An operator can change specifications of network control mechanisms.
- An operator can down-line load programs.
- An operator can initiate a dump of programs in peripheral machines, possibly transmitting the dump to a larger machine for printing.
- An operator can initiate trace or statistics-gathering programs.
- An operator can initiate performance measurement aids.
- Network performance can be measured, analyzed, and possibly experimented with.
- Information is collected for billing users and bills are prepared.

*Reference: Martin, James, *Computer Networks and Distributed Processing, Software, Techniques, and Architecture*, Prentice Hall, Inc., Englewood Cliffs, N.J., 1981

Figure 4.1.3-2. Generic Network Management Functions*

	Functions	Characteristics/Allocation
1	REAL TIME CONTROL Includes operation of the hardware and software functions associated with network data flow after a session is established. This encompasses OSI layers 1-7.	Real time, automated, distributed space and ground NIUs and SDPs
2	SESSION MANAGEMENT Refers to functions not included in 1 above that are required to initiate/terminate sessions, and provide for checkpoint/restart, automatic recovery, and switchover.	Real time; automated, distributed space and ground, but principally allocated to function 4.2.5.1, Communication Network Control.
3	MAINTENANCE Refers to the primarily automated activity of keeping the network running. Nodes in the network log errors and provide overall statistics to this function which responds with commands to execute diagnostics to fault-isolate failed components.	Real and nonreal time, automated and interactive, allocated to space and ground elements
4	ADMINISTRATION Refers principally to the human activities associated with operating the network. The administrator monitors network performance (e.g., statistics for utilization, lost data events, . . .). The administrator is a special type of end user and requires activity reporting functions throughout the network.	Nonreal time, interactive and manual, allocated to NCC

Figure 4.1.3-3. Network Management Functions

used in the session are agreed to by the communicating parties. Examples of services and resources are as follows:

- Full- and half-duplex, and virtual and real communication channels with requested bandwidths
- Protocol selection (EBCDIC, ASCII, NAPLBS, ...)
- Context selection (Virtual File Transfer, ...)
- Processing resources (Ops/sec) at DHC, POCC, RDC, ...
- Memories (main, mass, raw data buffers, ...) onboard or at DHC, POCC, RDC, ...

There are alternatives to the establishment of a session (e.g., connectionless or datagram services) but it is felt that established sessions will provide the transport reliability required by most customers (see Figure 4.1.3-4). A distinction between connection and connectionless service is shown in Figure 4.1.3-5 for an (N)-Layer (N=2,3,...7) entity in the OSI model (the customer's interface with the OSI model is discussed later in paragraph 4.3).

Data Type	Volume	Delay Requirements	Reliability Requirements	Transport Service (Layer 4)
Voice	S	H	L	Connection, Class 0
Video	L	H	L	Connection, Class 0
Bulk Digital Data	L	L	H	Connection, Class 4
Payload Data Quicklook	M	H	M	Connection, Class 0
Production	L	L-H	L-H	Connection, Class 0-4
Commands — Payload — Core	S	H	H	Connection, Class 0-4
Engineering Telemetry and Payload Performance	S	H	M	Connection, Class 0
Data Base Queries and Maintenance	M	H	H	Connection, Class 4
	S = Small M = Medium L = Large	H = High (or "Strict") Requirements M = Medium Requirements L = Low Requirements		

Figure 4.1.3-4. Data Types and Transport Service

One final point concerning Function 2, Session Management, in Figure 4.1.3-2 is that this function can be implemented in a centralized or distributed manner as shown in Figure 4.1.3-6. Both approaches are used in modern data networks and both have desirable features for the SSDS, as shown. In the distributed approach, the payload, for example, when activated would autonomously establish and maintain its session with the appropriate elements (e.g., POCC, SDC, MPAC, ...) and would disconnect those elements when requested by the POCC or the Function 3.0 scheduler. In this approach the network nodes do not have the global visibility required for optimal resource allocation and are more susceptible to security breaches. Centralized management offers other features as shown in the figure. The multi-centered option has been selected for the SSDS and is discussed further in paragraph 4.5.10

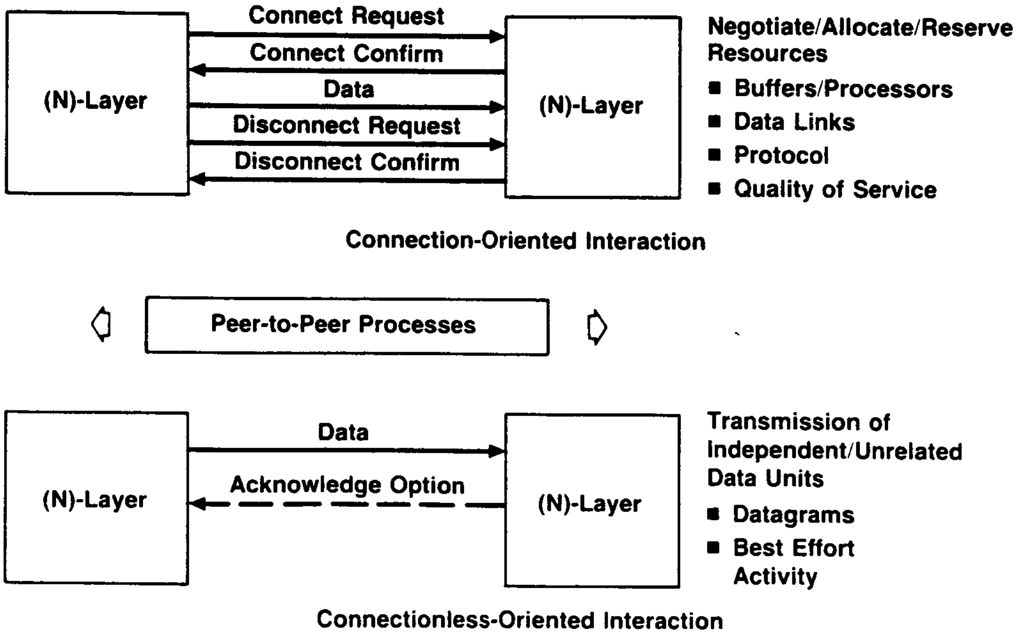
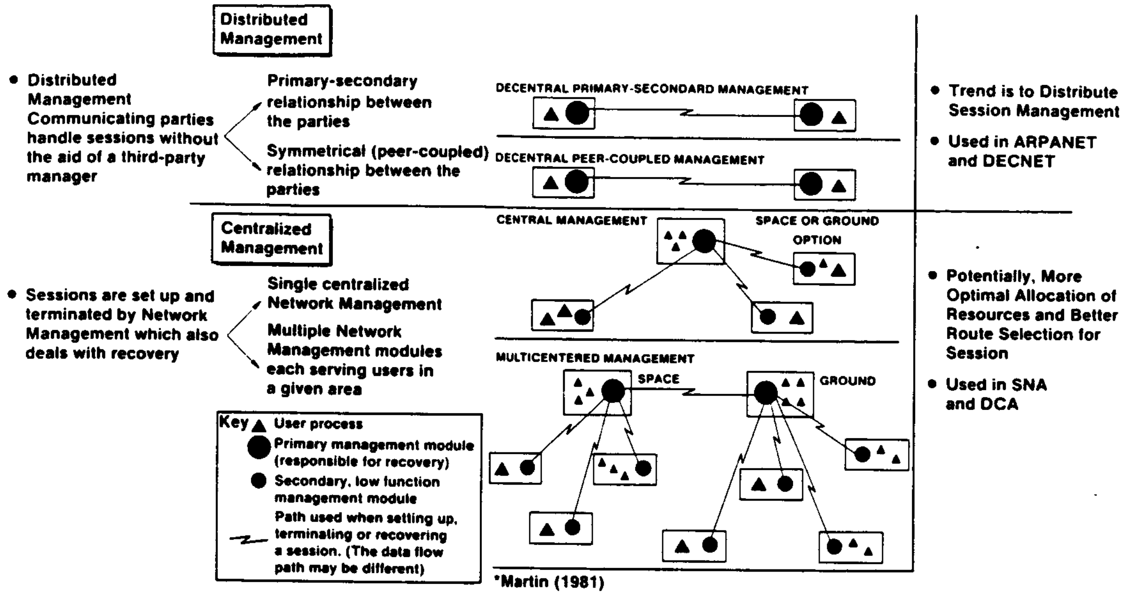


Figure 4.1.3-5. Connection/Connectionless Service



*Martin (1981)

Figure 4.1.3-6. Centralized/Distributed Network Management Options*

4.1.4 Payload Development and Activation

Ground Tests

The customer software and hardware must be integrated and verified before being transported to space and ground elements. The integration testing will generally be done initially in the customer's facility where he can, as required, employ commercial-quality equivalents for MPACs, onboard data processors, or a local area network/data network simulator which emulates the end-to-end wide-area and local-area networks including communication delays. A second phase may be conducted where the customer performs crew training and validates his payload interfaces and operations via the SSDS Develop, Support, Integrate and Train facility.

Software Transport to Space and Ground Facilities

In the development herein, it should be recalled that there are four components of customer software that support the payload: ground and space workstations and ground and space processors.

The ground programs for both workstation and processors are delivered to ground facilities by electronic transfer or by portable media (tape, etc.). The programs are loaded into the ground facility mass storage devices and appropriate directories are updated to allow the ground facilities management function and system executive to recognize a request (from a ground workstation or a telecommand from orbit) for these programs to be loaded into the ground workstation and ground processor for execution. On the ground this will likely be managed by a modified commercial system executive. This machine management is transparent to the customer.

The customer programs to be uploaded to the space system are loaded in a similar fashion. An electronic transfer is accomplished via a telecommand which contains the code and will also contain labels defining restricted and constrained command sequences embedded in the code. The incoming programs are addressed to a mass storage utility function which places the programs on mass storage and then updates appropriate directories to allow the onboard facilities management function and system executive to recognize a request for these programs to be loaded into the payload processors and on-orbit customer workstations for execution. The origin of this request for loading and execution may be a telecommand from ground or from an on-orbit workstation configured to communicate with the ground facilities management function.

Payload Activation/Deactivation

Payloads are activated via the request sequence discussed earlier in section 4.1.3. Requests can be initiated from ground workstations or onorbit workstations. Typical scenarios would be 1) where a customer would LOGON from his workstation in anticipation of his upcoming scheduled session with his payload and query the schedule function to verify there had been no schedule changes, and 2) where a customer would LOGON to request a non-scheduled session with his payload.

The sequence depicted earlier in section 4.1.3 will validate the authorization of the customer and coordinate the planning for an unscheduled session. If authorization is not approved due to scheduling or unrecognized user ID, then the user would be blocked and his workstation would receive an abort message (with abort reason). If the customer is authorized to proceed with activation and control of his payload the onboard DMS establishes a session with all elements required in the session, and they are automatically configured to support the payload operations. Workstations and processors throughout the SSDS will be loaded with appropriate software communication resurces will be reserved for the duration of the session.

At this point the customer is now in contact with his supplied application programs which can power up and sequence the experiment and gather, analyze and process data. This data can also be acquired and delivered to ground and/or space processors through the data distribution and communication link for analysis. The customer may self-buffer his data or use the onboard mass store and data base manager.

The session establishment may have included a part-time or full-time high-bandwidth communication channel to route quick-look data to the POCC prior to entering the production phase. Other scenarios could include consideration for payload integration, diagnostics, checkout, maintenance, quality tests, combined ground crew and space crew operations, and so forth.

When the experimenter has completed his mission or his scheduled time has elapsed, the payload will be deactivated. Prior to scheduled time expiration the customer will receive a message alerting him that his payload is scheduled to be deactivated at time XXX.XXX. If the programs are controlled from the ground, then the ground site must first request that the onorbit programs be terminated and entities in the session be disconnected. This will remove these programs from execution and release the resources used in the session. The programs will still remain on the mass storage devices until these files are requested to be purged. The customer can then deactivate the ground programs by requesting the ground site facilities management to terminate his programs. This will cause the ground resources to be released.

4.1.5 Interactive Communication

The discussion in this section is in terms of the diagram in Figure 4.1.5-1 which uses processors and workstations both onboard and on ground, in this example, at a POCC.

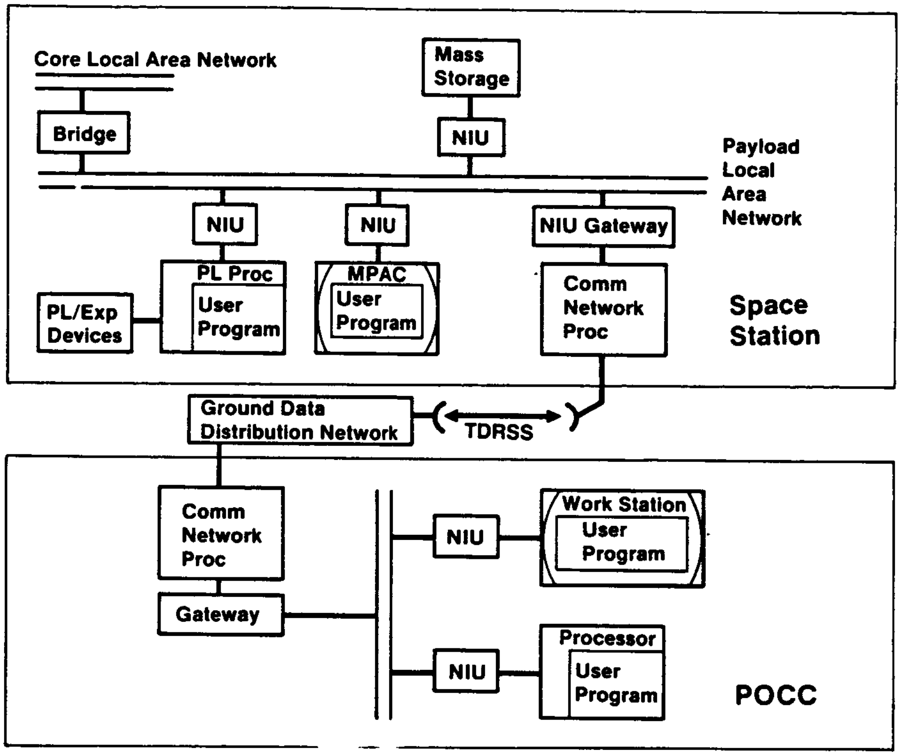


Figure 4.1.5-1. Interactive Operations

When the payload is delivered to the SS and physically connected to the LAN, the NIUs physical address embedded in the NIU is provided to the network manager who will associate it with an object name and one or more application process IDs. At session establishment time, the network manager attaches each of the customer's tasks (located in processors and workstations) to the network. At the time a task is loaded into a processor or a workstation, the system executive recognizes that the object address corresponding to the task must be attached to the network and requests the network manager to do so. A message from the network manager to the NIU programs, which are capable of updating object address tables, accomplishes this attachment. If there are bridges or gateways that must be informed that they should receive and retransmit messages for the object address being attached, then this is also accomplished by the network manager by sending messages to the appropriate bridge or gateways as sessions are established.

Real–time monitor and control can be accomplished from the ground or onorbit or both depending on where the workstation software is resident for a specific session.

4.1.6 Accommodation of Telescience

The concept of telescience derives from the notions shown in Table 4.1.6–1.

The principal components of the SSDS that accommodate the above telescience concepts are as follows:

Table 4.1.6–1 Telescience and the User

1. Payload Control from home institution
2. Data delivery to user with merged multi sensor and ancillary data, with SSDS–supplied standard processing (option), for quick–look and production processed data
3. Transparency — the real complexities of the data system are hidden from the user
4. Easy electronic access to numerous data archives and data bases for building comprehensive data libraries
5. Interactive and realtime operation
6. User operations in concert with colleagues in a coordinated multi–sensor and multi–discipline data capture activity
7. User selections of equipment (workstations, processors,...) of his choice

1. Control—A customer will have the capability to control his payload from his own facility or a NASA-supplied facility, home institution, or he can be mobile and operate at both facilities within certain constraints such as the man-machine interfaces of the workstations at the various locations.

2. Access—A customer will have free and easy access to his payloads subject to resources, constraints and restrictions, as described later. A principal design objective of the SSDS is that it be as friendly to users as is possibly; some limitations in this "friendliness" is necessary based on considerations of safety, equipment damage, payload cross-compatibilities and quality of data capture, and other reasons, as outlined later. Electronic access to SSDS/SSIS data bases will be provided.

3. Transparency—The SSDS will "hide" all of the real complexities of the command and data packet formation and the transport of these data. The intricacies of the data system (i.e., layering, error control management, encryption, data synchronization, data reconstruction,...) are totally hidden from the user.

4. Interactive and Realtime Operations—A customer will be able to communicate and control his payload as though it were physically located in the same room as his workstation. The SSDS will only add sub-seconds-to-seconds delays to the transport delay that would be associated with an immediately adjacent experiment. As an example, for the solar flare activity where conditions change rapidly, capabilities will be in place to implement instrument adjustments in a matter of minutes.

5. Communication and Coordinated Team Involvement—Voice and video teleconferencing will be implemented between multiple ground sites and the space station to coordinate multiple team activity in an integrated multi-sensor data capture of scientific phenomenon.

6. Operation in a Heterogeneous Environment—The customer will be able to configure the operations center with the hardware/software of his choice subject to the constraint that he comply with the network security requirements and "open" communication protocols specified by the SSDS. In the heterogeneous environment, computer-to-computer networking will be accommodated via the use of international and national standards as opposed to private and proprietary protocols.

4.2 Interface Services

Table 4.2-1 shows a summary of onboard and ground interface services. It includes the principal SSDS services and only those SSIS services necessary to show completeness from an end-to-end operations perspective. The services are discussed in more detail in the following subparagraphs.

4.2.1 Mechanical, Electrical, and Thermal Services (SSIS)

The physical mounting of the payload will be defined in an interface control drawing (ICD) which is prepared by the customer and agreed to by the Space Station Program Office. The ICD also specifies power, signal, and thermal interfaces including connectors. These interface standards must be conformed to and will be tested during system integration. The power supplied to the customer is protected against overload by remote power controllers. The facilities management function coordinates the use of power and therefore experiment activation will be blocked when power is not available. This coordination is accomplished between the system executive and the scheduling functions.

Table 4.2-1. Interface Services Summary

ONBOARD SERVICES

1. Pallet - Mechanical, thermal, power, pointing, motion decoupling, ... (SSIS).
2. Crew - Onboard operations, IVA/EVA, servicing, diagnostics, repair, ... (SSIS).
3. TV/Audio Distribution - Internal, external, space-to-ground, space-to-space, realtime/delayed, conferencing, ... (SSIS).
4. Processors - SDPs, local RAM, standard I/O including serial/parallel and backplane I/Fs, distributed operating systems, ...
5. Mass Store - Programs, files, instrument data, procedures, ...
6. Work stations - MPACs with standard software packages: interactive command/control. graphics, word processing, ...
7. Data Base - File management and query.
8. Payload Sequencing - Activation, scheduled, targets of opportunity, on-demand, ...
9. Command Management - Restricted/constrained checks.
10. Distribution of ancillary data including time.
11. Error Free Data Distribution - Between payload, SDPs, mass store, C&T gateway, ...
12. Logistics - Sparing of cards/modules for SDPs, standard I/O, ... (SSIS).

GROUND SERVICES

1. Data capture and error-free transport to customer designated facilities, quick-look and production.

2. Processing level 0 (standard) and level 1A (optional), archives electronically accessible.

4. Ancillary data via electronic access.

5. Software Support Environment - Local/remote access, SDP development support: HOL compiler, simulators, assembler, ..., standard programs (library).

6. Develop, Simulate, Integrate and Train - Payload development, SSDS integration, crew and mission specialist training, simulators, ...

7. Payload Operation Facilities - Workstation, processors, mass store, ..., at POCC, RDC, ...

ONBOARD AND GROUND COMMON SERVICES

1. End-to-End Error Free Data Transport.

2. Security/Privacy - Physical payloads, programs, data, procedures, ...

3. End-to-End Voice/Video Services.

4. End-to-end scheduling including suport of on-demand services.

5. Control of payloads: onboard, on ground at POCC or at home institution.

In general, the customer's payload will dissipate energy and active thermal control will be required. The customer will be provided with a thermal control subsystem (TCS) interface which is activated prior to the equipment being powered ON. In the event of an overload the customer may be deactivated to reduce the load on the TCS. The facilities management function coordinates the use of the thermal control capacity and may block activation of the payload when capacity is exceeded.

4.2.2 EVA Services (SSIS)

The customer experiment can be serviced by EVA for refurbishment or repair.

4.2.3 Pallet Pointing (SSIS)

Active decoupling of platform motion can be provided by an isolated pallet for customer payload precision pointing.

4.2.4 Operations and Crew Interaction (SSIS)

The payload can be designed to be operated from space and/or ground, with the use of onboard/ground crews or a customer supplied onboard payload specialist, and from the customer's own facility or an SSIS facility.

4.2.5 Ancillary Data

Two options are available for obtaining time stamped ancillary data: it can be provided onboard for real time merge by the customer, or in non-real time on the ground via electronic access to data archives.

4.2.6 Command Sequencing

The command and control program for a payload may be stored in an onboard SSDS mass store, uplinked in real time for interactive operations, or embedded in the customer's supplied payload controller.

4.2.7 Payload Activation

Activation of a payload can be schedule driven with near-realtime adjustments to the schedule, event driven for acquisition of targets of opportunity, or on demand subject to availability of resources and checks for cross-interference with other payloads and restricted modes of operation.

4.2.8 Space/Ground Communication

Space/ground communications can utilize the standard TDRSS/TDAS (a scheduled resource) or the customer can supply his own space/ground communication link (which will also be scheduled as a power consuming device and checked for cross-interference).

4.2.9 Time Management

The customer may provide his own time reference system or use the SSDS supplied reference which has an accuracy of ±1 msec. Since this reference is distributed via the LAN the customer will also be required to understand the statistics associated with delays in receiving this time reference. The reference may contain ephemeris time plus offsets to other references (i.e., universal time) and will be formatted per CCSDS requirements.

4.2.10 Data Transport

Space/ground customer-to-application interfaces will utilize the CCSDS packet formats (slightly modified, as discussed later) for message transport. Within the data field of the packet, the customer can package his data using his own procedures within the following option categories:

1. No processing, package "raw" data

2. Signal processed/reduced

3. Compressed

4. Encrypted with own key

5. Error protected beyond the standard SSDS 10^{-6} BER

6. Real-time merge of SSDS supplied ancillary data

He may also elect to package the data using an "open" format specified, for example, by a CCSDS Standard Format Data Unit (SFDU) or keep the format "closed" and private to himself.

4.2.11 Production Data Transport

Production data delivery can be real-time, or delayed by seconds, minutes, ..., next orbit, next shuttle visit, depending on priorities and other factors. An end-to-end BER of 10^{-6} shall be provided by the SSDS.

4.2.12 Ground Processing of Production Data

Standard ground processing of production data will be to Level 0 and with added cost, to Level 1A.

4.2.13 Archiving

Standard short term ground archiving is for one week after receipt of customer quality acceptance, and for Level 0 data and Level 1A (if specified per paragraph 4.2.12).

4.2.14 Logistics (SSIS)

Standard card set modules will be stored onboard and available (on a priority basis as established by function criticality) for maintaining payloads, via automated diagnostics, or interaction with trained crew person or a payload specialist. Customers can elect to 1) have a sealed payload package with no intention of onboard servicing, 2) provide spare modules and crew maintenance training or a payload specialist.

4.2.15 Standard Programs

The customer will be able to use standard library programs which can be linked into his programs by referencing these library programs. Examples could be: Fast Fourier Transform, digital filters, Kalman filter, eigenvalue and eigenvector extraction, quaternion routines (multiply, vector transformation, euler angle extraction).

4.2.16 Data Base Support Programs

A data base capability is provided as an option to the customer. This capability includes sequential data file management and a data base query language. Although the data base structure is hidden from the customer, he will have to be familiar with the data base command interface when building application software to store and subsequently retrieve data blocks for manipulation or transmission to a ground site (delayed delivery).

4.2.17 Customer Program Development

The customer will develop the payload applications software and SSE facilities are available as an option to accomplish this. The customer can be resident at this facility or these facilities may be linked to remote sites so the customer can develop programs from the customer's site with customer supplied terminals or the customer may subcontract for software development to a programming organization. In the following subparagraph the term "customer" refers to whomever is developing the customer software.

4.2.17.1 Development Support Environment

The customer is provided with numerous options within the software development support environment; these include:

a) Data set creation/storage capability for source programs and data

b) Security of programs (access control)

c) Editor to modify and update source code

d) Compiler to convert to object code of target processor

e) Linker to integrate program into processor load module

f) Simulation environment to verify system integration

g) Standard library program which can be linked to customer programs

Special customer supplied models can be integrated into the simulation environment.

4.2.17.2 Development Language

The development support environment will support commonly used development languages such as PASCAL and also real time languages such as Ada (Ada is a registered trademark of the US Department of Defense, Ada Joint Program Office). A high order command and control language for developing test and control sequences will also be available.

4.2.17.3 System Executive

If the customer elects to only supply application programs to be executed in an SDP, then his programs will have to be integrated into an executive structure and an understanding of this structure by the customer will be necessary. Included here are the techniques for:

a) Creating tasks

b) Activating a system task (control segment) which controls the scheduling of aplication tasks.

c) Real-time control such as: events, messages, semaphores

d) Local I/O control

e) Access to distributed resources (mass store, workstation,...)

The customer will be required to become familiar with the real-time features of the language; since these include macros that interface with the system executive. A specification describing these features will be available to the customer.

4.2.18 Onboard Data Processing Resources

The customer may elect to use a standard onboard data processor, mass memory and workstation or he may elect to provide almost all of the processing resources. These options were discussed previously, in paragraph 4.1.3.

4.3 Data and Command Transport Services

This section discusses end-to-end data and command transport services in terms of a standards model that illustrates the protocols used and the degree of standardization, compatibility, and commonality that should be realizeable in the SSPEs and SSDS.

Emphasis will be on the use of international standards, specifically, the Consultive Committee for Space Data Systems (CCSDS) Recommendations for Space System Standards, the International Standards Organization's (ISO) Open System Interconnect (OSI) seven-layer reference model and emerging (international and national) specifications for the various layers, being developed by the Institute of Electrical and Electronic Engineers (IEEE), the American National Standards Institute (ANSI), National Bureau of Standards (NBS), European Computer Manufacturers Association (ECMA), and others.

The end-to-end operations perspective encompasses the following physical nodal extremes: core subsystems and payload packages integrated via point-to-point links and the onboard local area networks (LANs) in the various SSPEs, space/ground communications and the use of special TDRSS uplink/downlink protocols, and the ground-to-ground world-wide area communications network. The wide area network includes long haul communications that interconnects ground-based local area networks and end-point nodes.

The SSDS network has unique characteristics, as compared with public and other data networks, including:

- significant control by NASA,
- the use of high level coding such as Reed-Solomon to guard against errors,
- transport of both interactive (realtime) and non-interactive messages,
- functions such as data capture which support recovery of lost application data,
- data that is transported through the network that can be interpreted as commands and, hence, must be checked, in some instances in realtime, for restrictions and constraints (payload cross-interference),
- high- and low-rate quick-look and production data,
- image and non-image data and in both realtime and (delayed) non-realtime, and
- commercial quality imagery, low-resolution, freeze-frame, and high resolution TV.

A preliminary configurations for the onboard data system is given in Figure 4.3-1, and the variety of data types that must be transported through the SSDS are functionally shown in Figure 4.3-2, with an important subset of these types also characterized and presented earlier in Figure 4.1.3-4 in terms of data volume, delay and reliability requirements, and the range of transport services that will be required.

The onboard data network model shown in Figure 4.3-1 is comprised of a series of LANs dedicated to modules but with a backbone interconnecting the module LANs via bridges. Specific points to be made are that:

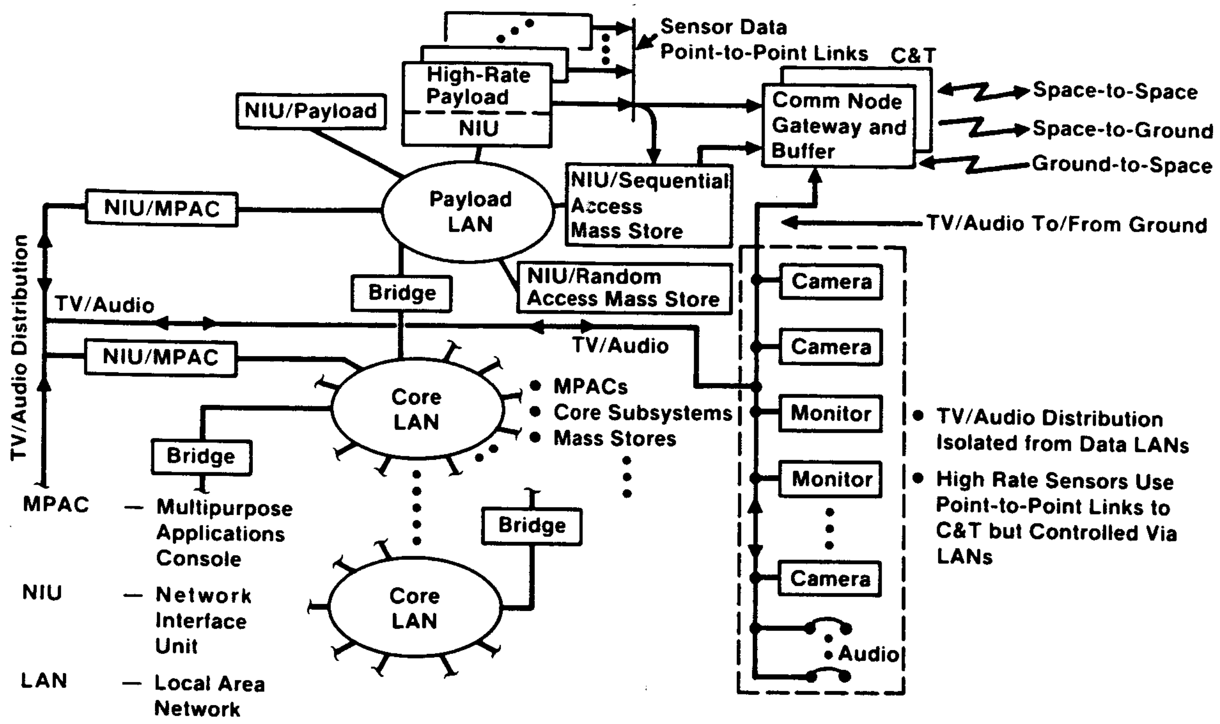


Figure 4.3-1. Onboard Data System

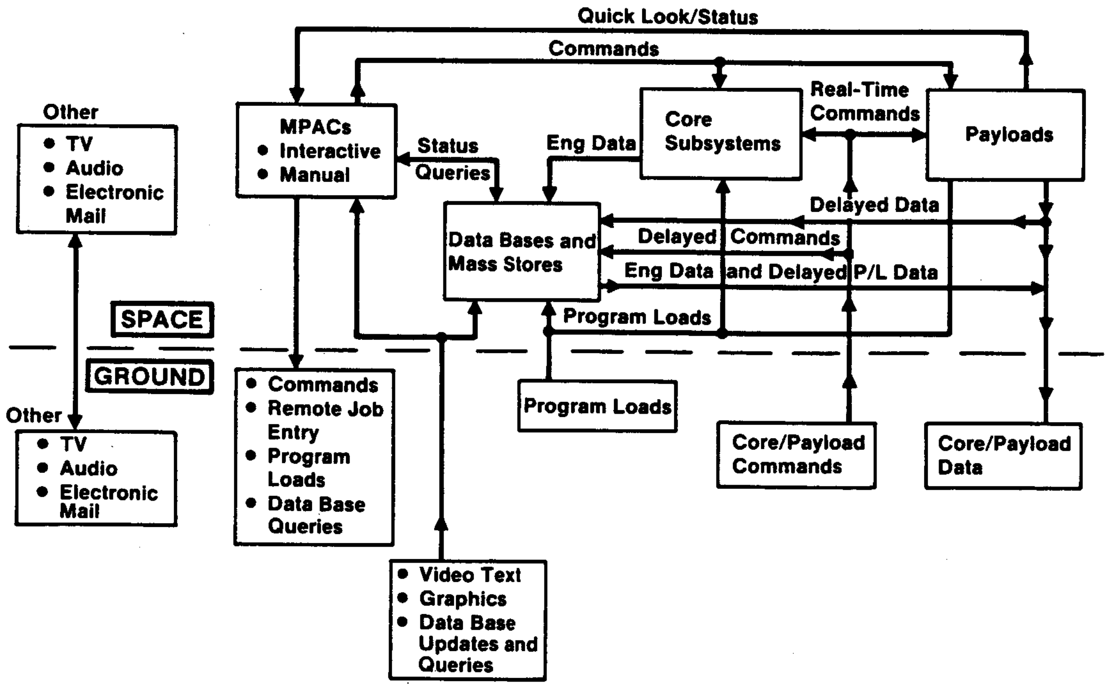


Figure 4.3-2. SSDS Message Types

1. TV/audio has it own distribution subnetwork and is isolated from the LANs.

2 High rate payloads have dedicated point-to-point data links with the communication and tracking subsystem (gateway to earth station).

3 Data transport for low rate payloads, core subsystems, and control of high rate payloads is implemented using the LANs.

4 All units interfacing with the LAN have a Network Interface Unit (NIU) which implements the lower layers of the distributed operating system.

4.3.1 On the Use of International Computer Networking Standards

The CCSDS telecommand (TC) and telemetry (TM) packet standards are documented in References 2 to 12 and are in various stages of being ratified as international standards. In the end-to-end space-to-space and space-to-ground flow developed herein, the customer/operator interfaces with the SSDS is at the top layer of the CCSDS model (TM/TC Packets) as shown in Figure 4.3.1-1. The key points to be noted in this figure are as follows:

1. Customer/operator generates telecommand (TC) packets, either onboard or ground, which are transparently delivered to his application on the SS/POP or via the SS, routed to the COP, or to ground components.

2. Onboard the SS, POP or COP, the customer's equipment (or core subsystems) generate telemetry (TM) packets which are delivered to ground facilities designated by him (his own facilities, POCC, RDC, CC, ...). TM packets can also originate on ground and be delivered to a space application.

3. In all cases, the complexities of the data distribution network are transparent to the customer.

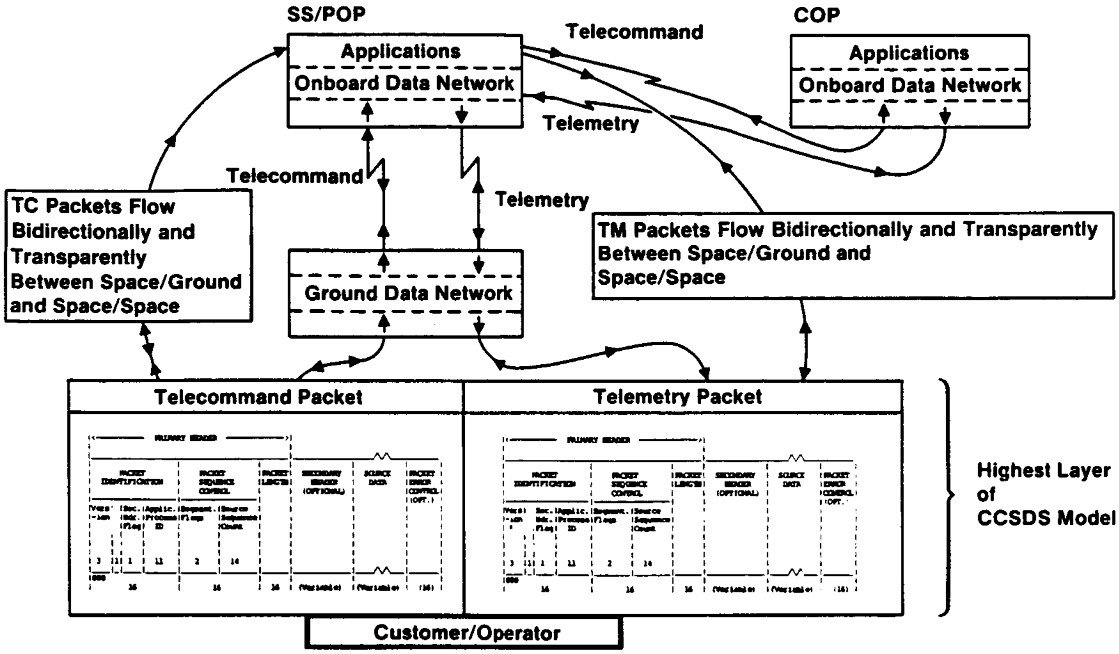


Figure 4.3.1-1. CCSDS Telemetry and Telecommand (End-to-End)

4. The TC and TM packets must conform to the CCSDS formats including primary/secondary headers, max packet size, ...

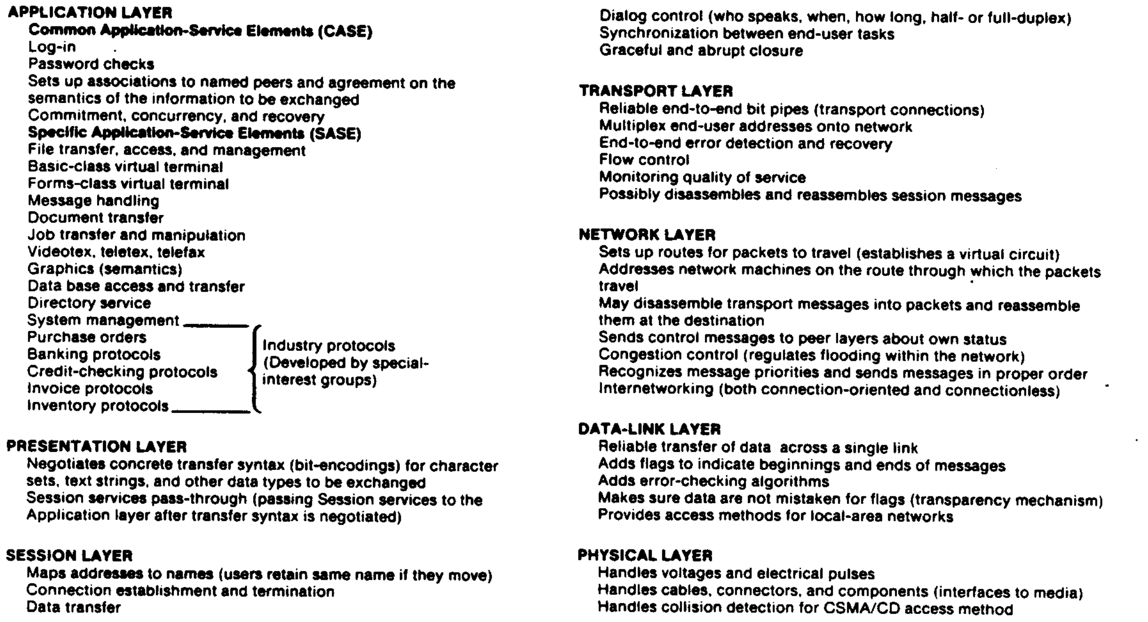
5. TM and TC packets are bidirectional, e.g., TM or TC packets can be generated onboard/ground and transmitted to ground/onboard.

The three layer CCSDS model is characterized as follows:

1. The upper layer (telemetry/telecommand packet layer) is intended for customer/operator interfaces as described above, for data to be transported between space and ground.

2. The lower two layers are intended for use in noisy space data links: space-to-ground, ground-to-space and space-to-space.

To provide for complete automated internetworking in a heterogeneous environment, additional capabilities are required which can be found in the International Standards Organizations (ISO) Open System Interconnect (OSI) seven layer reference model. The functions of the OSI layers are summarized in Figure 4.3.1-2, and draft proposals associated with these layers are also in various stages of being ratified as international standards (see, for example, reference 13).



APPLICATION LAYER

Common Application-Service Elements (CASE)
- Log-in
- Password checks
- Sets up associations to named peers and agreement on the semantics of the information to be exchanged
- Commitment, concurrency, and recovery

Specific Application-Service Elements (SASE)
- File transfer, access, and management
- Basic-class virtual terminal
- Forms-class virtual terminal
- Message handling
- Document transfer
- Job transfer and manipulation
- Videotex, teletex, telefax
- Graphics (semantics)
- Data base access and transfer
- Directory service
- System management
- Purchase orders
- Banking protocols
- Credit-checking protocols
- Invoice protocols
- Inventory protocols

Industry protocols (Developed by special-interest groups)

PRESENTATION LAYER
- Negotiates concrete transfer syntax (bit-encodings) for character sets, text strings, and other data types to be exchanged
- Session services pass-through (passing Session services to the Application layer after transfer syntax is negotiated)

SESSION LAYER
- Maps addresses to names (users retain same name if they move)
- Connection establishment and termination
- Data transfer
- Dialog control (who speaks, when, how long, half- or full-duplex)
- Synchronization between end-user tasks
- Graceful and abrupt closure

TRANSPORT LAYER
- Reliable end-to-end bit pipes (transport connections)
- Multiplex end-user addresses onto network
- End-to-end error detection and recovery
- Flow control
- Monitoring quality of service
- Possibly disassembles and reassembles session messages

NETWORK LAYER
- Sets up routes for packets to travel (establishes a virtual circuit)
- Addresses network machines on the route through which the packets travel
- May disassemble transport messages into packets and reassemble them at the destination
- Sends control messages to peer layers about own status
- Congestion control (regulates flooding within the network)
- Recognizes message priorities and sends messages in proper order
- Internetworking (both connection-oriented and connectionless)

DATA-LINK LAYER
- Reliable transfer of data across a single link
- Adds flags to indicate beginnings and ends of messages
- Adds error-checking algorithms
- Makes sure data are not mistaken for flags (transparency mechanism)
- Provides access methods for local-area networks

PHYSICAL LAYER
- Handles voltages and electrical pulses
- Handles cables, connectors, and components (interfaces to media)
- Handles collision detection for CSMA/CD access method

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Figure 4.3.1-2. Functions of the OSI Layers

In the development herein the position taken is that the lower two CCSDS layers provide the space transport services required in the lower two layers of the OSI model (i.e., data link layer and physical layer) and the upper layer TM/TC packets are transported to/from the customer using interprocess message tranfer services in the OSI application layer.

Figure 4.3.1-3 shows a bidirectional space to ground packet flow with the CCSDS packets originating as a service in layer 7, and using layers 1-4 for LAN transport services to the communication gateway where CCSDS packets are then recovered and embedded in the CCSDS lower two layers for transport to ground (space). In the ground (space) segment, the lower two CCSDS layers are removed, the TM/TC packets are recovered and ISO services are then used again for data transport to/from the ground terminal node.

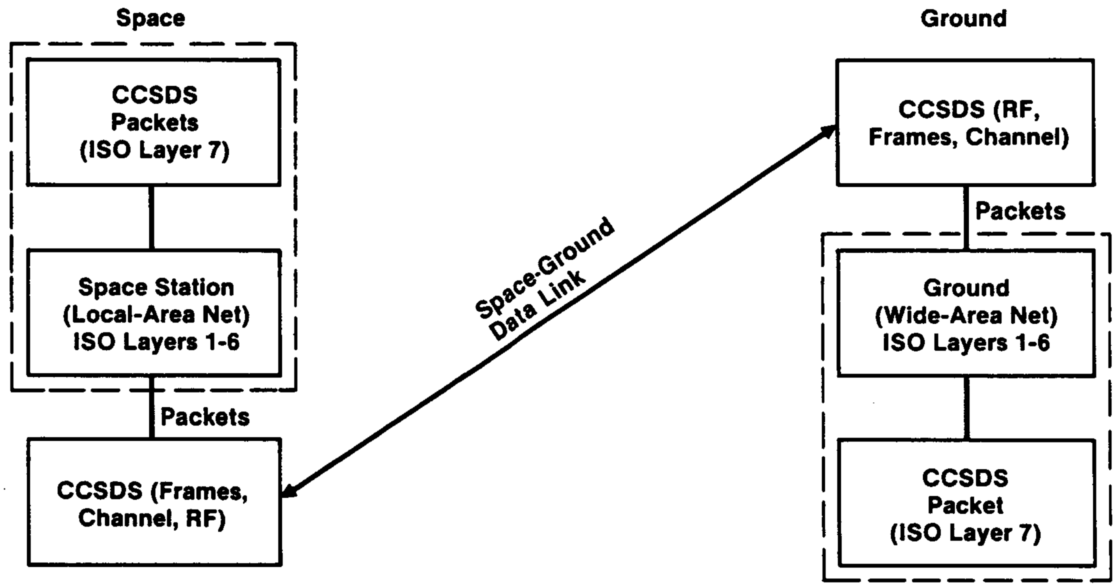


Figure 4.3.1-3. CCSDS Packets Standard in ISO Upper Layer Logical View

4.3.1.1 Onboard SSDS Interfaces

A generalized interface diagram is given in Figure 4.3.1.1-1 that shows the end-to-end interface options in a reference model configuration combining the ISO and CCSDS layered models. The interpretation to be given to the diagram is that data originating in the payload traverses a thread that goes from Layer 7 to Layer 1 on the LAN (exits the payload NIU) back up to Layer 7 (through the NIU in the communication gateway) down to CCSDS Layer 1 (exits the SS antenna) up to Layer 2 (frame processing in the earth station) up to Layer 7 where the packets are recovered for transport as an OSI message, down to Layer 1 to enter the WAN medium and then back up to the application layer for final delivery to the ground customer. Various other end-to-end threads could also be developed in a similar manner for cases of internetworking, circuit switched networks, ..., but are not included here. Other points to be noted are as follows:

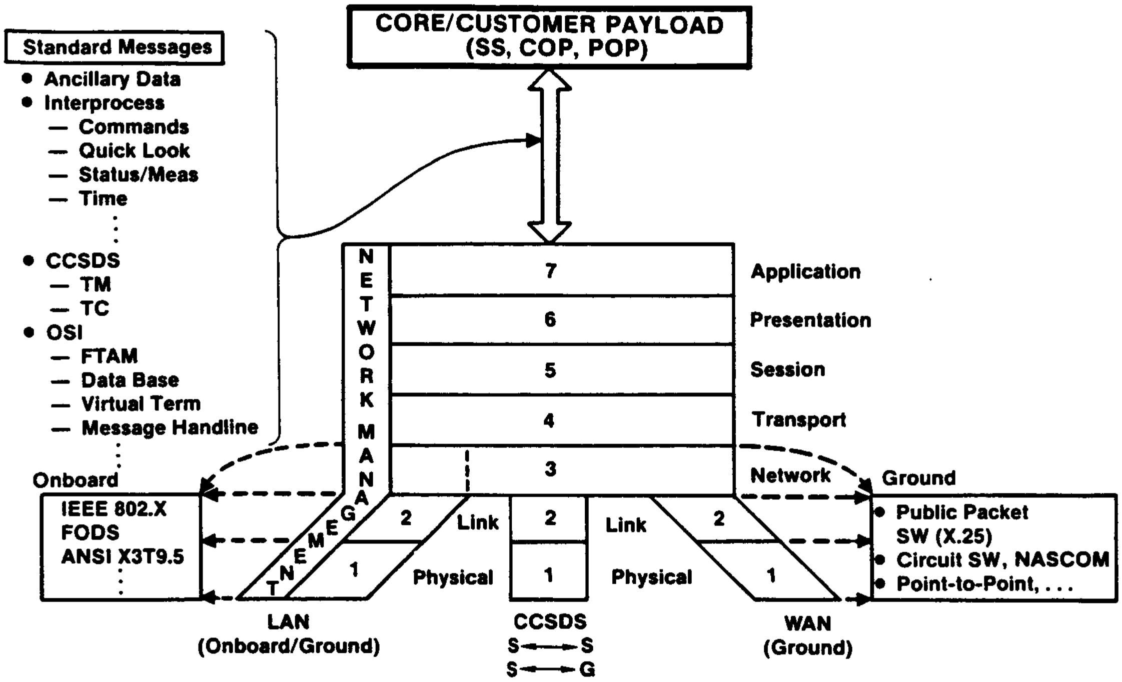


Figure 4.3.1.1-1. Onboard Interfaces to SSDS

1. Standard message protocols are shown at the application layer which would be defined by HOL record type or SFDU data type declarations. CCSDS TM/TC types would be transported through the space ground medium and the others would be transported onboard.

2. Representative onboard and ground LAN and WAN options for the lower two layers are identified.

3. The SSDS Time Management function provides time to the payload with an accuracy of ± 1 msec in one of the CCSDS standard formats.

4. A network management function resides at the application layer gathering data/statistics from the lower layers and reporting these to the network manager.

5. The user interface at the application layer is further expanded in Figure 4.3.1.1-2

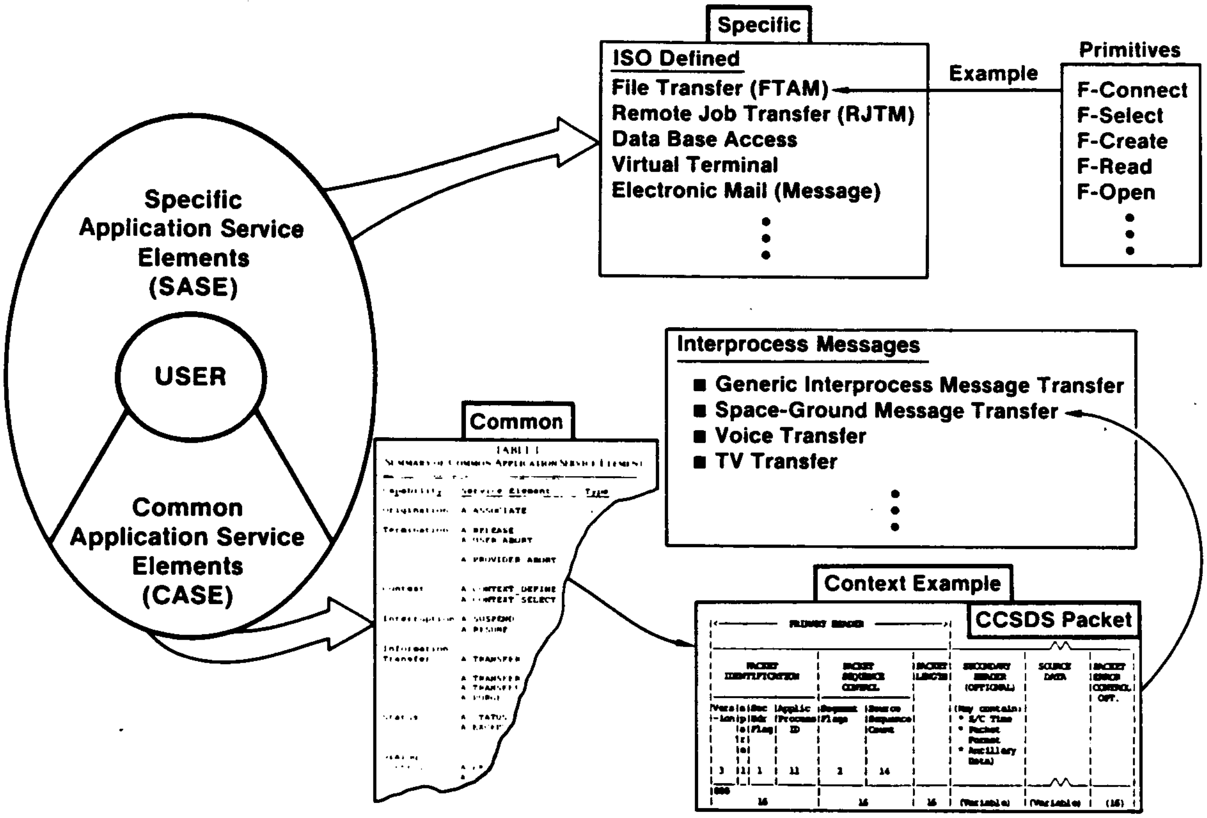


Figure 4.3.1.1-2. User Interface at the Application Layer

4.3.1.2 Ancillary Data

A representative set of ancillary data is shown in Figure 4.3.1.2-1 and its size is estimated to be 512 bytes. At this time the preferred distribution approach would be to allocate these parameters to three groups (State, Activities, and Environment) and to multicast the groups to the appropriate payloads. The components in each group would "slowly" change based on payload changeout.

4.3.1.3 Global Addressing: Physical, Object Name, Application Process ID and Spacecraft ID

DATA TYPES

- 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

•
•
•
•

DISTRIBUTION OPTIONS

- Payloads Poll for Data
- Broadcast Every TBD msec Using Dynamically Changing "Standard"Package(s)
- Combination of Broadcast/Poll

SIZE

Estimated To Be 512 Bytes

OTHER

Use "Open" Format for Data (i.e., SFDU)

Figure 4.3.1.2-1. Ancillary Data

Server Name and Physical Address

In a distributed computer network, nodes are entities that may have resources that can be globally addressed as object names remotely from other nodes. Some examples of distributed entities are printers, files, remote jobs, terminals, peripheral devices, payloads and core subsystems. A service is implemented by a process called a server who provides requested services to authorized customers. An example is a file server, printer server, or payload data server whose logical, or object address, is a character string (a name). One implementation of the server concept is to have each object (NIU) LISTEN for its (layer 4) transport (physical/NIU) address; to use a server a customer requests a CONNECT specifying the appropriate server address. The problem for the customer is to determine which object is listening to which transport address? The customer will want to request a service by NAME, which is generally a character string intended for use by operators rather than machines (NIUs respond to binary-encoded physical addresses). To obtain the

NAME:ADDRESS mapping a DIRECTORY SERVICE whose address is well known and never changes is consulted and the global physical address is received; this sequence is all transparent to the customer.

CCSDS Addressing Structure

The CCSDS packet and transfer frame ID/addressing structures are summarized as follows:

SPACECRAFT/APPLICATION	ADDRESS FIELD
Spacecraft (SSPE) ID (Transfer Frame Protocol) used for routing in space-to-space	10 Bits
Telemetry ID (Source ID within one SSPE)	11 Bits
Telecommand ID (Destination ID within one SSPE)	11 Bits

Spacecraft ID is assigned by the CCSDS international organization and an example of routing data using the spacecraft ID is shown in Figure 4.3.1.3-1 (the case is for earth to COP via Space Station).

The CCSDS packet format for TM and TC is shown in Figure 4.3.1.3-2 and includes an 11 bit Application Process ID addressing field that is assigned by the program office for each SSPE and which is logically equivalent to the OBJECT NAME entity previously discussed (i.e., a logical address). The 10 bit SSPE address and 11 bit Application ID assignment concept is illustrated in Figure 4.3.1.3-3.

End-to-End Addressing

With respect to the end-to-end SSDS design shown in Figure 4.3.1.3-4, messages are transported onboard the SS within an OSI environment, and on ground within an OSI environment, between elements that have unique physical addresses. When leaving the space or ground OSI environment (i.e., space-to-ground, or

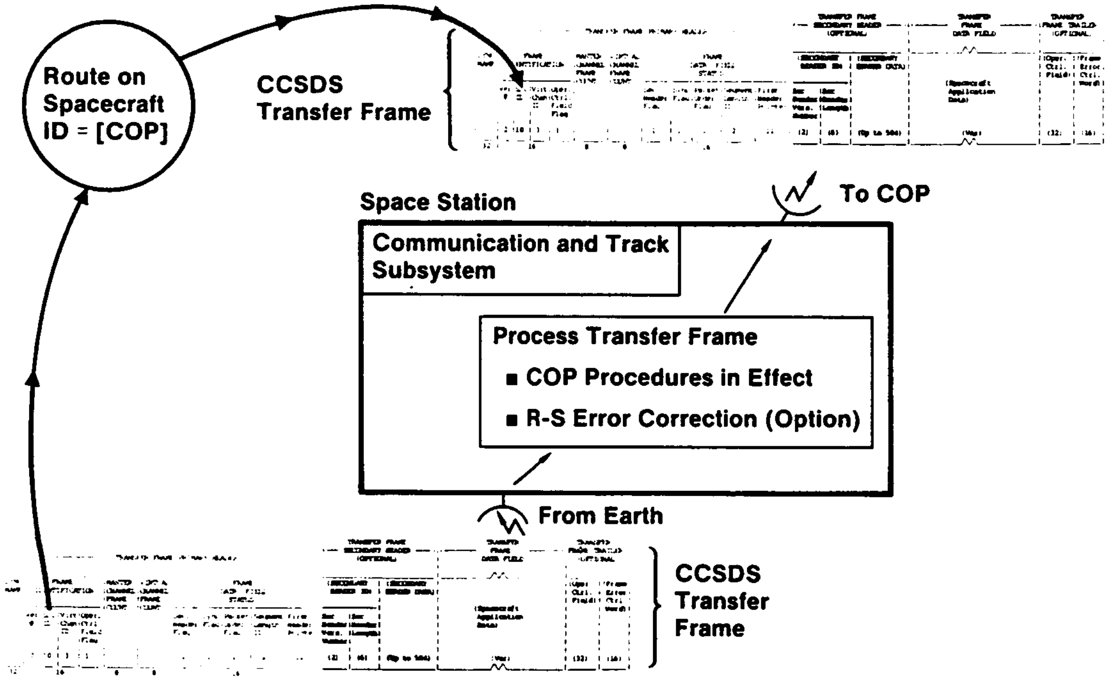
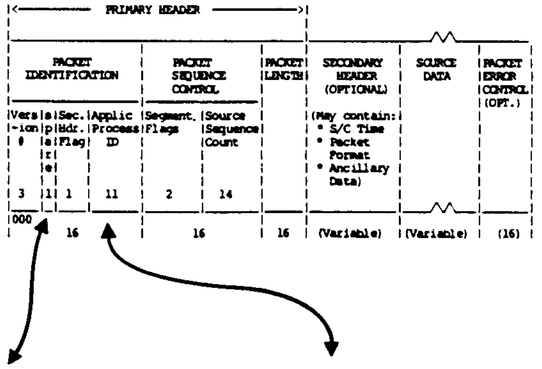


Figure 4.3.1.3-1. Space-to-Space Routing Example

- For Bidirectional TM/TC Packet Concept
- Single Packet Type Designated for TM or TC
- Global Application Process ID (Logical Address) Maps to Physical Address(es) at Session Establishment Time



Packet Type	ID Function
1 = Telemetry Packet	Source of Packet (On Board or Ground)
0 = Telecommand Packet	Destination of Packet (On Board or Ground)

Figure 4.3.1.3-2. CCSDS Packet Format (Revised)

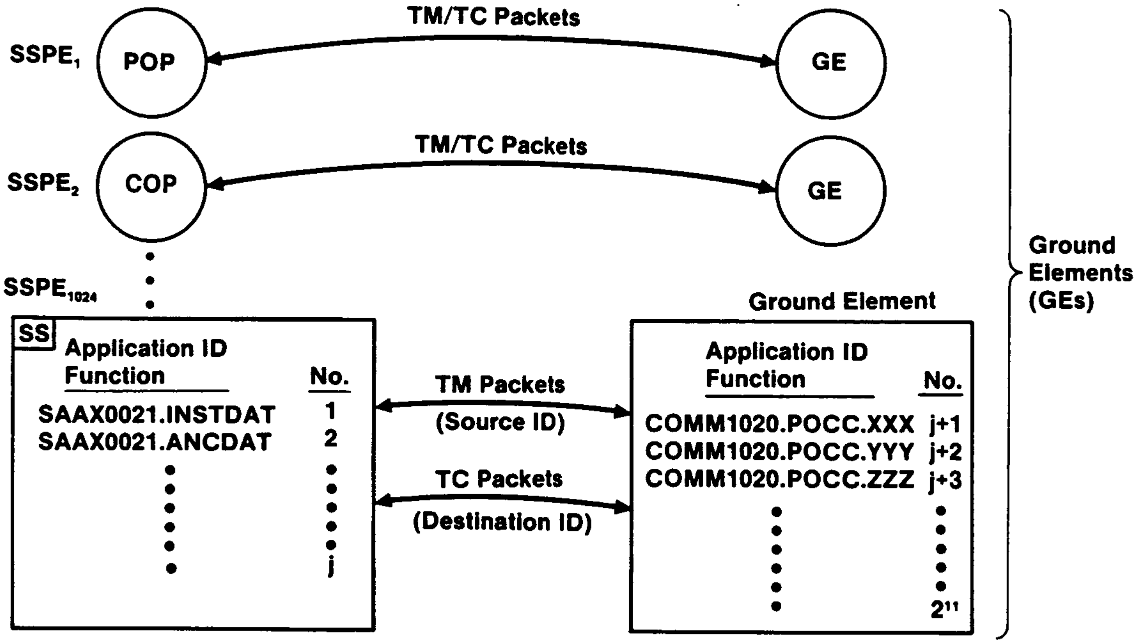


Figure 4.3.1.3-3. CCSDS Mapping/Assignment Space

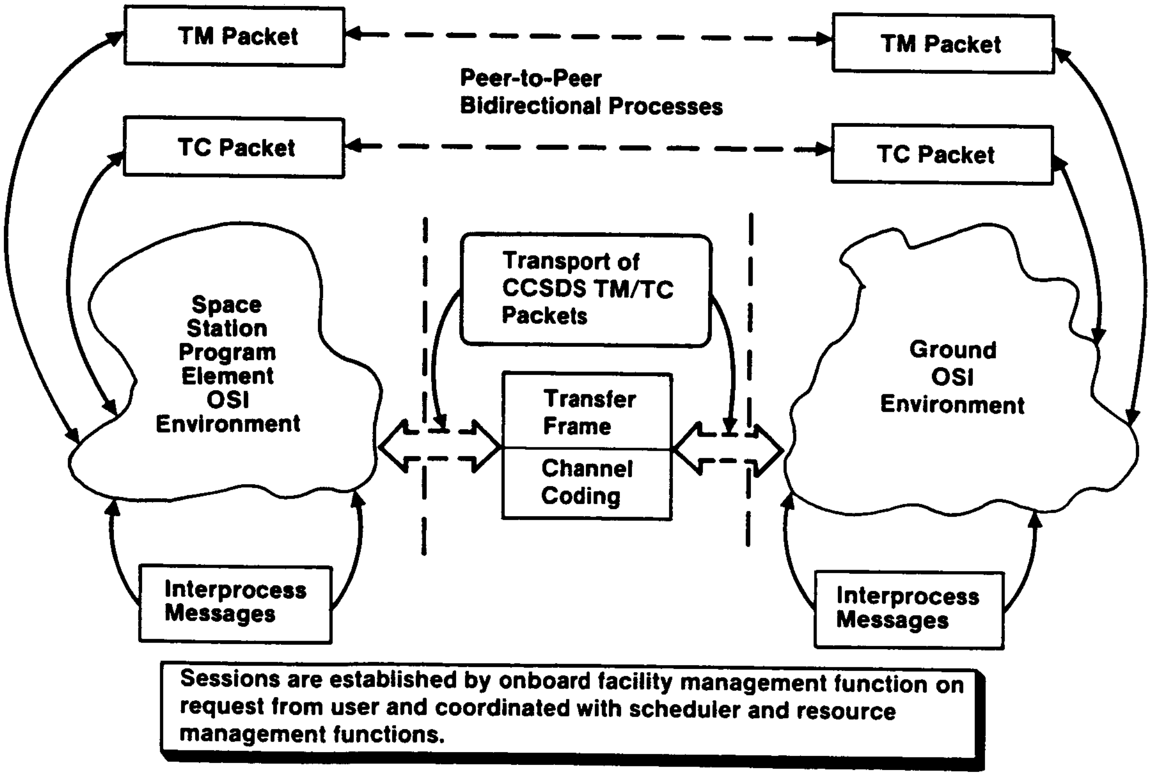


Figure 4.3.1.3-4. End-to-End SSDS Design Concept

space-to-space transport), TM or TC packets are transported from/to Application Process IDs which are also unique and which map to a unique physical address. Application IDs, like OBJECT NAMES, in general can be relocated to different physical (NIU) addresses and the mapping at the two nodes on each end of the layer 2 space-to-ground data link must be determined (via the DIRECTORY SERVICE) at session establishment time, or the routing algorithm can use tables that are preset by the network management function to accommodate a slowly changing network topology.

End-to-End Routing

At session establishment time communication resources including data paths through the network will be bound for the term of the session (realtime dynamic routing through a ground packet switched network is not precluded, however).

Figure 4.3.1.3-5 demonstrates the ISO/OSI and CCSDS protocols used on an end-to-end basis showing communication within a space or ground OSI environment and through space in a CCSDS environment. For a connection (non-datagram) service the end-to-end connection options are shown in Figure 4.3.1.3-6. An example of the mapping concept required in the onboard C&T gateway to deliver a customer packet from his ground operation center to his onboard application is given in Figure 4.3.1.3-7.

4.3.1.4 Onboard User Interfaces and Data Delivery to Ground

As stated earlier, the customers principle SSDS interface for message transport through space is the CCSDS packet and for transport within space or within ground the data is transported in standard interprocess messages. Another item also discussed was data transport transparency, on an end-to-end basis, to the customer. These two elements will be demonstrated later using a hypothetical payload and showing the important interfaces that transport the data through the distribution network.

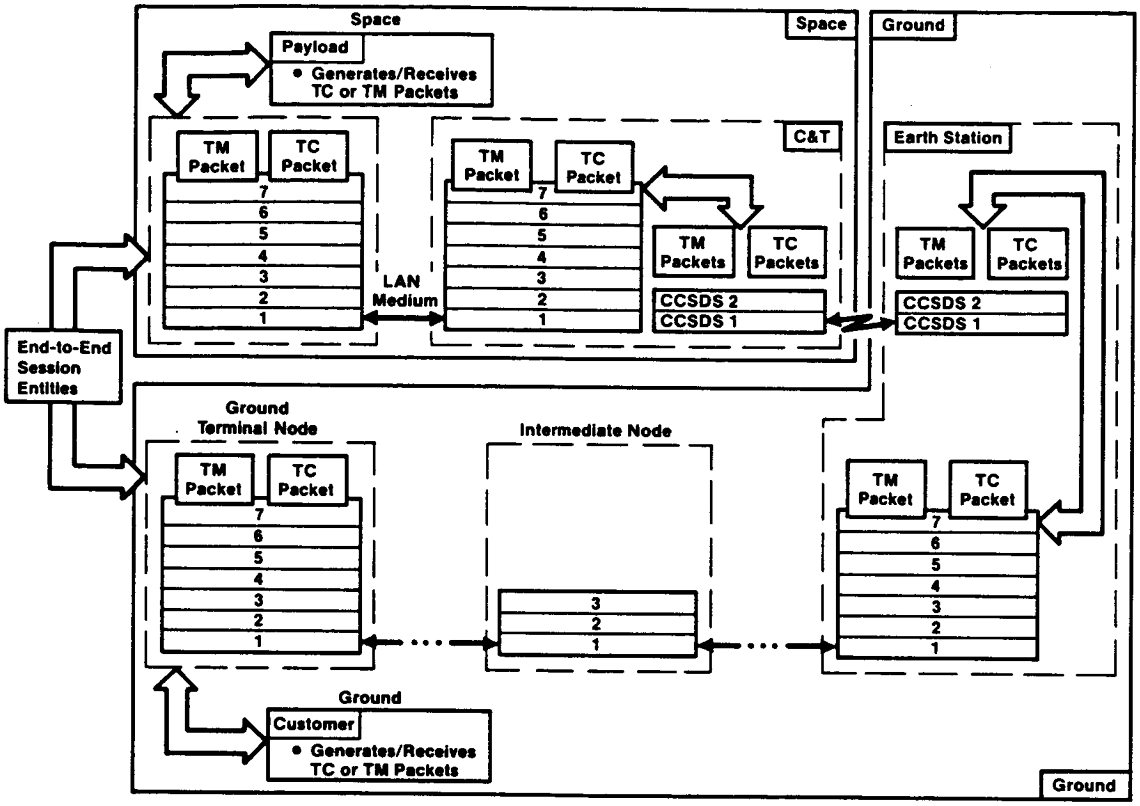


Figure 4.3.1.3-5. End-to-End Protocols

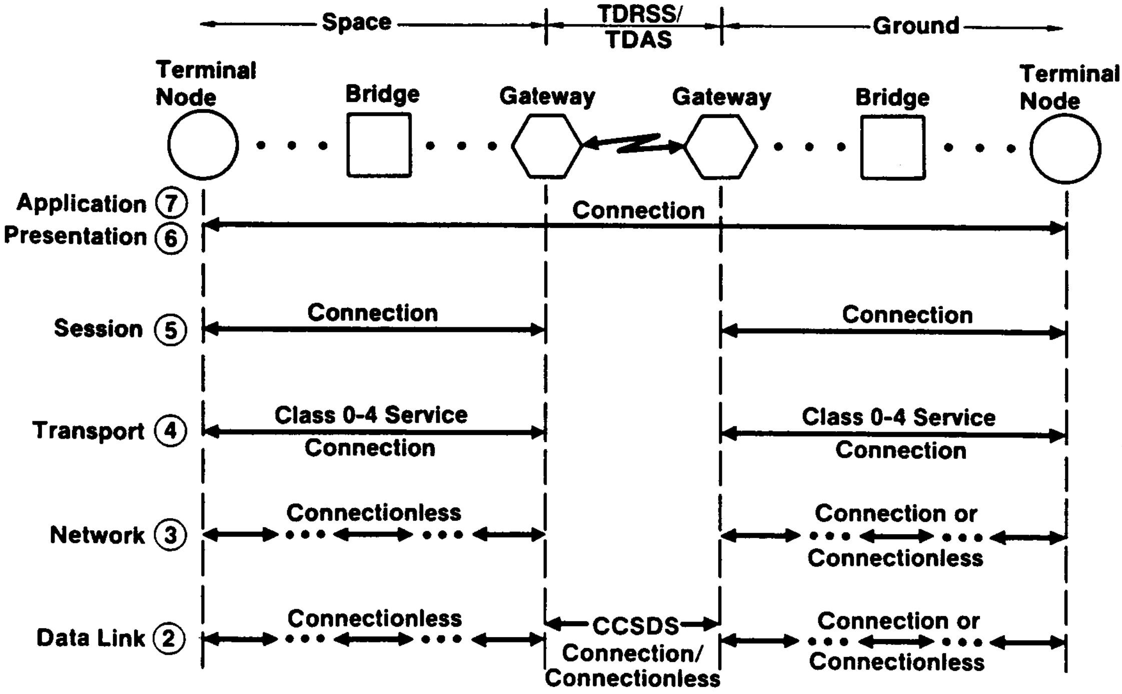


Figure 4.3.1.3-6. End-to-End Connection Diagram

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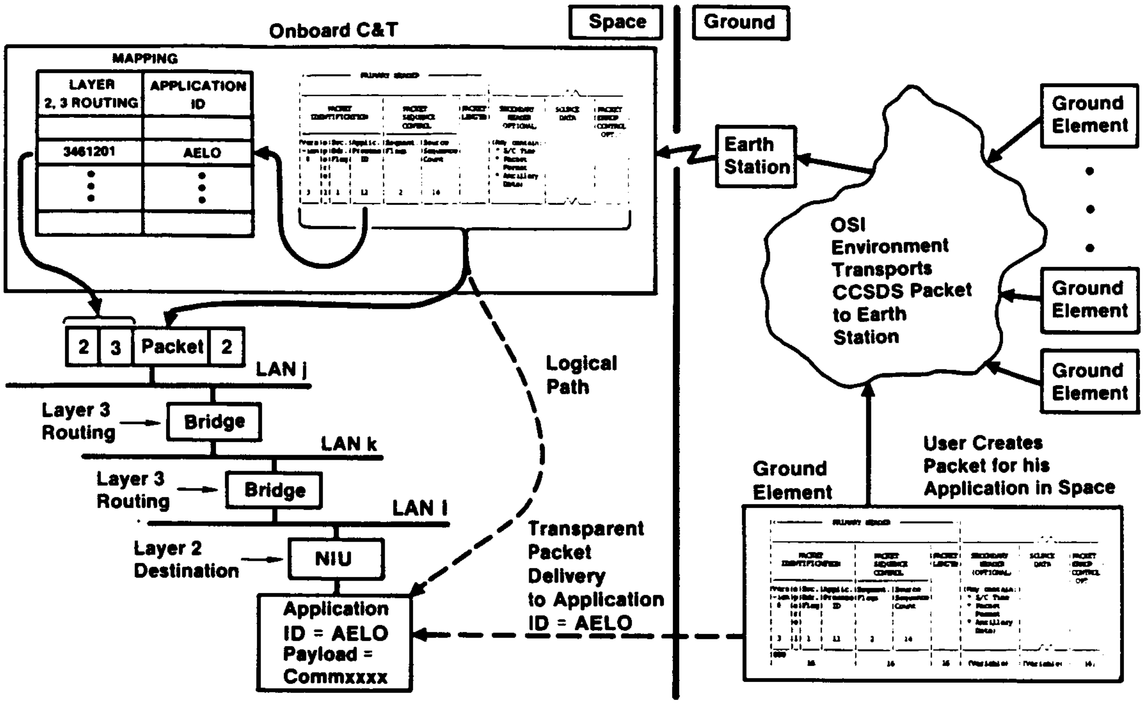


Figure 4.3.1.3-7. End-to-End Packet Delivery (Example)

Core/Payload Telemetry Interface

Figure 4.3.1.4-1 shows the CCSDS packet that will be used as the payload's data carrier through the space network. The details of using this message structure are given in references 2-12 and only the boxes in the diagram will be discussed here. Source Data and Secondary Header fields are delineated in the packet structure; the customer/customer packages data into the primary Source Data field using the indicated options. Associated with data in the primary field, the customer may elect to use the secondary field to package ancillary data, time, various flag designations, and other parameters. Alternately, he may elect to embed these secondary data items in the primary field with a unique Application Process ID. The SSDS has a requirement to transport this message to the ground customer (possibly delayed in which case it is stored prior to transmission) with an end-to-end bit error rate (BER) of less than 10^{-6}. The customer has several options to improve this BER as shown below:

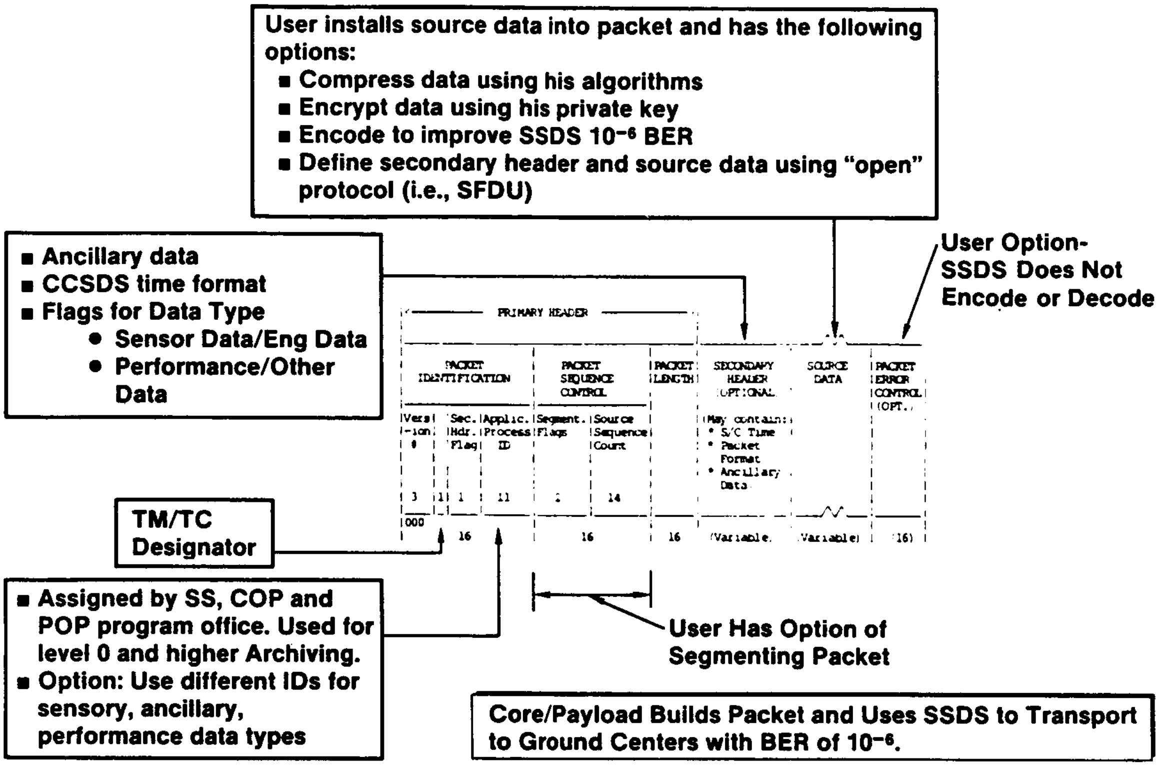


Figure 4.3.1.4-1. Core/Payload Telemetry Interface

1. At session establishment time, specify quality of transport service desired at ISO layer 4 and CCSDS layer 2.

2. Specify forward error correction in CCSDS layer 2 (i.e., Reed-Solomon encoding with parameters 255,223) or encode the data using his own algorithm prior to inserting the data into the source data field.

3. Use the two byte Packet Error Control field (e.g., compute a 16 bit CRC for the entire message and use for error detection requesting retransmission at the application layer).

Lost and Out-of-Sequence Packets

As CCSDS data packets (or segments of CCSDS packets) are transported from their point of origin (e.g., a command from a workstation in a POCC or data from an A/D converter/formatter) to their final destination (end-to-end transport) they can be transformed enroute in many ways:

1. They can become corrupted by noise-induced bit-reversals so that the data delivered is not identical to the data at the point of origin.

2. They can become electronically and physically lost at intermediate points (nodes) in the transport chain due to storage media overlows (temporary buffers), node processor failures, communication link (between node) failures, and other reasons.

3. Data packets may arrive out-of-order (out-of-sequence) due to their transport over different physical (e.g., cable) or logical (e.g., CCSDS Virtual Channels) links.

The above problems are real ones and are ones that are addressed in commercial data transport networks (e.g., TYMNET) and in the CCSDS and the ISO/OSI standards models. Recall that layers one, two, and three of the OSI model form a <u>Network</u>, with possibly multiple end-to-end paths between any two connected nodes, and that layer four, thee end-to-end Transport Layer, considers the Network to be intrinsically unreliable (i.e., noisy and subject to link failures). The Transport Layer, guarantees in-sequence delivery of packets and provides a class of service that guarantees error free data delivery on an end-to-end basis. These services are basically provided by incorporating end-point buffering to re-order packets at the receiving node, enroute (data capture) buffering which is released only upon positive acknowledgement of a "window" of data, and fault-tolerant operations to provide rapid alternatives following communication processor and link failures.

The SSDS will provide the same class of service as above but the implementation will be more expensive due to the higher data rates and the larger.end-to-end extent of the SSDS. It is expected that all users do not require and do not want to pay for the above quality of service and that reduced classes of services (per CCSDS and the OSI models) can be defined with corresponding reduced data transport charges. The extremes in these services are as follows:

1. The event to be captured is short-lived, is an opportunity of the century, and no recapture is possible. In this case the user may want data captured in multiple locations and will want the highest quality of data transport services. All packets will be transported to the terminal node(s) in sequence with no missing data and virtually error free.

2. The data is extremely redundant and updated at a high rate so that the loss of a single frame or subframe of data is of little consequence provided that incomplete frames are so noted and that frames are delivered in sequence.

In addition to the classes of service specified in the CCSDS and OSI standards, the customer at the application level (above layer 7) can do the following:

1. He can encode his data to provide for increased error protection (forward error correction).

2. He can provide his own buffer/store and use an end-to-end application-to-application acknowledgement of receipt.

3. He can specify that data be recorded (captured) onboard and transmitted to ground for capture

4.3.2 System Design for a Hypothetical Payload, COM XXXX

Introduction

Figure 4.3.2-1 shows the system design for the hypothetical payload COM XXXX which has the following features and interface requirements:

- A pointing and tracking system, teleoperated from ground or onboard.

- An imaging sensor array of dimension 100 x 100 (10^4 pixels), a 10 bit A/D converter (10^5 bits per image), so that at an image rate of 50 per second, the total image data rate is $5*10^6$ BPS.
- Payload performance (engineering) data is acquired and packaged for transport.

- The I/O Electronics, Payload Processor, Memory and NIU circuit assemblies are integrated via a standard backplane bus (e.g., VME Bus).

- The memory is divided into several components; one of these, as shown, is a shared RAM where the sensor and performance data is stored as directly received from the A/D converter. This segment of memory is subdivided into LAN packet-sized elements (64 1K packets) and the payload processor builds the CCSDS and OSI headers and trailers around the packets without moving the data.

- The Time Management Function provides time to the payload via the NIU and the Payload Processor embeds it in the CCSDS packet, as required.

- The NIU and processor implement the network operating system.

- The payload communicates with other LAN-connected components as shown and based on sessions established by the network manager.

In this development the customer has provided his own electronics package but uses certain SSDS standard cards: specifically the card sets for the SDP, memory, and the NIU. He has provided the custom I/O electronics that have unique interfaces to his instrument (i.e., torque motors, gyros, scan control interface, A/D converter, and so on). The sensor data can be displayed on an MPAC display at the same resolution as the sensor and by mapping the pixel value to the display's color code, the quality of the data can be validated via quick look by a pre-trained crew person. (By doing this the customer has provided for both onboard and ground operations.)

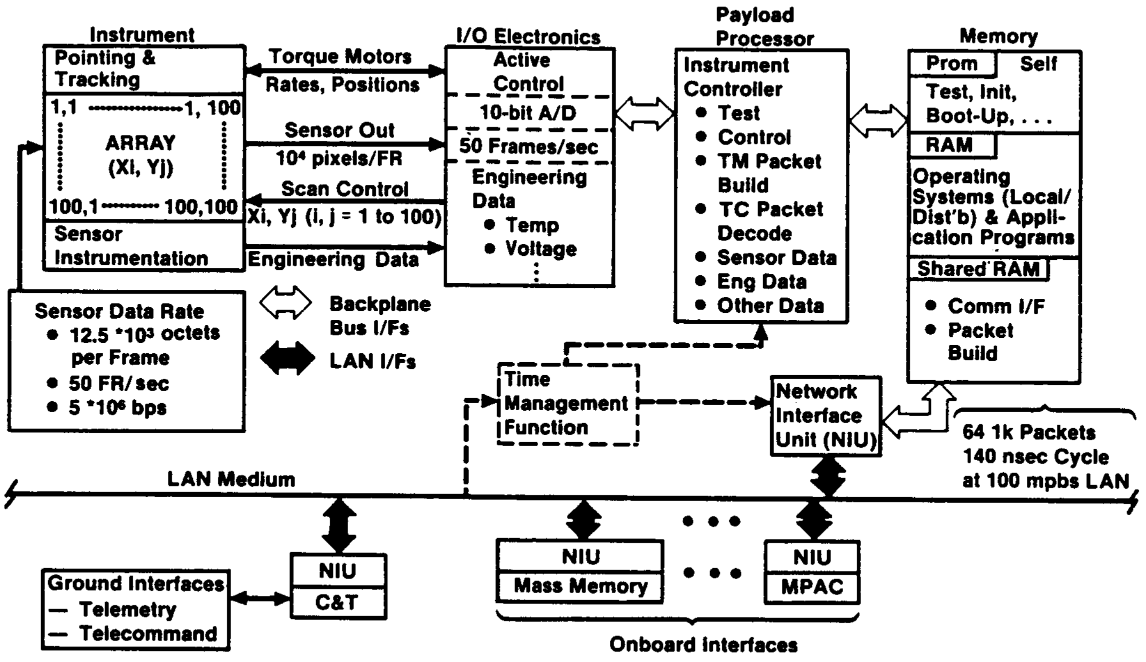


Figure 4.3.2-1. System Design for Payload/Mission COM XXXX (Example)

The payload has a duty cycle of 5% so that power is normally disconnected from the package. When the schedule time for payload activation has arrived the following events occur:

1. Thermal control to the unit is activated.

2. Prime power is applied and sensed for abnormal current.

3. The payload processor is reset to the POWER ON state by an internal power on discrete.

4. In the POWER ON state the processors program counter is reset to memory location zero, the location of the PROM-embedded self-test routine. Self-test is then initiated and the results are stored.

5. The NIU then performs a self-initialization procedure to become an addressable LAN entity using procedures such as can be found in

IEEE Standard 802.5 paragraph 4.2.3, entitled Standby Monitor Finite-State Machine.

6. Sessions between the payload and other devices assigned by the schedule function, are now established by the network manager. This assures that all resources are communicating that are required to support the session.

7. Numerous scenarios are now possible for payload operations:

   - Autonomous payload operation vs step-by-step operator direction.

   - Quick look mode via onboard or ground operations followed by a production mode with data stored onboard or transmitted to ground.

   - Interactive operations in a browse mode (quick look) followed by an automated inertial track mode (production data acquisition) followed by repeats of this cycle throughout the whole session.

The processor could have had the command sequences (program) stored in PROM, booted from mass store, or provided from ground. The processor application functions include mode control, test, TC packet decode, TM packet build for sensor and performance data, ancillary data extract and merge, teleoperate interface for instrument pointing, instrument auto-track, and so forth.

When the session schedule expiration nears, the session entities will be notified, allowing for an orderly disconnect: the processor will secure the instrument, and the core subsystem manager for power and thermal will disconnect their services in a sequence that provides thermal protection against an over-temp condition.

COM XXX TM Packet Flow – End-to-End

End-to-end TM packet flow for COM XXXX is shown in three parts in Figure 4.3.2-2. This flow is based on the functionality previously described and illustrates the protocols used in the end-to-end data transport. The discussion herein will be based solely on this three-part figure.

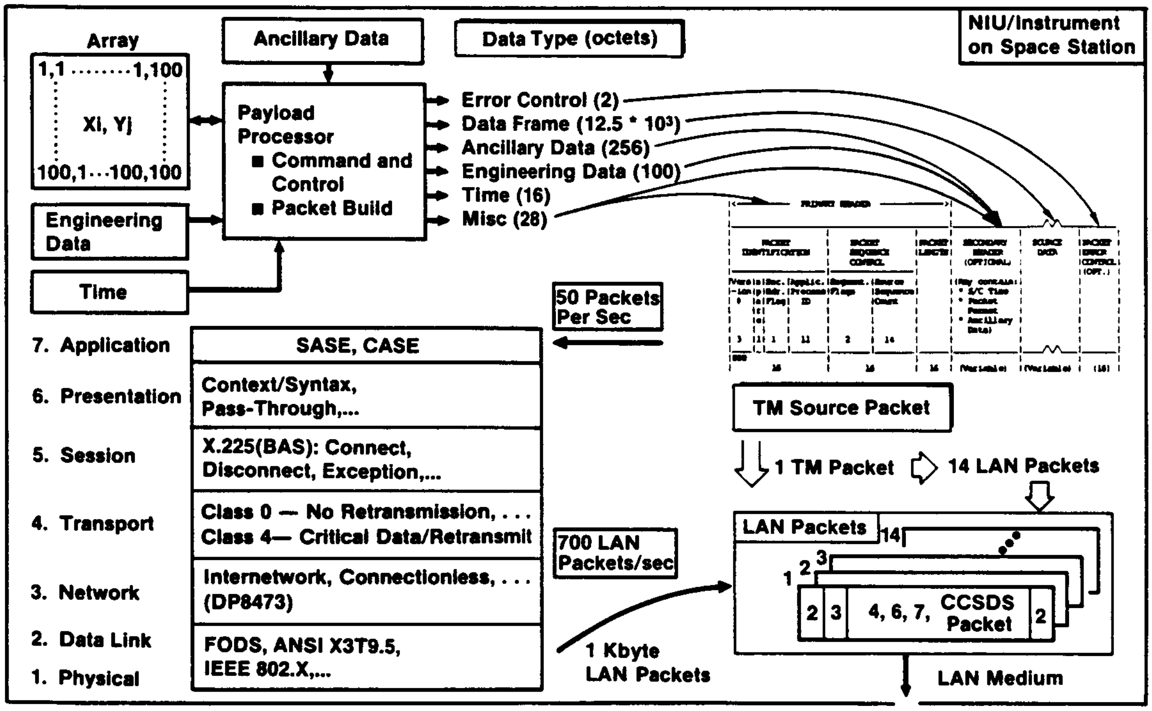


Figure 4.3.2-2. End-to-End TM Packet Flow (1 of 3)

This scenario shows one message type (the TM packet) being built and transported through the C&T mode to the ground terminal node. Telecommands would traverse the opposite path and the processor would have the "opposite" function of interpreting the contents of the command packet. Likewise, other message types from onboard entities would be built for transmission and received messages would be interpreted based on a message-type label.

In the first figure (1 of 3) the TM packet is being built using one image scan ($12.5*10^3$ octets) per packet and the processor packages other data (ancillary, performance, time. ...) into the secondary header (an alternative would be to create individual packets for secondary data). The maximum packet size ($2^{16}-1$ octets) easily accommodates the data. Packet segmentation, a flow control mechanism, is not required since the NOS at layer 4 will segment "large" messages prior to transmission on the LAN. In this example the customer has elected to add the two (optional) Error Packet Control octets which he will interpret (error detection with/without correction) when the packet is delivered to him.

The NOS implements services and primitives associated with the seven layer model shown in the first figure. For this payload, connections would be established at the top four layers and Class 2 services would be specified at layer 4. In this case the Common Application Service Element (CASE) provides a message service for the indicated 50 packets per second to be transported to the C&T node. Layer 3 disassembles the 13K octet packet (message) into 14 LAN packets, adds two routing headers (possibly null if bridges are not involved) and layer 2 frames the data for transmission by adding the layer 2 header and trailer. The trailer is a CRC code used for error detection at the receiving node, and the header includes the address of the C&T node. If a token ring is assumed, and for this example a 1 Kbyte LAN packet is assumed, then 14 token acquisitions will be required to transport this image-frame of data to the C&T node.

Part 2 of the figure shows the seven layer processing at the C&T node to recover the COM XXXX TM packet; the C&T is also receiving packets fom other sources (layer 2 LAN packets and TM/TC packets from the high rate payloads via point-to-point links). Additionally, TV and audio is being received from the TV/Audio subnet and being digitized and compressed. All of these data are being segmented (if required) and installed into CCSDS Transfer Frames for space transport to earth. A virtual channel concept is employed to time-divide the TDRSS bandwidth to implement flow control ("link hogging") and to provide timely access to the channel for realtime data like TV and audio. The output of the virtual channel multiplexer (itself a virtual device) is serialized and Reed-Solomon encoded (an option exercised at session establishment time) and then interleaved prior to entering the modulator and RF section of the C&T.

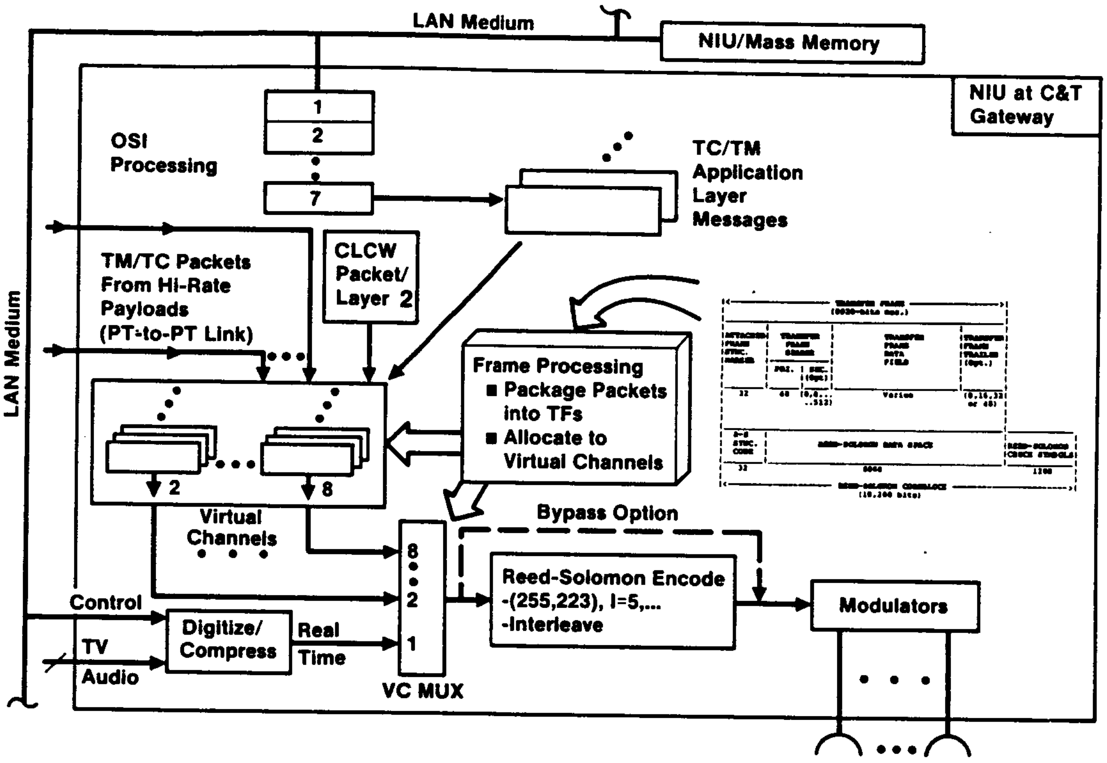


Figure 4.3.2-2. End-to-End TM Packet Flow (2 of 3)

In part three of the figure, the transfer frames are recovered in the receiver as they enter the Data Handling Center for routing to their ultimate destination. At this point the data (TV, voice, TM/TC packets) are embedded in transfer frames. When Reed-Solomon Sync Codes are detected, real time R-S decode and error correction is performed prior to frame processing. Uncorrectable errors would be flagged, and in the event that a connection-oriented service was in effect for the session associated with the frame, then a retransmission of the frame would be requested (i.e., this is in the case that a TC packet was transmitted from space — recall that in the CCSDS TC concept, retransmission is mandatory when a TC error is detected and not correctable. In the MDAC concept, Reed-Solomon coding has been substituted for the Hamming code normally used for TCs). The transfer frame processing is basically the inverse of the processing initially done onboard. TV/audio is recovered and retransmitted over point-to-point links and the TM/TC packets re-enter the ISO/OSI environment as shown with the indicated distribution options.

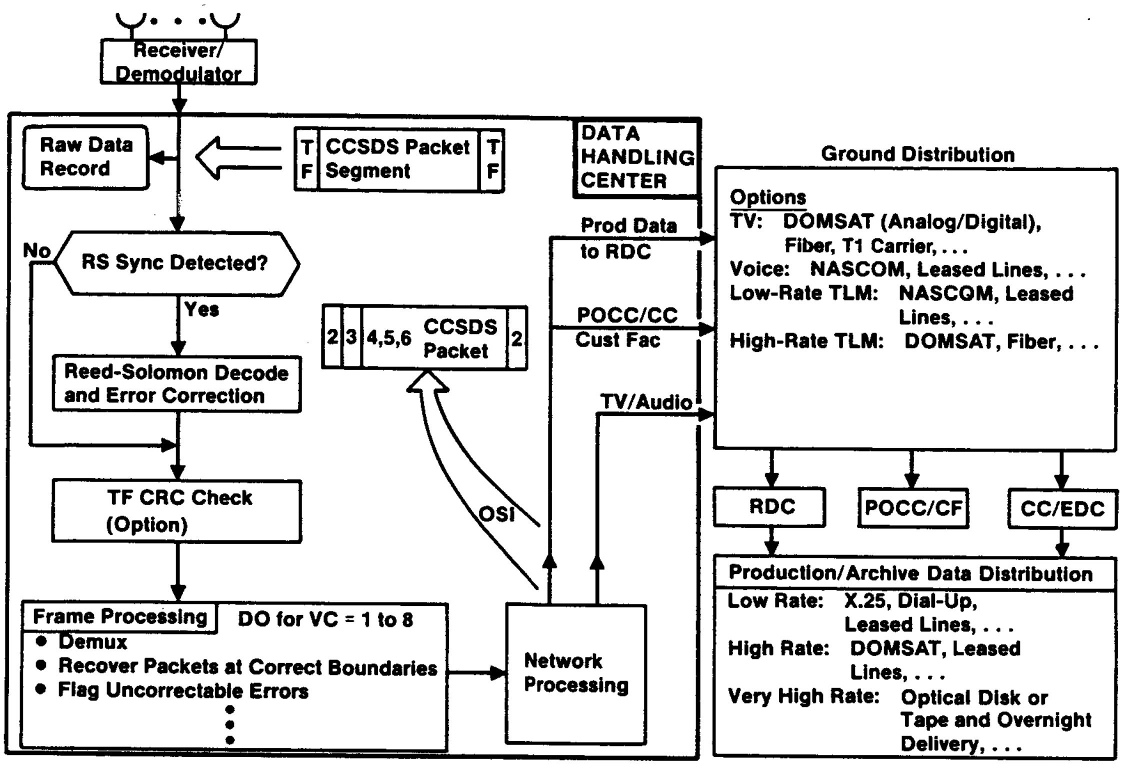


Figure 4.3.2-2. End-to-End TM Packet Flow (3 of 3)

4.4 System Control/Management Definition within the SSDS

This section provides 1) a summary of the systems management and control decisions and design allocations; 2) a summary of systems management definitions; 3) a pictorial description of the interrelationships and data flows among the different management functions; and 4) a baseline systems management definition and allocation among elements of the SSDS.

4.4.1 Summary of System Control/Management Design Decisions and Functional Allocations

This section summarizes definitions of systems, facilities, resource, command, configuration, and administrative managements, their interdependencies, and their functional allocations to the SSPEs as part of the strawman SSDS definition.

The basic design approach has been to assign a high level of management function autonomy to each SSDS facility. With the exception of centralized SS system communications coordination, each facility has responsibility for managing local resources, validating and executing commands, and monitoring its performance. A Ground Services Center (GSC) facility is proposed to coordinate inter-element communications, coordinate management of resources allocated to common elements (such as the Data Handling Center), and coordinate customer interactions with the SSDS.

Arguments are presented for space/ground resource management autonomy (subsequent to the man-tended Space Station era). Key design drivers in allocating system management functions are discussed. Guidelines for the scope of management and monitoring function implementation are presented. A summary of key issues, such as potential national security involvement and accommodation of international customers, concludes this section.

4.4.2 Definition of Key Management Terms

The definitions below are with respect to the strawman system definition proposed for the Space Station Data System (SSDS) Architecture Study. The key types of management defined are systems management, facilities management, command management, configuration management, and administrative management.

SYSTEMS MANAGEMENT: Systems management is the management of the overall SSDS and its associated elements. The systems management function is the highest in the hierarchy of SSDS related management functions. Systems management encompasses inter-facility management; overall SSDS communications network scheduling; system-wide monitoring and performance assessment; system maintenance procedures; and overall system control. In support of these functions a predetermined inference and arbitration rule-set will need to be established to support efficient resource utilization, to coordinate operational procedures, and to resolve conflicts.

The ultimate system control of the Space Station and other SSPE's is included in this top level systems management function. System control refers to the coordinated control of payloads, core resources, facilities, and all standard user resources via the issuance of controls and the prioritized allocation of resources to effect desired actions. System control here refers to the higher level control and coordination functions required to effect orderly actions within the SSDS, not simply for individual resource or payload-specific actions of minor importance to overall system functioning.

FACILITIES MANAGEMENT: Facilities management is the management of subsystems within a specific facility. A facility represents a distinct physical entity having a well defined focus or goal, such as a payload operations control center (POCC), a level zero processing facility (LZPF), or the NASCOM TDRSS network (strictly speaking, an institutional facility utilized by the Space Station program, and not a part of the SSDS). The facilities management function includes most of the above system control, management, and resource scheduling functions, but at a lower level, i.e., for each specific facility. The management of facility reconfiguration, i.e., the reallocation of facility resources for changing mission requirements, is included in the facilities and systems management. Facilities management will also include resource management.

RESOURCE MANAGEMENT: The management, control and scheduling of subsystem resources such as computer processing, data storage, local communications links and capabilities, crew utilization, and SSDS core functions (such as power, thermal management, ECLSS). The overall coordination of the communications network, which may require interfacility scheduling, is part of the higher level systems management function. The resource management function controls, schedules, monitors, maintains, and reports on the usage, performance, and reserve capabilities of the individual resources for each facility within the SSDS network.

COMMAND MANAGEMENT: The handling, checking, validation, and authorization for command execution. Command management can be localized to a particular payload or core subsystem, or it may extend to a facility or the overall SSDS. Restricted commands will require more checking and coordination than unrestricted commands, which can be passed in a transparent manner to the payload. Restricted/constrained commands can be executed as conditions permit (safety, interference, resource availability), where executability is determined by the onboard SSDS, scheduling/negotiation functions to reserve time/resource envelopes for future utilization Command management will normally be a subset of systems and facilities resource managements and is discussed in-depth in Paragraph 4.5.

CONFIGURATION MANAGEMENT: The management and control of system upgrades, updates, and associated documentation. Configuration management deals with assuring control of hardware and software versions and updates, update documentation control, and updates logistics. Included are updates to command and control tables and data access authorization tables.

ADMINISTRATIVE MANAGEMENT: The management of accounting and resource usage data, the provision of standard system documentation, the facilitation of the customer interface for SSDS information, etc. Administrative management is required within systems management and facilities management, but at different levels.

4.4.3 Interrelationships/Dependencies of Different Management Categories

Figure 4.4.3-1 shows a hierarchy of management functions and their relationships among themselves and among the different SSPEs. Management-related data flows between the SSPEs and associated management functions are indicated.

4.4.4 System Control/Management Design Definition

This section presents a rationale for separate, autonomous facilities management and control functions within the space elements and within the ground elements of the SSDS as depicted in Figure 4.4.3-1. The characterization of key interfaces among SSDS elements in the area of systems management and control is also delineated in this figure.

The definition of key space and ground elements and the allocation of key management and control functions among these elements is presented next. Many of these allocations will of necessity be repetitive in that many different elements will require the capability to perform subsets of these functions autonomously of other elements.

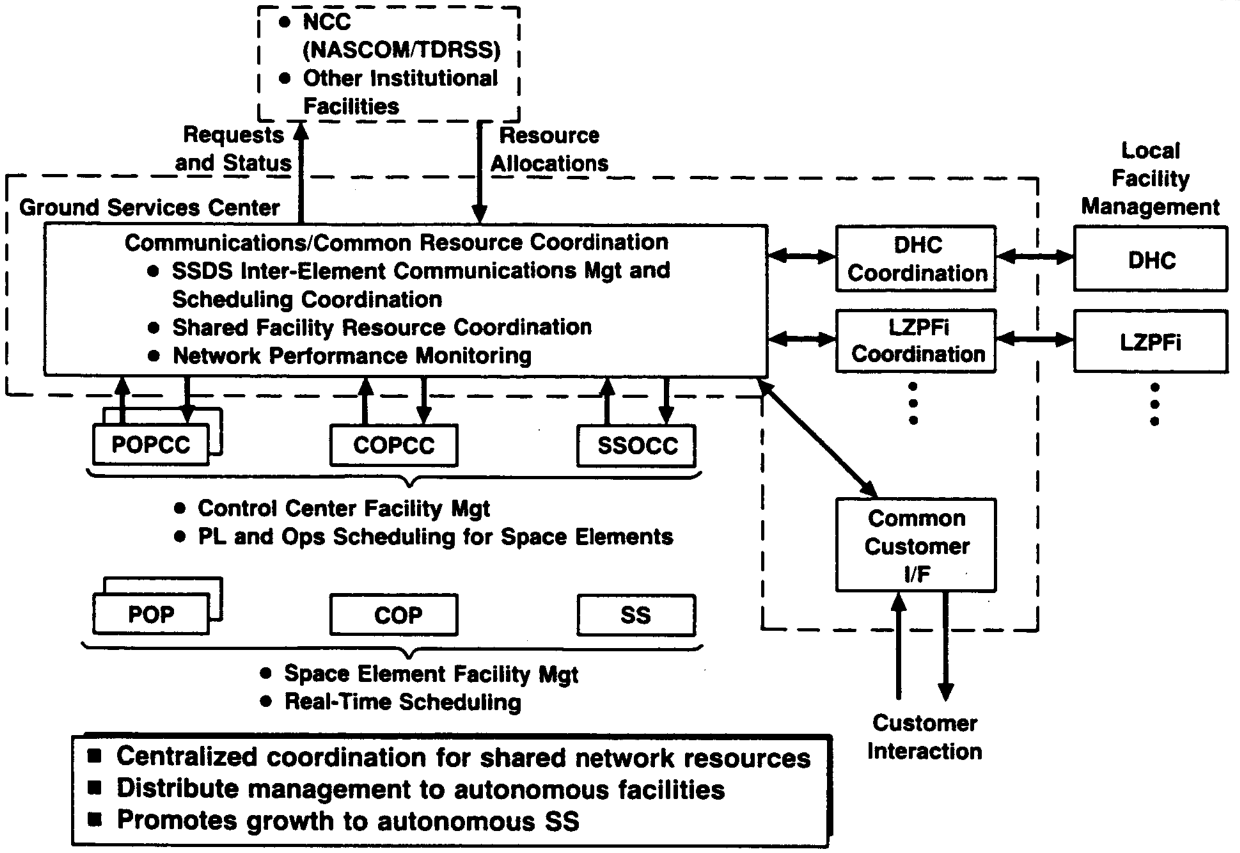


Figure 4.4.3-1. Interrelationships Among SSDS Management Functions and SSPEs

4.4.4.1 Ground and Space Autonomy Philosophy

In the baseline SSDS design, facilities management will be distributed among ground facilities and space facilities. This division will be necessary –

1) to facilitate Space Station autonomy for normal operations, and to control space facilities in emergency, real-time critical situations where transmission delay times to ground might be detrimental and where the control of operations by trained crew might be invaluable; and

2) to coordinate and manage the distributed array of ground facilities, the management of which will be burdensome and inefficient if centralized in a space node, such as the Space Station base.

The space segment will require responsiveness and real-time human interaction capability in emergency situations; the space segment is also best equipped to perform dynamic onboard command management and onboard resource allocations. The ground elements will best manage themselves due to the disparate locations and diversity of functions among these elements and the impracticality of controlling any portion of them from space.

Since the ground LZPFs and DHC may serve multiple missions and multiple customers located at diverse facilities, an additional coordinators management function is proposed, which will coordinate multiple customer requests and manage inter-facility resources shared in common by a broad spectrum of customers. In space, multiple customer requests to the Space Station will also require only the resources of this single facility with the exception of shared or common communications resources.

With regard to the question of whether space or ground has ultimate control, for situations where unresolvable systems management conflicts may occur, it is proposed that the ground be the ultimate location of decision-making authority for the simple reason that top NASA administrators, who have ultimate Space Station program responsibility, are almost surely to be on ground in such situations. This is not to imply that the Space Station crew will not have definitive decision-making authority for most ongoing and emergency situations. Backup control capability on the ground is also valuable, however, in cases of extensive crew incapacitation, severe onboard facilities damage, etc.

An important area for coordination and priority specification will be the scheduling of communications resources. Emergency situations will require the highest communications scheduling priority.

It is proposed that a predetermined set of arbitration rules and procedures be established to coordinate space and ground communications control and resource allocation for predictable situations likely to occur during ongoing Space Station Program operations and missions. A sample set of such rules was presented at a high level in Section 3.6.

Another important area for management coordination is the control of updates and access to data bases required by both ground and space nodes. Each data base will be under control of each facility management function, with shared data bases controlled by the system management and communications coordination functions.

4.4.4.2 Definition of SSDS Space and Ground Elements and Associated Management Functions.

The space SSDS elements which will need to be managed and controlled include the Space Station and the Co-Orbiting and Polar Orbiting Platforms, as discussed in Section 3.3.

The ground SSDS elements needing management and control will include the Space Station and platform operations control centers (SSOCC, COPCC, and POPCC), the LZPFs, the Engineering Data Center(s) (EDC), the Data Handling Center (DHC), the Payload Operations Control Centers (POCCs), and the Develop, Simulation, Integrate and Train (DSIT) facility, as described in Section 3.3.

In addition, there is proposed on the ground a Ground Services Center (GSC) which would be responsible for the management of common ground facilities (DHC and LZPFs); the SSDS network communications coordination and scheduling; and the interfacing of customer access to other SSDS elements and services.

The common facilities Management function of the GSC will encompass the resource management condition of the common facilities, the inter-facility coordination, and prioritized resource allocation and conflict resolution among and within these facilities.

The Communications Coordination function of the GSC will coordinate Space Station Program requests for network communications services with other institutional facilities such as the NCC, the DSN, the GPS, or the NASCOM TDRSS network. The GSC will serve as the network scheduling interface between these existing institutional facilities and the SSDS and Space Station Program elements.

The functional architecture proposed here, with significant autonomous management within individual facilities, should facilitate function migration from ground to space with minimal impacts on other facilities.

4.4.5 Major Assumptions/Design Drivers

The management-related SSDS functions and interrelationships developed in the Task 1 functions data base and data flow diagrams served as the basis for management function partitioning and SSPE allocations. In addition, four design drivers had a major impact on the allocation of SSDS systems management functions. These were the requirements 1) for protection of Space Station system assets; 2) for system responsiveness and transparency in customer interactions; 3) for high-level and broad based automation and autonomy implementation; and 4) for flexibility of ongoing subsystem upgrades throughout the life-cycle of the Space Station Program. These are discussed further below.

4.4.5.1 Protection of Space Station Resources/Assets

A primary Space Station Program requirement is the protection of onboard and ground assets and people. Life threatening situations can occur in numerous ways onboard if adequate safety precautions or subsystem redundancy are not available in times of emergency or subsystem failures. With respect to the SSDS, a high level of operational reliability, functional adequacy, and assured and secure command and control procedures are necessary.

This set of requirements for safety and security imply that system management functions such as configuration management control, efficient and dynamic resource allocations and/or conflict resolutions, and well formulated inference and arbitration policies and associated technology to effect them are necessary. The need for efficient management as well as high fault tolerance and redundancy of functionality escalate the assorted systems management functions in priority within the SSDS.

4.4.5.2 System Transparency/User Responsiveness

The priority of transparent data handling and commanding as well as near real-time responsiveness for customers translates into a very efficiently managed and coordinated system. This suggests that many functions which may otherwise have been centralized at remote locations should be distributed to effect quick, straightforward responses. Command checking and data handling cannot be extensive for normal non-threatening situations or user responsiveness may be impacted. A basic philosophy has been to reduce the hierarchy and number of management functions so as to reduce necessary functional and inter-facility interfaces in command management and resource scheduling. A clearly defined set of policies and associated management functions are thereby required for these reasons. This implies rapid transparent command routing and distribution. In conjunction with the safety requirements noted above, this implies a highly secure and well engineered Space Station base DMS operating system, where ultimate control and allocation of onboard resources will be managed.

Network monitoring and performance assessment will be needed to assure adequate and reliable system performance, but a highly centralized control of all of this monitoring data may impact system performance. This likewise suggests a highly distributed monitoring and performance assessment function, at least at the facility level, with coordination of overall network data required only for small subsets of higher level performance data.

Similarly, command management is best distributed on the ground, with the capability for command authentication and final authorization occurring within the onboard SSDS. In this manner non-restricted commands generated by geographically separated customers can be efficiently routed within data streams without the necessity of centralized ground validation and verification. Ground validation of ground related commands will be required, but, as much as possible, in a distributed fashion, and at the facility level or lower.

4.4.5.3 Operational Autonomy/Automation Key Requirements

A major Space Station Program goal is to maximize autonomy of operations and to maximize the implementation of automated processes. For many routine operations, automation is both cost effective and more reliable. Automation is expected to be implemented stepwise during the Space Station Program as automation technology processes mature.

An eventual highly automated system will require thorough configuration management during its development and integration, and ongoing monitoring and assessment of its functioning. A distribution of the monitoring function is again valuable in detecting failures in automated subsystems and in providing quick functional backups.

4.4.5.4 Upgradeability of SSDS Elements

As technology develops, both ground and space SSDS components will be upgraded, and an ever-increasing number of functions will migrate from a ground-based implementation to an autonomous space functionality. Again, this will require a broad and thorough system-wide configuration management function to assure adequacy of updates, logistical feasibility, and adequacy of functional redundancy in case of failures. Assurance of inter-subsystem data exchange and communication compatibility will also be necessary.

4.4.6 Architectural Design Decisions/Management-Related Functional Allocations

Table 4.4.6-1 are summarizes the major architectural functional allocation decisions with respect to systems management and control within the SSDS. As can be seen in the Table, each facility will have autonomous responsibility for local performance monitoring, configuration management, and administrative management. Appropriate subsets of data from these functions will be sent periodically to the higher level ground facilities management and/or systems management functions.

Table 4.4.6-1. Systems Management SSPE Allocations

	Space SSPE			Ground SSPE							
Management Function	SS	COP	POP	GSC	SSOCC	COPCC	POPCCs	EDC	POCCs	DHCs	LZPFs
Systems Management				X							
1. Communications Coord				X							
2. System Performance Monitoring				X							
Facility Mgt	X	X	X	X	X	X	X	X	X	X	X
a. Resource Management	X	X	X	X	X	X	X	X	X	X	X
b. PL/Ops Scheduling	X				X	X	X		X		
1) Long Term					X	X	X		X		
2) Short Term (2 wks → 1-2 hrs)					X	X	X		X		
3) Near Term	X				X	X	X		X		
c. RT Command Management	X	X	X		X	X	X		X		
d. Performance Monitoring	X	X	X	X	X	X	X	X	X	X	X
e. Configuration Management	X	X	X	X	X	X	X	X	X	X	X
f. Administrative Management	X	X	X	X	X	X	X	X	X	X	X

Each facility will have responsibility for managing its own SSDS resources. In addition, a proposed ground facilities management function will coordinate resources and resolve conflicts among ground elements serving multiple SSPEs, i.e., the DHC and LZPFs. The Space Station and platform control centers will be dedicated to a single SSPE or mission set and, except for communications coordination, will not require significant interfacility coordination.

The systems management function, located in the proposed Ground Services Center, will coordinate the scheduling of TDRSS network communications with the NCC and coordinate and negotiate space/ground communication requests. Although space and ground elements will primarily downlink and uplink data, respectively, some traffic the other way will occur in each case. Onboard payload specialists may request data from the ground and ground customers may send operational payload information to the station. The systems management function at the GSC will also perform system-wide network assessment and configuration management.

4.4.6.1 Management/Control Hierarchical Design - Ultimate Control Locations

The proposed SSDS design does not encompass much hierarchy above the facility level. Each facility will operate autonomously except for the communications resource scheduling, common ground facilities coordination, and high level systems monitoring and configuration management.

The Space Station will therefore have ultimate control over its normal operations. In the event of emergencies or Space Station subsystem malfunctioning, the ultimate control can revert to the ground with the Space Station Operations Control Center assuming a backup role in this area.

4.4.6.2 Extent of Centralization/Distribution of Key Management/Control Functions

An important design philosophy is the decentralization of function implementation as much as feasible. This distributed philosophy will facilitate the user-friendliness and transparency desired of the SSDS. This distribution will be feasible due to the rapid advances in networking technology and associated software developments (AI, expert systems, etc.).

The resultant autonomy of operations will require extensive validation and verification of function implementation as well as rigorous configuration management control for updates.

4.4.6.3 Scope of Management/Control Allocation per Ground/Space Element

Each SSPE will control itself to the extent necessary. For example, at a POCC a customer may request Space Station resources requiring coordination via a mode change. If scarce onboard resources are required, this would need to be determined either at the SSOCC or onboard, if real time in nature. A highly centralized or hierarchical command management scheme is not warranted if each facility has the ultimate control of executing commands and allocating resources. The Space Station will be the controller of its resources and will need to protect itself from erroneous or harmful commands, either by physical means or logical DMS controls.

In general each facility may also distribute resource management responsibilities to individual autonomous facility subsystems and only serve as an overall coordinator and monitor of facility operations.

4.4.6.4 Scope of Monitoring/Accounting/Tracking Performed

The basic philosophies regarding of performance monitoring, data accounting, and process tracking to be performed within the SSDS are:

1. These functions should not significantly affect system responsiveness, impact resource availability, or impact system development or operational costs.

   As a guideline impacts should be less than 10% of that resulting from functions implemented for basic Space Station operations, unless these monitoring and accounting functions are deemed essential for Space Station system effectiveness.

2. Within these guidelines, monitoring and accounting should be implemented only to the extent justifiable on cost and utilization basis. If clear and important uses of the data gathered are not evident, the data should not be taken or stored.

3. The SSDS should be designed as much as possible, however, to straightforwardly incorporate new capabilities in these areas as needs arise with time and evolving mission requirements.

4.4.6.5 Coordination of Space/Ground Management Via a Pre-established Set of Inference Rules for Conflict Resolution

In the man-tended Space Station era, few management related functions or decision-making will be implemented onboard. AI techniques will still not be mature and the absence of crew will affects the amount of ground implemented management of space resources. The eventual goal, however, will be a nearly autonomous manned station, with most management and decisions performed onboard, either by expert systems or, as needed, by crew intervention.

Conflicts over resource utilization and activity priority, however, will inevitably arise between the crew and onboard systems and the ground-based control center operators and customers. Inasmuch as possible, the use of a prenegotiated, pre-established set of decisions to guide the SSP in these conflict areas is desirable. The development of these inference rules will require planning and contingency analysis, as well as pre-mission negotiations, on the part of customers and NASA prior to mission actualization.

For unforeseen conflicts, it is suggested that the ground program managers have final decision authority with the exception of time critical or life-threatening onboard occurrences for which the crew will need to act with real-time responsiveness. The minimization of onboard conflicts suggests the development of a thorough DSIT facility.

4.4.7 Key Issues and Recommendations for Further Investigation

4.4.7.1 Variation of Functional Allocations for Customer Classes/Data Types

No analysis has been performed to determine if different types of customers or data types will require special management or will be particularly impacted by the proposed management design. No impacts are obvious. Requirements of foreign customers have also not been evaluated in this regard.

4.4.7.2 Impact of Possible Future National Security Requirements

If national security requirements become an eventual part of the SSP, a separate highly secure command and control system may be necessary. Depending on specific hardware and software architectures selected, compatibility problems may arise with respect to interfacing to approved national security processing systems or encryption devices.

Re-evaluation of resource allocation priorities and revised management strategies would be likely. If the utilization of SSP assets for national security purposes appears likely, the programmatic issues need to be addressed as soon as possible.

4.4.7.3 Potential Impacts of International Requirements

A key issue is who has ultimate authority over the commanding of foreign modules or payloads attached to the U.S. Space Station. How can the U.S. be assured that foreign operations may not inadvertently damage or impact U.S. space assets? How will common communications resources be coordinated and allocated?

Another policy issue relates to the liabilities on NASA if it impacts foreign users or causes a loss of data or privacy. This is an extension of liabilities to U.S. based customers, but program management coordination with foreign countries and foreign customers will be difficult. Some experience has been gained with Spacelab but not without policy and programmatic difficulties.

Another issue is whether NASA will be responsible to foreign customers for the range of customer services currently specified for the SSDS. Negotiations with regards to data processing and data delivery responsiveness, data handling transparency and provision of DSIT services, among others, need to be initiated as soon as possible to assess possible impacts on SSDS and SSIS designs.

4.5 COMMAND MANAGEMENT

4.5.1 Introduction

Definition

A definition of an SSDS command is that it is an electronic entity that conveys information from a user to his payload or core subsystem, to initiate the execution of a computer directed sequence (program) that results in some desired action or response. For the present purposes, commands can be thought of as being initiated by users directly, or indirectly, vocally (voice recognition), manually (touch panel), automatically (via future scheduled activity), internal to an SSPE or external at a POCC, CC, etc. via telecommand initiation, real- and non-realtime initiated, and so forth.

Commands may be batch-assembled onboard or on-ground for future automatic execution and they may be transported indirectly via optical or magnetic storage media or directly (electronically) via the SSDS. Commands may be issued in realtime, on a one-at-a-time basis, from within the SSPE or from a ground-based center. Numerous options will be supported by the SSDS as will be described later.

Commands can also be considered in a hierarchical sense and at a macro- and micro-level and can exist in numerous encoded formats at an instant of time, as illustrated by the following examples:

COMMAND	COMMAND ENCODING
"OPEN VALVE 13"	13 ASCII characters in a telecommand packet.
"OPEN VALVE 13"	256 Bytes of MIL-STD-1750A Code.
"ACTIVATE ATTITUDE CONTROL SUBSYSTEM"	8 Bytes in the information field of a LAN (Layer 2) packet.

COMMAND	COMMAND REALIZATION
"ACTIVATE ATTITUDE CONTROL SUBSYSTEM"	64 KBytes of embedded and distributed subsystem control instructions.
"ACTIVATE SAX 0123"	A sequence of 20 subcommands that direct the attachment of physical and communication resources that support this experiment.

Micro-level commands are the lowest level of command—for an effector command, this would be the voltage signal delivered at an analog or digital output port. Macro-level commands are then recursive and nested sequences of sub-macro and micro-commands. Example of these commands are shown below where the brackets,[], indicate parameters or arguments associated with the command.

MACRO COMMANDS

- Configure Subsystem J []
- Execute Momentum Dump []

- Position Antenna K []
- Execute Auto-Calibrate Procedures SAX 5678 []
- Deploy UVW []
- Retract XYZ []
- Activate Payload Com 1234 []

MICRO COMMANDS

- Open/Close Valve [M]
- Position Effector [N,....]

As an example, a user might send the command OPEN VALVE 13 as an english character sequence (e.g., EBCDIC encoded) which could be interpreted in an SDP by a computer subprogram, or he may send the entire computer subprogram for execution. Either approach results in the same effector (VALVE 13) action.

Using this same example, the implementation of the command OPEN VALVE 13 is shown in Figure 4.5.1-1, where: 1) the command is initiated externally and manually, at a workstation (trace with solid line), and 2) where the command is initiated automatically and internally (trace with dashed line) in an SDP program. In both cases a command interpreter (subprogram) is called, with argument [13], that initiates the I/O subprogram that activates effector (valve) number 13.

Two final points here are that: 1) Command management involves the consideration of criticality, where commands may be restricted or constrained based on the current operations being conducted in an SSPE, i.e., criticality varies with time as a function of SSPE state and possibly other parameters, and 2) Command management also involves the consideration of the availability of resources to implement a specific command at any instant of time.

FUNDAMENTAL ISSUES

Some fundamental issues (and options for implementation) in command management are summarized Table 4.5.1-1 in an end-to-end event sequence in the processing cycle of a command.

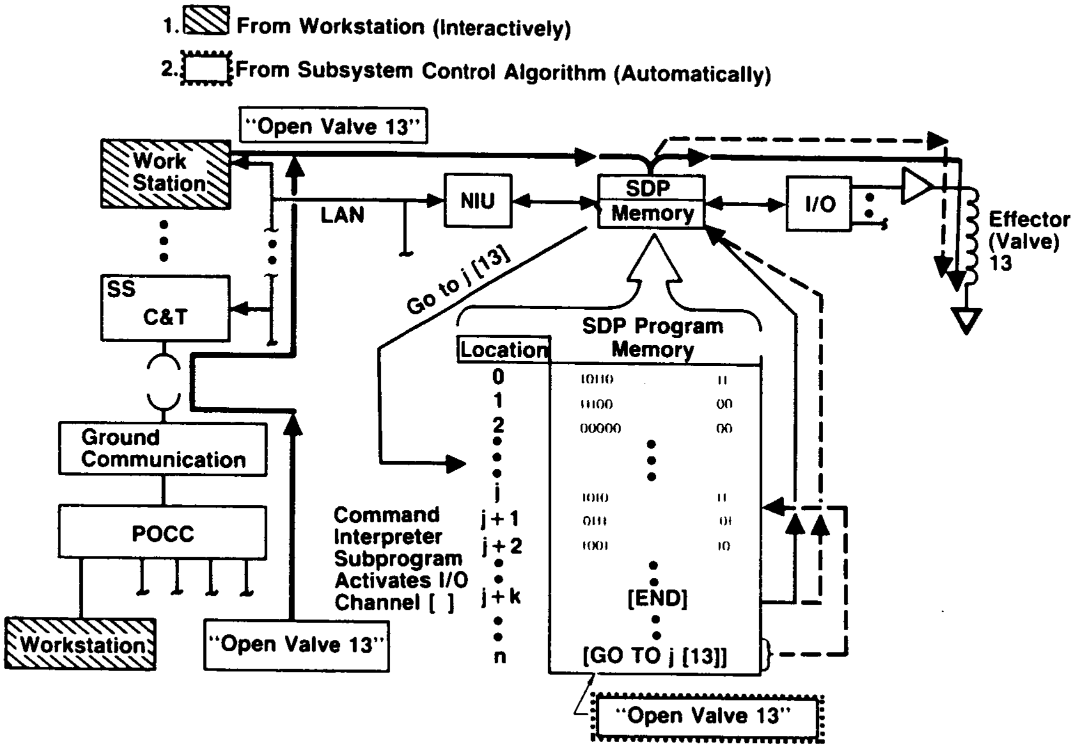


Figure 4.5.1-1. Micro-Command Implementation with Two Instances of Initiation

Table 4.5.1-1. Issues in Command Management

- Authorization to initiate/transmit commands
- Command Receipt (Data Transport) Validation
  - Forward error checking
  - Re-transmit at OSI transport and CCSDS transfer frame layers
  - Re-transmit at application layer
- Checks for executability
  - SSIS or SSDS resources may not be available to implement the command (resources are finite).

  - The command will result in a mode of operation that interferes with another payload, i. e., the quality of data captured by one or more of the payloads is affected. This situation is referred to as <u>constrained</u> operations

  - The command will result in a mode of operation that endangers the crew, an SSPE's or its payloads—physical damage and loss of life are possible. This situation is referred to as <u>restricted</u> operations.

- Verification of Command Execution
  - Application-to-application verification
  - Indirect verification (data F/B observations: Video, T/M,....)

- Command Traceability (Command Logging)
  - At sending end
  - At receiving end
  - At both ends (end-to-end verification/logging)

Command Authorization

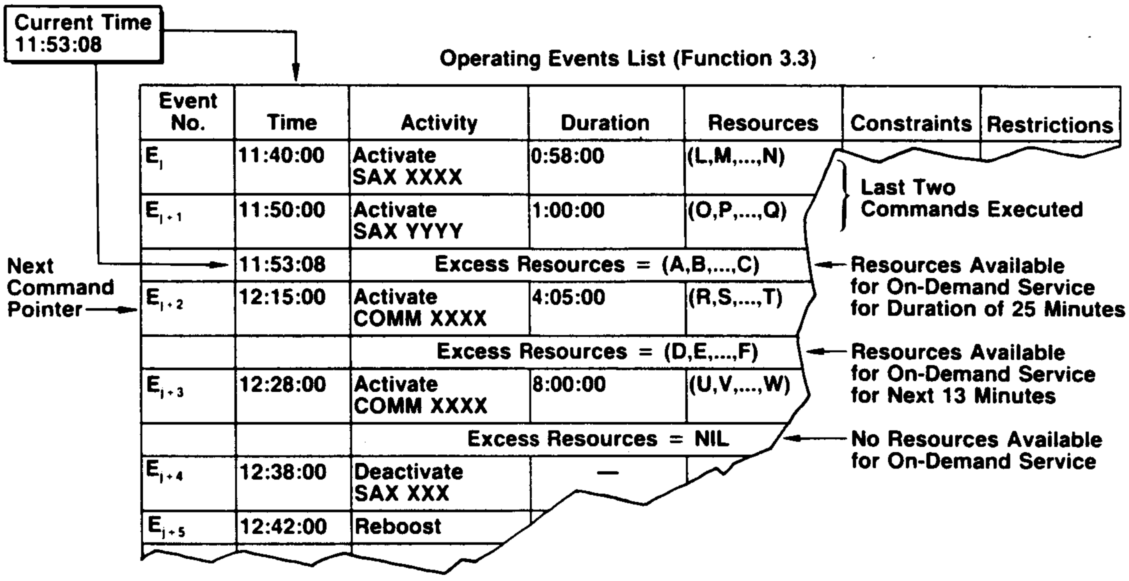
Users are required to be authenticated prior to transmitting any command. This is accomplished by LOGON and possibly other procedures (e.g., voiceprint, fingerprint, badge, etc.). Specific users identified at LOGON time will only be allowed to be attached (connected) to specific pre-assigned SSDS entities (workstations, certain sectors of mass store, a specific payload or subsystem, etc.); browsing throughout the SSDS will not be allowed and attempts to violate privileges are reported to the network control center via the distributed operating system. (Privacy and security are always significant parts of any private or public data network.)

Onboard Command Management

SSDS Function 3.0 (See Task 1 report) includes all of the user scheduling activity and subfunction 3.3 (which is onboard allocated) executes commands contained in an Operating Events List (OEL), an example of which is shown in

Figure 4.5.1-2. This list is a table of time-ordered commands stored for future sequencing, and is updated and adjusted in near-realtime as on-demand requests for payload activations and sequencing are received. This listing results from user commands and SSDS/SSIS coordination and negotiation for on-demand and future-scheduled payload and core systems activity.

- **Operating Events List (OEL) Is Time-Ordered and Executed in Sequence by Function 3.4**
- **At Any Point in Time, Resources, Constraints, and Restrictions Are Defined that Can Support On Demand Event Initiation**
- **OEL Is Onboard With Identical Copies at CC and GSC**



Event No.	Time	Activity	Duration	Resources	Constraints	Restrictions
E_i	11:40:00	Activate SAX XXXX	0:58:00	(L,M,...,N)		
E_{i+1}	11:50:00	Activate SAX YYYY	1:00:00	(O,P,...,Q)		
	11:53:08	Excess Resources = (A,B,...,C)				
E_{i+2}	12:15:00	Activate COMM XXXX	4:05:00	(R,S,...,T)		
		Excess Resources = (D,E,...,F)				
E_{i+3}	12:28:00	Activate COMM XXXX	8:00:00	(U,V,...,W)		
		Excess Resources = NIL				
E_{i+4}	12:38:00	Deactivate SAX XXX	—			
E_{i+5}	12:42:00	Reboost				

Figure 4.5.1-2. Operating Events List

Function 3.3 is implemented in a computer program that receives the OEL from Function 3.2 and steps down this time-ordered listing based solely on time. Function 3.2 assembled the OEL taking into account requirements for resources, restrictions and constraints, however, these components of the OEL are re-validated in terms of the current real operating mode prior to executing each command. The principal points to be noted here are that: 1) Function 3.3 steps down the time-ordered Operating Events List issuing the required commands that activate and deactivate payloads, subsystems, ..., and 2) commands for on-demand payload activation and sequencing are coordinated by Function 3.2 and when resources, restricted and constrained demands can be satisfied (or when priority allows deactivating an active payload to satisfy the demands) then the OEL is updated immediately to include the on-demand request (which was received in the form of a command). Various scenarios are possible here; one that allows for immediate payload activation, activation within a short time (e.g., seconds or minutes, whenever the resources, constraints or restrictions can be satisfied) or the user may be notified that based on his priority, and his demand for some specific resource (or constrained or restricted operation) he cannot be immediately attached and the next window of operation for his payload is at time XXX XXX, and for a duration of XXX units of time.

Scheduling Activity

It is the intent here that the SSDS be as friendly to users as is possible and that he have full access to his payload with the least constraints and limitations. The scenario envisioned is that after he executes LOGON procedures (at a minimum: password, account no., and application process ID) and is authenticated by the SSDS, he can freely communicate with his payload, e.g., turn it ON, turn it OFF, execute diagnostics, perform calibration, quick look, ... Some limitations in this procedure, however, are obviously mandatory based on common sense safety and engineering principles. These include the following:

1. SSIS or SSDS space/ground resources may not be available to implement the command.

2. The command will result in a mode of operation that interferes with another payload so that the quality of the data captured by one or more of the payloads is affected. (This situation is referred to as constrained operations.)

3. The command will result in an operation that endangers the crew, an SSPE, or another payload — physical damage is possible. (This situation is referred to as restricted operations.)

The following key points are reiterated:

1. SSIS and SSDS resources in space and ground are finite and must be carefully managed.

2. Constrained operations affects the quality of data captured, the effects of which may not be immediately observable.

3. Restricted operations involves hazardous situations that endanger crew life and/or affect equipment damage.

Obviously, the user may have the priority to adjust the current SSPE's operations so that his command can be immediately executed or, if not, he must enter an interactive negotiating phase with Function 3.2 (scheduling activity) to arrive at an agreed-to future timeline of operation. This scenario is depicted in Figures 4.5.1-3 and -4 which shows users coordinating with control centers to develop this agreed-to-schedule.

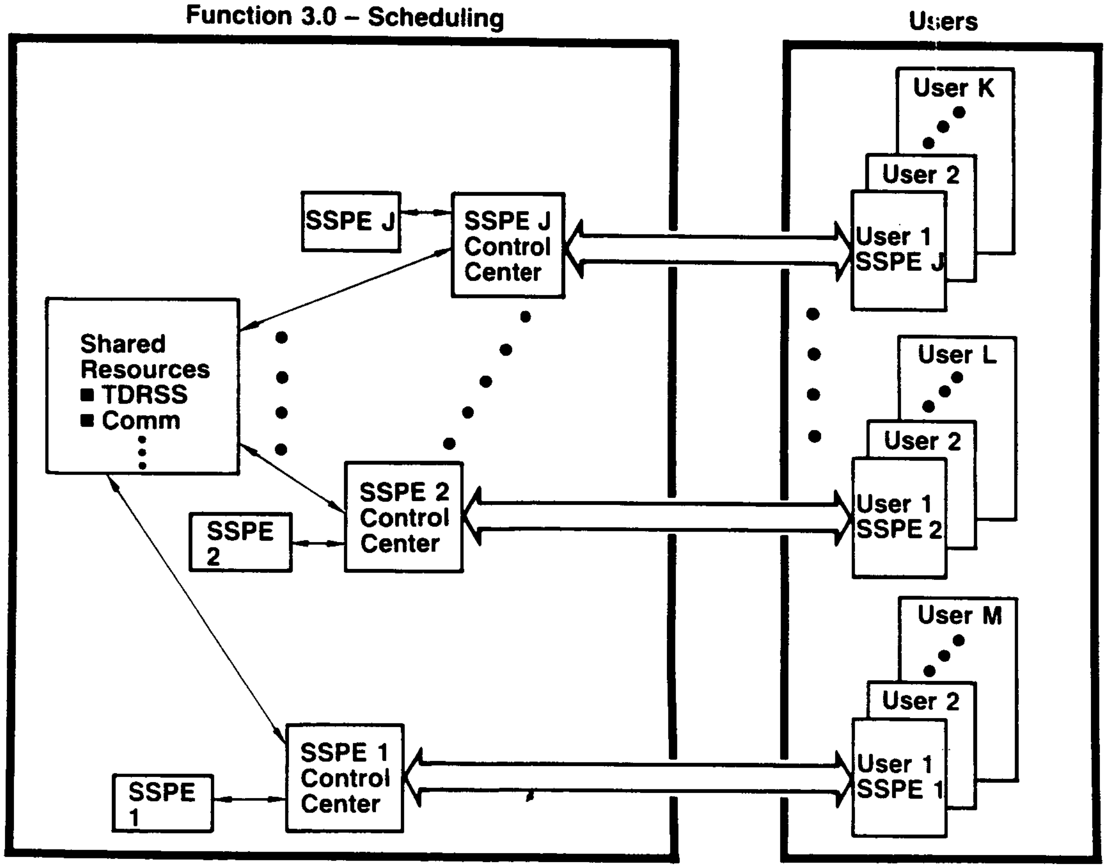


Figure 4.5.1-3. Schedule Development

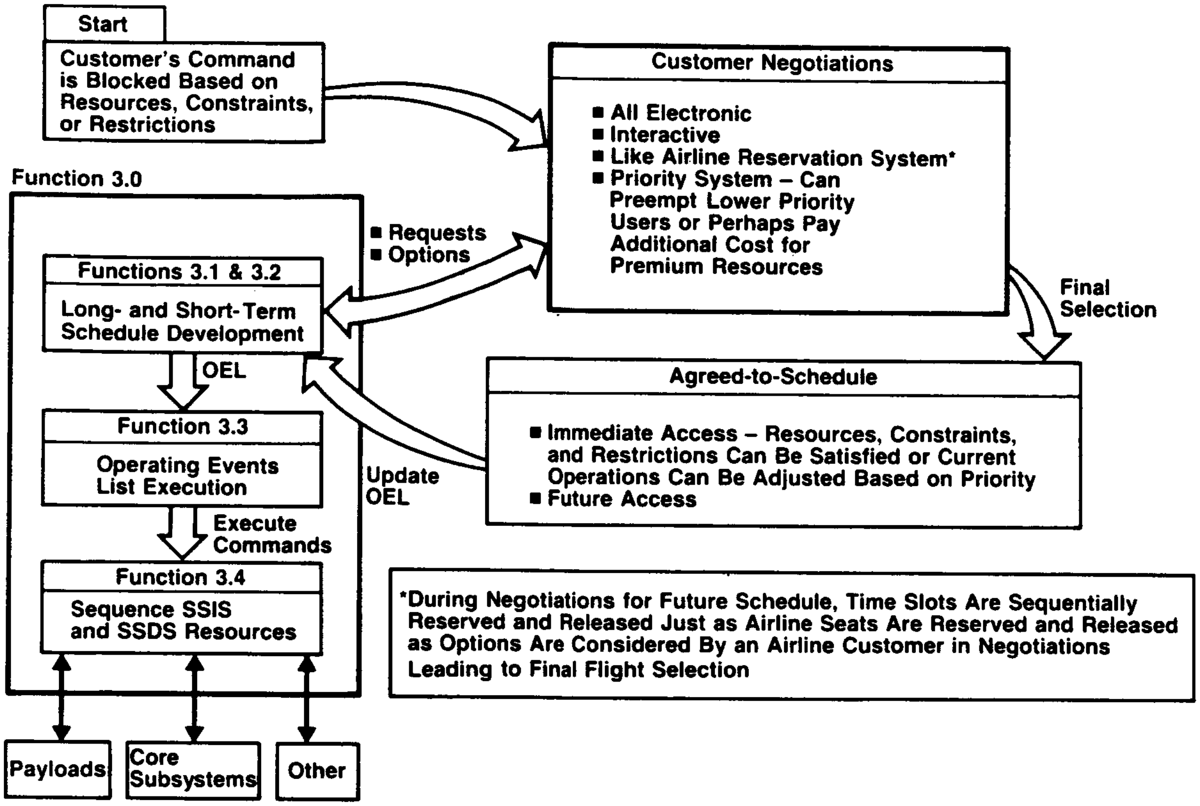


Figure 4.5.1-4. Schedule Development

Realtime Payload Command Management

At this point a preview and summary of the recommended payload command management system is given with details to follow later. The management concept proposed is automated and implemented onboard and in realtime — users are given maximum flexibility to interact with their payloads and subsystems, but will be disconnected (reactive control) if their operations exceed parameters associated with the original connect/attach commands. Additionally, the system also includes a priority structure so that lower priority payloads can be automatically disconnected to provide resources for higher priority operations. This leads to a totally automated management system that can be driven by one of the following: schedule, on-demand requests, and event-oriented observations experienced by a payload. This is especially important for the unmanned SSPEs.

Numerous strategies and options for command management have been proposed and many appear to be reasonable until one attempts to implement them in realistically sized hardware and software. The problem one encounters is that the systems become extremely complex with large overheads and time delays and even then "sneak circuits" may still exist that could allow a restricted command to be executed in certain extremely remote and in unusual circumstances. It is expected that safety will be a principal consideration in the management of commands and that command management systems cannot be implemented in a way that cannot be analyzed to be proven to be free of hidden logical and physical paths that could lead to the execution of a restricted command and a subsequent catastrophic event. For this reason the system described later will use an independent "electronic key" that controls resources (predictive control) required for restricted operations.

Core command management is considered separately, later.

4.5.2 Resource-limited, Constrained, and Restricted Operations

This paragraph will introduce a formalism that attempts to capture the problem of payload command management in terms of a model that allows or inhibits commands to a payload based on the three considerations previously discussed: resource limitations, mutual compatibility and cross-interference associated with multiple payload operations (Constrained Operations), and hazardous operations that affect crew safety and physical damage to payloads/core/SSPE structures and equipment (Restricted Operations). Associated with these three considerations, we shall define a triplet T of vector components RSCRCS, CONSTR, and RESTRICT, defined as follows:

$$T = [(\mathrm{RSCRCS}), (\mathrm{CONSTR}), (\mathrm{RESTRICT})]$$

where

Resources = RSCRCS = $(a_1, a_2, \ldots a_j)$,
Constraints = CONSTR = $(b_1, b_2, \ldots b_k)$,
Restrictions = RESTRICT = $(c_1, c_2, \ldots c_n)$.

The components of each of the three vectors are an ordered set of not-necessarily numerical components, as will be described in detail later. For now a brief description of each vector is given below:

RSCRCS - Has components which are the SSIS/SSDS resources available at some instant of time or that are required to support a certain payloads operation immediately or at some future time and in some specific mode of operation.

CONSTR - Has components that specify the compatibility between payloads; compatibility here relates to interference between payloads that may affect data quality captured by one or more payloads.

RESTRICT - Has components that specify non-compatibility of a payload and other SS functions that affect hazardous operation associated with safety and physical damage considerations.

The problem in command management can now be stated as follows: At no time shall an SSPE's payload be operated so that constraints associated with RSCRCS, CONSTR, and RESTRICT are violated. The implementation of this rule is discussed later.

4.5.3 Modes of Operation

The normal flow for a payloads space operation is: delivery to space, SSPE integration, production, and finally disconnect and transport back to earth. Within the integration and production phases one can usually identify several modes of operation (e.g., test, checkout, diagnostics, calibration, production mode 1 (high power), production mode 2 (low power), and so forth) where the RSCRCS, CONSTR, and RESTRICT vectors may have different values for each mode. The point here is that at some instant of time, a payload may be allowed to operate in MODE 1 (e.g., checkout/diagnostics) but not in MODE 3 (e.g., production), for reasons associated with violations in these constraints. These concepts are illustrated in Figures 4.5.3-1 and -2.

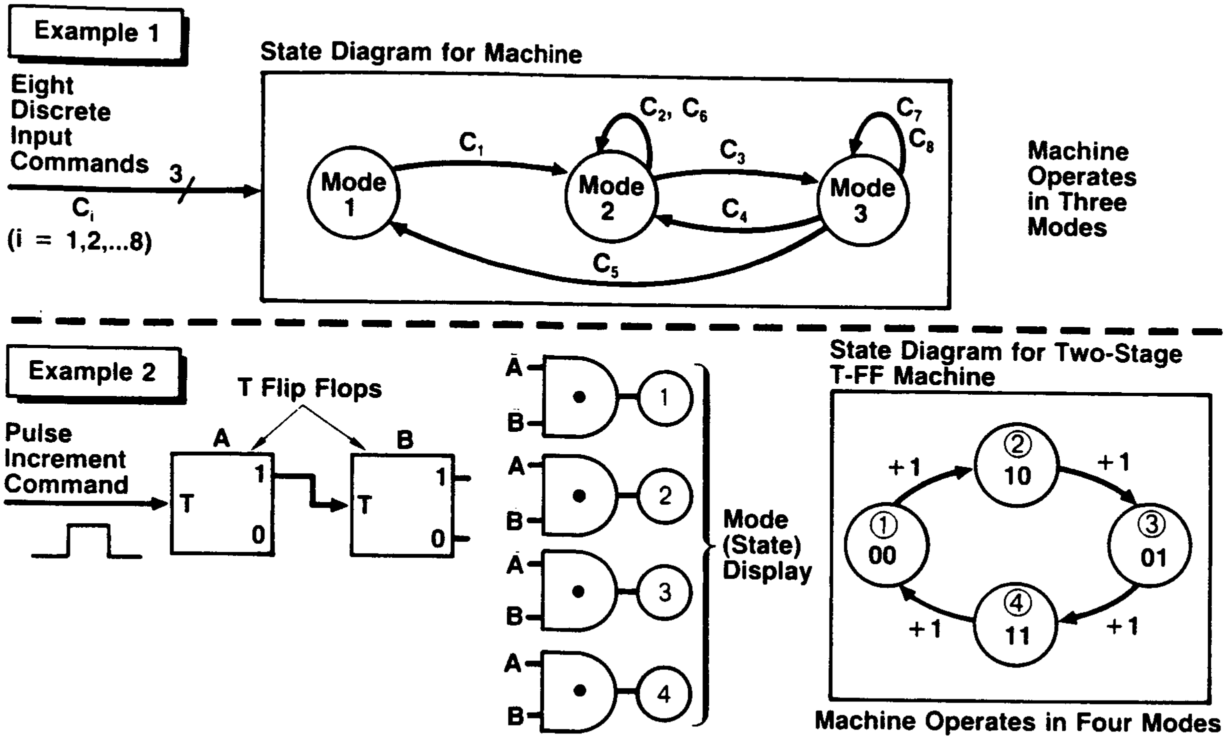


Figure 4.5.3-1. Finite State Automata (Mode Diagrams)

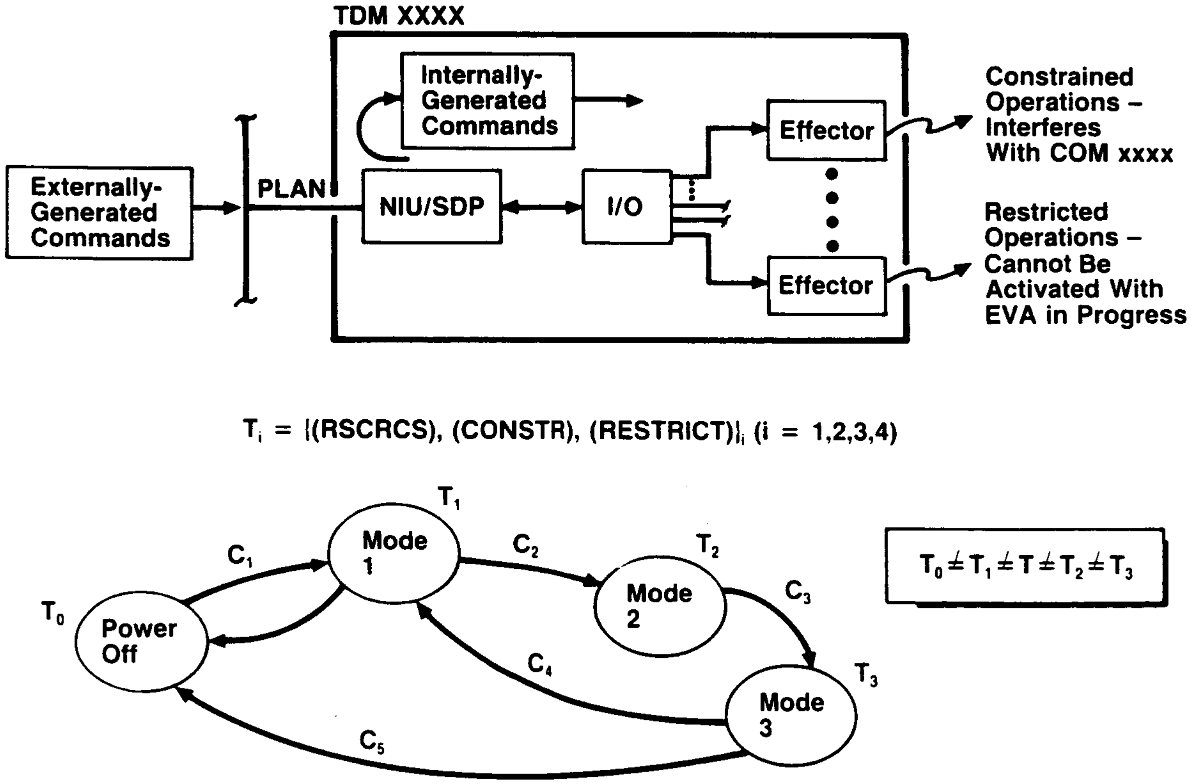
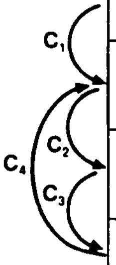


Figure 4.5.3-2. Command Classification Example (1 of 2)



Mode	Resources	Constraints	Restrictions	T_i
Mode 0 (Power Off)	NIL	NIL	NIL	$\{(NIL), (NIL), (NIL)\}_0$
Mode 1 (Diagnostics)	Pwr = xx kW TCS = xx GPH Crew = xx Mins	NIL	NIL	$\{(a_1 \ldots ,a_j), (NIL), (NIL)\}_1$
Mode 2 (Calibrate)	Pwr = xx kW TCS = xx GPH SDP = xx OPS	Incompatible With SAX 1234 and θ · 35°	NIL	$\{(a_1 \ldots ,a_j), (b_1 \ldots ,b_k, (NIL)\}_2$
Mode 3 (Production)	Pwr = xx kW TCS = xx GPH SDP = xx OPS	Incompatible With COM 4567 and θ · 25°	■ No EVA ■ Crew Monitor Mandatory	$\{(a_1 \ldots ,a_j), (b_1 \ldots ,b_k), (c_1 \ldots ,c_n)\}_3$

	Command Checking		
Command	Resource Availability	Constraints	Restrictions
C_1	Y	N	N
C_2	Y	Y	N
C_3	Y	Y	Y
C_4	Y	N	N

Y = Yes
N = No

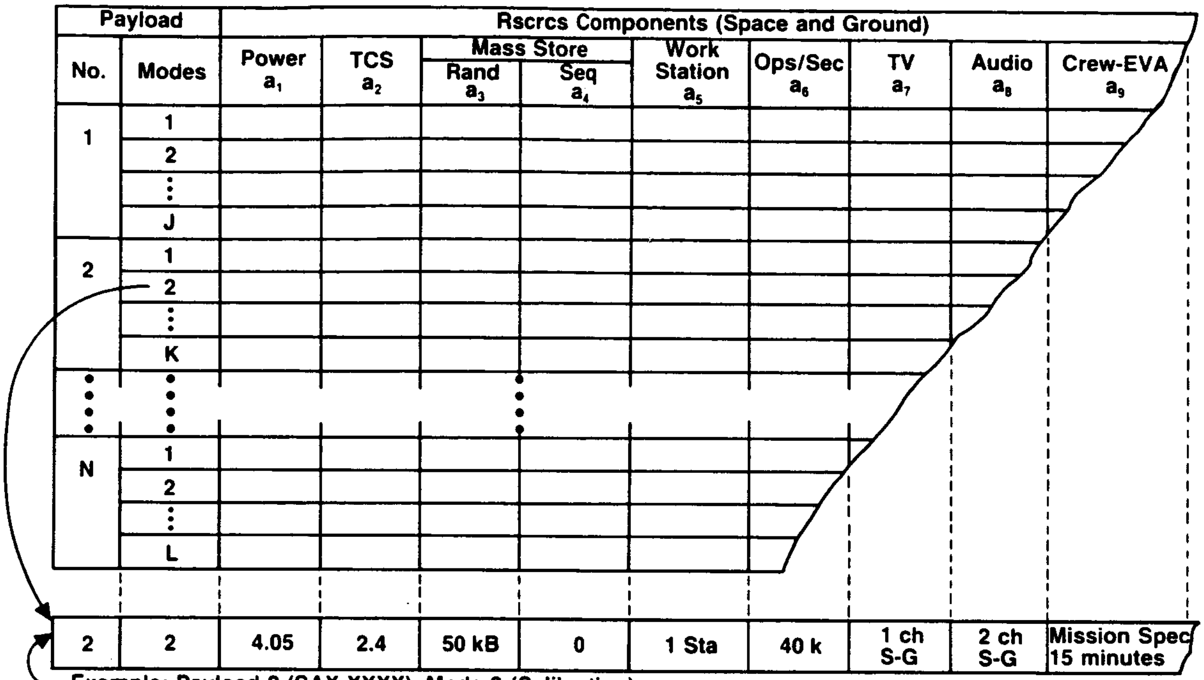
Figure 4.5.3-2. Command Classification Example (2 of 2)

4.5.4 Definition of RSCRCS (Resources)

The components of RSCRCS are an ordered set of SSIS/SSDS resources required to support the operation of a payload(s) or the excess SSIS/SSDS resources that are available at some instant of time. Figure 4.5.4-1 illustrates the notion in a table where the rows are the complete set of payloads, and the columns are the ordered and complete set of resources. The entries in row i constitute components of the vector RSCRCS(i) required for a specific mode of operation for the i'th payload. It follows then that the total resources required at any instant of time to support all active payloads is the vector quantity

$$SRES = \sum_{i=1}^{N} RSCRCS(i)*A(i)$$

RSCRCS = $(a_1, a_2, \ldots, a_i)$



Payload		Rscrcs Components (Space and Ground)								
				Mass Store						
No.	Modes	Power a_1	TCS a_2	Rand a_3	Seq a_4	Work Station a_5	Ops/Sec a_6	TV a_7	Audio a_8	Crew-EVA a_9
1	1									
	2									
	⋮									
	J									
2	1									
	2									
	⋮									
	K									
⋮	⋮				⋮					
N	1									
	2									
	⋮									
	L									
2	2	4.05	2.4	50 kB	0	1 Sta	40 k	1 ch S-G	2 ch S-G	Mission Spec 15 minutes

Example: Payload 2 (SAX XXXX), Mode 2 (Calibration)

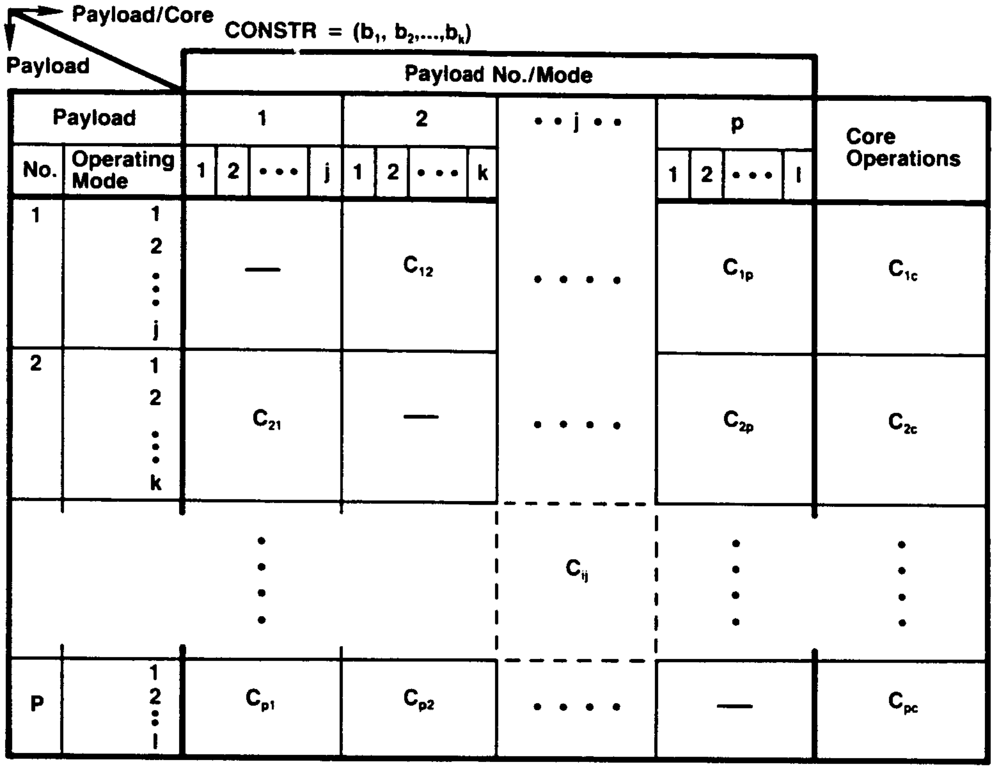
Figure 4.5.4-1. Resource Requirements

where A(i) is a binary-valued discrete that takes the value 1 if a payload is active or 0 if a payload is powered OFF. It is a function of the scheduler to assure that no planned operations exceed the capability of the SSIS/SSDS resources, and it is the responsibility of the command manager to disconnect payloads exceeding any one component of RSCRCS(i). Many of the components will be sensed directly (power, TCS, ...) and others will be sensed indirectly (e.g., crew time). In the case of crew time the customer may be given an option (and the cost, say at $50K/Hr) to continue, for example, diagnostics on his payload, or the SS commander may discontinue the operation once his allocation for this resource is exceeded. Excess resources are computed by subtracting the vector SRES from the vector ARES, the available resources at that instant of time.

4.5.5 Constrained Operations

The definition of constrained operations evolves around the mutual compatability of operation between PAYLOAD_i and PAYLOAD_j and between PAYLOAD_i and certain core operations. A constraint parameter C_{ij} (see

Figure 4.5.5-1) is defined to be the constraints that the i'th payload (in row i) places on the operation of the j'th payload (in column j). For example, the i'th payload may:



Definition: C_{ij} ≡ Constraints that the i^{th} Payload Places on the Operation of the j^{th} Payload or Core Operations

Figure 4.5.5-1. Payload-to-Payload/Core Constraint Matrix

1. Place no constraints on payload j.

2. Place limited constraints on payload j (e.g., the j'th payload can operate in the standby or calibrate modes but not in the production mode where it has a spectral emission that interferes with payload i).

3. Place total constraints that inhibit payload j from being powered ON in any mode.

The diagonal matrix elements are not meaningful and are not defined and the matrix is not symmetric.

The matrix will be initially prepared during the initial feasibility discussions with the customer to determine cross-interference impacts between payloads and realizable windows of operation. The matrix obviously changes with payload changeout and may be adjusted during space operations when unanticipated coupling between payloads is observed to degrade the quality of data collected by a payload.

4.5 6 Restricted Operations

Restricted operations include the hazardous operations resulting from activation of certain payload operating modes. The commands to activate these modes will be defined to be restricted and will be inhibited by the SSDS when incompatible with other operations. These other operations may include:

1. Other payload operations (e.g., possible hazardous operations resulting from production of incompatible byproducts including solids, gasses, ...).

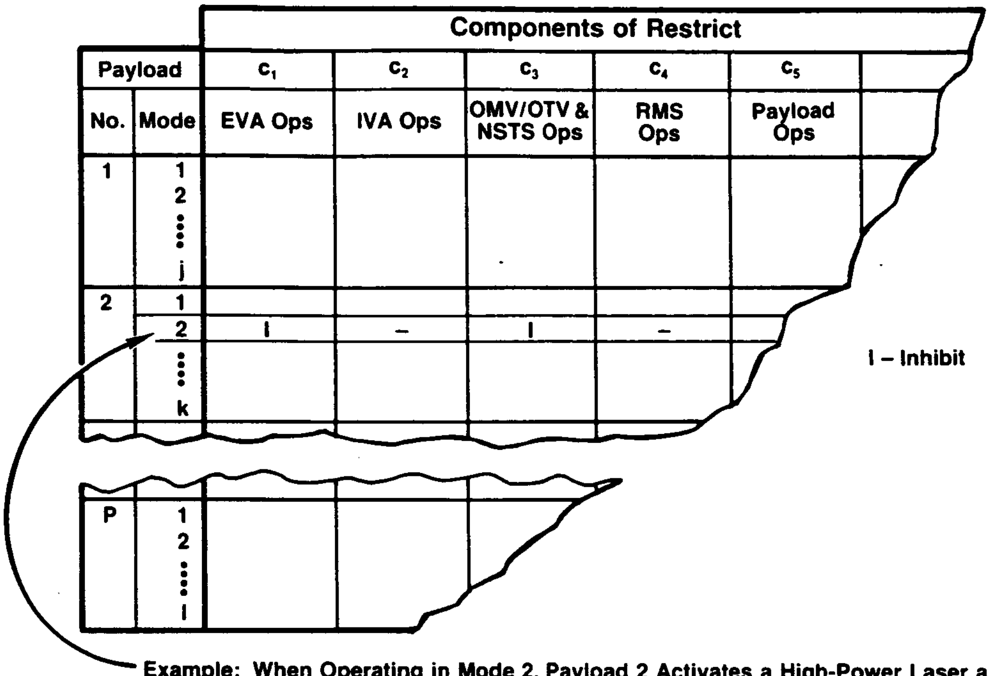
2. EVA Operation
   - Total SS sphere of proximity ops
   - Subset of total proximity sphere
   - With safety provisions such as laser protective eyewear

3. IVA Operation
   - Module must be unmanned when payload operating
   - Module must be manned to verify correct operation of payload

4. OMV, OTV, Orbiter Operations in proximity of an SSPE.

This concept is illustrated in Figure 4.5.6-1 with an example definition of the vector RESTRICT.

RESTRICT = $(c_1, c_2, ..., c_n)$



Payload		Components of Restrict					
		c_1	c_2	c_3	c_4	c_5	
No.	Mode	EVA Ops	IVA Ops	OMV/OTV & NSTS Ops	RMS Ops	Payload Ops	
1	1 2 ⋮ j						
2	1						
	2	I	–	I	–		
	⋮ k						
P	1 2 ⋮ l						

I – Inhibit

Example: When Operating in Mode 2, Payload 2 Activates a High-Power Laser and EVA and OMV/OTV/NSTS Ops Are Inhibited or Conversely, if EVA/OMV/OTV/NSTS Ops Are in Progress, the Command to Activate this Operating Mode Is Restricted and Will Be Inhibited by the SSDS.

Figure 4.5.6-1. Restricted Commands

4.5.7 Levels of Command Inhibition

The problem in implementing a command management system is to inhibit commands that violate constraints/requirements associated with the components of Γ (RSCRCS, CONSTR, and RESTRICT). Three levels of control can be identified:

1. Function 3.0 absolutely controls which payloads are consuming resources and the quantities of resources being used (e.g., power, flow rates, crew time, ...). The utilization of resources is sensed directly (e.g., current sensors for each payload) and also indirectly (use of crew people vs time). Payloads will be detached from resources when OEL-specified allocations are violated (reactive control).

2. Payloads are only allowed to communicate with certain subsystems/servers as determined by the OEL. Function 3.3 contains

the negotiated schedule for resources/entities and directs session establishment (connections) with only these authorized entities. Payloads will typically communicate (connect to) workstations, mass stores, C&T, and Function 3.0. Any attempt to communicate with other payloads/core systems directly will be reported (as an unauthorized access attempt) to Layer 7 Network Control/Security via Layer 4 Reporting Statistics.

3. This level is the problem area; where a payload has direct access/control over effectors that can violate constraints/restrictions that were placed on it when it was powered ON, e.g., a payload may be attached for diagnostics or calibration only, and is constrained/restricted from entering a mode where its primary instrument (e.g., a laser illuminator) is turned ON.

4.5.8 Command Management Options and Selected Approach

4.5.8.1 Payload operations

Command management options for payloads are discussed below:

1. Prior to enabling a payload, check its processor's executable code for restricted/constrained commands. The problems with this option are:

   a. Difficult to implement: I/O can be activated by numerous addressing options — direct/indirect/subroutine/random number generator/..., many possible instruction sets, and so forth.

   b. CPU generates "garbage" causing inadvertent I/O operation, resulting in a uncontrolled restricted operation.

2. For command checking after activation: route all commands thru Function 3.0 for checking prior to release to payload/subsystem — same problem as above.

3. Trust user: He states that his program does not include constrained/restricted operating modes and he will label all his commands in the "OPEN" (e.g., ASCII encoded) for Function 3.0 checking—still have the problem of 1.b above even if you can trust the user.

4. Implement "electronic key" that Function 3.0 uses to "unlock" resources associated with user's requested mode of operation specified in the OEL.

Command Management - Restricted Operation

It is expected that the NASA safety community will require an independent safety control function for all restricted operations and for this reason option 4 above (electronic key) is selected for restricted command management; Function 3.0 unlocks resources required for restricted operations and the user does not solely control these resources. (It can also be expected that mechanical locks/stops, locked/guarded safety switches, procedural operations, and other non-electronic management concepts will also be employed.)

Command Management - Constrained Operations

Constrained operations do not affect safety and option 3 above is acceptable. The recommended implementation is that payloads report their mode of operation at all times (when they are powered ON) to Function 3.0 at a rate of between 1 1/sec and 1/min. If a payload enters a constrained mode and reports it, or it does not report its operating mode at the required interval (e.g., software "bug" may have resulted in a branch to an undefined operating mode) then the payload will be powered OFF and the event will be recorded in the archives and also distributed via an ancillary data FLAG which alerts all users of the possible interference problem (recall that safety is not an issue in constrained operations). The flag will contain adequate information to route subsequent inquiries to the source and the time at which the anomaly occurred.

The risk in this approach is that a payload will enter a constrained mode of operation, and not report it to Function 3.0, thereby jeopardizing the quality of data being captured by other payloads. This risk is minimized by implementing NASA procedures for validating the reporting system during qualification/acceptance testing of payloads.

Command Management - Resource Allocation

As discussed earlier, payloads will require different resources for its different operating modes. If a payload is powered OFF, an activation command will be routed to Function 3.0 which puts the command in the OEL along with the resource (specified in RSCRCS) required, and whether it is for immediate or future execution, as discussed earlier. Thereafter, commands will be routed directly to the payload with no checking required.

4.5.8.2 Command Management - Core Operations

The management of commands to core subsystems are in a special category since subsystems are, in general, continuously active and may be required to provide normal services (e.g., attitude control) in parallel with diagnostic or other operations. Subsystems are also special since they are developed and operated by NASA, as opposed to a customer, and must endure for the life of the program. This last requirement will justify the development of large scale expert system command checkers whose cost can be "amortized" over the life of the program. Predictive command checking via expert system checkers will form the basis for core command management

Because of the complex and time-dependent interaction between certain subsystems or even within a single subsystem, commands must be rejected (e.g., turn OFF the life support system, VENT a crew-occupied module, CLOSE oxygen valve to a crew-occupied module, ...) based on the physical location of crew personnel and numerous other SSPE state parameters. This leads to the definition of yet another vector called SS STATE which is defined, by example, in Figure 4.5.8-1. The basic procedure for managing core commands requires the following steps for implementation:

1. Predefine all possible macro- and micro-commands, where a command is designated as $CMMD_i[\ ]$, $i = 1, 2, \ldots, L$. The integer L indicates

the total number of commands and the brackets indicate parameters or arguments of the command.

2. Prior to executing any arbitrary command perform a predictive test to determine the executability of the command given the current SSPE's state vector using the previously mentioned expert system checker.

An Ordered Set of Not Necessarily Numerical Components that at Any Instant of Time Characterize the State of an SSPE to the Degree Required to Implement a Command Management System.

SS State = $(d_1, d_2, \ldots, d_m)$
= (Payload Status, Subsystem Status, Crew Status,...)

Payload Status					Subsystem Status		Crewperson Status	
1	2	3	•••	P	G&N	ELSS	No. 1	No. 2
Off	Mode 4	Mode 1		Off	SDP No. 1, 3, and 5 Active SDP No. 4 Standby Momentum Dump 65% Completed GPS Receiver No. 1 Active GPS Receiver No. 2 in Diagnostics Inertial Package No. 2 Active Inertial Package No. 1 Standby Expandable Status = UVW ⋮		EVA at Location XYZ Time to Complete Estimate = 02:00:00	Hab Module No. 2 R&R

Figure 4.5.8-1. SSPE State Vector Definition

The end-to-end flow of core commands is shown in Figure 4.5.8-2 which also illustrates the concept of a core operator in a hierarchy of authorized operators that are allowed to transmit certain classes of commands.

4.5.9 Example of Payload Command Management

An example of command management is shown in Figures 4.5.9-1 and 4.5.9-2 for a hypothetical payload TDM XXXX. An electronic key is used to control the prime power resources to the high- and low-voltage laser power supply. In this case the user may enter the restricted mode (via restricted command that he issued) but no emission from the laser is generated and no hazardous operation results. Since he is reporting his mode to Function 3.0, he will be alerted and/or disconnected.

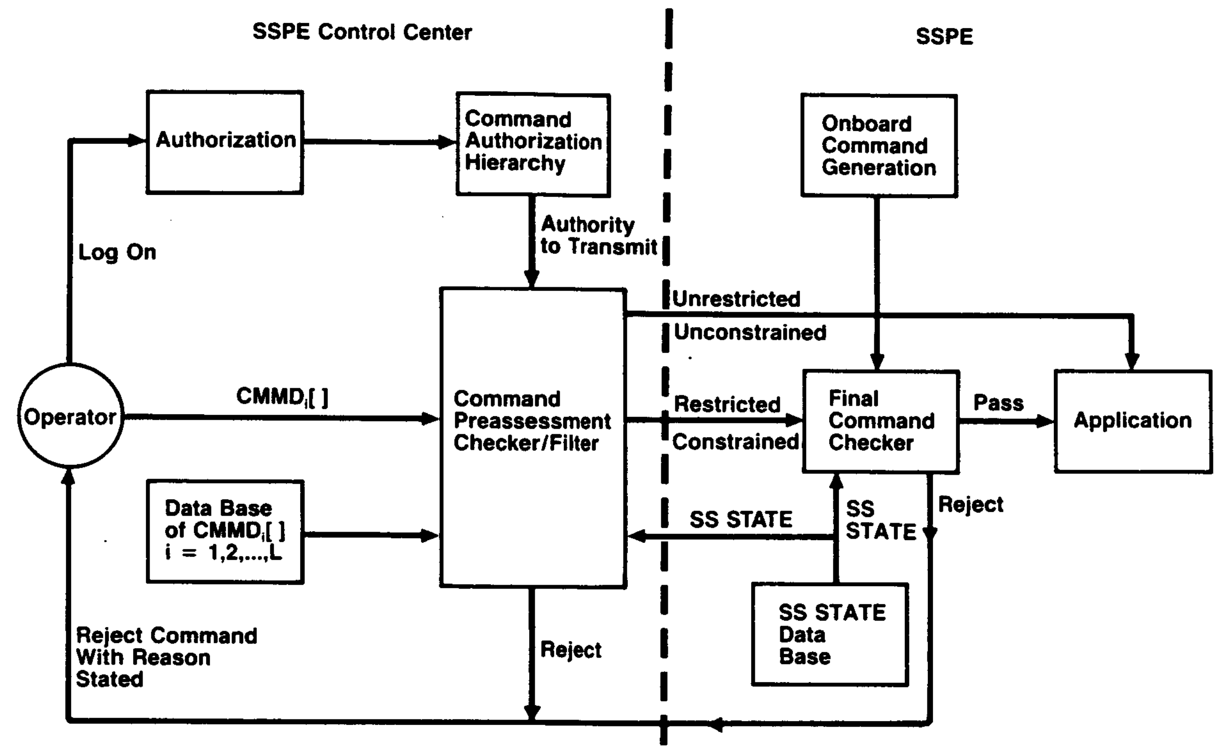


Figure 4.5.8-2. Core Command Checking

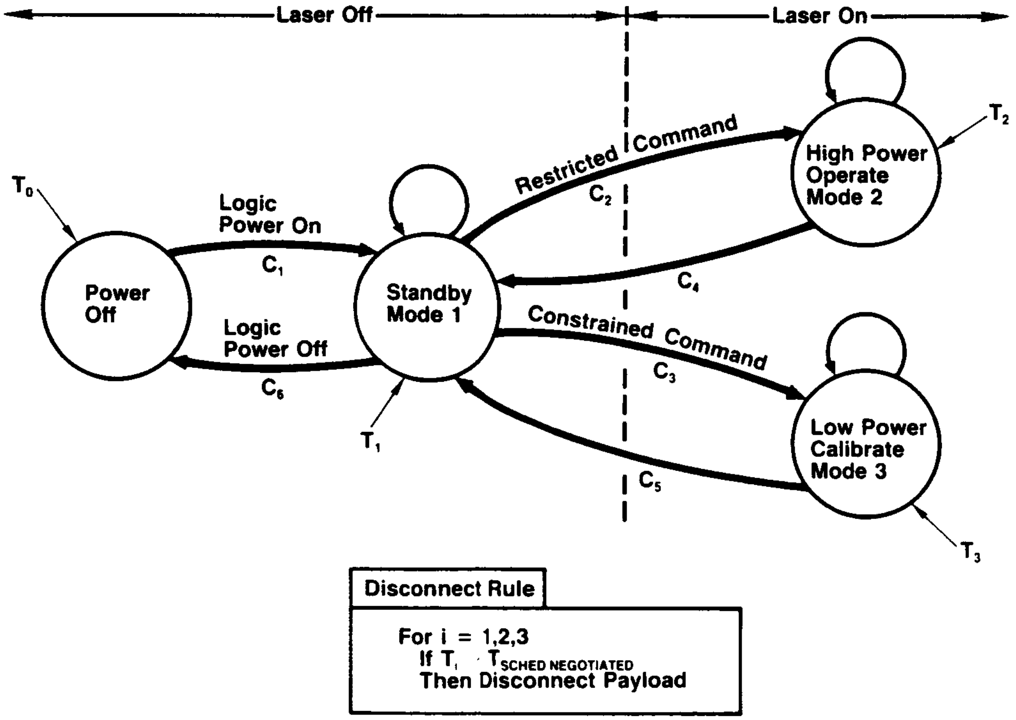


Figure 4.5.9-1. State Diagram – Hypothetical Payload TDM XXXX

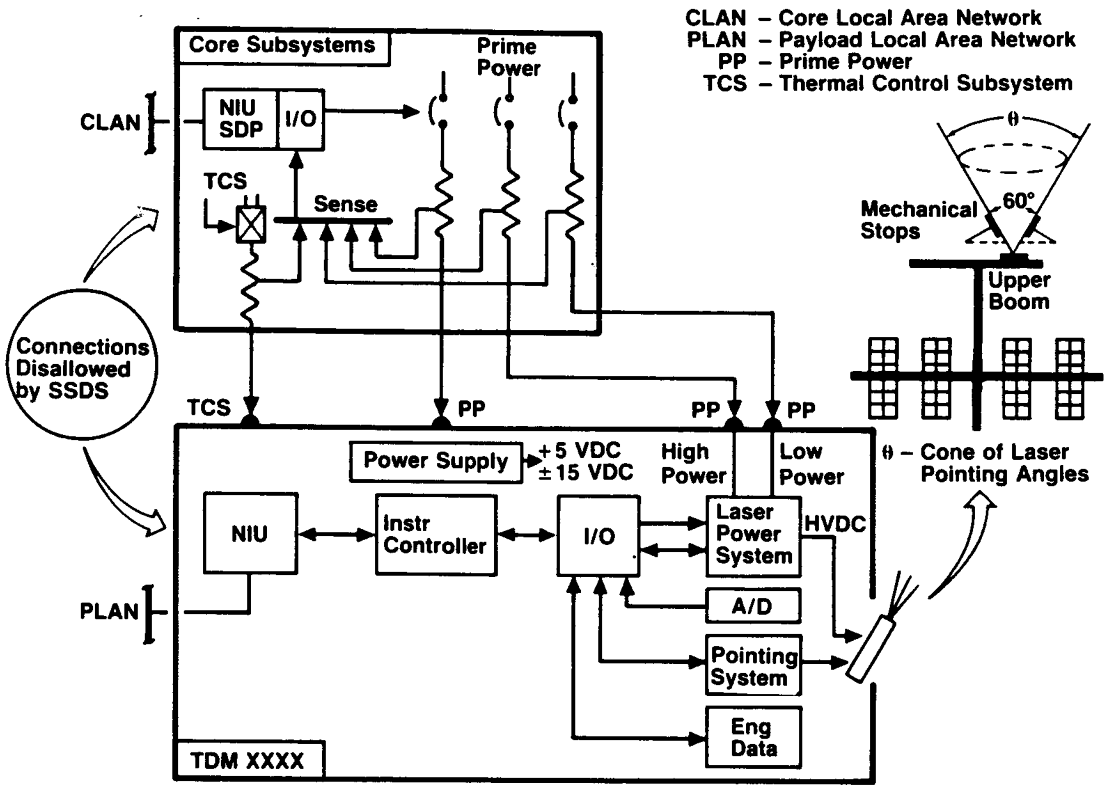


Figure 4.5.9-2. Block Diagram — Hypothetical Payload TDM XXXX

4.5.10 Command Management Scenarios

Numerous scenarios should be developed to validate the command management system previously described. Parameters that generate ideas for scenario sequences include:

1. Manned/unmanned SSPE's.
2. Onboard/Ground Operator/Customer.
3. Payload Duty Cycle: 100%/under 100%.
4. Maintenance, diagnostics, payload integration, buildup, ... operations.
5. Typical Core Operations – reboost, OMV/OTV operations, ...
6. Ground/Onboard interaction during hazardous operations – fueling, docking, ...
7. Unmanned SS operations.

.
.
.

Only one scenario is considered at this time and it is developed in the remaining subparagraphs.

4.5.10.1 Scenario No. 1: Payload Operations for COM 1234

In this scenario a customer is defined that operates from a POCC or from his own facility (he is mobile) and he has a payload (COM 1234 in the SS) that operates with a duty cycle of less than 100%. The payload has been qualified by analysis, test and inspection procedures (conducted by the customer and witnessed by NASA) to operate in these three modes (which are the basis for command management):

1. Mode 1 – COM 1234 is powered ON and will execute software transmitted via telecommand or accessed from the onboard mass store. Used for integration of new software modules and other miscellaneous functions.

2. Mode 2 – The data acquisition electronics (principally the DC offset and non-linearity in the A/D converter) are calibrated using a low-power stimulus; while presenting no safety or damage hazard, it has a spectral emission that interferes with payload COM 5678 and hence places a constraint on the simultaneous operations of these two payloads.

3. Mode 3 – Used for acquisition of quick-look and production data and has constraints and restrictions placed on its operation.

In the definition of this payload to the SSIS/SSDS, the resources, constraints, and restrictions are specifically characterized and quantified for each of the three modes. In addition, the payload will be required to report its operating mode to Function 3.0 so that constrained operations can be discontinued. To implement this reporting, COM 1234 will be required to measure parameters in its I/O section that confirm (even in the presence of a single failure) the ON/OFF status of the low power (Mode 2) and high power (Mode 3) stimuli. Recall that Function 3.0 is relying on the payload to correctly report its mode but in all cases has an independent electronic key controlling the restricted operations conducted in Mode 3.

On a particular day the customer is at the POCC and logs in for payload COM 1234.. He is authenticated and a menu of options is displayed on his terminal as follows:

```
SOFTWARE DEVELOPMENT
SCHEDULE OPERATIONS
PAYLOAD OPERATIONS
```

He selects the last option and is given a status summary of his payload as follows:

```
COMM 1234 IS CURRENTLY POWERED OFF.
NEXT SCHEDULED ACTIVITY IS AT TIME
04:00:12 AT LAT XXX AND LONG YYY
FOR A DURATION OF 12 MINUTES
```

The customer wants to activate his payload for calibration only, to investigate some anomalies he has observed in previously acquired data. He estimates that approximately 45 minutes will be required for this activity so he will request one hour of activation time in the CALIBRATE mode. Calibration for COM 1234 is not automated and the customer will necessarily interact with the payload to implement the calibration procedures. COM 1234's production data, however, is acquired automatically and the customer need not be involved (at his option) in this operation. Onboard implemented functions 3.3 and 3.4 will automatically sequence COM 1234 ON, the next time which will be at 04:00:12 corresponding to coordinates LAT XXX and LONG YYY, and will automatically sequence down the payload after the 12 minute production data acquisition cycle is completed.

The customer, interacting with the POCC-resident software develops an activation command that specifies the following:

```
MODE:  CALIBRATE
TIME ON:  60 MINS
START TIME:  IMMEDIATE
```

The command is transported from the POCC via the following transparent (to the customer) operations.

1. A session is established with the SS Control Center (CC) using option 1 in Figure 4.5.10-1. In this option the POCC is a node in an X.25 circuit providing network services (lower 3 OSI layers) to the CC.

2. After the connection is completed, the command is transmitted and will be automatically processed in the CC. The CC has knowledge of the operating modes of COM 1234 and retrieves from local memory the triplet T(CALIBRATION) that specifies the resources, constraints and restrictions associated with the calibrate mode of operation. The scenario splits into two scenarios (A and B) at this point: GO TO 3.A for the completion of scenario A and to 3.B for the next step in scenario B.

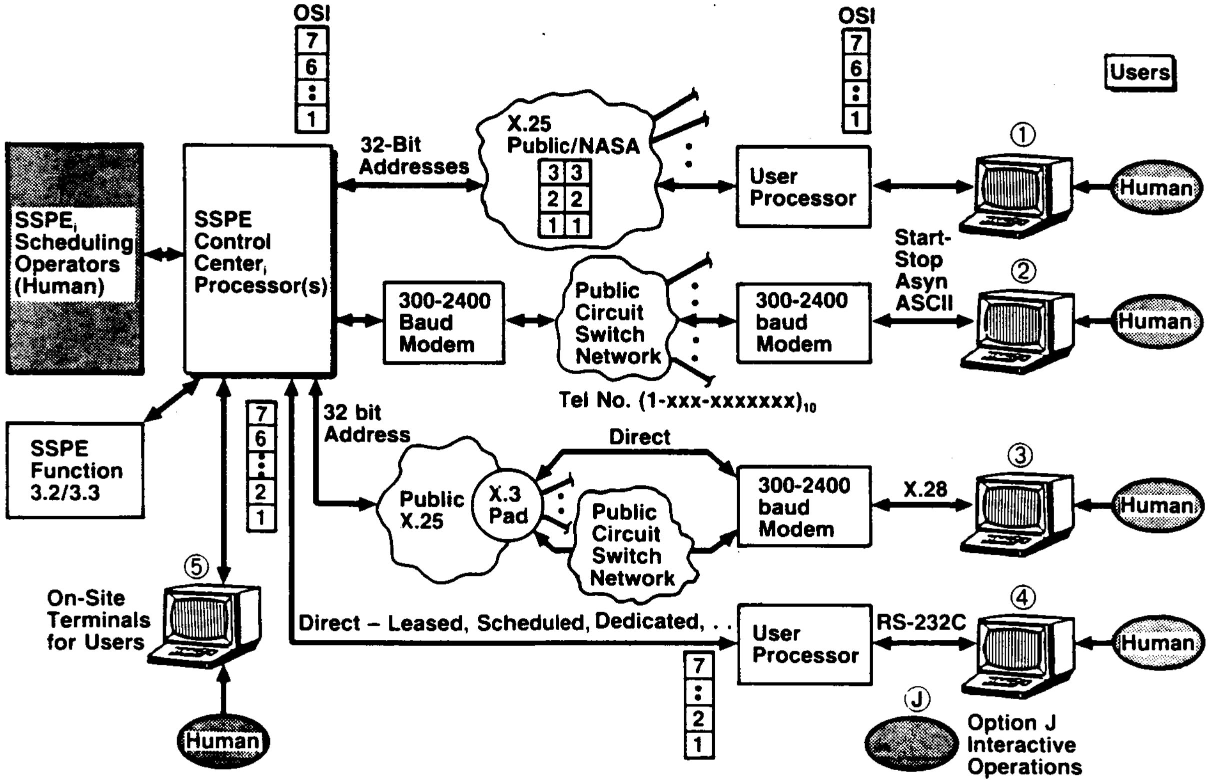


Figure 4.5.10-1. Communication Interfaces for Scheduling

3A. The CC has determined by a simple scan of the OEL and the current operating mode that T(CALIBRATION) for COM 1234 can be satisfied for the next 60 minutes: the payload can be immediately attached to all required resources and no restriction or constraints exist for this time period. The customer is notified, the onboard OEL is updated for immediate activation of COM 1234 (the onboard crew is audibly alerted that a OEL adjustment has been made but this class of change does not require their approval — the audible is an indication of a "for-information-only" type change). At this point two seconds have elapsed since step 1 was initiated.

3B. At the CC the onboard in-progress operations are scanned and it is determined that the resources are available, there is no restriction, but that a constraint exists (COM 1234 has a spectral emission in the CALIBRATE mode that interferes with COM 5678). It is further determined that the constraint will dissappear in 12 minutes when COM 5678 is scheduled to be deactivated, but then there will be a resource limitation in power. At this point two seconds have elapsed since step 1 was initiated.

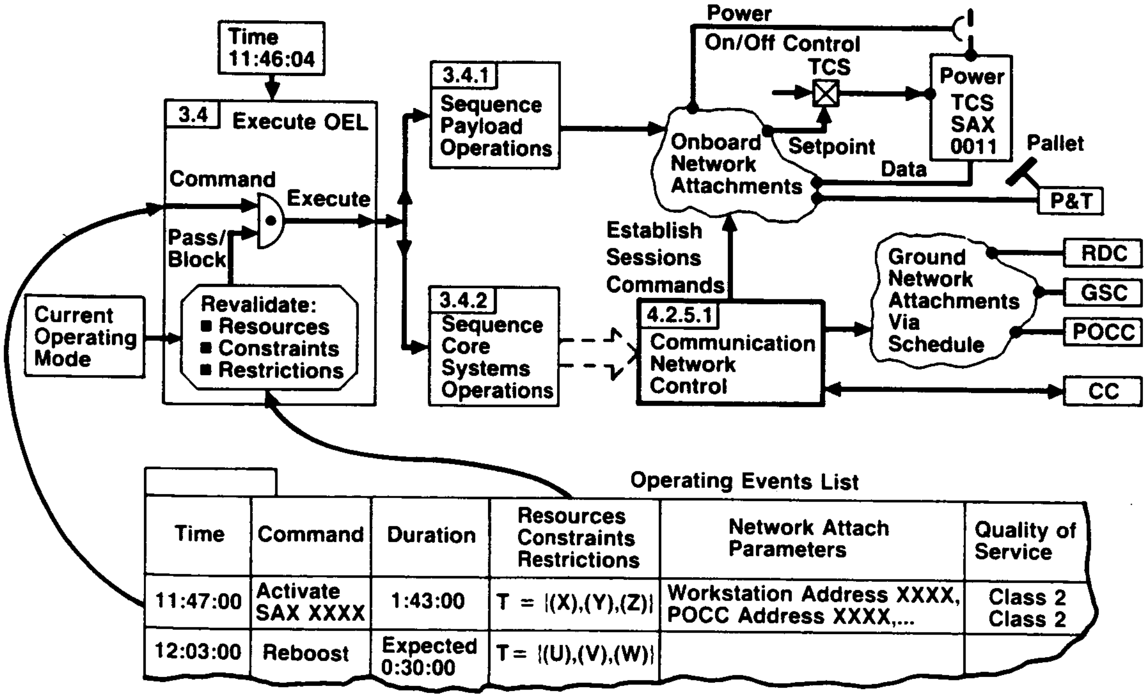
4B. Several options for future activity must now be considered since COM 1234 does not have the priority to adjust current in-progress operations and near future operations.

5B. The scheduling operator at the control center (see Figure 4.5.10-1) will interact with the scheduling program to develop an agreed-to future schedule (scheduling is not a fully automated function). This interaction with the customer will, in general, be all-electronic.

The customer at the POCC is informed that immediate attachment of COM 1234 is impossible based on his priority (priority adjustments are possible via voice telecommunications through the NASA hierarchy). The customer now interacts through his terminal examining the attach options sequentially presented to him in a menu similar to the way customers consider and select airline flight options. The scheduling operator in the SSCC develops options for the customer (after they are computer validated in terms of resources, constraints, and restrictions). "Limited" changes are authorized to be made in the CC without onboard crew approval, however, voice communications with the SS commander will be required for approval of certain options prior to their being presented to the customer.

ATTACH PROCEDURE IMPLEMENTATION

This scenario is common to most payload operations. The Operating Events List (OEL) is the master source for primary onboard sequencing (secondary sequencing is initiated from subsystems or payloads) and identical copies reside onboard and in the SSPEs CCs. The OEL was described earlier and is shown in Figure 4.5.10-2 as residing in Function 3.3 and is the driving source for Function 3.4, as a function of time. When the time of execution for a command has been reached, the triplet RSCRCS, CONSTR, and RESTRICT are revalidated against the current actual operating mode and then passed to subfunction 3.4.1 and 3.4.2 for execution. Resources for restricted operations are unlocked (as required) and attached in the required sequence



Time	Command	Duration	Resources Constraints Restrictions	Network Attach Parameters	Quality of Service
11:47:00	Activate SAX XXXX	1:43:00	T = {(X),(Y),(Z)}	Workstation Address XXXX, POCC Address XXXX,...	Class 2 Class 2
12:03:00	Reboost	Expected 0:30:00	T = {(U),(V),(W)}		

Figure 4.5.10-2. Payload Sequencing

(e.g., ATTACH TCS (COM 1234), IF TEMP LESS THAN T1, THEN ATTACH POWER (COM 1234), IF CURRENT (COM 1234) LESS THAN I1, THEN ...).

Since COM 1234 has been powered OFF (duty cycle less than 100%), then when powered ON it will automatically boot-up via EPROM-embedded code and then self-test and self-initialize itself to become an addressable entity on the payload LAN (this payload has a dedicated point-to-point data link to C&T for the primary sensor but is mode controlled via the LAN).

Function 3.4.2 (see Figure 4.5.10-2) indirectly activates Function 4.2.5.1 (see Figure 4.5.10-3) which is distributed between onboard and ground and from information in the OEL connects all of the onboard entities (binds into sessions) required to support COM 1234's commanded operation.

At this point in the development cycle of a command management system, the ground elements are assumed to be open-loop controlled via the OEL and no formal REQUEST/ACKNOWLEDGE message interchange for ATTACHMENT is required. The SSPE's CC coordinates with the various ground components to support the OEL and has a permanent session with onboard function 4.2.5.1 to indicate when a required ground resource will not be available to support the OEL.

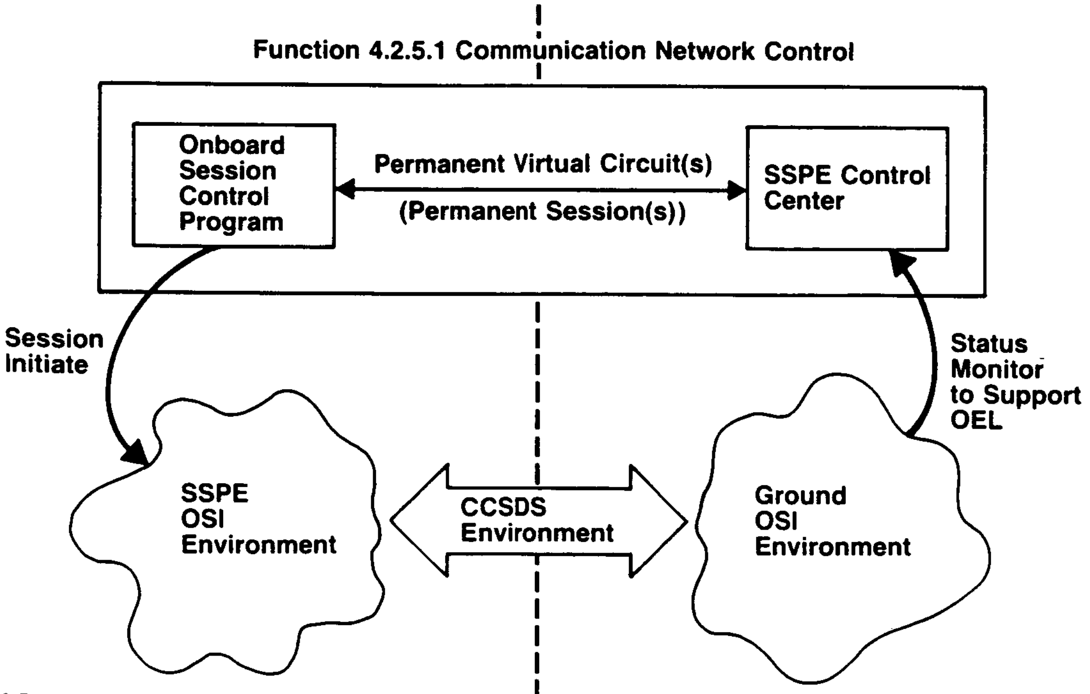


Figure 4.5.10-3. Network Control – Session Initiate

REFERENCES

1. Space Station Data System Analysis/Architecture Study, Task 1 - Functional Requirements Definition, DR-5, MDC Report No. MDC-1343, Revised 1 May 1985.

2. "Guidelines for Space Station Data Systems Standardization (Issue-1)," JPL D-1414, April 1985.

3. "CCSDS Reference Document on Space Data Systems Operation with Standard Format Data Units, System and Implementation Aspects," Issue 1, November 1984.

4. "Recommendation for Space Data System Standards: Standard Format Data Units — Concept and Primary Label," CCSDS Document, Red Book, Issue-0, December 1984.

5. "Recommendation for Space Data System Standards: Time Code Formats," CCSDS Red Book, Issue 2, November 1984.

6. "Recommendation for Space Data System Standards: Packet Telemetry," CCSDS Blue Book, May 1984.

7. "Recommendation for Space Data System Standards: Telemetry Channel Coding," CCSDS Blue Book, May 1984.

8. "Report Concerning Space Data System Standards: Telecommand, Summary of Concept and Service," CCSDS Green Book, Issue-4, July 1985.

9. "Recommendation for Space Data System Standards: Telecommand, Part-1: Channel Service," CCSDS Red Book, Issue-1, July 1985.

10. "Recommendation for Space Data System Standards: Telecommand, Part-2: Data Routing Service," CCSDS Red Book, Issue-2, July 1985.

11. "Recommendation for Space Data System Standards: Telecommand, Part-3: Data Management Service," CCSDS Red Book, Issue-2, July 1985.

12. "Recommendation for Space Data System Standards: Radiometric and Orbit Data," CCSDS Red Book, Issue-1, April 1985.

13. Proceedings of the IEEE, Special Issue entitled "New International Standard Architecture and Protocols for Distributed Information Systems", Volume 71, No. 12, December 1983.

5.0 COMMUNICATIONS ASSUMPTIONS AND TRAFFIC ANALYSIS

The purposes of this section are to define the communications-related assumptions that have been made in the process of defining an SSDS architecture and to summarize the methodology and results of a communications traffic analysis. The assumptions are necessary because, at this early stage of the Space Station program, many design and operating features external to the SSDS have not been defined. The communications traffic analysis provides an estimate of total traffic load on Space station communication links taking into account the best available definition of mission requirements, core requirements, and operational scenarios.

The key results of this traffic analysis are summarized below:

- A single TDRSS SA channel has sufficient capacity to support the IOC Space Station program.
- The allocation of two (or more) SA channels to the Space Station Program would reduce scheduling competition between the Space Station and the platforms.
- The S-band and Ku-band services in the SA channel allocation offer an attractive way to keep core and customer communications traffic functionally separated and to also provide a level of redundancy for critical communications.
- The growth scenario indicates that the currently planned TDRSS SA capability may be inadequate. However, there is significant uncertainty in the mission model and operational scenario, especially with respect to foreign payloads, for the growth time period.
- Video communicaton requirements will be a significant factor in the total communications traffic. There is a need to improve the definition and understanding of the uses, timelines and quality requirements associated with this video traffic.

5.1 Assumptions

A set of assumptions has been developed to support the communication traffic analysis and as a basis for the overall SSDS architecture development. For convenience, these are categorized as (1) TDRSS utilization assumptions, and (2) traffic analysis assumptions. The assumptions are intended to be consistent with the set of references listed in Table 5-1. In addition, internal team member work (e.g., Shuttle television system), and informal NASA sources were used as background material.

5.1.1 TDRSS Utilization/Capability Assumptions

1. The SSDS design should be compatible with allocation of either 1, 2, or 3 SA channels. Figure 5-1 uses two examples to clarify this assumption.

2. All Space Station data on TDRSS channels is digital.

3. The peak uncoded channel capacities for the TDRSS KSA service are 25 Mbps (forward) and 300 Mbps (return); the peak SSA channel capacities (with coding) are 300 Kbps (forward) and 3 Mbps (return).

4. Convolutional coding will probably not be used on the KSA return link. The Space Station requirement for a 10^{-6} maximum Bit Error Rate and application-specific requirements for a lower BER's can be met with lower overhead codes, such as a Reed-Solomon block code.

5. One candidate partitioning of the communications traffic is shown in Table 5-2. Space-to-ground and ground-to-space communications traffic for the Space Station manned core is allocated to the SA services. This candidate allocation puts core traffic on the SSA links and payload traffic on the KSA links, with voice and video being on both links. The capacity for the SSA links to handle the core video traffic is doubtful; the KSA links will have to be used. Other candidate partitions of the communications traffic can be identified, but this one (above) appears to be an attractive allocation.

6 The Space Station (manned core) and the COP will be designed so that the COP can either access TDRSS directly or can use the Space Station as a relay. Although the use of Space Station as a relay and buffer has advantages for TDRSS utilization efficiency and for COP system design, the COP needs to have an independent TDRSS capability to allow it to operate beyond the Space Station line-of-sight. This will affect the complexity, cost and power required for the onboard COP communications system.

Table 5-1 References

1. Space Station Definition and Preliminary Design Request for Proposal, NASA, Sept. 15, 1984.

2. Space Station Reference Configuration Description, NASA JSC, Aug. 1984.

3. GSFC Document, "Customer Requirements for Standard Services from the SSIS".

4. Space Station Mission Data Base (Langley).

5. TDRSS User's Guide.

6. Woods Hole Data Base (Extracted Information by MDAC).

7. Data/Communications Panel Report to the Woods Hole Mission Requirements Workshop.

8. Conceptual Design and Evaluation of Selected Space Station Concepts, JSC December 1983.

9. RFP and Corollary documents for the OMV.

10. Proceedings of 1984 Williamsburg Conference on Space Station Technology.

11. Deep Space Telecommunications Systems Engineering, M83-22226, J. H. Yuen, Jet Propulsion Laboratory.

		1 SA Channel	2 SA Channel	3 SA Channel
Example No. 1	SS	N Min/Day	$1440-T_{zoe}$	$1440-T_{zoe}$
	COP	(Via SS)	(Via SS)	$1440-T_{zoe}$
	POP	1440-N	$1440-T_{zoe}$	$1440-T_{zoe}$
Example No. 2	SS	N Min/Day	$1440-T_{zoe}$	$1440-T_{zoe}$
	COP	1440-N-M	1440-P	$1440-T_{zoe}$
	POP	M Min/Day	P Min/Day	$1440-T_{zoe}$

Figure 5-1. Example TDRSS Allocations

Table 5–2

Allocations to TDRSS Channels

	KSA–F	KSA–R	SSA–F	SSA–R
PAYLOAD CMDS & UPLINK DATA	X			
PAYLOAD MISSION DATA		X		
PAYLOAD HEALTH & SAFETY DATA		X		X
CORE CMDS & UPLINK DATA	X (backup)		X (prime)	
CORE ENGINEERING DATA		X		X
VOICE	X	X	X	X
VIDEO–HIGH RATE	X	X		
VIDEO–LOW RATE	X	X	X	X

5.1.2 Traffic Analysis Assumptions

1. The Langley mission data base, as modified and extended by the Woods Hole Workshop and by SSDS team analysis, represents the mission requirements.

2. The crew size growth profile is as shown in Table 5-4. This assumes a step increase from 6 to 12 during year 3 based on IVA man-hour growth and a final step to a crew size of 18 in year 7.

3. EVA man-hours per week are an average based on the EVA man-hours per year specified in reference 1.

4. The STS docking traffic is one Orbiter per 90 days for every 6 crewmen.

5. OMV and OTV events are per reference 1. Each event provides communication traffic for 8 hours.

6. The number of free-flyers grows from 0 to 8 as shown in Table 5-4.

7. MRMS operating hours per week is equal to 1/3 of the EVA hours plus 1 hour per OMV or OTV event.

8. Surveillance video time is 4 hours/day per IOC crewman plus 2 hours/day for each additional crewman.

9. The IOC core command and engineering telemetry rates are 4 Kbps and 256 Kbps, respectively, and increase as the crew size increases as shown in Table 5-4.

10. Training time is 1/2 hour/day per crew member.

11. Recreation/leisure time is 1/2 hour/day on working days, 2 hours/day on non-working days, for each crew member.

12. Video communications are assumed to be in three categories: (1) full resolution, full-motion commercial TV quality, (2) freeze-frame video, and

(3) an in-between quality with full resolution and slow frame rate. These video signals are assumed to be encoded and compressed into 22 Mbps, 400 Kbps, and 4.5 Mbps data streams, respectively. An extension of this assumption is that the 400 Kbps video is adequate to support the OMV teleoperation activity. This assumption is based on our interpretation of OMV documents. A brief discussion of these rates and the corresponding rationale is provided in paragraph 5.3.1.

5.2 Methodology

5.2.1 Scenario Development

The Space Station Traffic scenarios were derived from various operational functional modes as now understood, and included the following: EVA, orbiter docking and undocking, OMV operations, OTV operations, Free Flyer operations, co-orbiter operations, MRMS operations, internal and external surveillance video, core systems, training, recreation and leisure, and attached or internal experiments.

These scenarios were then individually examined to develop a time and use baseline which required interpretation of various documents, assumptions where necessary, and then linking that to the specific data rates for each class of traffic. For example, in the surveillance scenario, our baseline assumed that there would be fifteen internal cameras used to monitor most aspects of the interior spaces of the station and crew actions and docking ports, as well as two cameras used to monitor the external structure. Our thinking has been changed as a result of some discussions at the Prox Ops workshop in February 1985, since it was indicated that up to 18 external surveillance cameras will probably be required. (The effect of that information on the overall communications profile has not been incorporated at this point.)

For purposes of further explaining, the following is a sample discussion using a surveillance scenario. Several assumptions were made: a 10% duty cycle was assumed in terms of video use related to communications downlink use; thus, for 15 internal surveillance cameras, the equivalent of 1.5 full time video channels was assigned for this group, and the same rationale was used for the external cameras. It was also assumed that there would be increased use of the internal cameras based on an increase in the crew size, since there would be more crew activity.

The crew growth was based on the following: a) the RFP indicates an IOC crew size of six and a crew size not to exceed eighteen, b) in order to determine the steps in crew increase and the point of increase, information in the RFP on increases in crew activity was used. An indirect indicator was derived from the step functions in crew medical data (from Langley documents). The changes implied a crew change (six to twelve) in the third year, while achieving maximum crew size during the seventh year (see Table 5-4, Crew Distribution). Finally, the use scenario was related to communications bandwidth/data rates by assuming that a slow scan TV algorithm could be used for "normal" surveillance. The use of 4.5 Mbps rate represented a reasonable quality, (NTSC) full color picture, which uses a 'slow scan" frame rate of five frames/second.

5.2.2 Communication Profile Development

Space Station

The time related communications profile, as presented, is based on:

a) a broad scenario for each functional mode related to the C&T system;

b) attempting to quantify the scenario from explicit or implicit sources;

c) developing assumptions on gray areas, which relate to operational use considerations or reasonableness and reviewing some of these assumptions in areas of major criticality (e.g., the major Communication bandwidth drivers) with customer and study team personnel;

d) assigning rates to each source or sink which eventually contributes to the KSA/TDRSS down link based on the Woods Hole projections for the experiments, recommended rates for digital video where these are explicit in NASA related documents or based on filtering of discussions with NASA personnel, and assumptions on quality and adequacy of pictures;

e) some attempts at scheduling transmission to the ground where any specific operational scenario reasonably allows that, in order to smooth out peak short term (seconds or minutes) demands on the communications resources; a generic unit period was used as the basis for the link utilization.

f) placing the resultant profile into two time frames (IOC and "growth") and comparing each against the KSA bandwidth constraints.

COP

The assumption used for the traffic analysis was that the COP would generally be in view of the Space Station, and that both uplinked (program loading and commands) and downlinked (experimental data, video, and health/status telemetry) information would go through the Space Station.

POP

The information on this is derived from the Woods Hole Workshop data base and attendant experiments/sensors and it is assumed that Polar Orbiters would access TDRSS (KSA Channel) directly.

5.3 Detailed Strawman Scenario Development

Detailed Strawman communications system connectivity and link loading scenarios were developed for several Space Station related activities to provide a basis for a composite traffic profile analysis.

Those scenarios are as follows:

1) EVA
2) Orbiter Docking/Undocking
3) OTV/OMV
4) Free Flyer
5) MRMS
6) Surveillance (Internal & External)
7) Telemetry Command & Control (Core Systems)
8) Training
9) Recreation
10) Internal/Attached Payloads
11) Co-Orbiting Platform (COP)
12) Polar-Orbiting Platform (POP)

5.3.1 Standardization of Communications for use in Scenarios

Assuming digitization of all communications with elements external to the Space Station, several standardized methods of representing communications in the Scenarios were used.

The audio and video data rates used as standard throughout the scenarios are presented in Table 5-3. These rates were from NASA sources such as documents, contracted studies, and discussions with NASA personnel. Other possible options for audio and video (not used) include: 1) 64 kbps voice channels for high quality speech recognition; 2) 25 Mbps, or higher, video data rates for high resolution compressed video or uncompressed video; 3) 1.544 Mbps compressed video with T1 communication link compatibility; or 56 kbps for teleconference-quality video. Other data rates used in the scenarios, such as command and telemetry, were selected or derived from the Space Station references identified in Table 5-1.

Table 5-3.

Audio and Video Data Rates used in Traffic Profile

		REFERENCE (Table 5-1)
• AUDIO		
-STS ORBITER	32 KBPS	(1)
-ALL OTHER AUDIO	16 KBPS	(1), (10)
• VIDEO		
-COMPRESSED SLOW SCAN TV	400 KBPS	(9)
-FREEZE FRAME TV	400 KBPS	(2)
-NTSC, COMPRESSED	22 MBPS	(10), (5)
-NTSC, COMPRESSED	4.5 MBPS	(1)

The digital video rates which have been selected should not be considered as final rates to be used for the space station for either external or internal communications. These rates are only goals that are being considered for digital video. However, it is useful to consider how the 22 mbps was selected, as an example of how the rates were selected.

One reference was an article by Tu, Teasdale, Zimmerman, "A Communication system conceptual design for a low earth orbiting manned space station" (NTC 1982) which assumed 22 Mbps for quality video. The Reference Configuration uses the value 25 Mbps for compressed NTSC quality video. At this point in time during a conceptual analysis the difference between 22 and 25 Mbps is not particularly significant.

RCA, under contract to,NASA has been studying 27/28 Mbps digital video for use on the space shuttle orbiter, using a compression algorithm.

Before a truly definable digital video rate can be finalized, the compression algorithm must be selected. The selection of an algorithm will be dependent on several factors which include but are not limited to:

1) quality of image
2) speed of algorithm

3) volume, power, weight requirements of compression processor and that of the transmission equipment
4) cost
5) definition/resolution of image, and
6) operational/mission needs

At the current time, it appears to be technically reasonable and consistent with other NASA sponsored activity to use 22 Mbps as the rate for compressed, NTSC quality video.

In order to graphically portray traffic profiles and to classify data for analysis, three symbolic signal distributions were used to represent various types of data in the analysis. As portrayed in Figure 5-2 data generated during a unit time period (arbitrary length of time) can be represented by different distributions. A uniform representation over a unit period of time represents a continuous and constant data rate for the duration of the event or activity under consideration. For example, OMV telemetry rate is anticipated from an OMV while under control of the Space Station. A triangular representation is used for data generation for which the data rate will vary over a period of time, T. A pulse representation is used for constant rate data generation which occurs only for a fraction of the time period in question.

- Signal Distributions Are For a Generic Unit Time Period

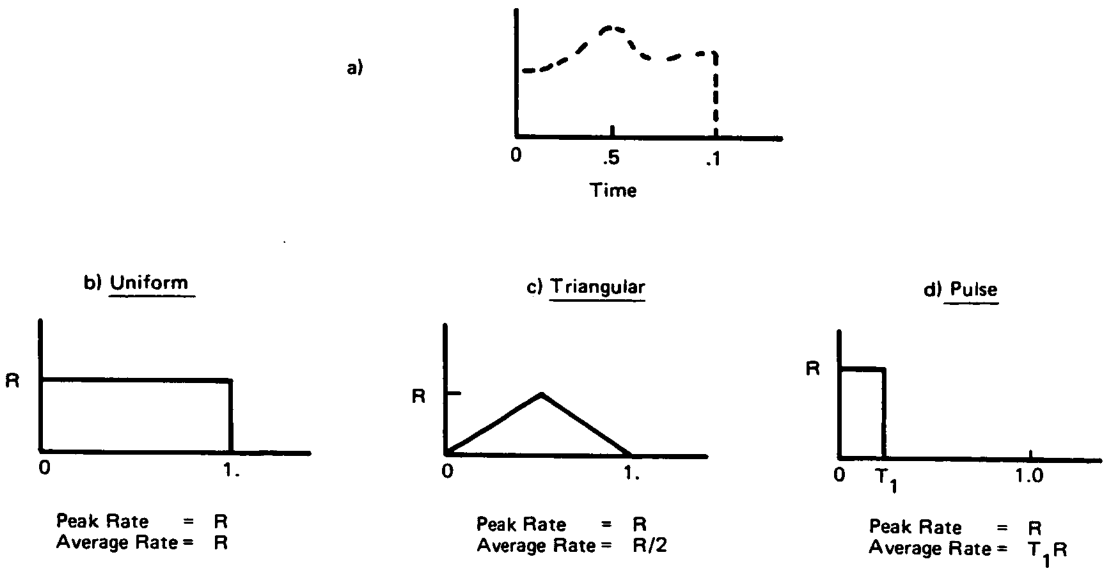


Figure 5-2. Signal Distributions

5.3.2 Detailed Strawman Scenarios

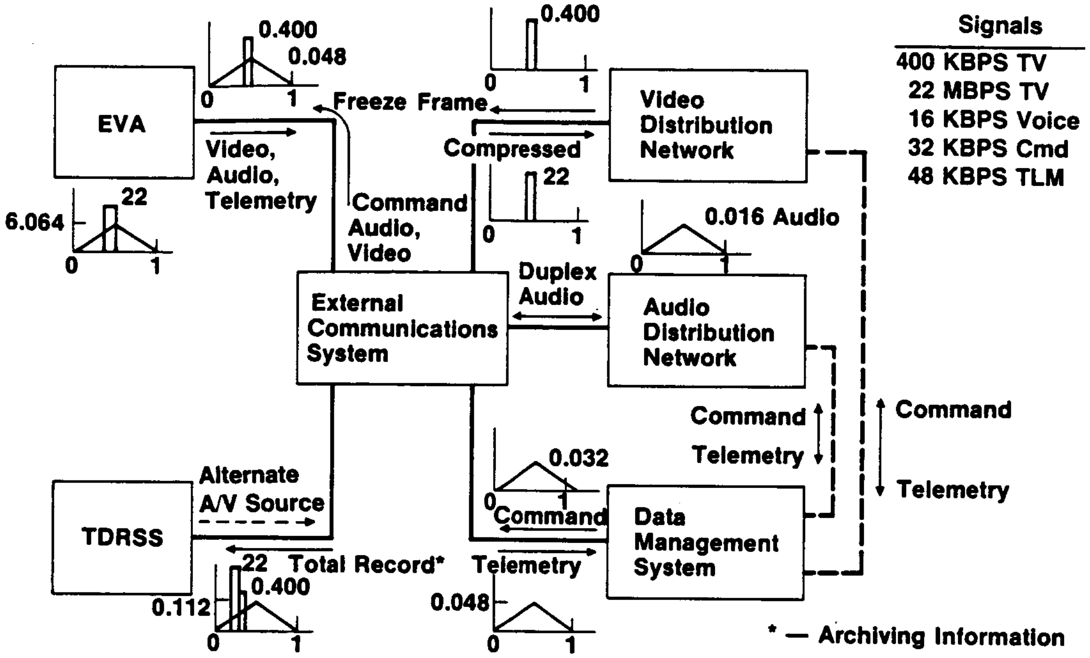
Figures 5-3 through 5-14 portray the 12 strawman communications scenarios. Each was designed to support the Space Station mission requirements and be consistent with requirements outlined in the Space Station Reference Configuration and Space Station SOW, (Ref. 1 and 2). The distribution of data through the linked systems is indicated with arrows and symbolic plots of signal distributions.

5.3.3 Space Station Activity Intensity

Table 5-4 lists the changes in activity intensity over a period of years from IOC to ten years into the Space Station Program. Assumptions and References for these values are described in paragraph 5.1.2. Because the latest information available on payloads does not provide a year to year listing of payloads, payload quantities are given only for IOC and a growth year. The growth year is assumed to correspond to a year shortly after year 6 or year 7 when 18 crewmembers may habitat the SS. It is not evident from sources whether year 6/7 through year 10 have significantly different total activity (i.e., some activities appear to increase, other appear to be reduced).

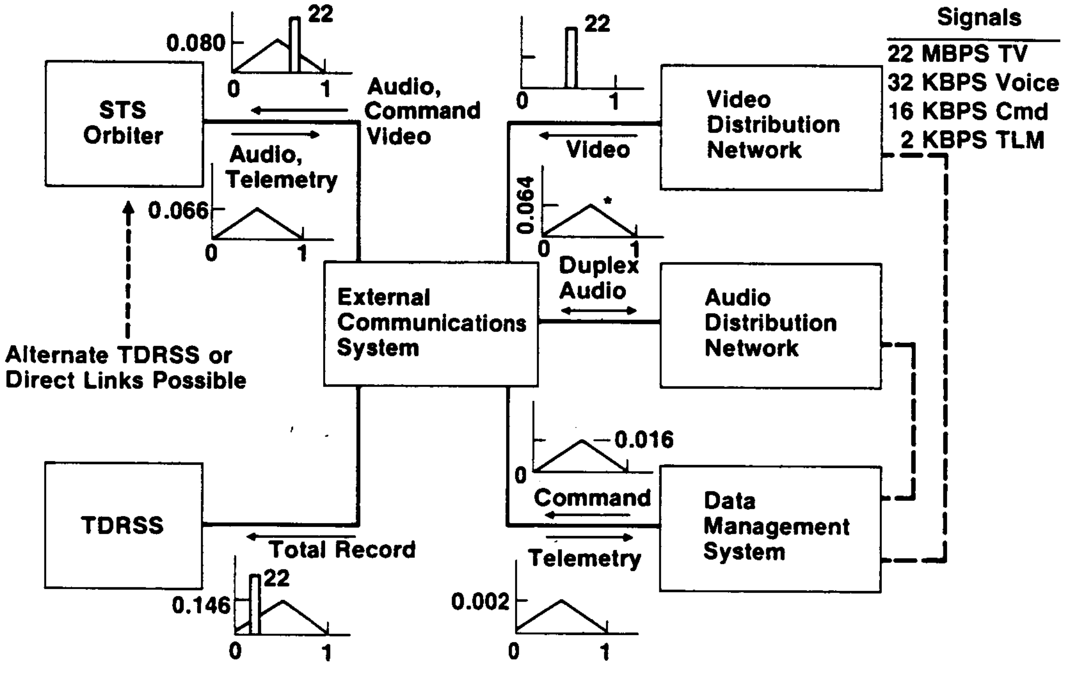
5.3.3.1 US Payloads (Missions). US attached payload communications statistics are presented in Table 5-5. The highest possible data rate (Peak Data Rate) for attached payloads is 433 Mbps during IOC. The Peak Data Rate was determined by adding up the data output rate of all Payloads, which means all experiments would operate simultaneously to provide the 433 Mbps, a demanding upper bound. As such, the Peak Data Rate establishes a maximum bound for data loading of the communications distribution system. With an average data rate of 26 Mbps for the 33 IOC payloads, scheduling and interleaving of data from the various payload experiments should allow for a more realistic loading on the communication distribution system fluctuating around an average rate near the 26 Mbps figure.

It was assumed that 4.5 Mbps TV (5 frame/sec compressed NTSC format) would support the payloads. In fact many payloads may require lower rate TV while other may require higher rate TV.



* — Archiving Information

Figure 5-3. EVA Scenario



* — 2 Voice Channels to Orbiter

Figure 5-4. Orbiter Docking/Undocking Scenario

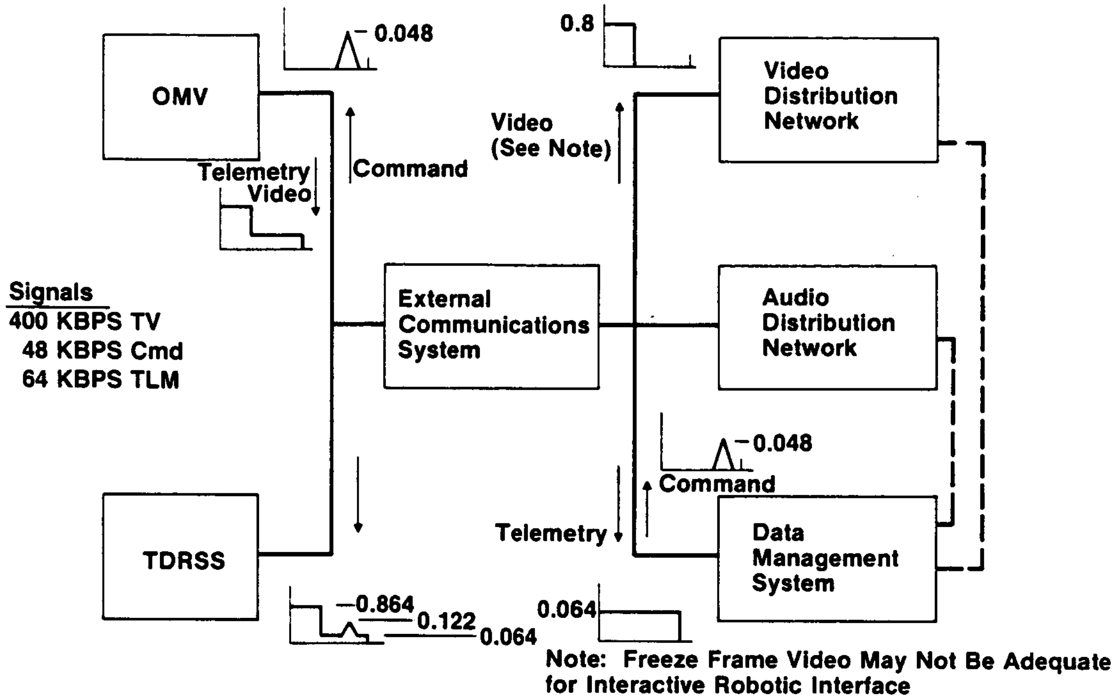


Figure 5-5. OMV Scenario

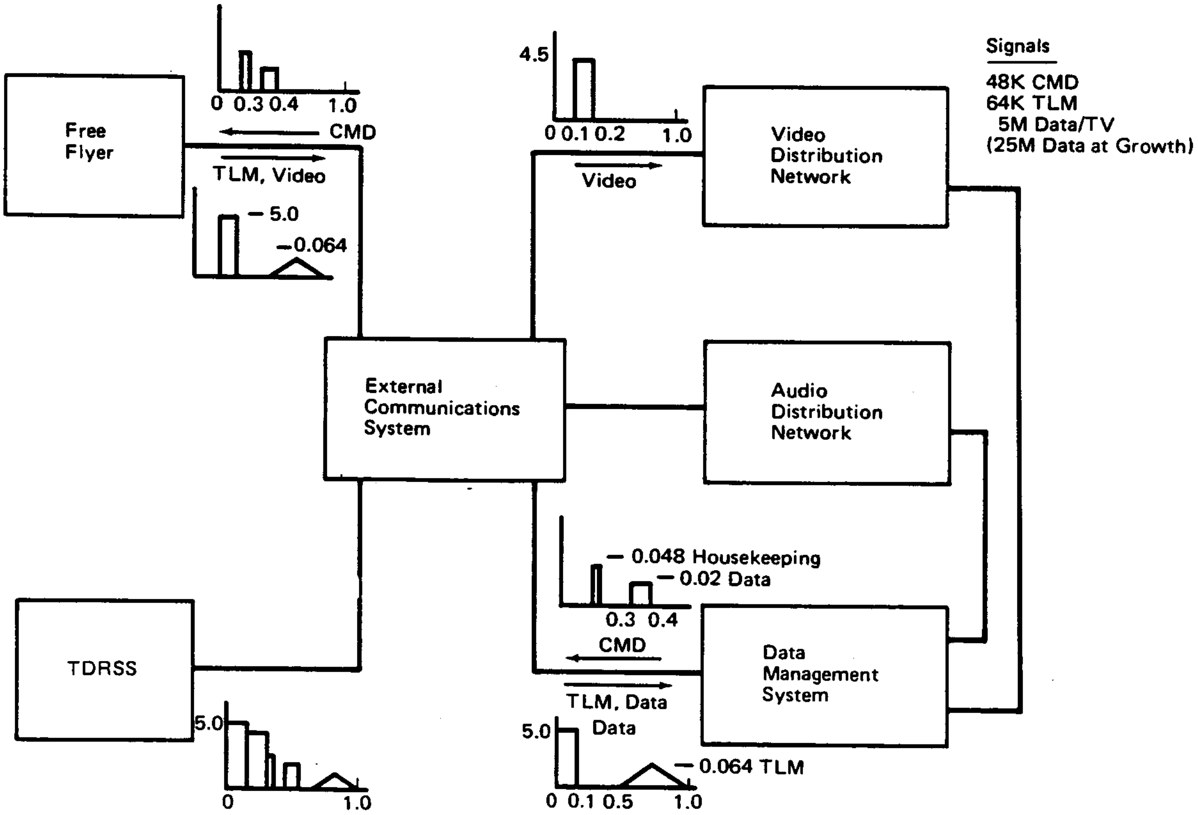


Figure 5-6. Free Flyer Scenario

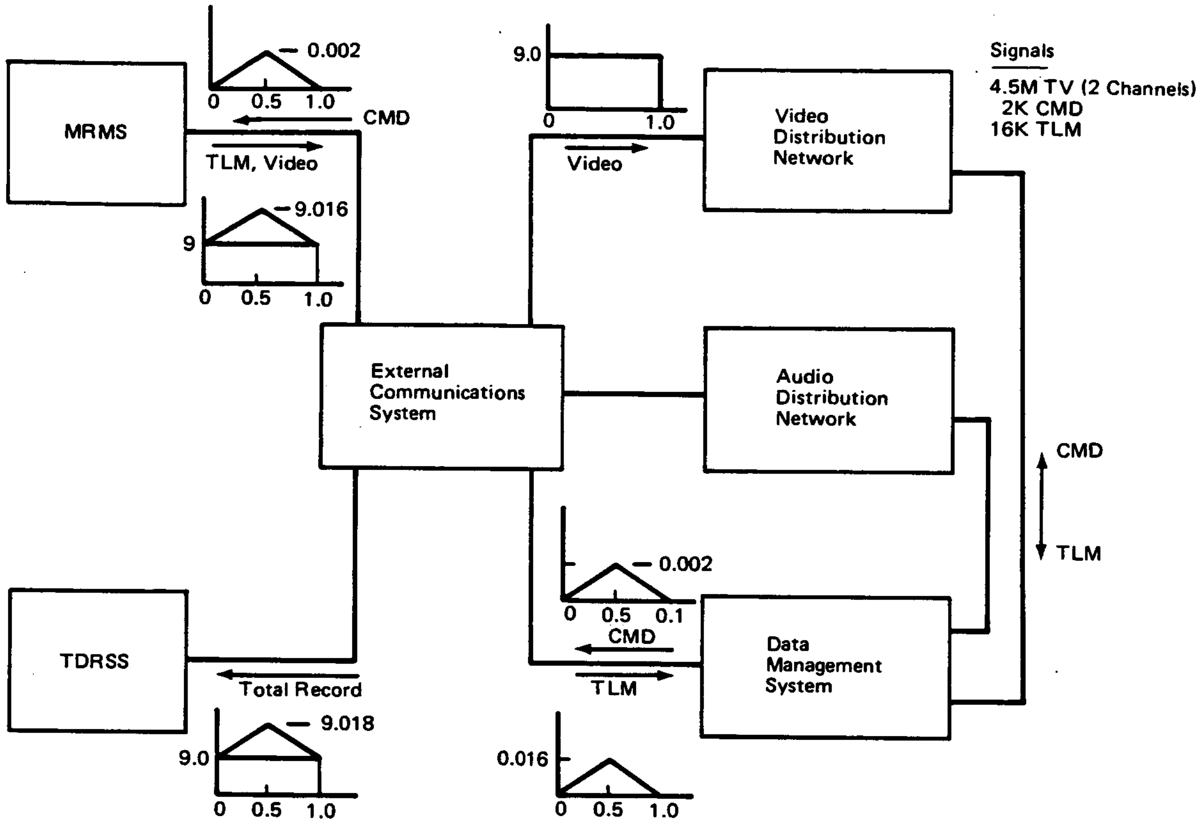


Figure 5-7. MRMS Scenario

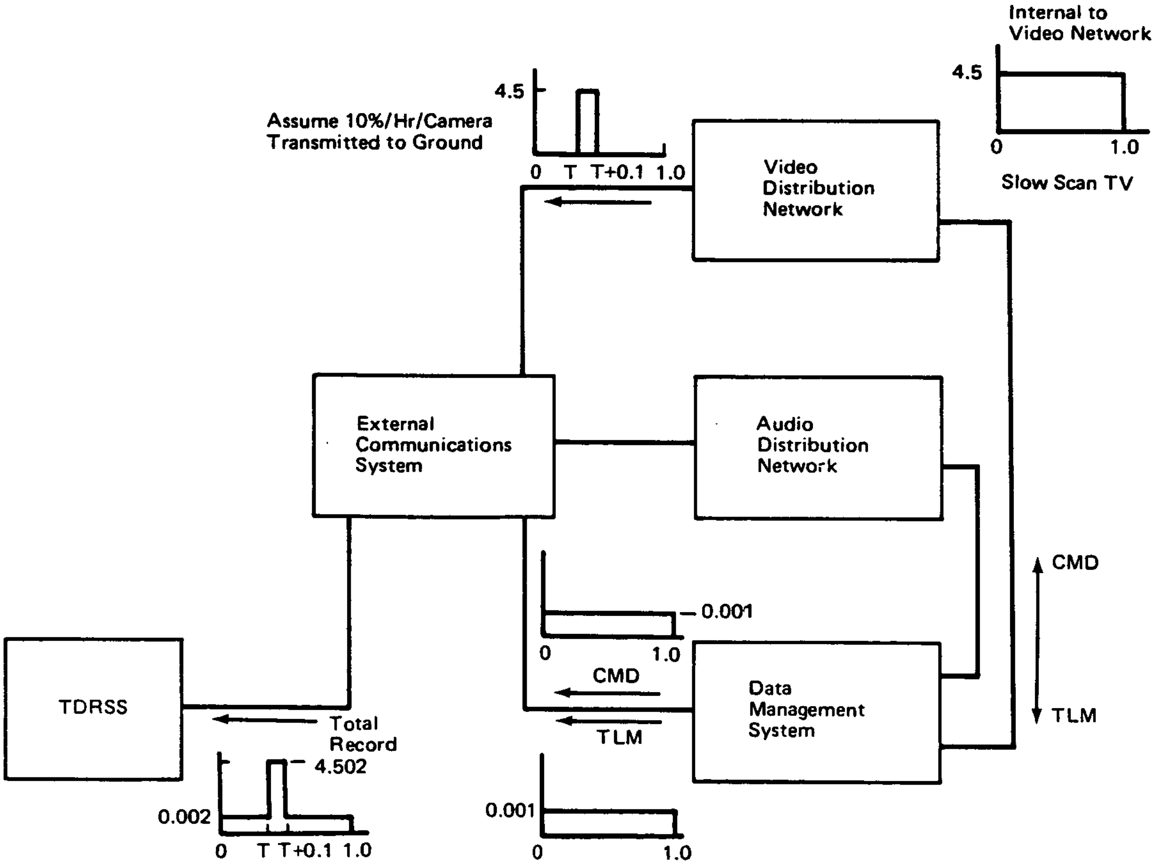


Figure 5-8. Surveillance Scenario

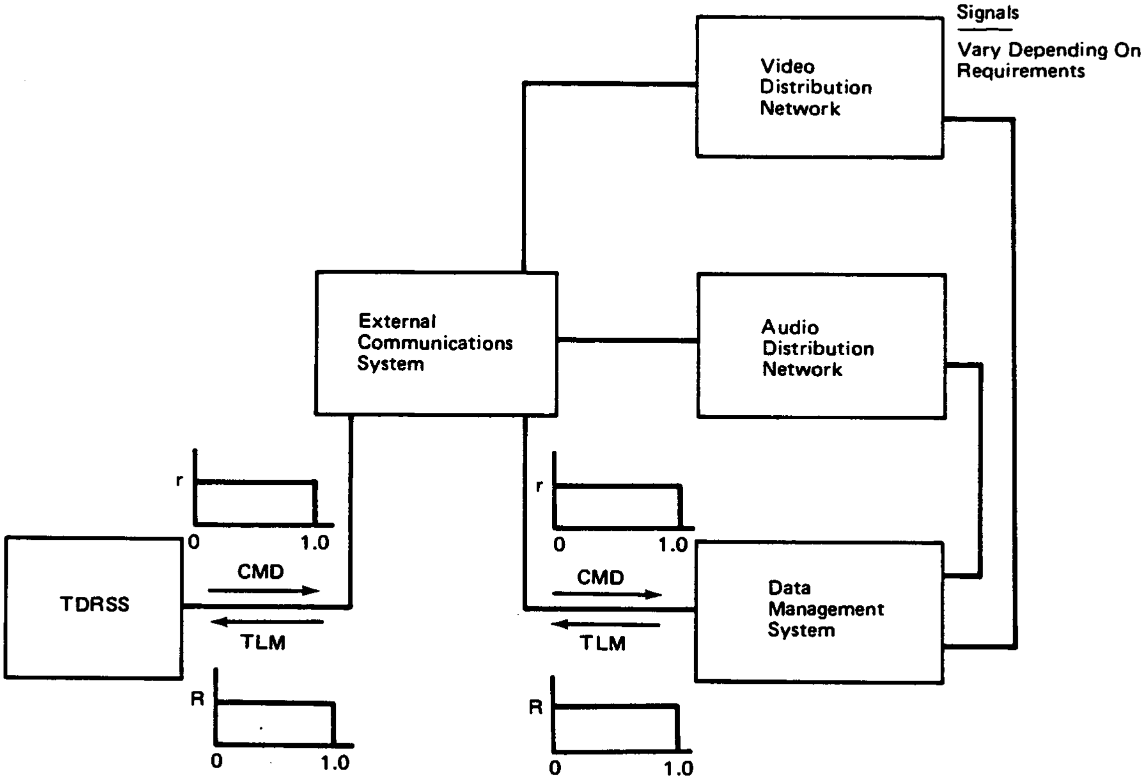


Figure 5-9. Telemetry Command Control Scenario (Manned) For Core Systems

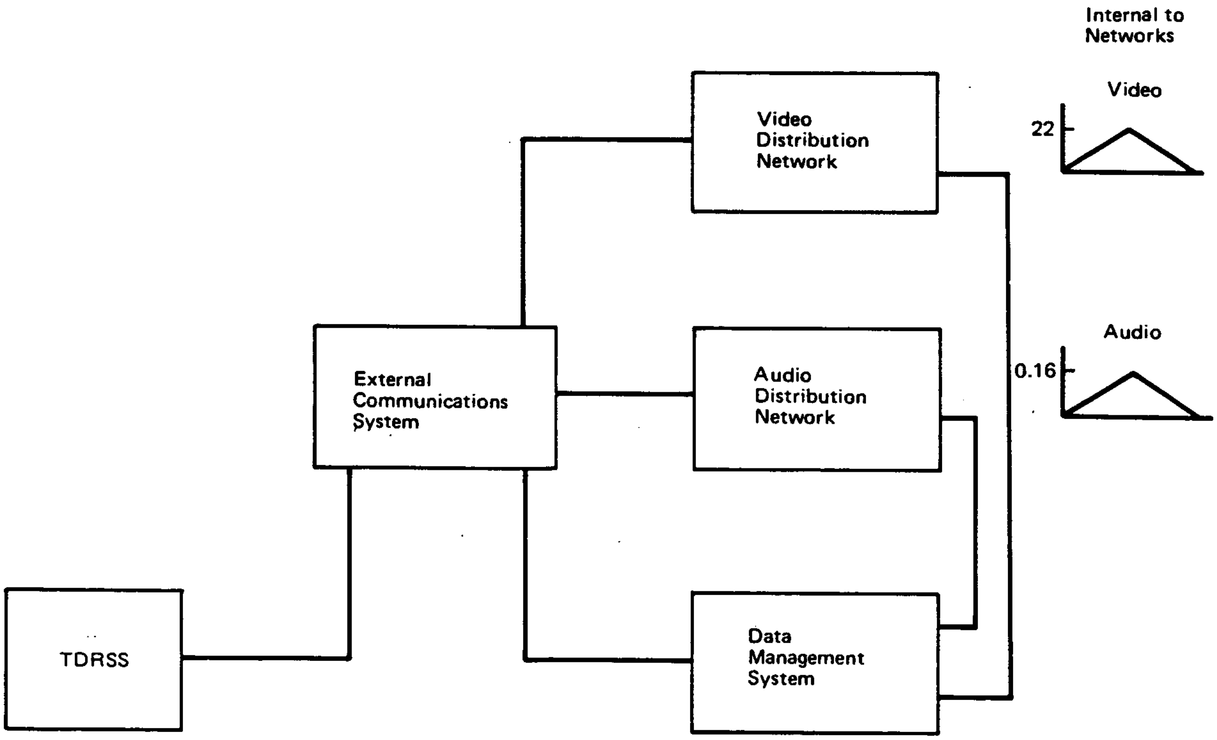


Figure 5-10. A Training Scenario

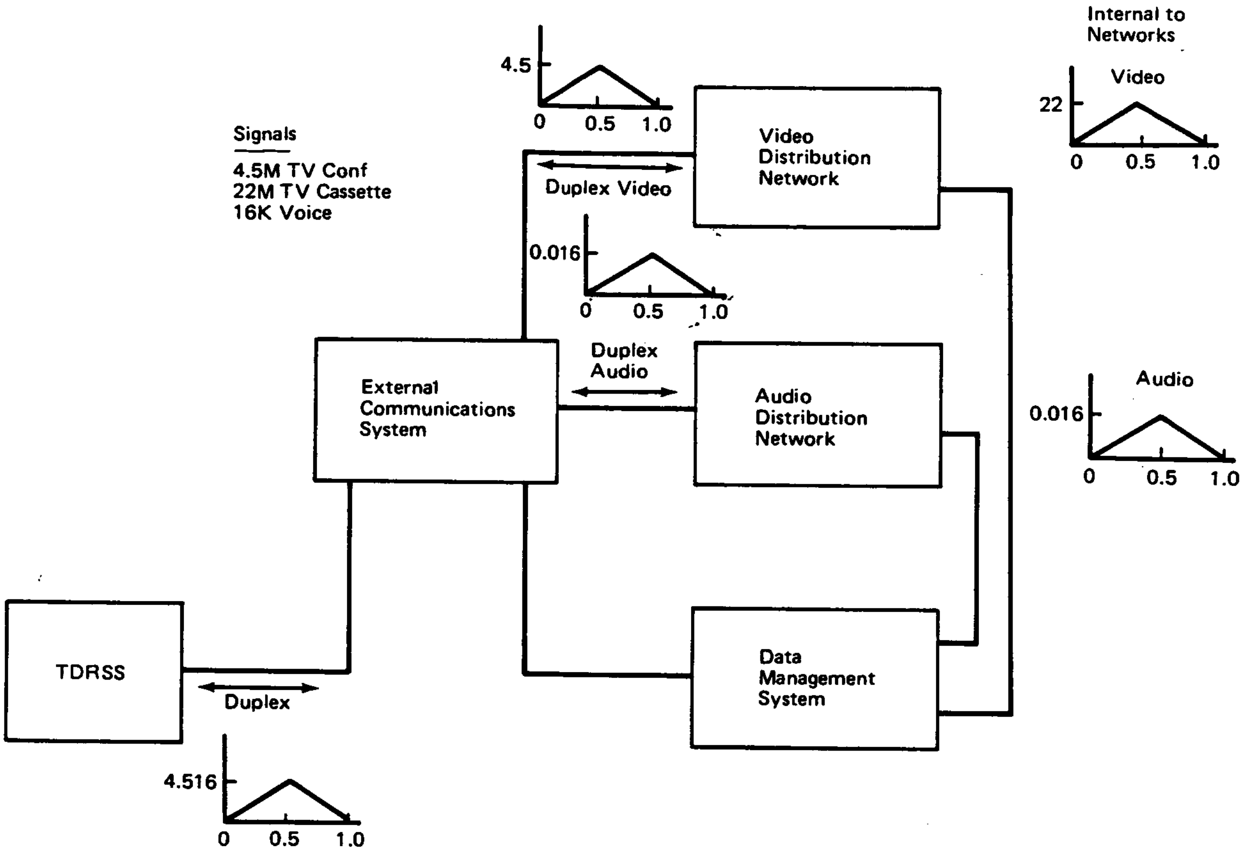


Figure 5-11. Recreation/Leisure Scenario

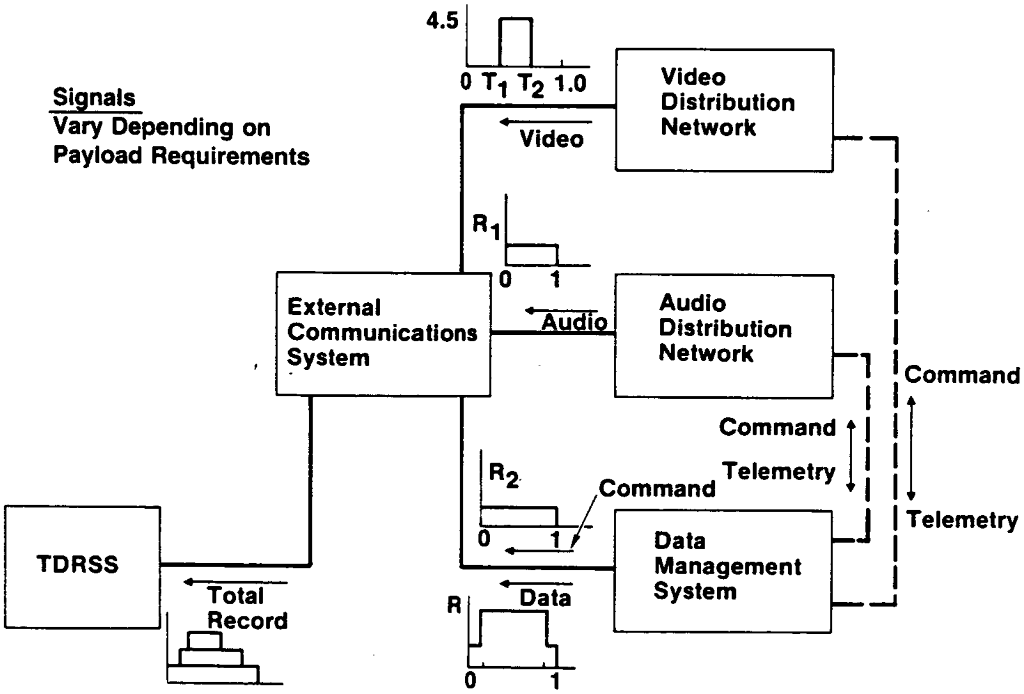


Figure 5-12. Internal/Attached Experiment Scenario

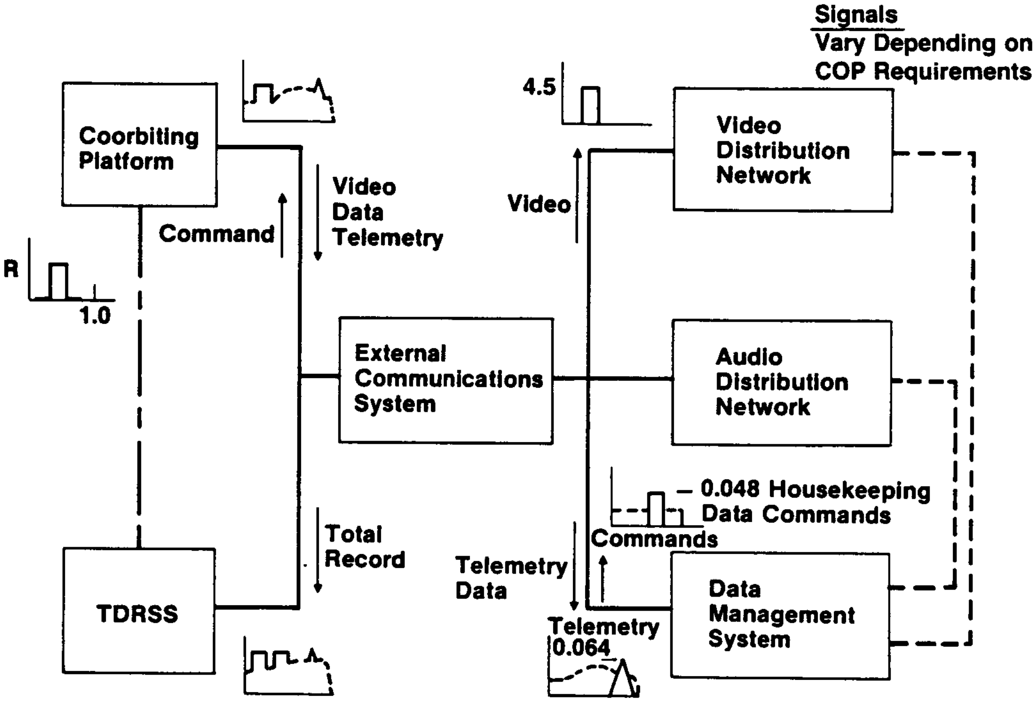


Figure 5-13. Coorbiting Platform Scenario

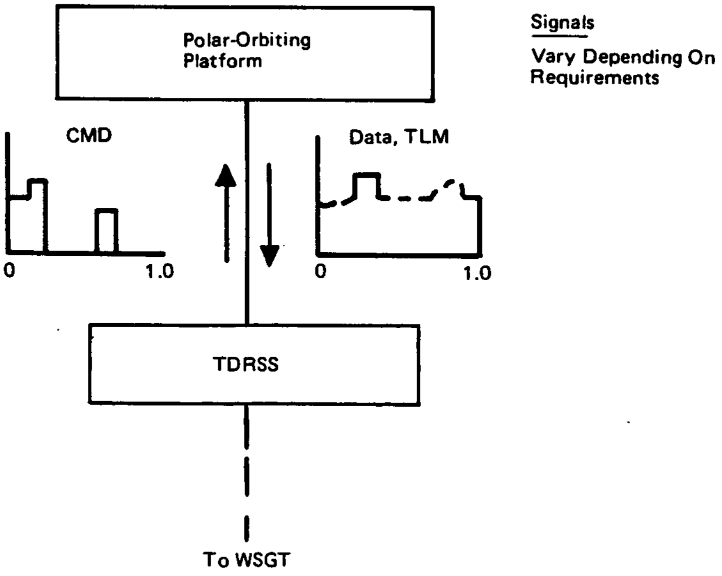


Figure 5-14. Polar-Orbiting Platform Scenario

Table 5–4. Summary of Space Station Activity Growth Scenario

		IOC									
YR. OF SSP FLIGHT		(1)	2	3	4	5	6	7	8	9	10
ACTIVITY											
CREW	QUANTITY	6	6	12	12	12	12	18	18	18	18
EVA AVG.	Man–HRS/wk	23.3	39.0	31.2	26.9	14.1	12.4	11.9	14.3	11.7	13.0
ORBITER DOCKING	DOCKING/YR	4	4	8	8	8	8	12	12	12	12
OMV	EVENTS/YR	12	16	16	15	3	10	2	27	29	27
OTV	EVENTS/YR	—	—	—	—	4	9	10	15	15	11
FREE FLYER	NUMBER	0	1	3	5	8	8	8	8	8	8
MRMS	HRS/WK	20	29	26	24	12	23	16	47	48	42
SURVEILLANCE VIDEO	(EXTERNAL)HRS/DAY	24	24	36	36	36	36	48	48	48	48
	(INTERNAL)HRS/DAY	24	24	36	36	36	36	48	48	48	48
TELEMETRY COMMAND/	TLM KBPS	256	256	384	384	384	384	512	512	512	512
CONTROL SS/COP/POP)	CMD KBPS	4	4	8	8	8	8	12	12	12	12
TRAINING	HRS/DAY	3	3	6	6	6	6	9	9	9	9
RECREATION/LEISURE	HRS/WK	33	33	66	66	66	66	99	99	99	99
											<u>GROWTH</u>
ATTACHED US PAYLOADS	QUANTITY	33									16
COP US PAYLOADS	QUANTITY	1									1
POP 1 US PAYLOADS	QUANTITY	10									11
POP 2 US PAYLOADS	QUANTITY	11									11
POP 3 US PAYLOADS	QUANTITY	0									4

Table 5-5. Attached Payload Statistics

ATTACHED PAYLOADS SUMMARY

	IOC	GROWTH
Payload Quantity	33	16
Peak Data Rate	433 Mbps	402 Mbps
Avg. Data Rate	26 Mbps	51 Mbps
P/L Video	61.8 Hrs/Day	80.2 Hrs/Day
Avg. Rate (4.5 Mbps TV)	11.6 Mbps	15.0 Mbps

ATTACHED PAYLOAD COMMUNICATIONS DRIVERS

IOC	GROWTH	DESTINATION	TRIGGER	DELAY	PEAK (Mbps)	AVERAGE (Mbps)
X	X	COMM 1014 Remote Sensing	Land	24 Hrs.	300	2.5
	X	SAAX 0011 Adv. Solar Obs.	Sun	0 Hrs.	50	31.25
X		SAAX 0207 Solar Terrestrial	Sun	0 Hrs.	10	2.5
	X	SAAX 0227 Plasma Exp.	Poisson	0 Hrs.	50	16.7
X		TDMX 2542 Tether Const.	Poisson	N/A	120	20.0

ATTACHED PAYLOAD VIDEO DRIVERS

X		SAAX 0009 Pinhole Occult	Sun	24 Hrs.
	X	SAAX 0011 Adv. Solar Obs.	Sun	0 Hrs.
X	X	SAAX 401 Micro Gravity Lab.	Cont.	3 Hrs.
X	X	SAAX 404 Materials Lab	Cont.	3 Hrs.

N/A = Not Available

Reference 6 and 7 (Table 5-1)

Payload communications and video drivers were determined to support the development of a composite payload data profile. Only five payloads were found to have a peak output rate greater than 1.5 Mbps and/or an average rate greater than 1.0Mbps. Four payloads were found to generate video more than two hours per day.

The Trigger and Delay characteristics of payloads determine when the payload is assumed to generate data and what delay for delivery of data (to the customer) is acceptable. Triggers are of four types. Some payloads are triggered for land or sun observation only. If the payload should operate continuously while in view of the land or sun, it would operate 33% of the time for land or approximately 62% of the time for the sun. Other payloads have a continuous trigger, i.e., operate continuously. A fourth trigger assumes that the probability of a payload operating at any given time is dependent upon a poisson probability distribution, but than an average data rate can be determined over a long period of time.

Figure 5-15 presents attached payload profiles. These profiles portray the most likely distribution of payload data rates over the period of an orbit, that will minimize channel bandwidth at all times. The growth profile will be used as an example to show how a profile is determined. Payload COMM 1014 can accept a 24 hour data delivery delay, so to minimize communications bandwidth the average 2.5 Mbps rate is used over the full period of time. The video can be shown at an average rate of 15.0 Mbps because all but one of the video

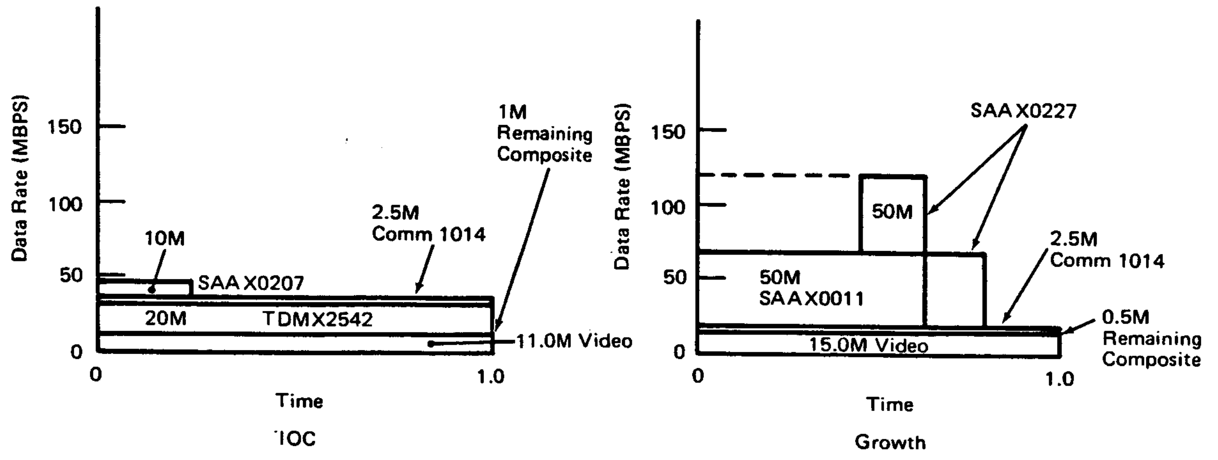


Figure 5-15. Attached Payloads

drivers will accept a three hour delay or more, thus allowing throttling of video data at the average rate. Because payloads SAAX 0011 and SAAX 0227 require minimal delay, their data must be transmitted at the generation rate of 50 Mbps for the fraction of time these payloads operate. The partial overlapping of transmission of data for these payloads is due to the independent triggers (sun or poisson) for the payload. Thus, the figure primarily reflects the major effects of SAAX 0011, 0227 and COMM 1014 (from the Woods Hole work), the timeliness requirements and the triggers. Other experiments contribute little to the loading.

Uplink communications to the space station for attached payloads are characterized in Table 5-6.

As indicated in Table 5-7 the communications for the Co-orbiting Platform are uniform throughout the space station life time. The Woods Hole data base only presents one payload. It should be noted that the previous Langley MRWG data base listed several payloads for the COP.

TABLE 5-6.

Attached Payload TDRSS Uplink Command and Audio Communications

	IOC	GROWTH
Simultaneous	51.1 kbps	78.2 kbps
Average Data Rate	11.9 kbps	12.4 kbps
Voice	60 Hrs/Day	80 Hrs/Day
Avg. Voice Channels	2.5	3.3
Avg. Voice Rate	40 kbps	53 kbps
Combined Ave. (Voice & Data)	101 kbps	131 kbps

Reference 6 and 7 (Table 5-1)

Table 5-7

Co-Orbiting Platform Payload Statistics

CO-ORBITING PLATFORM PAYLOADS SUMMARY

	IOC	GROWTH
P/L QUANTITY	1	1
DOWNLINK		
PEAK DATA RATE	1 Mbps	1 Mbps
AVG. DATA RATE	1 Mbps	1 Mbps
P/L VIDEO	0 Hrs.	0 Hrs.
UPLINK		
PEAK DATA RATE	10 Kbps	
AVG. DATA RATE	.67 Kbps	

COP PAYLOAD COMMUNICATIONS DRIVERS

IOC	GROWTH	DESTINATION	TRIGGER	DELAY	PEAK (Mbps)	AVG. (Mbps)
X	X	SAAX 004 SIRTF	Cont.	24 Hrs.	1.0	1.0

Table 5-8 lists the statistics on the 3 Polar-orbiting Platforms. Because the communications drivers for each platform can tolerate a full orbit delay (1.5 hours) or more in delivery of data, the average data rate is adequate for the data transmission profile. Figure 5-16 shows the projected total mission data loading of TDRSS return links for the SS, COP, and POP's (IOC and growth).

Table 5-8
Statistics for Payloads on Polar-Orbiting Platforms

PAYLOADS ON POLAR-ORBITING PLATFORMS (POP) SUMMARY

	POP-1		POP-2		POP-3	
	IOC	GROWTH	IOC	GROWTH	IOC	GROWTH
P/L QUANTITY	10	11	11	11	–	4
PEAK DATA RATE	393 Mbps	669 Mbps	302 Mbps	302 Mbps	–	76 Mbps
AVG. DATA RATE	80 Mbps	154 Mbps	18 Mbps	18 Mbps	–	41 Mbps

POP COMMUNICATIONS DRIVERS

IOC	GROWTH		TRIGGER	DELAY	PEAK (Mbps)	AVG. (Mbps)
POP-1						
X	X	COMM 1019 STEREO IS	LAND	24 Hrs	200	54
	X	COMM 1020 STEREO IS/SAR	LAND	24 Hrs	276	75
X	X	SAAX 209 HIRIS	LAND	3 Hrs	160	22
X	X	SAAX 0228 THERMAL IR	LAND	3 Hrs	30	3
POP-2						
X	X	SAAX 0212 SAR	LAND	6 Hrs	300	16
POP-3						
	X	COMM 1023 STEREO SEA SAR	WATER	1.5 Hrs	76	41

REFERENCE 6 and 7 (Table 5-1)

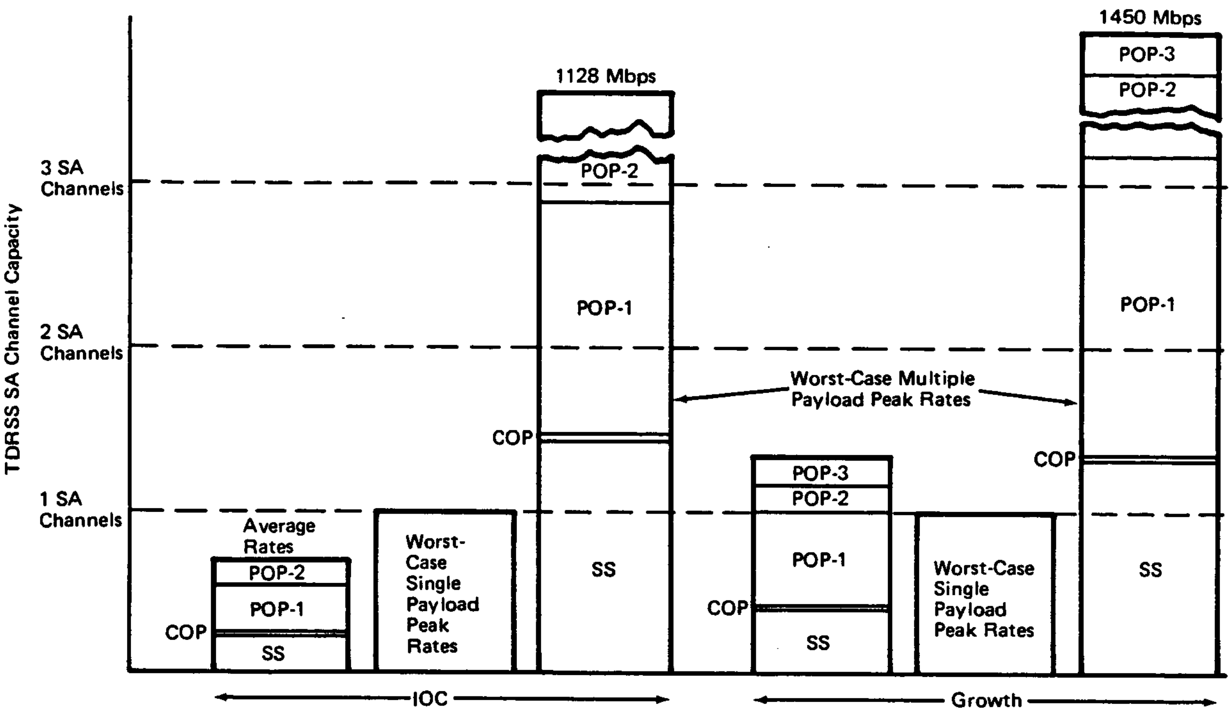


Figure 5-16. TDRSS SA Channel Traffic Versus Capacity

5.3.3.2 Foreign Payloads (Missions).

Tentative foreign payload communications drivers are presented in Table 5-9. They are considered tentative because; 1) they have not been included in the Woods Hole data base information in our possession as of this writing; 2) many details on the payloads are missing including an SSPE allocation, and 3) several caveats were provided in the document (i.e., Ref. 7) from which the data was taken. One caveat was that many foreign payloads duplicate US payloads and may not need to be listed separately in later listings of payloads. It is not apparent whether this means there are multiple similar experiments (US and foreign) or time phased use of the same experimental equipment.

As can be seen in Table 5-9 several foreign payloads on polar platforms could generate data at rates as high as 300 Mbps. The communications loading from these payloads will demand more of the TDRSS in terms of management, scheduling, etc.

The "Other Payloads" in Table 5-9 have sufficiently low data rates and/or sufficient communications delay, that addition of these to the US payload scenarios would have minimal impact.

Table 5-9

Foreign Payload Communications Drivers

POLAR-ORBITING PAYLOADS

GROUP	DUPLICATE		DELAY	PEAK (Mbps)	AVG. (Mbps)
CANADA	Y	COMM 4002 EARTH RESOURCE SENS.	24 Hrs.	300	100
	Y	TDMX 4000 RADARS	24 Hrs.	300	100
JAPAN	Y	E006 EARTH OBSERVATION FACILITY	0 Hrs.	300	10
EUROPE	N	EOB210 OPTICAL INFRARED	24 Hrs.	300	24
	Y	EOB220 LAND SAR MULTIPURPOSE	24 Hrs.	300	75
	Y	EOB230 LAND APPL. SAR AGR.	–	300	38
	Y	EOB300 OCEAN SAR	6 Hrs.	300	38

OTHER PAYLOADS (PLATFORM UNIDENTIFIED)

CANADA	–	SAAX4006	24 Hrs.	10	1.5
JAPAN	–	T004 SPACE ENERGY EXP.	24 Hrs.	5	2.8
	–	S001	24 Hrs.	8	8.0
EUROPE	–	EOBXXX LIDAR	–	150	1.8
	–	SCN060 ARTIC COMM.	0 Hrs.	1.6	1.6

Table 5-10 lists the current estimate of video required for foreign payloads (Avg. 10.4 Mbps). It is not known whether all the payloads generating this video will be operational during the same years or whether they will be on the same platform. Again the foreign payload data is only a first cut at defining the payload requirements.

Table 5-10
Foreign Payload Video
(Reference 4; Table 5-1)

VIDEO

EUROPE	9.8 Hrs/Day
CANADA	.5 Hrs/Day
JAPAN	45.5 Hrs/Day
TOTAL	58.8 Hrs/Day

Avg. Video @ 4.5 Mbps 10.4 Mbps

In summary, the primary impact of foreign payloads on communications will potentially result from POP payloads and perhaps payload video. However, because of the uncertainty regarding foreign payload definition they will not be included in the composite analysis, which follows.

5.4 Composite Communications Systems Loading

Composite communications loading and link loading is developed below by examination of data derived thus far.

5.4.1 Internal Distribution System Loading for the Space Station

Table 5-11 and 5-12 indicate the communications data inputs and resulting composite internal distribution systems loading for the IOC and growth space station scenarios, respectively. Distribution of information in all digital format on the Space Station has been assumed primarily to simplify analysis of the digital downlink loading of the TDRSS. Digital distribution channels can easily be taken out of the potentially several digital distribution networks on the Space Station and be assigned as analog on analog distribution

Table 5-11

Strawman Internal Space Station Communications at IOC During Heavy Loading

	NO. OF FUNCTIONS	TV 400K	TV 4.5M	TV 22M	VOICE 16K	VOICE 32K	CMD	TLM	DATA	NO. OF CREW MEMBERS
EVA	2	800k		44M	32k		64K	96K		2
ORBITER DOCKING	1			22M		64k	16K	2K		1
OMV/OTV	0									
FREE FLYER	0									
MRMS	0									
SURVEILLANCE	4		18M							
TELEMETRY COMMAND/ CONTROL	12						4K	256K		
TRAINING	1			22M	16K					1
RECREATION	1		4.5M	(22M)[1]	16K					2
ATTACHED PAYLOADS	1		11.6M				12K		33.5M	
COP PAYLOAD	1						1K		1M	
TOTAL		800K	34.1M	88M	64K	64k	97K	354K	34.5M	6
NO. OF CHANNELS		2	8	4	4	2				
			123,028 Kbps				34,951 Kbps			
			Audio/Video				SSDS			

1 – Cassette source (not distributed)

2 – Includes facilities/core information

Table 5–12

Strawman Growth Internal Space Station Communications at Heavy Loading

	NO. OF FUNCTIONS	TV 400K	TV 4.5M	TV 22M	VOICE 16K	VOICE 32K	CMD	TLM	DATA	NO. OF CREW MEMBERS
EVA	2	800k		44M	32K		64K	96K		2
ORBITER DOCKING	1			22M		64k	16K	2K		2
OMV/OTV	0									
FREE FLYER	7						1K		3.5M	1
MRMS	1		9M				2K	16K		2
SURVEILLANCE	8		36M							1
TELEMETRY COMMAND/ CONTROL	13						12K	512K		1
TRAINING	2			44M	32K					2
RECREATION	1		4.5M	(22M)[2]	16K					5
ATTACHED PAYLOADS	1		15.0M		32K		12.4K		103M	2
COP PAYLOAD							1K		1M	
TOTAL		800K	64.5M	110M	112K	64k	108K	626K	107.5M	18
NO. OF CHANNELS		2	15	5	7	2				
			175,476 Kbps Audio/Video				108,234 Kbps SSDS			

2 – Cassette source (Not Distributed)

3 – Includes Facilities/Core Information

networks. An objective of this analysis is to identify boundary conditions and probable loading levels of the communications systems. This can be done for both the digital designs and analog designs by identifying data rates and channel quantities.

The objective of the data analysis in Table 5-11 and 5-12 was to determine a probable, or an order of magnitude type determination of an instant in time when a heavy instantaneous communications loading would be placed on the Space Station communications systems. This then provides an estimate of the upper bound on communication capacity. The data rates used for each line of the tables were taken from the detailed strawman scenario diagrams, Table 5-4, or from the statistics presented on payloads.. The column labeled "No. of Func." lists the number of functions that would occur simultaneously for the composite scenarios developed in each table. In the case of EVA there are two functions (two simultaneous EVA crewmen) which result in all the data rates in the EVA scenario (from Figure 2) being multiplied by 2 and listed in the appropriate communications service column (TV, Voice, etc.). The actual distribution of functions was determined for both Table 5-11 and 5-12 by attempting to involve crew members in as many communications-intensive activities as appears reasonable, and is based on crew work schedules presented in References 1 and 6. Although the simultaneous involvement of crewmen in the selected activities presented here represents a judgement at this point, it is useful to bear in mind that the primary objective was to establish a heavy loading scenario to determine an upper bound on communications loading.

In Table 5-11 the attached payload video and data rates were selected from the highest loading point in the payload data profile of Figure 5-15. The command rate was taken from uplink communications in Table 5-6. Voice interaction for payloads during this scenario are not significant because none of the crew is available to interact with the payloads. It is however recognized that mission specialists may require audio and video interaction with principle investigators while setting up an experiment and at other times.

After summing the input information the required number of voice and video channels are listed along with the digital audio/video (123.028 Mbps) and the

SSDS data (34.951 Mbps). Again, these rates reflect a created model reflecting a heavy loading scenario.

In the growth scenario (Table 5-12) the input data rates were selected in a manner similar to that for the IOC scenario (Table 5-11). As in the IOC scenario, no OMV or OTV activities have been included for the purpose of this analysis because crew members have been assigned to functions with more demanding communications requirements. For other scenarios not included here crew interaction with the OMV and OTV would be included. The interaction with free flyers is not well defined for the space station; the command and data rates for these were arbitrarily assigned a composite average of 1 Kbps and 3.5 Mbps, respectively, which are loosely derived from the Free Flyer scenario in Figure 5-6. The composite upper bounds reflected in this growth scenario resulted in a 175.476 Mpbs audio/video rate and a 108.234 Mbps SSDS rate.

In postulating more realistic communications scenarios, it is useful to consider replacing some higher payload data rates with average rates and reallocating crew activity. This is particularly true when one recognizes that EVA and Orbiter Docking activities are not daily activities and the crew would likely be involved in some of the attached payload functions or a sleep period. This has been done in Table 5-13 and 5-14 for IOC and growth, respectively, which attempts to postulate a more "typical" scenario. The data rates for attached payloads have also been changed to the average data rates for payloads.

The composite communications loading for both the heavy and "typical" communications loading are summarized in Table 5-15.

Table 5–13

Strawman Internal Space Station Communications at IOC During "Typical" Loading

	NO. OF FUNCTIONS	TV 400K	TV 4.5M	TV 22M	VOICE 16K	VOICE 32K	CMD	TLM	DATA	NO. OF CREW MEMBERS
EVA	0									
ORBITER DOCKING										
OMV/OTV	0									
FREE FLYER	0									
MRMS	0									
SURVEILLANCE	4		18M							
TELEMETRY COMMAND/ CONTROL[2]	12						4K	256K		
TRAINING	1			22M	16K					1
RECREATION	1		4.5M	(22M)[1]	16K					2
ATTACHED PAYLOADS	1		11.6M		40K		12K		26M	3
COP PAYLOAD	1						1K		1M	
TOTAL		0	34.1M	22M	72K	0	17K	256K	27M	6
NO. OF CHANNELS			8	1	5	0				
			56,172 Kbps Audio/Video				27,273 Kbps SSDS			

1 – Cassette (not distributed)

2 – Includes facilities/core information

Table 5-14

Strawman Growth Internal Space Station Communications During "Typical" Loading

	NO. OF FUNCTIONS	TV 400K	TV 4.5M	TV 22M	VOICE 16K	VOICE 32K	CMD	TLM	DATA	NO. OF CREW MEMBERS
EVA	0									
ORBITER DOCKING	0									
OMV/OTV	0									
FREE FLYER	7						1K		3.5M	1
MRMS	1		9M				2K	16K		2
SURVEILLANCE	8		36M							1
TELEMETRY COMMAND/ CONTROL[2]	1						12K	512K		1
TRAINING	2			44M	32K					1
RECREATION	1		4.5M	(22M)[1]	16K					5
ATTACHED PAYLOADS	1		15.0M		53K		12K		51M	4
COP PAYLOAD	1						1K		1M	
TOTAL		0	64.5M	44M	101K	0	28K	628K	55.5M	18
NO. OF CHANNELS		0	15	2	7	0				
			108,601 Kbps Audio/Video				56,154 Kbps SSDS			

1 - Cassette Source (Not Distributed)

2 - Includes Facilities/Core Information

Table 5-15.
Summary of Space Station Internal Communications Loading

IOC	HEAVY LOADING SCENARIO	"TYPICAL" LOADING SCENARIO
Table No.	9	11
Audio/Video	123.0 Mbps	56.2 Mbps
SSDS	35.0 Mbps	27.4 Mbps
Total	158.0 Mbps	83.6 Mbps
GROWTH		
Table	10	12
Audio/Video	175.5 Mbps	108.6 Mpbs
SSDS	108.2 Mbps	56.2 Mbps
Total	283.7 Mpbs	164.8 Mbps

5.4.2 Space Station Downlink Loading of TDRSS

The internal communication load includes communications which is for intra space station purposes as well as communications from/to external sources. Table 5-16 addresses the potential TDRSS downlink (KSA) communications loads for IOC and growth depicting upper level loading and hypothetical "typical" scenarios. Therefore the methodology used to arrive at external loading was to subtract internal communications loading that did not require transmission to the ground.

Table 5-16. Downlink Loading of TDRSS

	HEAVY LOADING SCENARIO	"TYPICAL" LOADING SCENARIO
IOC	119.8 Mbps	45.4 Mbps
GROWTH	207.3 Mbps	88.4 Mbps

Only 10% of the surveillance video will be transmitted to the ground (see Figure 5-8). As can be seen in Figure 5-10, no training information is transmitted to the ground. These two assumptions are based on our development of those two scenarios; this may require review as various NASA elements comment on the model. Video for PAO (Public Affairs Office) has not been specifically identified in the scenarios. It should be recognized that some PAO video includes the video previously addressed and that other PAO video would be added to the hypothesized scenarios during special occasions.

5.4.3 SS Uplink Loading of TDRSS

The continuous uplink loading of TDRSS is minimal as indicated in Table 5-17. The only possible heavy loading of the channel would result from Space Station to Ground conversation, video conferencing, transmission of training video or uplink video instruction for setting up payloads. The loading from these would be intermittent and for the most part could be scheduled to be appropriately interleaved with any unexpected heavy loading of the uplink channel. Special uplink loading, such as program loading or emergency information, have not been included since the scenarios pertaining to these situation are not defined at this time.

Table 5-17. Space Station Uplink Loading of TDRSS

	IOC	GROWTH
Attached Payloads (Table 5-6) Avg.	101 Kbps	131 Kbps
SS Command/Control (Table 5-4) Avg.	2 Kbps	4 Kbps
Crew Member Voice/Video	Variable	Variable

5.4.4 Communication Link Loading for EVA

Two crewmen will be on EVA simultaneously while performing activities outside the Space Station. The communications link to each crewman should support loading up to 448 Kbps and 22,064 Kbps for the forward and return links (see Figure 5-3). Lower loading levels would occur depending upon the audio, video, telemetry and command required for supporting EVA.

5.4.5 Orbiter Communications Link Loading

The Space Shuttle Orbiter (SSO) has a variety of communications capabilities, many of which may not be required for communication with the Space Station. Further analysis of the communications requirements is needed.

Based on References 1 and 2, communications loading between a SSO and the Space Station should require a communications capability similar to that presented in Figure 5-4. That scenario requires two voice channels (32 Kbps each) and some telemetry/command (2 Kbps) on the communication channel to the Space Station. Video, audio, and command/telemetry to the SSO could require a composite capacity of 22,080 Kbps.

It should be noted that Reference 2 indicates that 2 analog TV channels (4.5 MHz each) be used for transmission of MRMS video to the SSO. The MRMS scenarios in Figure 5-7 assumed 4.5 Mbps TV for distribution on the Space Station. This is not intended as a recommendation for a digital TV link to the Orbiter; rather, it is a convenient assumption for purposes of this traffic analysis.

5.4.6 Communications Link Loading for OTV/OMV

Both the OTV and OMV will provide similar support functions with the primary difference being that the OTV will have more extensive transportation capabilities. Our understanding of the OMV design currently under study by NASA that it will support transmission of telemetry and/or video at a rate of approximately 448 Kbps and reception of commands at a rate of approximately 64 Kbps (see Figure 5-5). The average rates could of course be less, depending on the OMV activity level. The use of this video rate has been questioned on several occasions because it may not be sufficient to support some OMV activities, such as robotic repair, maintenance, and docking. A higher 22-25 Mbps video rate may be required-perhaps even on two channels simultaneously.

Until the design of the OMV is better defined the communications loading will be uncertain. The communications loading for the OTV, although assumed similar to the OMV, is even less certain since this will be a growth addition to the Space Station.

5.4.7 Free Flyer Communications Link Loading

Free Flyers are essentially of two types:

1. Satellites being launched and serviced
2. Special purpose vehicles that may operate in the vicinity of the Space Station.

Until specific mission requirements can be defined for free flyers, communications loading cannot be defined except for the link capacities (5 and 25 Mbps IOC and growth as identified in Reference 2).

5.5 Recommendations for Further Study

5.5.1 The baseline and assumptions which are used in this report represent a viewpoint which is based on the "best" information available to use at this time. This includes rates and guidelines which in some cases were derived from explicit NASA sources; in other cases, were arrived at via indirect sources or engineering judgement. This should be reviewed as new information and guidance are made available.

5.5.2 Areas where specific further investigation is suggested are discussed in the following paragraphs.

VIDEO. An example of the factors relating to the relative "softness" of the assumed video rates and mission needs is described below, using the OMV for reference purposes: the OMV requirements document does not identify a specific quality of video, nor an attendant rate. However, discussions over the past year with contractors on the Phase B - OMV study, have identified the use of a relatively low (digital) rate for TV purposes, i.e., 448 KB/S. Further, this appears to be a total video channel allocation. The OMV requirements document asks for two TV cameras, and one or both cameras shall use that channel separately or together. This rate implies a slow scan (e.g., 5 frames/sec) approach, with either a compression or a "special spot" algorithm, and probably black-white.

Discussion with video technology personnel at NASA have indicated that they believe a much higher resolution video requirement exists – probably requiring the equivalent of NTSC, full color; this implies a video rate in the order of 22–25 MB/S, depending on an acceptable compression algorithm (see discussion in 5.3.1).

These differences are dramatic enough to require a revisit of the communications profile, since they impact the capacity, power, and flexibility of the SSDS, as analysis of video standards determines that rates may be increased.

EXPERIMENTAL PAYLOADS. The information used for representing communications profile for the US payloads was derived from the Woods Hole Mission workshop outputs, which are reasonably complete and are in the available data base. However, the information related to foreign payloads is much less complete and also appears to overlap with some U.S. experiments. IOC–growth transition schedule information in minimal. As these foreign experiments are delineated in greater detail, the SSDS system requirements may require modification.

END–TO–END DELIVERY DELAYS. The communications profile does not address end–to–end delivery of data. However, as traffic builds, the delays due to service queues, buffer delays, and routing increase. Therefore, it is suggested that this area be investigated with particular emphasis on queue delays; transmission delays should be essentially constant. If true time transparency could be guaranteed (i.e., T_D specified delay) regardless of traffic conditions, this could be accomplished by faster processing and buffer service and/or by assigning different delivery times to various classes of data.

TDRSS ACCESS. The total TDRSS channel allocation and the access protocol that is used obviously drives buffer sizes and affects delays. Dynamic schedule algorithms should be investigated in order to reduce the effect of contention/conflicts as well as for mitigating predictable data throttling periods. These would give some insight into worst case delays and assist in developing buffer use and sizing options.

BIT ERROR RATE/DATA INTEGRITY. The end-to-end objectives for data integrity (the acceptable BER) may not be the same for the three categories (data, video, voice) of information; they may even vary within any category. Error detection and correction codes for individual links in an end-end connection affects power, processing requirements, effective link efficiency, etc. The use of error protective codes within the data, within a frame, and/or within a packet format are areas which requires further investigation.

It is probably worth reiterating that video and audio have sufficient redundancy (i.e., assuming that compression algorithms are not too severe) in terms of information patterns that the ability of human senses to integrate across relatively short errors could reduce error coding requirements to those necessary for frame, synch, headers, etc.

It is also useful to consider adaptive code strategies to accommodate different conditions; e.g., in periods of high activity but good quality links, a reduced code may be acceptable, while in periods of poor quality more robust codes may be required. Also, within a constrained environment, as within a LAN on the Space Station, or from a TDRSS ground terminal to a terrestrial network interface (e.g., COMSAT terminal to a switched network node) error detection (ACK/NACK) may be adequate rather than a more complex FEC approach.

6.0 ONBOARD SSDS DEFINITION

Section 6.0, presents the definition of the onboard Space Station Data System (SSDS) and the onboard Platform (POP and COP) Data System. The Space Station System is described in sections 6.1 to 6.8; the Platform system is described in section 6.9.

6.1 Space Station Onboard Introduction and Overview

For the purposes of this study, the onboard SSDS has been defined to include the onboard networks, the network interface units (NIU's), subsystem data processors (SDP's), workstations (MPACs), mass storage units and the software that resides in or supports these elements. It should be noted that the subsystem application software is included in this definition. The architecture and system definition described herein are products of the SSDS A/A Study approach and methodology outlined in Section 2.0. This architecture definition is preliminary. Some elements are defined in more detail than others to explore specific design or technology driver aspects of the architecture. The prime inputs used to develop this preliminary definition were:

- Task 1 – Requirements Definition
- Task 2 – Options Development
- Task 3 – Trade Studies
- Space Station Phase B RFP
- Space Station Reference Configuration
- Team Systems Engineering Practices
- NASA Guidance and Feedback
- Langley Mission Data Base and Woods Hole Data

The major metrics utilized throughout this task to evaluate architectural alternatives and influence key design decisions are also common to all supporting analyses (options development, trade studies) and include the following:

- Cost
- Standardization/Commonality
- Technology Insertion and Readiness
- Performance
- Growth and Flexibility
- User Acceptance

The primary steps of the onboard system definition process include:

- Partition/allocate the Task 1 Functional Requirements to onboard subsystems, physical modules and computing elements for traceability.

- Describe and characterize the onboard elements including rational.

- Present an architecture and topology rationale that connects the distributed elements.

- Document the System Definition and key design decisions made to date.

The supporting trade study results and options development were major inputs into the system definition process. Recommendations and supporting data in the following trade studies and related options categories were important influencing factors in most key design decisions:

- Network Media options
- NIU options
- Onboard LAN trade study and options
- Operating System trade study and options
- Data Base Management trade study and options
- Fault tolerance trade study and options
- Time management options

The key design decisions made to date are summarized in Table 6.1-1.

Table 6.1-1

System Definition Decision List

ITEM	DRIVERS FOR DECISION	DOCUMENTED	DECISION/COMMENTS
1. Central vs. Distributed	● Basic architecture decision ● Growth	Section 6.0	Distributed ● Build-up steps ● Safe-haven ● Growth
2. Voice/Video Integration with data on Single Media	Basic information distribution choice	LAN Trade Study and Section 6.0	Separate voice, video from Core and Payload Network ● Commercial off the shelf H/W availability ● Optimized network components ● Growth capability
3. NIU and SDP Back-end Connectivity	Fundamental Architectural Tradeoff Factors ● Flexibility/Adaptability ● Reliability ● Subsystem Autonomy	● Section 6.0 Architecture Topology shows no back-end to SDP ● Section 6.6 discusses options	● Still open, key issue ● Needs more evaluation
4. LAN Configuration	Single vs. Multiple LAN	LAN Trade Study	Multiple LANS ● Reliability ● Build-up ● Reconfiguration ● Security ● Safe-haven ● Handle more data

Table 6.1-1 (continued)

System Definition Decision List

ITEM	DRIVERS FOR DECISION	DOCUMENTED	DECISIONS/COMMENTS
5. LAN Standards	● Initial Cost ● Network Complexity ● Growth & Evolution	LAN Trade Study	IOC – Single (Commonality) Growth – Multiple (Technology Insertion)
6. LAN Topology & Access Method – ANSI X3T9.5 FDDI token ring – IEEE 802.4 token bus – AIPS – SubACS – FODS CSMA/CD/TS – Langley Mesh – SAE/AE-9B	● Network Performance ● Accepted Standard	LAN Trade Study	ANSI X3T9.5 Type ● A standard (proposed) ● Determistic ● Fault tolerance ● Growth capability
7. ISO/OSI Layer Residence	● Network Performance ● Packaging Complexity	LAN Trade Study	NIU: Layers 1-4 SDP: Layers 5-7
8. NIU Commonality – Single vs. multiple	● Number of units ● Complexity/reliability ● User selection	LAN Trade Study	Several types ● SDP connection ● Back-end device options (serial, parallel) ● Bridges (layers 1-3) ● PL LAN unique is open question

Table 6.1-1 (continued)

System Definition Decision List

ITEM	DRIVERS FOR DECISION	DOCUMENTED	DECISIONS/COMMENTS
9. Connection oriented vs. connectionless transactions	• Performance • Flexibility	LAN Trade Study and section 6.0	• Connectionless for periodic messages • Connected for aperiodic messages • Connections at layers 4-7
10. Back-end Interfaces to NIU or SDP • IEEE-488 • RS-232,422 • NIDS (Navy) • MIL-STD-1553B • MIL-STD-1773 • Skylab Set	• Standardization • Flexibility	LAN Trade Study and section 6.0	• None really eliminated • 1553B as good as 1773 for long wiring needs. • Skylab set flown (IEEE-595, 596, 683) • Multiple options to accommodate customer hardware
11. Computing Elements Distribution (SDPs, NIUs, workstations)	• Maintenance/reliability • Safe-haven Access • Flexibility	Section 6. 0	• Most elements distributed • Back-up in place spares • Safe-haven
12. Subsystems Distribution	• Subsystem Autonomy • Number of SDP's • Number of NIU's • Safe-haven	Section 6.6	• Combine smaller subsystems into SDPs to save resources • Minimum hardware and enhanced system flexibility • Single or multiple SDP's for subsystems not precluded

6.2 Partitioning/Allocation of Functional Requirements into Onboard Subsystems

This section describes the allocation of onboard SSDS functional requirements to subsystems. Functions were previously allocated to onboard the Space Station as a result of the Autonomy/Automation Trade Study. For clarity, the subsystem allocation process is accomplished in two steps:

- Functional requirements partitioned into the reference configuration defined subsystems as a starting point. Some restructuring will be described in subsequent sections.
- Subsystem functional requirements allocated to resources (SDPs, NIUs and workstations).

The design characteristics (sizing data) of allocated SSDS functions, functional interface connectivity, discipline orientation, subsystem (functional) autonomy and the advantage of recognizable subsystem names were major factors in our core subsystem definition.

Table 6.2-1 presents an "application subsystem" overview of prototype memory sizing in kilobytes (Kbytes) and mean processing rates in kilo-operations per second (KOPS) using the reference configuration subsystem names. A detailed breakout of each of the subsystems are tabulated in Section 6.8. The exception is "Propulsion" which we assumed contained no software that is resident in an SDP. The IOC and Growth subsystem summations represent only the application code and data sizing and computational rates. The operating system sizing and rates are added later when SDP memory configurations are presented (total software load).

The application memory size for each subsystem is conservative from the standpoint that it represents an arithmetic sum. Not all elements of each subsystem are necessarily main memory resident in an SDP at all times. This also naturally applies to their computational rates.

Table 6.2-1

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

SUMMARY DATA

SUBSYSTEM	MEMORY (KBYTES)		MEAN DATA PROCESSING (KOPS)	
	IOC	GROWTH	IOC	GROWTH
1. ELEC PWR 4.2.1.1-7	443	863	76	148
2. GN&C 4.1, 2.5.3.3, 2.5.4.3	878	1181	267	379
3. THERMAL CONTROL 4.2.2.1-4	76	131	11	16
4. ECLS 4.2.4.1-7	117	119	17	17
5. PROPULSION	NO SOFTWARE -- CONTROLLED BY GN&C			
6. STRUCTURES/MECHANISMS 4.2.3.1-5	108	252	52	106
7. CREW SYSTEMS 4.3.1, 4.3.3, 4.3.4	210	292	50	75
8. COMM & TRACKING 1.1.1-5, 1.2.1-5, 4.2.5.1-7, 2.5.3.5, 2.5.4.6	851	1608	622	753
9. INFORMATION & DATA MGMT SYSTEM 2.1, 2.2, 2.3, 3.3, 3.4 4.3.2, 4.3.5, 4.5, 4.1.6, 5.1.1, 5.1.2	2578	4126	45	113
10. PL & SERVICING ACCOMMODATIONS 2.4, 2.5.1, 2.5.2, 2.5.3.1, 2.5.3.2, 2.5.3.4, 2.5.4, 2.5.5, 4.4	2466	3122	26	49

A comparison of these sizing estimates to Shuttle software memory requirements illustrates the magnitude of the problem. The Shuttle AP-101 onboard computer application software total code and data size is approximately 400,000 32-bit words or 1600 Kbytes.The results of the comparison is shown below.

	Space Station	
Current Shuttle	IOC	Growth
1600 Kbytes (Application Code)	• 8127 Kbytes • 5.1 times Shuttle	• 12,404 Kbytes • 7.8 times shuttle

For reference, the current Shuttle AP-101 computer capability is 425 Kbytes and 450 KOPS. The upgraded AP-101S is 1081 Kbytes and approximately 1000 KOPS.

The IOC KOPS values in Table 6.2-1 are well within the capabilities of present space qualified processors for any subsystem. The Growth requirements indicate the need for newer technology (faster) processors in the Electrical Power subsystem.

6.3 Subsystems Allocation into Architectural Elements

The following discussion traces the onboard function allocations into SDP's. Later, workstation functionality is discussed that allows down loading from SDP's, (Section 6.4.6 and 6.6)

Table 6.3-1 describes the onboard subsystem allocation into SDP memory configurations. A memory configuration is defined as a collection of one or more sets of subsystem application software. Most of the subsystem function groups of Table 6.2-1 are retained intact with respect to the Reference Configuration names. The most notable exception is that the Information and Data Management has been partitioned into a DMS Operational Data Base (ODB) grouping and Facility Management (see Table 6.3-2). The DMS grouping represents a generic set of services that are available to all core subsystems and are also available as options for the payload community. Tables 6.3-2 and 6.8-1 (Section 6.8) together, provide the sizing data for these DMS services. These will be discussed later. The remaining DMS items (Tables 6.2-1/6.8-1) are considered as standard System Services.

The Facility Management grouping of Table 6.3-2, in conjunction with

Table 6.3-1

SSDS A/A Core and Payload Memory Configurations

No.	Name/Function	IOC Mem(1)/CPU(2) (KBYTES/KOPS)	Growth Mem(1)/CPU(2) (KBYTES/KOPS)
1.	GN&C ● NAV ● Guidance ● ATT Cont ● Traffic ● Tracking ● OMV & OTV Deploy/ Retrieve	1038/307	1341/436
2.	● Elec Pwr ● Thermal Control ● Communications	1530/815	2852/1055
3.	● ECLSS ● Crew Systems ● Str & Mech	595/137	913/228
4.	DMS ODB	1280/38	2071/62
5.	Facility Mgmt	1618/14	2555/68
6.	Payload Processing (Function 2.5.1)	360/1	650/1
7.	Payload Processing (Function 2.5.1)	360/1	650/1
8.	Payload and Servicing Accommodations	2626/30	3372/57

(1) Application size from Tables 6.2-1/6.8-1 +160 KBYTES for operating system (+250 KBYTES for growth).

(2) KOPS from Tables 6.2-1/6.8-1 + 15% of total application KOPS for operating system overhead.

Table 6.8-1, describe functions which are collected together as a required central service for the Space Station. The functions are global in nature and allow central status monitoring and command control for both the core and payload systems.

The remaining subsystem sizes were significantly smaller than the IDMS. The memory configurations of Table 6.3-1 were derived by the following rules:

- Retain well recognized function group names (discipline oriented)
- Reasonable balance of memory and throughput loads (minimize power/thermal resources required by onboard SSDS)
- Grouping of functions that may be required for one or more physical modules (e.g., power, thermal and communication and ECLSS, crew systems and structure/mechanism.)
- Separation of functions (as much as possible) between those identified with core operations and payload operations.
- Minimize network interaction
- Growth of memory configurations

The Communications and Tracking Subsystem of the reference configuration was restructured to include only the communications related functions (under function 4.2.5). The tracking function of pointing all steerable hardware (solar arrays, antennas, payload pallets, and movable mounts) were allocated to a tracking Subsystem. The hardware associated with sensing and self-locking on radiated signals is associated with the Communications Subsystem.

Appendix C defines all SSDS external interfaces including the SSDS to subsystem sensors/effectors derived from the Task 1 developed functional requirements data base. Table 6.3-3 provides cross-correlation of the Task 1 defined externals (abbreviated) to the sensor/effector terminology used in this system definition report.

Table 6.3-2
PARTITIONING OF IDMS FUNCTION SET*

DMS ODB		FACILITY MANAGEMENT	
4.1.6	TIME & FREQUENCY MGMT.	2.1	VALIDATE PL CMMD
5.1.1	FIGHT DATA BASE MGMT.	2.2	CHECK PL CMMD RESTRICTION/ CONSTRAINTS
5.1.2	FLIGHT RESOURCE MGMT.	2.3	VALIDATE CORE CMMD/DATA
5.1.3	DISPLAYS & CONTROLS	3.3	DEVELOP OPS EVENT SCHEDULER
		3.4	SEQUENCE OPS
		4.3.2	SPACE STATION SAFETY
		4.3.5	OPS AND PROCEDURE SUPPORT
		4.5	MONITOR & STATUS SYSTEM

*Sizing data for these functions appears in Table 6.8-1 (Section 6.8)

The data of Table 6.3-1 were used to select the size of the SDP. To cover growth and provide an adequate margin, an SDP size of 4 megabytes and 2 MIPS is recommended. Large elements of Payload and Servicing Accommodations (P&SA) are candidates to be either loaded into an SDP or a workstation for execution because of their infrequent use. For example, Function 2.6 SSPE Checkout and Service (Table 6.8-1) is 1100 Kbytes. If this is saved in secondary mass storage, the P&SA SDP memory configuration can be reduced by 1100 Kbytes. Therefore, the largest SDP memory configuration in Table 6.3-1 then becomes No. 2 (Elec. Power, Thermal and Comm) at 3408 Kbytes (growth). This leaves an additional margin of more than 33% beyond the estimated growth size. This technique can be applied to the other memory configurations as well.

The sizing estimates do not include any consideration of extensive AI processing. The data in our Function Data Base for the onboard functions generally represents traditional sizing methods. A policy that augments these base numbers for AI needs, when they become defined, should be addressed.

TABLE 6.3-3 (Page 1 of 3)
ONBOARD ARCHITECTURE CONFIGURATION SENSORS & EFFECTORS MAP TO APPENDIX C EXTERNAL INTERFACES

SENSORS & EFFECTORS ABBREVIATION*	DEFINITION	APPENDIX ABBREVIATIONS	
Align	Structural Alignment Sensors and Controller	ALIGN S MODESENS	
α, β ACT	Solar Array Gimbal Control Actuators	PNTG MNT	
CMG	Control Moment Gyros	CMG	
Comm I/F	Communication Gateway	COMEQUIP COMM I/F COMMSYS CONSTI/F	OMVOTVIF OMV I/F OTV I/F
Crew Sys	Crew Systems	EMU MMU PHYS MON	WASTE AN
ECLSS	Environmental Control and Life Support System	PRESCOMP AIR TEMP AIR TOX AIRCIRC AIRMAKUP ATM CTL GREYWATR HUMIDITY	TEMP/HUM POT SUPL CABNPRES CONTAMSR ECLSS FIRE CTL FIREDECT OX LEVEL

*See Figures 6.6-1 and 6.6-2

TABLE 6.3-3 (Page 2 of 3)
ONBOARD ARCHITECTURE CONFIGURATION SENSORS & EFFECTORS MAP TO APPENDIX C EXTERNAL INTERFACES

SENSORS & EFFECTORS ABBREVIATION*	DEFINITION	APPENDIX C ABBREVIATIONS
GPS	Global Positioning System	GPS TRAK
MAG Torq	Magnetic Torquer	MAGTORQ
Mech	Mechanical Latches, Connectors	AIRLKCTL AIRLOCK MECH STR MECH
MRMS	Mobile Remote Manipulator System	MRMS
MTU	Master Timing Unit	TIMEFREQ
PL's PL Mount	Payloads and Pallets	PALLET P/LCONST P/LCSTIF POP/COP SS P/L
Prox Ops	Proximity Operations	TRAKSENS PORT PROXTRAK

*See Figures 6.6-1 and 6.6-2

TABLE 6.3-3 (Page 3 of 3)
ONBOARD ARCHITECTURE CONFIGURATION SENSORS & EFFECTORS
MAP TO APPENDIX C EXTERNAL INTERFACES

SENSORS & EFFECTORS ABBREVIATION	DEFINITION	APPENDIX C ABBREVIATIONS	
Pwr	Power System	CHRG/REG ENERGYST PWR SYST	PWRSWTCH SLRARRAY SWITCHGR
RAD Cont	Radiator Control	PNTG MNT RADIATOR	
RCS	Reaction Control System	RCS	
Star Tracker	Star Tracker	STARTRAK	
Strap Down	Strap Down Gyro or Inertial Measurement Device	RATEGYRO	
THM	Thermal Control System	THERMCAP COOL CTL FL LOOPS FLUIDCTL	THERMCTL HTEMPCTL LTEMPCTL P/L IFHX RADIATOR
Trk	Long Range Trackers	L/R TRAK TRAKSENS	

*See Figures 6.6-1 and 6.6-2

6.4 Architecture

6.4.1 Overall Partitioning

The overall onboard architecture presented here has most of the same connectivity generalized in the NASA Reference Configuration. However, the system definition process of this study has resulted in a more specific and detailed configuration. An overview of the significant architectural features and a comparison with the Reference Configuration is provided in Table 6.4-1.

6.4.2 Network Configuration

The onboard local area network (LAN) provides the means for information transfer between communicating Onboard SSDS elements. Local area networks basically consist of transmission media, Network Interface Units (NIUs), and the Network Operating System (NOS) (Figure 6.4-1 shows a generic representation of a LAN). The NOS is discussed in more detail in Sections 6.4.2.2 and 6.4.4.

The Space Station onboard LAN must accommodate requirements for high performance, reliability, maintainability, and evolutionary growth, in a cost-effective manner. This results in a design that must provide features such as high network bandwidth, fault tolerance capabilities, modularity and the appropriate application of standards to allow design extendability and to incorporate new technology.

6.4.2.1 LAN Definition

In defining the Space Station onboard LAN, the configuration, level of standardization, transmission media, topology and media access method, as well as the functions performed by the network communication system must be addressed.

TABLE 6.4-1

REFERENCE CONFIGURATION	SSDS A/A
TWO LAN NETWORKS - CORE - PAYLOAD	SAME
SINGLE COMM GATEWAY TO TDRS AND CONSTELLATION	SAME
PAYLOAD AND CORE LAN GATEWAY TO COMM NODE	SAME
● BACK-END SDP I/Fs TO SENSORS AND EFFECTORS	● NO BACK-END I/F TO SDP
● NIU I/Fs TO SENSORS AND EFFECTORS	● SAME
● SINGLE I/F BETWEEN NIU AND SDP	● SAME
● GN&C SET OF SDP's SEPARATED FROM IDMS SDP SET	● SIMILAR - - ASSIGNED SDP TRIAD WITH BACKUP FLEXIBILITY
● GN&C SPLIT INTO TWO MEMORY CONFIGURATIONS (NAV/TRAFFIC, G/C)	● GN&C PRELIMINARY SIZING DOES NOT DRIVE SDP SIZING (NO GN&C FUNCTION SPLIT)
DEDICATED SDP(s) TO SUBSYSTEMS (H/W INTENSIVE)	COMBINE SMALLER SUBSYSTEMS INTO SINGLE GPC(s) (SOFTWARE PARTITIONING)

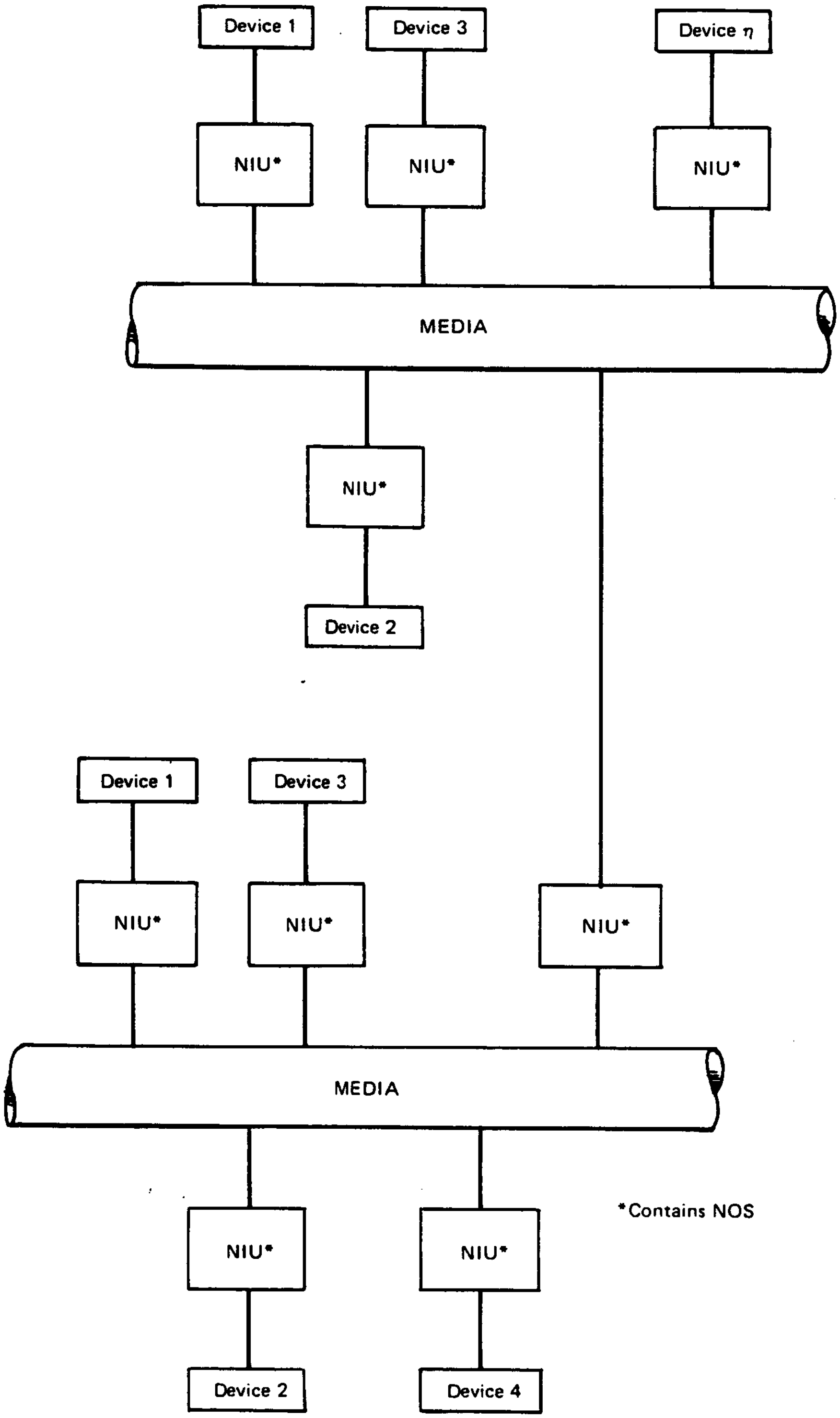


Figure 6.4-1. Generic Local Area Network

6.4.2.2 Configuration

Onboard the Space Station there are two alternatives for configuring the network communications: 1) one LAN interconnecting all devices and 2) multiple LANs interconnected by bridges/gateways. The multiple LAN option was determined to be the most suitable configuration onboard the Space Station per the Onboard LAN Trade Study (Task 3). This configuration provides a highly reconfigurable system which would potentially handle more data with minimum resource contention. It not only allows for an easier build-up (integration, test, verification) with one or more LANs per module, but also enhances security/privacy since the payload and core devices would be on physically different LANs.

6.4.2.3 Level of Standardization

The multiple LANs should all conform to the same standard at IOC, but this does not preclude the use of multiple standards for LANs in the growth phase. The single standard for LANs at IOC allows for a simple bridge with no need for gateways while also satisfying the commonality requirement. Having a single standard for LANs at IOC provides the most cost-effective solution. Simulation analyses has shown that there would be relatively little performance gain to warrant matching LAN Topology and access methods to variations in module network traffic characteristics (i.e. frequency distribution, mean packet sizes, etc.).

However, since future requirements and technology developments may vary, multiple LAN standards after IOC should be allowed. This is consistent with the Onboard LAN Trade Study (Task 3).

6.4.2.4 Transmission Media

The transmission media for the primary LANs onboard the Space Station should be optical fiber. This media has a high bandwidth allowing it to support high rate applications such as payloads, and also provide a high growth potential. It is also highly secure and has a high noise immunity, low weight, and an extremely low Bit Error Rate (BER). Optical fiber can be used for inside the modules and outside. Outside the modules, fiber can be placed along the structure to allow for the connection of payloads and core devices located on the structure to the LAN; however these fibers may require additional shielding for large temperature variations and radiation.

Between the NIU's and back-end devices and between the SDP's and NIU's (sensor/effectors, workstations, payloads), high bandwidth fiber optics are not required. Therefore, twisted shielded pair can normally be used for serial and parallel transmissions. This media is low cost, highly reliable and can operate above 1 Mbps which will satisfy most back-end rate user needs.

Specific high rate payloads require data rates that currently exceed the computational and input/output capabilities of todays NIU's and SDP's. These cases require dedicated media such as coax or fiber to move their data directly to the onboard C&T interface to be multiplexed with lower rate data and transmitted to a ground receiving station(s).

6.4.2.5 Topology and Media Access Method

The topology and media access method selected for the LANs is token passing rings (e.g., ANSI X3T9.5, FDDI system) with redundancy paths. The cost and risk associated with the ANSI X3T9.5 FDDI should be relatively low since this is an emerging standard. Since this system is not currently available, the cost, physical characteristics, and environmental characteristics have not yet been determined and, therefore, could not be evaluated. It is felt, however, that these characteristics, once defined, will satisfy the Space Station requirements.

6.4.2.6 Network Communications Functions

The functions performed by a network communications system will be described in terms of the International Standards Organization Open Systems Interconnect (ISO/OSI) model for layered communications systems. The layered architecture provides flexibility in revising and augmenting the system. The possible set of functions performed by each of the seven ISO/OSI layers are shown in Table

6.4-2. The ISO/OSI model allows for the absence of some of the functions or layers if they are not required for a given communications system. As the need arises, however, these functions or layers may be added with minimal impact to the existing system.

In order to provide a high performance, cost effective system for the onboard LAN, only the required software services should be provided at IOC. However, the hardware must be sized at IOC to allow for additional software services to be incorporated for planned growth.

One significant question regarding performance addresses the issue of whether message transfers should be connection-oriented or connectionless or both. A secondary part of the question is what ISO/OSI model layers should support connection oriented transactions if they are required. Connection-oriented service at the Data Link layer (layer 2) implies sequencing and error control. However, due to the robust nature and low bit error rate of the transmission medium, these services can be performed at a higher layer (layer 4) and still provide efficient yet reliable communications. The Data Link Layer will therefore provide connectionless service.

Connection oriented service at the network layer allows large networks (such as multiple LANs interconnected by bridges) to be operated as one large network with deterministic global resource allocation. When routed, each packet of a message follows the same path. Each packet transmitted through a connectionless network layer is routed independently. For the onboard LAN, connectionless service at the network layer will provide efficient services with less overhead.

At the transport layer, connection oriented service implies end-to-end flow control, sequencing, and error checking. Since these essential services are not provided by the connectionless network and data link layers, the transport layer should be connection-oriented. Of the ISO Transport Layer classes of service, Class 4 will provide timely and reliable data transfer for mission critical data. The functions available with Class 4 include data transfer with segmenting, multiplexing, error detection and recovery, flow control, and expedited data transfer. Class 2 service, which provides for data transfer with flow control, may be satisfactory for sensors with over-sampled or

Table 6.4-2: ISO/OSI Functions (Part 1 of 2)

ISO/OSI layer	FUNCTIONS	IOC	GROWTH
7 application	Connection Oriented	x	
	-bulk file transfer	x	
	-virtual terminal usage	x	
	-message handling services	x	
	-job transfer and manipulation	x	
	-stream oriented access to devices	x	
	Connectionless Oriented	x	
	-data collection	x	
	-outward data dissemination	x	
	-broadcast / multicast	x	
	-request / response applications	x	
	Connection / Connectionless Services	x	
	-ID of communicating partners	x	
	-Establishment of authority comm.	x	
	-Authorization of intended partn.	x	
	-Application Layer Management	x	
6 presentation	-security - encryption		x
	-data compression	source	x
	-character code conversion		x
	-graphics syntax conversion		x
	-presentation layer management		x
5 session	-expedited delivery	x	
	-multiplexing sessions		x
	-resynchronization (checkpointing)	x	
	-dialog control	x	
	-binding	x	
	-quarantine service		x
	-sequencing		x
	-session layer management	x	

perishable data. It is recommended that at least two classes of service be offered at this layer.

The transport layer connections for NOS-to-NOS messages should be established when an NIU is initialized with all other NIUs on the LAN. These connections are to remain in effect as long as the NIU is operational. Other connections

Table 6.4-2: ISO/OSI Functions (Part 2 of 2)

ISO/OSI layer	FUNCTIONS	IOC	GROWTH
4 transport	-connectionless management	x	
	-connection management	x	
	-segmentation / reassembly	x	
	-sequencing	x	
	-blocking / deblocking	x	
	-header error control	x	
	-data multiplexing connections	x	
	-expedited delivery	x	
	-resetting	x	
	-flow control	x	
	-error detection / control	x	
	-address mapping	x	
	-service type conversion	x	
	-transport layer management	x	
3 network	-routing / switching / relaying	x	
	-congestion control	x	
	-packetization /reassembly	x	
	-sequencing		x
	-header error control	x	
	-quality of service maintenance		x
	-expedited delivery	x	
	-error control		x
	-accounting (financial)		x
	-network layer management	x	
2 data link	-framing	x	
	-error control / notification		x
	-media access	x	
	-sequencing		x
	-flow control		x
	-data link layer management	x	
1	determined by medium	x	

are established by tasks and are disconnected when the task terminates. A connection-oriented transport layer provides the essential error control and sequencing and also provides a higher throughput by allowing a connectionless network and data link layer.

The session, presentation and application layers should offer both connection-oriented and connectionless service. The type of service requested at these layers should be the same in all three layers. Connections at these layers should be established for each process-to-process communication and should have a limited lifetime.

The functions provided at IOC, should be those which support connectionless network and data link layers and a connection-oriented transport layer. The higher layers (application, presentation and session) support both connection-oriented and connectionless service. These functions, which are necessary to support a reliable data transfer service, are categorized in Table 6.4-2 as being present at IOC. Other functions can be added as needed beyond IOC. These are categorized in Table 6.4-2 as possible growth items.

In the presentation layer, the syntax negotiations should not be necessary at IOC since common elements (hardware and software) will be utilized wherever possible. As shown in the table this results in a null presention layer for IOC. Data compression and encryption services can also be employed by customer/subsystems requiring such services, but this will not be provided by the data management system as a standard service at IOC. However, these services could be provided for growth.

The application layer functions serve both connection-oriented and connectionless types of data transfers as shown in Table 6.4-2.

6.4.3 NIU Functional Description

As determined by the Onboard Local Area Network Trade Study (Task 3), the NIU should perform the functions corresponding to the physical, data link, network, and transport layers of the ISO/OSI. The functions corresponding to the session, presentation, and application layers of the ISO/OSI model should reside in the host device. The division of layers between the host and NIU are possible because the session-transport interface allows for transparency with minimal impact on NIU performance. The NIU software can be standardized since only common communications services are provided by the NIU. This configuration of the NIU is also functional as a bridge/gateway as it provides for buffering and flow control in the NIU.

When sensors and effectors are attached to the back-end of an NIU, these NIU's only provide a subset of the software services discussed above. For example, only the Class 2 transport layer functions may be provided.

6.4.4 Operating System/Application

The onboard distributed operating system (DOS) will provide the environment enabling customers, operators, and application processes to share the capabilities of the resources connected through the Space Station local area network. The "transparency" of the network will be achieved through a highly reliable and flexible interprocess communication facility and layered communication protocol. In addition to the DOS, each NIU and SDP will run its own traditional operating system to handle such tasks as interrupt handling, task management, etc.

The DOS will be physically divided between network interface units (NIUs), and Subsystem Data Processors (SDPs) in the network. Functions which execute in every NIU or every SDP may be thought of as the actual operating system (OS) component. The remaining functions to be performed by the DOS will reside in certain SDPs and may be thought of as application components of the DOS. This section will describe functions which may be considered as responsibilities of the DOS, Figure 6.4-2 illustrates the division of the DOS between the NIU and SDP, and distinguishes those as functions which form the OS component, and those which comprise the application component. Further, the division of the OS component between NIUs and SDPs will also be discussed.

6.4.4.1 Generic DOS Functions

The list below is a summary of the wide range of functions provided by the DOS. Another important component of the DOS, the layered protocol used for communiation across the network (which is also split between the NIU and SDP), has been described in context with the discussion of local area networks and network interface units (6.4.2, 6.4.3).

1. The management of peripheral resources such as output devices and file systems.

2. The reconfiguration of memory loads when necessary. DOS will provide for automated switching to a cold backup and automated loading of spare computers in the event of primary failure. If fixed memory configurations are utilized, it may be possible to employ an expert system or some other technique to automatically replace lower priority functions with higher priority functions when all processors are being utilized.

3. An efficient interprocess communication facility (IPC) to obtain data or to initiate an interactive session with another process. The syntax and semantics of this facility should make it applicable for communication between processes on a single machine or ones on different machines.

4. A method of delivering frequently requested data. A method other than IPC will be utilized to avoid disturbing the owner of the data and for potentially faster response times. The results of the DOS

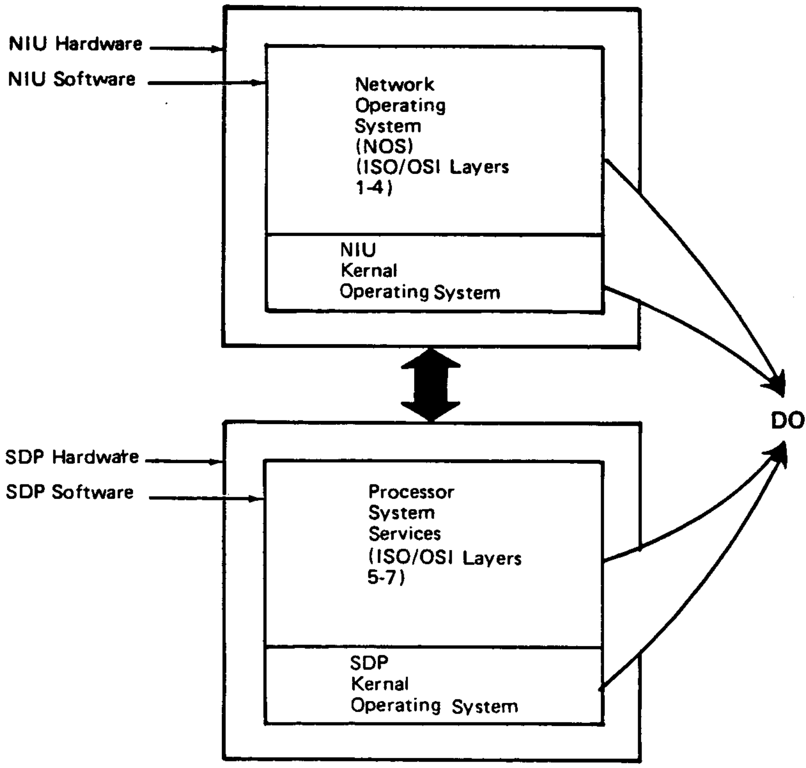


Figure 6.4-2. DOS Division NIU and a SDP

trade study suggest that any of the following techniques may be utilized:

- The owner of the data sends the values to a database, from which the values may be obtained by applications.
- The owner of the data multicasts the values.
- The owner of the data broadcasts the values. The content of the broadcast will be indicated in a special field in the layer 2 header so that every NIU is not forced to read in the packet in order to determine its contents. This scheme is the most questionable of the three.

5. Monitoring the network for performance, trending, and errors.

6. Network reconfiguration – This includes initializing and shutting down NIUs/SDPs and keeping a record of where checkpoint information may be obtained for each SDP. Such a record will be utilized in reinitializing functions of that SDP in a cold backup. Switching to hot backups will be application dependent.

7. Scheduling commands and functions. The need for scheduling often arises in accessing network resources. Such scheduling may be based on classification as emergency, real time, non-real time, background, etc.

8. Verification of commands – determination of whether a command is restricted/constrained (i.e., potentially hazardous to Station or crew, or may interfere with other SS or payload operations) or unrestricted/unconstrained.

9. The implementation of individual functions associated with network communication, including addressing, routing, congestion control, and flow control.

6.4.4.2 The Application Component of the DOS

Several of the functions listed above need not be performed in every NIU or every SDP. Still others require a sufficient amount of available CPU and memory resources such that it is not feasible to perform the function in every NIU or every SDP (e.g., such a function is a name server for determining physical addresses from logical ones). This study has determined that the following functions will be performed in only certain SDPs and therefore should be thought of as application functions of the DOS.

- Command verification and command preprocessing functions.
- All network-wide file management, output device management, and database management will be at the resource providing the service or if the device is unintelligent, management will be assigned to a designated SDP selected to manage that resource.
- Global monitoring functions for the purpose of assessing global network performance, trending, and error logging.
- Network reconfiguration: i.e, warn an operator to shut down an NIU, and to actually shut down and reactivate NIUs once such commands are given by the operator. This function will also provide the means by which a processor (NIU or SDP) may be initialized with a memory load.

6.4.4.3 The Distributed OS Components of the DOS

The functions listed below for the component of the DOS which is present in every NIU and SDP. The portion which is resident in the NIU is defined as the Network Operating System or NOS. That portion which is resident in the SDP will be an interface between the traditional operating system running in the SDP and the NOS. The functions are listed in their probable sequence of execution.

SDP resident portion of the DOS:

- The SDP will contain a set of commands for use by applications in specifying requests for data, sensor values, variables, communication with another process, etc. Such a command may be GET_SENSOR_VALUE_(SENSOR), for example.

- The interprocess communication mechanism. Once a command such as GET-SENSOR-VALUE is issued by the application, the SDP resident portion of the DOS determines whether the sensor is local or remote, and if remote, issues a message containing a request for the reading of the sensor.

- The decision of whether to use broadcast, multicast, or point-to-point IPC to deliver the message is made at this point. Such a decision will be based on the needs of the application sending the message.

- Other Layer 7-5 functions of the ISO/OSI protocol are executed as needed.

- At layer 6 (presentation), negotiations between the sender and receiver will determine if any protocol conversions are required. Our recommendation is that this layer should be null for IOC due to the use of homogeneous protocols.

- Certain layer 5 (session) functions are then performed including segmentation of a long message into pieces that the NIU can handle, if necessary. Similarly, reassembly is done on incoming segments. An SDP header containing at least the following information is then attached to the message (or segment):

  - The segment number of the current transmission.

  - Source process (physical ID) and destination process, sensor, effector, etc. (logical ID)

  - Indication of whether point-to-point, broadcast, or multicast service is to be used.

Note that this header which is passed to the NIU will be reformatted by the layer 4 protocol of the NIU. For example, all logical addresses will be replaced with physical addresses.

NIU Resident Portion of the DOS:

- Once a message or segment is received from the host, the layer 4 functions are performed. The most important of these is determining a physical address for the logical destination address. The operating system trade study determined that a "cache" of frequently requested addresses will be maintained, with all other addresses being obtained from the centralized name server. A request for the address will be broadcast if the name server is unavailable. Since connection service is to be used at layer 4, flow control will be achieved through the credit window scheme. The destination NIU is contacted to determine the length and rate of transmission which can be accepted.

- Layer 3 functions will then be executed, including determining routing for any internetwork messages. If routing tables are not maintained as every NIU (left as a TBD design decision), all internetwork messages will be sent to a designated bridge of the LAN where the message originates. The bridge's routing table will be utilized to forward the packet on its way to the destination.

  Segments will be divided into packets and transmitted through the network using the layer 2 and layer 1 protocols. Variable length packets will be utilized to make maximum use of available bandwidth. Connectionless service is used at this level.

  The NOS software in the NIU will also have the following capabilities:

- The ability to broadcast, multicast, or send point-to-point messages.

- The ability to place connected SDPs on or off-line when commanded to do so.

- The ability to monitor the NIU in terms of logging transactions and detecting errors.

- The ability to place the NIU on or off-line when commanded to do so.

6.4.5 Subsystem Data Processor

The Phase B RFP identifies the need for a standard Subsystem Data Processor (SDP). This study concluded that this level of commonality is appropriate for IOC but should not preclude future options to support growth and technology insertion. However, any new technology processor brought into the program should strongly consider maintaining the same instruction set architecture (ISA) to maximize software recovery/transportability. To support the expected storage, computation capability and data transfer rates the IOC SDP is characterized as follows:

- Main Memory: 4 megabytes
- Computational Speed: 2000 KOPS
- DMA Channel Speed: 1MHZ, 16 bit parallel

These requirements were established based on subsystem sizing estimates (with a sizable margin for growth) and an evaluation of what the technology should support at the time (1988) SDP technology will be selected.

6.4.6 Onboard Workstations

The Phase B Reference Configuration indicates three basic types of operator interfaces to distributed workstations. They are:

- Operations Center in HAB Module 2
- Multi Purpose Applications Consoles (MPACs)
- Portable MPACs

Our view of the MPAC characteristics is the same as the Reference Configuration. They are:

- Easy to use (keyboard, displays, etc.)
- Lightweight, power efficient
- Standard interface (100% interchangeable)
- Configurable by operator

Functionally, the MPAC hardware and software should provide the following capabilities:

- Access to and interaction with the onboard data base.
- Load and run selected application programs (initiated by operator actions) that are executed infrequently, thereby reducing SDP loads and possibly network loads. This could leave the SDPs to execute mostly cyclic programs.
- Common interface for core and payload operators.
- Commonality with ground operator interfaces, which simplifies training for inflight operations.
- Ability to define (through the use of a standard User Interface Language (UIL)) and execute ad-hoc operations on data contained in the onboard or ground data bases. This would include the generation of displays for trend analysis, subsystem monitoring, etc.

Finally, the possibility of having the same processor in the SDP, the Operations Center (in HAB2) and MPAC should be studied to significantly reduce costs, maintenance and training.

6.4.7 Operational Data Base

6.4.7.1 Onboard Operational Data Base Management System (ODBMS)

Current estimates of the onboard ODBMS Storage Requirements for IOC are as follows:

1) The DMS must provide the capability for approximately 256 Mbytes of non-volatile storage for the core subsystems based on the following:

90 Mbytes	application program loads
10 Mbytes	checkpoints
10 Mbytes	engineering data
10 Mbytes	procedures
10 Mbytes	schedules
50 Mbytes	telemetry data acquisition
76 Mbytes	margin

2) Storage requirements for the payload ODBMS are not as easily estimated. For this report we are assuming that the payload ODBMS storage requirements are the same as those for the core ODBMS (256 Mbytes). As payload requirements are better understood this estimate will be refined.

The ODBMS which provides this storage can be structured as presented in Figure 6.4-3. Separate ODMBS services exists in the Core Local Area Network (CLAN) and the Payload Local Area Network (PLAN). These ODBMS's are homogeneous and communicate to support ancillary data distribution, and other standard core services.

The data acquisition interface to the ODBMS is presented in Figure 6.4-4. The subsystems collect data into records and deliver these records to the ODBMS on a dynamically negotiated basis. (More details are given in the Data Base Management trade study, Section 1.5.2.1.) The ODBMS supports Telemetry Traffic Control (TTC) in building Telemetry Buffer Units (TBU's) for delivery to the communication toggle buffers. The same interface exists for PL/EXP except the PL/EXP delivers data in the CCSDS telemetry packet format. The TTC segments these packets (if necessary) when building the TBU's.

For the build-up of the onboard mass storage configuration it is recommended

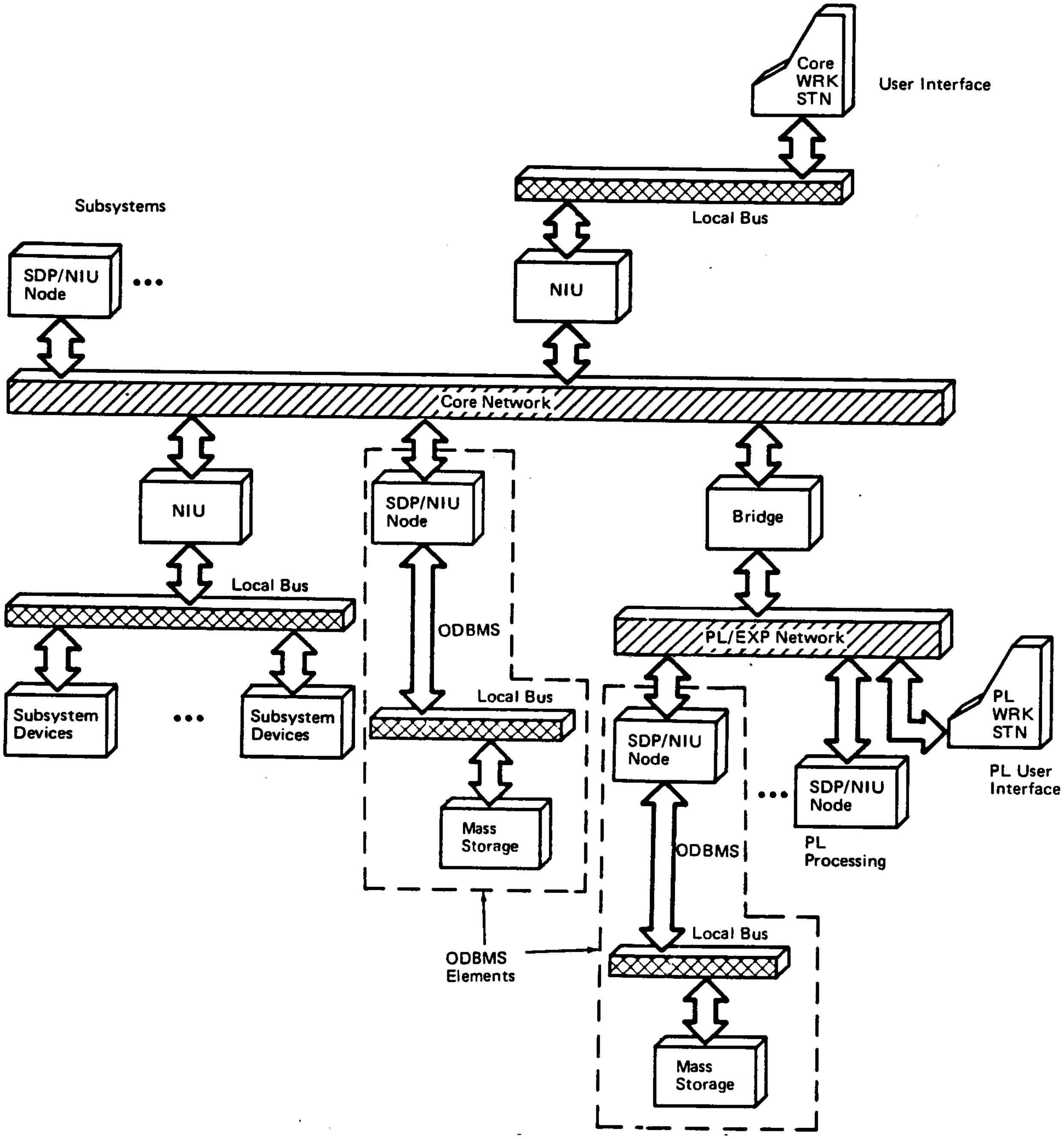


Figure 6.4-3. Onboard Data Base Management System Interfaces

that the scenario presented in Figure 6.4-5 be used. In this configuration the SDP/NIU nodes manage local non-volatile memory for the first two flights and then mass storage units are delivered in the first pressurized module (HM1). The mass storage units are distributed into the pressurized modules.

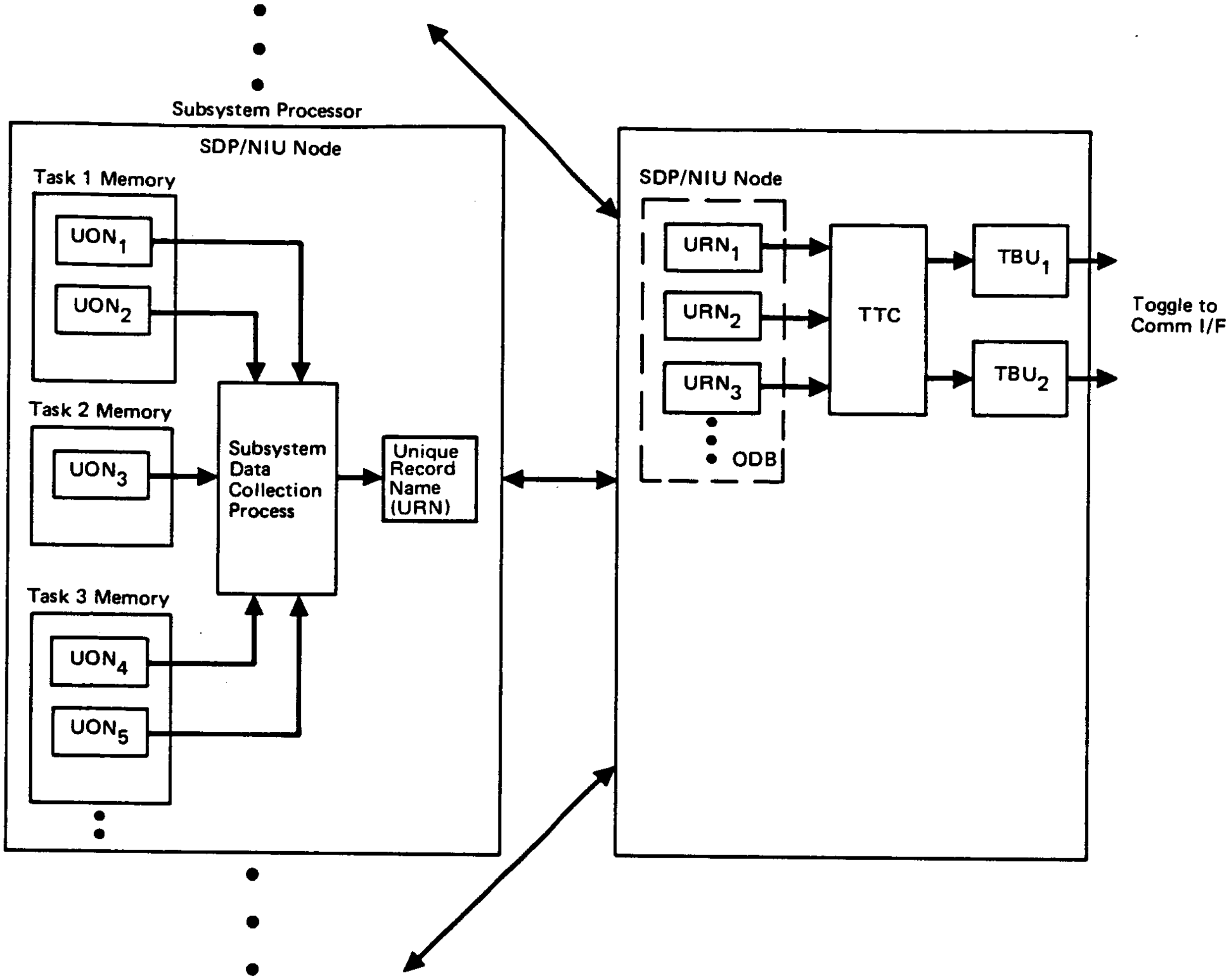
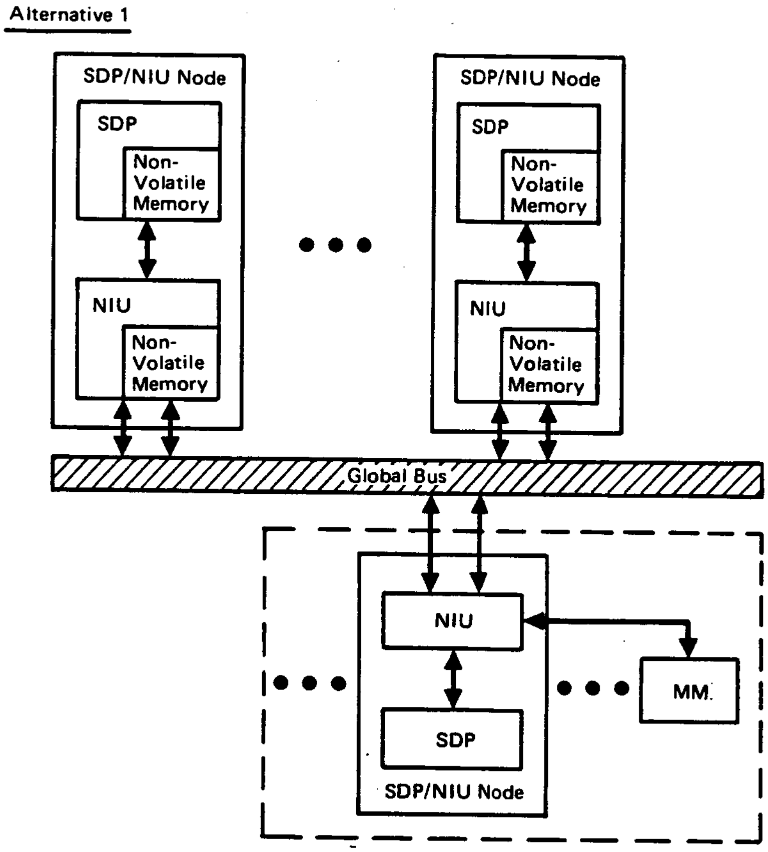


Figure 6.4-4. TTC Interface

The recommended mass storage integration with other Onboard SSDS elements is presented in Figure 6.4-6. In this configuration the mass storage is on a standard local bus (serial or parallel to be determined) on the backend of an NIU.

6.4.7.2 Mass Storage Devices

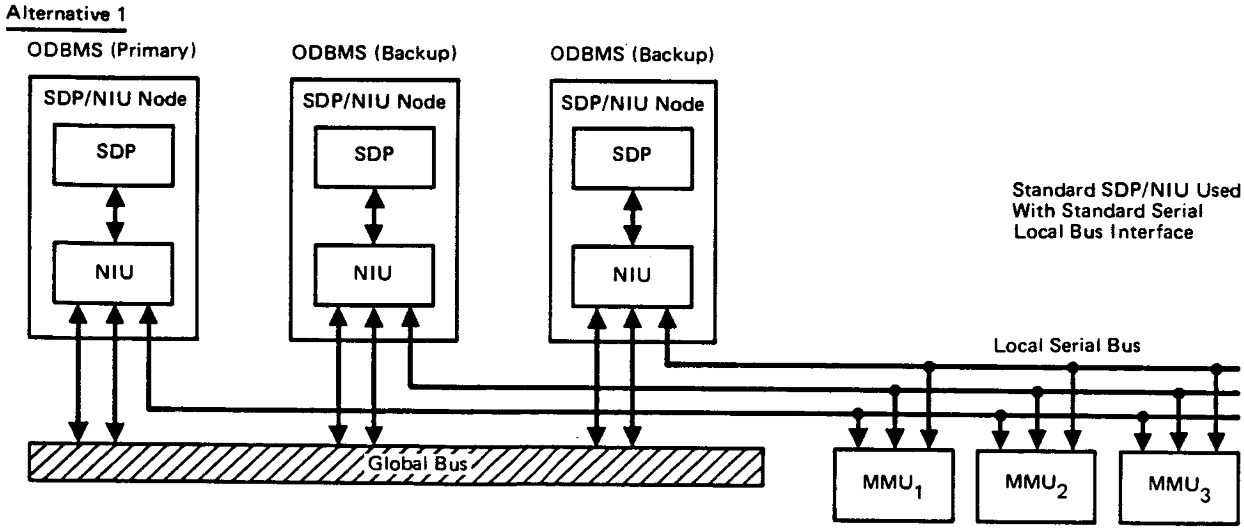
The SSDS will have many applications that will use many different kinds of mass storage devices. The three most driving onboard space station application areas are:



Local SDP/NIU Non-Volatile Memory For First Flights (Recovery of Non-Volatile Memory By Transfer From Redundant Elements or Ground)

Added on Later Flight in Pressurized Module

Figure 6.4-5. ODBMS Flight Build-Up



Standard SDP/NIU Used With Standard Serial Local Bus Interface

Figure 6.4-6. ODBMS Mass Memory Integration

1. Onboard Data Base Management System (ODBMS) mass store.
2. High rate data buffer.
3. Payload Local Area Network (PLAN) communication data buffer.

The requirements and design characteristics for these applications were developed through mission set analysis, simulations, function set analysis, and engineering design judgement. The derived requirements and design characteristics for each of the above applications are:

1. DBMS MASS STORE
   2×10^9 BITS CAPACITY
   10 Mbit/second transfer rate
   40 millisecond access time

2. HIGH RATE DATA BUFFER
   2×10^{11} bits capacity
   300 Mbits/second in
   600 Mbits/second out (assuming two KSA links)

3. PLAN COMMUNICATION DATA BUFFER
   12×10^9 bits capacity
   10 Mbits/second transfer rate

The recommended mass storage option for all of the above application areas is eraseable optical disk if the technology can be developed and demonstrated by IOC. This recommendation is based on the desire for hardware commonality across all onboard mass storage applications. The driving requirement is the high rate data buffer where the optional disk offers random access capability (eliminate's need for subsequent bit/packet reversal), enhances buffer design flexibility and provides significant capacity for growth.

If eraseable optical disk cannot be developed as recommended for IOC then magnetic disk (Winchester Technology) should be used for the ODBMS mass store, and magnetic tape for the buffers. Regardless of the technology used for the IOC configuration, eraseable optical disk should be developed for use in the growth Space Station.

The Function Data Base contains sizing estimates for secondary storage and archival storage. These are yet to be evaluated in detail and will be included in a future update to this report.

6.4.8 Communication Gateway

The "communication gateway" is a term that is associated with the functions performed to receive and deliver messages into and out-of the onboard local area networks. These functions are actually distributed into three DMS functions; data acquisition (DATA ACQ), Telemetry Traffic Control (TTC), and Telecommand Interface (TLMCMD I/F), and also functions in the Communication Subsystem. The interface is depicted schematically in Figure 6.4-7. The DMS functions are performed in the SDP's attached to the local area networks and also mass storage devices managed by the DMS. The Communication Subsystem functions are performed by a baseband processor (possibly an SDP), mass storage, toggle buffers and RF processors.

The DATA ACQ function collects data from subsystems or PL's on a periodic or aperiodic basis, as required, in support of the return link. This is done in cooperation with the ODMBS. The TTC function assembles segments of this data into Telemetry Buffer Units (TBU's) along with return link telecommands or telecommand acknowledgements. These TBU's are transmitted to the communication subsystem for the real-time return link (SSA). The TLMCMD I/F function disassembles forward link TBU's.

The TLMCMD I/F uses the addressed provided in segments of the forward link TBU's to deliver data and commands to core and PL local area networks.

6.4.9 TRAFFIC ANALYSIS

The following two sections derived the network traffic requirements and the network packet sizing. The requirements are presented in terms of messages per second, a more meaningful traffic parameter than bytes per second.

6.4.9.1 TRAFFIC SIZING

Analysis of the network traffic model (both core and payload networks) shows the communication and tracking NIU receives over 70% of the total traffic for both the core and payload networks.

The network traffic model was derived from the McDonnell Douglas Requirements Data Base (Appendix-1) using an analysis tool developed in PL/I. The tool allows functions in the Requirements Data Base to be arbitrarily distributed across a multi-computer environment. The process allows the operator to interactively specify, for example:

Computer 1	Computer 2	Computer N-1	Computer N
Function #	Function #	External 1	External 3
1.1.1	2.1.1	External 2	
1.1.2	4.3.1		

From this input, a search of the data base is made to determine the following reports:

- Computer 1 to/from Computer 2
- Computer 1 and 2 to External Sets 1 and 2
- Computer 1 and 2 to External Set 3

Proper selection of the inputs, functions and externals, resulted in statistical reports to evaluate the I/O requirements. From these inputs the following statistics were determined:

- Subsystem to subsystem I/O
- Subsystem to subsystem sensors/effectors
- Subsystem to operational data base, ancillary data
- Subsystem to displays
- Subsystem to Comm for telemetry, operations instrumentation data

The network traffic model was developed from several sources:

(1) Analyses of Functions Data Base I/O Relationships
(2) Engineering Modifications to (1) Above
(3) Engineering Judgement

Additions to the Network Traffic Model included:

(1) Telemetry Data
(2) Operations Instrumentation Data
(3) Ancillary Data
(4) Ground Forward Commands

Table 6.4.9.1-1 identifies specific assumptions employed in the network traffic analysis. Figure 6.4.9.1-1 and 6.4.9.1-2 show the processing distribution for both the core and payload networks. Figure 6.4.9.1-3 shows a detailed payload distribution for the payload network. The illustrated payload attachments were arbitrarily made and are not important to the network traffic load. Only low data rate traffic under 1 MBPS was considered in the payload traffic model. Payload traffic with data rates greater than 1 MBPS is hardwired to the C&T subsystem.

TABLE 6.4.9.1-1 NETWORK I/O TRAFFIC ASSUMPTIONS

o Requirements Sources
  - Mission data sets for P/L telemetry rates (includes only P/L instruments with data rates less than 1 MBPS)
  - Analysis of core traffic results and engineering judgement to model remaining non-telemetry payload network traffic nodes.
  - Assume all P/Ls run simultaneously (some have duty cycles less than 24 hours/day)

o Topology
  - Integrated P/L instrument data access off backend of SDPs
  - Files/Data stores in each Subsystem SDP
  - DMS ODB has it's own SDP
  - P/L files/data stores in P/L SDPs
  - P/L data base in P/L network

TABLE 6.4.9.1-1 (CONTINUED)

- Packet/Message Length
  - Message length equals packet length

- Telemetry
  - 25 KBytes/sec per Subsystem
  - 1 KByte Message size to satisfy Consultative Committee for Space Data Systems (CCSDS) efficiency
  - Telemetry messages sent from P/L network to C&T node

- Displays
  - Multiple panels possible per Subsystem per MPAC
  - Four Windows per MPAC possible
  - One 2 KByte message/sec per Subsystem to MPAC

- Overhead
  - OSI/CCSDS message overhead not included

- Ancillary Data (AD)
  - Subsystems send AD to DMS ODB
  - DMS ODB blocks AD and sends to P/L Network ODB
  - P/L's read AD from P/L ODB as required

- Ground Forward Commands (GFC)
  - Comm receives GFC for each subsystem
  - Comm routes GFC to individual Subsystems
    - Dependent on CMD VAL implementation
  - P/L GFC are routed to P/L network for response
  - 0.1 message/sec per subsystem

- Operations Instrumentation Data (OID)
  - OID collected by each subsystem from backend
  - Subsystems send blocked OID to COMM for downlink

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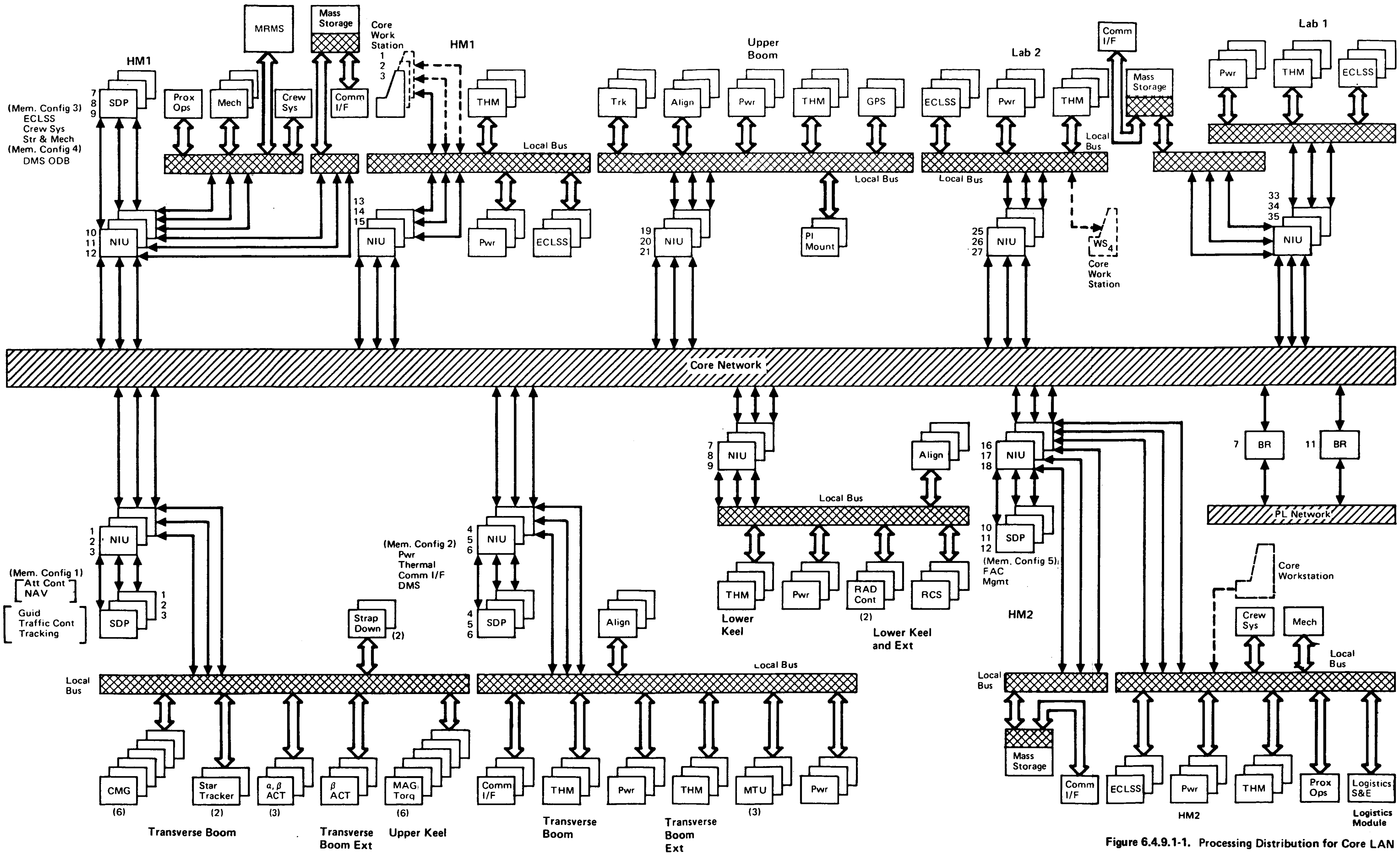


Figure 6.4.9.1-1. Processing Distribution for Core LAN

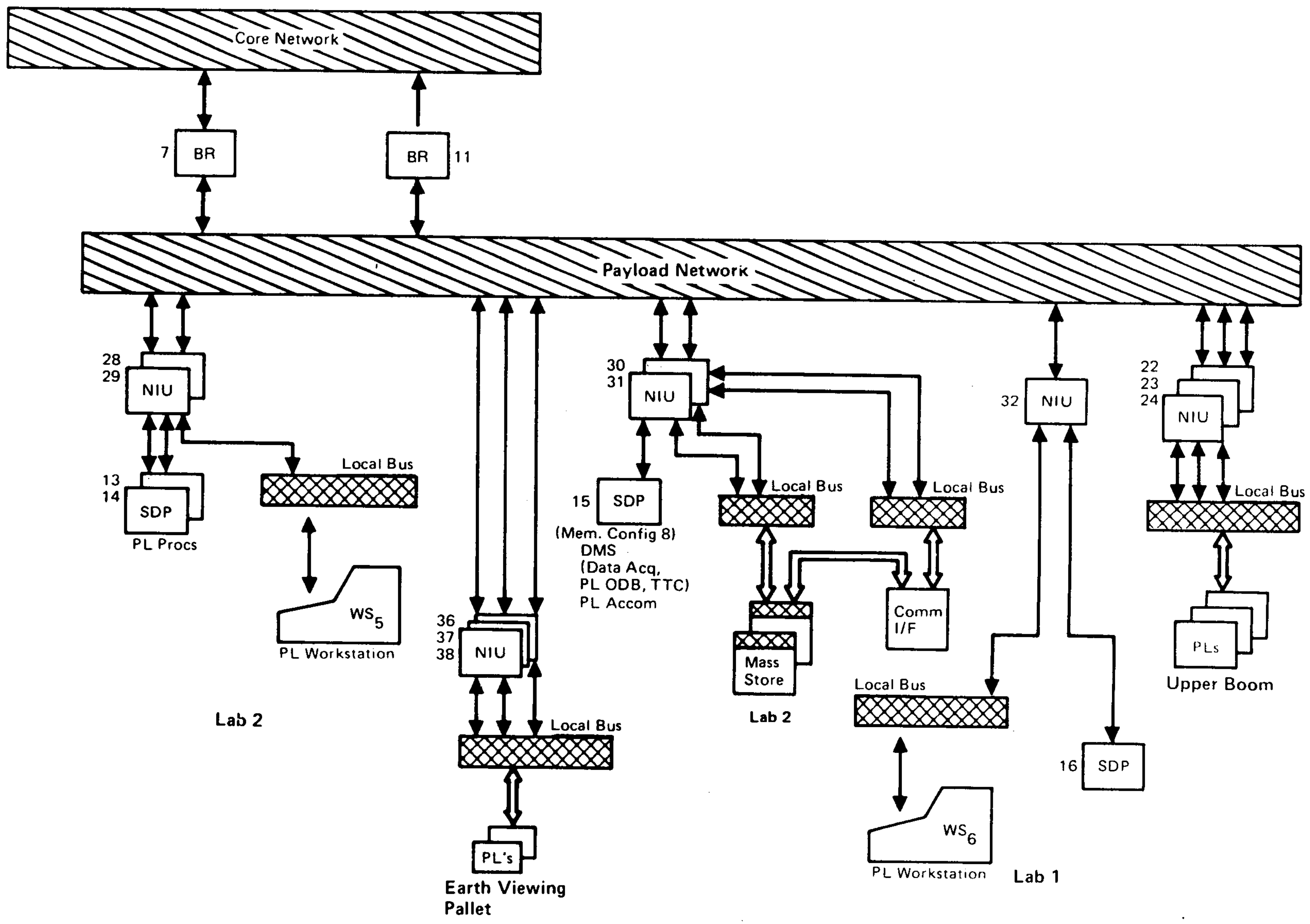


Figure 6.4.9.1-2. Processing Distribution for Payload/Ewperiment LAN

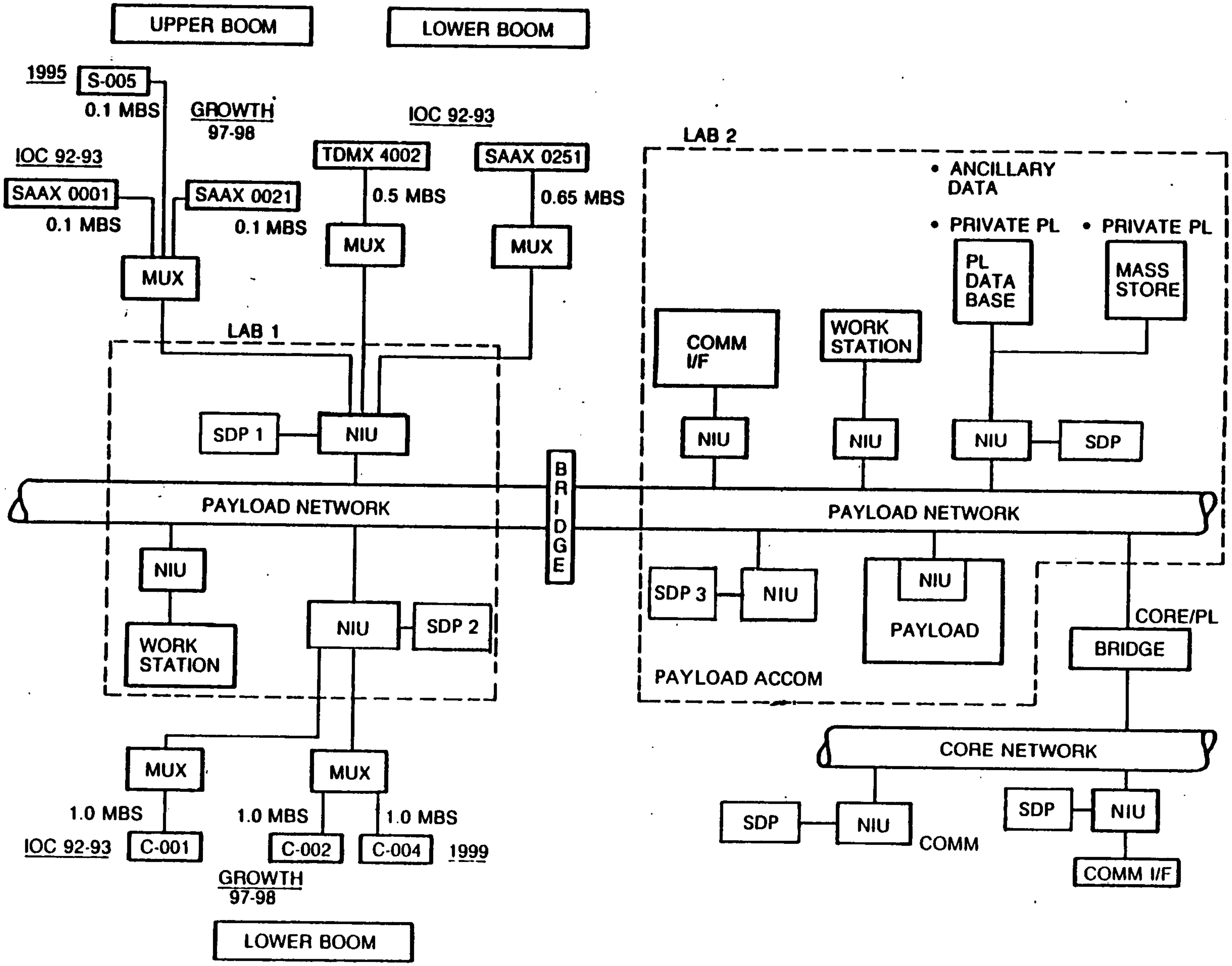


Figure 6.4.9.1-3. Typical Connectivity of Low Rate Payload Experiments

Table 6.4.9.1-2 and 6.4.9.1-3 show the network traffic results for the core and payload networks, respectively. These tables show for the core network the traffic due to telemetry is approximately 60% of the total load and the elemetry traffic on the payload network is over 80% of the total traffic load.

6.4.9.2 PACKET SIZING

A 2048 byte packet has been selected as the baseline packet size for network trades, analyses and design tasks. The MDAC function data base was accessed to identify potential network messages. These were screened to identify those which enter the network. Figure 6.4.9.2-1 shows that the majority of the messages entering the network are telemetry messages whose length is less than 2048 bytes. Figure 6.4.9.2-2 shows that a 2048 byte packet can accommodate 95% of all network messages without segmenting messages.

Table 6.4.9.1-2. Core Network I/O Traffic Model

DESTINATIONS (MESSAGES/SEC)

SOURCES			SUBSYSTEM SDP'S								SUBSYSTEM SENSORS/EFFECTORS					DISPLAYS	TOTALS *
			GN&C	POWER/COMM/THERM			ECLS CREW STR&M	DMS/ODB		FAC MGMT	GN&C	POWER COMM THERM	ECLS CREW STR&M	DMS	FAC MGMT		
				I/O	TELEM	OI		I/O	ANCILL								
SDP	GN&C		*23.8	4.3	28.0	2.0	1.0	2.0	2.0	3.0	9.0					2.0	53.3
	POWER COMM THERM	I/O	1.1	*25.0	72.0	3.0		3.0	3.0	3.0		2.0				3.1	90.1
		GND CMMDS	0.2	0.3		0.1	0.3	0.1		0.1							1.1
	ECLS/CREW/STR&M		0.3		72.0	3.0	*66.0	6.0	3.0	2.5			7.0			4.0	97.8
	DMS/ODB		1.0	0.1	24.0			*2.0	1.0	4.0				0.1		1.0	31.2
	FAC MGMT		0.2	3.1	24.0		1.2	3.1	1.0	*33.0					0.5	2.7	35.7
SENS/EFF	GN&C		11.0														11.0
	POWER/COMM/THERM			22.2													22.2
	ECLS/CREW/STR&M						36.0										36.0
	DMS																0.0
	FAC MGMT																0.0
DISPLAYS			0.2	0.3			0.4	0.1		0.2							1.2
TOTALS *			13.9	30.3	220.0	8.1	38.9	14.3	10.0	12.8	9.0	2.0	7.0	0.1	0.5	12.7	379.6

* INTRASUBSYSTEM, LOCAL BUS I/O TRAFFIC NOT INCLUDED IN GLOBAL NETWORK TOTALS

Table 6.4.9.1-2. Core Network I/O Traffic Model (Continued)

PAYLOAD NETWORK TRAFFIC

SOURCES			DESTINATIONS (MESSAGES/SEC)										TOTALS
			SDP'S					OTHER NIU'S					
			SDP 1	SDP 2	PAYLOAD ACCOM	DATA BASE		COMM TELEM	CORE/PL BRIDGE		MASS STORE	MESSAGE PER DISPLAY	
						I/O	ANCILL		FAC MGT	GRD CMD			
SDP	NO. 1 (TLM=1.25 MBPS + 1%)		-	0.0	1.0	2.0	1.0	145.0	1.0	0.01	0.1	4.0	154.1
	NO. 2 (TLM=1.00 MBPS + 1%)		0.0	-	1.0	2.0	1.0	117.0	1.0	0.01	0.1	4.0	126.1
	PAYLOAD ACCOMODATIONS		2.0	2.0	-	1.0	1.0	2.0	1.0	0.01	0.1	2.0	11.1
	DATA BASE	I/O	2.0	2.0	1.0	-	0.0	0.01	1.0	0.01	0.1	1.0	7.1
		ANCILLARY	1.0	1.0	1.0	1.0	-	1.0	0.0	0.01	0.0	1.0	6.0
OTHER NIU	COMM TELEMETRY		0.0	0.0	0.0	0.0	0.0	-	0.0	0.0	0.0	0.0	0.0
	BRIDGE	OMS (FAC MGMT)	1.0	1.0	1.0	1.0	1.0	0.0	-	0.0	0.1	0.0001	5.1
		GROUND COMMDS	0.2	0.2	0.2	0.2	0.0	0.0	0.0	-	0.2	1.0	2.0
	MASS STORE		0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1	-	0.1	0.7
	WORKSTATION		0.2	0.2	0.2	0.2	0.2	-	0.2	0.1	0.2	-	1.5
TOTALS			6.5	6.5	5.5	7.5	4.2	265.0	4.3	0.3	0.9	13.1	313.8

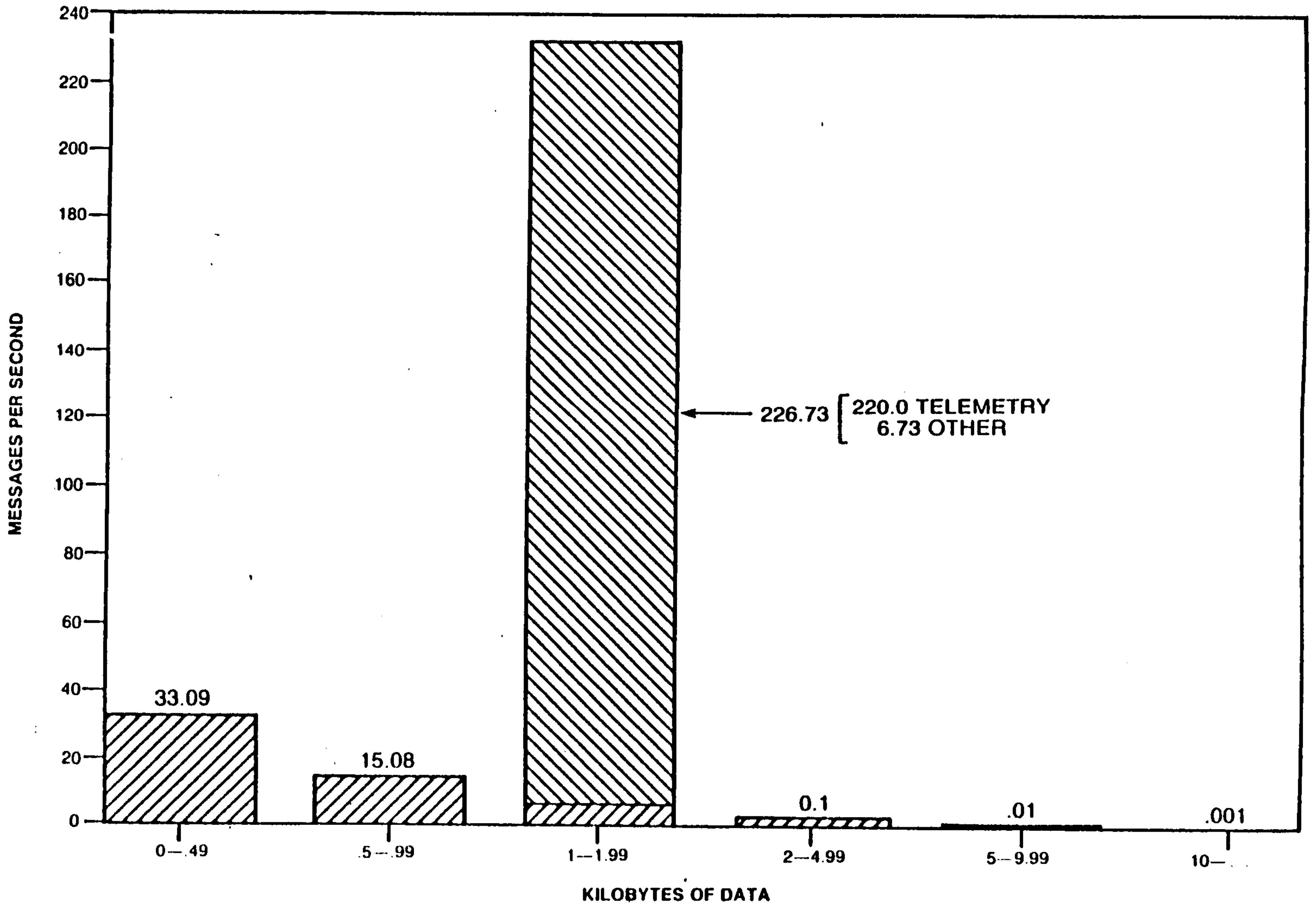


Figure 6.4.9.2-1. Number of Telemetry Messages Vs Total

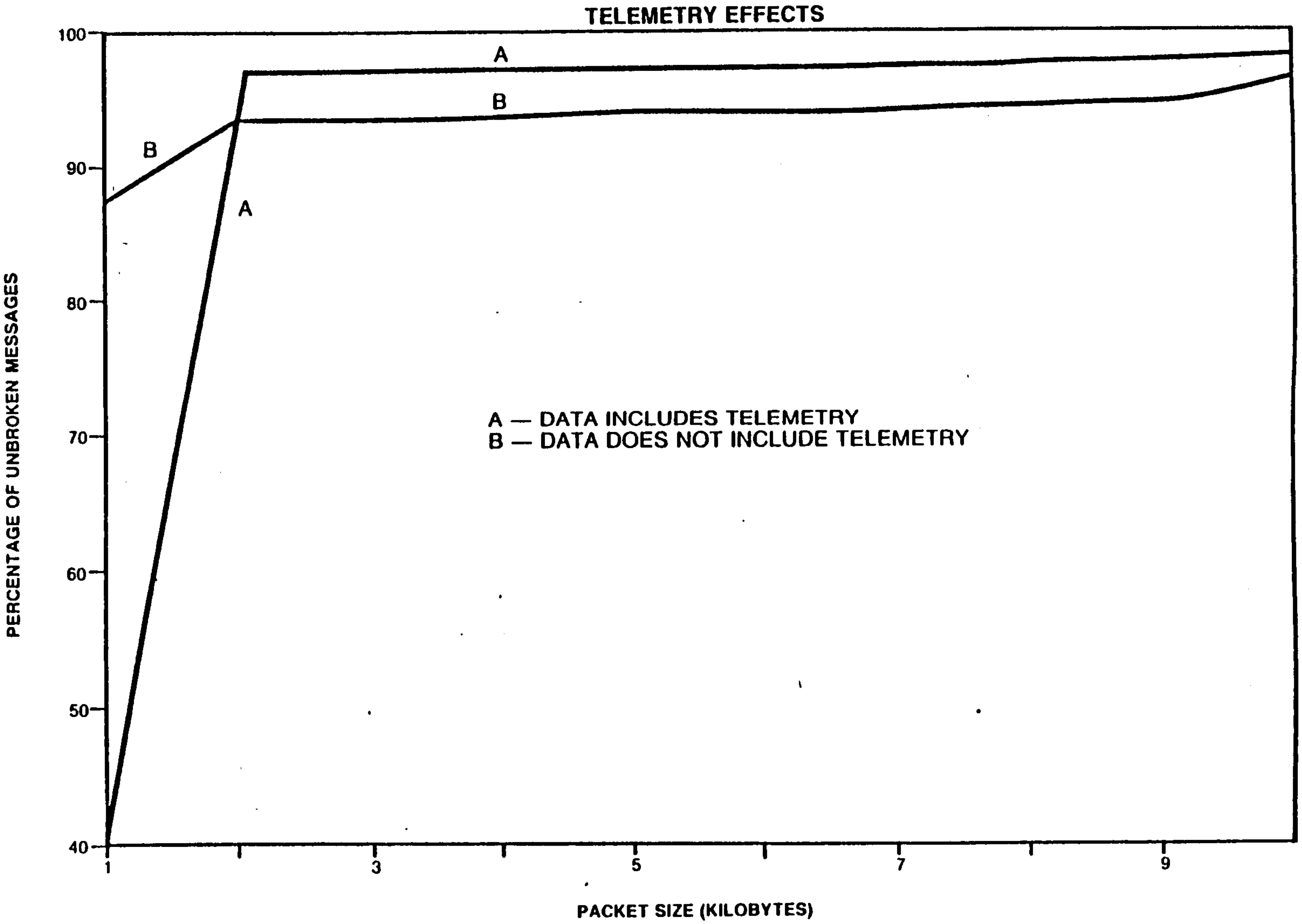


Figure 6.4.9.2-2. Percent Total Message Vs Packet Size

6.4.10 Fault Tolerance

The explicit fault tolerance requirement in the Phase B RFP is that "critical subsystems" be fail-operational, fail-safe, restorable (FO/FS/R). The final FO/FS/R decisions of which subsystems or their functions are critical has not been made. The Phase B SE&I NASA/Contractor teams will study this issue. At this stage, the SSDS A/A team believes the following functional areas are the most critical:

- Docking/Berthing Operations
- Proximity Operations (NSTS, COP, Free-flyers, OTV, OMV)

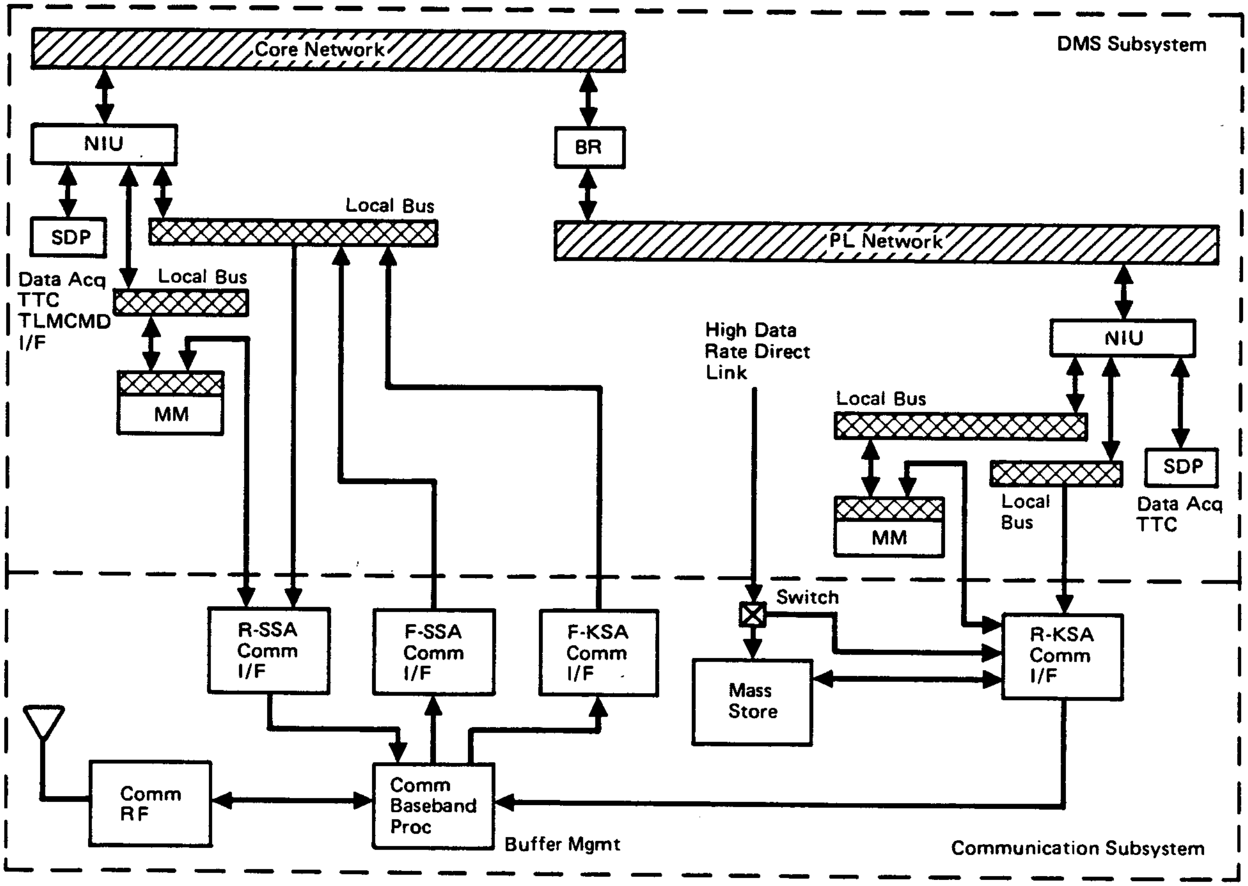


Figure 6.4-7. Communication Gateway

- Transfers of Particular Fuels (e.g., OTV fueling)

A key point is that it is unlikely that any subsystem must be FO/FS/R with no interruptions in functionality at all times. If this were really true, the only solution is triple (or higher) redundant simultaneous execution. Shuttle experience has shown that assigning redundant computers has a large impact on the system design and verification is extremely costly. This should be avoided for Space Station.

The Space Station environment on orbit is much more benign than the atmospheric flight phases of Shuttle. The key to the solution is the restoration time. It seems reasonable that a design which allows the loss of a few seconds during recovery is acceptable for most subsystems if not all.

The Fault Tolerance option development and Trade Study documentation provides more supporting detail and analysis on this subject. The presentation of this work is primarily in the form of what could be done to handle various levels of subsystem availability and fault recovery time. The remaining sections below summarize the four basic areas of fault tolerance:

- Replication
- Fault Detection
- Damage Assessment
- Error Recovery

6.4.10.1 Replication

Several functions may have the need for a very high probability of detection of faults, with enough time to allow recovery by use of a checkpoint restart. The recommendation is that such functions be designed for duplex operation in critical time phases with at least one spare SDP. The system configuration is such that the preferred spare is the SDP in the same triad with the primary SDP. Reference Figure 6.6-1 for the overall architecture that indicates the SDP triads. However, the network is connected such that any other SDP can assume the processing task by communications over the network instead of more directly through an SDP/NIU set. While this connection exceeds FO/FS/R requirements, there is a substantial improvement in overall reliability, especially in man-tended operations when no one is onboard to replace failed SDPs within a few hours or days of the failure. The operating system will be designed so that the application is unaffected by the location of the SDP (other than time delays for network communications).

Subsystems which have no need for very high probability of detecting a fault will execute in simplex. This mode has the important advantage of minimizing Space Station resources for power and cooling.

6.4.10.2 Fault Detection

The recommended fault detection is based on separating the "system" function of detecting a faulty unit (SDP, NIU, network) from the subsystem function of detecting its own processing faults. The first part of fault detection is the use of common hardware fault detection techniques such as built-in test equipment (BITE), parity types of detection (including cyclic redundancy checks, error correction coding, and other multiple bit protection), and watchdog timers at major hardware interfaces. The recommended second part of fault detection is a background or periodic self-test program execution, which tests as much of the unit (SDP, NIU, or network) as possible without interference with any application or operating system function. This combination is usually able to detect solid faults with probabilities of about 95 percent. The recommended third part of fault detection is the inclusion in the operating system of a periodic monitor which talks with each SDP and NIU to assure basic stopped/running status. It is recommended that this monitor function execute in the duplex operation mode.

The recommended fourth part of fault detection requires the help of application programs executing in duplex or higher redundancies to achieve fault detection much above the 95 percent level, and detection of transient faults. Presumably, these applications have been designed to cross compare sensor inputs and computed results as part of the applications' own fault detection. A method will be provided for the application to alert the operating system of failure to compare, especially persistent miscompares, including the option to request termination of the application followed by a reload from mass storage and resumption from a checkpoint. (Note that the effectiveness of this fourth part depends on the maturity and thoroughness of testing of the applications. Use is expected to be restricted to the more critical core functions.)

6.4.10.3 Damage Assessment

A two part approach is recommended for damage assessment. The intent is both to determine which of a duplex pair is faulty (if this is not immediately obvious) and to isolate the faulty component adequately for repair and maintenance activities. Many faults must be assessed immediately in-place in order to minimize the number of very expensive problems which cannot be recreated on a test bench. The first part of the assessment is to record any unusual conditions (such as input/output errors, BITE detected errors, or machine-check indications). These conditions are routinely recorded as part of the operating system functions. The second part of the assessment is to immediately execute a complete self-test of any suspect unit and to record the results. Unless the unit is totally bad (e.g., loss of a power supply), the self-test can often both confirm which unit is faulty and isolate which orbit replaceable unit (ORU) needs to be exchanged to restore the unit to operational status as a spare.

6.4.10.4 Error Recovery

The recommended approach to error recovery is to have each application generate any checkpoints which are required for timely resumption following a failure. Specification of specific data content and checkpoint intervals will be a part of the detail design of each application, and is beyond the scope of the current study. However, the operating system will provide the basic capability to write and recall checkpoints up to some redundancy level (for example, keep only the last 5 checkpoints), and to detect the important case of a checkpoint which was incomplete because the failure occurred in the middle of writing. Verification of the contents of the checkpoint is the responsibility of each application program, beyond the usual checksum or cyclic redundancy check provided by the operating system or storage medium.

6.4.11 Time Management

The four topics of time management in the onboard data management system are: time reference source; time distribution; time tagging of data; and frequency distribution. Reference the Time Management Option Development report for more background detail.

6.4.11.1 Onboard Reference Source

Both the global positioning system (GPS) and a master timing unit (MTU) are recommended as the time reference sources. The local oscillators of each NIU and SDP are available as emergency references if both the GPS and MTU become unavailable (which exceeds the FO/FS/R requirement). The order of precedence is the GPS, the MTU, and the local oscillators. The primary reason for both the GPS and the MTU is the lack of GPS during early buildup.

6.4.11.2 Time Distribution

The recommended method of time distribution throughout the DMS is via the network. The three steps are: equalize the time in the NIU attached to the reference source (GPS or MTU) to match the reference source; distribute time from this NIU to all other NIUs in the network; equalize time in each SDP to the time in its attached NIU. Details of the method are described in the options development report on time management. The expectation is a time skew within the network of less than one millisecond, and probably less than 0.1 milliseconds. The process will be repeated every one to ten seconds to prevent short term drifts at any NIU or SDP from becoming excessive.

6.4.11.3 Time Tagging of Data

Two forms of time must be provided. One form is continuous, with no discontinuties at points such as end of day, end of year, or leap seconds. This time form is the international time (TAI) recommended by CCSDS for ephemeris time. The other form includes leap second corrections for the slowing rotation of the earth. The continuous form will be Earth Mean Equator 1950 (EME-50). The discontinuous form will be Universal Coordinated Time (UTC).

Standard time formats will be used for communication. Selection of specific standard formats is not a key design driver at this point in the project.

6.4.11.4 Frequency Distribution

Both the GPS and MTU provide precision frequency sources. The recommendation is to use the MTU as the frequency reference source, since the MTU is available throughout buildup. Frequency distribution will be by direct wiring to each required user. The communications subsystem is expected to be the prime user.

6.5 Operational Scenarios

6.5.1 Initialization

The onboard data management system will need to be intialized on orbit when the first structures are in place, during buildup and operation if an upgrade requires removing power from existing modules, and as the recovery mode from major loss of power. The source of software programs is assumed to be one or more mass storage devices onboard the Space Station, and accessible through the core LAN. These mass storage devices are initially loaded on the ground, with subsequent modifications by uplink data (either by onboard requests or ground initiated updates) or by replacement at a resupply cycle. This section describes an approach to the "cold start" of the entire data system. Initialization of individual subsystems during build-up, upgrades, and failure recovery is a subset of these procedures.

This description assumes that the various units (SDPs, NIUs) may be turned on in any order. Further, each SDP and NIU is assumed to have a non-volatile memory (ROM) that contains the minimal program necessary to load (boot) the operating system into the SDP or NIU through the network. This initial program load (IPL) ROM is forced to execute when power is first applied to the unit, either by direct execution or by first copying the IPL program from the ROM into main memory.

The general procedure has three phases. First, each NIU attached to a load source (mass storage) recognizes this function by its physical identification, and uses its direct attachment to load itself with the network operating system (NOS) and a the full set of mass storage control programs. Second, the other NIUs are loaded with the NOS through use of the mass storage on the LAN. Third, the SDPs are loaded using the NOS contained in their attached NIUs. At this point the crew or ground will have basic communication with the data system to control subsystem initialization either by predefined tables or by manual overrides of these tables.

6.5.1.1 NIU Attached to Mass Storage

The ROM in all NIUs will be the same. When this ROM is given control at power application, the program will use the physical identification of the NIU to determine whether this NIU is attached to a mass storage, and follow this procedure or the one in the next section.

The NIU will first access a predefined location on the mass storage to read the directory of the contents of the mass storage. The directory will next be searched for the name of the entry for the network operating system (NOS). If no such entry is found, then this NIU is not really a load source, and will revert to the procedures of the next section. The directory entry will identify key items for loading the program into the NIU, typically the starting address on the mass storage, the load address in the NIU memory, the length of the program, and the address to branch to after the program is loaded. This program is then loaded into the main NIU memory and started in execution to complete the formal IPL procedure of the NIU.

The program which was loaded may be the full NOS or may be the next step of a multiple stage IPL procedure. Experience indicates that the maximum flexibility results from loading only a small initial program through the formal IPL (perhaps 1024 bytes). This small program then loads the main program. The current recommendation is to include such a minimal program in the ROM of the NIU.

At the conclusion of this step, the NIU will announce itself to the onboard LAN (log-on) as a source of program loads for any other device. This information is needed by bridges or gateways in order to transfer messages between local area networks.

6.5.1.2 NIUs Not Attached to Mass Storage

Any NIU not attached to mass storage cannot procede until at least one mass storage has announced itself on the LAN, as above. The ROM in these NIUs will detect the presence of a load source somewhere in the LAN by periodically attempting to attach itself to any load source, perhaps once per second. The request is repeated indefinitely until acknowledged so that if the mass storage is not currently available, or if the NIU is turned on before the mass storage, the NIU IPL will simply wait until a load source is available.

Once the attachment is made between the NIU and the mass storage (via the LAN), the ROM program will request that the file named NOS-IPL (or equivalent) be sent to the NIU. This request will be repeated indefinitely or until a successful copy is obtained. After the file is loaded, the ROM program will branch to a predefined main memory location in the NIU to begin execution of the loaded program, completing the formal IPL of the NIU.

Again, the file may be only the first step of a multiple stage IPL procedure. If the NIUs are not all identical, it is likely that the first stage, above, will load the common part of the NOS, and a later stage will load any device dependent NOS.

6.5.1.3 SDP Initialization

The SDP contains a ROM with the minimal program needed to communicate to the NOS in the attached NIU, and through the NOS to a mass storage on the LAN. This SDP IPL program may be executed either directly or after being loaded into the main memory of the SDP.

The first step of the SDP IPL will be to determine if the attached NIU has been loaded with the NOS. The SDP IPL will therefore interrogate the NIU until the status shows that the NOS is available for use. The ROM will then register (log on) to the NOS, using the physical identification of the SDP to assure a unique name within the network. Next the SDP ROM will request that file SDP-IPL (or equivalent) be copied from the mass storage to the SDP by use of the LAN. At completion of this procedure, the ROM program will branch to a predefined address in the SDP main memory completing the formal SDP IPL.

As with the NIU, this may be only the first step of a multiple stage IPL procedure. Other stages may complete the loading of a full operating system, location dependent programs, and special applications such as the ODBMS software.

6.5.1.4 Application Programs

During the early build-up phases the initialization process may wait at completion of the above steps until a crewman or the ground directs further loading of particular programs into each SDP. Alternatively, a set of tables on mass storage may define a default configuration of SDPs and workstations to be automatically loaded and executed as the last steps of the IPL. The approach recommended is to have both a table of default assignments to be started automatically, and the capability to move subsystem processing within the onboard network by modification of the tables.

6.5.2 Subsystem Control

Control of the onboard SSDS and associated subsystems is nominally automatic. However manual overrides via direct keyboard inputs from an onboard MPAC or from telecommands from the ground will be provided. It is envisioned that <u>all</u> subsystems can be controlled in this manner. This implies there will be no dedicated manual switches onboard.

The ground telecommands will be in one of two forms:

- equivalent MPAC keyboard entries
- special commands

The "equivalent MPAC keyboard entries" option has several advantages. First, it minimizes the onboard impact of ground originated commands since the same onboard command processing software can be used regardless of the source of the command. Secondly, this approach provides commonality between ground and onboard control functions. A ground operator would make the same keystrokes on his MPAC as would the onboard operator to accomplish a given control operation.

Special commands would be those for which no equivalent onboard command capability exists. One example might be the capability to update the Space Station state vector in the event of a GPS system failure.

Subsystems will normally have pre-built displays and keyboard entries to manually monitor and control their operations. For unplanned situations, a user interface language (UIL) will allow general access to subsystem data through the operational data base and provide the capability to construct displays and control sequences to monitor and control operations.

6.5.3 Facilities Management

This section presents the centralization aspect of our onboard distributed system definition. The strawman system is primarily distributed as indicated in the memory configuration summary in Section 6.3 and in Section 6.6. However, a set of functions were collected together and defined as Facility Management to basically provide centralized knowledge and control of onboard operations. In summary, the key operations performed by Facilities Management (Tables 6.2-1/6.8-1) are:

- Checking of restricted commands generated onboard and from the ground
- Onboard coordinated operations control
- Centralized collection of key health and status data from subsystems and any safety related data from the payloads
- General diagnostic and systems test and evaluation

The Task 1 Functional Requirements Report and the above referenced tables provide more details regarding these functions.

Restricted/constrained commands are those core and payload commands whose execution scheduling is dependent on specific Space Station event and resource conditions. Onboard generated commands are checked onboard. Ground supplied restricted commands may be pre-checked on the ground, but the final execution decision is made onboard. Command and resource management is addressed in Section 4.0 of this Task Report.

Facility Management coordinated operations control and system monitoring is raised to a summary level for crew casual monitoring. The FM caution and warning system will alert the crew to significant problems and indicate the problem area. At this point, the crew can bring up system and subsystem displays for more information. FM also provides diagnostic and system test support. The operators can request more detailed data, request data for trends, etc.

FM displays are ideal for the Operations Center presented in the Reference Configuration which has large display equipment. However, each workstation will provide caution and warning alerts, so that the crew can access the nearest unit.

6.5.4 Telemetry and Commands

The onboard SSDS interfaces to other SSPE's through the communication gateway. This gateway handles the return and forward SSA and KSA links to TDRSS as well as other communication links. The SSDS interface to the communication subsystem for utilization of some portion of the TDRSS KSA and SSA links is the subject of this section. Other links are discussed elsewhere (i.e., links to co-orbiting platform, free-flyers,...).

6.5.4.1 Core Realtime Return Link

Data are collected from subsystems by data acquisition and assembled into telemetry packets and packet segments. Telemetry packets and return link telecommand packets are interspersed. The telemetry packet and telecommand packets are organized into telemetry buffer units (TBU's). TBU's are constructed using a prioritization algorithm. Telecommand packets are inserted with high priority. TBU's are transmitted on a local bus to a set of toggle buffers at the communication SSA return link interface depicted in Figure 6.5-1. The TDRSS SSA return link is used for this data, although it may be redundantly transmitted on the KSA return link.

6.5.4.2 Core Buffered Return Link

The process of storing and merging buffered data into the return link is depicted in Figure 6.5-2. The data acquisition function is informed by the communication subsystem when data must be buffered because of communication link dropout (zone of exclusion or reconfiguration). The buffered data is stored on mass memory in the TBU format. When the communication link is reestablished the SSDS'data acquisition function is informed by communications. The location of the buffered data is then transmitted to the communications subsystem. The real time data transmission to the communications interface start again and the communications subsystem merges the buffered TBU's and the realtime data on the TDRSS SSA return link.

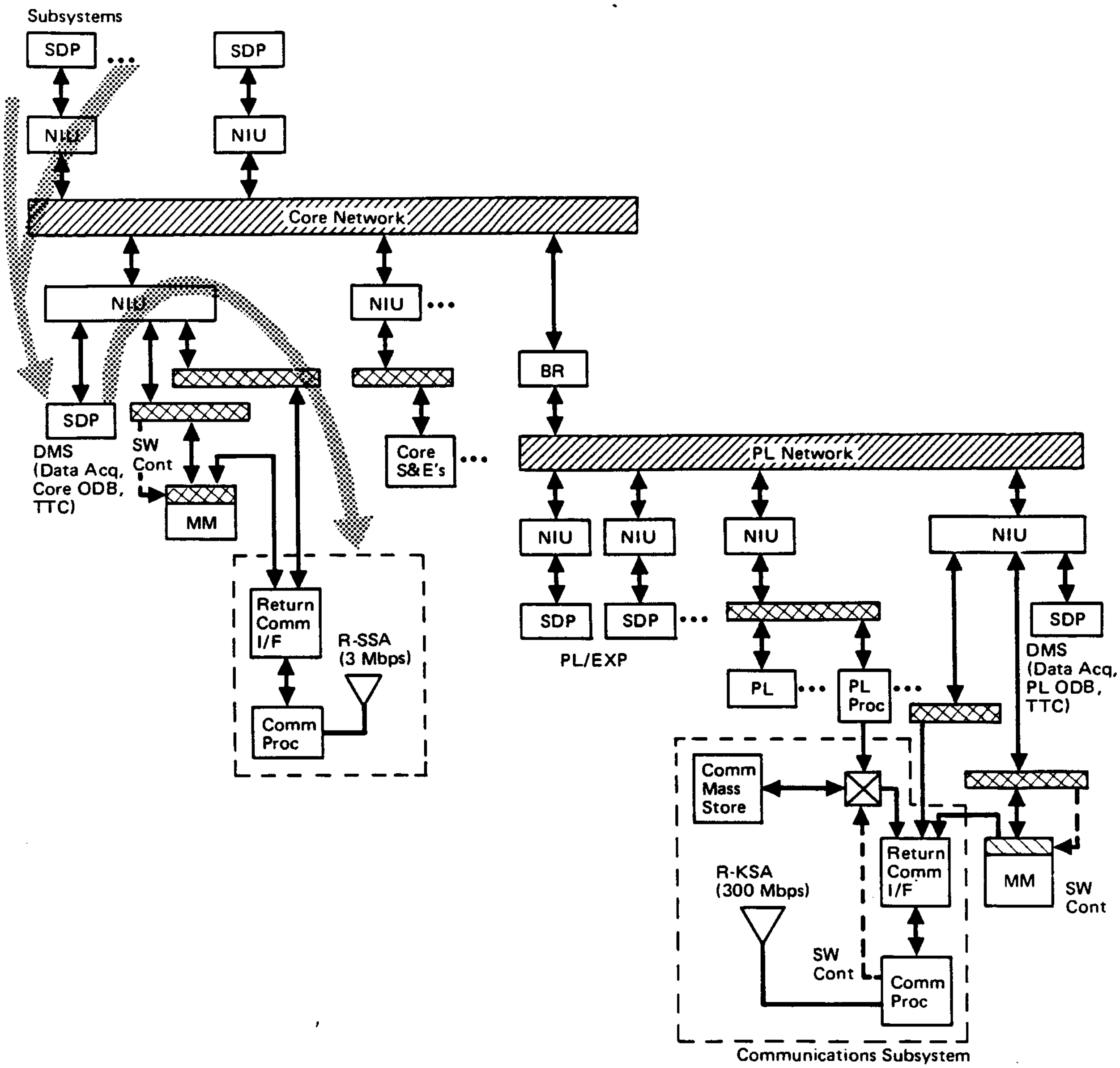
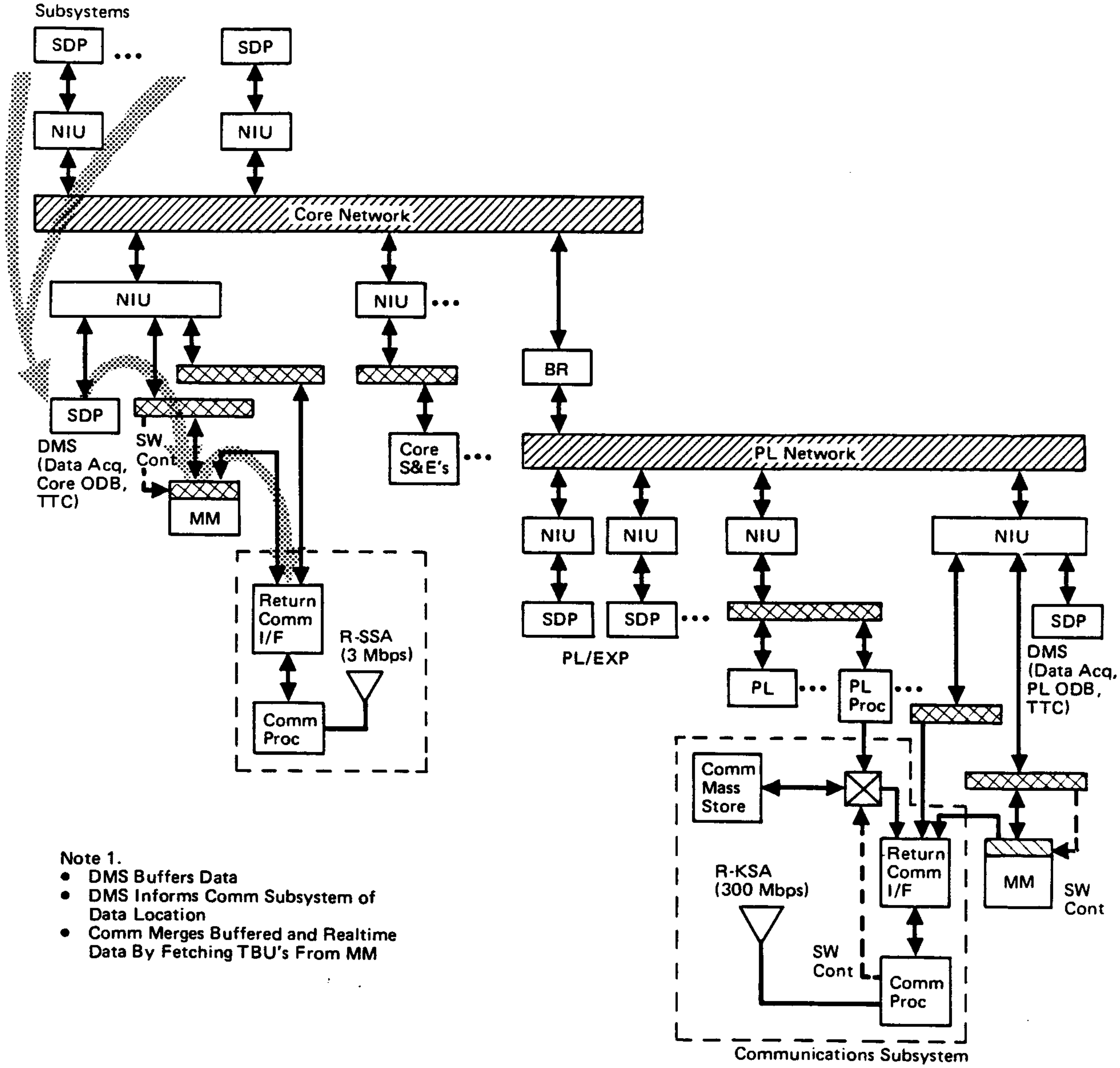


Figure 6.5-1. Return Link for Core Realtime Data



Note 1.

- DMS Buffers Data
- DMS Informs Comm Subsystem of Data Location
- Comm Merges Buffered and Realtime Data By Fetching TBU's From MM

Figure 6.5-2. Return Link for Core Buffered Data

6.5.4.3 Payload Real Time Low Data Rate Return Link (Figure 6.5-3)

Payload low data rate (defined currently as less than 10 Mbps) is collected by the SSDS data acquisition function in the P/L local area network (PLAN). The data is received from the P/L's in CCSDS telemetry packet format. Data acquisition builds TBU's by segmenting long TLM packets and handles priority access to the telemetry stream. Telecommands are given priority over data. The TBU's are transmitted on a parallel local bus to the communication subsystem toggle buffers. These TBU's use the KSA return link.

6.5.4.4 Payload Buffered Low Rate Data Return Link (Figure 6.5-4)

During telemetry link dropout payload low data rate is buffered in mass storage on the PLAN. The buffered data is then merged with realtime data when the KSA link is re-established. The merge is accomplished by the communication subsystem.

6.5.4.5 Payload Realtime High Data Rate Return Link (Figure 6.5-5)

The P/L high data rate interface to the SSDS is through a point-to-point link with the communication subsystem. The communication subsystem merges high rate data with low data rate TBU's on the KSA link. This data is in packet telemetry format or it is assigned to a virtual channel by the communications subsystem.

6.5.4.6 Payload Buffered High Data Rate Return Link (Figure 6.5-6)

During communication link dropout the communication subsystem buffers high rate data on communication subsystem mass storage. The communication subsystem merges this data with real time data when the link is reestablished.

6.5.4.7 Core Forward Link Telecommands (Figure 6.5-7)

Forward link telecommands and data are merged in the TDRSS SSA channel. The DMS telecommand interface function (TLMCMD I/F) polls the SSA communications forward link buffer on a parallel local bus. The buffer contents are examined

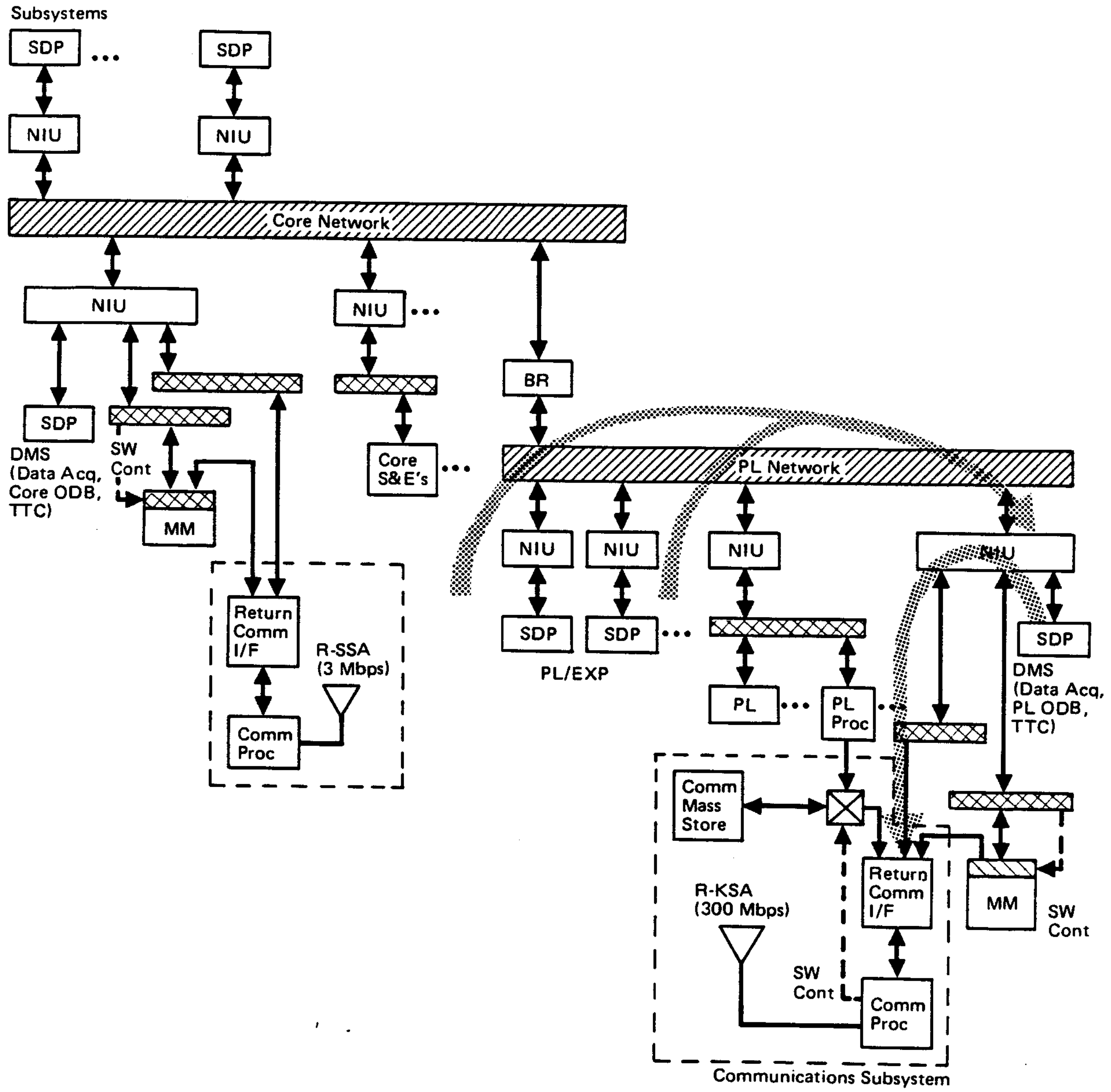


Figure 6.5-3. Return Link for PL Realtime Low Data Rate

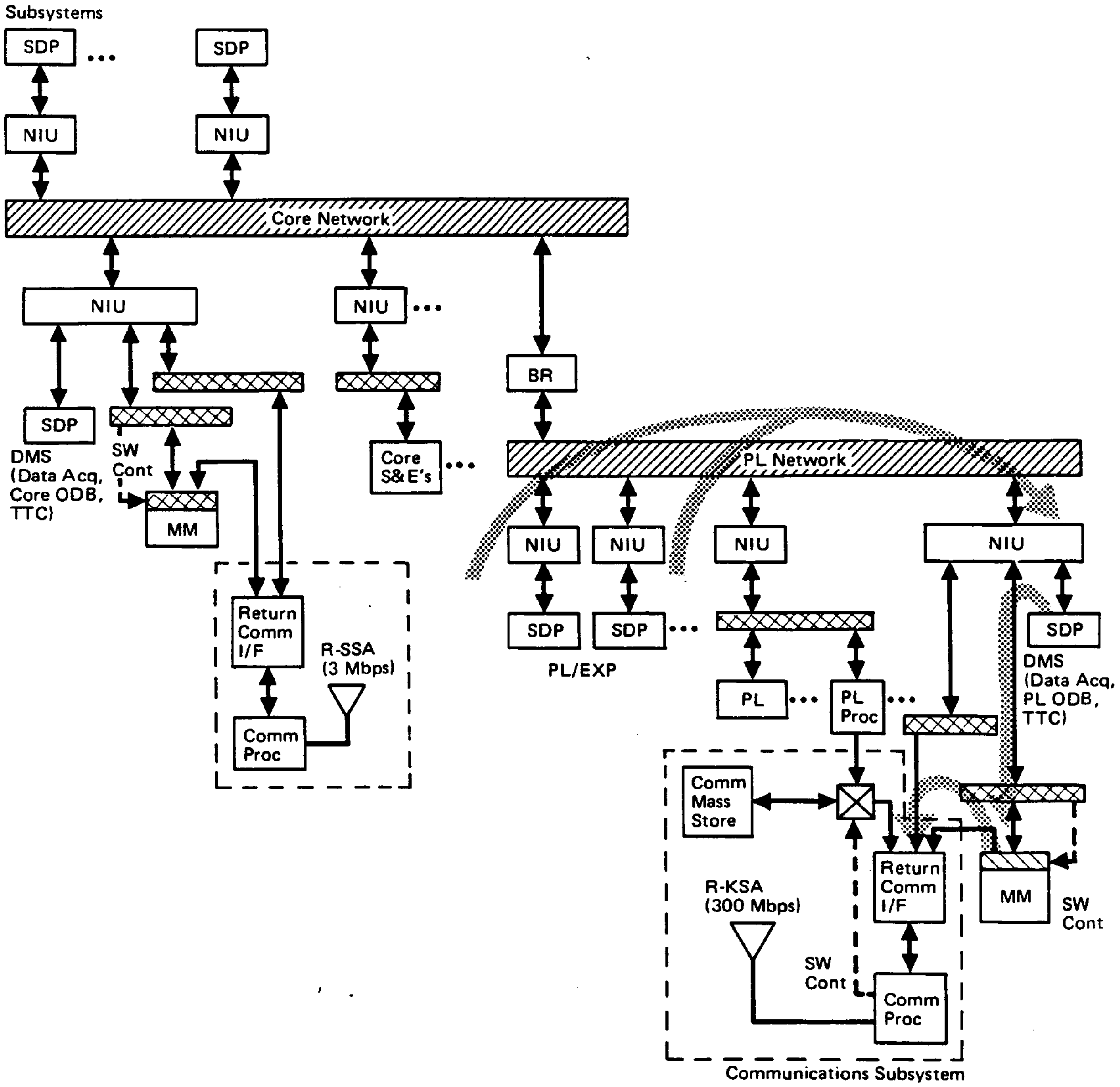


Figure 6.5-4. Return Link for PL Buffered Low Data Rate

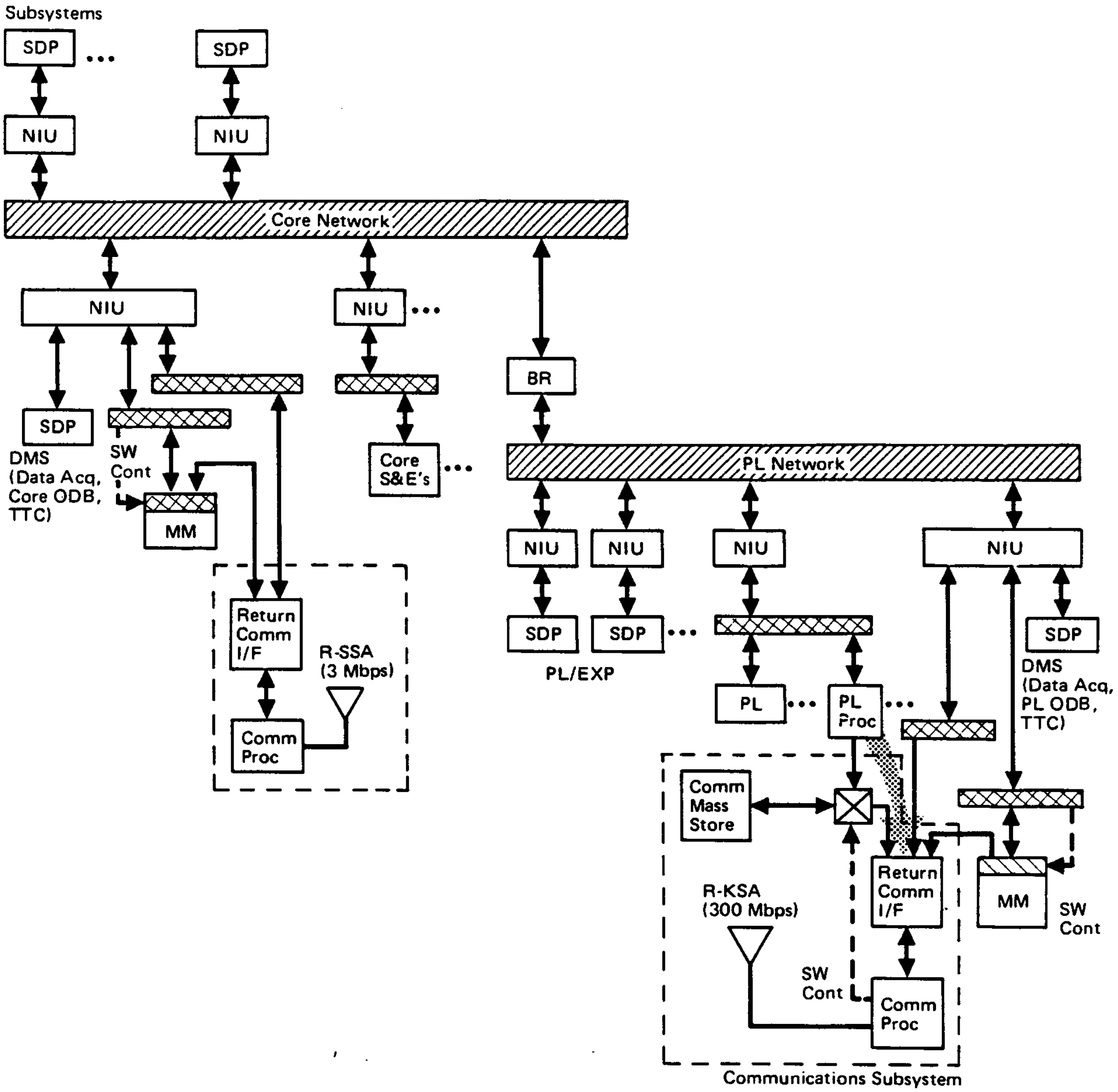


Figure 6.5 -5. Return Link for PL Realtime High Data Rate

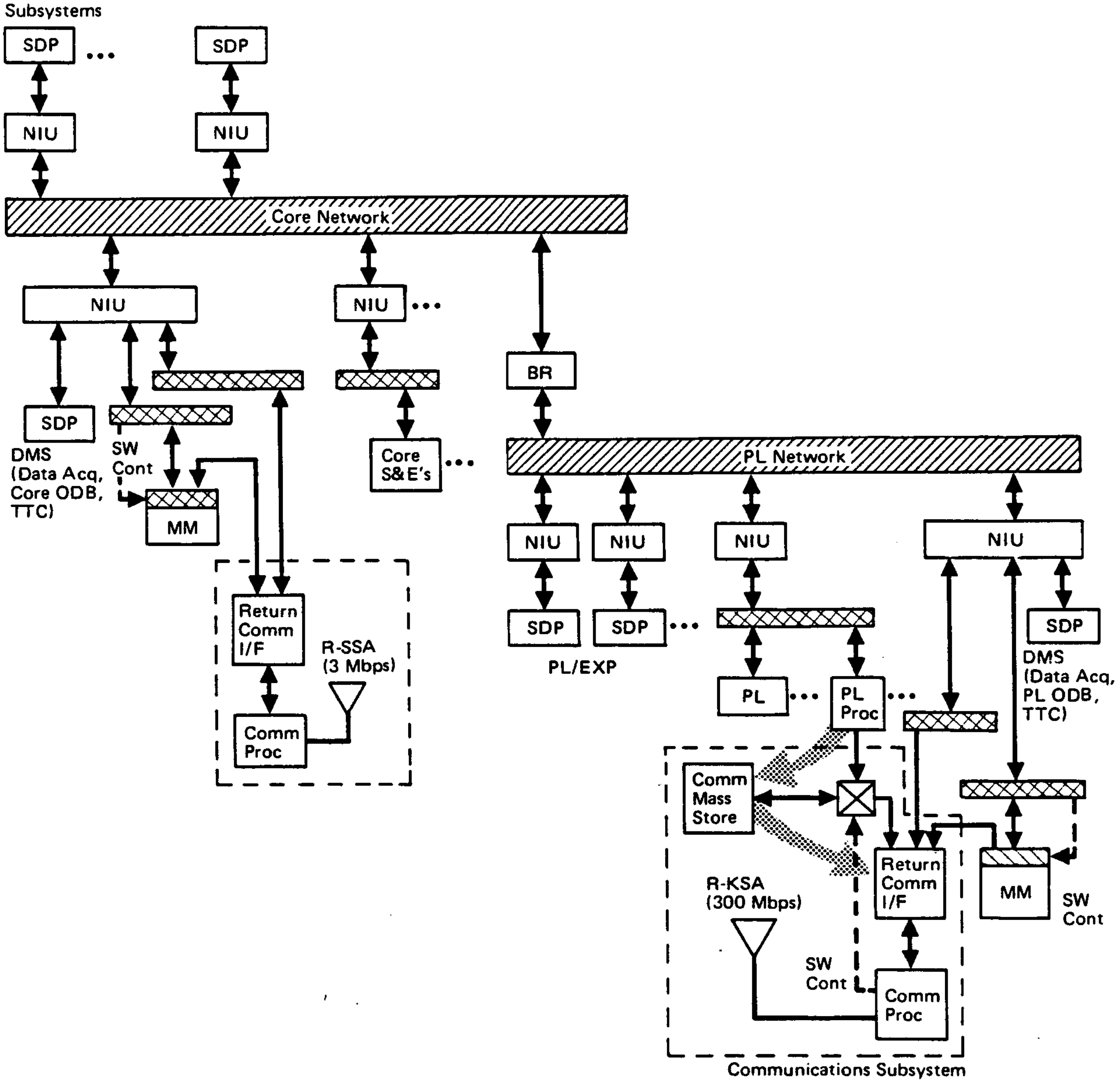


Figure 6.5-6. Return Link for PL Buffered High Data Rate

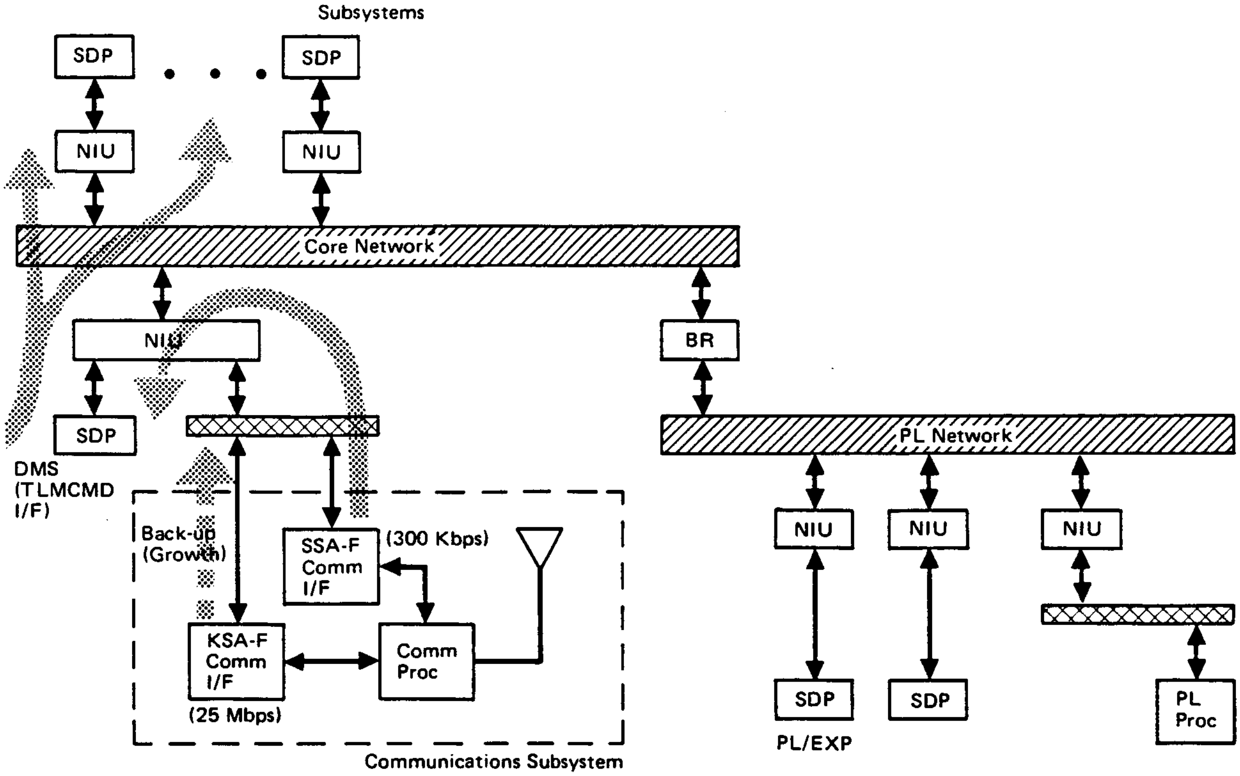


Figure 6.5-7. Forward Link for Core Telecommands

and disassembled by TLMCMD I/F. If the buffer contains data segments, those data segments are delivered directly to the destination mailbox. (As an example, a segment of a new program load would be delivered to the ODBMS for storage on mass memory and then transferred to the targetted SDP).

The KSA forward link is used as a backup in the event of SSA forward link interruption. This interface is also used for growth in the forward link.

6.5.4.8 Payload Telecommands (Figure 6.5-8)

Payload telecommands are delivered through the KSA forward link channel. The same delivery service is provided by the TLMCMD I/F function. The commands are delivered to the P/L mailboxes across the core to P/L network bridge.

6.5.5 Examples of Onboard Data Flow

The following sections describe selected examples to illustrate typical onboard SSDS data flow implications.

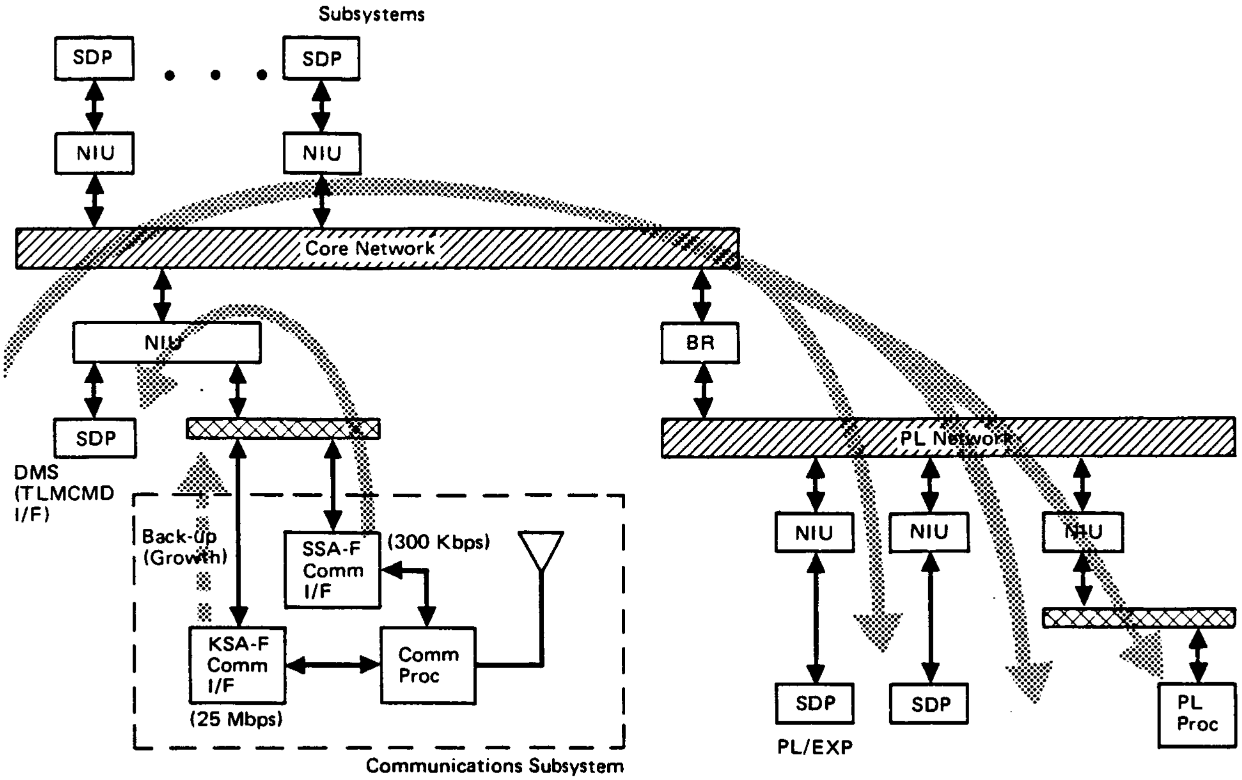


Figure 6.5-8. Forward Link for PL Telecommands

6.5.5.1 Payload without an Integrated SDP.

In this example the payload is developed as a separate unit to be eventually integrated into the SS with a standard subsystem data processor (SDP). The scenario developed herein is for the case of a very low data rate experiment (under 10 Kbps), one relatively simple so that requirements for onboard crew resources (after installation) would not be required for interactive control or maintenance operations. The payload is a university developed experiment and the interfaces selected are based on minimal use of SSDS resources (i.e. graduate students would be available to develop the payload, its interfaces and facilities to support its operation).

In this case, the customer's payload operation facility is on campus and his interface with the SSDS will be via CCSDS TM/TC packets. SDP application programs that control his payload, and certain ground facilities will also be required.

After examining the standard SSDS onboard SDP I/O interfaces available, this customer has elected to use a serial, EIA RS422, synchronous I/F since this requires the least hardware and easily satisfies his data rate. He has analyzed the control and data flow involved and has concluded that a personal computer (PC) will satisfy his Control Center workstation and quick look data processing requirements and that a mainframe-to-PC interface will satisfy his production data processing and archive requirements.

Based on the above and on discussions with the SS program office, his perspective of his interface with the SSDS and with his payload will be as shown in Figure 6.5-9.

He will have electronic interfaces with his payload via TM/TC packets, with the OMCC for schedule development and operations, and with the EDC (if required) for acquiring additional ancillary data beyond that obtained onboard at the time of original payload operations. Voice interfaces with the OMCC and for conferencing with the SS crew are also provided.

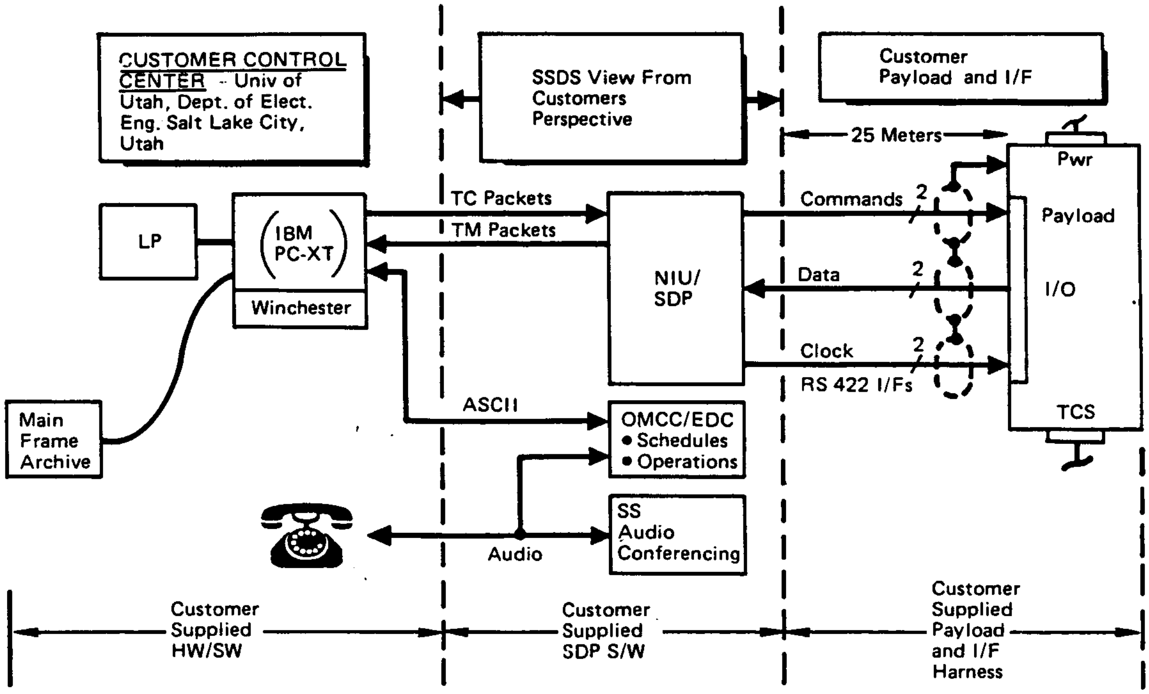


Figure 6.5-9. Payload Operations — Customer Perspective (Example)

The payload will be approximately 25 meters from the NIU/SDP node and will be connected using three shielded twisted wire-pairs. Power and TCS interfaces will also be supplied as shown.

The protocols that the customer will be involved with are those shown in Figure 6.5-10. The CCSDS protocols for TM and TC are discussed in depth in Section 4 and are only summarized in the figure (note that a specific Application Process ID number has been assigned). The RS 422 interface is serial with 8 bit characters (octets) and the customer will develop his own data field assignments for command and data (see examples). His other electronic interfaces with the EDC and OMCC will use a standard ASCII, asynchronous protocols, a 300-2400 Baud modem, and a dial-up telephone.

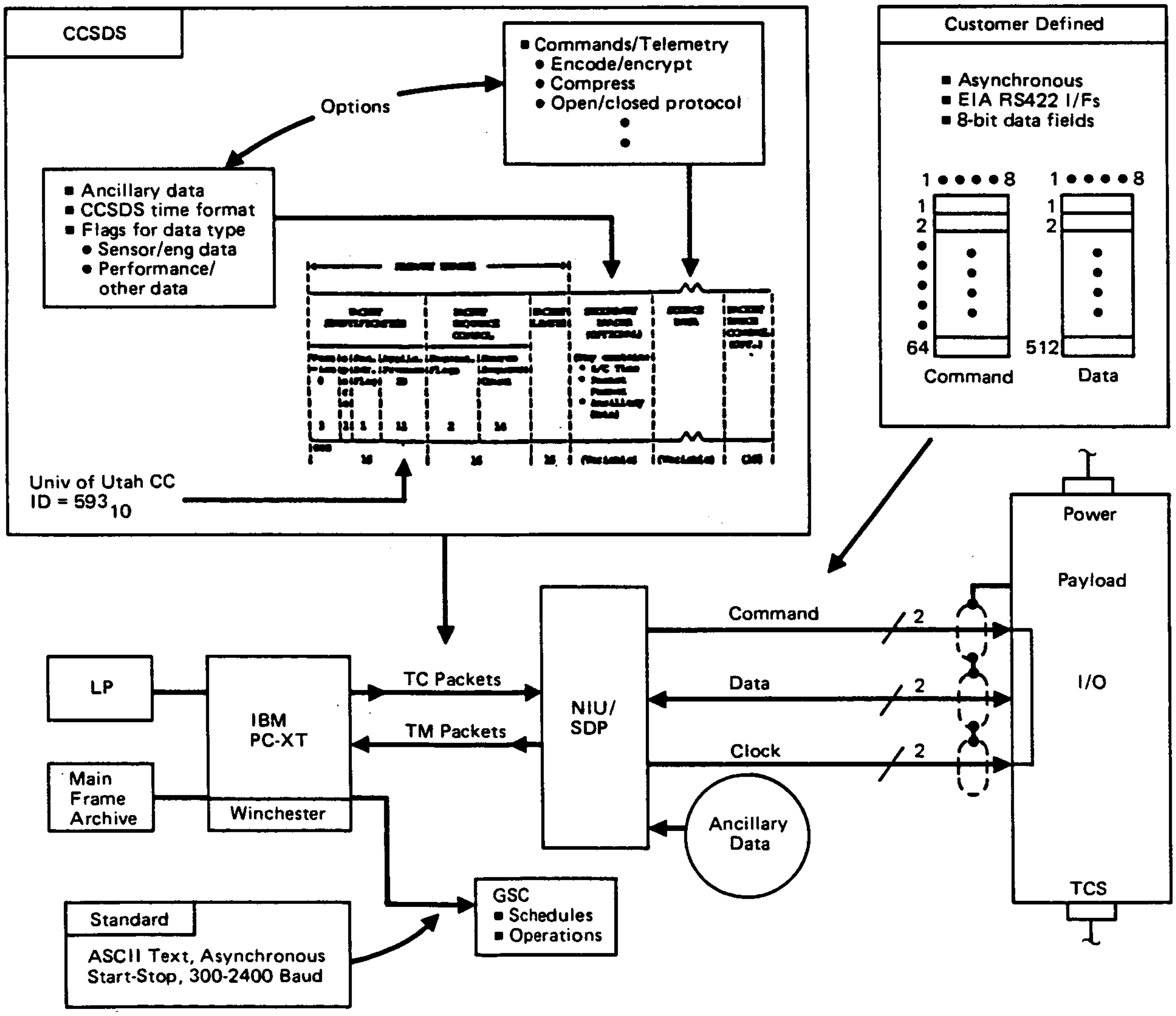


Figure 6.5-10. Protocols in Payload Operations

The real physical communication network that the customer does not see (transparent) is illustrated in Figure 6.5-11. In this example, his link with the Data Handling Center (DHC) at White Sands will be via public circuit-switched and packet-switched networks, as shown. His TM/TC packets are transmitted through space and routed at the DHC and the onboard C&T node as was described previously in Section 4. Onboard, ISO layers 2 and 3 provide routing information for transport to the final destination NIU and the upper ISO layers in the SDP recover the TM/TC packets resulting in the peer-to-peer TM/TC communications shown in the figure. On the return link the customer data is separated from other downlink data at the DHC and routed to his control center where all of his data processing is done. Packets may not arrive in the correct sequence, but can be readily reordered using packet headers.

To implement the operations described above, the customer will supply the control center, the onboard payload and interface harness, and in addition, he will reserve and provide the onboard resources shown in Figure 6.5-12. Engineering or ancillary data will be provided through a real time interface with the core DMS or retrieved from the EDC as required.

CUSTOMER OPERATIONS

A scenario for customer operation will now be described for this customer and his payload and using the protocols described, and the interfaces shown in Figure 6.5-9 thru -12. In this case the customer is requesting a session which is not currently scheduled (his payload is currently powered OFF) because a scientific event-of-opportunity has just presented itself that he would like to capture via his payload sensor. This scenario will involve only electronic data exchanges with the SSIS/SSDS, no voice exchanges will be required (since no anomolies occur). Additionally, the customer is providing his own data link to the DHC which is not implemented with the full seven layer ISO model. It includes a two-layer interface through the circuit switched network (to the TYMNET PAD) and a three-layer interface through TYMNET's public packet switched network (i.e., he is not willing to pay the cost for full ISO/OSI services). He is implementing a message passing service at the Application layer, he will not have Session services to recover data in

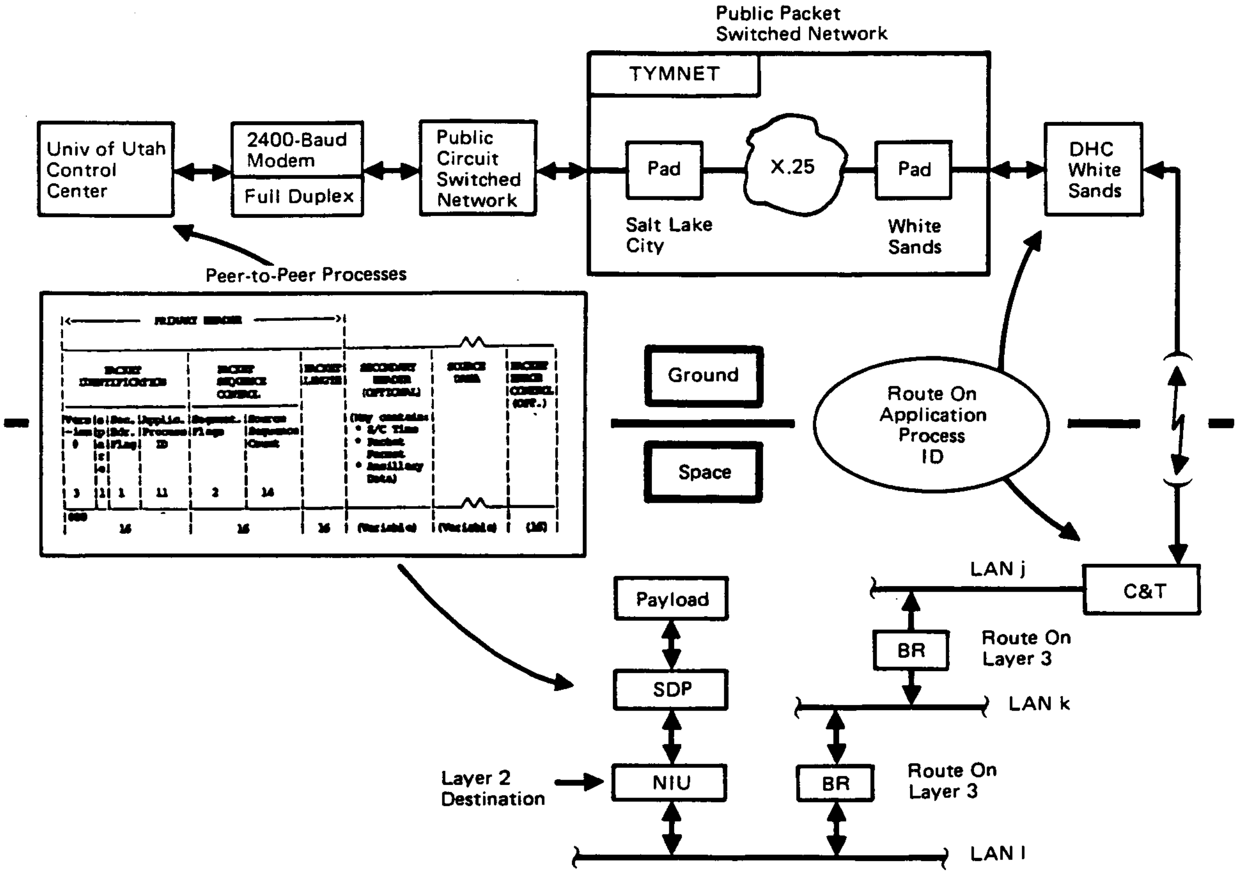


Figure 6.5-11. End-to-End Physical Communication Network

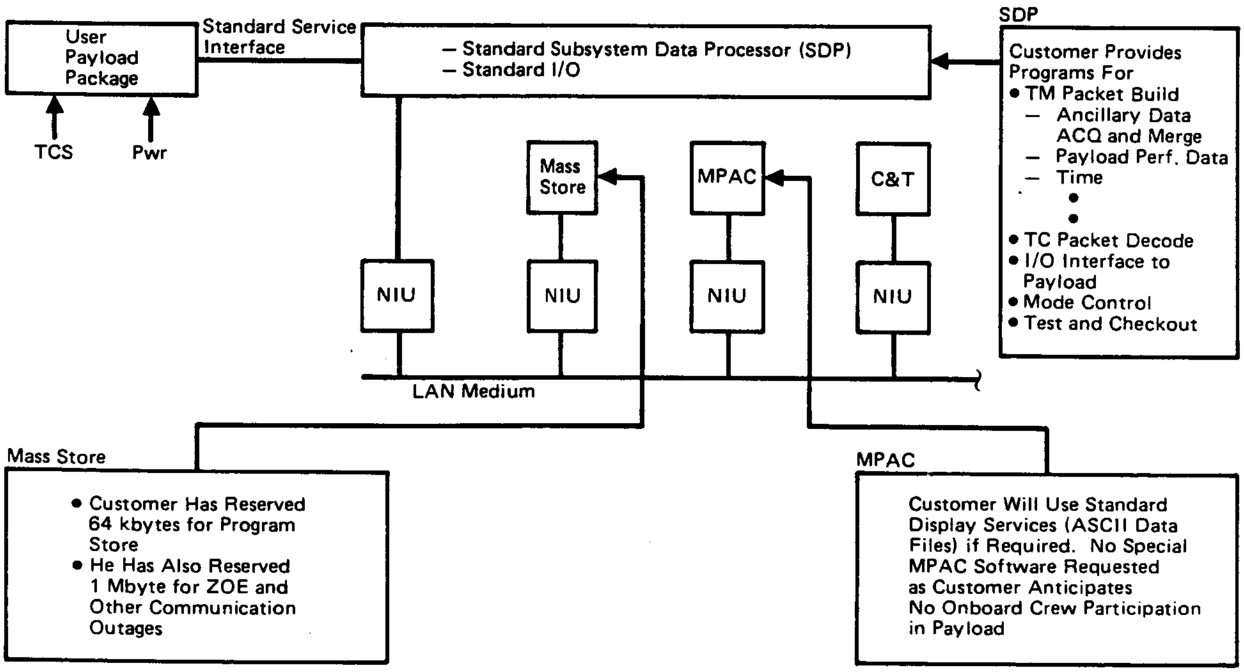


Figure 6.5-12. Onboard Resources

the event of a disorderly disconnect to/from White Sands, and he will not have end-to-end error protection (to/from White Sands) via Transport layer services. To provide for a degree of error protection, his payload software in the SDP that packages the payload data will compute a module 2^{16} check sum and insert the result into the optional Packet Error Control field in the CCSDS TM packet (see Figure 6.5-10). Highlights of this sequence are presented in Table 6.5-1.

TABLE 6.5-1 - CUSTOMER OPERATIONS

Negotiate For Non-Scheduled Services

1. The customer's PC autodials via public telephone to OMCC, prompt appears on PC screen to LOG ON, provide ID, and then provide PASSWORD. OMCC authenticates customer.

2. Service menu appears on screen to select option:
    1. Display Schedule
    2. Request Schedule
    3. ...

3. Customer selects option 2 and via keyboard display, menus, prompts, HELP,...negotiates a schedule to start in six minutes and to terminate after a 2.55 hour session. He is informed that there will be a ZOE outage, but that his data will be stored in an onboard file which he can request to be downlinked at his convenience. (The file will be sequential, time stamped CCSDS TM packets.)

4. Customer LOGS OFF from GSC

Payload Session Establishment

5. Customer has a TYMNET service to White Sands/DHC which he assesses via local public circuit switched network. (NOTE: TYMNET is a public packet switched network providing three layer data delivery services and basically charging on a per packet basis).

6. Prompt appears indicating that he is connected to White Sands/DHC.

7. He now repeats LOG ON, ID, and PASSWORD sequence for DHC authentication.

TABLE 6.5-1 - CUSTOMER OPERATIONS (Continued)

8. Menu options for services are displayed and the customer responds that he wants his payload activated. He is informed that his session is scheduled with no delays and will be activated in 4.00 minutes, and to standby to initiate operations.

9. A countdown clock is displayed and the payload activation sequence is presented followed by a message that the network manager has attached his payload to the network and he can now communicate with his payload.

10. The customer now initiates his local communication and control program which generate TC packets for the following commands that are transported to his payload.

    o Bidirectional communication test
    o Program load from onboard mass store
    o Payload self test
    o Sensor activation and TM packet delivery to CC

11. He will now go through the following sequence in his control center:

    o Quick look data with window for display of sensor performance data (engineering units and graphic displays).
    o Initiate storage of production data on local disk store
    o Monitors production data and performance data for duration of session

12. As his session nears its scheduled completion a window will appear on his screen indicating that a message (TM packet) has been received from the resource manager that he will be disconnected in 3.00 minutes and that he should secure his payload for an orderly shutdown. He does so via TC packet, LOGS OFF from the DHC and disconnects from TYMNET and the local telephone company.

13. Via his mainframe interface, he transmits the production data files for processing and archiving on magnetic tape. Mainframe processing provides him with his desired output in his selected format.

6.5.5.2 Payload with an Integrated SDP

Onboard operations with an integrated SDP/payload showing data flow from the payload to the C&T node were discussed in section 4.3.2 for a hypothetical payload, COM XXXX.

In this example, the customer has a more sophisticated payload than in the previous case and has developed his own package incorporating SSDS standard circuits and his own unique I/O interface circuits. The payload is normally powered OFF and the scenario described in Section 4 discussed the initialization and session establishment sequence.

6.5.5.3 Onboard Inter-Subsystem Data Flow

A generic model (example) for inter-subsystem data flow is shown in Figure 6.5-13 in terms of an SSDS subsystem interface. In order to simplify the intent of the discussion in this paragraph, the SSDS side is shown without any replications for fault tolerance considerations.

On the SSDS side shown in the figure, three different configurations of an NIU, I/O Controller and SDP are shown; in all cases the DOS is distributed between the NIU (layers 1-4) and the I/O Controller or SDP (layers 5-7).

Implicitly, at least two configurations of the I/O Controller will exist and, in fact, multiple versions will exist to facilitate the various backend standard I/O interfaces described elsewhere in this document.

The equivalent of an ICD between the SSDS and the subsystem would be embodied in the requirements that specify (in this example) a MIL-STD-1553B interface for the physical and data link layers (equivalent to layers 1 and 2 in the OSI model) and at the application layer, the message configurations for the 32 word (16 bits/word) Control Frame and Data Frame. These frames would be defined to specify the formats that receive sensor data values and those that

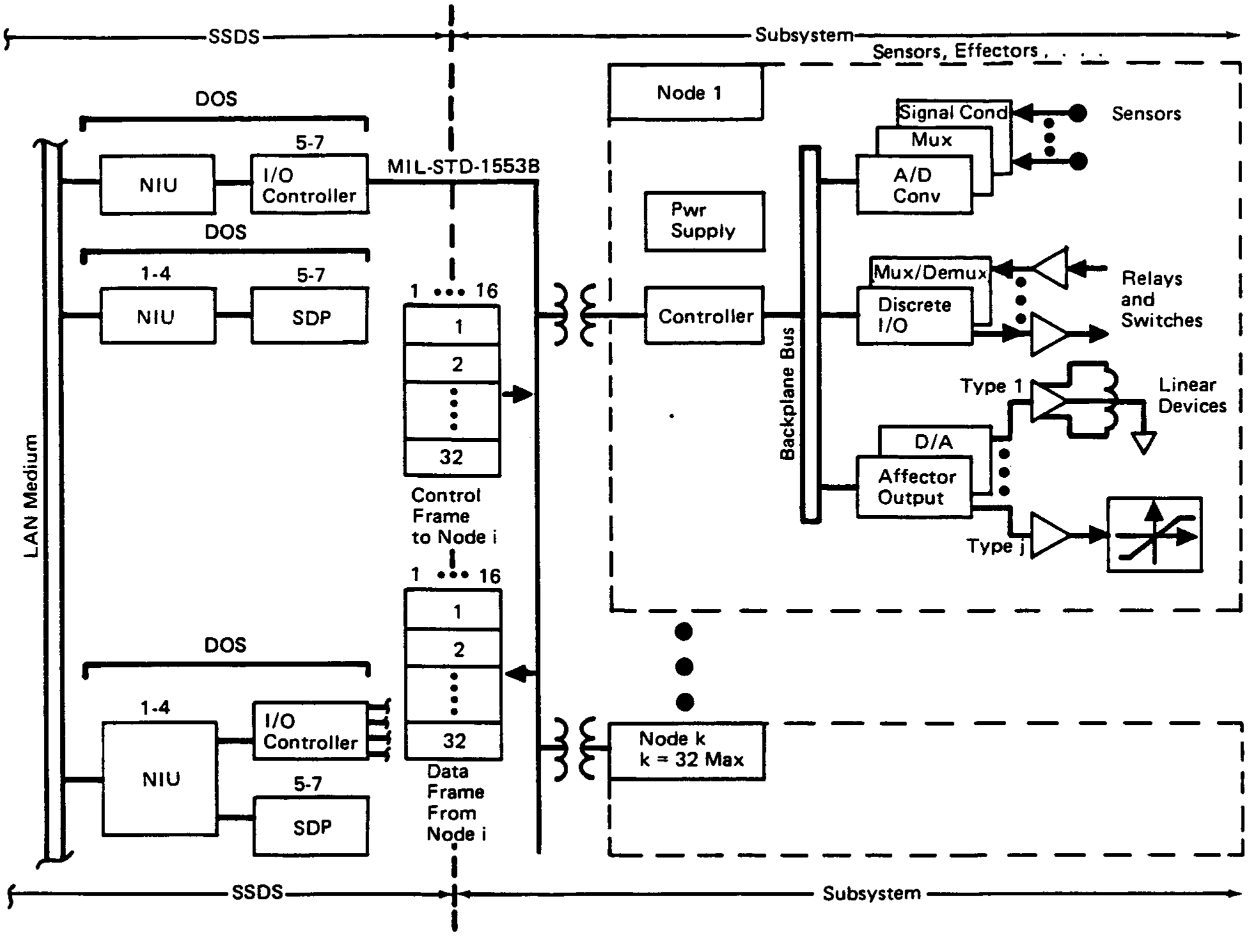


Figure 6.5-13. Intersubsystem Data Flow

transmit effector or output values. These formats would also be specified for various modes of operation in which the subsystem would be required to operate. Different modes (various operational, test, maintenance, etc.) would require, in general, different measurement data sets and with various measurement (update) frequencies.

CASE 1: INTRA-LAN

For this first case, (Figure 6.5-13) k nodes (k = 32 max) would be distributed throughout a region acquiring sensory data and responding to effector output commands. Each node, as shown, would include a controller and power supply and various combinations of data acquisition and data output circuits (e.g., A/D converter, multiplexers, amplifiers of various types, signal conditioning, etc.).

By way of review, MIL-STD-1553B is implemented with twisted shielded wire pairs (TSWP), is transformer coupled at every node, and has a data transmission rate of 1 Mbps. The logical link control (LLC) sublayer specifies a polling procedure between a single master and multiple secondary stations. Control frames are sent from the primary or master, and data frames are received from the secondary nodes.

CASE 2: INTER-LAN

The case considered now is for a distributed subsystem, one where sensors and effectors are distributed throughout a module and between modules. In the example developed here, data acquisition from these distributed sensors is implemented as shown in Figure 6.5-14 using various standard I/O interfaces as required by the application. Likewise, the effector values computed in the SDP would be transmitted using the same I/O capabilities.

The application program in this example is shown to be resident in only one SDP, but with distributed data sources and sinks interconnected locally via standard backend interfaces and throughout the SS via the LANs interconnected by bridges. Interprocess message transfer via the LAN utilizes the layer 3 NOS services described earlier.

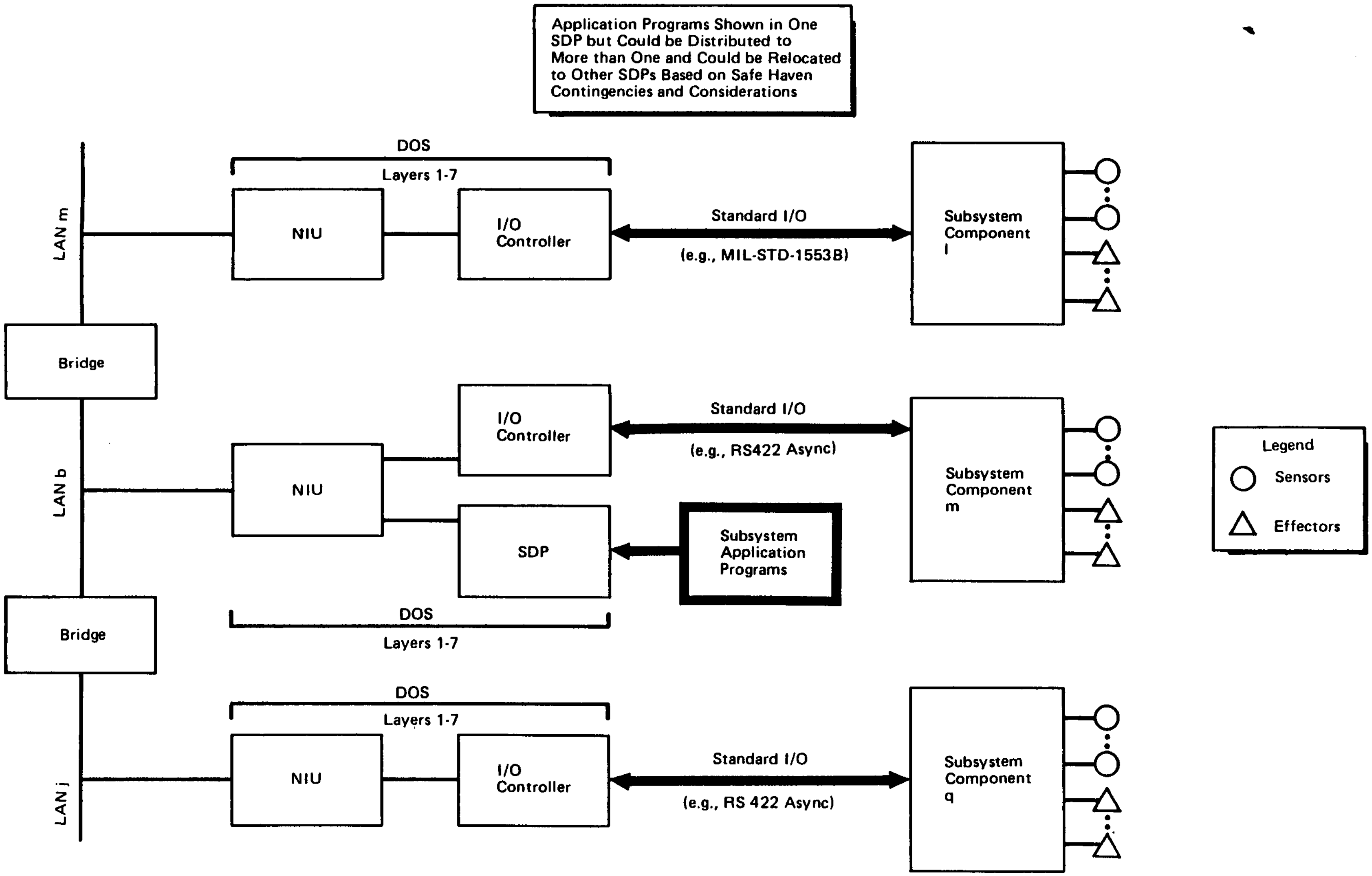


Figure 6.5-14. Distributed Subsystem Data Flow

6.6 Onboard SSDS Architecture

6.6.1 Distribution of Processing

The distribution of processing into the onboard SSDS is based on traditional subdivisions of spacecraft functions, function sizing estimates, function criticality and fault tolerance requirements, interfunction communication, safe haven requirements, minimization of DMS elements, and the desire for subsystem autonomy. The memory configurations and their respective distribution are presented in Table 6.6-1. The total network that supports this distribution is shown in Figure 6.6-1 and Figure 6.6-2. The PL/EXP and core functions are separated to insure the highest degree of traffic isolation and, therefore, functional autonomy.

The architecture selected is based on derived requirements for growth, functional subsystem autonomy, the build-up of functionality, and the flexibility to select fault tolerant options.

The main features of the architecture are: (1) the ability of any SDP to assume any memory configuration (one or more subsystems allocated to an SDP memory load); (2) a single high-speed, DMA interface between the SDP and NIU; (3) the incorporation of the standard, traditional I/O functions between computers and sensors and effectors into the NIU (which makes possible feature 1; (4) the workstation as a computing element with potentially the same power as the SDP plus user interface capability so resources can be shared for infrequent interactive tasks.

Processor fault tolerance is accomplished by a system service function which detects failures and initiates fault down to preferred spares. NIU failures do not require memory reconfigurations since the programs are the same for any triad group. Only port moding is required or reassignment by the network manager (this reassignment accomplishes changes in routing which are then static - no dynamic routing). For failure detection the SDP and NIU are considered a node.

Table 6.6-1. Memory Configurations

IOC

Group	Computing Element	Memory Configurations												
		Core					PL			Work Station				
		1	2	3	4	5	6	7	8	9	10	11	12	13
		Nav Att Cont Guid Traffic Cont Tracking	Pwr Thm Comm I/F	ECLSS Crew Sys Str & Mech	DMS ODB	Fac Mgmt	PL Proc	PL Proc	PL Accom PL Comm I/F PL ODB	DMS Reconfig	Core Work St Load 1	Core Work St Load 2	PL Work St Load 3	PL Work St Load 4
Trans Boom Triad 1	SDP 1	Primary												
	SDP 2	Backup 1												
	SDP 3	Backup 2												
Trans Boom Triad 2	SDP 4		Primary											
	SDP 5		Backup 1											
	SDP 6		Backup 2											
HM 1 Triad 1	SDP 7			Primary										
	SDP 8				Primary									
	SDP 9			Backup 1	Backup 1	Backup 2								
HM 2 Triad 1	SDP 10					Primary								
	SDP 11			Backup 2		Backup 1								
	SDP 12				Backup 2									
PL Lab 2	SDP 13						Primary	Backup						
	SDP 14						Backup	Primary						
	SDP 15								Primary					
PL Lab 1	SDP 16								Backup					
	WS 1									•	•	•		
	WS 2									•	•	•	(Any PL Workstation Can Assume Backup Function)	
	WS 3									•	•	•		
	WS 4									•	•	•		
	WS 5									(Any Core Workstation is Primary or Backup)			•	•
	WS 6												•	•

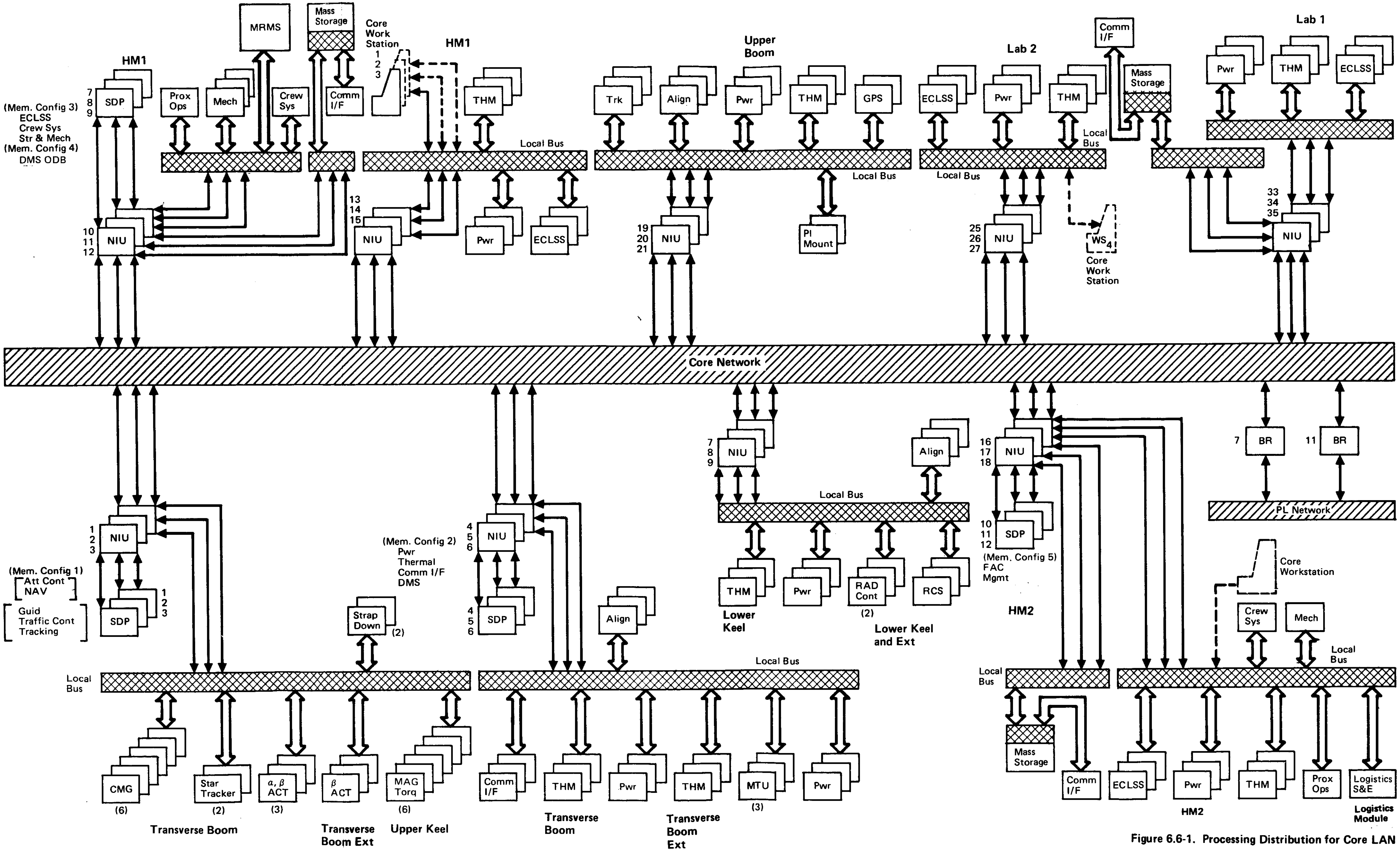


Figure 6.6-1. Processing Distribution for Core LAN

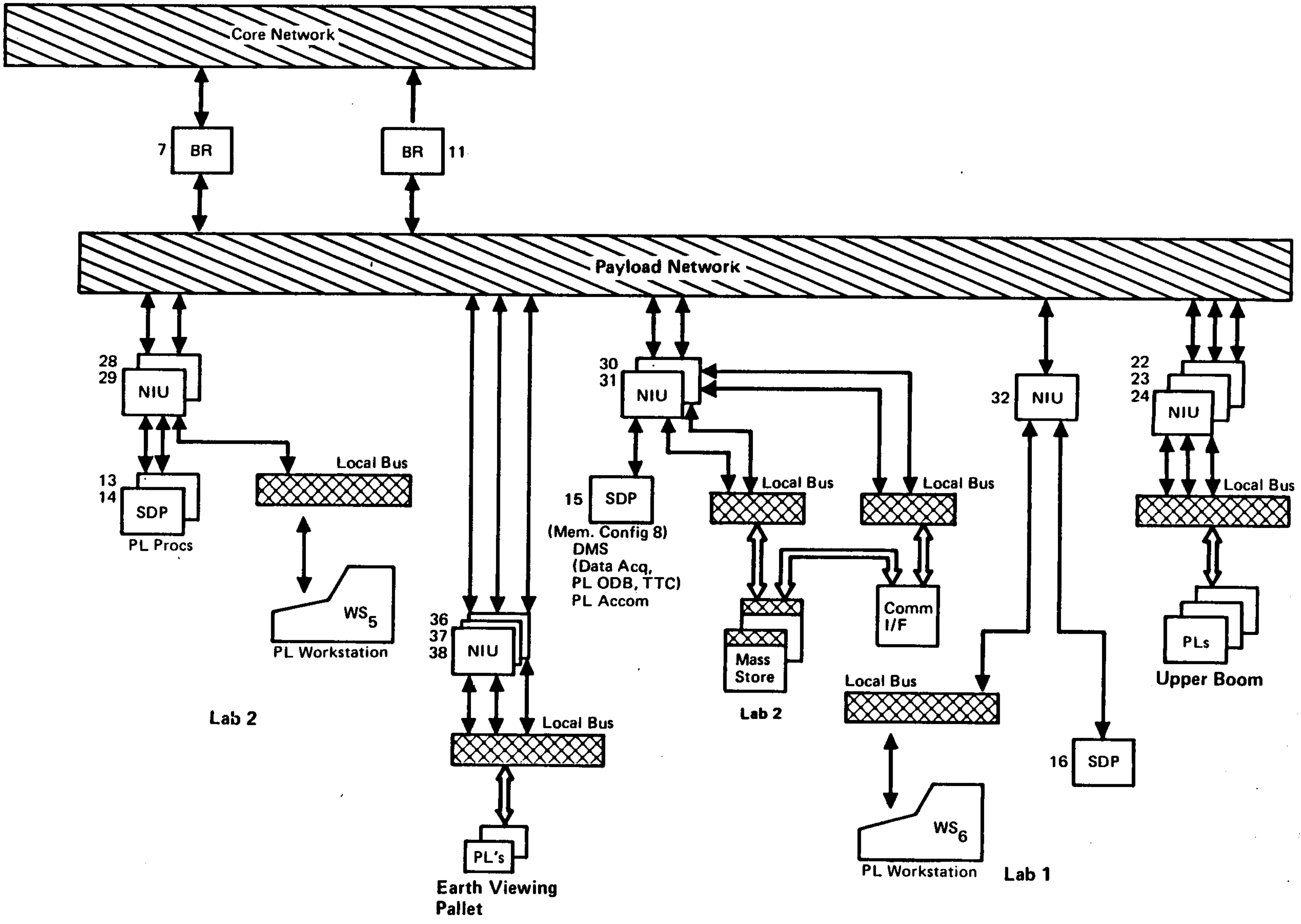


Figure 6.6-2. Processing Distribution for Payload/Ewperiment LAN

The SDP sparing strategy is presented in Table 6.6-1. Spare computers within a triad are preferred as backups for failures in the triad but safe haven requirements make it necessary to be able to transfer memory configurations to another physical module. This is the case for all the SDP's except those on the transverse boom which only have spares within the local triad. These are called preferred spares for the following reason: even though it is possible to use a member of these triads for some other memory configuration for some period of time, if several failures occur in this triad then the "visiting" memory configuration is bumped to another SDP (or a degraded mode occurs because no spares are available).

The triad in HM1 operates in a "shared spare" mode. In other words the preferred spare is the spare in the local triad but this is shared by the two memory configurations (memory configurations 3 and 4) active in the HM1 triad 1. Additional spares are located in the HM2 triad 1. Safe haven requirements are met in this sparing strategy. The HM2 triad 1 uses the local spares as the preferred spares for memory configuration 5 but resorts to the HM1 triad for safe haven backup.

With this architecture it is possible to absorb growth by having a currently inactive triad member become active and at the same time introduce a SDP into a "spare pool" on the core network.

The preferred spare strategy used for the transverse boom triad 1 also results in deterministic I/O timing, a requirement for the hard real-time functions such as attitude control. Predictability in I/O delays comes from the fact that traffic to the local bus is on a string which is not shared with any other functions even if a "visiting" memory configuration is executing in this triad (i.e., no traffic interference occurs in the NIU because traffic only couples when reaching the core network).

The SDP memory configurations are described in Table 6.6-2. These memory configurations are distributed into a total network of 16 SDP's. Six workstations and 38 NIU's are also provided. The memory configuration for the workstations is described in Table 6.6-3. The core and P/L network contain 12 bridges. Each bridge has the same software which includes layers 1-4 of DOS (See section 6.4.2).

Table 6.6-2
SDP MEMORY CONFIGURATIONS (IOC)

MEMORY CONFIG	CONTENT	SIZE (KBYTES)	RESIDENCE		
			PRIME SDP	FIRST BACKUP	SECOND BACKUP
1	NAV, ATT CONT (FLT 1-2) GUID, TRAFFIC CONT, TRACKING, OMV DEPLOY	1038/307	1	2	3
2	PWR, THM, COMM I/F	1530/815	4	5	6
3	ECLSS, CREW SYS, STR & MECH	595/137	7	9	11
4	DMS ODB	1280/38	8	9	12
5	FAC MGMT	1618/14	10	11	9
6	PL PROCESSING	360/1	13	14	—
7	PL PROCESSING	360/1	14	13	—
8	PL ACCOM PL COMM I/F PL ODB	2626/30	15	16	—

Table 6.6-3
WORKSTATION
MEMORY CONFIGURATIONS (IOC)

MEMORY CONFIG	CONTENT	SIZE (KBYTES)	RESIDENCE
9	DMS RECONFIG	(774/36)	*

* ALL WORKSTATIONS ARE CANDIDATE TARGETS FOR LOAD & BACKUPS

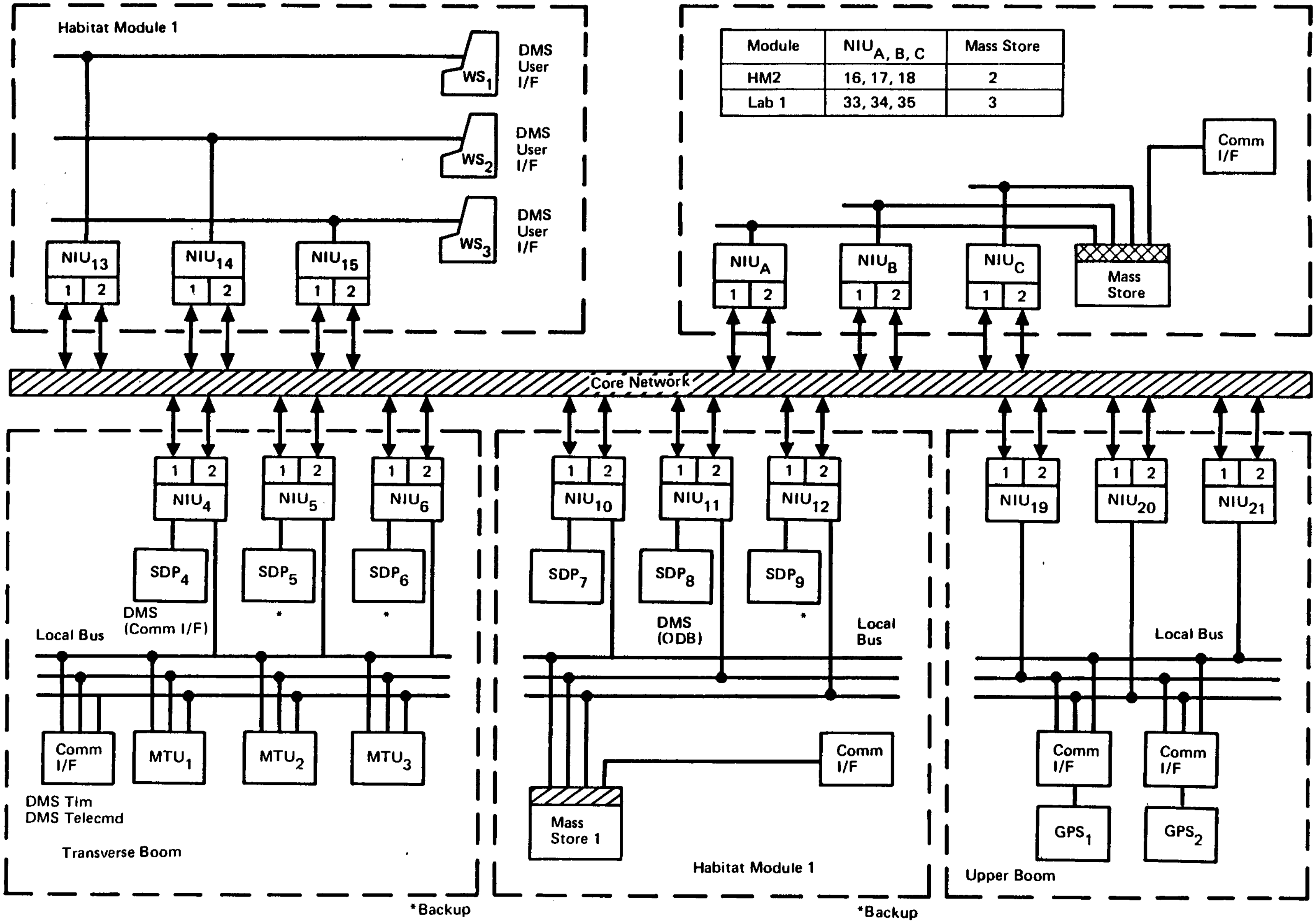
It should be noted that the term "memory configuration" mentioned above implies an SDP memory load containing the application software for one or more subsystems. The decision to combine subsystem application software into memory configurations was motivated by the following considerations:

- Desire to minimize the total number of SDP's and NIU's required. This reduces program costs, power/cooling resource demands and network complexity.
- Group together subsystem application software with high data exchange requirements.
- Group together subsystem application software which must be relocated to address safe haven requirement.

The ability of a subsystem contractor to design and checkout his subsystem without significant interface to a central integration facility can still be accomplished. A functional equivalent of the SDP/NIU and appropriate data bus interface simulator can be used in a standalone test verification mode. With a standard DOS the linkage of subsystem applications software within an SDP should be (largely) transparent.

6.6.1.1 Data Management Subsystem (Figure 6.6-3)

The DMS "application" functions are resident in two SDP's; SDP4 and SDP8. SDP4 is backed up by SDP5 and SDP6 in the transverse boom triad 1. SDP8 is backed up by SDP9 in HM1 and SDP12 in HM2. SDP4 nominally contains memory configuration 2 which performs the functions required to interface to the communication subsystem for the return and forward SSA link. Time management is also contained in memory configuration 2. The master timing units (MTU's) used by SDP4 are attached to a local bus. When the GPS receivers are added to the upper boom, time management can use the time reference provided by GPS as an addition reference source.



Module	NIU$_{A, B, C}$	Mass Store
HM2	16, 17, 18	2
Lab 1	33, 34, 35	3

Figure 6.6-3. Data Management Subsystem

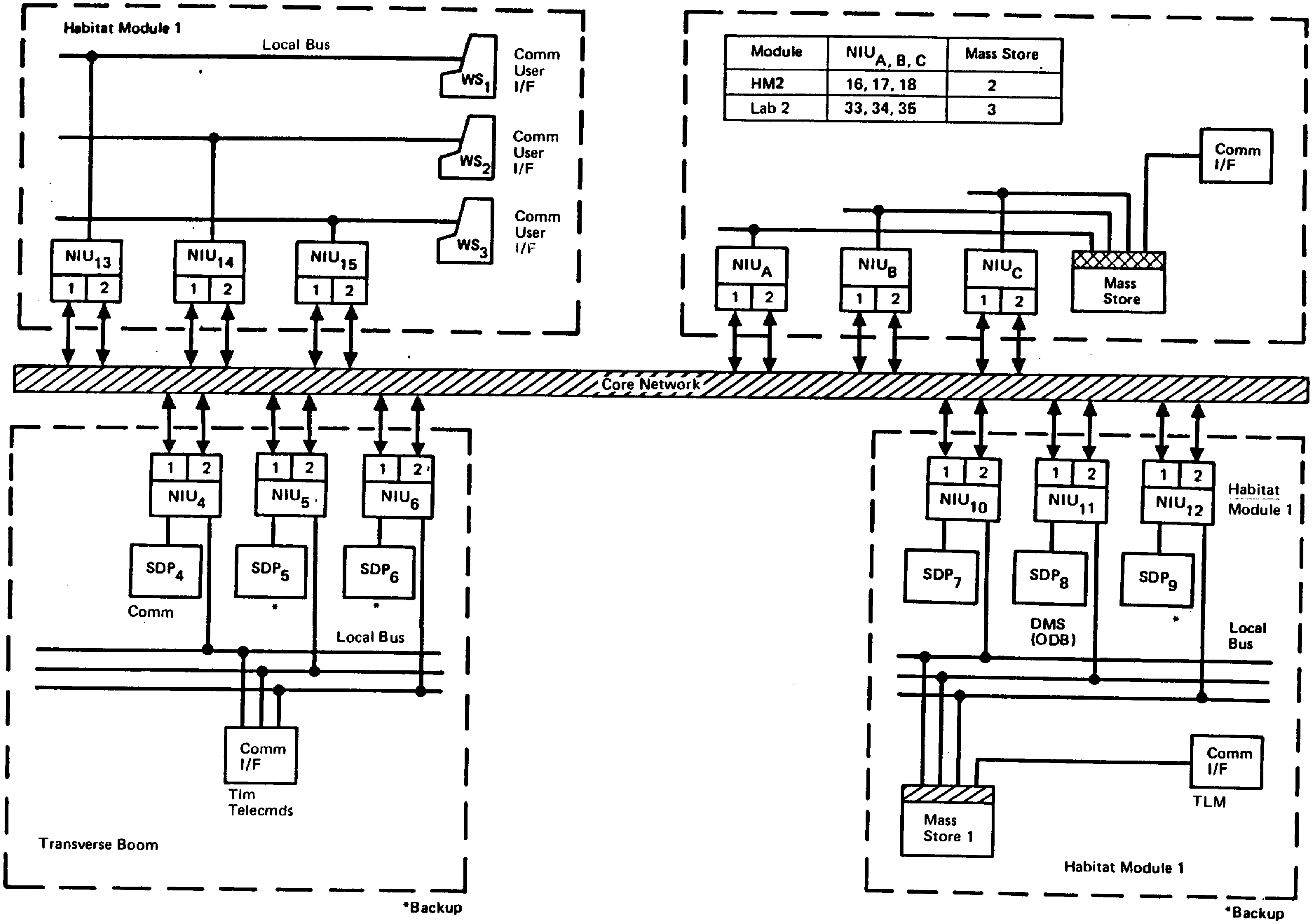
The DMS operational data base (ODB) is nominally resident in SDP8 (memory configuration 4). The mass storage is distributed in HM1, HM2 and LAB2. The DMS stores telemetry data on mass storage during return link dropout. After the return link has been restored the DMS allows the communication subsystem to retrieve this buffered data from mass storage for merging with realtime data.

For illustration purposes, the DMS can be reconfigured as shown in Figure 6.6-3 using the work stations resident in HM1. This control location is illustrated in many subsequent figures. However, any workstation can be configured to control any subsystem. Other workstations locations are shown in Figures 6.6-1 and 6.6-2. Menu panels are presented at all active work stations. These panels allow the work station to be configured by crew selection. Programs are then loaded in the work station which supports interaction with the crew for DMS status and reconfiguration.

6.6.1.2 Communication Subsystem (Figure 6.6-4)

The communication subsystem is resident in SDP4 (memory configuration 2) and backed up by SDP5 and SDP6 in the transverse boom triad 1. Telemetry for the SSA return link is transmitted in packet telemetry format on a local bus to the communication toggle buffers. Telecommands are also received on this local bus by a polling process. The forward SSA link buffer is polled by transferring the communication interface buffer to SDP4. Packet segments in the forward link buffers are then disassembled and transported to the onboard destination task.

Reconfiguration of the communication subsystem is through programs loaded into any of the core workstations (similar to description in 6.6.1). This reconfiguration process is highly automated with (mostly) optional crew interaction.



Module	$NIU_{A, B, C}$	Mass Store
HM2	16, 17, 18	2
Lab 2	33, 34, 35	3

Figure6.6-4 Figure 6.6-4. Communications Subsystem (DMS Interface)

6.6.1.3 Attitude Control (Figure 6.6-5)

Attitude control is nominally resident in SDP1 (memory configuration 1) and backed up by SDP2 and SDP3. All of these computers are in transverse boom triad 1. Attitude determination is generally considered to be a navigation function, but is embedded within attitude control for this description. Communication with the CMG's, strap-down assemblies, star trackers and solar panel activators is through a local bus on the transverse boom triad 1. When the solar panel extensions and magnetic torquers are added they also use the same local bus for communication. The RCS is distributed along the lower keel and lower keel extension. NIU7, NIU8 and NIU9 located on the lower keel are used to communicate from the transverse boom triad 1 to the RCS on a local bus.

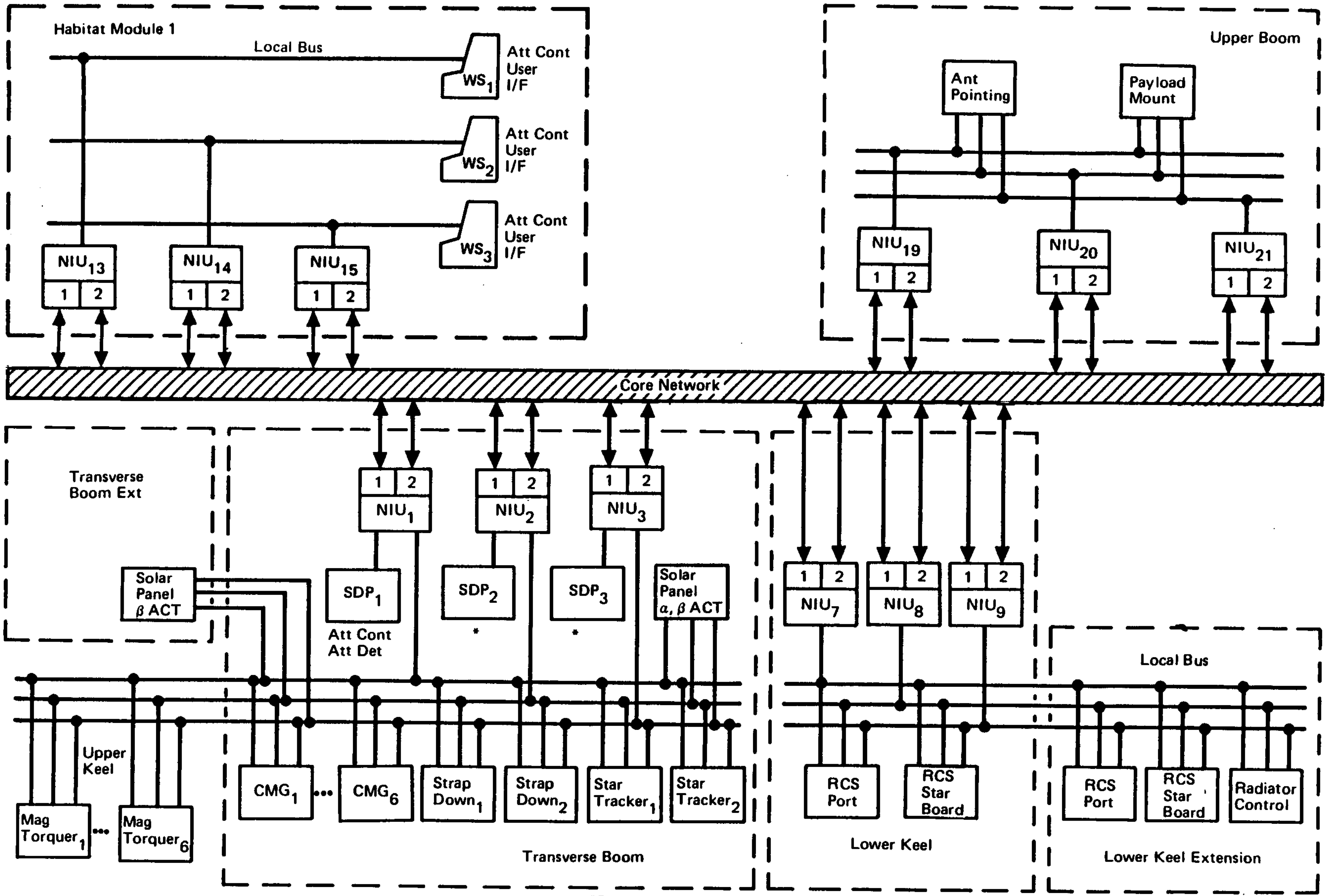
The user interface to the attitude control function is via the core workstation shared resources as described previously.

6.6.1.4 Tracking Subsystem (Figure 6.6-6)

The tracking subsystem resides in memory configuration 1 which is nominally assigned to SDP1 and backed up by SDP2 and SDP3 on the transverse boom. The tracking function collects data from various transponders and radars distributed on the upper boom and also proximity trackers on HM1 and HM2. This data is conditioned and transmitted to navigation and traffic control functions.

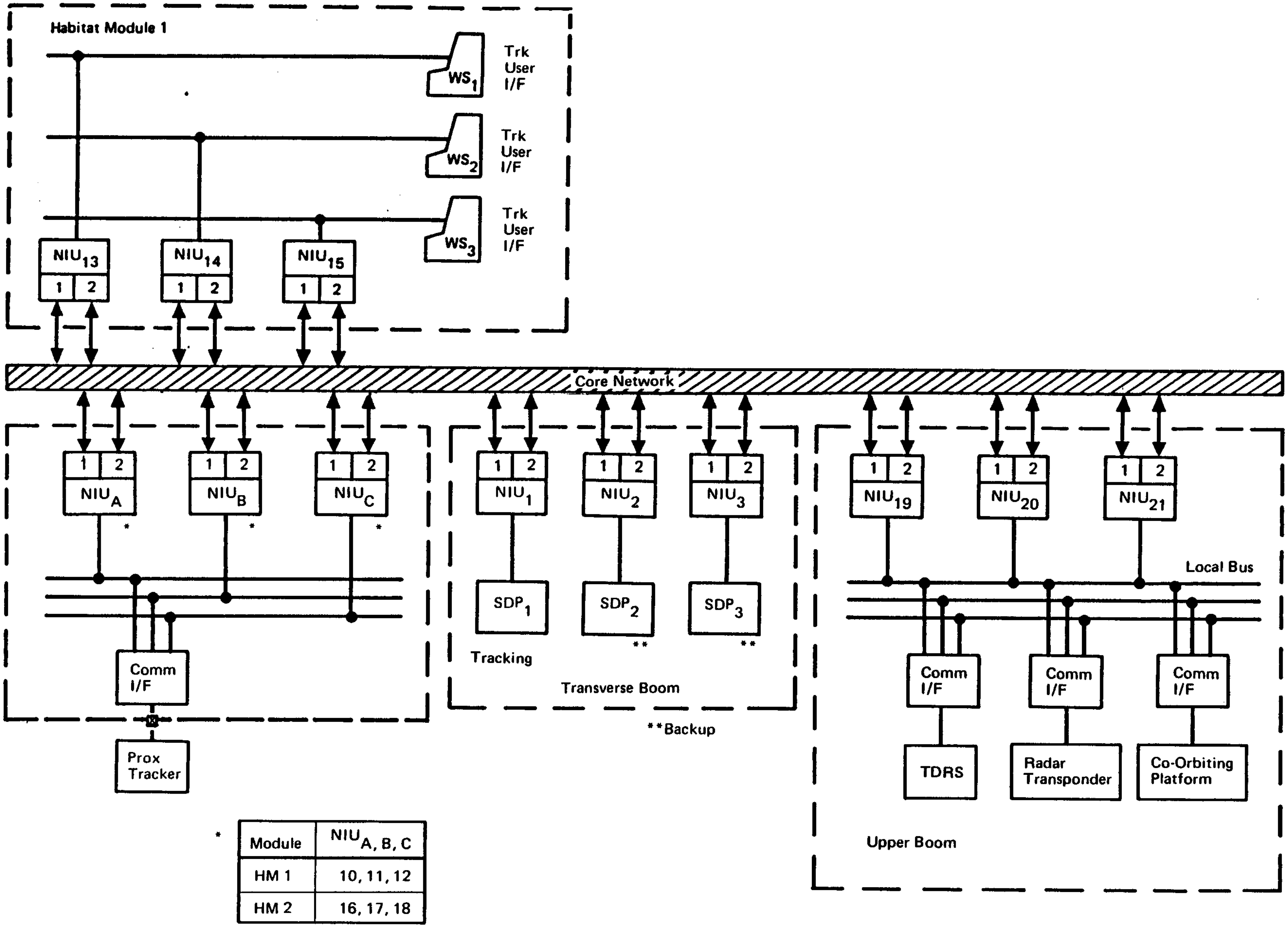
6.6.1.5 Navigation (Figure 6.6-7)

The navigation function is contained in memory configuration 1 which is resident in SDP1 and has preferred backups in SDP2 and SDP3. The navigation function receives GPS data from instrumentation on the upper boom. TDRS tracking data is also received from the TDRS S-band transponder on the transverse boom (this function may migrate to the upper boom). User interface to the navigation function is through any of the core workstations as described previously.



*Backup

Figure 6.6-5. Attitude Control (and Attitude Determination Support Function)



*

Module	NIU$_{A, B, C}$
HM 1	10, 11, 12
HM 2	16, 17, 18

Figure 6.6-6. Tracking Subsystem

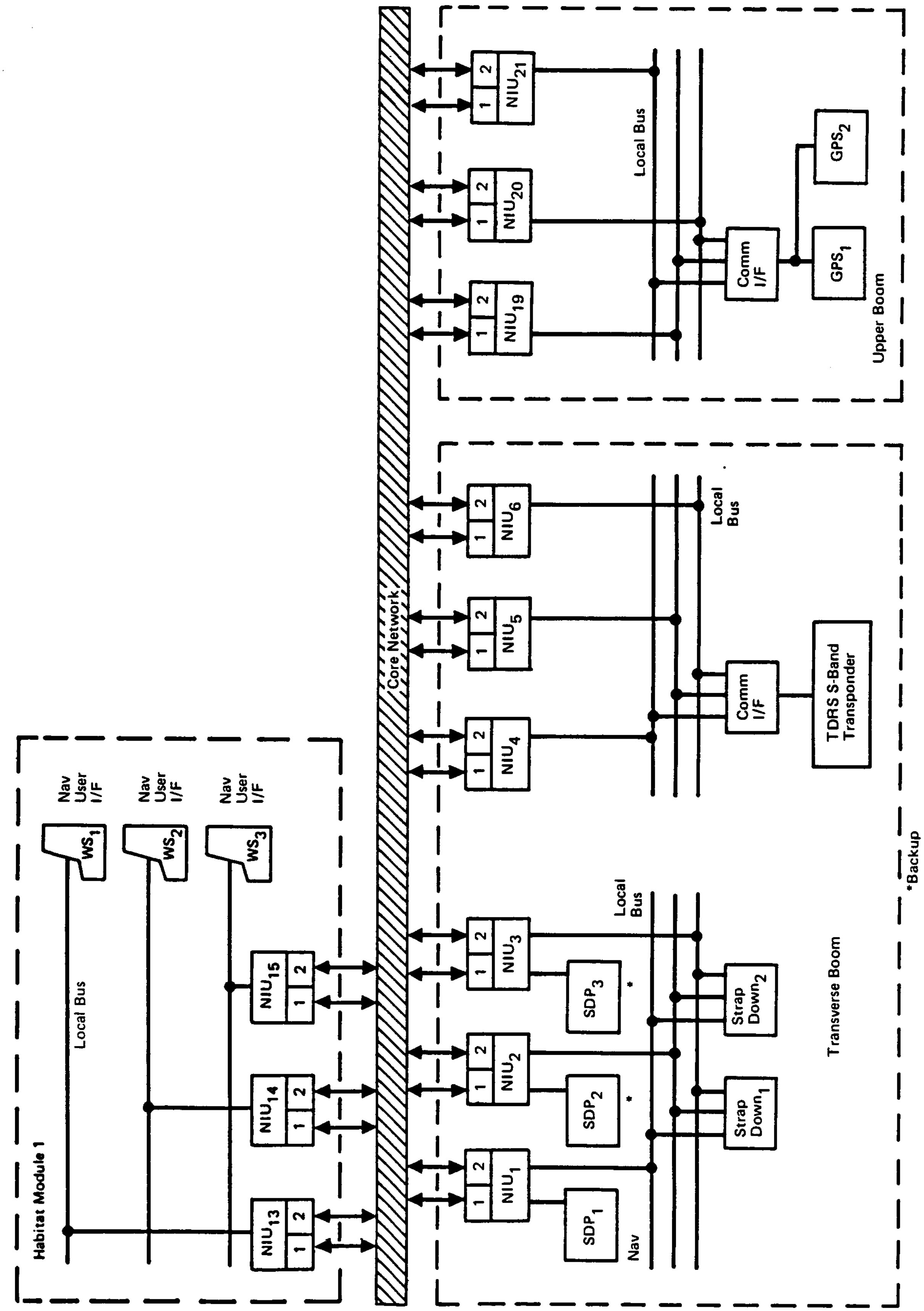


Figure 6.6-7. Navigation

6.6.1.6 Electrical Power Subsystem (Figure 6.6-8)

The electrical power subsystem is contained in memory configuration 2 and resident in SDP4 with preferred spares SDP5 and SDP6. Electrical power sensors and effectors are distributed on the truss and within the pressurized modules. The local buses and associated NIU's are shown in Figure 6.6-8. The NIU's within HM2 also have a connector on the local bus for the logistics module.

6.6.1.7 Thermal Control Subsystem (Figure 6.6-9)

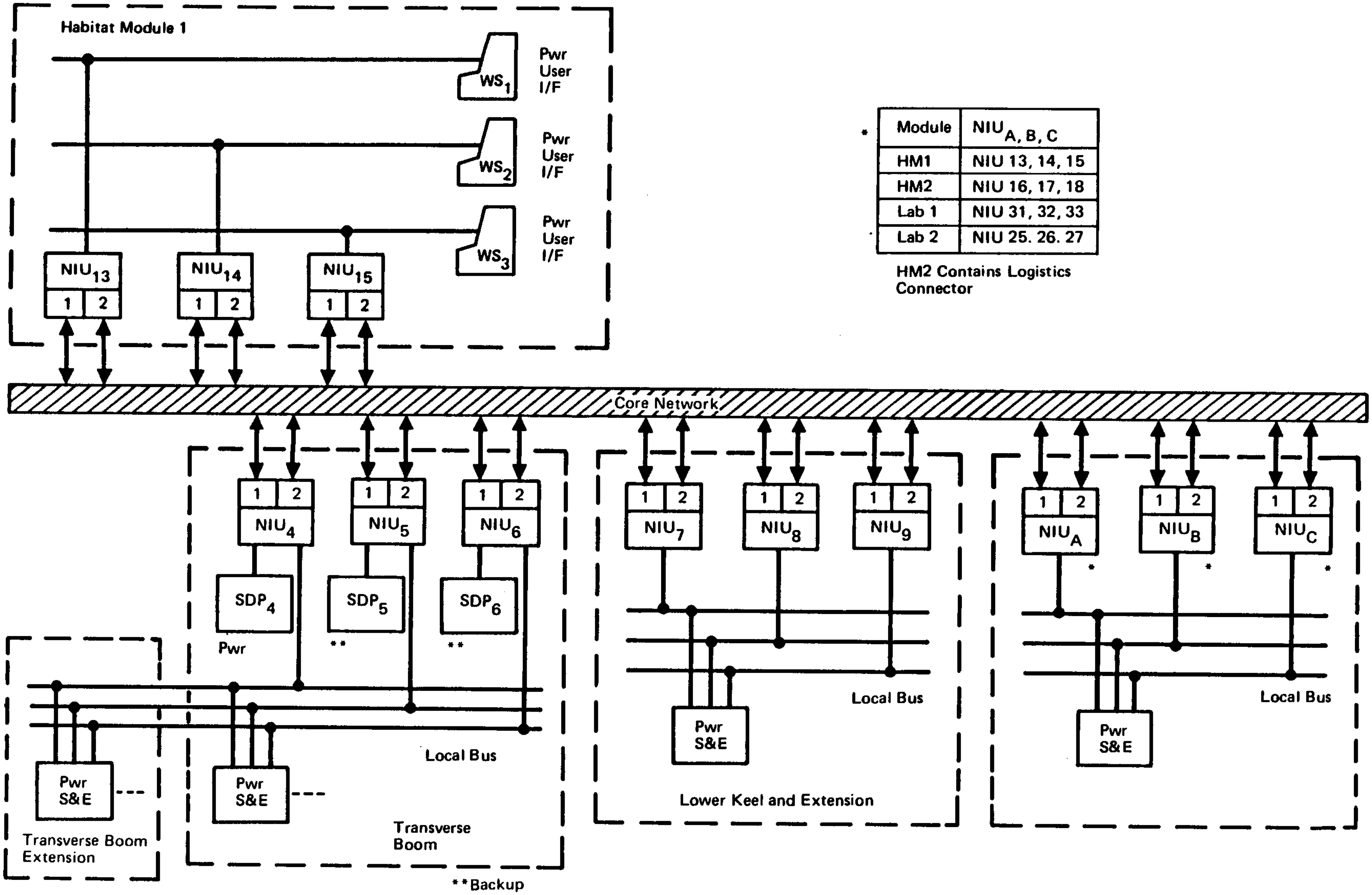
The thermal control subsystem is contained in memory configuration 2 and resides in SDP4 with preferred backups SDP5 and SDP6. Thermal control is distributed on the truss and in the pressurized modules. This subsystem shares local buses with the electrical power subsystem since these subsystems are similarly distributed. The local bus on the NIU's in HM2 have a connector to the logistics module in the event thermal control is required in this module.

6.6.1.8 Environmental Control and Life Support Subsystem (Figure 6.6-10)

ECLSS is contained in memory configuration 3 and resides in SDP7 (HM1 triad 1) with a local preferred spare (SDP9) and safe haven spare SDP11 in HM2 triad 1. The ECLSS sensors and effectors are distributed in the pressurized modules and share local buses with power and thermal subsystems. The preferred spare in the HM1 traid 1 is shared with memory configuration 4. Communication with the logistics module can be on a local bus connected to the HM2 local bus.

6.6.1.9 Traffic Control (Figure 6.6-11)

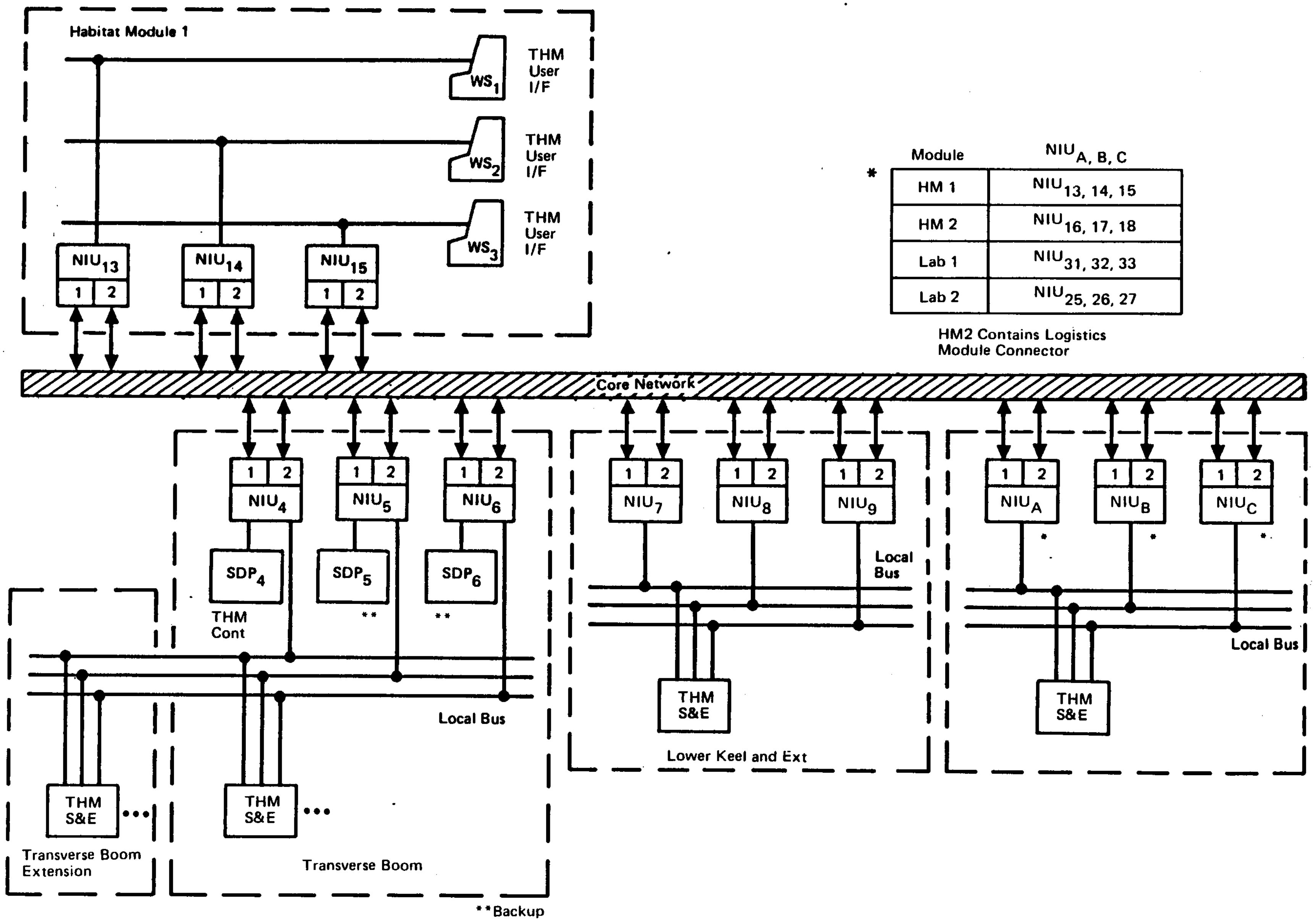
The traffic control function is contained in memory configuration 1 and resides in SDP1 and is backed up by preferred spares SDP2 and SDP3. Traffic control has no sensors or effectors but inputs from other subsystems and sends commands to those subsystems on the core network. User interface is through any of the core workstations.



Module	NIU$_{A, B, C}$
HM1	NIU 13, 14, 15
HM2	NIU 16, 17, 18
Lab 1	NIU 31, 32, 33
Lab 2	NIU 25. 26. 27

HM2 Contains Logistics Connector

Figure 6.6-8. Electrical Power Subsystem

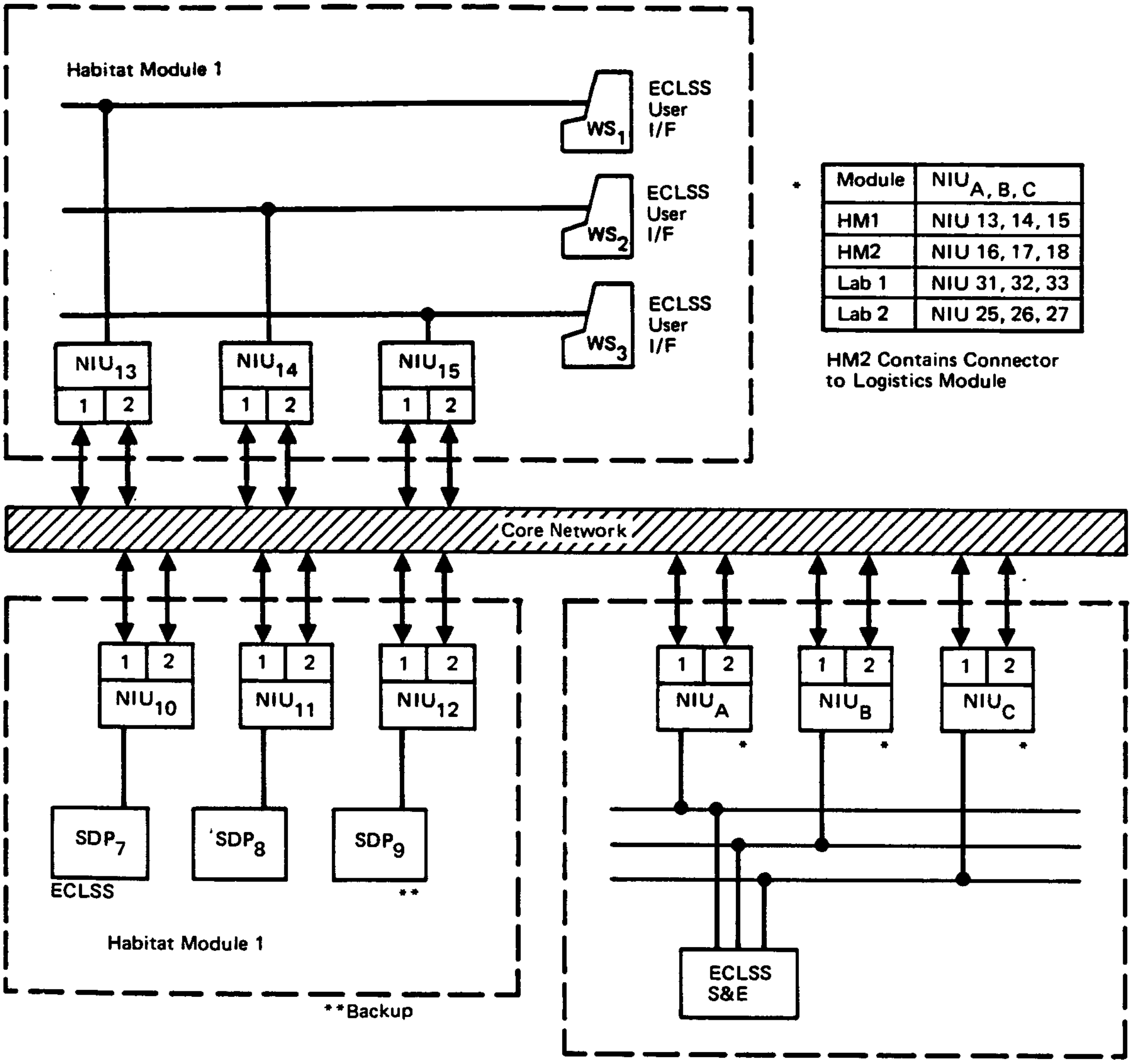


*

Module	NIU$_{A, B, C}$
HM 1	NIU$_{13, 14, 15}$
HM 2	NIU$_{16, 17, 18}$
Lab 1	NIU$_{31, 32, 33}$
Lab 2	NIU$_{25, 26, 27}$

HM2 Contains Logistics Module Connector

Figure 6.6-9. Thermal Control Subsystem



*

Module	$NIU_{A, B, C}$
HM1	NIU 13, 14, 15
HM2	NIU 16, 17, 18
Lab 1	NIU 31, 32, 33
Lab 2	NIU 25, 26, 27

HM2 Contains Connector to Logistics Module

Figure 6.6-10. Environmental Control and Life Support Subsystem

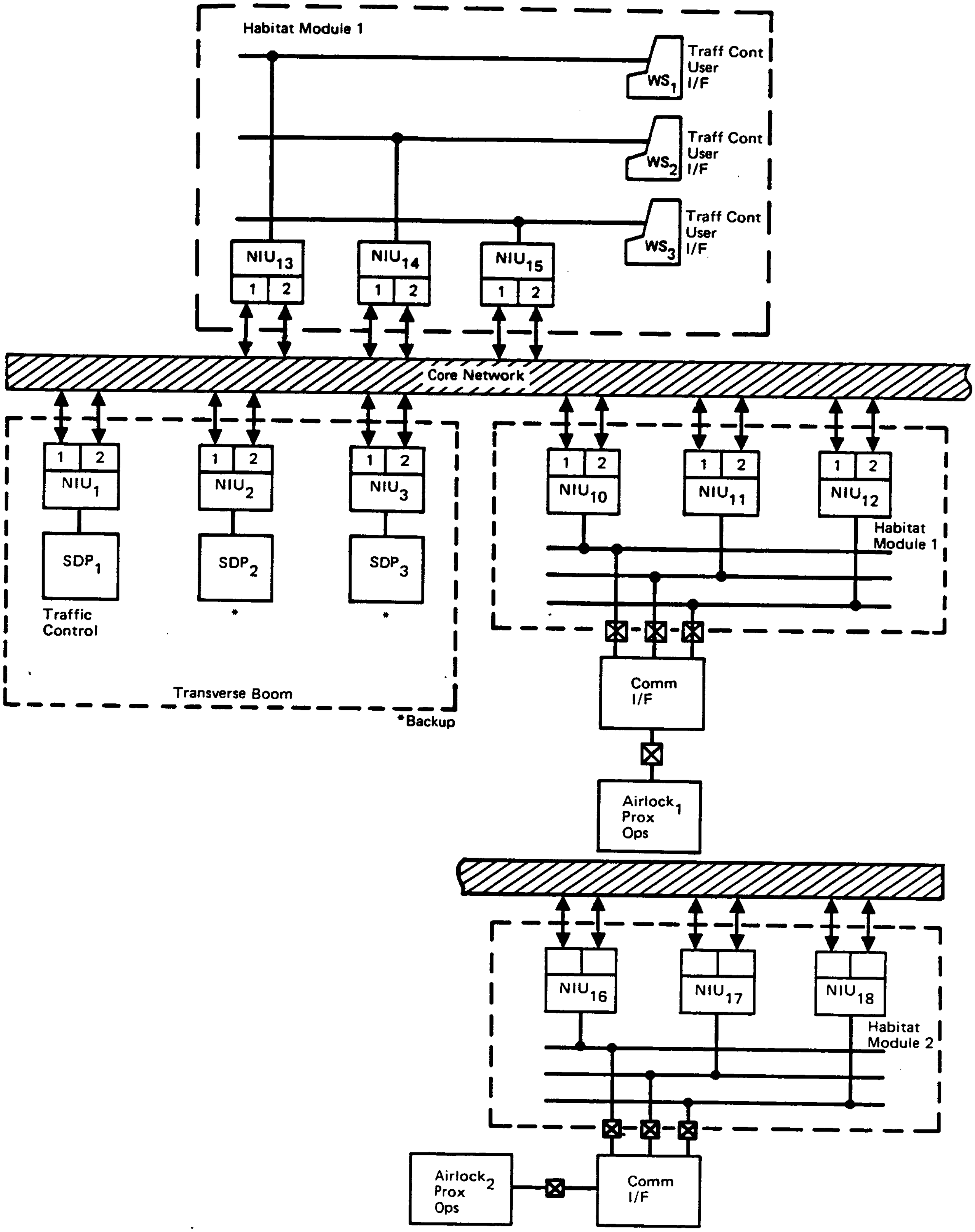


Figure 6.6-11. Traffic Control

6.6.1.10 Facility Management Subsystem (Figure 6.6-12)

The facility management subsystem is contained in memory configuration 4 and resides in SDP8 with preferred backup SDP9 and safe haven backup in SDP12 (HM2 triad 1). Facility management has no sensors or effectors but receives inputs from other subsystems and sends commands to those subsystems on the core network. User interface is through any of the core workstations.

6.6.1.11 Structures and Mechanisms Subsystem (Figure 6.6-13)

The structures and mechanisms subsystem is contained in memory configuration 3 and resides in SDP7 of HM1 triad 1. The preferred backup spare is SDP9 and the safe haven backup is SDP11 in HM2 triad 1. This subsystem has alignment and mode sensors distributed on the truss and modules.

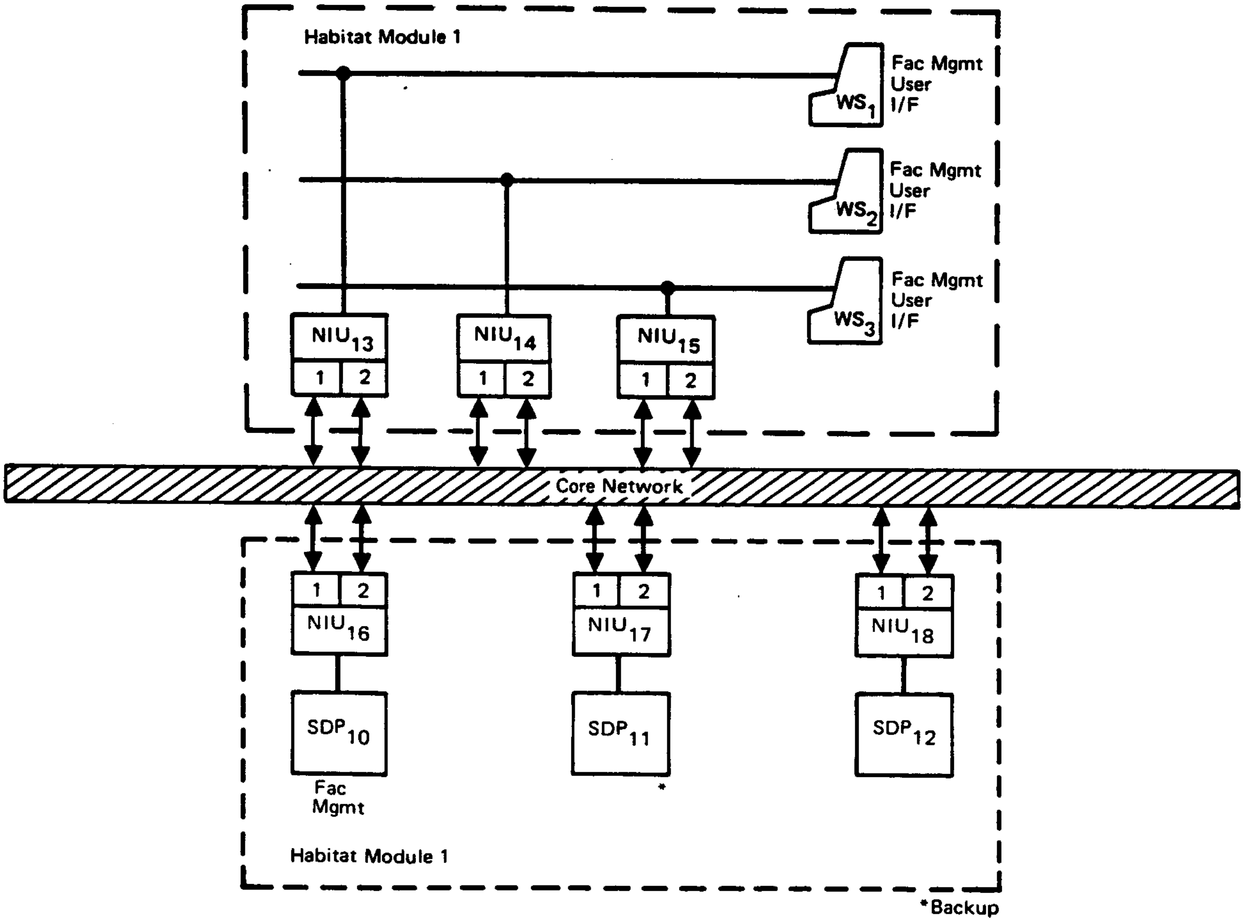
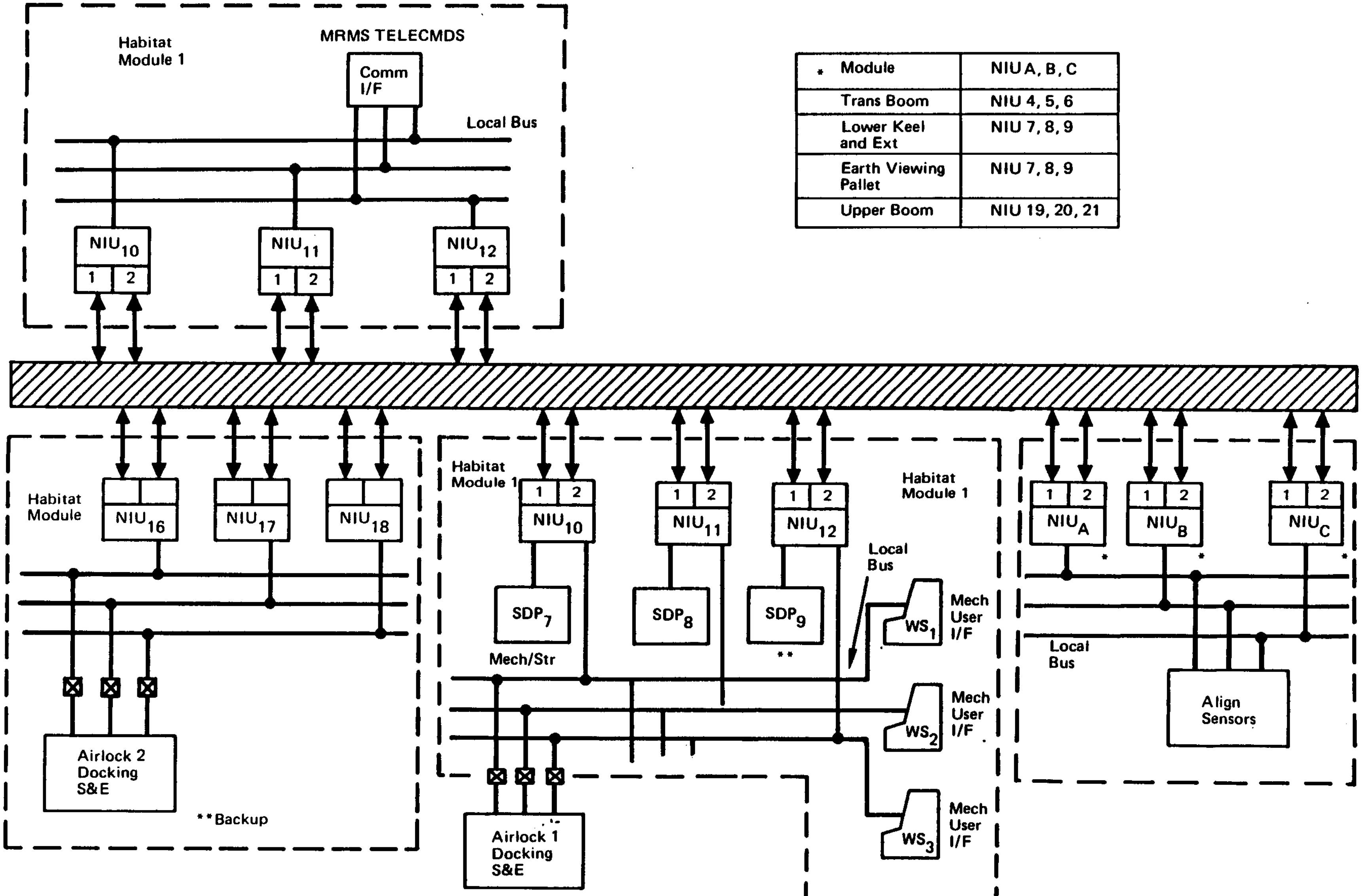


Figure 6.6-12. Facility Management Subsystem



* Module	NIU A, B, C
Trans Boom	NIU 4, 5, 6
Lower Keel and Ext	NIU 7, 8, 9
Earth Viewing Pallet	NIU 7, 8, 9
Upper Boom	NIU 19, 20, 21

Figure 6.6-13. Structures/Mechanisms Subsystems

Interface to the airlock modules is across local bus connectors from the HM1 and HM2 modules. The control of the MRMS is through telecommands transmitted to the communications system interface. User interface is through any of the core workstations. Manual control of the MRMS is through the fixed workstation which is configured for MRMS manual inputs.

6.6.1.12 Crew Systems/Subsystems (Figure 6.6-14)

The crew systems subsystem is contained in memory configuration 3 and resides in SDP7 of HM1 triad 1. The preferred backup is SDP9 (also in HM1 triad 1) and safe haven backup SDP11 in HM2 triad 1. Crew system sensors and effectors are distributed in HM1 and HM2. User interface is through any of the core workstations.

6.6.1.13 Payload Support (Figure 6.6-15)

The PL support for return link telemetry and data base services are contained in memory configuration 8 which is resident in SDP15 (LAB2) with backup SDP16 (LAB1). SDP15 interfaces with PL mass storage devices and the communication interface to provide the return link telemetry service. Buffering is accomplished on the PL mass storage. Forward link PL services originate in the core network in SDP4 (memory configuration 2). The telecommand interface service delivers telecommands to destination tasks in the PL network across a bridge.

PL programs can be uploaded to the mass storage devices and execution initiated in SDP13 and 14 in LAB2 and SDP16 in LAB1. A PL workstation is also provided in LAB1. Communication with earth viewing experiments is accomplished using NIU 36, 37, 38 on the earth viewing pallet. Communication with upper boom experiments is through NIU 22, 23, 24. Experiments internal to the lab modules communicate using NIU 28, 29, 30, 31 and 32.

Ancillary data can be obtained by communicating with the core operational data base across the bridge.

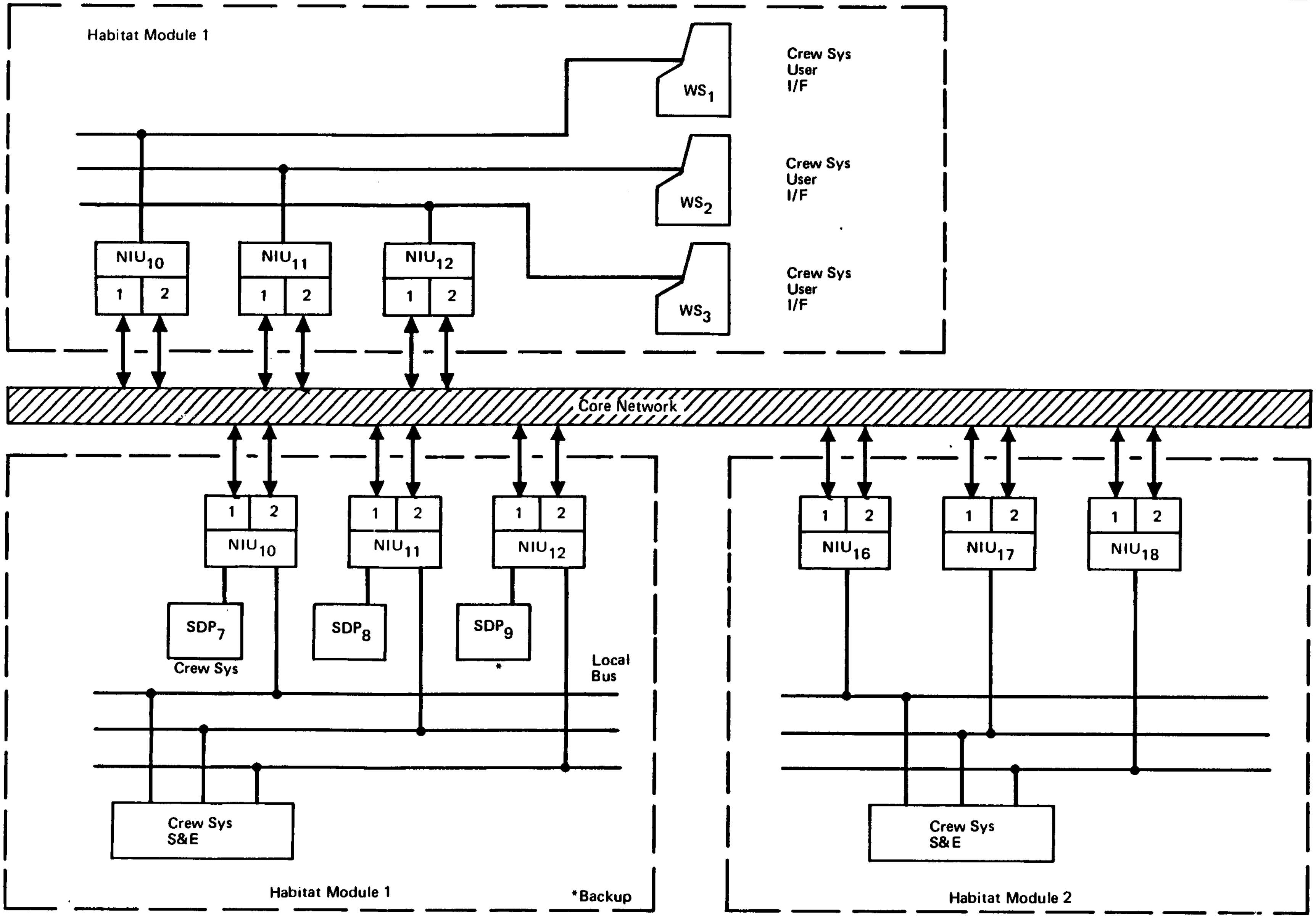


Figure 6.6-14 Crew Systems Subsystem

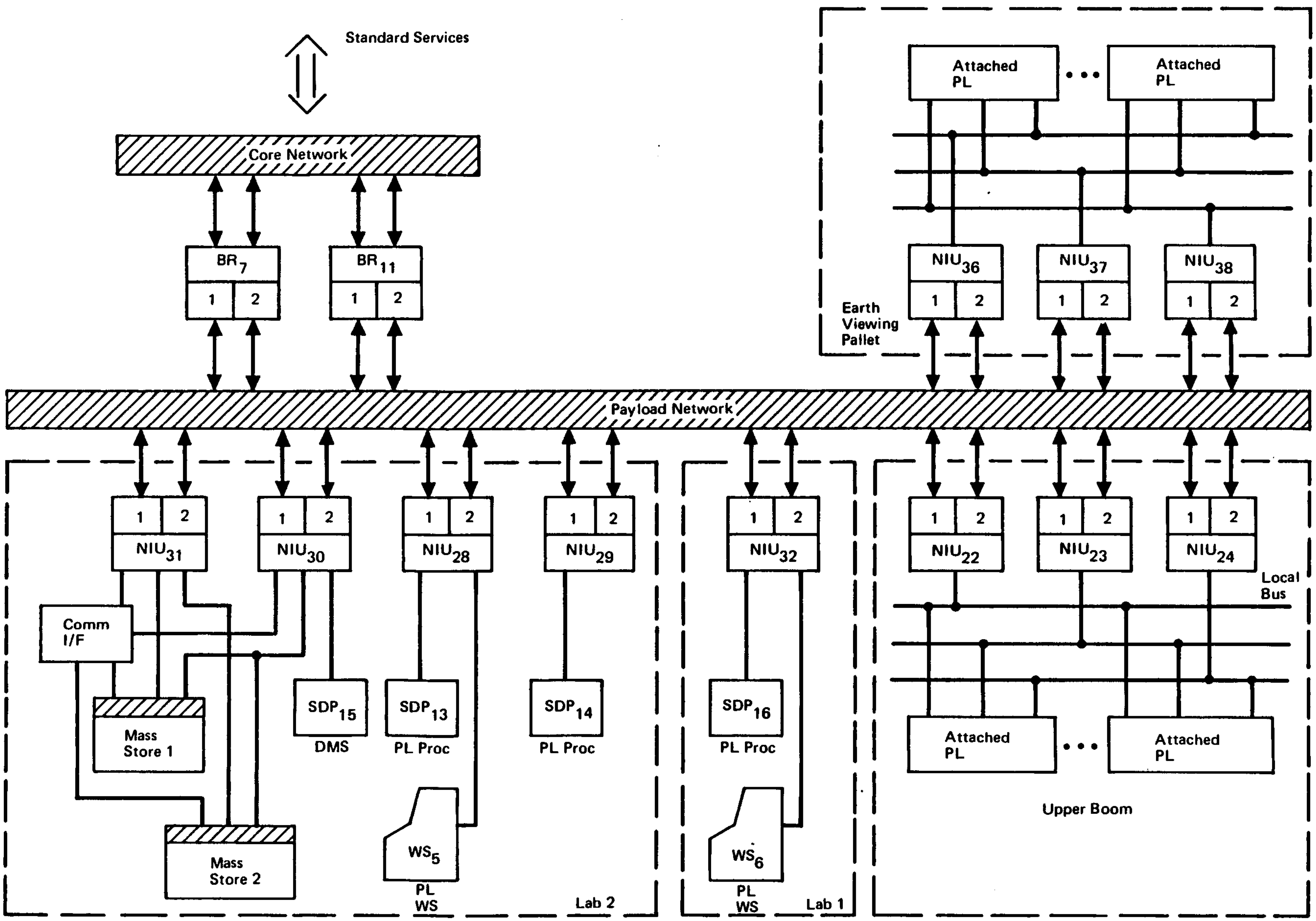


Figure 6.6-15. Payload Support

6.6.2 Network Architecture

6.6.2.1 Topology

The "strawman" onboard local area network configuration consists of two major network partitions isolating PL/EXP traffic from core traffic. There is a bridge between the network partitions to support core and PL/EXP data exchange. Ancillary data and forward link telemetry flow from the core network to the PL/EXP network across the bridge. The topology of the network is a group of interconnected dual redundant token rings each with a multi-port ring concentrator. The physical distribution of the network elements is shown in Figure 6.6-16. The network topology is shown in Figure 6.6-17 a and b. Dual redundancy exists in the bridges, ring concentrators and optic-to-optic connectors.

6.6.2.2 Access Protocol

A separate token circulates in each ring. A bypass capability is provided at the ring concentrator for inactive or failed ports. Port moding allows individual ring ports to switch between the two redundant rings.

The network access is through a priority token circulating within each ring. The message priority is assigned to periodic traffic on a rate monotonic basis (higher rate has higher priority). Aperiodic traffic has lowest priority.

6.6.2.3 Network Operating System (NOS)

The NOS supports the interface to the network for object oriented task-to-task message passing. It is a subset of the overall onboard Distributed Operating System (DOS) described in section 6.4.4 and consists of the functions corresponding to layers 1 through 4 of the ISO/OSI model. The NOS resides in the NIU's. A brief summary of the applicable functions in these layers is shown below in tabular form.

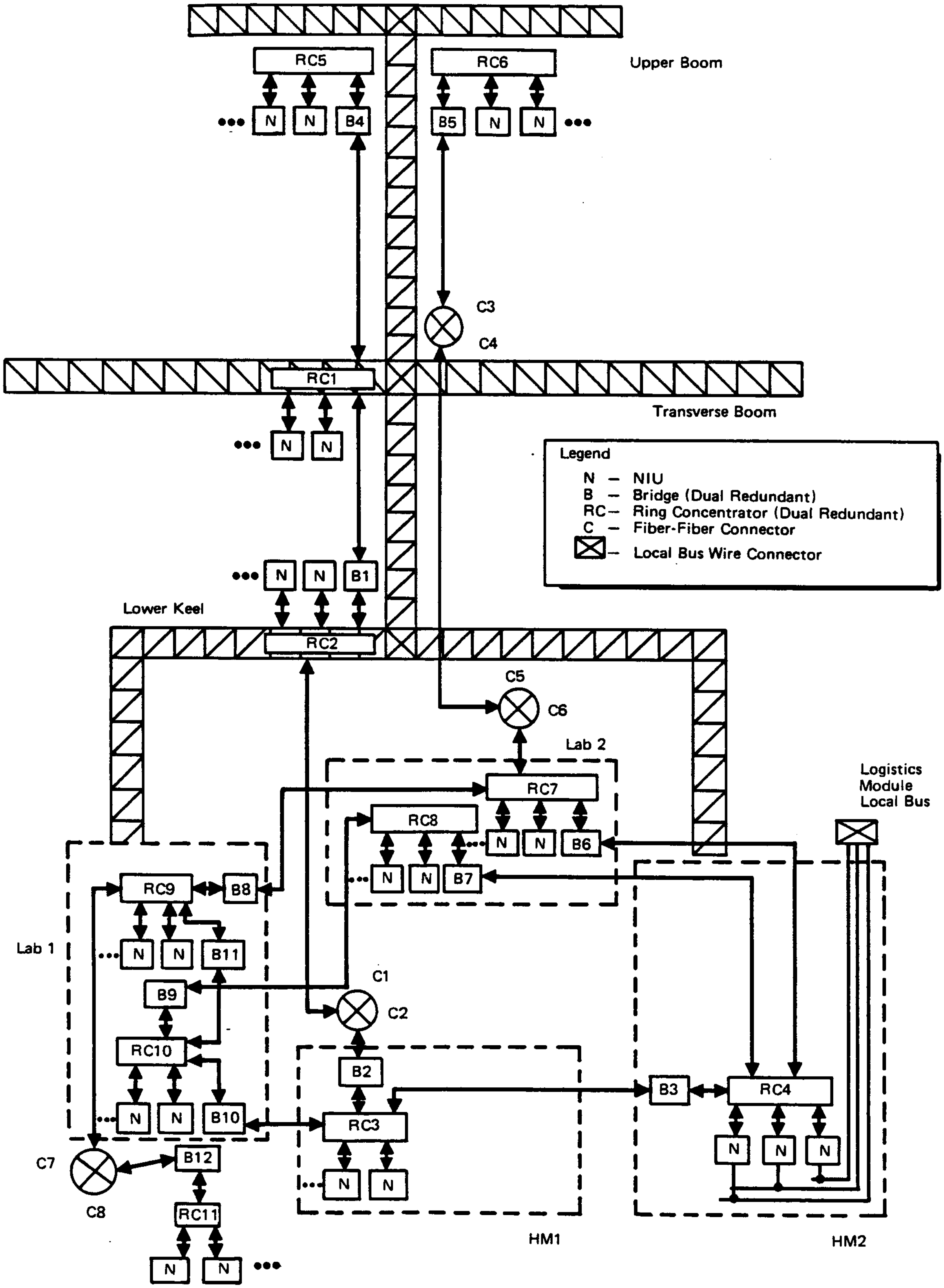


Figure 6.6-16. Network Physical Distribution

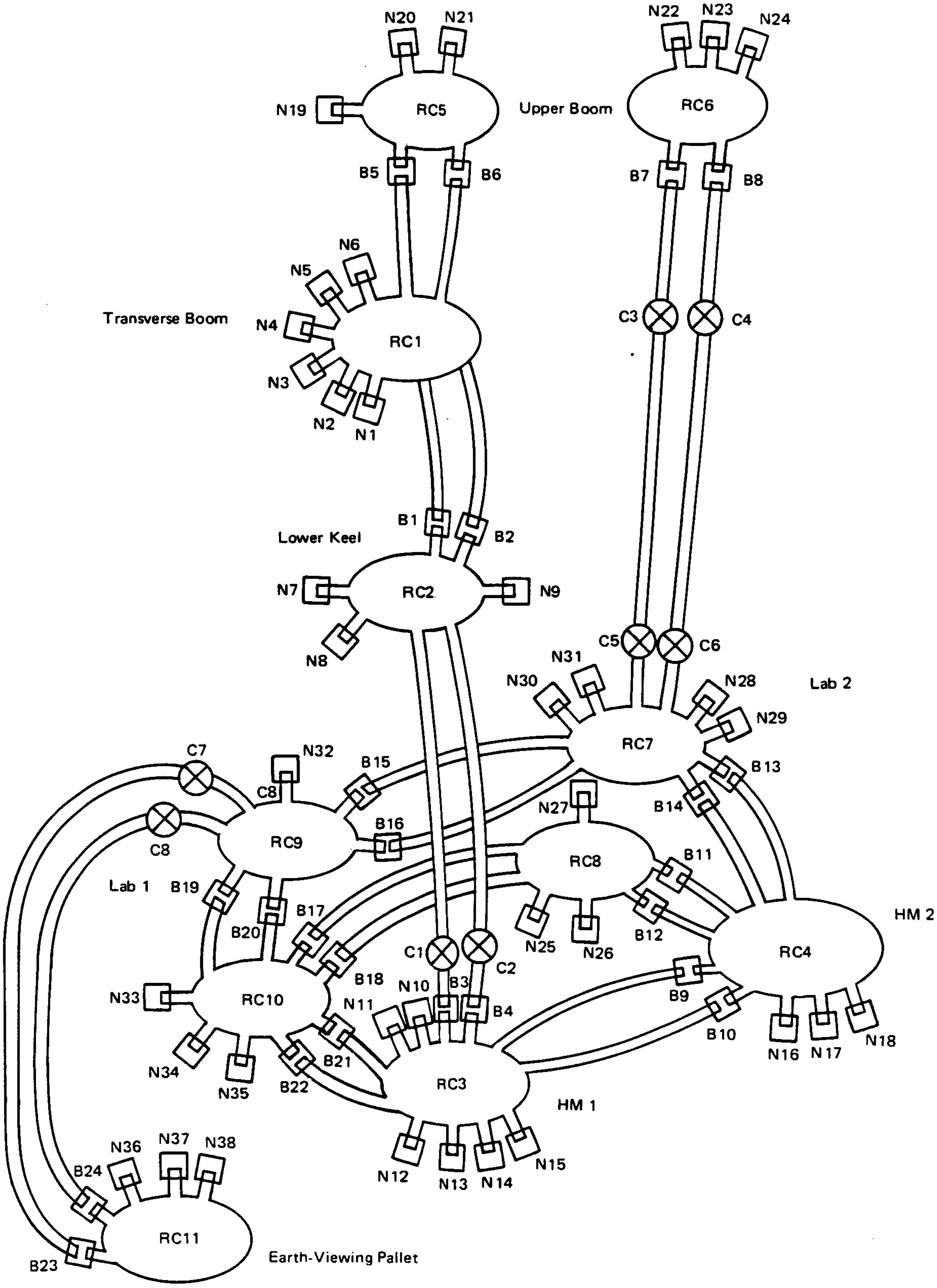


Figure 6.6-17A. Network Topology Backbone

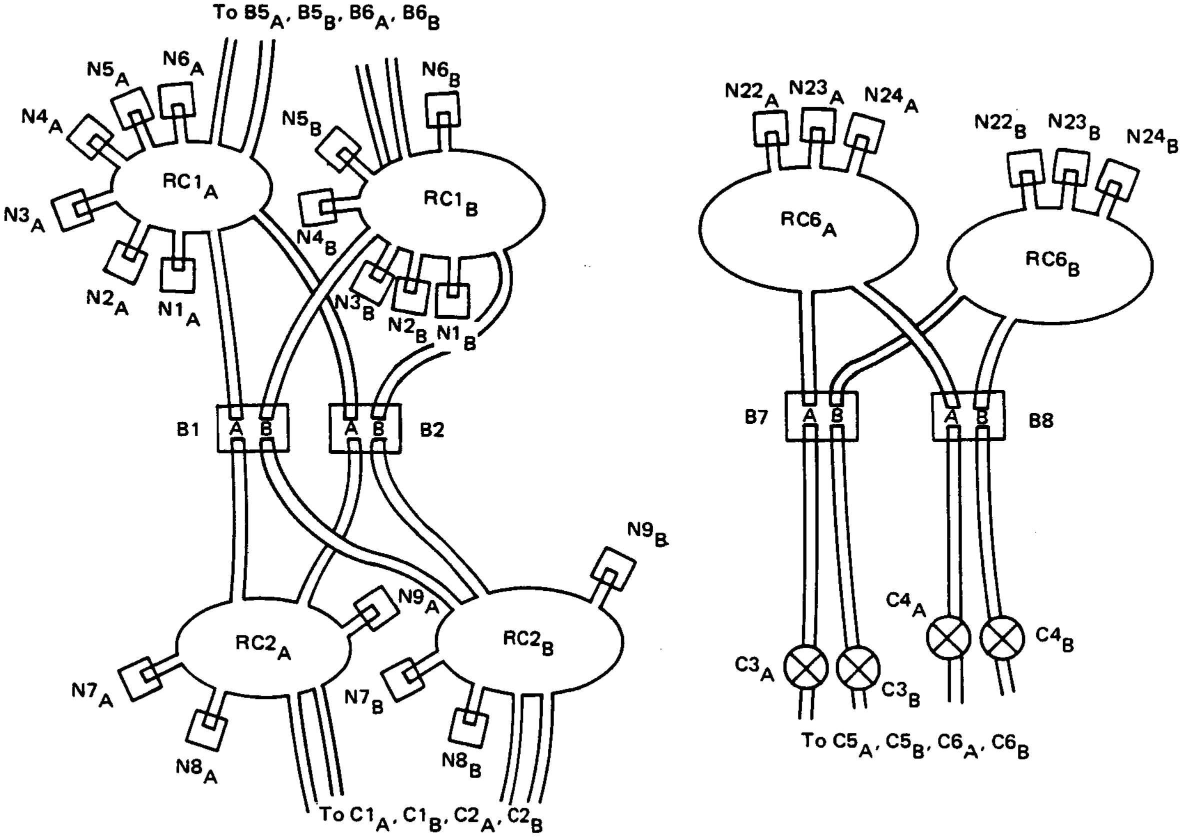


Figure 6.6-17b. Backbone Redundancy Example

1. PHYSICAL LAYER
   - Handles voltages and electrical pulses
   - Handles cables, connectors, and components (interfaces to media)
   - Handles collision detection for CSMA/CD access method

2. DATA-LINK LAYER
   - Reliable transfer of data across a single link
   - Adds flags to indicate beginnings and ends of messages
   - Adds error-checking algorithms (CRC, ...)
   - Makes sure data are not mistaken for flags (transparency mechanism)
   - Provides access methods for local-area networks

3. NETWORK LAYER
   - Sets up routes for packets to travel
   - Addresses network modes on the route through which the packets travel
   - May disassemble transport messages into packets and reassemble them at the destination.
   - Sends control messages to peer layers about own status
   - Congestion control (regulates flooding within the network)
   - Recognizes message priorities and sends messages in proper order
   - Internetworking (both connection-oriented and connectionless)

4. TRANSPORT LAYER
   - Reliable end-to-end data transfer (connection service)
   - Multiplex end-user addresses onto network
   - End-to-end error detection and recovery
   - Flow control
   - Monitoring quality of service
   - Possibly disassemblies and reassembles session messages

6.6.3 Major Architecture Issue

One major feature of the presented strawman architecture needs special discussion. In the strawman architecture it is possible to communicate with any NIU local bus from any SDP on the network. The reference configuration does not allow access to all the local buses from any SDP. Some SDP's have dedicated local buses that are controlled by that SDP. The flow of communication in the strawman architecture is shown in Figure 6.6-18a and the reference configuration is shown in Figure 6.6-18b.

In both the strawman architecture and reference configuration architecture the interface between NIU and SDP is similar. Both architectures also have an interface to local buses through ports on the back-end of the NIU. This is for sensor and effector (S&E) communication.The I/O programs to accomplish this S&E I/O must reside in the NIU and these programs are unique to the configuration of the back-end S&E configuration.

The key differences in the architectures are in the way local buses are communicated with when the NIU and SDP are co-located. The ref. config. allows for a sensor and effector (S&E) interface to the SDP. This means that only this class of SDP can be used to perform the functions associated with the S&E attached to the SDP local buses. No other SDP's can backup this function in case of failure because communication is through the failed SDP. The spare SDP's with S&E interface back-ends still could be used for other functions only requiring communication via the network.

The strawman architecture has no S&E interface to the SDP. The strawman architecture has a configuration with both an SDP and local bus on the same NIU back-end to accomplish a measure of commonality for SDP's.

In Figure 6.6-18a, the configuration with an SDP and local bus on the NIU back-end is shown. If the co-located SDP's request data from the local bus, the communication must be through the NIU. The SDP does not know if the S&E's are co-located or remotely distributed on some other NIU back-end. The local NIU knows that the S&E I/O programs being addressed by the SDP are co-located and does not use the layered protocol (i.e., network communication) but just

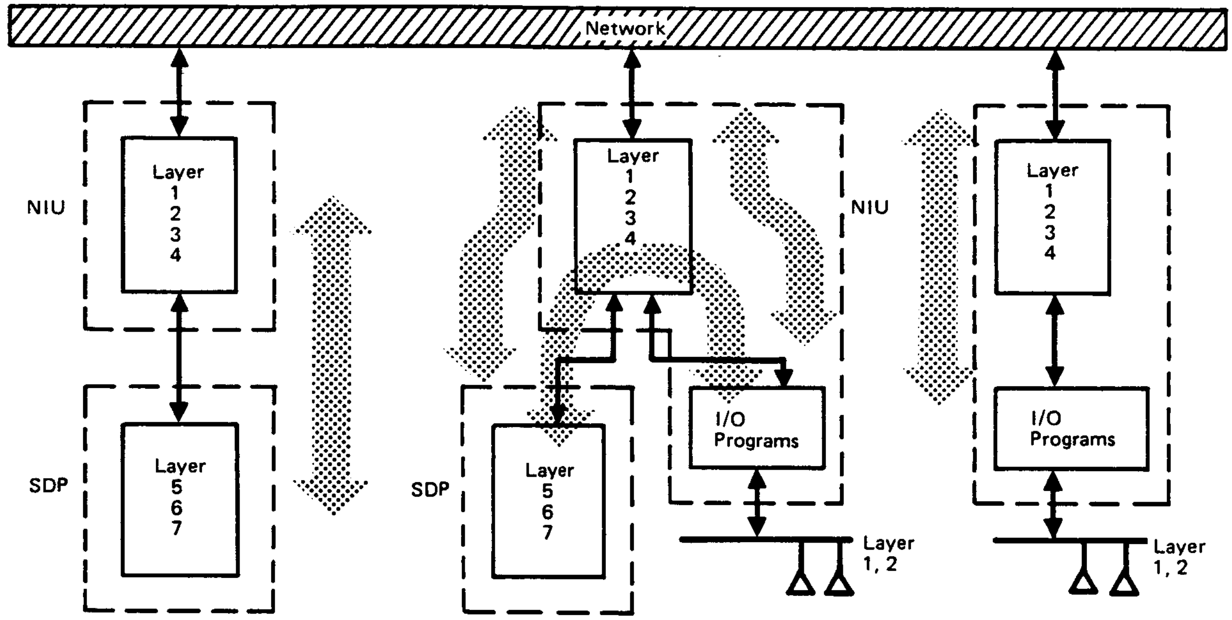


Figure 6.6-18a. NIU Alternative 1 (Recommended Architecture)

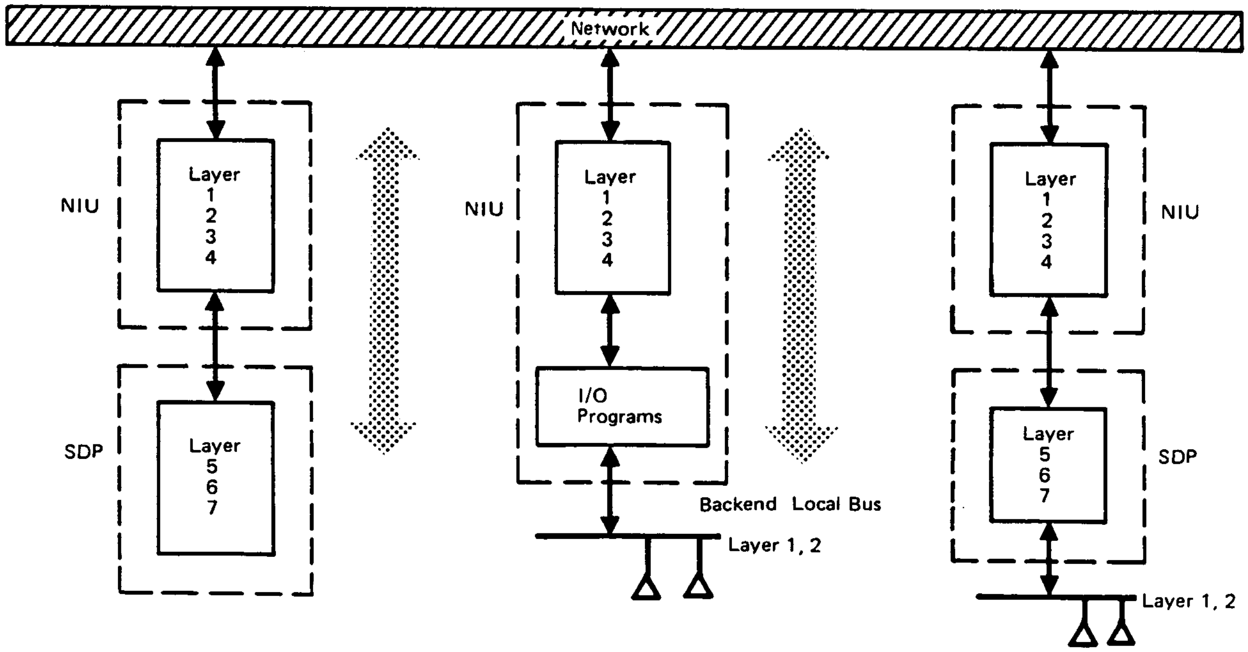


Figure 6.6-18b. NIU Alternative 2 (Ref Configuration)

triggers the local I/O programs directly. This architecture allows any SDP in the network to assume any function, a powerful option when dealing with fault tolerant strategies.

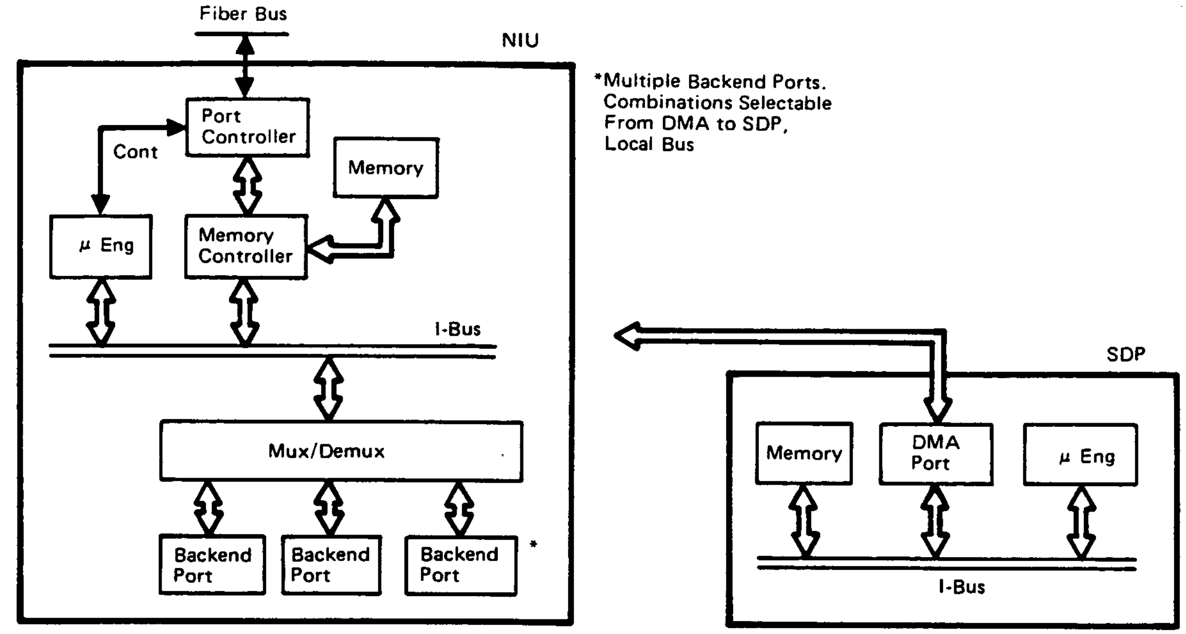
The hardware to accomplish either architecture is presented in Figure 6.6-19 and Figure 6.6-20. The reference configuration requires an S&E interface for the SDP's with local buses which is equivalent to the MUX/DEMUX function on the back-end of the NIU in the strawman architecture. Both architectures support options for the back-end of the NIU's. The selection of the strawman architecture can have multiple options resident in the same NIU but the reference configuration always has a single back-end port.

Table 6.6-4 summarizes the comparison of the two architectures. The strawman architecture is a distributed system which minimizes hardware by allowing for full distribution of functions while sacrificing little in functional autonomy. Autonomy will be functional instead of physical. The table hardware count and software size is expected to be similar in either architecture which leads to the recommendation.

6.7 Buildup

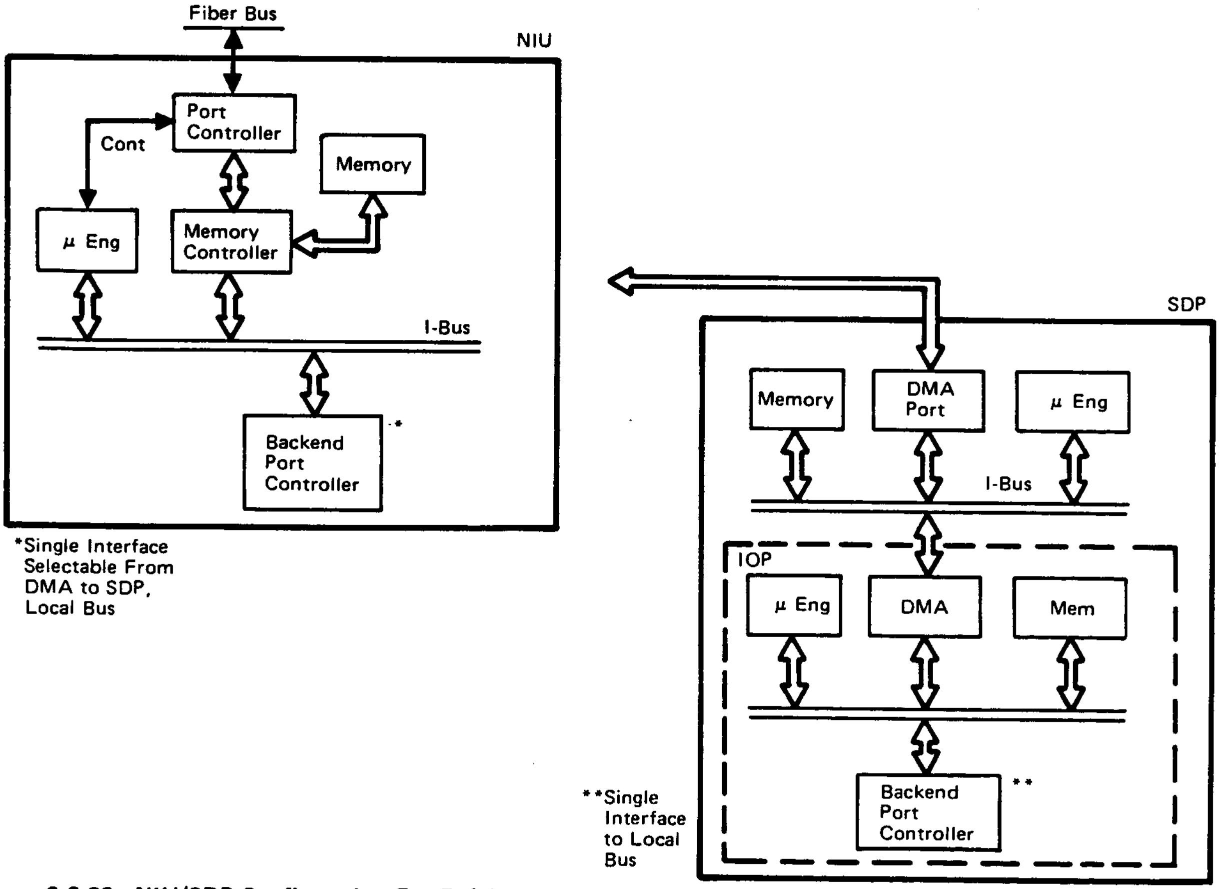
The buildup of the onboard SSDS is partitioned into 7 segments that are integrated into the 7 launch packages. Each segment is ground tested after integration with the launch package. The DMS launch segments are then placed in an unpowered state for launch. The SDP and NIU programs for flight 1 and 2 are stored on non-volatile memory resident within the SDP and NIU. The buildup of capabilities and onboard SSDS elements on a flight basis is presented in Table 6.7-1.

For the buildup sequence discussed in the following subsections reference back to Figures 6.6-1 and 6.6-2 will be required to identify the physical locations of the onboard SSDS elements discussed.



*Multiple Backend Ports. Combinations Selectable From DMA to SDP, Local Bus

Figure 6.6-19. NIU/SDP Configuration For Recommended Architecture



*Single Interface Selectable From DMA to SDP, Local Bus

**Single Interface to Local Bus

Figure 6.6-20. NIU/SDP Configuration For Ref Configuration Architecture

Table 6.6-4

Architecture Comparisons

COMPONENTS & FEATURES	REFERENCE CONFIGURATION	STRAWMAN ARCHITECTURE
SDP Hardware	More (needs IOP)	Less (doesn't need IOP)
NIU Hardware	Less in any one unit but same back-end options	More in any one unit but same back-end options
SDP Software	More complex (I/O Programs)	Less complex (no I/O programs)
NIU Software	Simpler	More complex (I/O programs, NOS bypass to local buses
Fault Tolerance Options	Less depth in sparing (could use same system S/W failure detection)	More depth in sparing (uses system S/W failure detection)
Subsystem Autonomy	Physical	Functional
Total Hardware	More (dedicated hardware)	Less (combine functions)

The MRMS is activated and checked out for subsequent use in constructing the Space Station. An operational scenario requires the MRMS software to be located in an SDP or MPAC located in the orbiter with a hand controller. An RF link from the orbiter to the MRMS antenna provides the media for video and crew commands. The MRMS contains the electronics and mechanisms for arm movement. The software can be recovered for subsequent migration to HM1 Triad 1 with backup in SDP11. The HM2 operations center will be the primary MRMS control station with a back up in HM1.

6.7.1 Flight 1

On flight 1 the transverse boom is delivered to Space and deployed. The flight 1 onboard SSDS configuration consists of 6 SDP's 6 NIU's, 3 master

TABLE 6.7-1
BUILD-UP

FLIGHT NUMBER	DMS ELEMENTS DELIVERED	ADDED FUNCTIONAL SUPPORT	ISSUES
1	SDP 1,2,3,4,5,6 NIU 1,2,3,4,5,6 RC 1 MTU 1,2,3	ATT CONT NAV COM I/F THM TRANSVERSE PWR BOOM	ACTIVATION MASS MEMORY DMS BUS INTEGRATION ON TRUSS MRMS CHECKOUT COMM INTERFACE
2	NIU 7,8,9 RC 2 B 1	RADIATOR CONT	MRMS CONTROL INTEGRATION OF PL NETWORK ON TRUSS
3	SDP 7,8,9 WS 1,2,3 NIU 10,11,12,13 14,15 RC3 B2 MMU 1	ECLSS HM1 PWR THM ODB PROX OPS CREW SYS AIRLOCKS MECH	AIRLOCK INTERFACE WORK STN. NIU/LOCAL BUS PORTS COMM I/F TO MASS MEMORY WORK STN BUILD-UP (NEED 3) ASSEMBLY OF FIBER-TO-FIBER CONNECTORS
4	SDP 10,11,12 NIU 16,17,18,19 20,21,22,23,24 RC 4,5,6 B 3,4,5 MMU 2	GUID TRAFFIC CONT TRACKING OMV DEPLOY RCS LOWER MAG TORQUER KEEL PWR THM HM2 ECLSS PWR, THM, GPS UPPER BOOM	LOCAL BUS TO RCS AND MAG TORQUERS DIRECT GPS INTERFACE COMM I/F CHANGE FOR UPPER BOOM ADDITION
5	NONE	PWR,THM LOGISTICS ECLSS TRANSVERSE SOLAR BOOM ACT EXT	LOGISTICS MODULE INTERFACE
6	SDP 13,14,15 NIU 25,26,27,28 29,30,31 RC 7,8 B 6,7 WS 4,5 MMU 4,5	PWR THM ECLSS PL PROC PL UPPER BOOM DATA INTERFACE AL POINTING	
7	SDP 16 NIU 32,33,34,35 36,37,38 B 8,9,10,11,12 MMU 3	PWR THM LAB 2 ECLSS PL EARTH VIEWING PALLET INTERFACE	EARTH VIEWING PALLET REQUIREMENTS

timing units (MTU1,2,3) and a ring concentrator (RC1). This initial portion of the onboard SSDS is physically located on the Attitude Control Assembly (ACA). Subsystem functions supported are attitude determination, attitude control and semi-autonomous navigation (ground update).

The flight 1 onboard SSDS has attitude control and navigation resident in one SDP of a triad with 2 preferred spares. The other triad has electrical power, thermal control and the communication interface programs for telemetry.

6.7.2 Flight 2

On flight 2 the lower keel and lower keel extensions are attached. The onboard SSDS elements on this package are 3 NIU's, a ring concentrator (RC2) and a bridge (B1) to connect RC1 and RC2. The added NIU's are on the lower keel extension and provide communication to the radiator controls (and eventually the RCS). This NIU's also support lower keel electrical power and thermal control. Control of the MRMS is through telecommands originating in the DMS and sent through RF communication channel.

6.7.3 Flight 3

On flight 3 the first habitat module (HM1) and the airlocks (AL1, AL2) are delivered and attached. The onboard SSDS elements in this package are 3 SDP's, 3 work stations (WS's), 6 NIU's, a mass storage unit (MMU6), a ring concentrator (RC3) and a bridge (B2). This configuration supports the ECLSS subsystem and extensions to electrical power and thermal control. The operational data base can now use the external mass storage unit (previously it was using local memory). The crew systems and mechanisms associated with the airlocks are now supported, as well as any proximity tracking for approaching the airlocks. The core network optical fibers are connected across the HM1 bulkhead to the internal bridge (B2) which connects to RC3. Work Stations for crew interface are available at multiple stations.

6.7.4 Flight 4

On flight 4 the upper boom is assembled and habitat module 2 (HM2) is attached. The onboard SSDS elements in this package are divided into the upper boom package and HM2 package. In the upper boom package there are 6 NIU's (3 core network and 3 PL network), 2 bridges (B4, B5) and 2 ring concentrators (RC5, RC6). The core network elements on the upper boom support remote electrical power and thermal control as well as communication to the GPS and antennaes. The other elements are put in place for PL support once the PL network is completed (flight 6).

The habitat module 2 had 3 SDP's, 3 NIU's, a bridge (B3) and ring concentrator (RC4). These SDP's have the facility management memory configuration. The NIU's support remote sensing and control by ECLSS, electrical power and thermal control. A local bus connector is also on these NIU's for the logistics module. The core network is extended by bringing the optical fiber into HM2 and connecting to B3.

6.7.5 Flight 5

On flight 5 the transverse boom port and starboard extensions are attached. No additional onboard SSDS elements are delivered on this flight. Connectors on local buses already attached NIU1,2,3 support electrical power and thermal control on the extensions as well as the solar panel actuators. The logistics module is also attached. Communication to the logistics module is on a local bus connected from HM2.

6.7.6 Flight 6

On flight 6 labratory module 2 (LM2) is attached. The onboard SSDS elements in this package are 3 SDP's, 7 NIU's, 2 mass memory units (MMU4,5), 2 ring concentrators (RC7,8) and 2 bridges (B6,7) and 2 work stations (WS4,5). The PC network is connected across the LM2 bulkhead and connected to RC7. The core network is extended by bringing the optical fiber into LM2 and connecting to B7. The core and PL networks are connected across B6 in LM2.

Payload processing is now supported in the SDP's as well as a PL operational data base. The Pl ODB utilizes two MMU's resident in LAB 2 on the PL network.

6.7.6 Flight 7

On flight 7 the laboratory module 1 (LM1) is attached. The onboard SSDS elements in this package are 1 SDP, 7 NIU's, 1 workstation (WS6), 1 mass memory unit (MMU3), three ring concentrators (RC9,10,11) and 5 bridges (B8,9,10,11,12). The remote communication to core functions such as ECLSS, electrical power and thermal control are supported on local buses. The SDP and workstation increase the PL processing capacity.

The PL network is extended across a bulkhead fiber-to-fiber connector to reach the NIU's on the earth viewing pallet.

6.8 Memory and Processing Function Sizing Summary

The data in table 6.8 provide summaries of the memory and processing loads for the Task 1 onboard functions grouped in terms of the Reference Configuration Subsystem Names.

Table 6.8

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

ELECTRICAL POWER

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.1 OPERATE POWER SYSTEM						
4.2.1.1 Eval. Array Per.	5	12	18	48	2.5	10
4.2.1.2 Conf. Pw. Dist.	50	150	80	300	28	50
4.2.1.3 Power Source Mgmt.	30	100	60	200	19	35
4.2.1.4 Array Deployment	1	2	4	8	0.5	2
4.2.1.5 Project Energy Avail.	15	6	15	6	1.2	1.2
4.2.1.6 Device Mgmt	50	2	100	4	25	50
4.2.1.7 Cmmd I/F Proc.	15	5	15	5	small	small
	166	277	292	571	76.2	148.2
	---------		---------			
TOTALS	443		863			

THERMAL CONTROL SYSTEM

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.2 OPERATE THERMAL CONTROL SYSTEM						
4.2.2.1 Manage T. Load	1	1	1	2.5	10	15
4.2.2.2 Thermal Device Mgmt	50	2	100	4	0.5	0.7
4.2.2.3 Project Thermal Cop.	1	1	1	2.5	0.33	0.33
4.2.2.4 Cmmd I/F Proc.	15	5	15	5	small	small
	67	9	117	14	10.9	16.1
	---------		---------			
TOTALS	76		131			

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
GN&C (Page 1 of 3)

PROPULSION

Contains no Task 1 Functions: No Software Functions

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.1 NAV						
4.1.1.1 Spacecraft Orb. Det.	20	15	30	17	20	22
4.1.1.2 Const. State/Orb Det.	50	40	75	80	12.5	25
4.1.1.3 Determine Ephemerides (Sun, Moon, etc.)	2	4	3	5	0.02	.03
4.1.1.4 Attitude Det.	53	20	60	22	10	12
4.1.1.5 Nav State Propag.	20	4	25	5	5	5.5
4.1.1.6 Device Mgmt	30	20	40	25	15	20
4.1.1.7 Commd I/F Proc.	10	8	12	9	4	5
	185	116	245	163	66.6	89.6
	301		408			
4.1.2 GUIDANCE						
4.1.2.1 Reboost/Reentry Targ.	20	5	25	6	2	2.5
4.1.2.2 Maneuver Coord.	18	12	30	20	0.5	0.9
4.1.2.3 Collision Check	20	10	25	12	0.83	1.0
4.1.2.4 Reboost/Maneuver	10	4	15	06	5	6.0
4.1.2.5 Tether Control	-	-	15	4	-	0.1
4.1.2.6 Det. Pntg Mt. Cont.	5	1	7	1.5	5	7
4.1.2.7 Device Mgmt.	4	1	5	02	0.1	0.2
4.1.2.8 Cmmd Interface Proc.	20	5	25	07	5	7
	97	38	147	58.5	18.5	24.7
	135		205.5			

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

GN&C (Page 2 of 3)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.3 ATTITUDE CONTROL						
4.1.3.1 Control Aft & Trans.	48	07	56.2	10.8	150	225
4.1.3.2 Gen. Attitude Cmmds	20	4	22	5	2	2.5
4.1.3.3 Momentum Mgmt	14	1.8	16	2.0	1.5	2.0
4.1.3.4 Pointing Mt. Control	21	4.0	26	6	5.0	7.0
4.1.3.5 Device Mgmt	15	4	20	6	5.0	6.0
4.1.3.6 Cmmd I/F Proc.	30	4	32	4.5	6.0	6.5
	148	24.8	172.2	34.3	169.5	249
	172.8		206.5			
4.1.4 TRAFFIC CONTROL						
4.1.4.1 Comp/Prop Const State	8	1	9	2	1	1
4.1.4.2 Manage Const. Orb Man	10	2	15	3	1.5	1.8
4.1.4.3 Sched. Deploy/Rendez.	5	1	6	2	0.1	0.15
4.1.4.4 Manage Rendezvous	5	0.5	9	1	0.05	0.07
4.1.4.5 Target Coll. Avoid.	5	1	7	2	small	small
4.1.4.6 Cmmd I/F Proc.	15	2	18	3	small	small
	48	7.5	64	13	2.7	3.0
	55.5		77			

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

GN&C (Page 3 of 3)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.5 TRACKING						
4.1.5.1 Long Range	40	5	50	6	5	6
4.1.5.2 Prox.	40	5	50	7	5	6
4.1.5.3 Object Cat. Main.	25	10	30	12	.01	.02
4.1.5.4 Tracking Data Cond.	15	2	20	4	5	6
4.1.5.5 Device Mgmt	20	5	25	7	0.5	0.6
4.1.5.6 Cmmd I/F Mgmt	20	15	25	18	4	5
	160	42	200	54	19.6	23.7
	202		254			
2.5.3.3 OTV Deployment/Ret.	N/A		5	10	small	small
			15			
2.5.4.3 OMV Deployment/Ret	3	8	5	10	small	small
	11		15			
GN&C TOTAL	878		1181		267	379

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

STRUCTURES/MECHANISMS

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.3 STRUCTURES & MECH SUPPT						
4.2.3.1 Mechanism Control	7	5	14	10	1	1.5
4.2.3.2 MRMS Ups	21	10	42	20	45	90
4.2.3.3 Manage Dock./Berth.	5	4	15	12	2	6
4.2.3.4 Device Mgmt	10	10	20	20	0.5	1
4.2.3.5 Cmmd I/F Proc	27	9	74	25	3	7.5
	70	38	165	87	51.5	106
TOTALS	108		252			

ECLS

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.4 ECLSS OPERATION						
4.2.4.1 Control Press/Atmos	4	5	4	5	0.02	0.02
4.2.4.2 Control Temp/Hum	4	5	4	5	0.02	0.02
4.2.4.3 Potable H_2O Mgmt	4	5	4	5	0.02	0.02
4.2.4.4 Grey Water Mgmt	4	5	4	5	0.02	0.02
4.2.4.5 Fire Det. & Control	4	5	4	5	0.02	0.02
4.2.4.6 Device Mgmt	50	2	50	4	16.7	16.7
4.2.4.7 Cmmd I/F Proc.	15	5	15	5	small	small
	85	32	85	34	16.8	16.8
TOTALS	117		119			

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
CREW SYSTEMS (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.3.1 HEALTH MAINTENANCE						
4.3.1.1 Crew Phys. Monitor	5	2	7	3	0.04	0.04
4.3.1.2 Medical Diag. Supt.	10	5	15	7	small	small
4.3.1.3 Treatment Supt.	5	3	7	5	0.02	0.03
4.3.1.4 Nutrition Anal.	6	6	8	8	small	small
4.3.1.5 Exercise Planner	10	5	15	7	small	small
4.3.1.6 Phys. Data Trans & Anal.	20	5	25	7	small	small
	56	26	77	37	0.07	0.08
	82		114			
4.3.3 HABITABILITY						
4.3.3.1 Recreation Services	4	4	8	8	small	small
4.3.3.2 Crew/Grd Comm	0.4	0.4	1	0.8	small	small
4.3.3.3 Cmmd I/F Proc	0.2	0.1	0.4	0.2	small	small
	4.6	4.5	9.4	9.0	small	small
	9.1		18.4			

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

CREW SYSTEMS (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.3.4 EVA SUPPORT						
4.3.4.1 EMU Contam Control	1	0.5	1	0.5	small	small
4.3.4.2 EMU Monitor/Maint.	50	2	60	4	small	small
4.3.4.3 EMU Monitor/Maint.	20	1	30	2	small	small
4.3.4.4 Safety Interlock M/C	1	0.5	2	1	small	small
4.3.4.5 EVA Real Time M/C	2	1	4	2	small	small
* 4.3.4.6 EVA Visual Info.	50	10	75	15	100*	100*
4.3.4.7 Airlock Atmos Pres. Composition Control	2	0.5	2	0.5	small	small
4.3.4.8 Airlock Temp/Hum	1	0.5	1	0.5	small	small
4.3.4.9 Device Mgmt	15	1	20	2	50	75
4.3.4.10 Cmmd I/F Proc	15	5	20	7	small	small
TOTALS	107*	12*	140*	19.5*	50	75
	119		159.5			

* 4.3.4.6 Function separate from DMS System (Excluded)

CREW SYSTEM TOTALS	210.1	291.9	50.1	75.1

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
COMM & TRACKING (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
1.1 MANAGE REAL TIME DATA ACTION						
1.1.1 Acquire Real Time	10	30	20	60	100	'
1.1.2 Prioritize Real Time	4	2	8	4	10	'
1.1.3 Monitor Real Time	5	2	10	4	20	SAME
1.1.4 Dispatch Real Time	10	5	20	10	50	'
1.1.5 Format Real Time	20	10	40	20	80	'
	49	49	98	98	260	260
	98		196			
1.2 MANAGE DELAYABLE DATA RETURN						
1.2.1 Acquire Delayed PL	10	200	20	400	50	'
1.2.2 Prioritize Delayed	4	2	8	4	1	'
1.2.3 Monitor Delayed	5	2	10	4	2	SAME
1.2.4 Dispatch Delayed	10	200	20	400	50	'
1.2.5 Format Delayed	20	10	40	20	5	'
	49	414	98	828	108	108
	463		926			

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

COMM & TRACKING (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.5 COMMUNICATION						
4.2.5.1 Network Control	35	10	50	15	small	small
4.2.5.2 Equipment Control	15	15	25	10	25	35
4.2.5.3 Status Monitor	50	15	70	25	2	3
4.2.5.4 Failure Detection/R.	50	64	100	128	10	20
4.2.5.5 Cmmd Prve	5	2	10	4	10	15
4.2.5.6 Interface Control	5	2	6	3	5	6
4.2.5.7 Telemetry Control	5	5	5	5	200	300
	165	113	266	190	252	379
	278		456			
2.5.3.5 OMV Status (To remote customer)	N/A	N/A	10	5	N/A	3
2.5.4.6 OMV Status (To remove customer)	8	4	10	5	2	3
COMM & TRACKING TOTALS	851		1608		622	753

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
INFORMATION DATA MANAGEMENT SYSTEM (Page 1 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
2.1 Validate PL Cmmd	4	20	6	40	0.01	0.03
	24		46			
2.2 Check SSDS Ser. Req. Restriction/Constraint	20	50	30	100	1.7	3.75
	70		130			
2.3 Validate Core Cmmd/Data .1	4	20	6	40		
2.3.1 and 2.3.2 .2	10	25	15	50	small	small
	14	45	21	90		
	59		111			
3.3 Develop Ops Event Scld. 3.3.1 to 3.3.4	214	510	240	590	0.6	0.7
	724		830			
3.4 Sequence Operations 3.4.1 to 3.4.4	42	18	59	29	small	small
	60		88			
4.3.2 Space Station Safety 4.3.2.1 to 4.3.2.4	7.5	7	18	19	small	small
	14.5		37			
4.3.5 OPS & Procedure Supt. 4.3.5.1 to 4.3.5.5	140	153	152	152	0.3	0.7
	293		304			

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
INFORMATION DATA MANAGEMENT SYSTEM (Page 2 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.6 Time & Frequency Mgmt.						
4.1.6.1 Time Source	0.5	0.2	0.7	0.3	0.2	0.3
4.1.6.2 Time Update	2	0.5	3	1	small	small
4.1.6.3 Freq. Source Mgmt	1	0.3	2	0.5	0.5	0.7
4.1.6.4 Device Mgmt	0.3	0.1	0.5	0.2	0.2	0.3
4.1.6.5 Cmmd I/F Proc.	0.2	0.1	0.4	0.2	small	small
	4.0	1.2	6.6	2.2	0.9	1.3
	5.2		8.8			
5.1.1 Flt. Data Base Mgmt.						
5.1.1.1 Update/Access Synch	250	50	500	100	small	small
5.1.1.2 Data File Mgmt.	12	140	20	200	small	small
5.1.1.3 Mass Memory Res. Mgmt	10	4	20	10	small	small
5.1.1.4 Archival Storage	20	5	40	10	small	small
5.1.1.5 Device Mgmt	1	0.5	2	1	1	1.5
5.1.1.6 Cmmd I/F Proc.	1	0.5	2	1	small	small
	294	200	584	322	1	1.5
	494		906			

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
INFORMATION DATA MANAGEMENT SYSTEM (Page 3 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
5.1.2 Flt. Resource Mgmt.						
5.1.2.1 Load Scheduling	5	5	10	10	small	small
5.1.2.2 System Executive					% of	% of
- OPERATING SYS. (OS)*	160		250		Application	Application
- Network OS (NOS)*	410		450		100	130
5.1.2.3 Initialized Conf. Cont	30	18	50	30	small	small
5.1.2.4 Configur. Data Proc.	50	125	100	200	small	small
5.1.2.5 Facility Status	22	60	40	80	small	small
5.1.2.6 Recept. Dist. PL	80	175	100	200	30	50
5.1.2.7 Device Mgmt.	10	20	20	30	0.2	0.2
5.1.2.8 Cmmd I/F Proc	15	5	25	10	0.5	1.0
	212	408	345	560	30.7	51.2
	620		905			

*5.1.2.2 Excluded from 5.1.2 total because OS applies to memory configuration and NOS is contained in NIU.

5.1.3 Displays & Controls				
5.1.3.1 Device Mgmt	0.4	0.2	0.5	0.3
5.1.3.2 Cmmd I/F Proc	0.2	0.1	0.4	0.2
	0.6	0.3	0.9	0.5
	0.9		1.4	

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
INFORMATION DATA MANAGEMENT SYSTEM (Page 4 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.5 Monitor & Status System						
4.5.1 Monitor Core	4	2	8	4	0.5	1
4.5.2 Monitor Customer	4	2	8	4	0.4	0.8
4.5.3 Mass Prop. Conf.	7	3	14	6	0.1	0.2
4.5.4 Diagnostic Suppt.						
4.5.4.1 to 4.5.4.3	45	42	405	82	4.5	40.5
4.5.5 System Test & Eval	20	15	20	15	1.0	2.0
4.5.6 Cmmd I/F Proc.	52	17	134	59	3.0	9.0
	132	81	589	170	9.5	53.5
	213		759			
IDMS TOTALS	2511.6		4036.2		44.8	112.6

Table 6.8 (continued)
TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION
PAYLOAD AND SERVICING ACCOMMODATIONS (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
2.4 Provide Ancillary Data	2	10	3	20	4.4	9.0
	12		23			
2.5 Support Customer Ops						
2.5.1 Customer Data Proc.	100*	100*	200*	200*	0.02	0.02
2.5.2 Customer PL OPS	25	25	50	50	small	small
2.5.3 Support OTV OPS						
2.5.3.1 OTV Service	N/A	N/A	25	10	N/A	0.1
2.5.3.2 OTV CO & Diag	N/A	N/A	100	100	N/A	0.5
2.5.3.4 OTV Operation	N/A	N/A	10	20	N/A	small
	25	25	185	180	0.1	0.7
W/O*	50*		365*			
2.5.4 Support OMV OPS						
2.5.4.1 OMV Service	15	6	25	10	small	small
2.5.4.2 OMV CO & Diag.	75	75	100	100	small	small
2.5.4.3 Remote Ops Co.	15	6	21	10	10	15
2.5.4.5 OMV OPS	8	15	10	20	small	small
	113	102	156	140	10	15
	215		296			
2.5.5 Customer Payload Checkout Service	25	1000	30	1200	small	small
	1025		1230			
2.6 SSPE CO AND SERVICE	100	1000	100	1000	small	small
	1100		1100			

Table 6.8 (continued)

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

PAYLOAD AND SERVICING ACCOMMODATIONS (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.4 Provide Cust. Avionic Sev						
4.4.1 GN&C Service						
4.4.1.1 Grd Track	3	1	6	2	0.5	1
4.4.1.2 Magnetic Field	1.5	0.5	1.5	0.5	0.3	1
4.4.1.3 Pallet Coarse	10	2	20	4	10	20
4.4.1.4 Relative Align	13	9	13	9	0.2	0.2
	27.5	12.5	40.5	15.5	11	22.2
	40		56			
4.4.2 Contamination Control						
4.4.2.1 Venting Effects	8	4	24	12	0.2	0.6
4.4.2.2 Environ. Monitor	12	8	24	16	0.4	0.8
	20	12	48	28	0.6	1.4
	32		76			
4.4.3 Tracking Services	3	1	9	3	0.1	0.3
	4		12			
PAYLOAD AND SERVICING ACC. TOTALS	2478		3158		26.2	48.6

6.9 ONBOARD PLATFORM SSDS DEFINITION

6.9.1 Introduction and Overview

This section presents an overview of the onboard Platform SSDS. The SSDS includes the onboard networks, the network interface units (NIU's), subsystem data processors (SDP), mass storage units and the software that resides in or supports these elements. Subsystem application software is included in this definition. The architecture and system definition described herein are products of the SSDS A/A Study approach and methodology outlined in Section 2.0. This architecture definition is preliminary. Some elements are defined in more detail than others to explore specific design or technology driver aspects of the architecture. The prime inputs used are the same as those detailed in Section 6.1

The major metrics utilized throughout this task to evaluate architectural alternatives and influence key design decisions are the same set described in Section 6.1.

The primary steps of the platform onboard system definition process proceeded in a similar manner to that described in Section 6.1 for the Space Station SSDS.

The supporting trade study results and options developed were major inputs into the system definition process. Recommendations and supporting data in the Space Station trade studies and related options catagories were important influencing factors in most key design decisions. Commonality was a key consideration in all these trade studies and in our platform system design.

6.9.2 Partitioning of Functional Requirements into Onboard Subsystems

The same process reported in Section 6.2 for the Space Station SSDS was followed for the platform.

Table 6.9.2-1 presents an application overview of memory sizing in kilobytes (kbytes) and mean processing rates in kilo-operations per second (kops) using the reference configuration subsystem names. A detailed breakout of each of the subsystems are tabulated in Section 6.9.8.

The application memory size for each subsystem is conservative from the standpoint that it represents an arithmetic sum. Not all elements of each subsystem are necessarily main memory resident in an SDP at all times. This also naturally applies to their computational rates

6.9.3 Subsystem Allocation in Architectural Elements

The discussion of Section 6.3 for Space Station in general applies equally well to the platform. The basic difference is in the sizing values for each memory configuration. Table 6.9.3-1 provides the summary data by memory configuration. Section 6.9.8 provides the detailed sizing data extracted from the Task 4, Appendix G which contains the sizing data for all the platform functions.

The major differences between the Platform System and Space Station are the smaller and fewer application functions. The following is a brief difference summary:

1. No ECLS is required for the Platform (Functions 4.2.4.1-7)
2. No onboard Displays and Controls are required (5.1.3)
3. Some Space Station GN&C functions are not required for the platform:
   - Traffic Control (4.1.4)
   - Tracking (4.1.5 and 4.4.3)
4. No onboard Displays and Controls are required (5.1.3)
5. The remaining onboard functions are required, but are reduced in size.

Table 6.9.2-1

TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

SUMMARY DATA

SUBSYSTEM	MEMORY (KBYTES)		MEAN DATA PROCESSING (KOPS)	
	IOC	GROWTH	IOC	GROWTH
1. ELEC PWR 4.2.1.1-7	103	227	69	127
2. GN&C 4.1, 2.5.3.3, 2.5.4.3	370	468	190	255
3. THERMAL CONTROL 4.2.2.1-4	68	127	3	4
4. ECLS 4.2.4.1-7	NOT APPLICABLE TO PLATFORM			
5. PROPULSION	NO SOFTWARE -- CONTROLLED BY GN&C			
6. STRUCTURES/MECHANISMS 4.2.3.1-5	24	43	3	5
7. CREW SYSTEMS 4.3.1, 4.3.3, 4.3.4	NOT APPLICABLE TO PLATFORM			
8. COMM & TRACKING 1.1.1-5, 1.2.1-5, 4.2.5.1-7, 2.5.3.5, 2.5.4.6	606	1077	499	747
9. INFORMATION & DATA MGMT SYSTEM 2.1, 2.2, 2.3, 3.3, 3.4 4.3.2, 4.3.5, 4.5, 4.1.6, 5.1.1, 5.1.2	2271	3689	42	84
10. PL & SERVICING ACCOMMODATIONS 2.4, 2.5.1, 2.5.2, 2.5.3.1, 2.5.3.2, 2.5.3.4, 2.5.4, 2.5.5, 4.4	2231	2801	15	29

Table 6.9.3-1

Platform SSDS Core and Payload Memory Configurations

No.	Name/Function	IOC Mem(1)/CPU(2) (KBYTES/KOPS)	Growth Mem(1)/CPU(2) (KBYTES/KOPS)
1.	GN&C o NAV o Guidance o ATT Cont	370/2197	718/293
2.	o Elec Pwr o Thermal Control o Communications o Str. & Mechanisms	961/660	1724/1016
3.	Information & Data Managememt System	2431/48	3939/97
4.	Payload and Servicing Accommodations	2391/17	3051/66
5.	Payload Processing (Function 2.5.1)	360/1	650/1
6.	Payload Processing (Function 2.5.1)	360/1	650/1

(1) Application size from Tables 6.2-1/6.8-1 +160 KBYTES for operating system (+250 KBYTES for growth).

(2) KOPS from Table 6.9.2-1 + 15% of total application KOPS for operating system overhead.

6.9.4 Architecture

6.9.4.1 Overall Partitioning

The overall platform architecture presented here has most of the same connectivity generalized in the NASA Reference Configuration. However, the system definition process of this study has resulted in a more specific and detailed configuration.

6.9.4.2 Network Configuration

A major deviation from the Reference Configuration is the partitioning of the network into two networks: core and payload. The reasoning for this decision is the same as for the Space Station as discussed in Section 6.4.2.

The discussion in Section 6.4.2 concerning the network configuration, level of standardization, transmission media, topology and media access method and communication functions equally apply to the onboard platform SSDS.

6.9.4.3 NIU Functional Description

The NIU for the platform is the same one as the Space Station. Again, commonality was the key driver in this decision. Basic hardware and software functionality is the same in both systems.

6.9.4.4 Operating System/Application

The discussion for the Space Station on this subject applies to the Platform system. As discussed earlier, their are fewer functions on the Platform than the Space Station. Most of the platform application functions will require the same support services as the Space Station. The most notable difference are Displays and Controls and other onboard man machine interfaces. A common DOS and OS as described in Section 6.4.4 is recommended for the Platform to take advantage of reduced development and maintenance costs for both systems. It might be possible to build the man-machine interfaces in the common DOS/OS so that they can be excluded for the platform system to save memory.

6.9.4.5 Subsystem Data Processor

It is recommended that a common subsystem data processor (SDP) be used for both the Platform and the Space Station. The characteristics of the SDP were discussed in Section 6.4.5.

6.9.4.6 Onboard Workstations

There are no onboard work stations for the Platform. This section was retained to keep a similar numbering system for traceability to the Space Station sections.

6.9.4.7 Operational Data Base

The same general needs for an operational base and mass storage exist for the Platform as for the Space Station (ref. section 6.4.7). The size for the Platform system is greatly reduced because the Platform is unmanned and maintenance will be performed at discrete intervals.

6.9.4.8 Communication Gateway

The discussion for this subject is the same as that for the Space Station (ref. section 6.4.8).

6.9.4.9 PLATFORM TRAFFIC ANALYSIS

The following section derived the network traffic requirements for the platforms. The requirements are presented in terms of messages per second, a more meaningful traffic parameter than bytes per second. Analysis of the core network traffic model shows the communication and tracking NIU receives over 2/3 of the total traffic load.

The network traffic model was derived from the McDonnell Douglas Requirements Data Base (Appendix-1) using an analysis tool developed in PL/I. The tool allows functions in the Data Base to be arbitrarily distributed across a multi-computer environment. The process allows the operator to interactively specify, for example:

Computer 1	Computer 2	Computer N-1	Computer N
Function #	Function #	External 1	External 3
1.1.1	2.1.1	External 2	
1.1.2	4.3.1		

From this input, a search of the data base is made to determine the following reports:

- Computer 1 to/from Computer 2
- Computer 1 and 2 to External Sets 1 and 2
- Computer 1 and 2 to External Set 3

Proper selection of the inputs, functions and externals, resulted in statistical reports to evaluate the I/O requirements. From these inputs the following statistics were determined:

- Subsystem to subsystem I/O
- Subsystem to subsystem sensors/effectors
- Subsystem to operational data base, ancillary data
- Subsystem to displays
- Subsystem to Comm for telemetry, operations instrumentation data

The network traffic model was developed from several sources:

(1) Analyses of Functions Data Base I/O Relationships
(2) Engineering Modifications to (1) Above
(3) Engineering Judgement

Additions to the Network Traffic Model included:

(1) Telemetry Data
(2) Operations Instrumentation Data
(3) Ancillary Data
(4) Ground Forward Commands

Table 6.9.4.9-1 identifies specific assumptions employed in the network traffic analysis. Figure 6.9.6.1-1 shows the processing distribution for the core network.

Table 6.9.4.9-2 shows the core network traffic results for the platforms. The traffic due to telemetry is approximately 2/3 of the total load on the core network.

6.9.4.10 Fault Tolerance

The basic discussion in Section 6.4.10 applies to the Platform

6.9.4.11 Time Management

The discussion in Section 6.4.11 applies to the Platform because this basic service is needed in both systems with the same degree of accuracy and availability. A common system design is recommended to save costs.

TABLE 6.9.4.9-1 NETWORK I/O TRAFFIC ASSUMPTIONS

- Requirement Sources
  - Analysis of core traffic results and engineering judgement to model remaining non-telemetry payload network traffic nodes
- Topology
  - Files/Data stores in each Subsystem SDP
  - DMS ODB has it's own SDP
- Packet/Message Length
  - Message length equals packet length
- Telemetry
  - 25 KBytes/sec per Subsystem
  - 1 KByte Message size to satisfy Consultative Committee for Space Data Systems (CCSDS) efficiency
- Overhead
  - OSI/CCSDS message overhead not included
- Ancillary Data (AD)
  - Subsystems send AD to DMS ODB
  - DMS ODB blocks AD and sends to P/L Network ODB
  - P/L's read AD from P/L ODB as required
- Ground Forward Commands (GFC)
  - Comm receives GFC for each subsystem
  - Comm routes GFC to individual Subsystems
    - Dependent on CMD VAL implementation
  - 0.1 message/sec per subsystem
- Operations Instrumentation Data (OID)
  - OID collected by each subsystem from backend
  - Subsystem send blocked OID to COMM for downlink

SOURCES			DESTINATIONS (MESSAGES/SEC)													
			SUBSYSTEM SDP'S								SUBSYSTEM SENSORS/EFFECTORS					TOTALS *
			GN&C	POWER/COMM/THERM			STR&M	DMS/ODB		FAC MGMT	GN&C	POWER COMM THERM	STR&M	DMS	FAC MGMT	
				I/O	TELEM	OI		I/O	ANCILL							
SDP	GN&C		*23.8	4.3	28.0	2.0	1.0	2.0	2.0	3.0	9.0					51.3
	POWER COMM THERM	I/O	1.1	*25.0	72.0	3.0		3.0	3.0	3.0		2.0				87.1
		GND CMMDS	0.2	0.3		0.1	0.3	0.1		0.1						1.1
	STR&M		0.3		24.0	3.0	*10.0	6.0	3.0	2.5			3.0			41.8
	DMS/ODB		1.0	0.1	24.0			*2.0	1.0	4.0				0.1		30.2
	FAC MGMT		0.2	3.1	24.0		1.2	3.1	1.0	*33.0					0.5	33.1
SENS/EFF	GN&C		11.0													11.0
	POWER/COMM/THERM			22.2												22.2
	STR&M						6.0									6.0
	DMS															0.0
	FAC MGMT															0.0
TOTALS *			13.7	30.0	172.0	8.1	8.5	14.2	10.0	12.6	9.0	2.0	3.0	0.1	0.5	283.7

* INTRA-SUBSYSTEM, LOCAL BUS I/O TRAFFIC NOT INCLUDED IN GLOBAL NETWORK TOTALS

TABLE 6.9.4.9-2 PLATFORM CORE TRAFFIC ANALYSIS

6.9.5 Operational Scenarios

With the exception of the discussion for onboard manned operations, the system initialization, subsystem control, facility management, telemetry and commands, and examples of onboard data flow for the Space Station (ref. section 6.5) applies equally well to the Platform.

6.9.6 Onboard Platform SSDS Architecture

6.9.6.1 Distribution of Processing

The Platform SSDS architecture and Space Station architecture are functionally the same. They differ only in specific subsystem needs and in physical configuration of the spacecraft structures. Commonality and the resultant cost savings were key considerations. Our studies show that commonality with the Space Station does not significantly compromise the SSDS differences between specific needs for the two systems. For example, the memory size and computational speed of the SDP can be based on convenient subsystem groupings for both systems with adequate margins. Both systems need to support core and payload functions; both need an operating system (OS) and a distributed operating system (DOS) to interface similar core sensors and effectors and payload measurements with their respective application software programs. For the above reasons, a functionally common architecture is recommended for both systems.

The main features cited in Section 6.6.1 for the Space Station applies to the Platform with the exception of using a workstation to offload processing from the SDP's.

The Platform SSDS memory configurations and their respective distribution are presented in Table 6.9.6.1-1. The six memory configurations are supported by 18 SDP, and NIU pairs. The SDP sparing strategy is two backups for all memory configurations.

The total network that supports this distribution is shown Figure 6.9.6.1-1 and Figure 6.9.6.1-2. The PL/EXP and core functions are separated to insure the highest degree of trafffic isolation and, therefore function autonomy.

Table 6.9.6.1-1 PLATFORM MEMORY CONFIGURATIONS

Group	Computing Element	Memory Configuration					
		1	2	3	4	5	6
		NAV Guidance ATT Control	Elec. Pwr. Thermal Communications Str. & Mech.	Information and Data Mgmt. Sys.	Payload & Service Accom.	Payload Processing	Payload Processing
Triad 1 (Core Flat Bed)	SDP 1 SDP 2 SDP 3	Primary Backup 1 Backup 2					
Triad 2 (Core Flat Bed)	SDP 4 SDP 5 SDP 6		Primary Backup 1 Backup 2				
Triad 3 (Core Flat Bed)	SDP 7 SDP 8 SDP 9			Primary Backup 1 Backup 2			
Triad 4 (Core Flat Bed)	SDP 10 SDP 11 SDP 12				Primary Backup 1 Backup 2		
Triad 5 (Core Flat Bed)	SDP 13 SDP 14 SDP 15					Primary Backup 1 Backup 2	
Triad 6 (Core Flat Bed)	SDP 16 SDP 17 SDP 18						Primary Backup 1 Backup 2

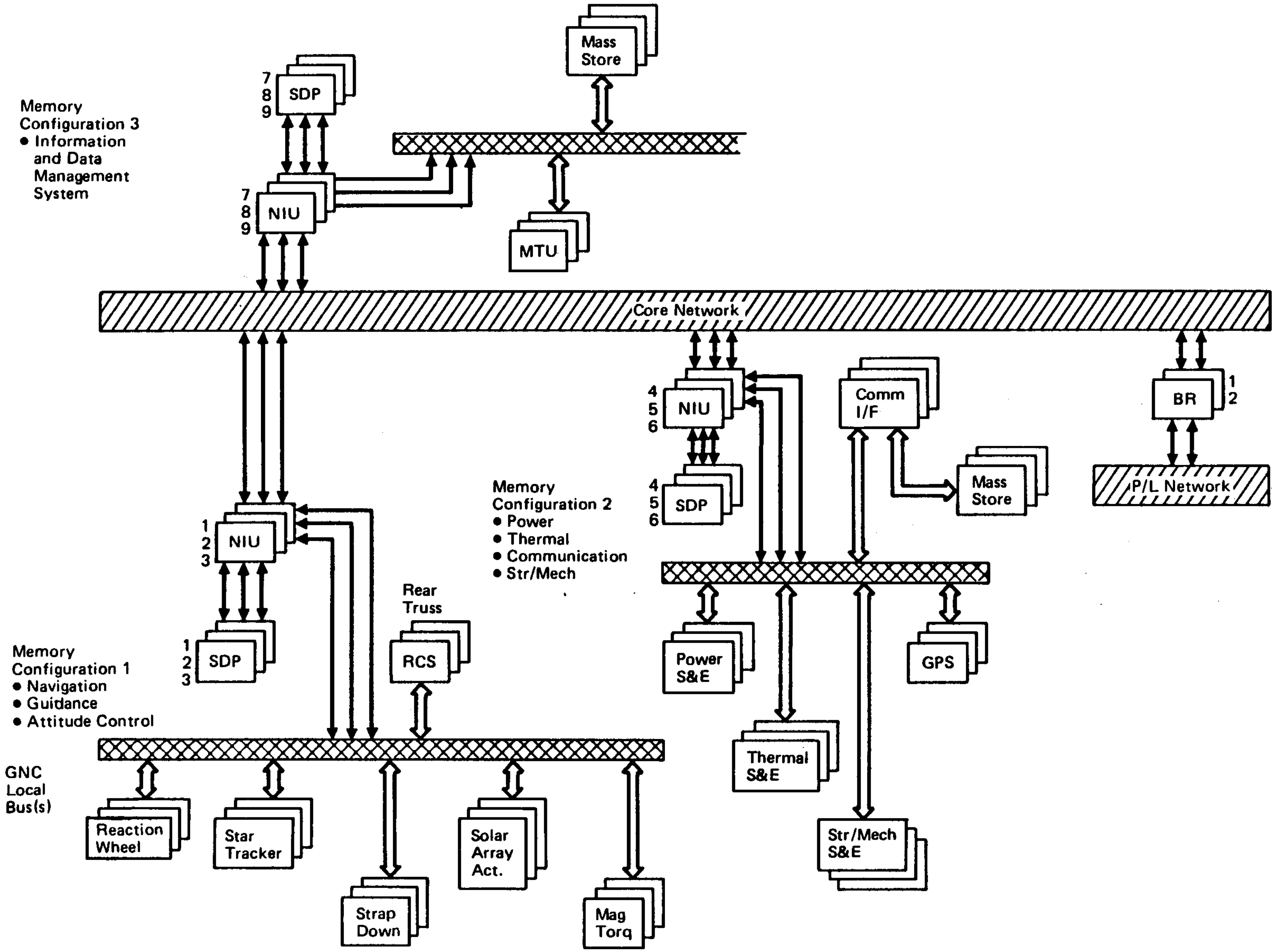


Figure 6.9.6.1-1. Platform Processing Distribution

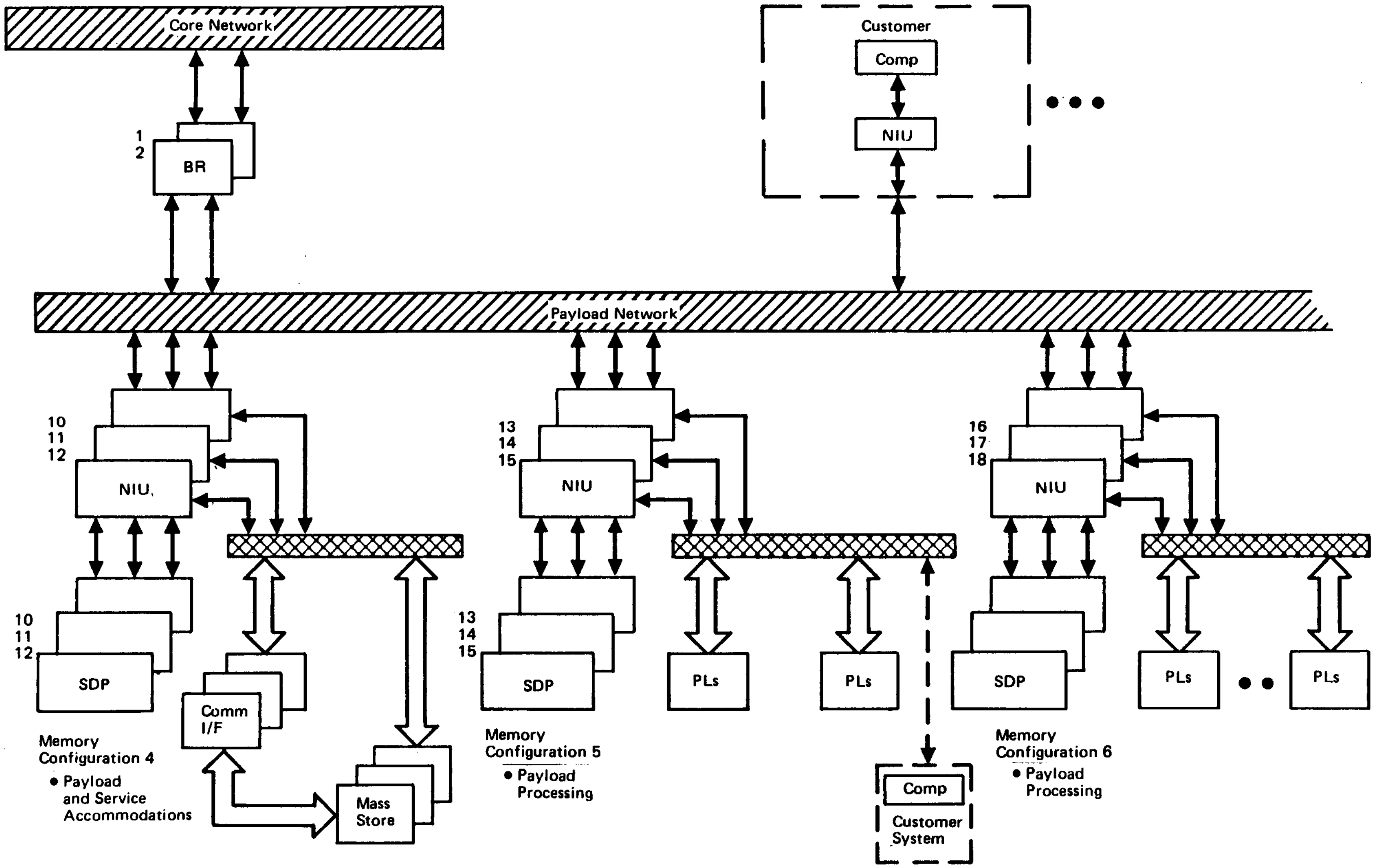


Figure 6.9.6.1-2. Platform Processing Function

6.9.6.2 Platform Network Architecture

The Platform "strawman" onboard local area network configuration consists of two major network partitions isolating PL/EXP traffic from core traffic.

There is a bridge between the two network partitions to support core and PL/EXP data exchange. Ancillary data and forward link telemetry flow from the core network to the PL/EXP network across the bridge. The topology of the network is the same as the Space Station; interconnected dual redundant token rings each with a multi-port ring concentrator. The physical distribution of the network elements is shown in Figure 6.9.6.2-1. The network topology is shown in Figure 6.9.6.2-2. Dual redundancy exists in the bridges and ring concentrators.

6.9.6.3 Major Architecture Issue

The architecture issue discussed in Section 6.6.3 for the Space Station also applies to the Platform SSDS architecture.

6.9.7 Buildup

The assumption is made that the platform is assembled with one NSTS flight and to date no impacts have been identified to the Platform SSDS Architecture.

6.9.8 Platform Memory and Processing Function Summary

The data in Table 6.9.8 provides summaries of the memory and processing loads for the Task 1 and Task 4 onboard functions grouped in terms of the Reference Configuration Subsystem names. The Task 1 and Task 4 Appendices provide detailed function descriptions and sizing data.

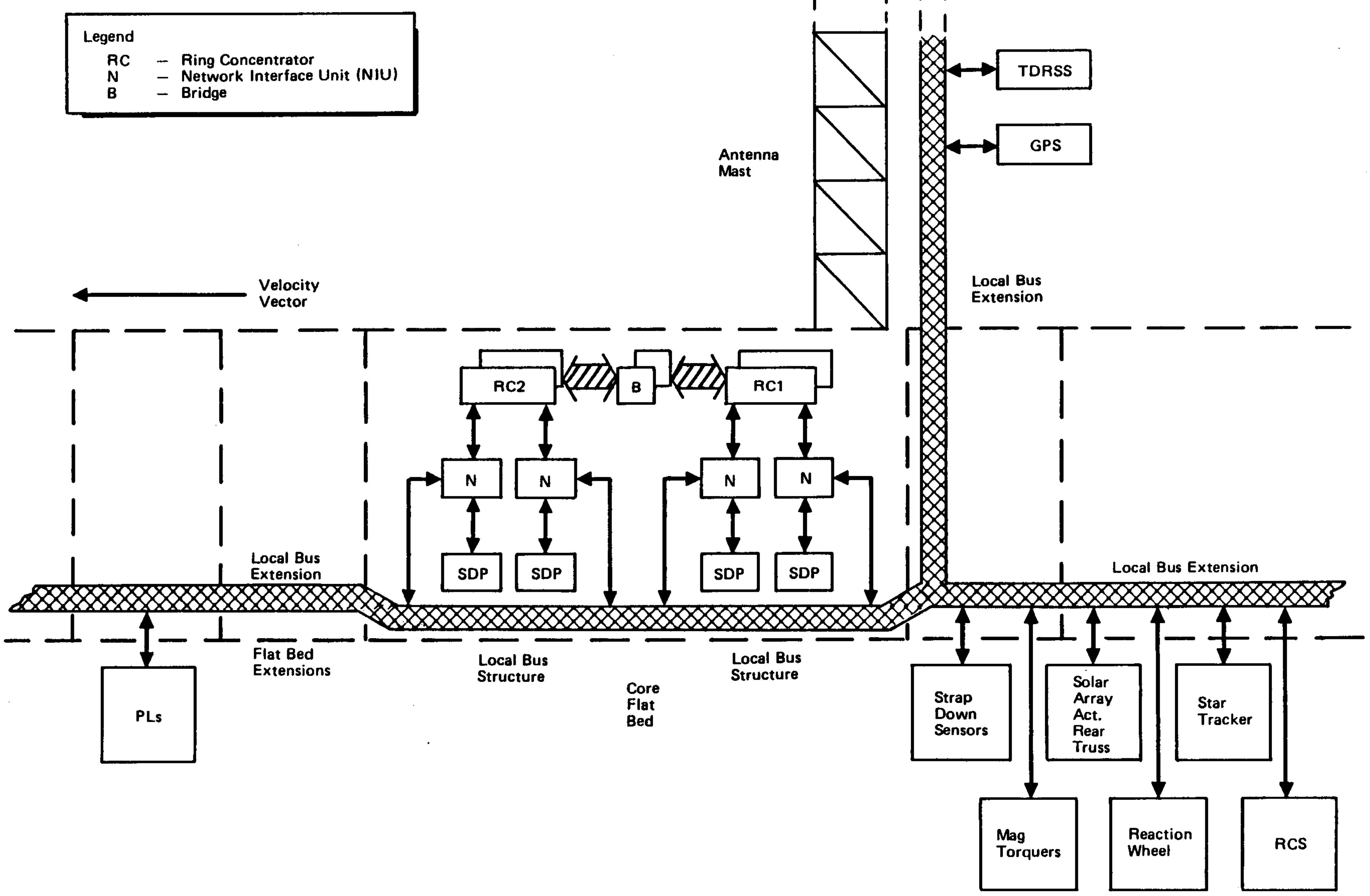
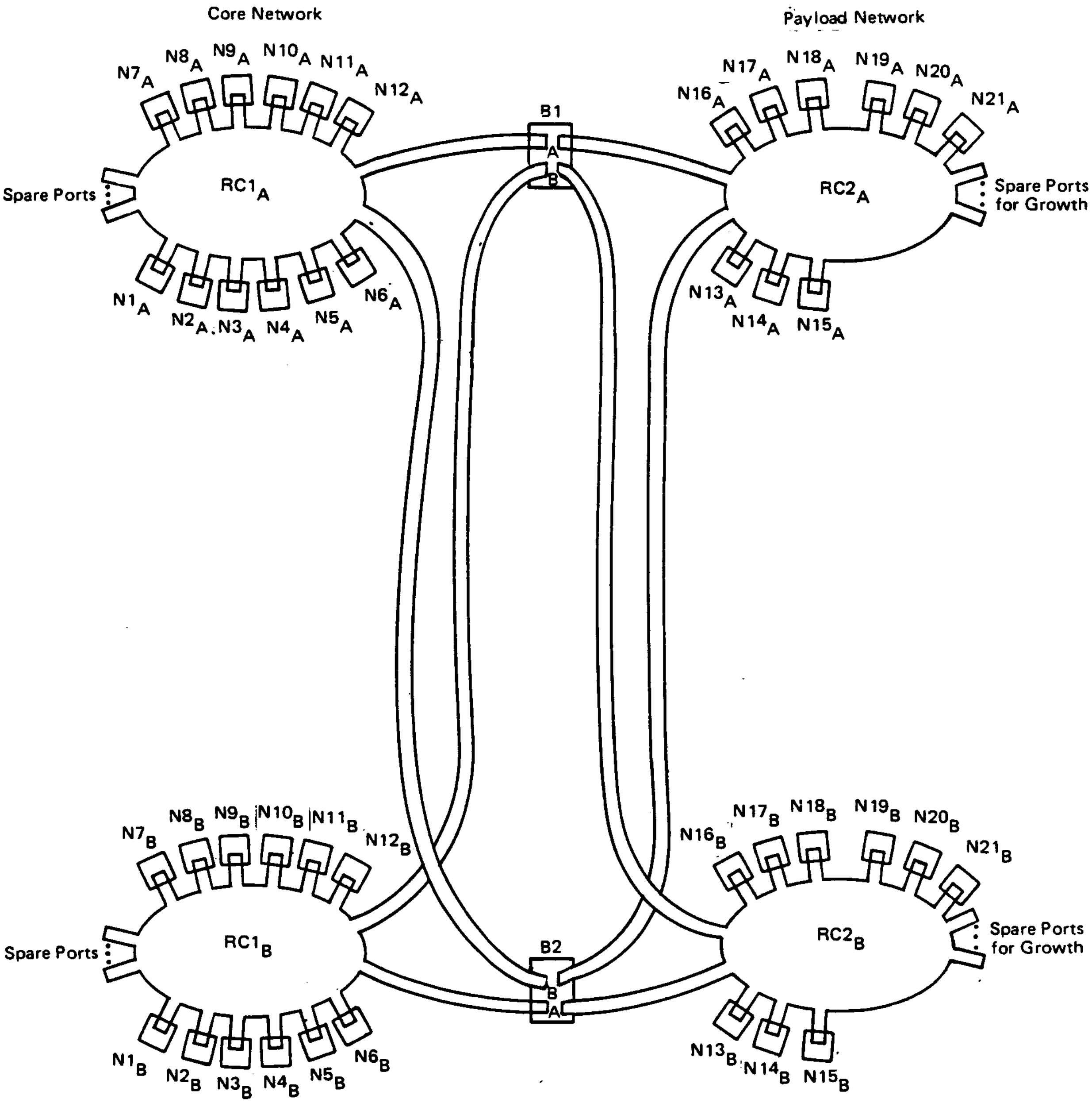


Figure 6.9.6.2-1. Platform Physical Distribution



Legend
RC – Ring Concentrator
N – Network Interface Unit (NIU)
B – Bridge

Figure 6.9.6.2-2. Platform Network Topology

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

ELECTRICAL POWER

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.1 OPERATE POWER SYSTEM						
4.2.1.1 Eval. Array Per.	5	4	6	6	2.5	2.5
4.2.1.2 Conf. Pw. Dist.	10	12	60	24	28	50
4.2.1.3 Power Source Mgmt.	10	10	20	20	19	35
4.2.1.4 Array Deployment	1	2	4	4	0.5	2
4.2.1.5 Project Energy Avail.	10	2	15	5	1.2	1.2
4.2.1.6 Device Mgmt	25	1.5	50	3	18	36
4.2.1.7 Cmmd I/F Proc.	7	3	7	3	small	small
	68	34.5	162	65	69.2	126.7
TOTALS	102.5		227			

THERMAL CONTROL SYSTEM

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.2 OPERATE THERMAL CONTROL SYSTEM						
4.2.2.1 Manage T. Load	1	3	1	4.5	0.13	0.20
4.2.2.2 Thermal Device Mgmt	50	2	100	4	2.5	3.5
4.2.2.3 Project Thermal Cop.	1	1	1	2.5	0.33	0.33
4.2.2.4 Cmmd I/F Proc.	7	3	10	4	small	small
	59	9	112	15	2.96	4.03
TOTALS	68		127			

PROPULSION

Contains no Task 1 Functions: No Software Functions

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

GN&C (Page 1 of 3)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.1 NAV						
4.1.1.1 Spacecraft Orb. Det.	20	15	30	17	20	22
4.1.1.2 Const. State/Orb Det.	NOT APPLICABLE TO PLATFORM					
4.1.1.3 Determine Ephemerides (Sun, Moon, etc.)	2	4	3.5	5	0.02	.02
4.1.1.4 Attitude Det.	35	14	42	16	5	7
4.1.1.5 Nav State Propag.	20	4	25	5	5	5.5
4.1.1.6 Device Mgmt	20	15	25	20	10	12
4.1.1.7 Commd I/F Proc.	5	4	6	5	2	3
	102	56	131.5	68	42.1	49.5
TOTALS	158		199.5			
4.1.2 GUIDANCE						
4.1.2.1 Reboost/Reentry Targ.	14	3.5	18	4.5	1.4	2.0
4.1.2.2 Maneuver Coord.	12	8	20	12	.35	0.6
4.1.2.3 Collision Check	NOT APPLICABLE TO PLATFORM					
4.1.2.4 Reboost/Maneuver	7	2.8	10	3.2	3.5	4.5
4.1.2.5 Tether Control	NOT APPLICABLE TO PLATFORM					
4.1.2.6 Det. Pntg Mt. Cont.	2.5	0.5	3.5	.75	.75	1
4.1.2.7 Device Mgmt.	1.2	0.3	1.5	.6	.03	.04
4.1.2.8 Cmmd Interface Proc.	6	1.5	7	2	3	4
	42.7	16.6	60	23.1	9.1	12.1
TOTALS	59.3		83.1			

C-5

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

GN&C (Page 2 of 3)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.3 ATTITUDE CONTROL						
4.1.3.1 Control Aft & Trans.	48	7	56.2	10.8	125	175
4.1.3.2 Gen. Attitude Cmmds	20	4	22	5	2	2.5
4.1.3.3 Momentum Mgmt	14	1.8	16	2.0	1.5	2.0
4.1.3.4 Pointing Mt. Control	21	4.0	26	6	5.0	7.0
4.1.3.5 Device Mgmt	10	4	15	6	2.5	3.0
4.1.3.6 Cmmd I/F Proc.	15	4	16	4.5	3.0	3.5
	128	24.8	151.2	34.3	139	193
TOTALS	152.8		185.5			
4.1.4 TRAFFIC CONTROL	NOT APPLICABLE TO PLATFORM					
4.1.4.1 Comp/Prop Const State						
4.1.4.2 Manage Const. Orb Man						
4.1.4.3 Sched. Deploy/Rendez.						
4.1.4.4 Manage Rendezvous						
4.1.4.5 Target Coll. Avoid.						
4.1.4.6 Cmmd I/F Proc.						
4.1.5 TRACKING	NOT APPLICABLE TO PLATFORM					
4.1.5.1 Long Range						
4.1.5.2 Prox.						
4.1.5.3 Object Cat. Main.						
4.1.5.4 Tracking Data Cond.						
4.1.5.5 Device Mgmt						
4.1.5.6 Cmmd I/F Mgmt						

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

GN&C (Page 3 of 3)

FUNCTIONS	MEMORY (KBYTES) IOC PROG	MEMORY (KBYTES) IOC DATA	MEMORY (KBYTES) GROWTH PROG	MEMORY (KBYTES) GROWTH DATA	DATA PROCESSING (KOPS) IOC	DATA PROCESSING (KOPS) GROWTH
2.5.3.3 OTV Deployment/Ret.	NOT APPLICABLE TO PLATFORM					
2.5.4.3 OMV Deployment/Ret	NOT APPLICABLE TO PLATFORM					
GN&C TOTAL	370.1		468.1		190.2	254.6

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

STRUCTURES/MECHANISMS

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.2.3 STRUCTURES & MECH SUPPT						
4.2.3.1 Mechanism Control	2.8	2.0	5.6	4.0	0.4	0.6
4.2.3.2 MRMS Ups	NOT APPLICABLE TO PLATFORM					
4.2.3.3 Manage Dock./Berth.	2.0	1.6	3.0	2.0	0.8	1.6
4.2.3.4 Device Mgmt	4.0	4.0	8.0	8.0	0.2	0.4
4.2.3.5 Cmmd I/F Proc	5.0	2.0	4.0	8.0	1.0	2.0
	13.8	9.6	20.6	22	2.4	4.6
TOTALS	23.4		42.6			

ECLS

4.2.4 ECLSS OPERATION	NOT APPLICABLE TO PLATFORM
4.2.4.1 Control Press/Atmos	
4.2.4.2 Control Temp/Hum	
4.2.4.3 Potable H_2O Mgmt	
4.2.4.4 Grey Water Mgmt	
4.2.4.5 Fire Det. & Control	
4.2.4.6 Device Mgmt	
4.2.4.7 Cmmd I/F Proc.	

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

CREW SYSTEMS (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.3.1 HEALTH MAINTENANCE	NOT APPLICABLE TO PLATFORM					
4.3.1.1 Crew Phys. Monitor						
4.3.1.2 Medical Diag. Supt.						
4.3.1.3 Treatment Supt.						
4.3.1.4 Nutrition Anal.						
4.3.1.5 Exercise Planner						
4.3.1.6 Phys. Data Trans & Anal.						
4.3.3 HABITABILITY	NOT APPLICABLE TO PLATFORM					
4.3.3.1 Recreation Services						
4.3.3.2 Crew/Grd Comm						
4.3.3.3 Cmmd I/F Proc						

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

CREW SYSTEMS (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.3.4 EVA SUPPORT	NOT APPLICABLE TO PLATFORM					
4.3.4.1 EMU Contam Control						
4.3.4.2 EMU Monitor/Maint.						
4.3.4.3 EMU Monitor/Maint.						
4.3.4.4 Safety Interlock M/C						
4.3.4.5 EVA Real Time M/C						
4.3.4.6 EVA Visual Info.						
4.3.4.7 Airlock Atmos Pres. Composition Control						
4.3.4.8 Airlock Temp/Hum						
4.3.4.9 Device Mgmt						
4.3.4.10 Cmmd I/F Proc						

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

COMM & TRACKING (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
1.1 MANAGE REAL TIME DATA ACTION						
1.1.1 Acquire Real Time	7	21	14	42	70	100
1.1.2 Prioritize Real Time	2.8	1.4	5.6	2.8	7	10
1.1.3 Monitor Real Time	3.5	1.4	5	3	14	20
1.1.4 Dispatch Real Time	7	3.5	14	7	35	50
1.1.5 Format Real Time	14	7	28	14	56	80
	34.3	34.3	66.6	68.8	182	260
	68.6		135.4			
1.2 MANAGE DELAYABLE DATA RETURN						
1.2.1 Acquire Delayed PL	7	150	14	300	35	50
1.2.2 Prioritize Delayed	2.8	1.4	5.6	2.8	.7	1
1.2.3 Monitor Delayed	3.5	1.4	7	2.8	.98	2
1.2.4 Dispatch Delayed	7	140	14	280	24,5	50
1.2.5 Format Delayed	14	7	28	14	3.5	5
	34.3	299.8	68.6	599.6	64.68	108
	334.1		668.2			
4.2.5 COMMUNICATION						
4.2.5.1 Network Control	20	10	30	15	small	small
4.2.5.2 Equipment Control	10	10	15	15	25	35
4.2.5.3 Status Monitor	25	15	35	25	2	3
4.2.5.4 Failure Detection/R.	25	64	50	64	10	20
4.2.5.5 Cmmd Prve	5	2	5	2	10	15
4.2.5.6 Interface Control	5	2	5	2	5	6
4.2.5.7 Telemetry Control	5	5	5	5	200	300
	95	108	145	128	252	379
	203		273			

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

COMM & TRACKING (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
2.5.3.5 OMV Status (To remote customer)	NOT APPLICABLE TO PLATFORM					
2.5.4.6 OMV Status (To remove customer)	NOT APPLICABLE TO PLATFORM					
COMM & TRACKING TOTALS	605.7		1076.6		498.68	747

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

INFORMATION DATA MANAGEMENT SYSTEM (Page 1 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
2.1 Validate PL Cmmd	4	20	6	40	0.01	0.03
	24		46			
2.2 Check SSDS Serv. Req. Restriction/Constraint	20	50	30	100	1.7	3.75
	70		130			
2.3 Validate Core Cmmd/Data .1	4	20	6	40	.01	.03
2.3.1 and 2.3.2 .2	10	25	15	50	.01	.02
	14	45	21	90		
	59		111			
3.3 Develop Ops Event Sched. 3.3.1 to 3.3.4	212	455	265	530	1.33	1.58
	667		795			
3.4 Sequence Operations 3.4.1 to 3.4.4	60	26	95	41	.2	.4
	86		136			
4.3.2 Space Station Safety 4.3.2.1 to 4.3.2.4	15	3.5	25	11	small	small
	18.5		36			
4.3.5 OPS & Procedure Supt. 4.3.5.1 to 4.3.5.5	130	133	132	132	0.3	0.6
	263		264			

Table 6.9.8

PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

INFORMATION DATA MANAGEMENT SYSTEM (Page 2 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.1.6 Time & Frequency Mgmt.						
4.1.6.1 Time Source	0.5	0.2	0.7	0.3	0.2	0.3
4.1.6.2 Time Update	2	0.5	3	1	small	small
4.1.6.3 Freq. Source Mgmt	1	0.3	2	0.5	0.5	0.7
4.1.6.4 Device Mgmt	0.3	0.1	0.5	0.2	0.2	0.3
4.1.6.5 Cmmd I/F Proc.	0.2	0.1	0.4	0.2	small	small
	4.0	1.2	6.6	2.2	0.9	1.3
	5.2		8.8			
5.1.1 Flt. Data Base Mgmt.						
5.1.1.1 Update/Access Synch	250	50	500	100	.25	.5
5.1.1.2 Data File Mgmt.	12	140	20	200	small	small
5.1.1.3 Mass Memory Res. Mgmt	10	4	20	10	small	small
5.1.1.4 Archival Storage	NOT APPLICABLE TO PLATFORM					
5.1.1.5 Device Mgmt	7	0.4	1.5	0.7	1	1.5
5.1.1.6 Cmmd I/F Proc.	0.7	0.4	1.5	0.7	0.1	0.2
	273.4	194.8	543	311.4	1.35	2.2
	468.2		854.4			

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

INFORMATION DATA MANAGEMENT SYSTEM (Page 3 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
5.1.2 Flt. Resource Mgmt.						
5.1.2.1 Load Scheduling	4	4	8	8	small	small
5.1.2.2 System Executive	570*	1000*	700*	1300*	% of	% of
- OPERATING SYS. (OS)*	160		250		Application	Application
- Network OS (NOS)*	410		450		100	130
5.1.2.3 Initialized Conf. Cont	30	18	50	30	small	small
5.1.2.4 Configur. Data Proc.	25	65	50	100	small	small
5.1.2.5 Facility Status	22	60	40	80	small	small
5.1.2.6 Recept. Dist. PL	65	140	80	160	30	50
5.1.2.7 Device Mgmt.	5	10	10	15	0.2	0.33
5.1.2.8 Cmmd I/F Proc	12	4	20	8	0.5	1.0
	163	301	258	401	30.7	51.33
	464		659			

*5.1.2.2 Excluded from 5.1.2 total because OS applies to memory configuration and NOS is contained in NIU.

5.1.3 Displays & Controls NOT APPLICABLE TO PLATFORM

5.1.3.1 Device Mgmt

5.1.3.2 Cmmd I/F Proc

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

INFORMATION DATA MANAGEMENT SYSTEM (Page 4 of 4)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.5 Monitor & Status System						
4.5.1 Monitor Core	2.4	1.2	4.8	2.4	0.3	0.6
4.5.2 Monitor Customer	2.4	1.2	4.8	2.4	0.25	0.5
4.5.3 Mass Prop. Conf.	0.7	0.3	1.4	0.6	0.01	0.02
4.5.4 Diagnostic Suppt.						
4.5.4.1	14	14	140	140	1.4	14.0
4.5.4.2	14	14	140	28	1.4	2.5
4.5.4.3	3.5	1.4	5.0	2.8	0.35	0.50
4.5.5 System Test & Eval	14	10	28	15	0.7	1.4
4.5.6 Cmmd I/F Proc.	20	8	60	24	1.2	3.6
	71	50.1	384	215.2	5.61	23.12
	121.1		599.2			
IDMS TOTALS	2246		3639.4		42.11	84.36

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

PAYLOAD AND SERVICING ACCOMMODATIONS (Page 1 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
2.4 Provide Ancillary Data	1.4	7	2.1	14	3.1	6.3
	8.4		16.1			
2.5 Support Customer Ops						
2.5.1 Customer Data Proc.	100*	100*	100*	200*	0.08	.08
2.5.2 Customer PL OPS	25	25	50	50	.03	.03
2.5.3 Support OTV OPS	NOT APPLICABLE TO PLATFORM					
2.5.3.1 OTV Service						
2.5.3.2 OTV CO & Diag						
2.5.3.4 OTV Operation						
W/O*	50*		365*			
2.5.4 Support OMV OPS	NOT APPLICABLE TO PLATFORM					
2.5.4.1 OMV Service						
2.5.4.2 OMV CO & Diag.						
2.5.4.3 Remote Ops Co.						
2.5.4.5 OMV OPS						
2.5.5 Customer Payload Checkout Service	25	1000	30	1200	small	small
	1025		1230			
2.6 SSPE CO AND SERVICE	100	1000	100	1000	small	small
	1100		1100			

Table 6.9.8
PLATFORM TASK 1 FUNCTIONS MAP TO REFERENCE CONFIGURATION

PAYLOAD AND SERVICING ACCOMMODATIONS (Page 2 of 2)

FUNCTIONS	MEMORY (KBYTES)				DATA PROCESSING (KOPS)	
	IOC		GROWTH		IOC	GROWTH
	PROG	DATA	PROG	DATA		
4.4 Provide Cust. Avionic Sev						
4.4.1 GN&C Service						
4.4.1.1 Grd Track	3	1	6	2	0.5	1
4.4.1.2 Magnetic Field	1.5	0.5	1.5	0.5	0.3	.3
4.4.1.3 Pallet Coarse	10	2	20	4	10	20
4.4.1.4 Relative Align	7	4	10	6	0.1	0.15
	21.5	7.5	37.5	12.5	10.9	21.45
	29		50			
4.4.2 Contamination Control	12	8	24	16	0.4	0.8
	20		40			
4.4.3 Tracking Services	NOT APPLICABLE TO PLATFORM					
PAYLOAD AND SERVICING ACC. TOTALS	2232.4		2801.1		14.51	28.66

7.0 GROUND SSDS DEFINITION

7.1 Introduction & Overview

This section provides the preliminary design of the ground Space Station Data System (SSDS). The ground program elements, the allocation of functions to the elements and element topology are presented in Section 7.2. Section 7.3 highlights the operational data flow between these elements for selected data types, which include core engineering data, payload data, uplink command data, and Mission Operations coordination. The ground SSDS architecture is presented in Section 7.4, beginning with an overview of the system architecture and followed by subsections devoted to the more detailed definition and architecture of each of the elements.

The prime inputs used to develop this preliminary definition were:

- Task 1 – Requirements Definition
- Task 2 – Options Development
- Task 3 – Trade Studies
- Langley Mission Data Base and Woods Hole Data
- Customer Requirements for Standard Services from the Space Station Information System
- Team systems engineering
- NASA guidance and feedback

Supporting options and trade studies include:

- AI options
- Standardization/commonality options
- Communications standardization trade study
- Distributed data base management trade study.
- System management options
- Command and resource management options and trade study
- Mass storage options and trade study
- Wide area processing options

- Space autonomy and function automation trade study
- Network topology trade study

The primary steps of the ground system definition process include:

- General buildup from Task 1's data flow diagrams and functional data sheets
- Allocate functions to space/ground as performed in the Space Autonomy and Function Automation Trade Study
- Define and characterize the ground elements through the allocation of functions to the elements
- Present a ground system topology and architecture that connects the elements
- Document the system definition and key design decisions made to date

A few points are noteworthy in understanding the scope of the ground definition process. The first is that wide area communications, considered an SSIS institutional service outside the SSDS, have been considered only to the extent necessary to determine the feasibility of the proposed designs.

Another point is that the system is sized based upon mission data derived from the Langley Data Base as modified by the Woods Hole Meeting. In many cases, the data is incomplete and requires supporting assumptions. For example, peak data rates and duty cycles alone are inadequate to ascertain a true data flow rate for some missions. Consideration of the interdependence among missions, observation times, and data delivery times is required. Core traffic has also been estimated based upon approximate requirements. The assumptions associated with data traffic as applied to the ground system definition are described in the Network Topology Trade Study. However, since many of these assumptions are open to interpretation, the design has emphasized system flexibility in order to accommodate growth and changes in data requirements.

Finally, it is important to note that each element of the ground SSDS is in itself a large data processing system. Therefore, the scope of this preliminary definition for each of the elements has been limited to the definition of its interfaces, functions, and key architectural features.

7.2 Ground System Definition

7.2.1 Summary Of Key Assumptions & Approaches

The following major assumptions, and design decisions were made with respect to programmatic issues, the space segment, SISS institutional elements, and intepretations of requirements. They are summarized below since they have major impacts on the system concept.

- the KSA-R downlink will operate at constant rates of either 100 or 300 Mbps with fill data added onboard as required.
- All low rate payload data will be multiplexed together onboard and will be sent on one of two virtual channels (real time or playback) on the KSA-R link.
- Each high rate mission will be allocated one virtual channel for real time and one virtual channel for playback data on the KSA-R link.
- The real-time core and payload engineering (housekeeping) data will be sent on the SSA. There will be one virtual channel each for core engineering real-time and playback data and one virtual channel each for payload engineering real time and playback data (four virtual channels total). The Space Element will be identified in the CCSDS Frame (Spacecraft ID). If customers have additional needs for real time core and payload engineering data, it must be included in their payload stream.
- Customers will be able to receive raw real-time data at any time it is sent.
- Data stored by the onboard SSDS or C&T system will be played back in the forward direction and will not require reversal.
- All core and payload telemetry and telecommand data are packetized, using an identical bi-directional CCSDS packet format. All packets

will be enclosed within bi-directional CCSDS frames. Convolutional encoding will not be used. All low rate missions will be Reed-Solomon (R-S) encoded in CCSDS codeblocks. R-S encoding is optional for high rate missions only.

- Ancillary data will be provided on-board to the payloads, with the Engineering Data Centers (EDCs) acting as a backup. NASA will not support processing of ancillary data, but rather will provide ancillary data in a standard form. Per the customer requirements, as reflected in Task 1, if the standard data is not sufficient for customer needs, more accurate or non-standard data is a customer responsibility.

- Processing is provided through Level 0 for all missions as a standard SSDS service for all packetized data. Data will be returned in the form it was when given to the onboard DMS or C&T system, on a 24 hour a day, 7 day a week availability.

- It is acceptable to low data rate customers to receive their data from a Level 0 Processing Facility.

- Payload Operations Control Centers (POCC's) will not perform Level 0 processing and will obtain Level 0 data from a Level 0 Processing Facility

- Upper level processing beyond Level 0 will be supported by NASA at Regional Data Centers (RDC's) but is not a standard SSDS service.

- All Level 0 data must be routed to an RDC for upper Level processing. RDCs are required to receive the level 0 data within at most 24 hours, as specified in the Langley Mission Database. Missions which specify a data delivery delay of "0" cannot be buffered, but must be delivered in real-time.

- POCC's will need real-time data for quick look analysis.

- As described in Sections 4 and 7.3.3, uplink payload data including command are transparent to the SSDS. Uplink payload packets are, therefore, routed directly to the DHC for transmission to the space element.

- The institutional Space Station data distribution network will be augmented to support transparent switching of the low rate data, both payload and core, using standard interfaces

Additional assumptions are listed as appropriate in the subsections below. These assumptions are consistent within the tasks of the SSDS Study, but are open to reasonable debate. Changes in some of the above may have a significant impact on the ground system, as described in the Network Topology Trade Study and as summarized in section 7.5.

7.2.2 Definition Of Ground System Elements

The following ground Space Station program elements have been defined as a result of the SSDS study. Some of these elements, such as Regional Data Centers (RDCs), are in the SSIS but are listed since their functions have impacts on the ground system concept. The proposed locations of the SSDS elements are described in the Network Topology Trade Study. Changes in the definitions and assumptions about these elements may impact decisions on the overall topology.

7.2.2.1 Data Handling Center (DHC)

The Data Handling Center serves as the space/ground gateway between the TDRSS Ground Terminals (WSGT and NGT) and the ground-to-ground data distribution network. It receives and buffers data, routes virtual channels onto/from the ground network, and provides uplink service authorization. The proposed DHC location is at White Sands.

7.2.2.2 Ground Services Center (GSC)

The Ground Services Center (GSC) provides communication and common resource coordination for the ground system. It serves to coordinate the scheduling of the communication and ground facility resources shared among the Space Station, COP, and POP operations control centers. These shared facilities include the Data Handling Center, and the Level 0 Processing Facilities. The GSC also collects status information from the shared facilities (outages, data quality monitoring, etc) and prepares reports of this information for both customers and the mission scheduling function at the OCCs. The GSC also performs SSIS functions involving the collection of information on customer usage of ground system elements and the processing of customer bills. The proposed GSC location is at GSFC.

7.2.2.3 Payload Operations Control Centers (POCCs)

The Payload Operations Control Centers (POCCs) provide ground support for the operation of a single payload instrument or complement of instruments. Control and monitoring POCC functions that are unique to the payload applications are outside the boundaries of the SSDS. However, the POCC functions that provide standard services — the interfaces to the DHC and the GSC, and that support ground system managment are within the SSDS. POCCs are distributed among NASA centers, RDCs, and customer sites.

7.2.2.4 Regional Data Centers (RDCs)

Regional Data Centers are SSIS elements that fall outside the SSDS boundaries, but their location affects the SSDS architecture. An RDC's basic function, as assumed in this study, is the support of higher level processing and archiving of a single scientific discipline or group of related disciplines (at each RDC). The RDC's receive, analyze (processing above Level 0) and archive data from many sources, including space entities as well as non-space sources. Based on an analysis of 1997 mission data it is assumed that RDCs will be established at GSFC, JPL, LARC, JSC, and MSFC and perhaps at customer sites.

7.2.2.5 Level 0 Processing Facilities (LZPFs)

These facilities remove space-to-ground artifacts within payload data. High data rate LZPFs are co-located with RDCs at GSFC, JPL, and LARC. A low data rate LZPF is centralized at GSFC to serve the other RDCs and customers.

7.2.2.6 Control Centers (CCs)

The Control Centers (CCs) provide ground support of core operations throughout all mission phases, including man-tended and build up, as well as back-up support. These centers include the Space Station Operations Control Center (SSOCC), the Co-Orbiting Platform Control Center (COPCC), and the Polar Orbiting Platform Control Center (POPCC). The SSOCC is located at JSC and the POP and COP Control Centers are located at GSFC.

7.2.2.7 Engineering Data Centers (EDCs)

The Engineering Data Centers (EDCs) provide archival storage of Space Station, COP, and POP core data and support program and customer requests for the retrieval and analysis of historical data. One Engineering Data Center is co-located with the SSOCC (at JSC), and a second EDC is co-located with the POP and COP Control Centers at GSFC.

The following describe important generic SSDS functions not generally centralized at a specific SSDS facility.

7.2.2.8 Operations Control Network (OCN)

The Operations and Control Network element (OCN) provides networking functions above layer 3 of the ISO/OSI model, that support the transparent connection of applications at the various NASA centers. It provides both software downloading control functions (linking together Control Centers, POCCs, etc) as well as Space Station Program information (for customer access) and is implemeted through a combination of commercially available ISO type software utilities and gateways at the various faciltiies.

7.2.2.9 Development, Simulation, Integration, and Training (DSIT)

The Development, Simulation, Integration, and Training (DSIT) functions support the development and integration of new or modified software, integration of customer payloads, end-to-end communications checkout, crew and ground controller training, and construction of simulation models for use at remote sites. While the DSIT is defined as a program element, it is recognized that, similar to the Customer Interface Element (CIE) functions, defined in 7.2.2.10 below, the DSIT functions will be distributed throughout the ground system and that elements of the DSIT will appear at each control center, LZPF, RDC, and facility that involves software development and simulation. A major part of this element, the Software Support Environment (SSE), is described in Section 8.2.

7.2.2.10 Customer Interface Elements (CIEs)

Customer Interface Elements (CIEs) provide a standard interface to customers and a connection between the customer and the services of the Space Station Program. The elements allow a customer to "dial in" to a NASA location (RDC, POCC, etc), access a menu-driven interface describing the services of the Space Station Program (scheduling, archival data catalogs, etc) and be connected via the Control Network to a selected service. The actual service might be local to that center or it might be located at another location. Specific functions accessed by this single point of Customer Contact to SSP Services include:

- Logon/Authorization to access SSIS Services
- Communication and common services coordination (access to GSC)
- Space Station Program Databases (Authorization and transparent access)
- Control Center services (Access to Scheduling)
- Archival data catalog services
- Uplink Access (Access to DHC)
- TMIS Interface
- Bulletin boards and electronic mail for sharing information among users and with the Space Station program

While the CIE is defined as a program element, it is recognized that the foregoing functions are actually distributed throughout the ground system and that CIE functions will appear at each NASA center. A detailed design for this element is therefore not shown. The implementation of these functions should present an identical interface to customers no matter which NASA center implements them.

7.2.3 Partitioning/Allocation of Functions to Elements

Table 7.2.3-1 maps the lower level functional requirements, which were derived during Task 1 of the SSDS A/A Study, to the ground elements. The tracing from the 2-digit level function is shown for completeness. Tracing back to Task 1 source requirements is provided in the Task 1 report. In many cases only a subset of the lowest level functions of a given portion of the function list are implemented. This is especially true for the Control Centers which provide support and back-up to the onboard functions. The strawman locations of the SSDS elements are shown on Table 7.2.3-2.

7.3 Key Operational Features

The purpose of this section is to describe data flow between the various ground elements defined in Section 7.2

7.3.1 Core Engineering Data Management

The SSDS provides core operations/administrative data to support the ground operations associated with the payloads and the core systems. The ground flow of core engineering data is depicted in figures 7.3.1-1 and 7.3.1-2.

7.3.1.1 Payload Operations Support

The onboard SSDS provides time-stamped core engineering ancillary data to the payloads. The data is provided in standard engineering units, and any reformatting/refinement of the data is a customer responsibility. The payload incorporates the ancillary data into its payload CCSDS packets, which are downlinked and distributed to the Level Zero Processing Facilities and POCC/customer facilities. (See Section 7.3.2 for a more detailed discussion of payload data management.) Thus, the ancillary data required for the ground control of the payload and for production data set generation is contained within the payload packets.

The SSDS also provides a non-real-time service of electronic access to the core engineering data archives, which are contained within the EDC, for the retrieval of historical data.

Table 7.2.3-1
Ground Element Function Allocation

Element	Functions
Data Handling Center (DHC)	1.1 Manage Real Time Data Return 1.1.4 Dispatch Realtime Data (reqs 5.3.1.1.a,b)
	1.3 Data Distribution 1.3.1 Preprocessing (Frames) 1.3.2 Data Capture (Bulk Record) 1.3.3 Routing & Transmission 1.3.4 Quality Verification
	2.1 Validate Payload COmmands/Data 2.1.1 Authorized User 2.1.2 Authorized Address
	2.3 Validate Core Commands/Data 2.3.1 Authorize Operator
	5.2 Manage Ground System Facilities 5.2.1 Interface Management 5.2.2 Schedule/Status Compare 5.2.3 Transmit Reconfiguration Schedule 5.2.4 Ground Status Database Management 5.3.5 Adjust For Unscheduled Mode Change 5.2.6 Displays & Controls
Low & High Rate Level 0 Processing Facilities (LZPFs)	1.1 Manage Real Time Data Return 1.1.4 Dispatch Realtime Data (reqs 5.3.1.1.a,b)
	1.4 Manage Deliverable Customer Data 1.4.1 Customer Data I/F Mgt 1.4.2 Customer Data Capture 1.4.3 Customer Data Handling 1.4.5 Level 0 Customer Data Processing 1.4.6 Customer Data Accounting 1.4.7 Routing & Transmission
Level 0 Processing Facility (LZPFs)	5.2 Manage Ground System Facilities 5.2.1 Interface Management 5.2.2 Schedule/Status Compare 5.2.3 Transmit Reconfiguration Schedule 5.2.4 Ground Status Database Management 5.3.5 Adjust For Unscheduled Mode Change 5.2.6 Displays & Controls

Table 7.2.3-1
Ground Element Function Allocation

Element	Functions
Ground Services Center (GSC)	7.2 Log Customer Usage Of System
	5.2 Manage Ground System Facilities
	5.2.1 Interface Management
	5.2.2 Schedule/Status Compare
	5.2.3 Transmit Reconfiguration Schedule
	5.2.4 Ground Status Database Management
	5.3.5 Adjust For Unscheduled Mode Change
	5.2.6 Displays & Controls
Control Centers (CCs)	1.5 Manage Deliverable Core Data
	1.5.1 Core Data Interface Management
	1.5.2 Core Data Capture
	1.5.3 Data Extraction
	1.5.4 Displays & Controls
	2.5 SupportCustomerSystem Operation
	2.5.3 Support OTV Operations
	2.5.3.4 OTV Operation
	2.5.4 Support OMV Operation
	2.5.4.5 OMV Operation
	2.5.4.6 OMV Status Report
	3.1 Develop Recurring Operations Masters
	3.1.1 Develop Normal Day Payload Operations
	3.1.2 Develop Normal Day Space Operations
	3.1.3 Identify Potential Conflicts
	3.1.4 Develop Major Event Payload Operations
	3.2 Develop Short Term Schedules
	3.2.1 Confirm Payload & Core Schedules
	3.2.2 Incorporate New/Revised Operations
	3.2.3 Check For Conflicts
	3.2.4 Check For Facilities Capabilities
	3.2.5 Resolve Conflicts
	3.2.6 Check Unresolved, Restricted/Constrainted Commands
	3.2.7 Maintain Short Term Schedules/Develop Operating Events List
	4.1 Operate GN&C Systems
	4.1.1 Navigation
	4.1.1.1 Space Station State/Orbit Determination
	4.1.1.7 Command Interface Processing

Table 7.2.3-1
Ground Element Function Allocation

Element	Functions
Control Centers (CCs) (Cont)	4.1.2 Guidance
	4.1.2.1 Reboost/Reentry Targeting
	4.1.2.7 Command Interface Processing
	4.1.3 Attitude Control
	4.1.3.1 Control Attitude & Translation
	4.1.3.2 Maneuver Coordination
	4.1.3.3 Momentum Mgt
	4.1.3.4 Pointing Mount Control
	4.1.3.5 Device Mgt
	4.1.3.6 Command I/F Processing
	4.1.4 Traffic Control
	4.1.4.5 Target Collision Avoidance
	4.1.4.6 Command I/F Processing
	4.1.5 Tracking
	4.1.5.6 Command I/F Processing
	4.1.6 Time & Frequency Mgt
	4.1.6.5 Command I/F Processing
	4.2 Operate Non-GN&C Systems
	4.2.1 Operate Power System
	4.2.1.7 Command I/F Processing
	4.2.2 Operate Thermal Control System
	4.2.2.4 Command I/F Processing
	4.2.3 Structures & Mechanism Support
	4.2.3.5 Command I/F Processing
	4.2.4 ECLSS Operation
	4.2.4.7 Command I/F Processing
	4.2.5 Communication
	4.2.5.5 Command Processing
	4.3 Support Flight Crew Activities
	4.3.1 Health Maintenance
	4.3.1.2 Medical Diagnostic
	4.3.1.3 Treatment Support
	4.3.1.7 Command I/F Processing
	4.3.2 Space Station Safety
	4.3.2.1 Caution & Warning
	4.3.2.2 Abnormal & Emergency Procedures
	4.3.2.4 Command I/F Processing
	4.3.4 EVA Support
	4.3.4.5 EVA Real Time Monitor & Control
	4.3.4.10 Command I/F Processing

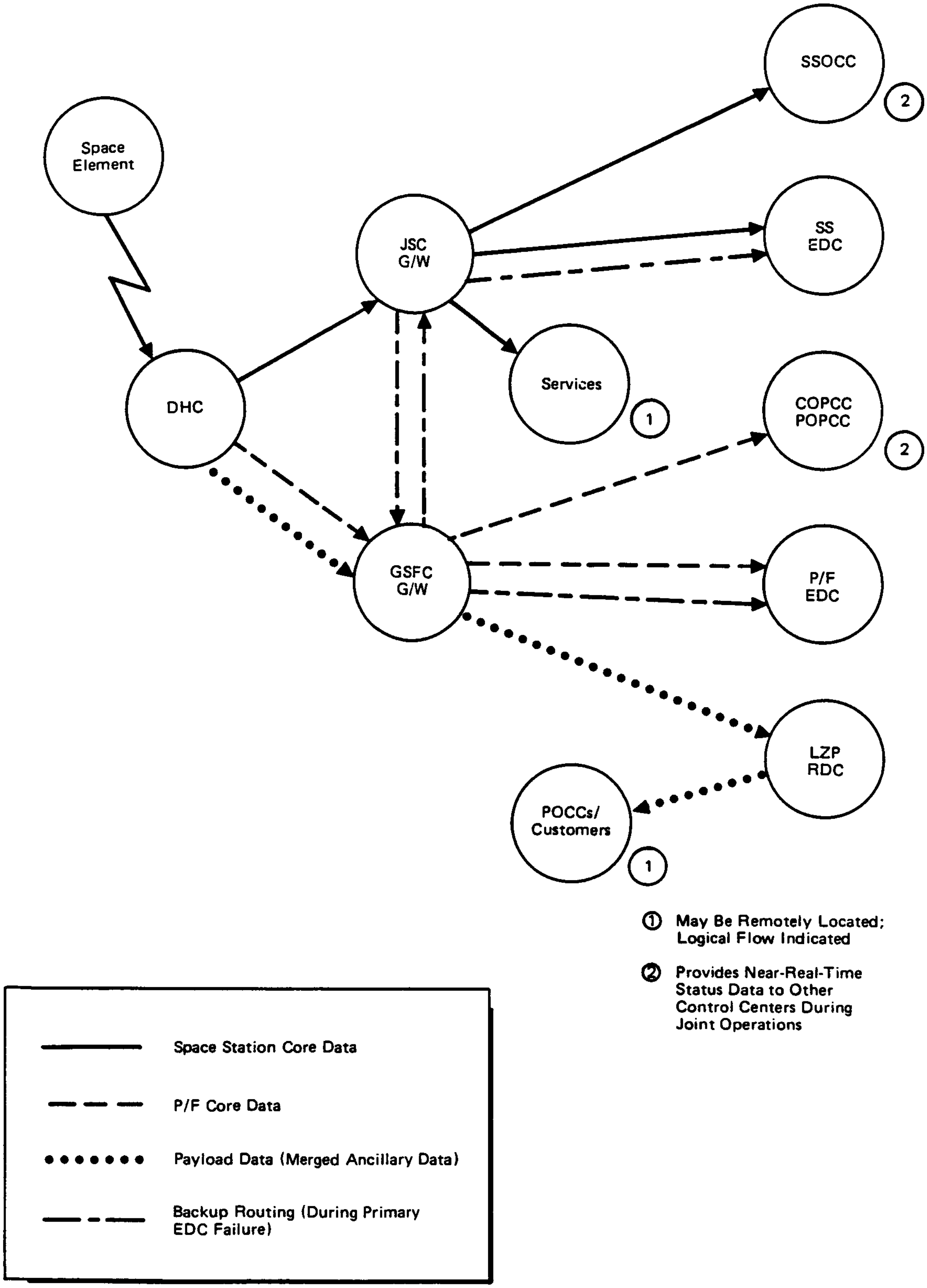
Table 7.2.3-1
Ground Element Function Allocation

Element	Functions
Control Centers (CCs) (Cont)	4.4 Provide Customer Avionics Services
	4.4.3 Tracking Services
	4.5 Monitor & Status System
	4.5.3 Mass Properties Configuration Update
	4.5.4 Diagnostics Support
	4.5.4.1 Fault Analysis
	4.5.4.2 Fault Correction
	4.5.4.3 Trend Analysis
	4.5.6 Command I/F Processing
	5.1 Manage Flight System Facilities
	5.1.1 Flight Data Base Mgt
	5.1.1.2 Data File Mgt
	5.1.1.6 Command I/F Processing
	5.1.2 Flight Resource Mgt
	5.1.2.8 Command I/F Processing
	5.2 Manage Ground System Facilities
	5.2.1 Interface Management
	5.2.2 Schedule/Status Compare
	5.2.3 Transmit Reconfiguration Schedule
	5.2.4 Ground Status Database Management
	5.3.5 Adjust For Unscheduled Mode Change
	5.2.6 Displays & Controls
Engineering Data	1.4 Manage Deliverable Customer Centers (EDCs) Data
	1.4.4 Ancillary Data Acquisition
	1.5 Manage Deliverable Core Data
	1.5.5 Engineering Data Analysis
	1.5.6 Core Data Accounting
	5.2 Manage Ground System Facilities
	5.2.1 Interface Management
	5.2.2 Schedule/Status Compare
	5.2.3 Transmit Reconfiguration Schedule
	5.2.4 Ground Status Database Management
	5.3.5 Adjust For Unscheduled Mode Change
	5.2.6 Displays & Controls

Table 7.2.3-2
Proposed Locations Of Elements
(Based on 1997 Mission Data Base)

Element	Proposed Location
Data Handling Facility	White Sands
Level 0 Processing Facility (Low Rate)	Goddard Space Flight Center
(High Rate)	GSFC, JPL, LARC
Space Station Operations Control Center	Johnson Space Center
Co-Orbiting Platform Control Center	Goddard Space Flight Center
Polar Orbiting Platform Control Center	Goddard Space Flight Center
Engineering Data Centers	1) Johnson Space Center 2) Goddard Space Flight Center
Payload Operations Control Centers (SSIS)	Distributed
Regional Data Centers (SSIS)	Goddard Space Flight Center Jet Propulsion Laboratory Langley Research Center Johnson Space Center Marshall Space Flight Center

This design approach offers the customer the advantage of immediate availability of the time-homogeneous ancillary data required for payload data processing and payload control. Other approaches, such as the obtaining of ancillary data from a ground replication of the onboard database, have the potential for imposing delays in the delivery of the data. Also, the problems associated with the provision of the data, be it through queries, broadcasting of data sets, etc., are the same whether they are to be solved onboard or on the ground. A ground-oriented approach adds the complexity of managing the replication of the birthsite, onboard database to satisfy the requirements of the payload users and is recommended only if the proposed approach proves infeasible due to onboard processing or bandwidth limitations.



① May Be Remotely Located; Logical Flow Indicated

② Provides Near-Real-Time Status Data to Other Control Centers During Joint Operations

Figure 7.3.1-1. Real-Time Core Engineering Data Flow

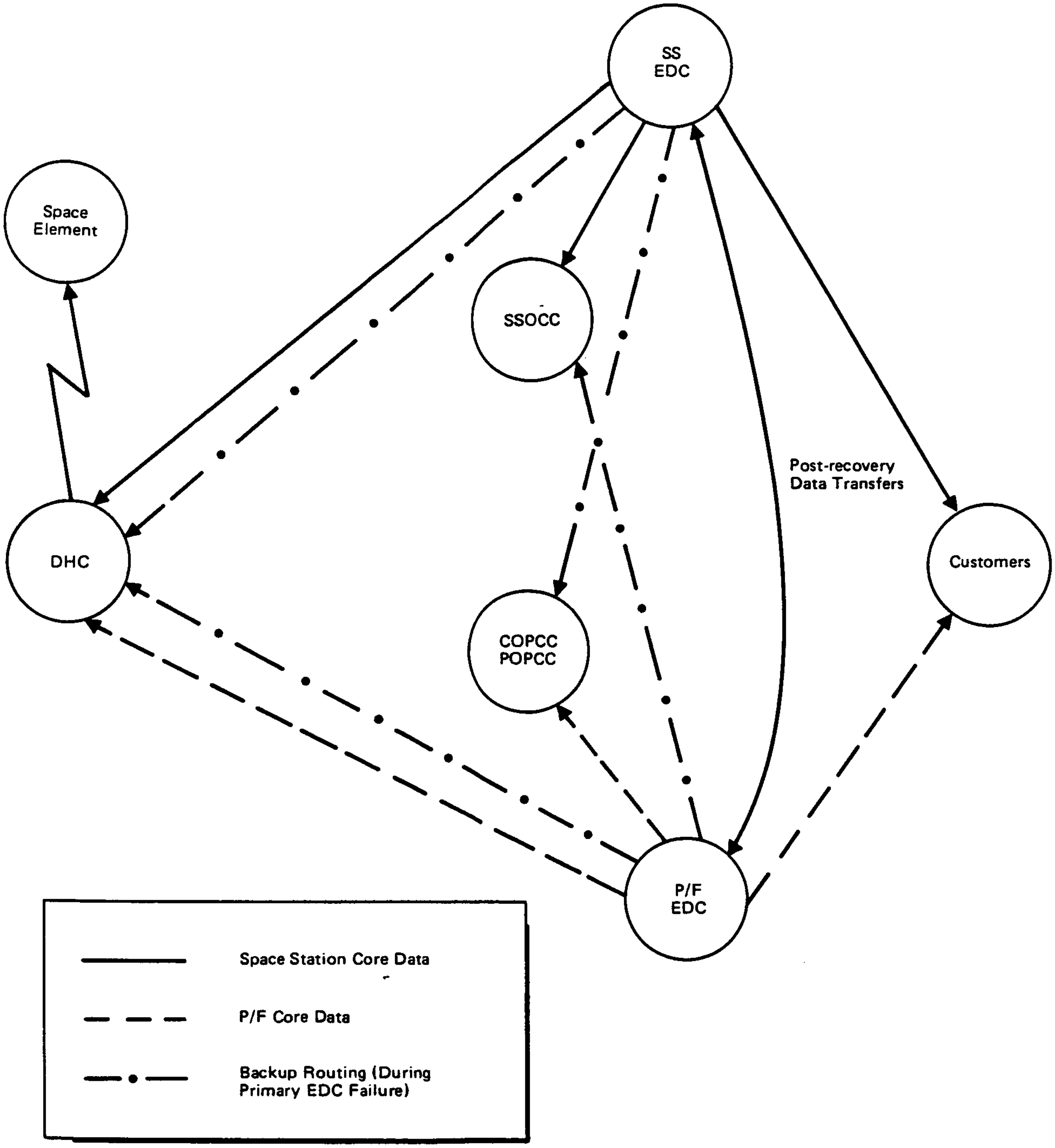


Figure 7.3.1-2. Retrieval of Archival Core Engineering Data

7.3.1.2 Core Operations Support

Core operations/administrative data packets to support the Space Element's core ground operations are downlinked within dedicated virtual channels (one real-time and one playback) within the SSA return link. The DHC routes these channels to the appropriate (JSC for Space Station and GSFC for platform) NASA Center gateway. At the gateway, the packets are extracted and, based upon the application ID, routed to the appropriate node(s). These nodes include the Control Center/Mission Scheduling, the EDC, and other Ground Services.

Packets containing core engineering (Space Element status) data are routed to the Control Center and the EDC. The Control Center utilizes the data for its core operation's monitoring and control functions. It also extracts Space Element status and incorporates it into operations messages which it sends to other Control Centers involved in joint operations and to supporting institutional facilities (e.g. the Flight Dynamics Facility for platform support).

The EDC creates and manages the full-rate full-sample core engineering database. It serves the Control Center and the Space Element as the highest priority users for the retrieval of core data sets, report generations, and common data analyses (e.g. plots). There are two EDC's, and they each provide a limited backup of the other's functions. In the event of the failure of a Control Center's primary EDC, data destined for the failed EDC is routed to the alternate EDC. The alternate EDC stores the data and services requests from the failed EDC's Control Center and Space Element. The available data sets are limited to those acquired since the failure-induced handover. The alternate EDC continues to provide its normal services, though it may reprioritize the requests. Upon recovery, the primary EDC requests the transfer of its saved data sets from the alternate EDC.

The ground system flexibility is also dependent upon the amount of preprocessing which is required (and which would have to be duplicated) to render the core engineering data useful to the EDC's and Control Centers. It is assumed the onboard system provides data with the following attributes:

- forward direction, no reversal required
- engineering units (level 1A), no PCM calibrations required

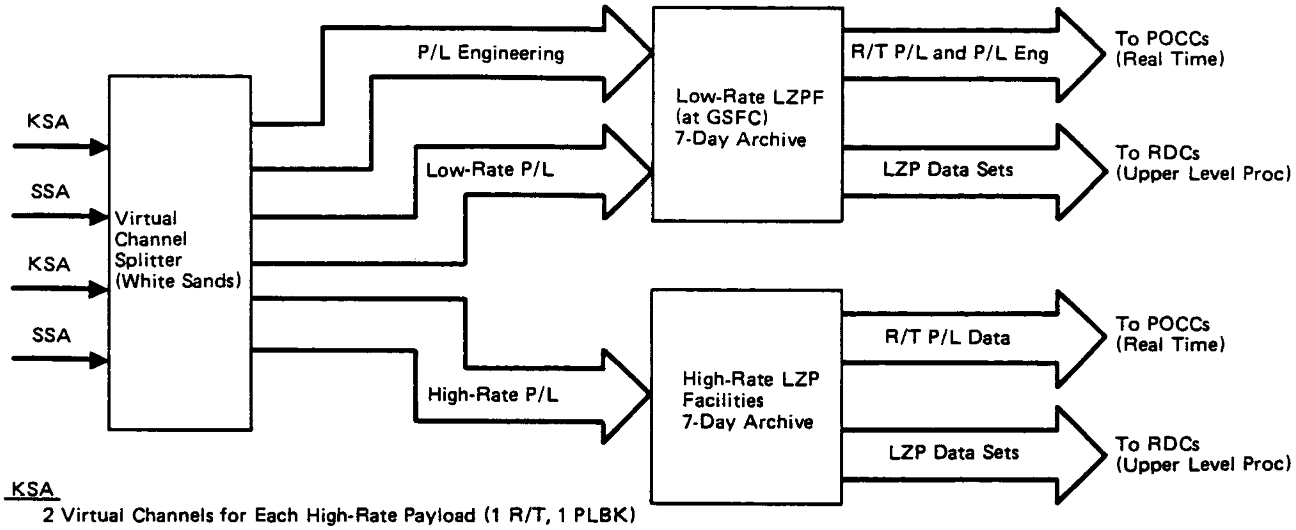
- stable formats, air/ground communicated formats, or formats that are defined by data contents (e.g. parameter ID's and pointers contained within the data), no offline reconfiguration processes required
- groupings by subsystem, minimal sorting required for inclusion into a database manager.

Packets containing Space Station service-oriented data messages are also managed by the JSC gateway. The gateway processing may include a service manager that provides protocol conversion and message routing between the air-to-ground, CCSDS format and the ground distribution, ISO format. It is assumed that there is an onboard service manager, analogous to the ground service manager, that manages the service-oriented messages. The extent of the managers' processing is dependent upon the compatibility of the CCSDS and ISO formats and the ability of the addressed services to handle the two formats. Source and destination identifiers within the CCSDS format would simplify the role of the service managers, since the services support multiple users and any user can choose among multiple services. An example is a scenario where a crewperson at an MPAC wants interactive access to one of the ground services, such as archival data query/retrieval. For roundtrip routing, both the user's MPAC and the archive must be uniquely identified. A multitude of ID's may be required to provide unique mappings for all possible combinations or application-level processing (service managers) of the packet data fields is required to determine the routing. A similar problem exists for space/ground inter-processor communications.

7.3.2 Payload Data Mangement

Payload data procesing will impose the greatest burden on the SSDS; the high data rates and rapid delivery requirements establish a significant technology demand on the ground system. Payload data flow is depicted in Figure 7.3.2-1.

As mentioned in Section 7.2.2, all low rate mission payload data (less than 10 Mbps) will be multiplexed together onboard and will be sent on one of two virtual channels (real time or playback) on the KSA-R link; and each high rate mission's payload data will be allocated one virtual channel for real time and one virtual channel for playback on the KSA-R link. In addition, a predefined subset of core ancillary data will be embedded into the payload packets for



KSA
2 Virtual Channels for Each High-Rate Payload (1 R/T, 1 PLBK)
2 Virtual Channels for Composite Low-Rate Payload (1 R/T, 1 PLBK)

SSA
2 Virtual Channels for Core Engineering (1 R/T, 1 PLBK)
2 Virtual Channels for Composite Payload Engineering (1 R/T, 1 PLBK)

Figure 7.3.2-1. Payload Data Flow

use in real time quicklook functions at POCC's and/or upper level processing functions at RDC's. All payload engineering data will be allocated one virtual channel for real time and one virtual channel for playback on the SSA channel. The DHC at White Sands performs the frame synchronization for all channels and removes fill frames.

Each frame synchronizer has a Reed-Solomon Error Correction Decoder and all data from the frame sync is fed to it. If the decoding is successful, the data is assumed to be R-S encoded, it is so tagged, and all further processing occurs on the corrected data. If the decoding is unsuccessful, it is so tagged, and processing is done on the uncorrected data. This is done on a frame-by-frame basis so that some virtual channel may be encoded and others not. Subsequent to this correction and check, the virtual channels are identified, separated and virtual channel accounting begun. The Processing, Accounting, Quality Monitoring and Fault Isolation Functions can be accessed by RDC's, POCC's and independent users.

The level 0 processing would then be performed either at the low rate LZP facility located within GSFC or at high rate LZP facilities collocated at RDC's. This process consists of packet reordering and gap filling to create contiguous data sets on a payload-by-payload basis. The real-time data will be packet routed to POCC's for quicklook purpose as needed.

Processing of payload data beyond level zero processing is outside the boundaries of the SSDS and, therefore, not discussed here.

Payload Data Traffic is provided in Figure 7.3.2-2 and is based on the Langley Data Base for the year 1997.

7.3.3 Uplink Command Data Management

In order to understand the ground topology for the flow of uplink command data, it is important to understand the end-to-end design for command management. This design is presented in Section 4. Table 7.3.3-1 summarizes the command management functions of each of the ground elements and provides reference to the sections that define these functions in greater detail.
The design feature which drives the ground SSDS topology is the transparent handling of the payload command data. Since the SSDS performs no checks on the payload commands, there is no requirement that they be routed through the Control Center. The uplink payload command packets generated at POCC's and customer facilities are routed directly to the ground/space gateway, the Data Handling Center.

Uplink core command packets generated at the Control Centers are also routed to the DHC. It is not necessary that COP core command packets be routed via the SSOCC.

The DHC maintains a log of received packets, collects the packets and frames them in accordance with the CCSDS formats. Encryption of the uplink frames for transport to the Space Element, if required by the Space Station Program, would also be a DHC responsibility.

The flow of uplink command data is depicted in figure 7.3.3-1.

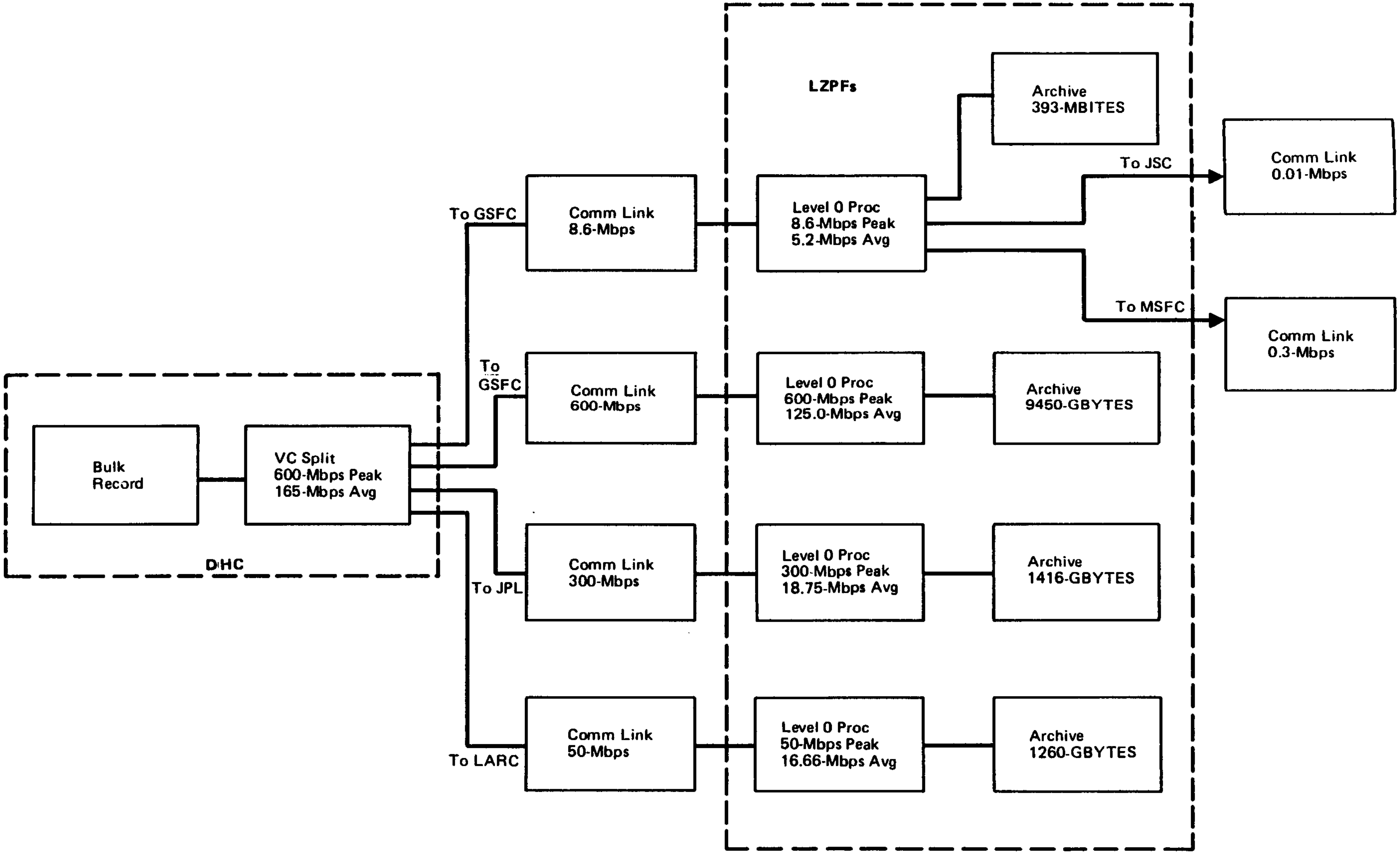


Figure 7.3.2-2. Payload Traffic, 1997

Table 7.3.3-1
Command Data Management Functions Map
To Ground Elements

ELEMENT	FUNCTIONS	REFERENCE SECTION
Control Center	Mission Scheduling • Development/Maintenance of Mission (P/L and Core) Operations/Attributes Database • Development/Maintenance (Change) of Operating Events Schedule	7.4.6.2.6
	Mission Operations: Core Cmd-Management • Operator Authorization • Access Control to Command Sets and Software Loads • Command Generation • Command Validation - Safety - Effectivity - Schedule Compliance - Etc. • Verification of Receipt/Execution • Management of Two-Stage and Stored Program Command Sequences • CCSDS Telecommand Packet Build	7.4.6.2.2, 7.4.6.2.4, 7.4.6.2.5
Engineering Data Center	Capture and Archival Storage of Command Data • Uplinked Telecommands • Downlinked Command Logs	7.4.7.1,
POCC's or Independent Customers' Facilities	Payload Operations: Payload Cmd. Mgmt. • Payload-Specific Functions Analogous to those performed by the Control Center for Core Commands: - Operator Authorization - Access Control to Command Sets - Command Generation - Command Validation - Verification of Receipt/Execution - Management of Stored Program - Command Sequences • CCSDS Telecommand Packet Build	None (Ground SSIS functions listed for completeness)
Data Handling Center	Ground/Space Gateway Management • POCC and Customer LOGON • Uplink Authorization • CCSDS Frame Build • CCSDS TC Transfer Layer Services	7.4.2.2

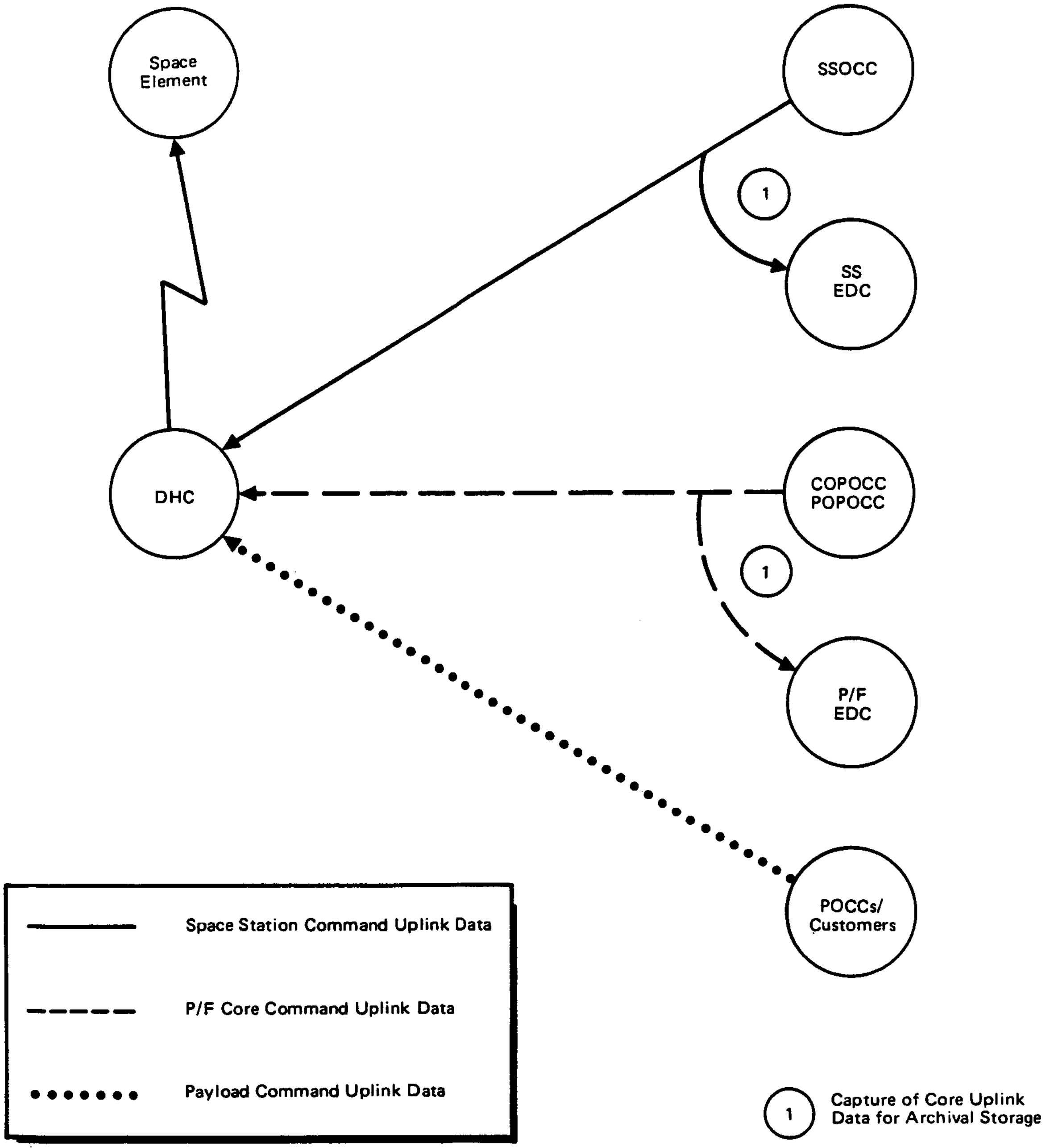


Figure 7.3.3-1. Command Uplink Data Flow.

7.3.3.1 Payload Uplink Command Data Management

Payload uplink packets can be issued from customer facilities and POCC's distributed throughout the ground system.

In order to issue uplink packets, the customer or POCC logs on to the Data Handling Center. LOGON includes providing a password ID. POCC's providing continuous support can remain logged on to the DHC. As an optional service, the user can request a schedule report containing information on his scheduled payload activities and information of general interest, e.g trajectories or TDRSS communication timelines. The report is requested from the Control Center's Mission Scheduling System which routes it to the user. The user can also request connection with the Mission Scheduling System to negotiate schedule changes.

After LOGON, the customer/POCC creates uplink CCSDS packets which are routed via the ground network to the DHC. The DHC performs an uplink authorization check on each of the packets by checking the application (destination) ID vs. a table listing the ID's which this source, the customer or POCC, is authorized to address. The authorization table is created prior to the mission and is controlled by the Ground Services Center (GSC). Packets which successfully pass this check are input to the frame build process. The payload frames are uplinked on the TDRSS KSA-F link. Packets which fail the uplink authorization check are rejected, and notifications are sent to the customer/POCC and to the GSC communications security monitoring function.

Provision of additional privacy/security measures, e.g. encryption of the command data, is a customer/POCC responsibility. The SSDS only requires that the header information remain clear.

7.3.3.2 Core Uplink Command Data Management

Core uplink CCSDS packets are issued from the Control Center. They are routed over the NASA Center Network, and the Engineering Data Center captures and archives the packets. From the Center's gateway the packets are routed to the Data Handling Center, where they are built into CCSDS frames for transmission on the TDRSS SSA-F link.

The Control Center is continuously logged on to the Data Handling Center. A threat analysis is necessary to determine the security measures required for the Control Center-to-DHC link. Encryption of the packet data fields, if required, would be a function of the NASA Center gateway.

7.3.4 Mission Operations Coordination

This section describes the flow of schedule and status data throughout the ground SSDS in support of mission operations. The end-to-end design for system control/management is presented in Section 4.4. Table 7.3.4-1 summarizes the mission coordination functions of each of the ground elements and provides reference to the sections that define these functions in greater detail.

Figure 7.3.4-1 depicts the interfaces for the flow of schedule and status data and the general order of precedence for schedule generation and status reporting. In general, the order reflects the hierarchical nature of the controlling elements. Each element provides to lower level elements the scheduling and status information required to perform their functions and receives from them only the status information which can impact the higher level schedule.

Considering the many interfaces required for mission coordination, the standardization of the SSP scheduling and status reporting systems is highly desirable. Commonality is particularly needed between the Space Station and Platform Mission Scheduling Systems considering the number of elements and customers which may require interfaces to both systems.

The types of schedule and status information required for mission coordination break into two basic categories: operations and communications.

7.3.4.1 Mission Operations

Mission operations information includes the scheduling and statusing of the mission activities. Mission scheduling is a function of the centers controlling the Space Elements. The hierarchy among the control centers is:

- STS MCC
- Space Station OCC
- Platform OCC
- POCC
- OMV/OTV Remote Operations CC
- Free Flyer OCC

Table 7.3.4-1
Mission Coordination Functions Map to Ground Elements

ELEMENT	FUNCTIONS	REFERENCE SECTION
SSOCC	Space Station Mission Scheduling/Status • P/L Modes • Onboard Core Operations • Proximity Operations • Ground Resources	7.4.6.2.6
	SSOCC Facility Management • Interface to SS Mission Scheduling • Interface to GSC Comm. Status	7.4.6.2.5
COPCC/POPCC	Platform Mission Scheduling/Status • P/L Modes • Onboard Core Operations • Ground Resources	7.4.6.2.6
	COPCC/POPCC Facility Management • Interface to Mission Scheduling	7.4.6.2.5
Ground Services Center	Communication Scheduling Status • Interface to Mission Scheduling and Network Control Center (NCC) • Status Interface to each Ground Facility	7.4.3.2.2
	Common Resource Scheduling/Status • Data Handling Centr (DHC) • Level Zero Processing Facilities (LZPF)	7.4.3.2.3
EDC's	Facility Management • Interface to Mission Scheduling/Status • Interface to GSC for Comm. Status	7.4.7.2.4
POCC's, Customers	Payload (Independent) Operations Scheduling/Status	None (SSIS function)
	Facility Management • Interface to Mission Scheduling/Status • Interface to GSC for Comm. Status	7.4.4.2.8

Table 7.3.4-1
Mission Coordination Functions Map to Ground Elements (cont'd)

ELEMENT	FUNCTIONS	REFERENCE SECTION
DHC, LZPF's	Facility Management	7.4.2.3.5
	• Interface to GSC Common Resource Scheduling/Status	7.4.5.2.5
NCC	TDRSS/NASCOM Scheduling/Status	None (SSIS function)
	• Interface to GSC Communication Scheduling/Status	
STS MCC	STS Mission Scheduling/Status	None (SSIS function)
	• Interface to Mission Scheduling	
OMV/OTV Remote Operations Control Center	OMV/OTV Remote Operations Scheduling/Status	None (SSIS function)
	• Interface to Mission Scheduling for Proximity Operations	
Free Flyer Control Center(s)	Free Flyer Scheduling/Status	None (SSIS function)
	• Interface to SS Mission Scheduling for Proximity Operations	

where layers are present only as applicable to joint operations. For operations within the proximity of the Space Station, the SSOCC is the controlling ground element with the exception that its schedule is generally dependent upon the STS schedule for operations involving the shuttle.

The mission schedule, as output from the Space Station and Platform OCC's, drives the scheduling of the ground resources. These resources include 1) the ground facilities dedicated to mission support, i.e. the Control Centers, POCC's, and EDC's; and 2) the shared communications and data handling resources managed by the Ground Services Center. The facility managers within the dedicated facilities and the GSC in turn schedule and status their resources, reporting to Mission Scheduling only the status and change requests that impact mission operations.

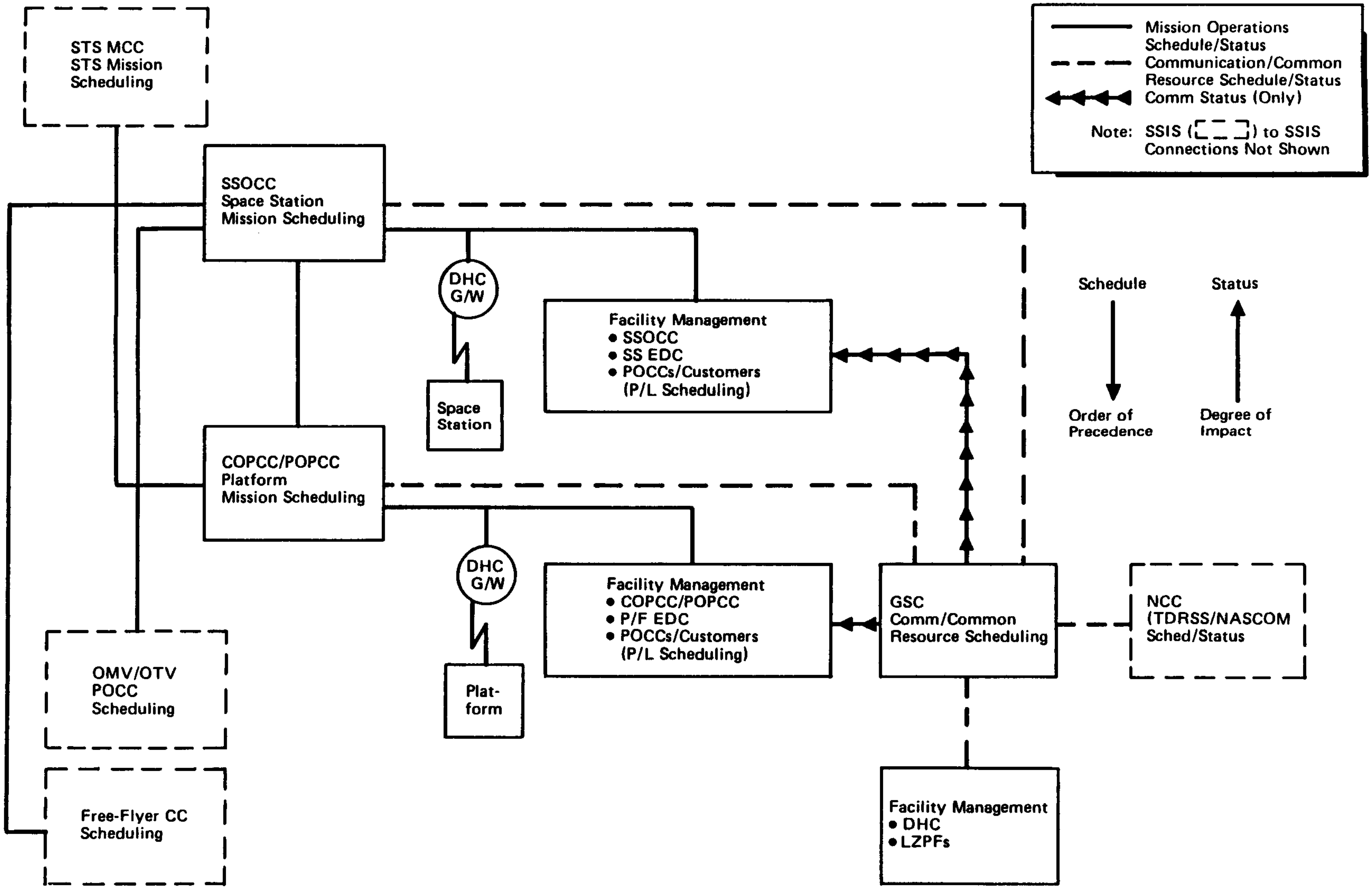


Figure 7.3.4-1. Mission Coordination Data Flow

The mission operations schedule and status data tends to be low volume and aperiodic (event driven) in nature. The exceptions are the periodic reporting of core status among the Control Centers and the periodic broadcasting of timelined information of general interest, e.g. ephemeris.

7.3.4.2 Communications

The mission schedules, as derived by the Space Station and Platform Mission Scheduling Systems, are input to the Ground Services Center. The GSC develops a communications schedule and schedules the common data handling facilities as required to support mission operations.

The GSC coordinates with the Network Control Center (NCC), on behalf of all SSP elements, the scheduling of the TDRSS and NASCOM communication resources. It also schedules and configures the data handling facilities, the DHC and level zero processing facilities, for mission support.

The GSC receives status reports from the NCC and from the DHC and LZPF facility managers and coordinates reconfigurations. The GSC provides data flow reports to the mission-dedicated facilities' managers and a summary report to the OCC's Mission Scheduling System. Problem resolution occurs on the facility level, and only those problems which cannot be resolved and which impact mission operations are reported to Mission Scheduling.
The scheduling data and status reports to Mission Scheduling tend to be low volume and aperiodic (event-driven) in nature. The data flow reports to the individual facilities are short status messages that are issued periodically (approximately every five seconds).

7.4 Strawman Architecture

7.4.1 Overview

This section provides an overview of the SSDS ground system. Subsequent sections will provide detail concerning interface definition, functional descriptions and design approach for each of the ground elements.

Figure 7.4.1-1 provides an overview of the ground system. Correspondingly, Figure 7.4.1-2 defines the space/ground data as a function of TDRSS single access K and S-Band channels between the ground and Space Station/Platform elements. Figure 7.4.1-3 defines the ground system traffic relative to the type of traffic which will flow between the ground system elements.

The approach to data distribution from the point of ground system receipt at the White Sands/NASA Ground Terminals and handling of the level 0 processing functions features a "hybrid system" — a hybrid of both centralized and distributed processing. The Network Topology Trade Study that supports this approach is provided in the Task III report, Volume I, Section III.

To review, the primary dependencies on the space element in implementing the hybrid approach are as follows:

- all data is packetized and framed in an identical CCSDS format
- all low rate payload data (less than 10 Mbps) is transmitted in either a real time or playback virtual channel
- each high rate payload uses two virtual channels, one for real time, one for playback
- core data is assigned two virtual channels (real time and playback)
- payload engineering data is sent as a composite of all payloads multiplexed on two virtual channels (real time and playback)

With this data definition onboard, the Data Handling Facility at White Sands splits and routes the virtual channels to the ground elements as follows:

- low rate payload data and payload engineering data to GSFC for real time distribution to POCCs (required for real time operations), and level 0 processing for data set distribution to designated RDC's.

- High rate payload data to high rate Level 0 Processing Facilities (LZPF) at GSFC, JPL, and LARC for as needed real time distribution to related POCCs, and level 0 processing for data set distribution to designated RDCs which are assumed to be co-located with the high rate LZPFs. Note that this identification is based on the 1997 Langley

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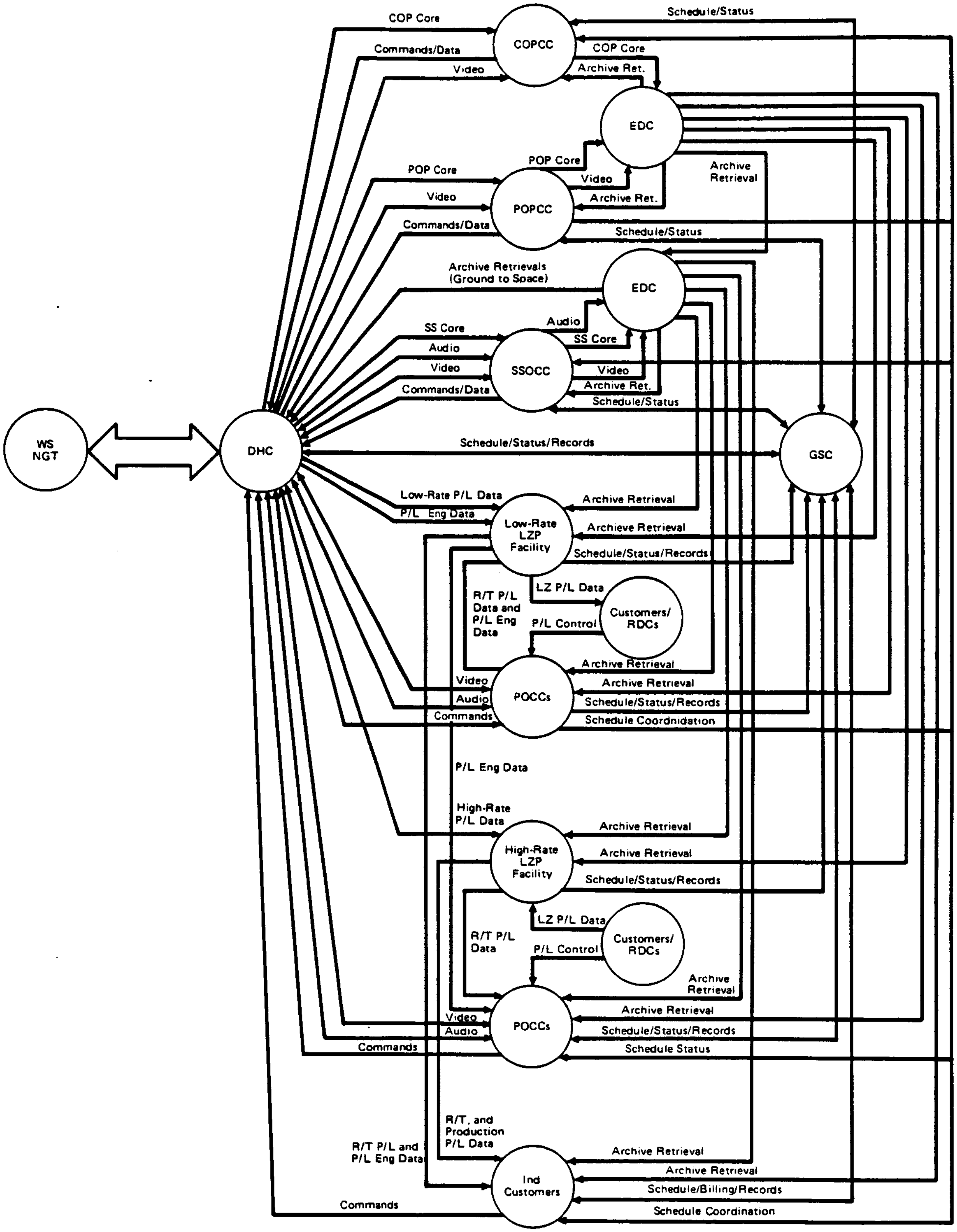

Figure 7.4.1-1. Ground SSDS Topology

	Payload Data	P/L Eng Data	Core Data	P/L Command	Core Command/Data	Audio	Low-Rate Video	High-Rate Video
Space Station								
SSA Up					X	X	X	
SSA Down		X	X			X	X	
KSA Up				X				X
KSA Down	X							X
POP								
SSA Up					X			
SSA Down		X	X				X	
KSA Up				X				
KSA Down	X							

Figure 7.4.1-2. Space-Ground Data Definition

database and could change as high rate missions are added or deleted from the program

- core data to the appropriate Control Center for real-time monitoring and control, and archive in the Engineering Data Center.

Customers interface into the ground system for payload control through an existing POCC (either at the POCC or via remote terminals connected via a Customer Inteface Element) or as independent customers with direct command interface through the DHC. Customers receive their level 0 processed data through an LZPF or through designated RDCs (not an SSDS element). It should be noted that independent customers, especially for high rate payloads, could provide their own level 0 processing function.

7.4.2 Data Handling Center (DHC)

In the strawman design, the Data Handling Center (DHC) serves as the space/ground gateway -- receiving, buffering, and routing data to the ground data distribution network from the TDRSS ground system and vice versa. The DHC is located at White Sands and directly interfaces to the existing and future NASA Ground Terminals, and to the Data Distribution Network (e.g.,

	TDRSS-SS KSA	TDRSS-SS SSA	SS-COP	TDRSS-POP KSA	TDRSS-POP SSA	DHC-SSOCC	DHC-COPCC	DHC-POPCC	DHC-POCC	DHC-LZPF	LZPF-POCC	LZPF-CUST	DHC-CUST	SSOCC-EDC	COPCC-EDC	POPCC-EDC	POCC-EDC	LZPF-EDC	DHC-EDC	CUST-EDC	GSC-DHC	GSC-POCC	GSC-LZPF	GSC-SSOCC	GSC-COPCC	GSC-POPCC
SS Core		X				X								X												
COP Core		X	X				X								X											
POP Core					X			X								X										
SS Cmd Up		X				X																				
SS Data Up		X				X																				
COP Cmd Up		X	X				X																			
COP Data Up		X	X				X																			
POP Cmd Up					X			X																		
POP Data Up					X			X																		
Archive Retrievals		X												X	X	X	X	X	X	X						
High-Rate Video Up	X					X			X					X												
High-Rate Video Down	X					X			X					X												
Low-Rate Video Up		X				X			X					X												
Low-Rate Video Down		X			X	X		X	X					X		X										
Audio Up		X				X			X					X												
Audio Down		X				X			X					X												
SS Payload Data	X									X	X	X														
SS Payload Eng Down		X								X	X	X														
SS Payload Cmd Up	X								X				X													
COP Payload Data	X		X							X	X	X														
COP Payload Eng Down		X	X							X	X	X														
COP Payload Cmd Up	X		X						X				X													
POP Payload Data				X						X	X	X														
POP Payload Eng Down					X					X	X	X														
POP Payload Cmd Up				X					X				X													
Schedule Coord		X			X																X	X	X	X	X	X

Figure 7.4.1-3. Traffic Link Assignments

NASCOM). The strawman design emphasizes a relatively simple DHC which directly pipes most data to LZPF's the SSOCC, or platform OCC's at major NASA centers for further processing. Uplink frame build and uplink authorization, however are performed at the DHC due to its centrality as the ground/space gateway.

7.4.2.1 Functional Interface Description

The functional interfaces for the DHC, illustrated in figure 7.4.1-1 are discussed in the sections below.

7.4.2.1.1 NASA Ground Terminal(s)

The Data Handling Center will be receiving and transmitting data to the NGT's, each of which will be receiving data from the Space Station Elements (SS, COP, and POP). Data and commands are in the CCSDS packet format, with internal core and payload data fully independent of transfer frame structure. In the strawman design it is assumed that none of the physical TDRSS elements themselves are dedicated to Space Station, including the NGT's. That is, Space Station data may be received through either of the NGT interfaces, and the physical interfaces are identical.

7.4.2.1.2 Ground Services Center

The DHC interfaces with the Ground Services Center for purposes of resource coordination. All communication with the NCC is through the GSC to assure coordination of SSDS requests. The DHC manages itself using the inputs provided by the GSC.

Specifically, the GSC provides the following to the DHC:

- TDRSS/Data Distribution Network Schedule Information — for scheduling of the NGT—DHC and the DHC—Data Distribution Network interfaces. The strawman design attempts to minimize the need for scheduling through the use of dynamic bandwidth allocation techniques, but automated scheduling of high bandwidth resources seems inevitable.

- Mission Schedules — also to allow support for high rate missions.

- Routing Tables — tables which map CCSDS application ID's to their uplink/downlink destinations and thus allow data to be correctly routed

- Authorization Tables — tables which map CCSDS application ID's with sources allowed to be sending uplink data and commands to that destination.

The DHC provides the following information to the GSC:

- Equipment Status — including configuration data and fault reporting which effects other SSDS elements
- Data Quality — as determined by the Reed Solomon decoding of CCSDS transfer frames
- Data Accounting Information — on a CCSDS transfer frame basis

7.4.2.1.3 Level Zero Processing Facilities (LZPF's)

Payload scientific and engineering data are sent directly to the LZPF's. The DHC acts as a bent pipe for this data, supporting basic services to remove space-ground link communications artifacts, to provide line outage protection, and to provide rate smoothing. The DHC does not provide store-and-forward service, batching, or merging of recorder data. These services are provided at LZPF's located at major NASA centers. High rate data is sent directly to the LZPF's associated with GSFC, JPL, and LARC. Low-rate data is sent directly to the LZPF at GSFC. The downlink CCSDS packets are error corrected and formatted by the DHC for transport over the ground data distribution network. The DHC does not require knowledge of the internal data formats since it routes to the LZPF's according to virtual channel.

7.4.2.1.4 Operations Control Centers (OCC's)

The SSOCC, COPCC and POPCC send uplink data to the DHC and receive downlink data directly from the DHC. Data traffic includes engineering data, commands, audio, and video. Payload OCC's interface directly with the DHC for command uplink as well as audio and video links, but receive downlink engineering and quicklook data through their corresponding LZPF's. The DHC will accept uplink traffic only if an appropriate authorization has been issued by the GSC and the source of the traffic has been identified through a secure session logon.

7.4.2.1.5 Independent Customers

The Independent Customers send uplink data to the DHC through links similar to those provided to the payload OCC's. As with the payload OCCs all downlink data is provided to the independent customers through the GSFC LZPF (which is responsible for the delivery of all low rate payload data).

7.4.2.2 Functional Description

The Data Handling Center is the direct interface between the space-ground communication link (TDRSS) and the ground data distribution network. Its functions are essentially limited to those of a gateway. In the strawman design, it will perform the following functions:

DOWNLINK DATA PROCESSING

Bulk Data Recording — to provide line outage protection

CCSDS Frame Synchronization — to support routing of CCSDS virtual channels to LZPF's, SSOCC, and platform CC's on a transfer frame basis

Reed-Solomon Error Correction — to remove ground-space link noise

Data Accounting — on a CCSDS transfer frame basis

Virtual Channel Routing — to pipe virtual channels to appropriate LZPF's, SSOCC, and platform OCC's

Link Performance Monitoring — to provide link quality data to the GSC

Retransmission Services — to support retransmission in the event of communications link or external element failure

Data Distribution Network Interface — to support distribution of virtual channels

UPLINK DATA COLLECTION

Data Distribution Network Interface — to support direct command and data uplink interfaces with all authorized SS ground elements

Uplink Authorization — to provide security and coordination of uplink access according to schedules and authorization tables provided by the GSC

Frame Synchronization/Build — to format and multiplex commands and data on the appropriate CCSDS uplink virtual channels

Reed–Solomon Error Encoding — to provide for uplink noise protection

Link Performance Monitoring — to provide link quality data to the GSC and issues of uplink requests

DHC FACILITY MANAGEMENT

Configuration Management — to manage equipment and gateway configuration

External Coordination — to accept schedules from and coordinate with other SSDS elements through the GSC

Cold Start, Restart and Switchover — to manage startup, restarts, and switchovers

DHC buffering of data is limited to functions required to accomplish line outage protection and data rate smoothing. Downlink payload data is separated on the basis of virtual channels, corrected, accounted for on a transfer frame basis, and routed to appropriate LZPF's for further Level Zero processing. The DHC is responsible for checking authorization for command uplink and merging data into appropriate virtual channels. However, the DHC has no command scheduling responsibilities, proceeding only on the basis of authorization tables issued by the GSC.

We have not included functions for routing audio and video data since these functions are not within the scope of the SSDS, but our implicit assumption is that this data is routed to the OCCs/POCCs and received from the OCCs/POCCs on dedicated CCSDS virtual channels.

7.4.2.3 Design

This section discusses a high level design approach to the DHC. The following key assumptions were made:

- Standards from the Consultative Committee for Space Station Data Systems are used for the TDRSS space-ground link, modified as described in Section 4 (end-to-end data flow). The proposed modifications support space/ground transparency in formatting and addressing and bi-directional telemetry and commands. The standards include the use of Reed-Solomon coding to guard against errors. Convolutional coding, however, is not used since it duplicates some of the functionality of Reed-Solomon coding at a high bandwidth cost. Customers requiring high levels of immunity to Gaussian noise are, of course, free to implement their own interior coding schemes independently of standard SSDS services.

- The CCSDS virtual channel construct, and not CCSDS segmentation, is used for all experiments. Individual virtual channels will be devoted to high rate experiments while low rate experiments will be multiplexed on a single virtual channel using the CCSDS packet telemetry standard.

- Standards compatible with the International Standards Organization (ISO) seven layer model for Open Systems Interconnect (OSI) are used for the ground data distribution network.

- The ground data distribution network provides OSI compatible services for data delivery from the DHC to the LZPFs and OCCs. In particular, the network header structure is independent of data format and data is delivered with all network artifacts removed.

- Payload scientific and engineering data is received on links organized so that individual CCSDS virtual channels may be routed directly to LZPFs and OCCs.

- Command and core engineering data are routed through separate CCSDS links through the TDRSS S-band forward and return link services.

- Data is delivered to the DHC by the NGT at constant rates with fill inserted as appropriate to maintain data rates.

- All audio and video will be sent on separate virtual channels. No conversion or reformatting is required at the DHC.

A detailed function diagram for the Data Handling Center is shown on Figure 7.4.2.3-1. Briefly, the downlink data is captured on high density data recorders (for line outage protection), frame synchronization is performed, Reed-Solomon error correction is done on the transfer frames, and the CCSDS virtual channels are split and routed to the LZPFs at GSFC, JPL, and LARC and to CCs (SSOCC, COPOCC, and POPOCC). For high rate data, a rate smoothing function can be implemented through a pool of magnetic disks or rewriteable optical disks. The tradeoff between storage costs (an SSDS element) and communication costs (outside the SSDS) for rate smoothing was addressed in the Network Topology Tradeoff Study. Expected improvements in communication technology may make the rate smoothing function unnecessary. No further processing is done on the downlink data at the DHC. Payload OCC's and independent customers receive their data through the LZPFs, primarily GSFC, which is the LZPF to which all low rate data is routed.

The uplink process involves an authorization step similar to those found in secure network gateways. The DHC routinely receives authorization tables from the GSC. These tables define uplink access schedules and privileges for SS users. Since command scheduling and mode change authorization are accomplished onboard the spacecraft, these tables define only a first line of protection against unauthorized spacecraft data system access and the user is presented with transparent access to the onboard system once a session is established. The DHC serves simply as a secure gateway to the onboard LAN rather than a

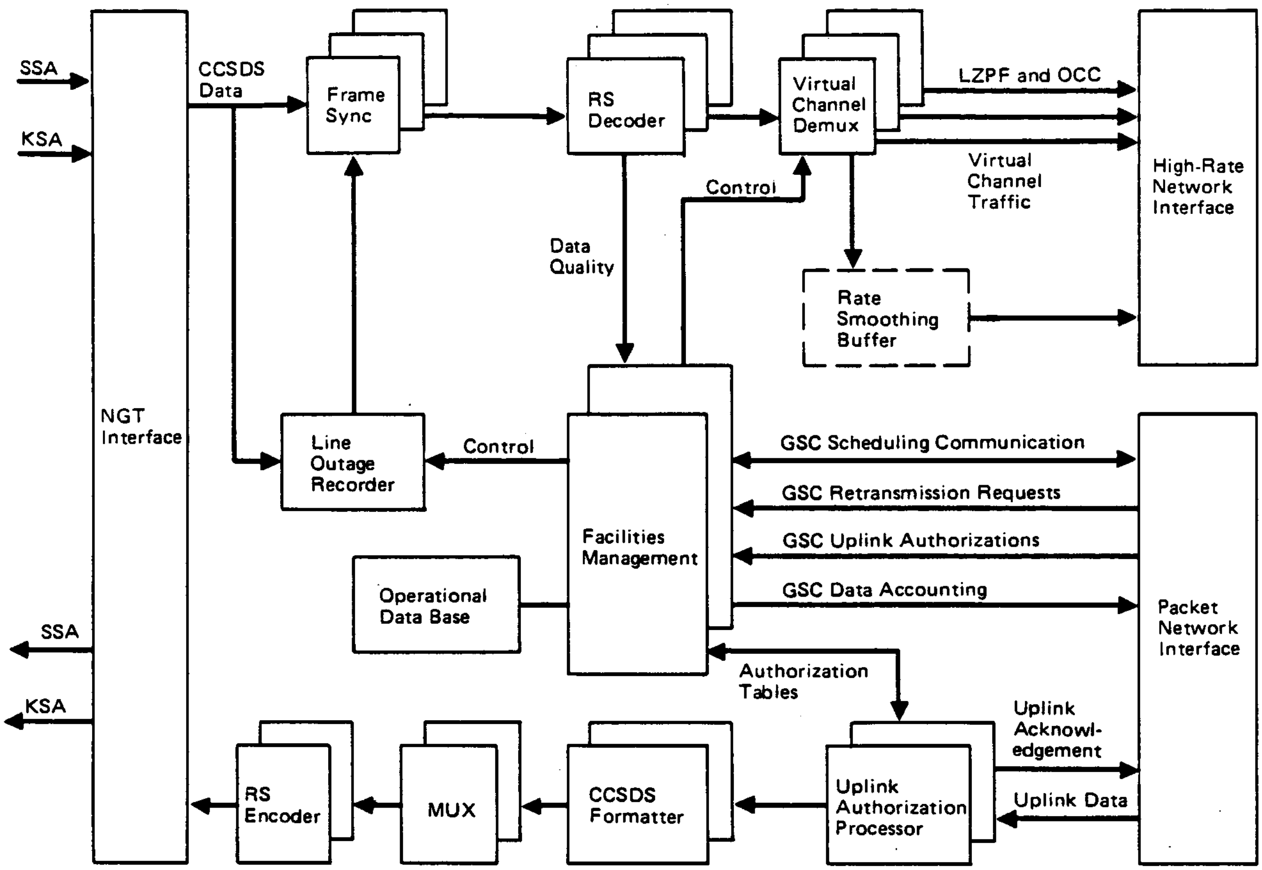

Figure 7.4.2.3-1. White Sands DHC

command verification station. The DHC will accept commands and uplink data packets from the data distribution network, multiplex them in dedicated virtual channels, performing framing, error encoding, and transmitting them to the NGTs.

The following subsections discuss each of the major functions within the DHC and our design approach to these functions.

7.4.2.3.1 Preprocessing

Preprocessing for the DHC is achieved primarily through the use of custom hardware (e.g. high speed CMOS or gallium arsenide IC's) to provide front end functions such as transfer frame synchronization, Reed Solomon decoding/encoding, and splitting of virtual channels. Use of the CCSDS transfer frame format for the ground-space communications link will greatly simplify design of this hardware assuming that a single fixed length is used for all transfer frames in a physical link and that all transfer frames are Reed-Solomon encoded. This efficiency is achieved through the relative simplicity of synchronizing to and decoding a fixed length format.

The use of monolithic IC's implementing these functions is motivated by the high bandwidths and associated timing problems. Tools for implementing this hardware (and presumably a number of off-the-shelf chips) will likely be available as by-products of the DoD VHSIC program.

7.4.2.3.2 Routing & Transmission

The CCSDS standard does not explicitly define the method for multiplexing transfer frames. To simplify scheduling and minimize reconfiguration burdens the design allows for fully dynamic allocation of bandwidth to individual virtual channels. Transfer frames may be multiplexed in any manner appropriate to the bandwidth requirements of a particular virtual channel. As individual transfer frames are received they are routed through the high rate network links to the LZPF's, and OCC's. Routing is done according to routing tables received from the GSC. The DHC's function is simply to translate the virtual channel number of the transfer frame to a network address and pass the frame and associated destination to the services associated with the high rate network. It is assumed that the ground network simply delivers the frame to the address with no communications artifacts added.

The design allows for a possible rate smoothing function. Certain payloads with high peak and relatively low average bandwidth requirements and no need for real-time data access may make use of this function to reduce communications cost.

7.4.2.3.3 Uplink Access Authorization

Since the design provides a sophisticated command management system onboard the space station elements, minimal command management is required on the ground. The DHC is required to determine whether a source sending uplink data is allowed to be sending data to the particular destination denoted by the application process ID in the CCSDS packet header. This must be done for all data, since it will not be possible to determine, with certainty, whether a particular set of bits is uplink data or uplink commands.

This function would be performed by comparing the origin and destination address in the network packets, with the application process ID in the CCSDS header. The processing would thus require the network interface to buffer and transmit the source ID to the DHC authorization processor.

7.4.2.3.5 DHC Facility Management

DHC facilities are managed by a fault-tolerant processor. Its primary functions are to:

- Receive schedules, routing tables, retransmission requests, and authorization tables from the GSC.
- Load routing tables in the virtual channel routing hardware.
- Load authorization tables in the uplink authorization processor.
- Reconfigure the line outage recorders and preprocessing hardware to implement retransmission.
- Provide equipment redundancy management.

7.4.3 Ground Services Center (GSC)

The Ground Services Center (GSC) provides communication and common resource coordination for the ground system. It serves to coordinate the scheduling of the communication and ground facility resources shared among the Space Station, COP, and POP programs. These shared facilities include the Data Handling Center, and the Level 0 Processing Facilities.

The GSC also collects status and accounting information from these facilities (outages, etc) and prepares reports of this information to both customers and the Global System Manager at the Control Centers. The GSC performs SSIS functions involving the collection of billing and usage information for ground element resources used by customers and the processing of customer bills.

7.4.3.1 Functional Interface Description

By the nature of its functions, the GSC requires interfaces to the various Space Station Program Elements and also to elements such as the NCC which are in the SSIS, as shown on Table 7.4.3.1-1. The traffic along these interfaces generally consists of low volume configuration, status, and administrative data, and voice communications. An exception to this may be the usage and accounting information, which could become voluminous.

The periodic status information is transmitted between the elements on a regular and frequent (seconds) basis in the form of standard status messages. Scheduling information will be transmitted between the elements on an aperiodic and less frequent (minutes and hours) basis as required in the form of schedule requests, responses, and reports. Usage and accounting information will be collected on a scheduled, polled basis from each element. That is, each element will be responsible for recording this information, and the GSC will poll each element on a routine schedule(e.g., hours or days) and a file transfer initiated.

Application level protocols for this information are necessary to facilitate operation of the distributed ground system elements. This is especially true since the control of the SSDS is split for programmatic reasons between that under the domain of the GSC (common resources) and that controlled by the Control Centers (development of mission schedules), leading to significant coordination issues. Coordination, rescheduling and status reporting to customers would be very difficult in this distributed environment without these appliation level interface agreements.

7.4.3.2 Functions

The GSC performs the following functions:

- Coordination Of Shared Resouces

Table 7.4.3.1-1
GSC Functional Interfaces To SSDS Ground Elements

Element	Interface Traffic	Purpose
DHC	Scheduling Messages	Resource & Schedule Coordination
	Status Messages	Perf. Monitoring, Redundancy, Configuration Mgmt
	Resource & Data Quality Records	Customer Billing & Fault Isolation
	Routing Tables, Authorization Tables	DHC Configuration
LZPFs	Scheduling Messages	Resource & Schedule Coordination
	Status Messages	Perf. Monitoring, Redundancy, Configuration Mgmt
	Resource & Data Quality Records	Customer Billing & Fault Isolation
SSOCC	Scheduling Reports Status Reports	Resource & Schedule Coordination Status Reporting
POPCC	Scheduling Reports Status Reports	Resource & Schedule Coordination Status Reporting
COPCC	Scheduling Reports Status Reports	Resource & Schedule Coordination Status Reporting
POCCs	Scheduling Reports Status Reports	Resource & Schedule Coordination Status Reporting
EDC	Scheduling Reports Status Reports	Resource & Schedule Coordination Status Reporting
NCC (SSIS Element)	Scheduling Messages Reports	Resource & Schedule Coordination
	Status Messages	Status Monitoring
	Resource & Data Quality Records	Customer Billing & Fault Isolation
Customer Interface Element(s) (CIEs)	Network Status/Schedule Data Accounting & Quality Reports. Usage Reports & Bills	Customer Support for Mission Coordination. etc.
Element and Center Gateways	Authorization and Configuration Tables	Network Management

  - Scheduling
  - Configuration Management
  - Redundancy Management
- Performance & Status Monitoring
- Usage Tracking, Data Accounting (system wide) and Fault Isolation (to common resource elements)

Shared resources are:

- Communications Resources
- Data Handling Center Resources
- Level 0 Processing Facility Resources

It is envisioned that the driver for scheduling and re-configuration will be the TDRSS resources. The other common resources will likely be far more stable as they are designed and sized to require a minimum of re-configuration in this design.

7.4.3.2.1 Control Center Facility Manager Interface

The scheduling of the LZPF and DHC common resources will be determined by the schedules received from the Control Center scheduling systems. Customers (independently or at POCCs) will first develop their mission schedules by communicating to the OCC scheduling systems via the Customer Interface Elements and the Development and Control Network.

The Control Centers will communicate these combined mission schedules in the form of reports to the GSC. The GSC and the Control Centers will then negotiate via scheduling messages.

The GSC thus receives the schedule reports for the SS, POP, and COP from the scheduling functions at each Control Center. It then configures the common resources of the ground system to support the SSP schedule.

The GSC receives status reports on communications resources from the NCC, summarizes them along with the status of other common resources in a manner appropriate for use by the Control Centers and provides these reports to the Control Centers facility managers.

7.4.3.2.2 Communications Resources

The GSC receives schedule requests from the Control Centers for the use of communications resources. These include both the TDRSS resources and the ground-to-ground communications resources. It is assumed that the SSP will be guaranteed a certain level of TDRS service. Changes to the schedule may result, for example, in changes to the TDRS schedule, re-configurations of the Transport Network DOMSAT and other links, and updating routing tables.

GSC thus provides an interface between the elements of the Space Station Program and the Network Control Center. It accepts the schedule requests from the Control Centers, integrates them, coordinates schedules and resolves conflicts with those other common resources, and coordinates on behalf of all SSP elements with the NCC to develop the schedule for the support of the SSP. It also interfaces with the SSP elements to communicate NCC initiated schedule changes. Finally, the GSC receives reports of communications resource use and data accounting.

7.4.3.2.3 DHC & LZPF Resources

The GSC receives schedule requests from the Control Centers for use of the DHC and LZPF resources. The GSC interfaces with the DHC and LZPF facility managers to assure that the DHC and LZPF configurations are consistent with other shared resources (e.g., that virtual channels are routed to/from available communication links) and support the Control Center SS schedule, and vice versa. It thus accepts the schedule requests from the Control Centers, integrates them, coordinates schedules and resolves conflicts in scheduling the communications resouces.

These services implemented by the DHC resources are described in Section 7.4.2:

Scheduling messages may be needed to assure that the configuration of the DHC is coordinated with other elements:

- o TDRSS/NASCOM interfaces
- o routing tables
- o authorization data

The services implemented by the LZPF are described in Section 7.4.5. The configuration of the Level 0 resources must be consistent with other ground elements to assure support of all payloads. Tables showing the correspondence between the packet telemetry application ID and the customer or other destination must be maintained.

The GSC receives status messages from the DHC and the LZPF and coordinates re-configurations as appropriate to respond to changes in status. An example of this might be re-routing or buffering of data in the event of an LZPF or communications failure, or messages to the Control Centers to reschedule missions if a by-pass configuration cannot be implemented.

The GSC also collects resource usage information from the DHC and LZPF for both SSDS and SSIS functions. An SSIS use of this data is for the preparation of bills for the use of chargeable resources.

7.4.3.3 Design Approach

The GSC requires the following components as shown on Figure 7.4.3.3-1:

- o Gateways
  - – DHC, LZPF
  - – NCC
  - – Control Centers
  - – DSIT Environment (Not shown)

The gateways accept the status, scheduling, and usage messages and reports and route them to/from the GSC local data distribution network (e.g., a LAN),

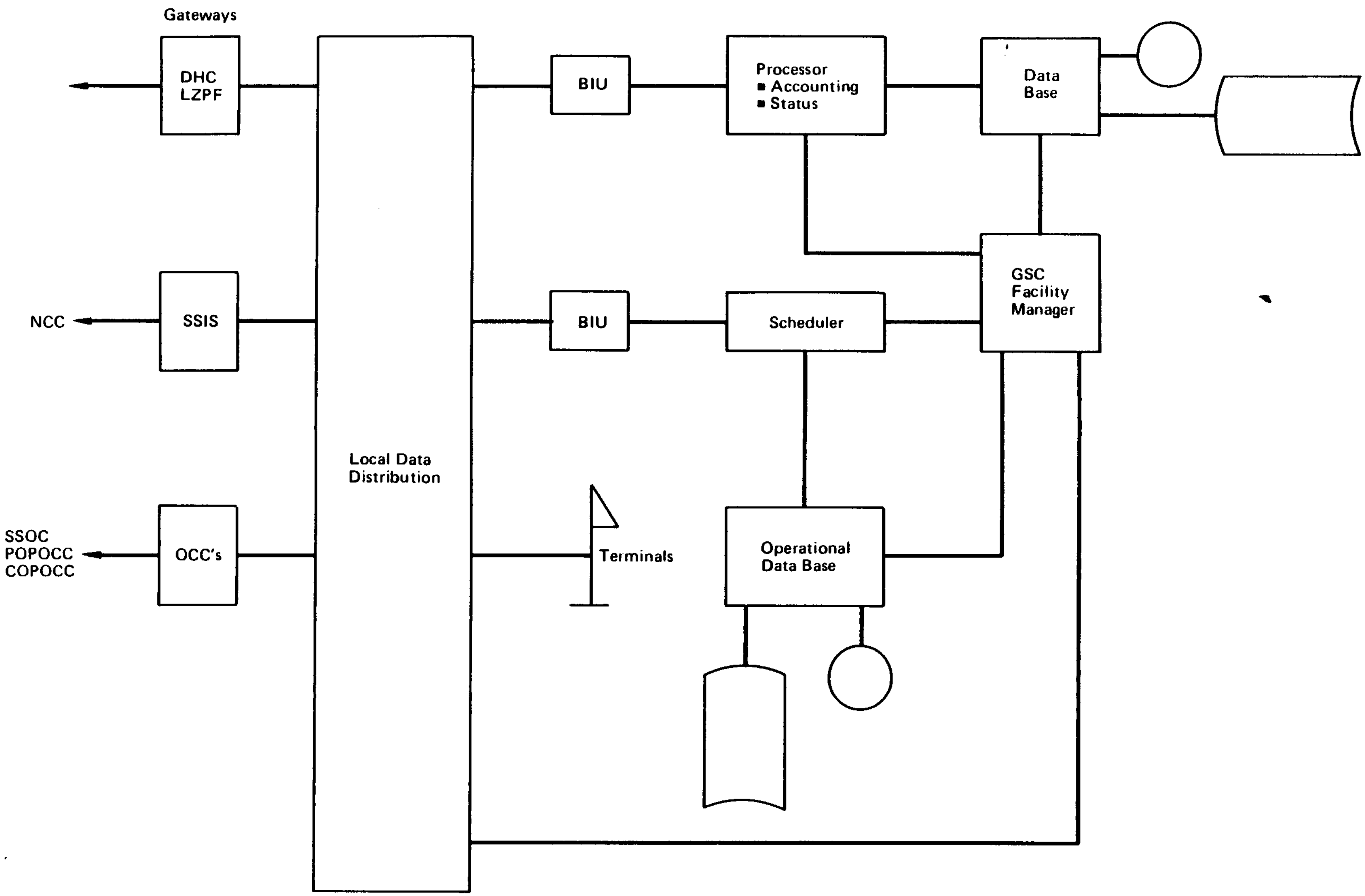

Figure 7.4.3.3-1. Ground Service Center

performing protocol conversion as necessary. The gateways will thus consist of modems, protocol converters, etc. The status and scheduling messages will be transmitted over dedicated lines, with dial-up back up, with the usage information collected on a polled basis.

- Local Data Distribution Network

The local area distribution network provides communication between the elements of the GSC. At least two processing capabilites are required:

- General Purpose Processor (for such functions as billing)
- Scheduling Processor (AI based)

The general purpose processor(s) must support:

- Monitoring of status data (e.g, threshold or outage alerts)
- report generators (database reports)
- Data Accounting Reports (system wide)
- Billing & Resource Tracking
- Trending/Utilization Analysis

It is noted that the processing required to support billing and usage tracking is an SSIS function. However, such usage information can be used for other functions than billing. For example, it could be sorted by processing element as opposed to user/customer, and a trend analysis performed to determine outage patterns and to generate availability reports. Data quality information could be analyzed to isolate problems to particular ground elements.

At least two databases and associated storage devices are required:

- Database Processor (Accounting & Status)
- Operational Database (Scheduling)

A modern database capability, such as relational, would likely be used to isolate changes in the database format from impacting the GSC applications software.

Finally, workstations are needed for operators support. It does not appear these workstations would need to be highly intelligent workstatations but need only support access to the processors and databases.

7.4.4 Payload Operations Control Centers (POCC's)

The Payload Operations Control Centers (POCC's) support all phases of operations for a single payload or complement of payloads. These phases include prelaunch integration and test of payloads, either at the launch site or at an off-site facility. The POCC must also support ground and flight crew training during the prelaunch phase. POCC Control and monitoring functions that are unique to the payload applications, training and simulations are outside the boundaries of the SSDS. However, the POCC functions that provide standard services — the interface to the DHC and the GSC, and that support ground system management are within the SSDS.

7.4.4.1 Interface Description

Figure 7.4.4-1 shows the POCC's interface diagram with six other SSDS elements. Brief descriptions of each interface are as follows:

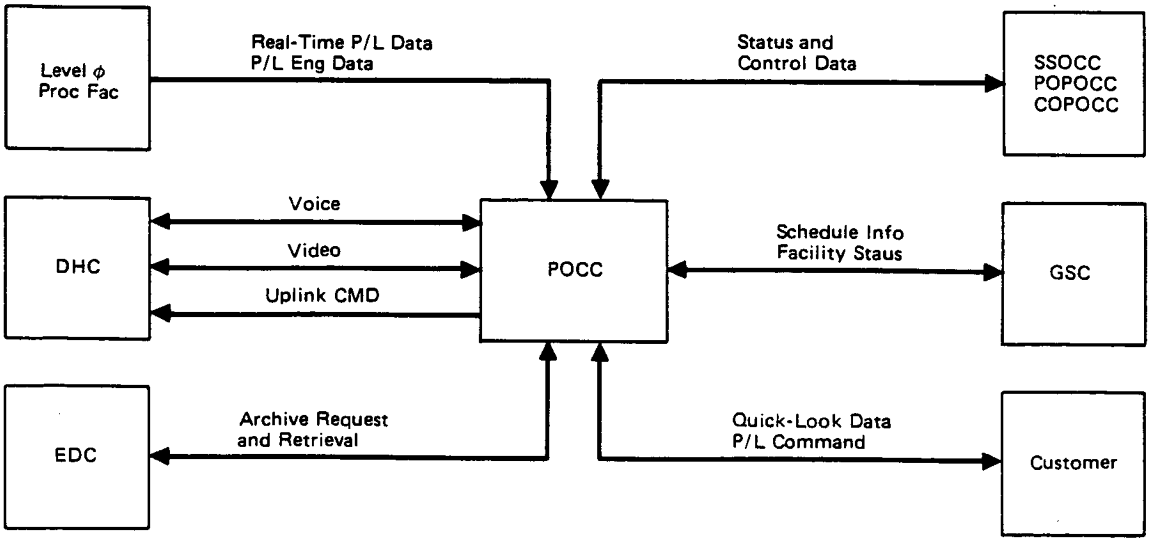

Figure 7.4.4-1. Payload Operations Control Center Interface

7.4.4.1.1 Level 0 Processing Facility (LZPF)

Both the real time payload science data and payload engineering data will be conditioned at the LZPF before routing from the LZPF to Payload Operations Control Centers (POCC's). The data will then be processed and displayed for operators in standard operator selected formats upon request. In addition, quicklook displays would be made available for customer use at this location.

7.4.4.1.2 Data Handling Center (DHC)

Both voice and video data are communicated between the DHC and POCC's in both uplink and downlink directions. However, the transmission method for both voice and video are outside the scope of SSDS study. All uplink payload commands are issued from POCC's to the the space elements via the DHC. The LOGON command authorization will be done at the DHC.

7.4.4.1.3 Engineering Data Center (EDC)

The operators and/or customers in a POCC may desire either core data not previously requested in the ancillary data package, or historical data from the Engineering Data Archives and could request the desired parameters over a low data rate line from the EDC.

7.4.4.1.4 Control Centers (SSOCC, POPCC, COPCC)

The interface between POCC's and the appropriate Control Centers provides for schedule coordination to establish the particular POCC's payload operations needs on the mission schedule.

7.4.4.1.5 Ground Service Center (GSC)

POCC's interface with the GSC for Network status, schedule and data accounting status, and data quality and usage reports.

7.4.4.1.6 Customers

Customers will interface with the POCC's either remotely or at the location of the POCC for the purpose of controlling their payloads. These functions will include quicklook monitoring of payloads and command control of payload operations.

7.4.4.2 Function Description

A functional block diagram of the Payload Operations Control Centers (POCC) is shown in Figure 7.4.4-2. As all functions are not within the SSDS, a design approach for POCC's is not included in this report.

7.4.4.2.1 External Interface Management

The External Interface Subsystem provides the interface to the wide area and/or local area networks connecting each POCC to the other SSPE's. The subsystem supports communication link monitoring, transmission error detection, and protocols requiring acknowledgements and retransmissions.

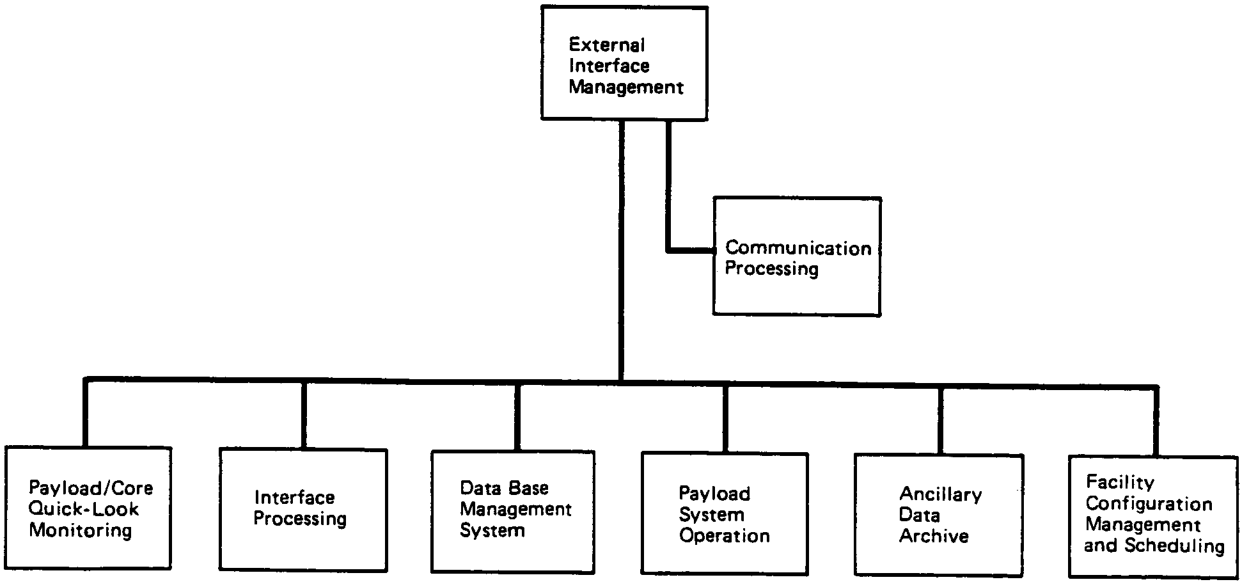

Figure 7.4.4-2. Payload Operations Control Center Functional Block Diagram

7.4.4.2.2 Payload/Core Quicklook Monitoring

Personnel at a POCC must have the capability to evaluate the performance of a specific payload. Payload data and preselected subsets of ancillary data will be processed for quicklook purpose. The quicklook displays are made available for customers use at the POCC location or remotely for customer evaluation of payload performance.

7.4.4.2.3 Communications Processing

This subsystem consists of the audio and video processing/distribution systems within the POCC.

7.4.4.2.4 Interface Processing

This subsystem manages the functional interfaces to the other ground elements - DHC, LZPF, other Control Centers, EDH, GSC and customers. The processing consists of interpreting incoming messages, establishing interface connection, building outgoing response or service request messages, and maintaining interface protocols.

7.4.4.2.5 Data Base Management System

This subsystem provides the data base definition for interpretation of all payload data and ancillary data received by
the POCC, and for the bit configuration of all payload commands generated by the POCC.

7.4.4.2.6 Payload Systems Operation

This function includes the generation of uplink real time payload commands and command loads from operator's/customer's initiation requests. The command management functions including authorization check, restricted and constrained commands check and scheduling conflicts check will be done at the DHC (authorization check) and onboard.

7.4.4.2.7 Ancillary Data Archive

Operators/customers may desire either core data not previously selected in the ancillary data package, or historical data from the Engineering Data Center. Via this subsystem, the POCC requests data from the EDC, and archives it for processing and display.

7.4.4.2.8 Facility Configuration Management and Scheduling

This subsystem configures the POCC processors for data monitoring, display and payload command and control operations. It also provides the scheduling functions and interface with appropriate Control Centers for scheduling payload operations. Its interface with the GSC provides for network and schedule status, data accounting and data quality and usage reports.

7.4.5 Level Zero Processing Facilities (LZPF's)

Level zero processing in the proposed design consists of the following functions:

- Capture of data routed as CCSDS virtual channels from the DHC
- Reed-Solomon decoding
- Extraction of CCSDS telemetry packets
- Merging of tape recorder data and deletion of redundancies
- Fill insertion
- Data completeness and quality accounting on a transfer frame and telemetry packet bases
- Routing of real-time payload science and engineering data
- Store and forward service for non-real-time data

Payload data level zero processing is performed at three sites in the strawman design, GSFC, LARC, and JPL. Most level zero processing is performed at GSFC, in particular low-rate data passes through GSFC prior to delivery. This includes real-time payload engineering data routed to the payload OCC's, but not core engineering data which is directly routed to the SSOCC and platform OCC's by the DHC. In particular, all Independent Customers receive their data through the GSFC LZPF. Other LZPF's are located at NASA facilities sponsoring particularly high bandwidth experiments which necessitate local access to Level Zero working data stores for high level processing. In the Langley data base the only other candidate facilities are JPL and LARC. However, the LZPF design presented here may be replicated at other centers as requirements change. It also may be feasible to colocate the LARC LZPF with the GSFC LZPF.

The design presented in this section is directed toward the GSFC LZPF which supports both high and low rate Level Zero processing. However, all elements of the design are appropriate (in scaled down form) to the other LZPF's.

7.4.5.1 Interface Description

The functional interfaces for the LZPF's which are illustrated on figure 7.4.1-1, are discussed in the sections below.

7.4.5.1.1 Data Handling Center

Downlink data in CCSDS transfer frame is routed directly from the DHC to the LZPF's. It is assumed that the data distribution network delivers transfer frames in exactly the same form as they are passed to the communications ports at the DHC with all network artifacts removed. The LZPF sees a stream of CCSDS transfer frames identical to those which arrive at the NGT interface. Optionally, Reed-Solomon encoding may be rechecked by the LZPF and appropriate error correction applied to correct for data distribution network noise. Expected data rates are as follows:

GSFC — High rate data 125 megabits/sec. average, 600.00 megabits/sec. peak

GSFC — Low rate data 5.2 megabits/sec. average

JPL — High rate data 18.75 megabits/sec. average, 300 megabits/sec. peak

LARC — High rate data 50.00 megbits/sec. peak

7.4.5.1.2 Payload Operations Control Centers

Payload OCC's receive all their engineering data through the GSFC LZPF either as real-time data or in store and forward mode. Audio and video, however, are received directly from the DHC. It should be understood that the SSOCC, COPCC, and POPCC communicate directly with the DHC and receive their engineering data directly through dedicated virtual channels.

7.4.5.1.3 Engineering Data Centers

Communications with the EDC's will primarily be to retrieve archived ancillary data. This will be performed through the packet network.

7.4.5.1.4 Customer RDC's

Customer RDC's receive their data directly from the LZPF's through packet network or high rate circuit switched links. Requests for data are mediated through an Access Control processor which isolates the requestor from Level Zero production activities. In many cases the RDC's will be collocated with the LZPF's and direct high-bandwidth access to Level Zero working stores through a LAN will be feasible.

7.4.5.1.4 Independent Customers

Independent Customers will receive data directly from the LZPF's using procedures similar to Customer RDC's.

7.4.5.1.5 Ground Services Center

The LZPF communicates with the GSC to coordinate schedule for high-bandwidth communications links and to occasionally request retransmission from the DHC. The LZPF also delivers accounting and quality data to the GSC.

7.4.5.2 Function Description

The LZPF is the SSDS node which captures data and prepares it for distribution in either real-time or store and forward mode. Processing paths are somewhat different for low and high rate data. In the stawman design, it will perform the following functions:

7.4.5.2.1 Preprocessing

Reed-Solomon Error Correction — a repetition of the correction applied at the DHC to CCSDS transfer frames to reduce noise introduced by the DHC-LZPF link.

Merging of recorder data — ordering of data and deletion of redundancies, but not including bit reversal since the onboard recorder is implemented in eraseable optical disk technology.

Data completeness and quality accounting — information provided both to users of data and to the GSC

7.4.5.2.2 Real-Time Data Routing

High Rate Data Routing — to provide direct routing of high rate data through the circuit switched links

Low Rate Data Routing — to provide direct routing

7.4.5.2.3 Short Term Storage and Forwarding

Data Capture — to store data prior to production or quicklook processing and to capture real-time data for temporary backup

File Management — to manage both offline and online storage file systems

Batch Forwarding — to group data into production and quicklook batches and route them to appropriate destinations

7.4.5.2.4 Access Control

Data Access Authorization — to control external access to Level Zero Data and prevent external interference with production operations

7.4.5.2.5 Facility Management

Configuration Management — to manage computer and communications gateway configuration

External Coordination — to accept schedules from and to coordinate with other SSDS elements through the GSC

Resource Scheduling — to coordinate internal LZPF facility usage and balance processing and bandwidth loading among processing elements

Cold Start, Restart, and Switchover — to manage startup, restarts, and switchovers

7.4.5.3 Design Approach

This section discusses a high level design approach to the LZPF's. The following key assumptions were made:

- Data is delivered from the DHC to the LZPF in CCSDS transfer frame format with no network artifacts added.
- No bit reversal of tape recorder data is necessary.
- Low rate data is organized as CCSDS telemetry packets within one or more dedicated virtual channels.
- Access to Level Zero processed data is through either a packet network or through dedicated high rate links.
- All requests for data retrieval or reconfiguration are routed through the packet network.

A function diagram for the LZPF appears as figure 7.4.5.3-1. Briefly, the system is organized around a high bandwidth LAN (100 megabits/sec) which serves routing system for commands, interprocessor communications, and low rate data. High rate data, however, is not carried on the LAN. It instead passes through separate links managed by a pool of high-speed I/O processors and storage controllers. External access to Level Zero data is controlled through an Access Control Processor which is connected directly to the packet network. The Access Control Processor provides a degree of isolation which is essential to the health of the LZPF since the high speed processors likely to be used to handle data typically have operating systems which provide poor data security. Store and forward data requests are handled through an Archive Processor which either arranges a direct high-bandwidth link from the storage system or passes low rate data through the LAN directly to the Access Control

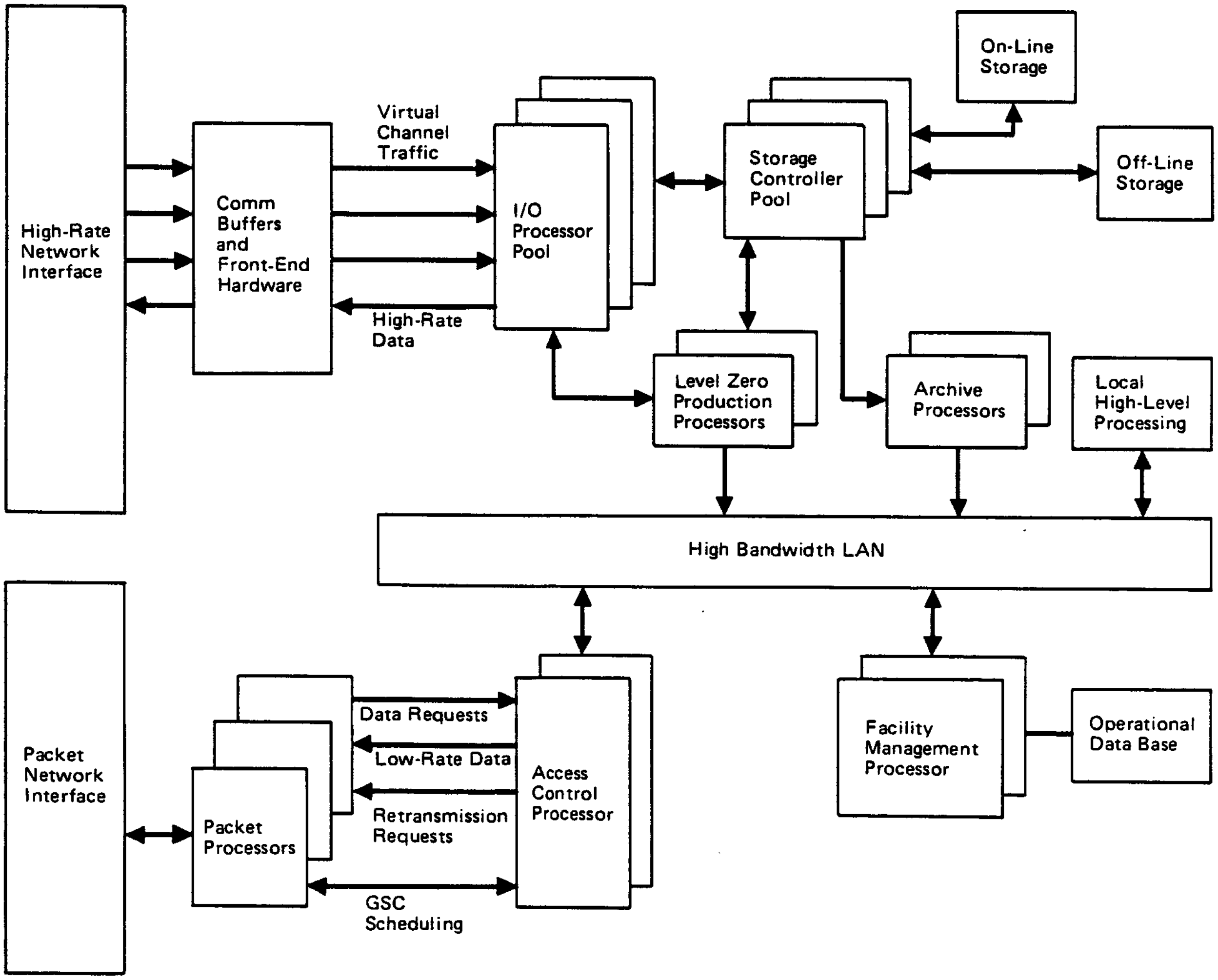

Figure 7.4.5.3-1. Typical Level Zero Processing Facility

Processor. The Facility Management Processor provides system reconfiguration capabilities, and serves to implement system restarts and failovers.

This configuration is similar to the CDC Cyber/Cyberplus processor being considered for the GSFC Advanced Telemetry Processor program (with a number of special purpose processors linked in through the high bandwidth LAN). However, there are quite a few architectural alternatives which provide similar types of high bandwidth data paths (albeit with different cost/performance ratios).

The next few sections describe some of the processing functions and associated data flow.

7.4.5.3.1 High Rate Data Real-Time Processing

We describe the end-to-end data flow and the steps required to initiate the processing. Initially, high-rate real time processing is set up through a scheduling request sent by the customer to the OCC. The GSC is responsible for arranging the link from the payload through TDRSS through the DHC to the LZPF to the customer facility receiving the data. This is accomplished through reconfiguration messages to the SSDS components and the NCC. Full automation of this process through a network call setup protocol is highly desireable. We assume that the customer has arranged appropriate high rate tail circuits to handle the communication with the LZPF.

As CCSDS transfer frames arrive at the High Rate Network Interface, they are decoded at the front end and sent to one or more dedicated I/O processors. CCSDS transfer frame headers are stripped, telemetry packets are reconstructed, data quality and completeness information is appended, fill is inserted where necessary, and appropriate transport information is appended. Data is then routed to the appropriate output port. The telemetry packets are also routed to an appropriate storage channel, depending on customer requirements for additional backup and/or store and forward service.

7.4.5.3.2 Low Rate Data Real-Time Processing

Low rate data is subject to a somewhat more complex process since multiple low rate experiments are multiplexed on a single CCSDS virtual channels. However, scheduling of circuit links through the GSC is not required. The low-rate real-time customer first enables his payload through appropriate interaction with the DHC command uplink and mission scheduling system. He then links to the LZPF through the packet network. Access to the LZPF is controlled through the Access Control Processor which implements secure access to LZPF facility (security controlled by the GSC). The customer then sends a message indicating the payload to which he wishes to link. This is checked against authorization tables sent from the GSC and serves to initiate a process which routes low-rate telemetry data to the customer through the packet network.

Several input virtual channels are devoted to low-rate data. The initial processing is similar to high-rate processing. As CCSDS transfer frames arrive at the High Rate Network Interface, they are decoded at the front end and sent to one or more dedicated I/O processors. CCSDS transfer frame headers are stripped, telemetry packets are reconstructed, data quality and completeness information is appended, and fill is inserted where necessary, and appropriate transport information is appended. If a real-time low rate link has been initiated the telemetry packets are then routed through the high bandwidth LAN to the Access Control Processor which then routes them through the packet network to the customer. The telemetry packets are also routed to an appropriate storage channel, depending on customer requirements for additional backup and/or store and forward service.

7.4.5.3.3 Store and Forward Processing

When data are not required in real-time, they are routed to store and forward processing which provides both quicklook and production services. Front end processing is identical to real-time processing. As telemetry packets are received they are grouped into batches and stored. Scheduled production runs merge batches of telemetry packets received in real-time and through recorder dumps, removing redundancies, and inserting fill wherever necessary. The batches are routed to storage and a batch file catalog is maintained through a standard DBMS product running on an Archive Processor. A user requiring a stored data file logs in through the packet network, is connected to the Archive Processor which supports browsing of file catalog data base. Data transfer can then be requested according to standard services which support access to data subsets by time interval and experiment. Transfer is supported through high-rate or low-rate packet services as appropriate.

7.4.6 Control Centers

The Space Station Program control centers consist of the Space Station Operations Control Center (SSOCC), the Co-orbiting Platform Control Center (COPCC), and the Polar Orbiting Platform Control Center (POPCC). The design assumes that the SSOCC is located at JSC, and the COPCC and POPCC are located at GSFC. The following sections apply generally to all the Centers unless otherwise noted.

The Control Centers must be capable of supporting all mission phases. Prelaunch activities include the integration and test of the space element and platform payloads, and flight and ground crew training. Launch phase activities include the monitoring and control of the Space Station buildup and deployment of the platforms. On-orbit operations include the supervisory control of the space element's autonomous operations during normal and emergency operations, payload integration and checkout, servicing, and the retrieval of platforms. The platform control centers must also have the capability of simultaneously supporting multiple platforms in various mission phases.

7.4.6.1 Interface Description

The functional interfaces of the Control Center are listed in Table 7.4.6.1-1. The interface descriptions are the same for the SSOCC, COPCC, and POPCC except where noted otherwise.

The traffic along these interfaces tends to be low in volume except for the uplink and downlink data. As noted in Table 5-4, the Space Station core telemetry rate is assumed to be 256 kbps, and the command rate is 4 kbps. For platforms, a telemetry rate of 64 kbps and a command rate of 4 kbps were assumed. The voice and video rates are undefined.

Table 7.4.6.1-1
Control Center Functional Interfaces to Ground Elements

Element	Interface Traffic	Purpose
Space Element (via DHC)	Core Uplink	Controls, voice, video
	Core Downlink	Status, voice, video
	Schedules	Resource and operating events scheduling
GSC	Schedules/Status	Communications/common resource schedule coordination
POCC's	Schedule Requests	Mission scheduling of Customers payload mode changes
	Schedules/Status	Mission/payload schedule coordination
Flight Dynamics Facility (COPCC, POPCC)	Orbit/Attitude	Mission planning Verification of onboard comps. (backup)
EDC	Core Uplink, Computed Data	Archival storage
	Queries/Responses	Archival retrieval
	Schedules/Status	Ground resource mgmt.
DSIT	S/WLoads	OCC modifications Onboard s/w modifications Development -- testing
	SimulationData	Flight controller and crew training Integration testing
Other CC:		
COPCC (SSOCC)	Schedule/Status	Coordination of COP servicing and utilization of SS resources
STS MCC	Schedule/Status	Coordination of shuttle visits
OMV/OTV Remote Ops. CC	Schedule/Status	Coordination of servicing (COPCC/POPCC)
		Coordination of prox. and remote ops. (SSOCC)
Free Flyer CC (SSOCC)	Schedule/Status	Coordination of prox. ops

7.4.6.2 Function Description

The subsections of 7.4.6.2, discuss the generic Control Center systems which accomplish the functions identified in Table 7.2.3-1. These Control Center systems for the Space Station Program will significantly differ from those of previous spacecraft programs in the following ways:

- the reduction of processing required due to the greater autonomy of the space element from the ground systems;
- the reduction of processing required to perform tracking data analysis due to the reduction of navigation data sources employed (GPS and TDRSS), and the improvement in ground navigation techniques;
- the addition of an interface to the ground and onboard scheduling systems for the control of mission operations;
- the increase of processing required for the automation of some ground support functions.

7.4.6.2.1 Communications

The Communications system provides the interface to the wide area and local area networks connecting the Control Center to the other SSPE's. The system provides:

a. External Interface management

- Support communication link monitoring
- Provide transmission error detection
- Support protocols requiring acknowledgements and retransmissions
- Provide performance monitoring data to GSC

b. Data Processing

- Perform required preprocessing (e.g.data extraction from CCSDS packets)
- Route data to processing systems

c. Intra–Center Distribution

  - Voice subsystem
  - Video subsystem
  - Local area networks

7.4.6.2.2 Monitor and Control

Monitor and control processing provides support for real–time operations and trend analysis. For initial Station operational phases (i.e. assembly/activation and buildup phases), the Control Center provides monitoring and primary control of onboard systems. As the onboard systems are implemented and mature, several of the initial ground telemetry functions take on a supervisory mode of operation.

The capability to perform special computations, limit sensing, logical processing, and trend analysis of real–time and historical core engineering data are provided in support of monitoring and control of on–board systems. Example system capabilities are:

- Monitor and Control of onboard Power systems
  - Electrical power generation
  - Power distribution
  - Power storage
  - Element lighting

- Monitor and Control of onboard Mechanical systems

  - Docking/berthing systems
  - Hatches
  - Vent Doors
  - Solar array booms
  - Servicing fixtures
  - Manipulators

Verification of command receipt and execution is also provided through the monitoring of the downlinked stored program command buffers and the command logs.

7.4.6.2.3 Trajectory

Trajectory computations and display processing are provided by the trajectory system in support of planning and mission operations. The Control Center's trajectory system works in coordination with onboard avionics systems to provide navigation, guidance, attitude control, traffic control, tracking, and time management. The Trajectory system is capable of accepting tracking data from the Global Positioning System (GPS) and TDRSS.

The Trajectory system's planning functions are:

a. Receive planning data for mission segments
  - Nominal state vectors/timelines from flight design activity
  - Schedule events data from mission scheduling activity

b. Generate trajectory profile data for mission segments
  - Ephemeris
  - Orbital events data (AOS/LOS, maneuvers, rendezvous times, sun/moon lighting, etc.)

c. Provide display capability for planning review of trajectory data

The following Trajectory system capabilities are provided during mission operations in support and backup of the onboard system:

a. Receive and process tracking data
  - TDRSS S-band tracking
  - GPS tracking

b. Generate/maintain trajectory profile data
  - Ephemeris
  - Orbital events data (AOS/LOS, maneuvers, rendezvous times, sun/moon lighting, etc.)

c. Generate/maintain maneuver planning data
  - Attitude maneuvers
  - Rendezvous/proximity OPS maneuvers
  - Orbital maintenance maneuvers

d. Generate/maintain general on-orbit computation data
  - Constellation relative states (including line-of-sight computations for SS to platforms)
  - Mass properties/consumables
  - Onboard/ground navigation state comparisons

e. Provide display capability for real-time monitoring/on-demand review of current trajectory-related data.

g. Provide for short-term retention of trajectory data
  - Tracking data
  - As-flown orbital events data

g. Perform orbital analyses (as required)
  - Quality of trajectory predictions
  - "Best estimate" trajectory reconstructions (of specified orbit/mission segments

i. Prepare mission trajectory data for archival storage in the EDC

7.4.6.2.4 Command

The Command system:

- Issues real-time and stored program commands for supervisory control of onboard subsystems during operations;

- Supports the building of single-stage and two-stage commands for real-time operations and planning

- Provides command validation, safing, and checking to ensure safety, effectivity, schedule compliance, etc.

- Provides for the loading of onboard computers (to main or mass memory)

7.4.6.2.5 Control Center Facility Management/Scheduling

The higher level interface for this system is the Mission Scheduling System and the lower level interface is to the subelements of the Control Center.

The Facility Management system manages the Control Center's hardware, software, and data elements. Its functions include:

a. Configure the Control Center to provide scheduled services

b. Interpret status data and issue appropriate controls to ensure optimal functionality

c. Ensure that the hardware and software within each node are appropriate to support its function

d. Verify authorization and provide access control to nodal software loads based upon:
    - operator identification
    - functions (e.g. flight director, payloads officer)
    - mission phase (e.g. rendezvous, deployment)
    - activity (e.g. mission support,training)

e. Provide real-time and historical ground system status

f. Monitor system maintenance

The Facility Scheduling system provides the interface to the Mission Scheduling System and performs the scheduling of the Control Center. The Scheduling system provides the coordination of mission operations with facility operations such as training, installation of new systems, hardware/software updates, and maintenance.

7.4.6.2.6 Mission Scheduling

The Mission Scheduling Systems are responsible for the generation, maintenance, and distribution of the Operating Events Schedule (OES). There are two systems: the Space Station Mission Scheduling System at the SSOCC and the Platform Mission Scheduling System at the COPCC/POPCC. Both systems generate bi- weekly schedules; however, the SSOCC system also coordinates with an onboard scheduling system which supports the crew in the near-term (1-2 days) refinement of the OES. It is proposed that platform scheduling be performed entirely on the ground; however, this design is sensitive to an assumption that communications coverage is sufficient to support a ground-based system without seriously inhibiting the autonomy of the platform and payloads. Both systems process ground-originated schedule change requests on the ground.

The following design-level functions of the Mission Scheduling System are derivatives of functions 3.2, Develop Short Term Schedule, and 3.3, Develop Operating Events Schedule. These functions are common to both the Space Station and Platform Mission Scheduling Systems except where noted otherwise.

a. Data Base Generation

- Provide services for multiple users for local/remote entry and modification of data
- Support a user friendly interface — menus, help functions, high level (or natural) query language, checking/validating of entries
- Provide configuration management for various levels of file certification — development through master operating files.

Table 7.4.6.2.6-1 lists some of the attributes defined in the Mission Scheduling Data Base and their sources.

Table 7.4.6.2.6-1
Mission Scheduling Data Base: Attributes Definition

DEFINED ATTRIBUTES	SOURCE
Mission Requirements Schedule - major events such as shuttle visits, extensive modifications/upgrades, crew changes, gross scheduling of reboosts, etc.	Space Station Program
Manifest - contractual agreements with customers.	Space Station Program
Characterization of payload modes - required resources, constraints, restrictions (components of vector triplets)	Mission Scheduling System (internal) -- customer/NASA inputs
Characterization of core operations that require scheduling, such as maintenance, docking/servicing, ventings, maneuvers	Mission Scheduling System internal) -- NASA inputs
Characterization of available resources - crew time, communications, power, data system, ground support such as POCC availability	Mission Scheduling System (internal) -- NASA inputs
Trajectory profiles - ephemeris, orbital events (AOS/LOS, maneuvers, rendezvous times, sun/moon/earth viewing, lighting, etc.)	Flight Design Activity - SSOCC Flight Dynamics Facility - COPCC/POPCC
Priority rulesets	Mission Scheduling System (internal) -- NASA inputs

b. Operating Events Schedule Generation and Maintenance

- Resolve conflicts through iteration and operator interaction to achieve a feasible (as opposed to optimal) schedule
- Support hypothetical, "what if," scheduling
- Support multiple users for interactive, electronic, local/remote entry of schedule change requests
- Support rapid replanning for unique payload opportunities
- Process schedule change requests and provide dispositions, which include alternative options if request cannot be met
- Coordinate schedule changes with the onboard scheduling system and crew (Space Station only) including the incorporation of onboard—originated changes
- Coordinate schedule changes that impact joint operations involving other Space Elements
- Coordinate communication/common resource support with the Ground Services Center
- Monitor status returned from onboard and ground facility and resource management functions and adjust schedule as required
- Support maintenance/development of the scheduling system, e.g. modifications to rulesets

The timeliness of the system's response to schedule change requests depends upon the characterization of the requested operation and the breadth of its impact to other operations, i.e. on the amount and nature (automated or human decision) of conflict resolution required. For example, the response time should be in the order of seconds to a simple activate/deactivate request for a payload whose mode is characterized as requiring minimal resources, offering no interference to other operations, and posing no hazards.

c. Operating Events Schedule Distribution

- Uplink modified schedule to onboard system
- Distribute schedule reports to ground users and facility managers — schedule execution status, schedule changes, opportunity alerts, orbital events, etc.

7.4.6.3 Design Approach

The design approach for control centers first addresses the generic design drivers common to all control centers. The unique design drivers for each control center are then described. The primary goal is to produce a general design that is common to all control centers while satisfying the unique design drivers of each control center. A familiarity with the functions described in section 7.4.6.2 is necessary in order to understand the design approach as well as the architecture.

7.4.6.3.1 Generic Design Drivers

The following items represent common design drivers for the SSOCC as well as the POPCC and COPCC. These design drivers focus on the changing technology and the evolution of requirements over the life of the project.

- FLEXIBILITY - This quality allows a control center to meet changing needs in a timely and cost effective manner.

- TECHNOLOGY INSERTION - As technology changes, upgrades should be possible without requiring a major redesign of the control center.

- GROWTH - As functions become mature they usually increase their resource requirements. While it is difficult to size all resources with great precision, a good design can allow for growth without excessive expense or initial over specification.

- LIFE CYCLE COST - The cost of a system reaches far beyond the purchase price. The operating costs must be considered in order to provide a cost effective solution.

- CORE DATA RETRIEVAL VIA EDC - In order to avoid excessive storage costs, the EDC will be the storage facility of core engineering data for all users.

- AUTOMATION – The system should utilize technologies that allow equipment to perform an increasing number of tasks in order to improve productivity and reduce staffing.

- COMMERCIAL OFF THE SHELF (COTS) – The use of standard commercial products in place of custom built equipment is highly desirable.

- REUSABILITY – The design should utilize hardware and software developed through other projects when possible

- CONTINGENCY SUPPORT – Even though the Space Station and platforms are designed to be highly autonomous, the Control Centers must retain the capability to provide critical support in the event of the failure of the onboard systems.

7.4.6.3.1.1 SSOCC Design Drivers

With the control centers for both Space Station and shuttle located at the Johnson Space Center, commonality is highly desirable. The major areas of compatibility are addressed as design drivers for the SSOCC.

- COMPATIBILITY WITH MCC/ERRP – The Mission Control Center is being upgraded under the current EQUIPMENT REPLACEMENT and REFURBISHMENT PLAN. This plan provides for the replacement of old equipment with a technology upgrade in about the same time frame as the SSOCC delivery. The result is the development of two facilities with the same technologies. Compatibility can be achieved without sacrificing state-of-the-art designs. Also, the potential for reusability is very high between these projects.

- FCR/MPSR SUPPORT CONCEPT – The support for the shuttle is provided through a combination of Flight Control Rooms (FCR) and Multi-Purpose Support Rooms (MPSR). The MPSRs provide support to the FCR activities with the final authority for operations resting with FCR personnel. In the case of routine operations or minimal activity periods, support may be provided by a single FCR or MPSR. This allows resources to be used for planning or other activities when not directly supporting a mission. It is highly desirable to design the SSOCC around this FCR/MPSR concept.

- MCC INTER-OPERABILITY - With the design drivers of compatibility and the FCR/MPSR concept, inter-operability is simply the next step. Inter-operability allows MCC and SSOCC resources to be interchanged. This reduces operational concerns about the training of controllers and scheduling of ground resources. The current operations concepts for the SSOCC are generally the same as those of the MCC. The possibility of using MCC-developed software and equipment for the SSOCC is virtually assured under inter-operability.

7.4.6.3.1.2 COPCC/POPCC

The design drivers for the various platform control centers are similar to those of the SSOCC. These control centers will be located at the Goddard Space Flight Center. While the magnitude of the support requirements for a platform differ from those of the Space Station, the same concepts of support are applicable.

- SUPPORT ROOM PER PLATFORM - Since the number of control positions necessary for a platform are smaller than those for a manned vehicle, a single support room per platform should be sufficient. This concept allows for incremental growth as the number of platforms increases.

- SUPPORT ROOM INTER-OPERABILITY - The potential for cost savings through inter-operability is great. The majority of the development costs are absorbed by the first support room. The remaining rooms should be mostly copies of the first. The remaining rooms should be made operational in less time than the first by using compatible equipment and software. Inter-operability also allows an unused room to act as a backup for other active support rooms. Personnel can be moved from one support room to another with little or no retraining concerning facilities.

7.4.6.3.2 Generic Configuration and Architecture

With most of the design drivers being generic in nature, a generic configuration and architecture is a desirable solution. A common philosophy makes the actual designs of the control centers consistent and allows consideration of common equipment and software procurements. The configuration and architecture are based on the following concepts:

- Functional Allocation and Physical Partitioning
- Network/Workstation Concept

A great deal of the effort in the design process involves defining functions and determining methods of implementation. The goal of the designer is that of isolating a function. This is generally accomplished by determining the inputs and the products along with the necessary transformations of inputs to generate the products. Understanding the relationships of all functions in the system gives rise to functional allocation. In general, the allocation is made by a global or local qualification. A global function provides a service or product necessary for all or most of its related functions. In the design of a spacecraft control center, the air-to-ground communications equipment represents a global function. In contrast, the monitoring of a spacecraft subsystem is a local function. Local functions tend to be unique activities in the system while global functions are of general interest.

Until recently, the functional allocation represented the major effort in the design process. Once all of the functions are sized, the only thing left to do is select a computer and begin development. Over the last few years communications and small computers have evolved to the point of providing an alternative to the large, multi-user mainframe. It is now reasonable to consider hosting a function in its own computer and linking these computers together by some type of network. This process is called physical partitioning. The use of physical partitioning can provide many important advantages. These include:

- Stable interfaces on physical boundaries

- Ease of growth
- Improved capability to utilize new technologies after implementation
- Improved flexibility
- Better performance
- Possible cost reductions

Functional allocation and physical partitioning are not without dangers. Improper hosting of functions can result in poor performance and excessive equipment and expense. However, the flexibility of the design will generally allow these errors to be corrected without a total redesign or reimplementation. Schedule and budget concerns strongly encourage proper allocation and partitioning prior to implementation.

The configuration and architecture used to satisfy the needs of the control centers is based on the concept of networks and workstations. The basic implementation involves a group of processors (workstations) connected by means of a Local Area Network (LAN). Most workstations are manned by flight controllers. But a workstation does not have to be manned and may range in size from a personal computer up to a supercomputer. A general control center architecture is shown in Figure 7.4.6.3.2-1. In this architecture, most flight control functions are considered to be local and are partitioned into their own workstations. Communications and the distribution of spacecraft data are global functions supported by the LAN. It should be noted that large functions or processors do not indicate that a function is global in nature. Uplink collection is a prime example. All commands from the control center are collected at a single workstation that formats them into uplink packets. Thus, the function is global in nature; however, a small computer can easily perform the function.

The LAN is the "glue" that holds the architecture together. The LAN provides a general communications service for the workstations. The workstations can send messages containing data, programs, files, or any information to each other without the necessity of going through a central computer. By meeting the protocol standards of the network, any type of device can be connected and can communicate over the LAN. While functions that wish to communicate must agree on information content, the LAN will provide the means of information exchange.

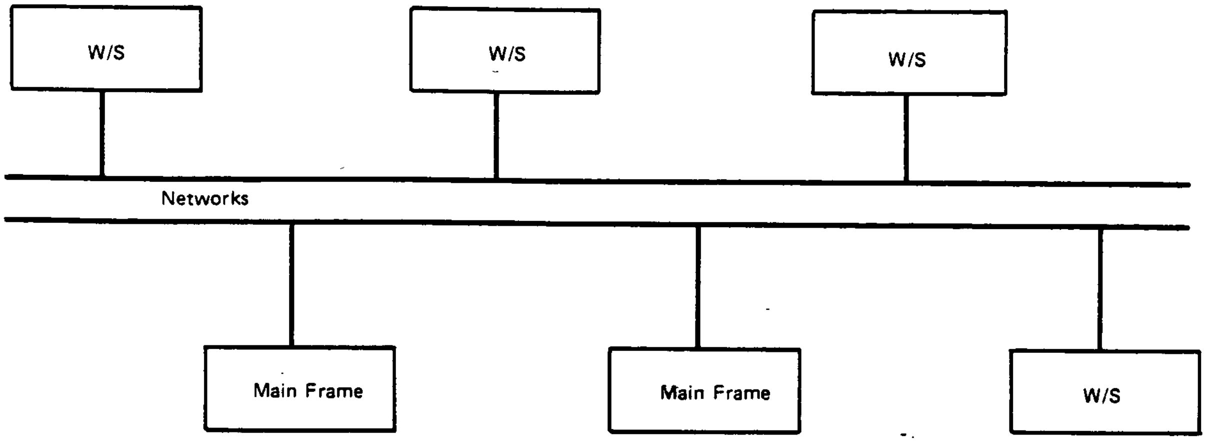

Figure 7.4.6.3.2-1. General Control Center Architecture

A generic control center architecture is produced by mapping the control center systems into the network and workstation concept. Figure 7.4.6.3.2-2 shows the result of the mapping. The front end interface receives the spacecraft downlink and separates the voice, video, telemetry and general messages. It also transmits command packets to the spacecraft. The telemetry is sent to workstations via the TLM net while commands and other general communications move along the general purpose net. Some workstations monitor and control spacecraft systems by receiving core engineering data and building commands. Workstations of another group receive tracking data necessary to perform the trajectory function. A third workstation collects all commands and builds uplink CCSDS packets which are

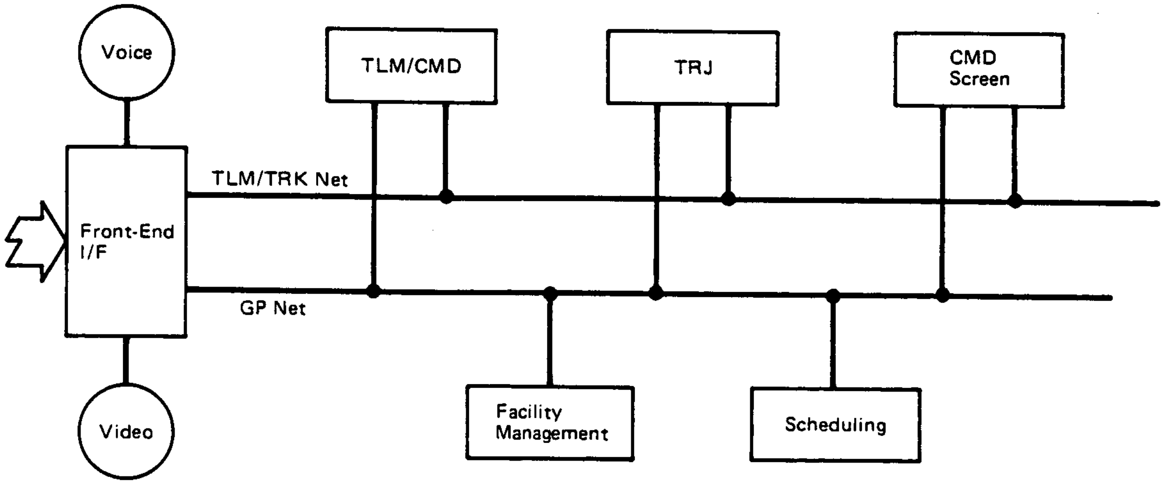

Figure 7.4.6.3.2-2. Generic Control Center Architecture

transmitted to the front end interface. The facility management workstations provide library and system management functions. Finally, the scheduler supports various mission scheduling activities.

The selection of workstations is accomplished in much the same way as any processor. The workstation provides the following capabilities:

- CPU/Memory System
- Disk Storage
- Graphics Display Device
- Keyboard and other input devices
- LAN Interfaces
- Special Interfaces

Other workstations in the system may have functional requirements that make them larger or smaller with different configurations. For example, the facility manager may need to be a mainframe computer in order to support the library function. While there is economic advantage in reducing the number of machine types, the architecture allows all machines to be of different types provided that they can communicate over the LAN(s). Since functions are hosted in a workstation with only related functions, other functions may grow and change and even migrate to a larger workstation without impacting other workstations in the system. The temptation to force a function to remain in a given processor over the useful life of the function is reduced. This is due to the reduced cost of equipment and the fact that many small processors rather than a single large mainframe are utilized. This also allows code to remain structured and straightforward rather than using special "tricks" to make modifications fit into the existing system. Equipment has gotten inexpensive while labor costs have increased dramatically. The lower equipment costs allow this architecture to be cost- competitive.

7.4.6.3.2.1 SSOCC Configuration and Architecture

The configuration for the SSOCC is shown in Figure 7.4.6.3.2.1-1. The control center is divided into two parts: monitor and control, and mission scheduling.

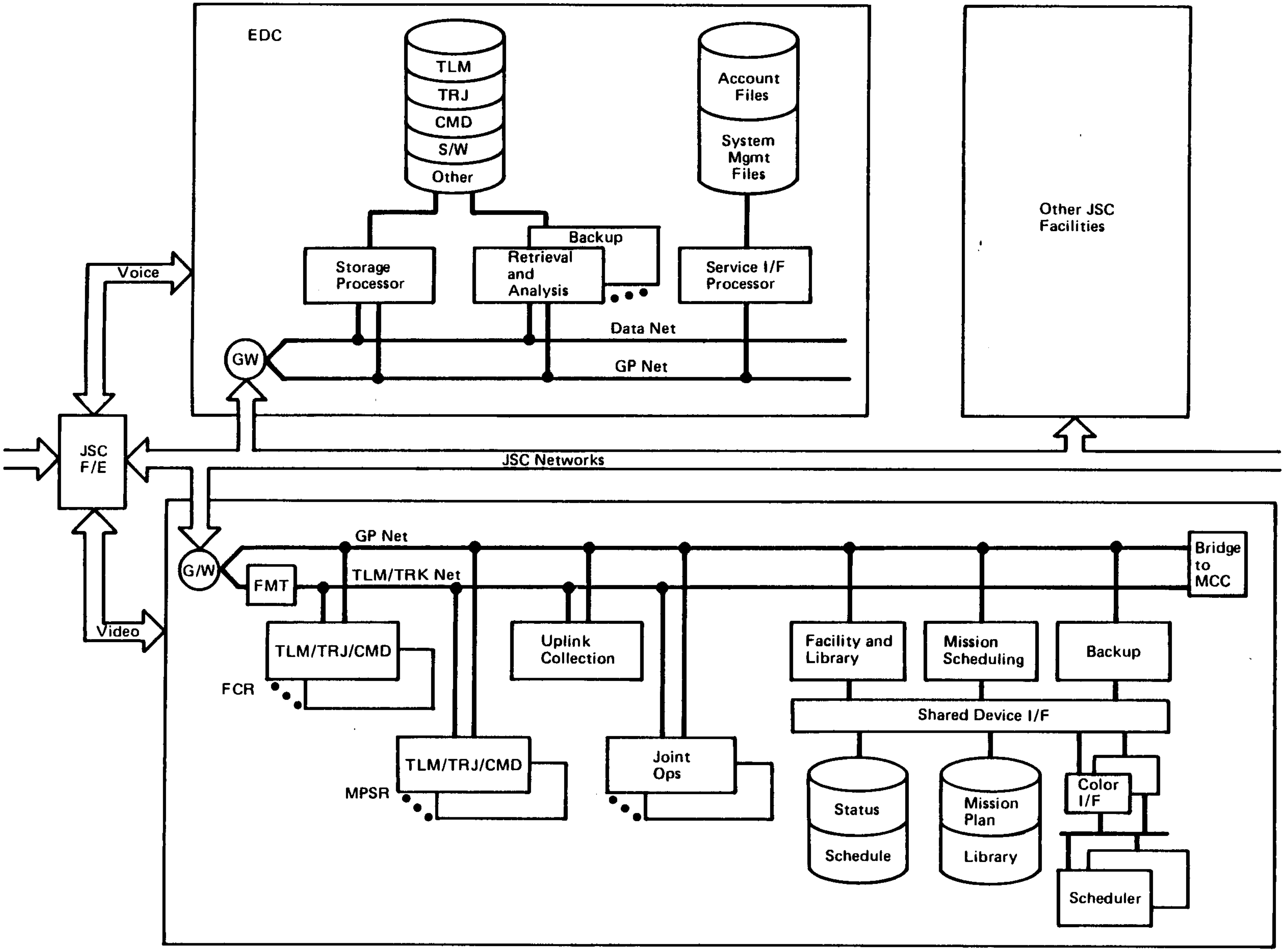

Figure 7.4.6.3.2.1-1. SSOCC Configuration

7.4.6.3.2.1.1 Monitor and Control

The monitor and control facility is divided into FCR and MPSR areas as described in section 7.4.6.3.1.1. The details of each FCR and MPSR are shown in Table 7.4.6.3.2.1.1-1. It is important to note that these quantities and configurations can be easily changed to support the buildup and mature operations without changing the overall architecture. The major functions performed by the monitor and control facility are as follows:

- Network Communications
- Monitor and Control
- Trajectory
- Command
- Data Presentation and Retention
- Facility Management
- Joint Operations Support

Table 7.4.6.3.2.1.1-1
SSOCC WORKSTATION QUANTITIES

AREA	FCR	MPSR
SYSTEM DIVISION	7(1)	14(2)
FLIGHT DIRECTOR	1	
CAP COMM	1	
EVA	1	1
CREW SYSTEMS		2
TRAJECTORY	3	6
PAYLOADS		6
FLIGHT PLANNING	1	3
LOGISTICS/MANIFESTING/SCHEDULING		3
TOTAL	14(1)	35(2)

( ) - Delta for OMV Proximity Operations

The network communications system is composed of the following items:

- Gateway to the JSC Net
- TLM Formatter
- General Purpose (GP) Net
- TLM Net
- Bridges to STS Mission Control Center (MCC) Nets
- Voice/Video Distribution

The gateway selects the packets of core engineering data addressed to elements in the monitor and control facility. These packets are divided into telemetry/tracking and general message types and routed to either the TLM Formatter or onto the GP Net. The TLM Formatter converts the telemetry/tracking parameters into the common JSC format for broadcast on the TLM/TRK Net. The GP Net provides standard OSI type network communications that are compatible with the STS MCC. The TLM/TRK Net provides a broadcast of information that is not compatible with the OSI seven layer model. It is fully compatible with the MCC counterpart, however. The bridges to the MCC nets allow the SSOCC and MCC to share information.

The telemetry function provides the ground monitor and control of onboard systems. Activities include trend analysis and limit sensing and other real-time operations. These activities are performed in workstations which are manned.

The trajectory workstations provide support for navigation, guidance, attitude control, tracking and traffic control. The workstation capabilities are similar to those described for telemetry. Both the FCR and MPSRs provide

The command function is divided into two parts. Some controller positions that monitor telemetry and tracking data are allowed to command various onboard systems. Through the use of both conventional and expert system consultants, a high degree of automation is achieved. This allows a workstation to generate command sequences and predict the effects of the command sequences. These predictions can include an assessment of the impacts of a command sequence with respect to safety, effectivity, conflicts with scheduled activities, etc. The commands are built at these locations and sent to the uplink collection processor. This processor represents the second part of the command function. This processor validates the command formats and builds them into CCSDS packets for uplink to the Space Station.

Data presentation and retention is accomplished by the workstations in support of mission support personnel. Information is displayed on color CRTs as well as printer or plotter type devices. A typical workstation of this type is shown in figure 7.4.6.3.2.1.1-1. Short-term data retention is done by these workstations in order to recall and process selected information for a time of at least two hours. Any information older than that stored in the workstation must be requested from the EDC. Local retention can be increased by increasing the amount of disk storage of the workstation. Typical workstation capabilities are shown in table 7.4.6.3.2.1.1-2. A functional block diagram is shown in figure 7.4.6.3.2.1.1-2.

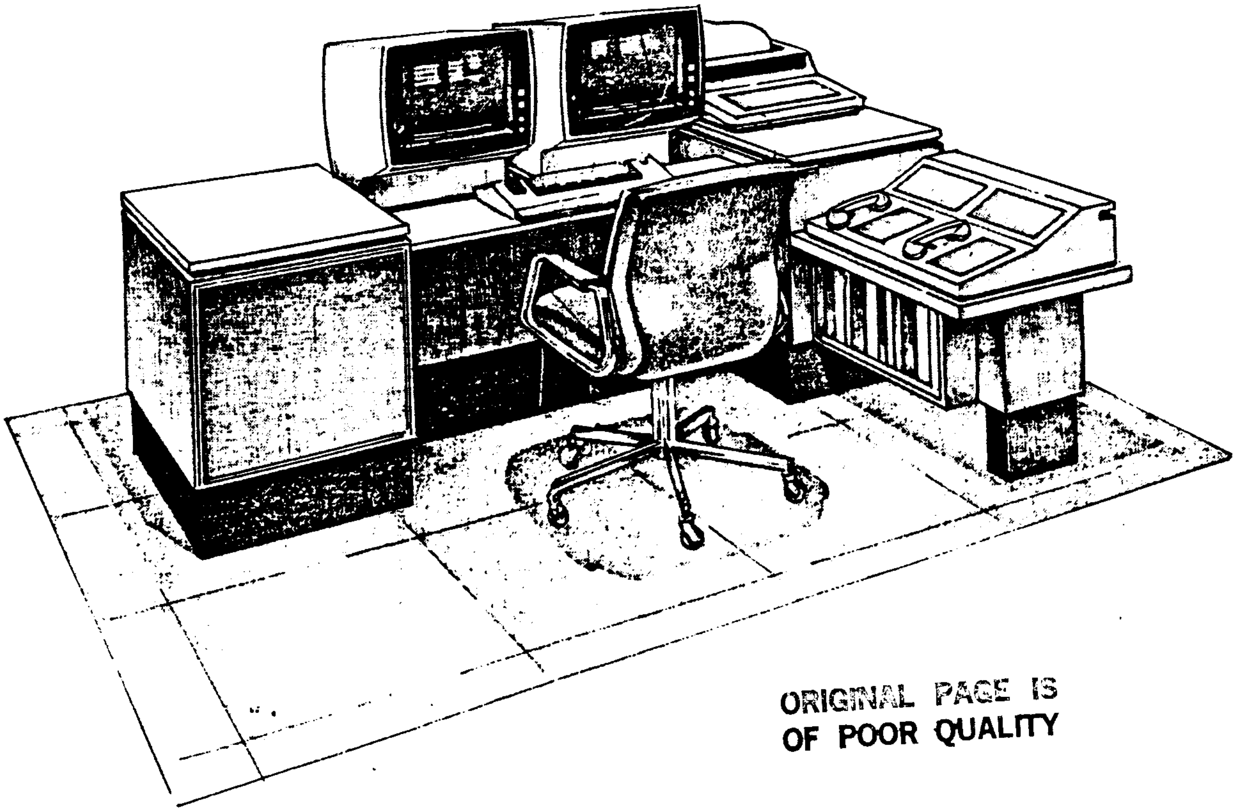

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Figure 7.4.6.3.2.1.1-1. Typical Work Station

Table 7.4.6.3.2.1.1-2. Workstation Capabilities

- Multiple 32-bit CPUs
- Floppy Disk
- 400-Mbyte Hard Disk
- Color Graphics
- Floating Point Processor
- Command/Visual Graphics Control
- Printer-Plotter Access
- Furniture
- LAN Interfaces

The facility manager provides data management for the workstations. It monitors and schedules the workstations and related equipment. This system uses a mainframe computer which collects inputs from workstations and provides the library services. These inputs are used by an AI (LISP) processor that produces facility schedules and supports the management of facility resources.

Joint Operations Support is provided by a group of workstations similar to those used for telemetry processing. These workstations collect various core engineering and computed data and transmit the information to other Control Centers. These workstations can be controlled by users at the other Centers. As a result, the man–machine interface equipment is not as sophisticated as those for telemetry processing.

The quantities and descriptions of the support rooms are shown below. These estimates are based on studies done by the Mission Operations Directorate at JSC.

1 FCR – Primary flight support
3 MPSR – Flight support
3 MPSR – Planning, training or other activities

The MPSRs for planning are not included in the workstation counts in Table 7.4.6.3.2.1.1–1.

The data formats of the LANs in the SSOCC fall into two groups based on the function of each LAN. The general purpose net is an implementation of the ISO seven layer model used in the STS MCC. The telemetry and tracking LAN

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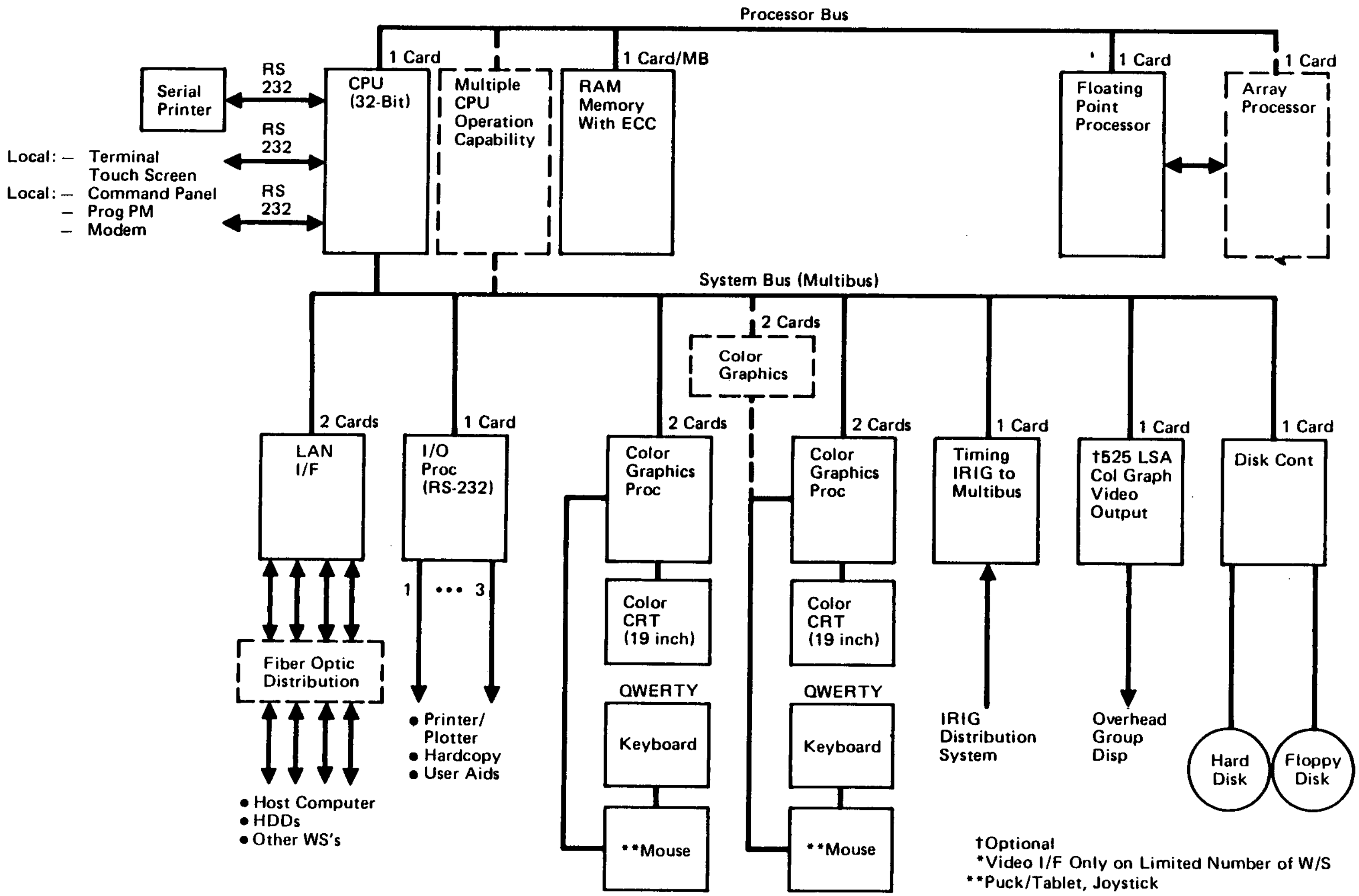


†Optional
*Video I/F Only on Limited Number of W/S
**Puck/Tablet, Joystick

Figure 7.4.6.3.2.1.1-2. Functional Block Diagram conforms to the JSC implementation in the STS MCC. The general message format is shown below.

HEADER	General block descriptor
DESCRIPTORS	Parameter number, type, location, length
DATA	Actual parameters

7.4.6.3.2.1.2 Mission Scheduling.

The Mission Scheduling System is composed of two types of computers. The service interface processor collects planning and scheduling information as well as necessary resource status and schedule requests. This information comes from various control centers and payload users as well as the onboard system. Various schedules are distributed to these same locations. Since this is mostly an information system, a large mainframe computer with a significant amount of disk storage is a reasonable choice. An IBM 3083 represents the class of machine needed. A group of LISP processors are attached to the mainframe to produce schedules. Machines of the SYMBOLICS 3670 class are representitive examples. On the order of six of these machines are required.

7.4.6.3.2.2 COPCC/POPCC Configuration and Architecture

The configuration for the COPCC/POPCC is shown in figure 7.4.6.3.2.2-1. This is similar to the architecture for the SSOCC described in section 7.4.6.3.2.1. The two major functions of mission scheduling and monitor and control are identical in nature to the SSOCC.

7.4.6.3.2.2.1 Monitor and Control

The monitor and control of platforms is accomplished through the use of platform control rooms. Each platform control room controls a single platform. This allows for easy expansion as the number of platforms increases. The functions of the monitor and control facility are as follows:

- Network Communications
- Monitor and Control

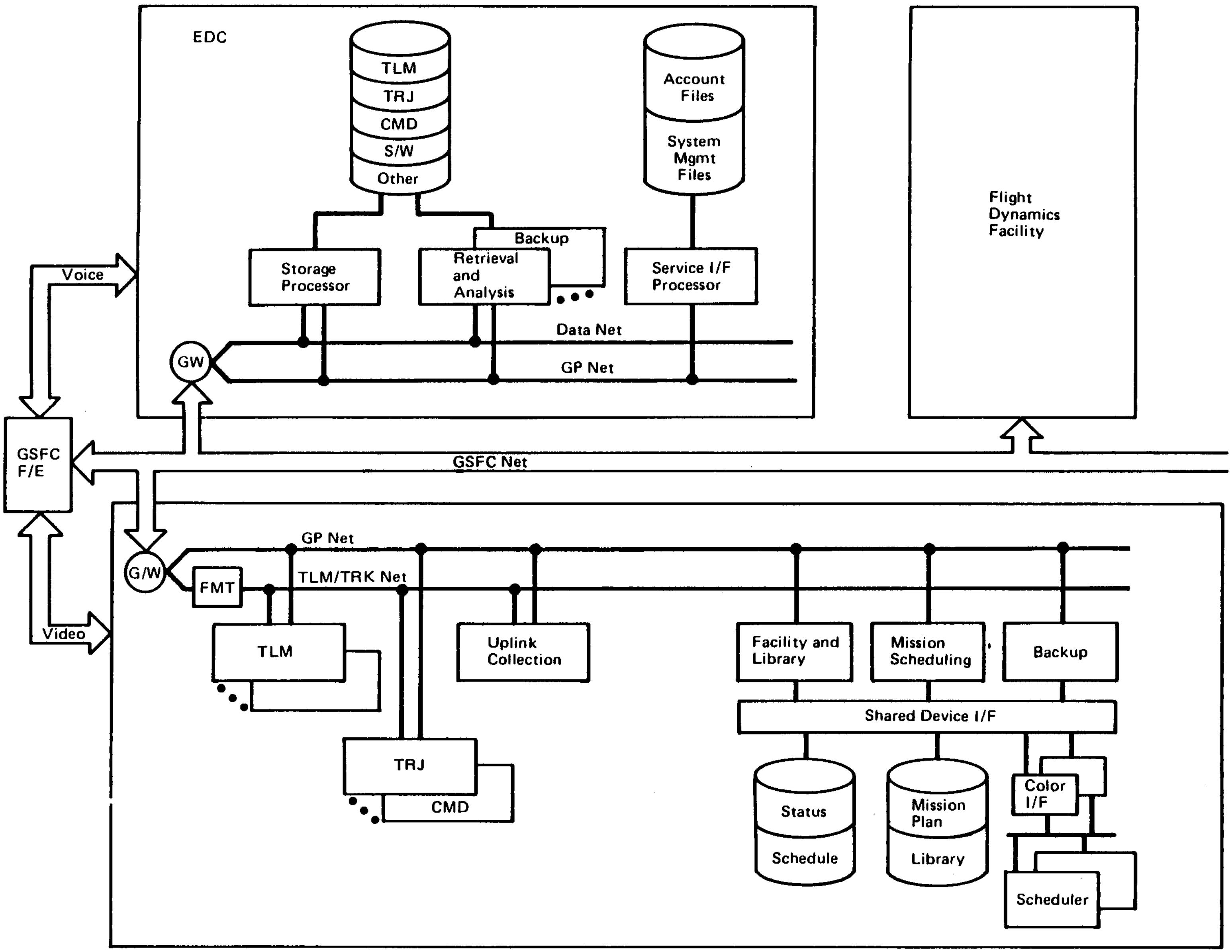


Figure 7.4.6.3.2.2-1. COPCC/POPCC Configuration

- Trajectory
- Command
- Data Presentation and Retention
- Facility Management.

The network communications system is composed of the following:

- Gateway to the GSFC nets
- TLM Formatter
- TLM Net
- GP Net
- Voice/Video Distribution

The gateway separates the telemetry/tracking data from the general type messages. The TLM Formatter converts the telemetry/tracking data into a format of self identifying parameters for broadcast. The TLM/TRK Net provides the physical means to deliver these parameters to the workstations. The gateway uses the GP Net to deliver the general type of messages. The message protocol conforms to the ISO seven layer model for the GP net. The TLM/TRK Net uses the same broadcast protocol described by the SSOCC.

The telemetry processing provides ground monitor and control support of the platform core systems. Workstations similar to those described in section 7.4.6.3.2.1.1 are needed to support these activities. The workstations are capable of storing at least two hours of selected parameters for review and analysis. The display of information and graphics support the human interface necessary for decision-making and command activity.

The trajectory functions are accomplished through the use of workstations and the Flight Dynamics Facility (FDF). The same type of workstations support trajectory as are used for monitor and control. The FDF provides computational support for such activities as orbit and attitude calculations. The trajectory activities include support for navigation, guidance, attitude control, tracking and traffic control.

Command processing is similar in nature to that performed within the SSOCC and includes verification, validation, safing, uplink formatting, etc.; however, authorization may be limited to a single workstation.

The data presentation and retention are accomplished through the use of workstations. Section 7.4.6.3.2.1.1 also contains a description and figures depicting a typical workstation used for this activity. Long-term data retention is done in the Platform EDC while short-term retention is accomplished by the workstations.

Facility management provides library services as well as equipment monitoring and scheduling for all equipment in the COPCC/POPCC. A mainframe computer manages the collection and distribution of information while LISP processors produce the actual schedules and provide conflict resolution and fault analysis and recovery. The library services provide global storage of files for the workstations.

The number of control rooms for platforms is as follows:

1 COP
2 POP
1 Training and development.

Six workstations are estimated for support of each platform.

The data formats for the LANs are the same as those described in section 7.4.6.3.2.1.1 for the SSOCC.

7.4.6.3.2.2.2 Mission Scheduling

The Mission Planning System performs the mission scheduling for all platforms. The same basic configuration that supports Space Station Mission Scheduling also supports Platform Mission Scheduling. The number of AI (LISP) processors is reduced from six to four, however.

7.4.7 ENGINEERING DATA CENTERS

The Engineering Data Centers provide archival storage of core engineering data. The data is kept within the archive for a minimum of two years with longer-term retention at the SSP's discretion or as arranged through negotiations with the customer. Per the design, there are two Engineering Data Centers — one for the storage of Space Station core data and one for the storage of platform data. The Space Station EDC is located at JSC, and the Platform EDC is located at GSFC. The capability exists via the Mission Scheduling System, in conjunction with the GSC's network management function, to route data destined for one of the EDC's to the other for temporary storage in the event of the primary EDC's failure.

7.4.7.1 Interface Description

The functional interfaces of the EDC are listed in Table 7.4.7.1- 1. Due to their near real-time nature, the functional interfaces to the Space Element and Control Center are managed at a higher priority than are the non-real-time interfaces to the other elements.

7.4.7.2 Function Description

The following subsections discuss the EDC systems that perform the functions identified in Table 7.2.3-1.

7.4.7.2.1 Communications

The Communications system provides the interface to the wide area and local area networks connecting the EDC to the other SSPE's and to the intra-EDC data distribution networks. The system provides:

a. External Interface Management
  - Support communication link monitoring
  - Provide transmission error detection
  - Support protocols requiring acknowledgements and retransmissions
  - Provide performance monitoring data to GSC

Table 7.4.7.1-1

EDC Functional Interfaces to Ground Elements

Element	Interface Traffic	Purpose
DHC (as gateway to Space Element)	Core Downlink	Archival storage
	Queries/Responses	Archival retrieval
Control Center	Core Uplink, Computed Data	Archival storage
	Queries/Response	Archival retrieval
	Schedules/Status	Ground resource mgmt.
POCC's LZPF's RDC's Customers	Queries/Responses	Archival retrieval
Alternate EDC	Data Records	Fault recovery
Central Catalog Service	Catalog Updates	Maintenance of Central Catalog
GSC	Resource Usage Records	Customer billing

b. Data Processing
  - Perform required preprocessing (e.g. core data level 0 processing and data extraction)
  - Route data to storage/retrieval systems

7.4.7.2.2 Archival Storage

The EDC's Archival Storage system provides for the entry of core data into archives. The services provided are:

a. Two year storage (nominal; longer if negotiated) of audio, video, and digital data
  - Provide data compression (if necessary)

b. Support the central cataloging functions of:
  - Inventoring of archive data
  - Information on where data is located
  - How to get it
  - Options on format and transmission media

7.4.7.2.3 Retrieval

The EDC's Retrieval system supports the search for and recovery of archival core data for transmission to SSPE's. Services include:

a. Process stored data request from SSPE's
b. Provide access control to stored data
c. Perform requested analyses of engineering data
  - Report generation
d. Support the transfer of data in standard format data units (SFDU))
e. Maintain usage records for customer billing

7.4.7.2.4 Facility Management/Scheduling

These functions manage the configuration of the EDC resources in order to minimize the impact of equipment failure and to ensure that the proper configuration is provided for scheduled support. The EDC's scheduling function interacts with its respective Mission Scheduling System, providing status and accepting and executing schedules. Per a schedule request, these facility functions configure the EDC to support the entry and temporary storage of the alternate EDC's data.

7.4.7.3 Design Approach

The design approach for the Engineering Data Center addresses common design drivers and architectures. Then the unique design drivers and architectures are addressed for each EDC. Since the basic functions are the same, most of the design drivers and architecture are common.

7.4.7.3.1 Generic Design Drivers

The generic design drivers for the EDC's are very similar to those of the control centers. These design drivers are discussed below.

- FLEXIBILITY - This quality allows the EDC to meet changing needs in a timely and cost effective manner.

- TECHNOLOGY INSERTION - As improvements are made in technology, they should be easy to incorporate.

- GROWTH - As demands and requirements increase, the system must allow additional resources to be added easily.

- LIFE CYCLE COST - The design should utilize concepts that reduce operating costs as well as controlling initial purchase price.

- RELIABILITY - The EDC's should be designed in such a way that one may at least provide data capture capability in the event that the other EDC is down.

- AUTOMATION - In order to reduce staffing and to improve response time, the retrieval of data from the archives should be as automated as possible.

- COMMERCIAL OFF THE SHELF (COTS) – The use of commercially produced equipment in place of custom built equipment is highly desirable.

- REUSABILITY – The design should utilize hardware and software developed through other projects when possible.

7.4.7.3.1.1 SS EDC

The SS EDC has a stable input data rate and a high retrieval activity as unique design drivers.

7.4.7.3.1.2 Platform EDC

The Platform EDC data rates and storage requirements change as a function of the number of platforms.

7.4.7.3.2 Generic Configuration and Architecture

The generic architecture is shown in figure 7.4.7.3.2-1. The primary components of the EDC are listed below.

- Communications
- Storage processing
- Data storage
- Retrieval processing/analysis
- Service interface processing

The communications system provides a gateway to select and route the data and messages. The Data Net provides for the transfer of core type information like telemetry and tracking data. The General Purpose Net carries the regular traffic associated with requests and control. Storage processing is responsible for data capture and any formatting associated with storing and organizing the data. The data store is the retention media. The retrieval/analysis handles queries and formats the results as well as sending the results to the requestor. The service interface processor manages the system and performs the accounting associated with the services.

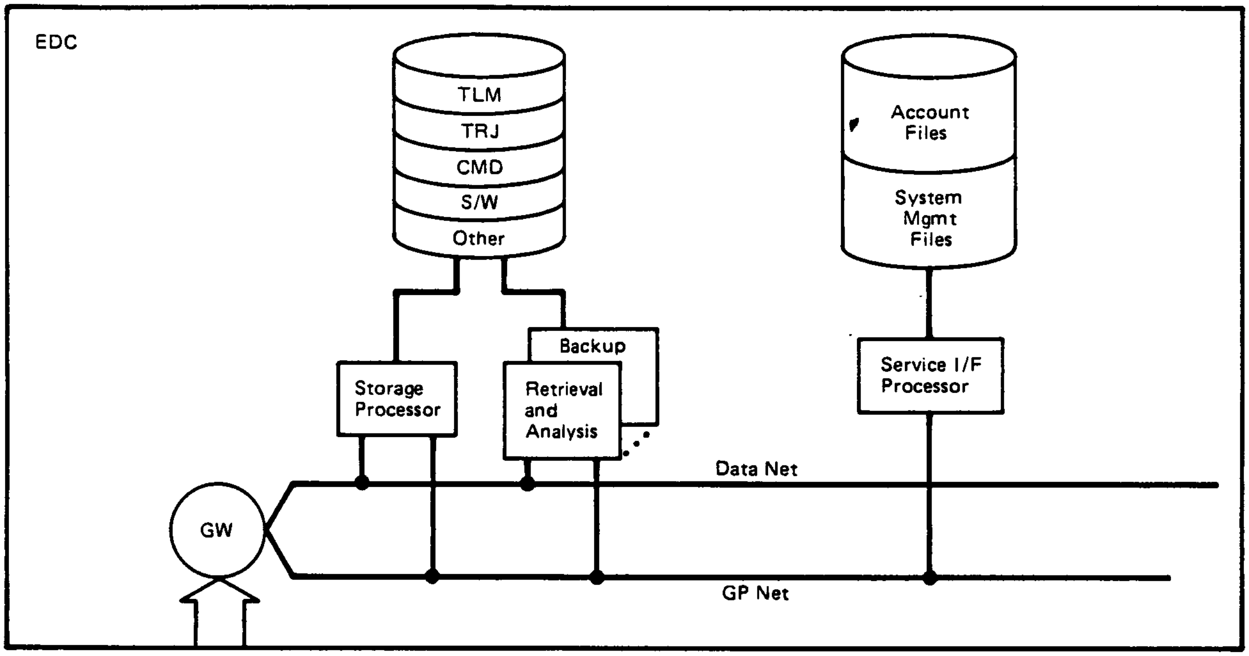


Figure 7.4.7.3.2-1. Engineering Data Center

7.4.7.3.2.1 Space Station EDC Configuration and Architecture

The storage and the retrieval processors are of the mainframe class. IBM 308X computers are representitive examples. The service interface processor is of the same type as well. The data store consists of magnetic disk that holds four to six hours of data. This is treated as a circular queue. This allows data to be replaced by that of better quality should it be available. Once the data is stable, it is transferred to optical disk for archival storage. A system like the RCA "Optical Disk Jukebox" identified in the Task 3 report is representitive of the technology required. By using a library manager, older data can be stored offline and loaded on demand. The system management and accounting files are magnetic disk. The amount of storage required is shown in the following table.

OPTICAL	4000 Gbytes (core engineering data without data compression)
MAGNETIC	10 Gbytes.

It should be noted that the performance of the storage processor is a function of the amount of reformatting necessary to place the data into the database system. If the downlink data is organized in blocks that are the same as database records, the processing is greatly reduced. Thus, coordination with the onboard system is very important. The cost of the storage processor could be reduced as a smaller machine could be used. The use of a database machine to support queries and storage represents a possible cost reduction by reducing the loading on both storage and retrieval processors.

7.4.7.3.2.2 Platform EDC Configuration and Architecture

The same configuration that supports the Space Station EDC can support the Platform EDC. As the number of platforms increase, additional processors and storage will need to be added.

7.4.8 Operational Control Network (OCN)

An essential component of the design is the Operational Control Network which ties together all system components, providing facilities for internal coordination of system functions, downloading of configuration controlled software and tables, remote fault diagnosis, and access to network components by internal and external users. The Operational Control Network is functionally separate from the network associated with the Software Support Environment/Software Development Environment (SSE/SDE), but supports gateway functions for transfer of approved software configurations. Although the functionality of the OCN is somewhat different than the SSE, the design anticipates that much of the associated software and network interface components will be identical. In the design the OCN is layered on the same packet network which supports low-rate data transmission and is supported through ISO-compatible network services associated with Layers 4 through 7.

7.4.8.1 Functional Interface Description

The Operational Control Network interfaces with all major SSDS ground components either directly through the packet network or indirectly through LAN connections to packet network servers. ISO-compatible services for remote terminal access, file transfer, and remote peripheral access are provided for all the general purpose processors in the SSDS configuration. The network is fully interconnected with network access security provided at all external gateways.

7.4.8.2 Function Description

The OCN is a backbone network which provides essential services for coordinating the operations of the ground elements of the SSDS. It will support the following functions:

Software Downloading — to provide for transfer of new software releases to target processors, and to support startup of software on remote nodes, particularly microprocessors which do not support local storage of software images.

Remote Terminal Access — to allow remote logon and system access by internal and external users through packet network facilities.

External Logon — to verify the identity and log access to network elements by external users entering through tail circuits and gateways. The OCN does not control access to individual components (e.g. DHC or LZPF) but does control network access.

Customer Interface — to provide menus of services and connect users to these services (e.g. in a manner like the Telenet logon menus).

Network Messaging and Reporting — to provide standard services which support scheduling of network resources, status and event reporting, and accounting messages, particularly through communication with the GSC.

Remote Diagnosis — to support the location and diagnosis of SSDS component failures.

Remote Device Access — to support network access of storage and output devices for remote data base access, reporting, and logging.

Network Cold Start, Restart, and Switchover — to accomplish essential coordination functions during network startup and switchovers associated with network element maintenance and failure recovery.

7.4.8.3 Design Approach

The design approach assumes that the underlying Layers 1 to 3 of the ISO model are provided by the low-rate services of the data distribution network and all ground elements of the SSDS have local gateways. Only the additional elements required to provide the above functionality are described. Issues of network control center design or network structure, other than those which are internal to the SSDS or are customer interfaces, are not considered.

7.4.8.3.1 Physical Structure

Each configurable element of the design is connected to the OCN. Connection may be directly to the packet network, indirectly through a LAN and packet network server, or through a host processor (for certain special purpose processors such as the high bandwidth I/O processors at the LZPF). Backup connections also exist for certain critical activities; for example, the Ground Services Center is equipped with alternate dialup links to all SSDS ground facilities for communications during packet network gateway failures. However, all routine control communication is normally routed through the packet network. The conceptual model for the physical system interconnection is similar to the structure currently provided by DECnet, which provides for multiple high and low bandwidth LAN's with reconfigurable interfaces and internet gateways for creating subLAN's and connecting them to external wide area data networks.

7.4.8.3.2 Gateway Functions

OCN gateways are provided at all SSDS facilities and at tail circuit locations. The structure of the gateways is not an SSDS design element, but has substantial impact on SSDS design and customer interface. Customer Interface Elements (CIE) located at tail circuit gateways provide a menu-oriented choice of network services and support easy access to the specialized capabilities of SSDS facilities (e.g. command uplink at the DHC, GSC communication, LZPF real-time or store and forward services). The gateways also serve to control access to SSDS nodes preventing entry by "hackers" and logging all sessions established by external users.

7.4.8.3.3 Network Services

OCN services at the Application layer were described in Section 7.4.8.2. The design uses a set of standard network services similar to the high level services provided by the NBS standards, DECnet, or SNA. The various SSDS-specific communications which will pass over the OCN were described in earlier sections on the individual ground system elements.

7.4.8.3.4 Network Management

The GSC provides network management services relevant the the SSDS elements. The GSC coordinates SSDS element startup and loads authorization and configuration tables throughout the SSDS utilizing the standard Applications Layer services provided by the OCN. Status, event, accounting, and data quality are reported directly to the GSC. A customer experiencing problems with data quality, data access, or any SSDS service uses the GSC as a single point of contact for problem reporting. In the event of a reported SSDS failure the GSC uses OCN facilities to localize the problem and coordinate problem solution working with appropriate data distribution network, NCC, or local SSDS facilities to resolve the problem and/or switch over to system backups.

Although it may be collocated with the packet network control center, the GSC does not provide packet network security services or fault diagnosis. The GSC does, however, cooperate with network elements in locating and diagnosing faults at the communications gateways and other SSDS boundary elements.

7.5 Summary

In the process of performing the SSDS A/A Study several key issues, assumptions, and uncertainties have been identified which impacted the choice of a ground system architecture, and which should be analyzed in greater detail in Phase B. Decisions on these areas will have a significant impact on the cost and operations of the end-to-end SSDS.

7.5.1 Level 0 Delivery Requirements

The definition of the "delay requirement" in the Langley database has important impacts. Does a "zero delay" requirement include Level 0 processing? Is it required to deliver the level 0 data for high rate missions within 24 hours, for a particular data set; or are longer delays allowed? In the SSDS Study, the maximum allowed delay is 24 hours. Longer delays, especially for high rate data, might allow non-electronic distribution of data, e.g, distribution of optical disks.

7.5.2 Real Time & Quick Look Data Requirements

An SSDS requirement is that the SSDS must be capable of transmitting the raw or quicklook data in real time to POCCs and customers. This requirement favors a distributed level 0 processing architecture, since it implies that communications are needed to the POCCs and RDCs anyway to meet the real time requirement.

7.5.3 Definition Of RDC

While assumptions have been made as to the number, locations, and responsibilities of Regional Data Centers, in reality these issues are uncertain and are in fact significantly affected by programmatic decisions. Further programmatic refinement of the assumptions regarding RDC's will be important in Phase B.

For example, in this study it has been assumed that the SSIS capabilities will be established to provide higher level data processing at the Regional Data Centers. A current example of this support is the Upper Atmospheric Research Program (UARS) Central Data Handling Facility. The impact of this assumption is that, regardless of where the Level 0 processing is done, the data must be sent to a few key locations. In addition, the advantages of co-location of Level 0 and upper Level processing for high rate missions — for example, to simplify retrieval from the seven day Level 0 archive — must be explored, as has been done in the Network Topology Trade Study.

Another contrasting view is that upper level processing support may migrate to users for some missions. For example, support for low rate missions might consist of archiving for data products only. An example of such support is the National Space Science Data Center. Data would be sent from the Level 0 processing facility directly to users via the data distribution network. The Gamma Ray Observatory (GRO) program takes this approach.

Another question is whether upper level processing must do, and have the capability to do the necessary processing to verify that they have a usable dataset, within 7 days since the data is discarded by the Level 0 SSDS site at this time. IF the Upper Level processing sites do not have substantial processing capability, then they may not be able to verify that the data is correct within the 7 day period.

Resource sharing between Level 0 and upper level processing is another issue, and it appears to be more significant for high rate missions. Resources to be shared include facilities and people, and it may be possible to share the processing, working storage, and archival resources between the level 0 and the upper level processing. For example, it would appear that the high rate missions would require high throughput processors in order to produce data products in a reasonable time period. Another example is sharing between 7-day and long-term level 0 archiving. Such sharing is speculative since the reliability and processing requirements are different, but the cost impact of the high rate missions appears to warrent it being investigated.

7.5.4 Uncertainty of requirements

While the Langley Mission requirements provided valuable input, these requirements have uncertainties, and these increase over time. Missions will be added and subtracted over the lifetime of the Space Station and the alternatives should be compared in terms of their ability to accommodate these changes. Flexible architectures are favored, and this is one reason the hybrid approach to Level 0 processing was chosen.

Definition of required "standard services" are also important. This study has taken the view that a standard service is one that must be provided to all customers, as opposed to the majority of customers.

7.5.5 Uncertainty of Ground System Traffic

The Langley Mission Requirements do not specify elements of key concern to the ground system, such as the ground destination for the data. The ground destinations for the mission data must be defined to determine the locations, data traffic to, and processing requirements of each Level Zero Processing Facility. An additional SSIS issue is electronic delivery to customer sites. Do these sites cluster in key geographic regions, or are customers widely distributed?

In addition to defining user requirements in these areas, the issue for Phase B is again flexibility — for example, to support changes in customer locations.

7.5.6 Sensitivity to Key Missions & Characteristics

A large number (about 60–75%) of the missions operate at fairly low rates (less than 0.1 Mbps) while a few key missions operate at extremely high rates (up to 300 Mbps). The issue for Phase B is which alternative both meets the mission requirements of all the missions, but also isolates the architectural impacts of changes in this mission mix and in the data from those missions.

For example, in this study it was assumed that all data would be packetized, including that from the very high rate missions. Level 0 processing for packet data is clearly a standard service.

However, concern has been expressed as to the ability of high rate payloads to perform packetization, or if packetization is used, whether the packet format would be identical to that of low rate missions. It may be very difficult to perform Level 0 processing as a generalized standard service unless the formats are identical. If this assumption is considered questionable or risky, there will be impacts on the choice of a Level 0 processing architecture.

The risk of a centralized Level 0 architecture approach would appear to depend in part on a) all data being in packets of identical format, or; b) if the formats are not identical, being able to build an advanced telemetry processor which can handle an arbitrary format. The feasibility of both of these issues warrants further attention in Phase B.

The hybrid approach has less risk since all the low rate missions are served with a centralized service where there is little concern as to the ability to packetize. The resources needed for the high rate missions can be phased in or out, and designed depending upon the requirements of the high rate missions and the technology then available.

7.5.7 Impacts And Uncertainties Of Communications

The Network Topology Trade Study made parametric assumptions with respect to communications costs, for completeness in cost analysis, but communications has only been addressed in terms of feasibility, and not advisability, of the technologies. This is due to the fact that the data distribution network was viewed as an SSIS institutional resource. In reality, both communications and processing should be examined and designed together, and Phase B studies should examine both technical and cost tradeoffs between them.

For example, a distributed Level 0 processing architecture might depend on being able to broadcast the full downlink to all sites. This would depend on using KA band technology, which may or may not be feasible due to rain attenuation. That is, any given broadcast site may be out due to rain, resulting in increased site outage, duplicate ground stations (site diversity), and/or additional re-transmission requirements all of which should be studied.

In addition to the Level 0 architecture, the rest of the ground system will be distributed and in such an environment processing (Nodes) and communications (links between the nodes - especially network (ISO layer 3 functions) — become more closely interdependent. The successful implementation of a distributed processing network could well depend on utilizing a sophisticated ISO communications architecture, including as packet switching, and could be viewed as migrating what are currently thought of as processing functions to the communications subsystem.

Problems also arise in estimating costs. Deregulation could have an unpredictable impact on communcations costs, affecting decisions as to the number and locations of processing centers (RDCs).

7.5.8 Optical Disk Technology

The overall cost of the ground system will be greatly impacted by the state of the art of optical disk technology. This not only includes the cost and storage size of the disk, but also the use of read-write technologies which support increasing numbers of writes. The Network Topology Trade Study showed that advances supporting 100 writes would result in significant savings. Magneto-optic technologies hold promise of millions of writes) greatly reducing the overall system cost.

7.5.9 Common Scheduling Statusing, and Database Interfaces

Key subsystems in the ground system must utilize standard interfaces if they are to inter-operate. Since scheduling is distributed between the Control Centers and the GSC, at different locations, rapid re-scheduling to support users requires electronic communication between the various scheduling systems. This will require application level protocols between the systems. Monitoring of common resources will also be facilitated by the use of standardized status messages.

The various databases distributed among the ground elements will need to intercommunicate easily and with users. The use of common external interfaces which inclde interfaces to the central catalog service and common query languages will facilitate this interaction.

7.5.10 Key Onboard Sensitivities

Key onboard decisions which impact the ground architecture which warrant further study in Phase B are:

7.5.10.1 Use Of Virtual Channels

In this study we have found that virtual channels can greatly simplify the ground segment design, and we have identified a number of key uses, as listed in Section 7.2. The wise use of virtual channels is critical for phase B. Additional virtual channels over that allowed by current standards may be needed.

For example, in the initial (strawman) onboard SSDS design, all payload science data was packetized and merged into one 100/300 Mbps stream. The manner in which playback data was to be identified was not determined, but this has a major impact on the ground system design. An important finding is that virtual channels be used for this purpose:

- two virtual channels should be devoted to each of the high rate payloads, one for real time, and one for playback data
- the low rate data can be packet multiplexed onto one virtual channel for real time and one virtual channel for playback
- the virtual channels are maintained all the way to the site(s) of level 0 processing

The Level 0 architecture could be impacted if these assumptions are changed and this should be studied in Phase B.

7.5.10.2 Onboard Command Management

The SSDS Study has proposed a command management approach which involves the scheduling of capabilities (modes) with enforcement by means of electronic keys and reactive control. Actual payload uplink data is transparent to the

SSDS. Changes in this approach would have a major impact on the ground flow of uplink traffic and on missing coordination of the ground system and should be examined in Phase B.

7.5.10.3 Packetization

Obviously the ground system is most affected by the assumption of all data being in the form of identical self identifying telemetry and telecommand packets. Changes in this assumption, for example, if high rate payloads are not packetized — would have major ground system impacts, as noted above.

7.5.10.4 On-board Optical Disks

The proposed ground segment design assumes the use of on-board optical disks, which allow playback in a forward direction. The backup technology is that of tape, which plays back in reverse. Level 0 processing is impacted if this occurs, since tape reversal is required.

7.5.11 Space/Ground Transfer Layer Services

It is recognized that a guaranteed delivery service for the transmission of error-sensitive data (assumed to be low rate) is desirable for the space/ground link. Such a service, such as the CCSDS transfer layer service, would be provided on a frame basis by the Data Handling Center in conjunction with the onboard C&T system. Design is pending recommendations from the CCSDS on modifications to the transfer layer standards to support a bi-directional "command class" service.

7.5.12 Conclusion

In summary, this definition of the Ground SSDS has:

- Partitioned and allocated functions to ground facilities:
  - Data Handling Center
  - Level 0 Processing Facilities
  - Control Centers (SSOCC, COPCC, POPCC)

  - Engineering Data Centers
  - Ground Services Center
  - Payload Operations Control Centers

- Presented key operational features for
  - core engineering data management
  - uplink command data management
  - payload data management
  - mission/operations coordination

- Provided, for each facility
  - an interface description to other ground elements
  - a function desciption, describing in more detail what the facility will do
  - design approach

- Summarized key sensitivities and issues which impact the ground system.

8.0 SYSTEM DEVELOPMENT CONCEPTS

8.1 Hardware Development/Procurement

Hardware development/procurement strategies can be divided into two categories; those for ground system hardware and those for space element hardware. Because of differences in the operational environments, it is expected that, in general, there will not be extensive hardware commonality between these different domains. There is potential for commonality in the exploitation of advanced hardware technology development even though the physical implementation of the technology may be different. (i.e., optical disk buffering technology may be applied to both ground and space elements). This study has primarily focused on strategies for space hardware development/procurement. Ground-based systems will generally use commercially available hardware products and traditional procurement practices will be employed. Some specialized hardware development for high data rate interfacing equipment can be anticipated for certain ground elements but this does not pose any unique procurement problems. While there are significant advantages to establishing some level of commonality for ground-based hardware (especially data processors), it is recognized that there are realities that will tend to inhibit this strategy (i.e., use of existing equipment, broad range of requirements, etc.). However, some level of commonality for newly procured ground hardware should be considered by NASA where appropriate. This is especially advantageous within each NASA center since training and maintenance costs can be minimized. In addition, when there is sufficient functional commonality across multiple centers (i.e., SSE's, control centers, etc.), common hardware will promote software portability and reusability as well as simpler interfaces.

The operational environment of space elements impose unique requirements for hardware procurement/development strategies that include the following:

a. Space environment (radiation, etc.)
b. Physical constraints (size, weight, power)

c. Reliability
d. Maintainability
e. New technology accommodation

In addition, the requirements in some areas vary significantly across the various space elements due to differences in orbit (radiation) and habitability (reliability/maintainability). These requirements generally apply to modular hardware components of the onboard DMS that includes the following key items described in section 6:

a. Network Interface Unit (NIU)
b. Subsystem Data Processor (SDP)
c. Mass Storage Devices
d. Multi-Purpose Applications Consoles (MPAC)

An evaluation of the requirements defined above will reveal many of the design features for an SDP that are common to many prior flight/space applications. That is the SDP must be low weight/volume/power, modular design, and space qualified (to levels required) as well as provide the throughput and storage capacity that technology will support for 1992 IOC. However, there are certain aspects of these requirements that are somewhat unique to the space station program due to the habitability environment, the goals for automation/autonomy, and the need to plan for substantial growth over the lifetime of the space station. The issues related to these unique aspects that pertain to space hardware development/procurement strategies are addressed in the following sections.

8.1.1 SDP Commonality

The concept of a common (standardized within the SSP) SDP for onboard applications has several cost-effective benefits for the SSP. Primary motivation includes the following advantages:

a. Maintainability and space parts inventory

b. Enhanced architectural flexibility to support fault tolerance, design extendability, and other architecture adaptability needs.

c. Promote transportability and reusability of software.

d. Lower development and operational costs due to the many advantages the SSE can provide.

To take advantage of these substantial benefits, it is necessary to address two important issues: (1) will a common SDP adequately meet the needs of all subsystems (IOC and growth)?, and (2) how can new SDP technology be incorporated during evolutionary growth? These issues were addressed by this study at two distinct levels of commonality; (1) across space elements, and (2) within a space element (SS, COP, POP).

In evaluating the commonality of SDP's across space elements, it is clear that significant differences exist in the operational environment (radiation, habitability). If a common SDP were adopted it would have to be designed to meet the more stringent requirements (radiation, reliability, maintainability) of the POP. It can be argued that if an SDP is to be developed anyway for the POP (non-recurring cost absorbed), the only penalty is the additional recurring cost when applied to other elements. However, the potential advantages identified earlier (a-d) are somewhat mitigated by the autonomous operation and unique servicing requirements of these elements. The transportability and reusability of software is still an important consideration but can be accommodated with a standardized Instruction Set Architecture (ISA) rather than a common SDP. This study recommends that a standard ISA be adopted across space elements. However, due to substantial differences in operational requirements, a common SDP may not be recommended for all space elements. This will be further evaluated as COP/POP requirements and designs are developed.

The advantages of SDP commonality are much more apparent within a space element (i.e., space station). This study strongly recommends that a common SDP be adopted for IOC. However, there is a related issue yet to be resolved; i.e., should an SDP be "tailorable" to specific subsystems needs such as optional I/O "cards" or variations in memory capacity. Such variations imply a different replacement and spare parts inventory strategy.

The more important issue is how to realize the benefits of commonality without unnecessarily constraining the incorporation of new technology for evolutionary growth. It is recognized that long-term growth must accommodate not only upgraded versions of conventional processors (faster, more memory) but also radically different architectures. If NASA goals for advanced automation are even partially realized during growth phases, an AI-oriented computer architecture may become an essential component of onboard networks. To maximize the advantages of SDP commonality while promoting growth, this study recommends the following:

a. Adopt common SDP for IOC
b. Accept the fact that onboard networks will become heterogeneous during growth and plan for it.

    - Minimize and control number of new types of SDP
    - Standardize ISA for conventional architectures (MIL-STD 1750)
    - Design networks and related operating system to promote growth and not preclude heterogeneous systems.
    - Standardize NIU interfaces.

8.1.2 Space Qualification

Space qualification is that effort required to insure that hardware elements will meet all performance requirements in the specified operational environment.

Prior space qualification programs have typically exposed samples of the target hardware to an exhaustive sequence of environmental, electro-magnetic and power tolerance testing with levels significantly in excess of mission profiles. A successful test sequence not only demonstrated compliance with requirements, but also insured that normal acceptance testing did not significantly fatigue the subsequent production units.

The project hardware was generally new development, tailored to the specific application and influenced by the qualification requirements to provide overly rugged enclosures, components and mounting. The hardware conservatism of the design and test requirements, however, were generally applied because:

1) the hardware was operational through the severe mechanical environments of launch and vehicle staging,

2) failures were generally intolerable, and

3) fault tolerance was generally limited to static redundancy techniques because of the continuing physical (size, weight, and power) constraints.

The Space Station program represents a significant departure from the above scenario because it will be manually assembled, activated, and repaired on orbit. This implies that the hardware (electronic) modules within each launch package need not be operational during the boost operation and can be packaged to survive the launch and staging stresses.

These differences provide opportunities for innovative qualification approaches during IOC and growth phases that satisfy identified programmatic goals of cost, commonality, protoflighting, technology accommodation and growth.

The key to maintaining program cost goals will be the minimization of development effort without significantly impacting subsequent operational costs. This can be accomplished in many cases by "buffering" or isolating the environment (i.e. shielding, mechanical/thermal isolators, etc.) to match existing hardware capabilities rather than requiring hardware with inherent environmental compatibility.

Lower, more tolerable environmental exposure levels will allow reduction or elimination of selected qualification tests with more reliance on qualification by similarity (if used on other programs) as well as computer based simulation and analysis. This approach will minimize fatigue on qualification samples and is therefore supportive of protoflighting goals.

The mechanical environments are considered to be primary driver for any space design. For the Space Station/Platform equipment, these environments are essentially limited to the boost operation, during which, the transported packages need not be operational. The launch configuration of each package is therefore a variable within the constraints of pre-launch checkout and assembly limitations. This suggests the use of special packaging/handling equipment to isolate the electronic modules associated with each package for the boost operation environments.

Space radiation will be a significant factor for some space elements of the SSDS (i.e., POP), but is not expected to be a driver for the inhabited Space Station itself unless commonality across space elements is warranted. Shielding and other design options should be fully explored before discarding the commonality goals and initiating new development activity.

The qualification program must also address technology insertion and growth components since they will be subjected to the same basic environments. This follow-on hardware will generally be transported as loose items, therefore, the special handling (environmental isolation) equipment discussed earlier, will be more viable.

With respect to the qualification effort, the study recommends:

a. Utilization of available techniques to reduce direct environmental exposure (shielding, mechanical/thermal isolators).

b. Analysis/utilization of prior qualification history of commercial hardware candidates for potential qualification requirement reductions (i.e., qualify by similarity).

c. The rigor of testing can be relaxed based on the number of flight units. Small quantities can be effectively bench tested utilizing "golden box" techniques as opposed to the required production test equipment, training and formalization of high volume projects.

8.1.3 Technology Capture

Historically, NASA space programs have incorporated data processing hardware technology that significantly lags the current state-of-the-art. There are many contributing factors that combine to cause this situation including stringent mission/environmental requirements and the availability of space qualified hardware. In particular, space radiation qualification has always been an expensive and time consuming activity. This generally does not present a problem if onboard processing demands are low and sufficient margin is provided for unanticipated changes during development (almost never the case). Onboard processing capability has often been traded off for low power demands, small volume/weight, and high reliability at the expense of autonomous operation. Failure to minimize this "technology gap" for the space station program could seriously jeopardize NASA goals for a high degree of space station autonomy and automation.

While certain space station mission/environmental requirements are unique (habitation) and offer the enhanced opportunity for capturing commercial technology, these requirements are also very diverse across space elements (SS, COP, POP). This may result in substantial variations on the degree to which commercial technology can be applied across elements. Space radiation environments are likely to be a key driver for the POP.

The following steps have potential for minimizing the "technology gap".

a. Selection of a standard ISA early in the program and defer the selection of the actual target hardware. This will allow initial software development to commence on schedule (long-lead item). Initial code and checkout can be accomplished on an emulator/simulator with target hardware required for subsequent test and integration.

b. Adopt widely-supported applicable standards to broader base of potential suppliers. This will substantially reduce the need for special development activities which often become long-lead items. In particular, the use of military standards (i.e., MIL-STD-1750) will not only provide a rich source of flight/space qualified components, but a highly visible growth path supported by DOD (VHSIC, DARPA, etc.).

8.2 SOFTWARE DEVELOPMENT

8.2.1 INTRODUCTION

The purpose of the SSE is to provide an environment to support the development of software for the Space Station. The SSE is a set of tools which are portable and will be made available for subsystem and payload developers. The tools included in the SSE will not dictate a specific methodology or set of procedures. The users will be able to define their procedures (with NASA approval) and utilize subsets of the tools as required to support those procedures.

The primary goal of the SSE is to reduce the life cycle cost and insure the quality of all software produced for the Space Station. This includes core, payload, ground support, and SSE software. This will be accomplished by the achievement of the following subgoals:

1. Provide a stable, common base for the development of the software.

2. Provide integrated support of the entire software life cycle, from conceptual definition through delivery, including configuration management at all stages.

3. Provide easily attainable status at many levels by providing tools which facilitate definition, scheduling and tracking of intermediate milestones.

4. Provide state of the art tools for each task in the software life cycle to increase overall productivity.

5. Provide a common, convenient interface for each of the tools to avoid the necessity of learning multiple interfaces.

6. Provide an easy way to expand the tool set in order to add new tools.

7. Provide a method of maintaining multiple versions of all documentation such that it is available on-line or it can be printed.

8. Provide tools which support and encourage commonality and the reuse of existing components.

9. Provide sufficient flexibility within the configuration management and software engineering methodology support to make the SDE attractive to payload customers as well as satisfying the needs of core and ground software developers.

10. Provide SSE capabilities such that support provided is independent of users physical location.

The types of software support by the SSE will include:

- Real Time Flight Software
- Ground Command and Control Software
- Ground Data Processing Software
- Support Software
- Integration and Test Software
- Emulation and Model Software
- Customer Application Software

In this document, the term "user group" will be used to define some set of users which is working on the same task and requires the same functions from the SSE.

The SSE will be used by development groups to generate software elements, and by the software integration site to combine the elements into integrated software loads. The support provided to each development user group will be identical. This support will be provided in a manner which will allow each group to develop their applications as autonomously as possible, but will encourage communications and software commonality among the groups. This is depicted in Figure 8.2-1. Each function in the figure is described in more detail in this document. The support for the integration will consist of many of the same functions as provided for the development groups, but it will also include facilities to integrate the software produced by all and it will provide more extensive system/integration test facilities. See Figure 8.2-2.

8.2.2 CONFIGURATION CONTROL AND MANAGEMENT SUPPORT

A set of tools will be provided by the SSE to support Configuration Control and to support management in their activities of planning and resource allocation. It is assumed that to maintain configuration control over the Space Station software, the project will utilize a series of NASA and contractor control boards (similar to what has been used in previous NASA projects) and an automated data base system for storing and enforcing decisions made by the boards. These tools will provide the functions discussed below.

8.2.2.1 CONFIGURATION MANAGEMENT DATA BASE

The Configuration Management Data Base is the repository for all of the configuration control and management support data. While thought of as a single data base, it is in actuality composed of several logically related data bases. Each contains the level of information which allows its users (i.e., management, development, testing) to plan, schedule and track its work.

Proposed software updates will be documented in the data base. The control boards will coordinate a review of the proposed updates by applicable project members to determine the benefits, cost and impacts of the update. Results of

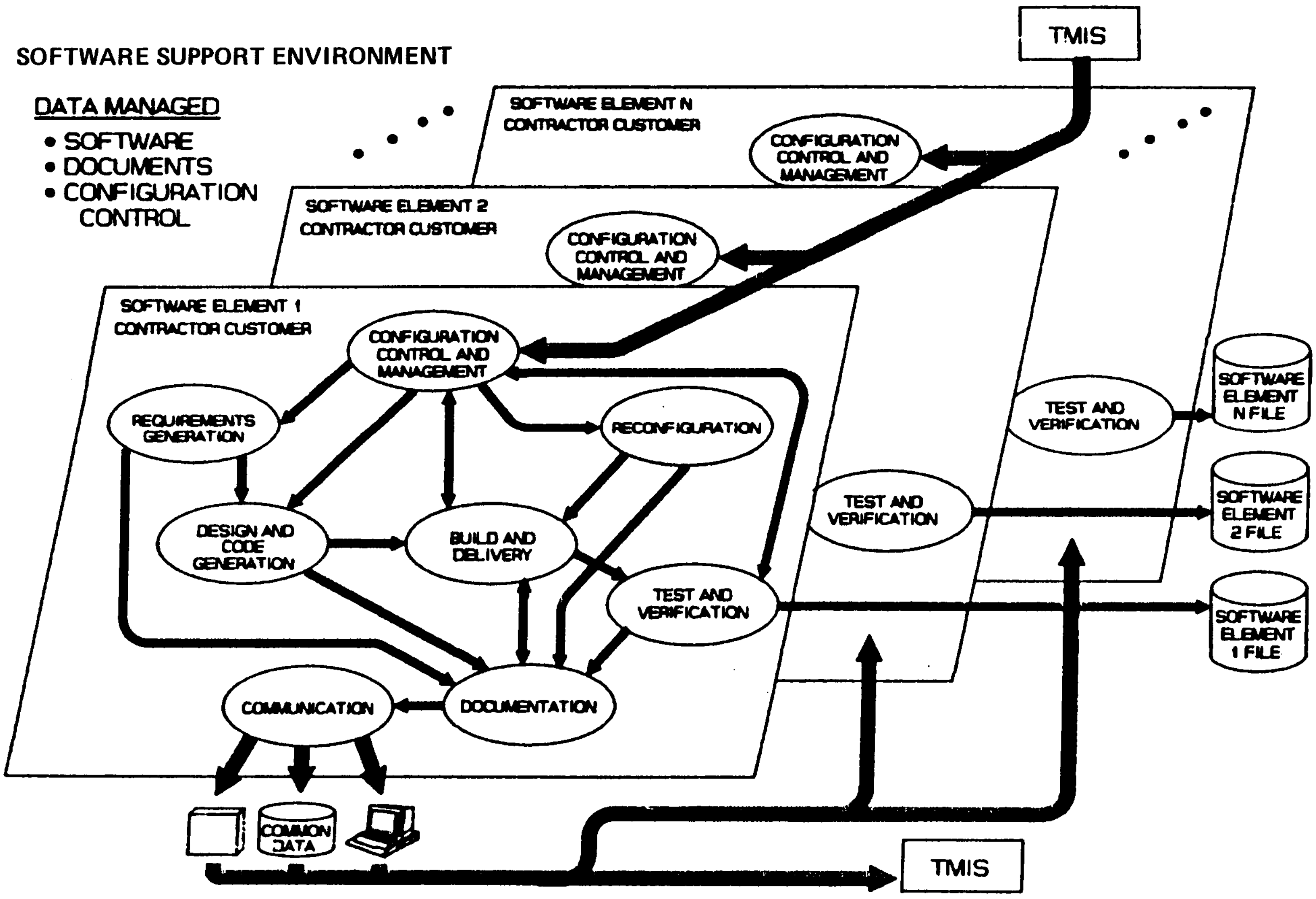


Figure 8.2-1. Software Development Site Support

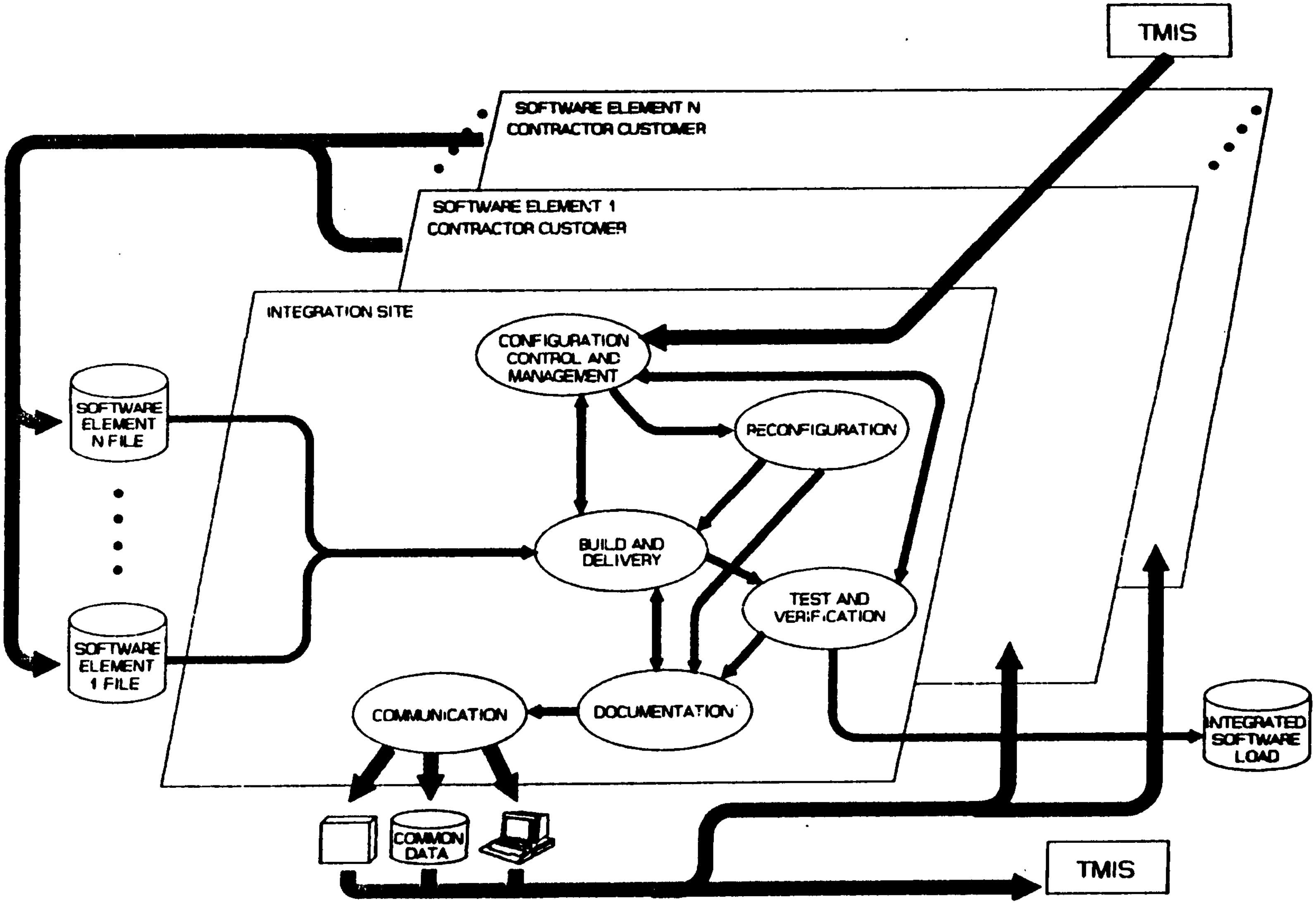


Figure 8.2-2. Software Integration Site Support

the review will be stored in the data base. The boards will then disposition the proposed updates and determine the implementation schedule. The control board structure is currently undefined. A proposed structure is depicted in Figure 8.2-3. The approval levels required for updates will have to be determined based on factors such as cost of change, number of systems impacted, etc. All data will be retained in the data base and will be used as inputs to other functions. See Figure 8.2-4.

8.2.2.2 SUBFUNCTIONS

8.2.2.2.1 DEFINITION OF SOFTWARE INCREMENTS

The Configuration Control function of the SSE will provide a method for defining and managing software increments. Some of the increments will be intermediate systems used by the development groups to checkpoint their progress and others will be released for further integration.

For each increment a set of data is maintained. This data includes the increment's name, dates associated with milestones in the increment's life (definition, build, release, delivery), and the increment's status (defined, baselined, integrated, delivered). This data will provide a means of tracking and controlling increments and of producing reports about system activity on the increments.

8.2.2.2.2 DEFINITION OF SOFTWARE CAPABILITIES

The CM function of the SSE must provide a method of identifying changes which must be made in the software being implemented. There are two basic types of changes; those which provide enhancements (and usually imply requirements updates) and those which correct errors in existing software. All changes will be documented by a 'control instrument'. This is a generic term which will be used in place of a multitude of specific terms such as Change Request (CR), Problem Trouble Report (PTR), Engineering Support Request (ESR), etc. The SSE must provide for maintenance of data pertaining to all control instruments. The primary information includes identifying information of the control instrument (number, title) and identification of the software

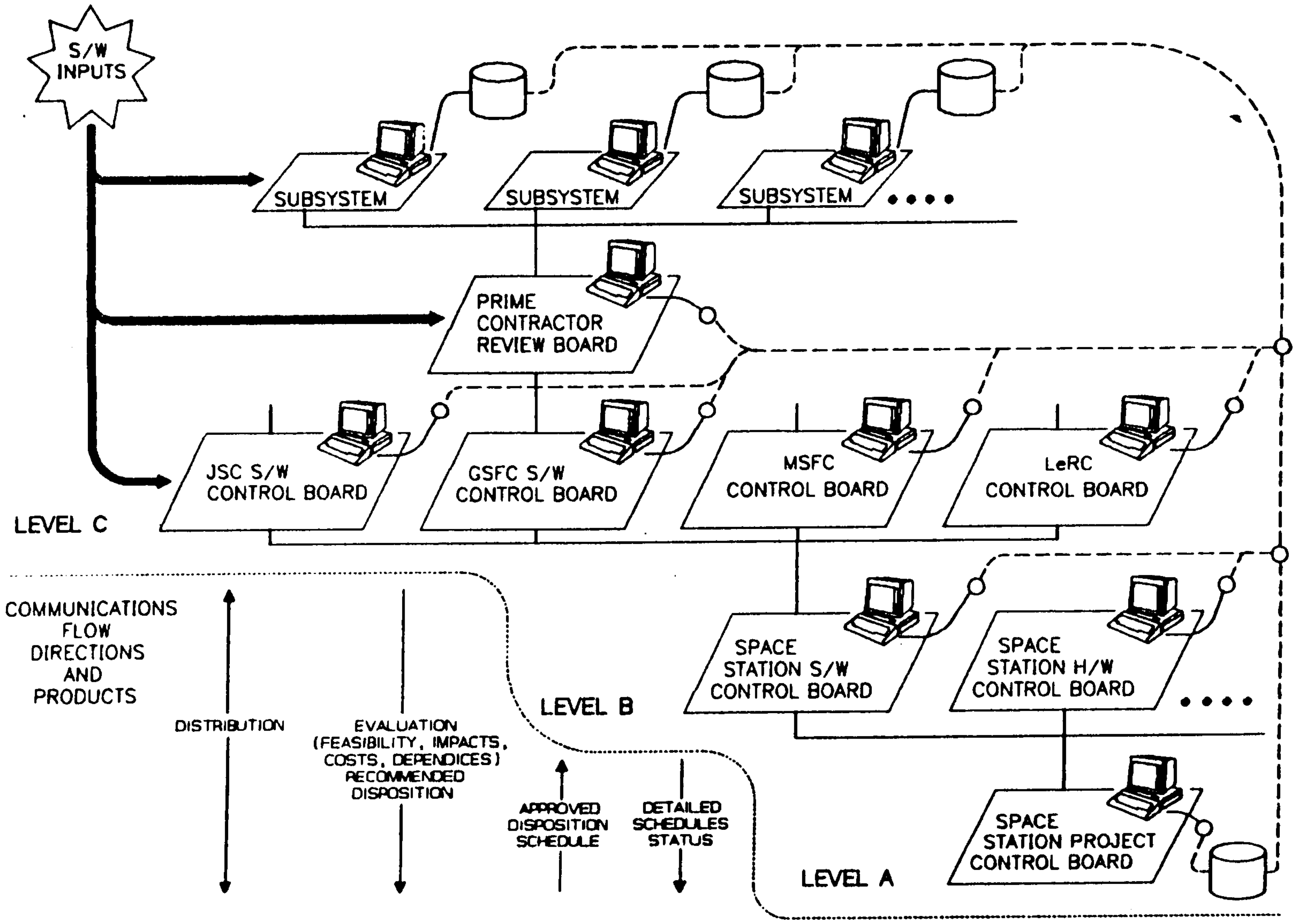


Figure 8.2-3. Review Board Structure

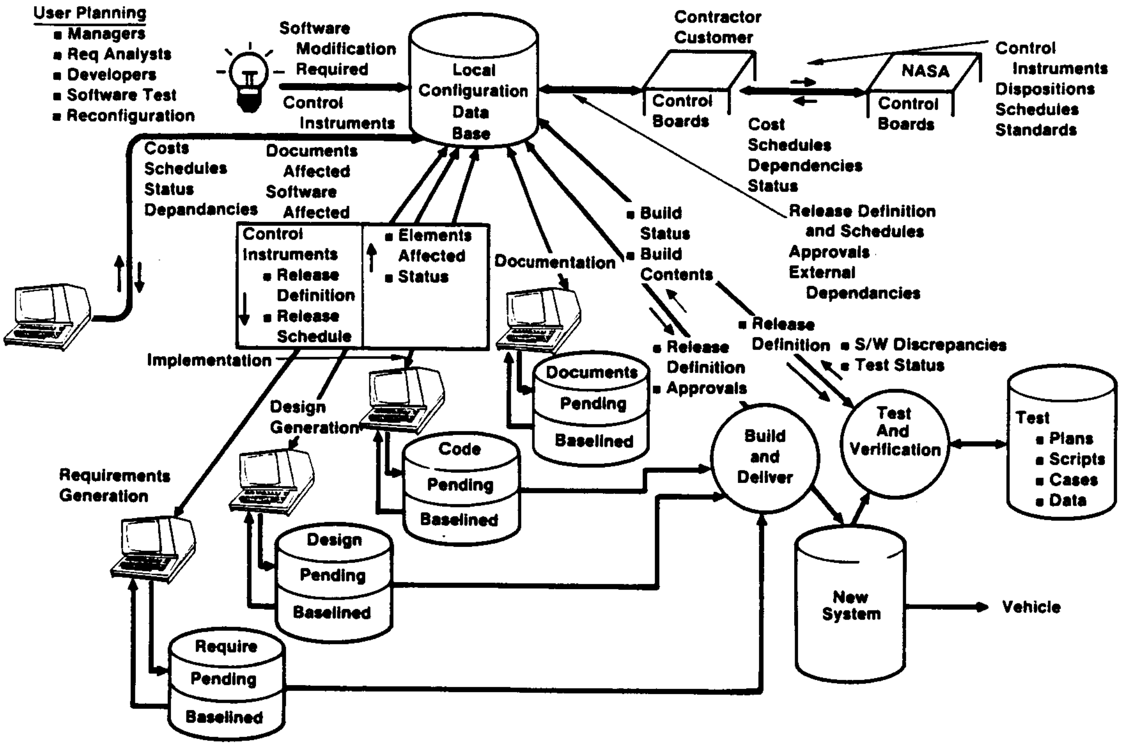


Figure 8.2-4. Space Station Configuration Control and Management Support

increments to which the instrument applies. Depending on the type of control instrument and on the needs of the subsystem to which the control instrument applies, other data can also be retained. This data might include more details about the control instrument's initiation (initiator name and address, reason for initiation, description), assessments (lines of code, core/CPU impacts, manpower), and affected elements (modules, documents, test cases). A particular kind of control instrument might have unique data. For example, an instrument documenting an error might have quality improvement data associated with it (how error found, where error created, how error can be avoided).

Whenever a control instrument is entered into the CM function, the appropriate control board is automatically notified and is sent the initial information regarding the instrument. As the control instrument is evaluated by the control boards and those affected, additional data is generated and is entered into the CM system.

8.2.2.2.3 ASSIGNMENT OF CAPABILITIES TO INCREMENTS

As a result of the control board review, each control instrument is assigned for implementation on one or more increments. The capability to make this assignment must be restricted to authorized users who represent the configuration control boards. The Build and Delivery system (discussed in "System Build and Integration") which creates each increment will incorporate only the control instruments assigned to that increment. This provides a single point of control for each entity to be baselined in a given system release. A single change can close several control instruments.

8.2.2.2.4 SCHEDULING AND TRACKING OF PROGRESS

The CM function must include the capability to schedule intermediate milestones of the implementation process. It must also provide the capability to extract, integrate, format and report scheduling data at all levels of the Space Station project, from individual module updates to major project enhancements which span multiple sites and user groups. Through this facility, managers are able to extract scheduling information with which to plan the control and use of departmental, project and system resources. Through the intermediate and final data entered for each change authorization, a detailed schedule can be produced tracking all steps in the progression toward the final implementation of the change or problem fix. Where conflicts occur (either with resources or personnel) the scheduling data should enable the manager to identify problem areas quickly and institute alternate plans.

8.2.2.2.5 DATA AVAILABILITY

The CM function must provide NASA and development managers with visibility into the capabilities being implmented, their schedules, status, etc. This will be provided via online data base queries and hardcopy report generation. Menus and commands will be provided by which the user may:

- invoke queries and reports predefined in the system;
- define and save (if desired), new queries or reports;
- invoke the new queries and reports.

8.2.2.2.6 ACCESS CONTROL

Since control instruments may have dependencies on other instruments not under the authority of the same user, the query and report facility must include several levels of access control to prevent unauthorized access to data belonging to one user by another. Further, the facility should include the ability to suppress the display and/or print of selected data fields in a record based on the level of access control granted to a user.

8.2.2.2.7 HISTORICAL REFERENCE.

The capabilities of each increment and all scheduling data must be kept to provide a permanent record of the activities of the project. This data must be available in formats similar to that mentioned in the section on scheduling and tracking.

8.2.2.2.8 INTERFACE WITH TMIS

The CM function must interface with the TMIS system. Many of the configuration control actions recorded in the TMIS will result in generation of control instruments within the SDE configuration management system. For these cases, a cross-reference capability must exist. The TMIS/SSE interface should also include items such as costing statistics, scheduling data, board approvals, user groups affected, and status. The disposition (approval, disapproval, schedule) of a control instrument in the TMIS must take precedence over local user disposition.

8.2.2.2.9 INTERFACE BETWEEN USER GROUPS

The CM function must be implemented in such a way as to encourage communication among user groups to facilitate overall project integration and scheduling while also providing appropriate levels of security. The capability for one user group to identify dependencies on other user groups must be included.

8.2.3.0 REQUIREMENTS GENERATION AND ANALYSIS

Requirements Generation/Analysis provides a foundation for software by identifying interface details, providing descriptions of functions, determining design constraints, and defining software validation requirements. On a project as large and complex as Space Station, each of the afore mentioned are crucial to maintain communication between the requirements initiator and the software developer. Figure 8.2-5 represents the scenario used to modify requirements.

8.2.3.1 SUBFUNCTIONS

8.2.3.1.1 MAINTAIN MULTIPLE LEVELS OF SOFTWARE REQUIREMENTS

The Requirements Generation Function must provide the capability to support multiple levels of software requirements such as conceptual, functional, and detail. The top level of Software(S/W) Requirements is refered to as Level A S/W Requirements or Conceptual S/W Requirements. Next are Level B S/W Requirements or Functional S/W Requirements and the lowest level of S/W requirements is Level C S/W Requirements or Detailed S/W Requirements. At each requirements level, there needs to be a tool to validate that all input/output table entries are defined.

8.2.3.1.2 PROVIDE SUPPORT FOR INTERFACE CONTROL DOCUMENTS

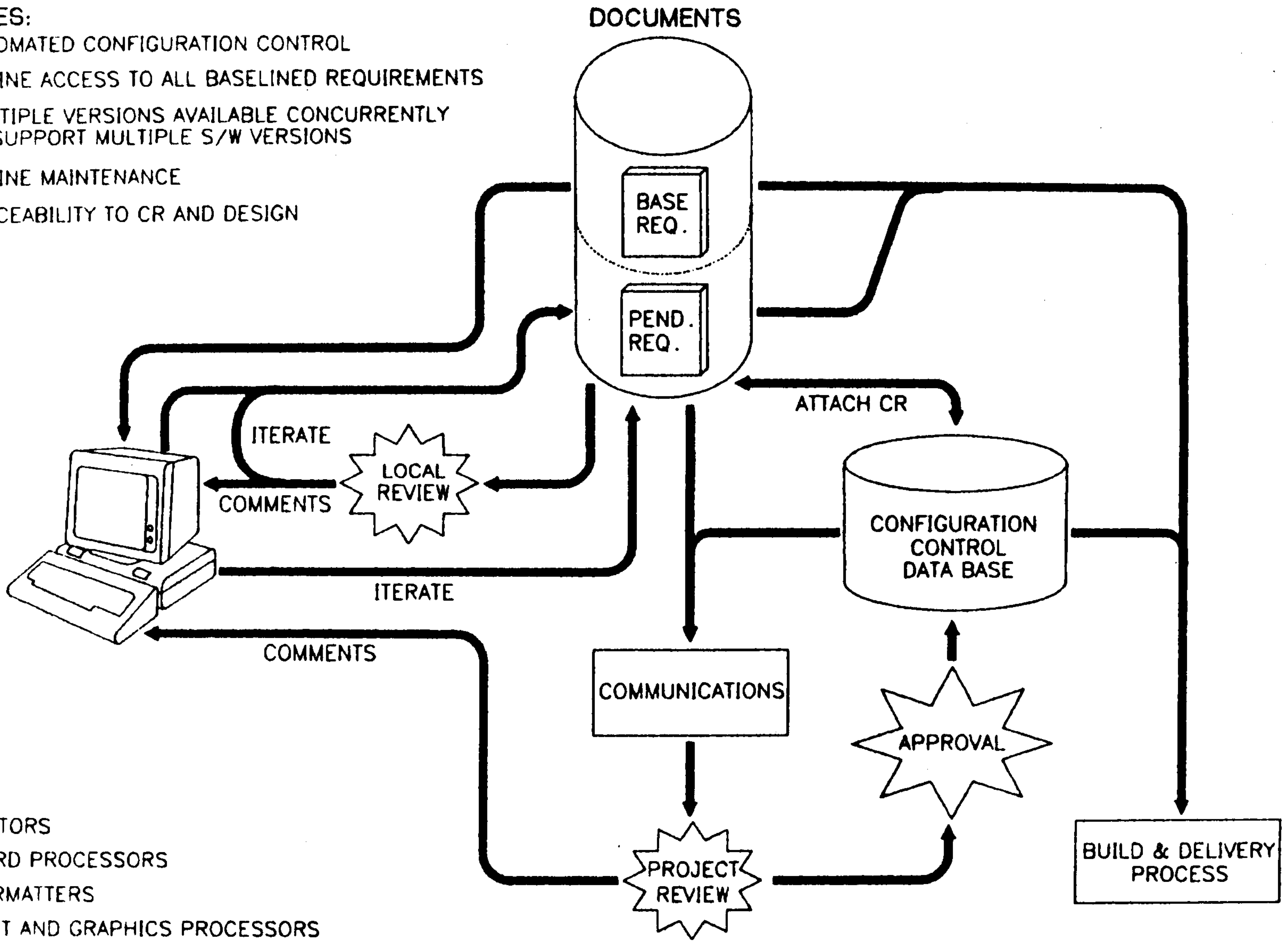
The Requirements Generation Function must also support Interface Control Documents(ICD) in the same manner as software requirements. ICD's should have input/output tables that a tool can verify the consistency across all ICS's.

8.2.3.1.3 PROVIDE TRACEABILITY OF REQUIREMENTS

Software requirements levels must be traceable from Request for Proposal through software design to insure consistency of requirements. At every level except the first level, each requirements section must list the reference requirements sections from the previous level. A tool will validate that the

FEATURES:

- AUTOMATED CONFIGURATION CONTROL
- ONLINE ACCESS TO ALL BASELINED REQUIREMENTS
- MULTIPLE VERSIONS AVAILABLE CONCURRENTLY TO SUPPORT MULTIPLE S/W VERSIONS
- ONLINE MAINTENANCE
- TRACEABILITY TO CR AND DESIGN



TOOLS:

- EDITORS
- WORD PROCESSORS
- FORMATTERS
- TEXT AND GRAPHICS PROCESSORS
- REQUIREMENTS ANALYSIS PROGRAMS

Figure 8.2-5. Requirements Generation Process referenced requirements sections exist. Later, another tool will validate that all sections from the previous level have been referenced at the current level and the tool will list any unreferenced sections from the previous level. Multiple versions of requirements must be supported to provide traceability between CM increments.

8.2.3.1.4 PROVIDE TRACEABILITY TO CM CONTROL INSTRUMENT

Each requirements section to be modified must reference a CM control instrument, thus providing traceability to all versions of software requirements that must be supported.

8.2.3.1.5 PROVIDE A STRUCTURED REQUIREMENTS LANGUAGE

Make available a structured requirements language for use if required. This language should be such that requirements can be described with a specification language that combines keyword indicators with a natural language narrative. The specification language is fed to a processor that produces a requirements specification and a set of diagnostic reports about the consistency and organization of the specification.

8.2.3.1.6 PROTOTYPING

In order to allow for early checkout of requirements concepts, tools such as display design and graphic analysis must be available which support rapid prototyping of executable software representing the requirements.

8.2.3.1.7 PROJECTED SYSTEMS PERFORMANCE

Tools must be provided to enable early system performance modeling. Input requirements to this type of tool are measures in terms of cycles per second, CPU demand on the system, and queue contention within the system. However, the original estimates for memory sizing and CPU demand are made by the analyst based upon knowledge of the system.

8.2.3.2 CHARACTERISTICS

In order for these functions to be useful to the project, they must be provided in a simple, consistent, straight-forward manner. All the data must be stored using a data base manegement system which facilitates on-line queries, report generation and quick response time. It must also support assignment of various levels of security (access, update, create and delete authority) over the data in the data base. Requirements maintenence must be configuration controlled (tracked to control instrument approval) and made as part of the integration process.

8.2.4.0 DESIGN AND CODE GENERATION

Design and code generation is the process by which programmers create new software and make changes to previously-created software. Because the process is a creative one, it tends to rely heavily on manual inputs made by skilled humans. In order to generate software for the Space Station in the most cost-effective manner, the SSE must provide tools to assist the human programmer in designing and coding in the most efficient and errorfree manner possible. See Figure 8.2-6 for a summary of the process.

8.2.4.1 SUBFUNCTIONS

8.2.4.1.1 DESIGN TOOLS

Tools must be provided to allow software designers to create a representation of the software at multiple design levels. Tools which allow generation and presentation of the design in a graphic format must also be supported. Provision must be made to use textual design languages (e.g., PDL/Ada) in cases where they are more appropriate than graphics. To ensure that all documentation is complete and consistent, automatic checks must be made between the design, the requirements specification, and other documentation (e.g., users guides).

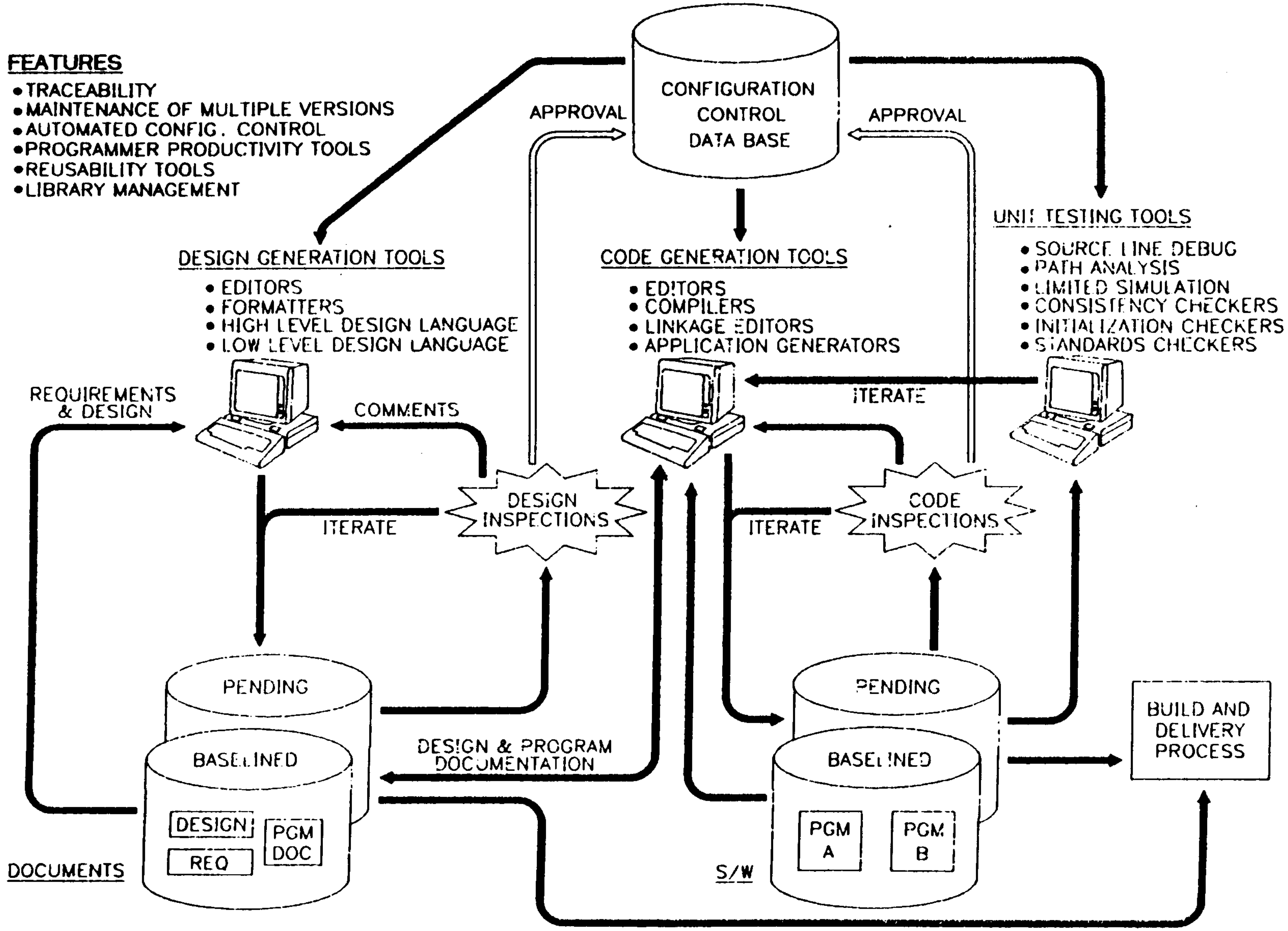


Figure 8.2-6. Design and Code Process

8.2.4.1.2 EDITORS

Language-reconfigurable "smart" editors must be available to support creation and modification of software. These editors must be capable of supporting insertion of software control structures, syntax analysis of entered code, and local semantic analysis of entered code, all tailored to the project's and user group's coding standards and to the language of the code being edited.

8.2.4.1.3 STATIC ANALYSIS

Since software errors are less costly to correct when they are found soon after they are inserted, the SSE must supply tools which provide static analysis of design and code as early as possible (ideally during or immediately following an edit session). This analysis will include standards checking (project and user-group defined), syntax checking, data flow analysis, complexity measures, and execution performance estimates.

8.2.4.1.4 INSPECTIONS

Since an important part of ensuring quality software is peer review, the SSE must provide tools which assist in the inspection process. These tools should aid in distributing the materials to be reviewed (mailing lists, automatic formatting of text), assist during the review (multiple windows, notepads), and provide a repository for the results of the review (history data, action items).

8.2.4.1.5 UNIT TESTING

Unit testing is a specialized part of testing which applies primarily to the code developer. The SSE must have the capability for symbolic execution of code and for executing the code with interactive queries and control at the source line level. See "Testing and Analysis" for an expanded discussion of testing.

8.2.4.1.6 REUSABILITY

There are two types of tools necessary to support software reusability. First, there must be tools which encourage software developers to use existing components. Second, there must be tools which allow developers of components which are reusable to make those components available for general use.

To encourage the use of existing components, the software developer must have easy access to a collection of reusable software components. To make this possible, three things are needed:

1. a collection of data describing the available components
2. tools which use that data to help find the components needed to solve a particular problem
3. tools to tailor a component to a user's requirements by asking questions about the intended use of the component and using the answers with a collection of knowledge about the component to interactively help the user create a configuration of the component which solves the user's problem.

Before the library of reusable components becomes useful, it will need to have a variety of components added to it. To encourage this growth, developers of potentially re–usable components must be encouraged to place these components into the library. To do this, tools must be available which prompt the user to enter data about the component and then store the data so that it can be used by the tools described above to find and tailor the component.

Reusable software components will be treated like any other module by the tools in the SSE (e.g., library management and source element configuration control will be provided by the normal build tools). The only thing different about reusable components will be the "reusability" knowledge associated with them.

8.2.4.1.7 STATUS

To assist in managing his time, the software developer must be able to track the status of the design and code on which he is working. Tools which provide this status from data maintained by the Configuration Management and Build and Delivery functions must be provided.

8.2.4.1.8 TRANSLATORS

The SSE must provide support for a variety of translators. This includes translators for the source elements of traditional programming languages (e.g., compilers) and translators for other types of source elements (e.g., documents formatters or data processors). The SSE must support translators for multiple programming languages and must allow multiple translators for a single programming language (e.g., for different target environments). The programmer's interface to each of the translators must be similar.

8.2.4.2 CHARACTERISTICS

For the design and code generation tools in the SSE to be most effective, the user of these tools must be able to spend the maximum amount of his time using the tools to generate software rather than discovering how the tools work. To accomplish this goal the following must be true:

- each of the tools must have an interface which is as similar as possible to the other tools' interfaces.

- the user must be able to produce only one form of input to the tools (e.g., the program source). The tools must be able either to use that input or to use the output from another tool as input. No manual reformatting of data for the various tools can be allowed.

- the inexperienced user must be able to see a view of the tools which provides step-by-step guidance (e.g., menus).

- the experienced user must be allowed to directly invoke tools (e.g., commands).

- All of the products produced by the programmer must be accessible on line in the SSE. This includes design, code, and documentation.

8.2.5.0 SYSTEM BUILD AND INTEGRATION

The System Build and Integration function of the SSE provides the tools necessary for orderly and controlled collection and integration of software systems (and their associated documentation and data) by their developers and testers and for controlled delivery of those systems to their users.

8.2.5.1 SUBFUNCTIONS

8.2.5.1.1 HIERARCHY MANAGEMENT

The Hierarchy Management function allows system coordinators to define and control the organization and flow of program development and integration through promotion hierarchies. See the section called "Promotion Hierarchies" for a more detailed description of promotion hierarchies.

8.2.5.1.2 PROMOTION

The Promotion function provides a controlled mechanism for moving modules and subsystems from one level of integration to the next. The promotion function locks out any further changes and makes the promoted object ready for baselining into the next higher subsystem in the promotion hierarchy. Promotion is allowed only if the proper authorization exists in the Configuration Management database.

8.2.5.1.3 BASELINE

The baseline function takes objects (modules and subsystems) which have been promoted into a subsystem and makes them a permanent part of the subsystem. The baseline function is the mechanism by which increments are created (as discussed in "Configuration Control and Management Support"). All actions taken by the baseline process are recorded in the subsystem's history file or in the Configuration Management database.

8.2.5.1.4 SUBSYSTEM INTEGRATION

Subsystem Integration performs the necessary transformations on a baseline subsystem to put it in the format necessary for the subsystem's integration level. For example, the baseline function may only operate on the source element of modules in the subsystem (as decided by the subsystem coordinator). The subsystem integration function in this case might be responsible for performing the translations (e.g., compilations) necessary to make the subsystem executable.

8.2.5.2 DEFINITION OF TERMS

The following are definitions of terms used in the Build and Integration section. In many cases these definitions represent extensions to the common definitions of the terms.

MODULE	Any entity which is configuration-controlled as a logical set. For example, a module may be a program, a data table, a test case or a group of database records. A module may consist of several elements (see the definition of element).
ELEMENT	One of the pieces associated with a module. Some examples of elements of a program module are the source, the object, and the compilation listing.
LIBRARY	A collection of modules which are related to each other. A library may consist of several physical files. Typically, libraries will be organized by subsystem and by module type (for example, different applications might store their modules in separate libraries and a single application might store its source and table modules in separate libraries.
SOURCE	The initially-generated element of a module. This is probably manually generated, but does not have to be. The common example is program source. Other examples include unformatted documentation, test case inputs, and unprocessed data records.

SUBSYSTEM	A collection of modules (and associated descriptive and historical data) which have a common purpose or use. For example, the modules associated with a particular payload might make up a subsystem. Depending on the level of integration, a subsystem might contain other subsystems as subsets. As an example, a subsystem containing documentation modules might be made up of subsystems each of which contains the modules for one of the volumes of the complete document.

8.2.5.3 CHARACTERISTICS

8.2.5.3.1 CONFIGURATION CONTROL OF ELEMENTS

The build function supports configuration control of all changes to the systems being built. Changes are tracked at all levels; from the system/subsystem level down to the source line level. No change may be promoted to or baselined into a subsystem without proper authorization in the Configuration Management database. Once an authorized change is begun (through a controlled retrieval process), no other user can make authorized changes to the same module. Temporary trial changes are allowed at any point (e.g., for proving a concept), but are not accepted by the build functions. Information retained about each change includes the reason for the change (e.g., control number) and the subsystem and version on which the change was made.

8.2.5.3.2 PROMOTION HIERARCHIES

Promotion hierarchies represent a planned path from development through integration to a delivered system. A separate hierarchy exists for each release (delivery) of a system. A system is divided into subsystems which are developed independently of each other. As each subsystem is completed (possibly after several cycles of updates to the subsystem) it is promoted to the next level where it is integrated with other subsystems.

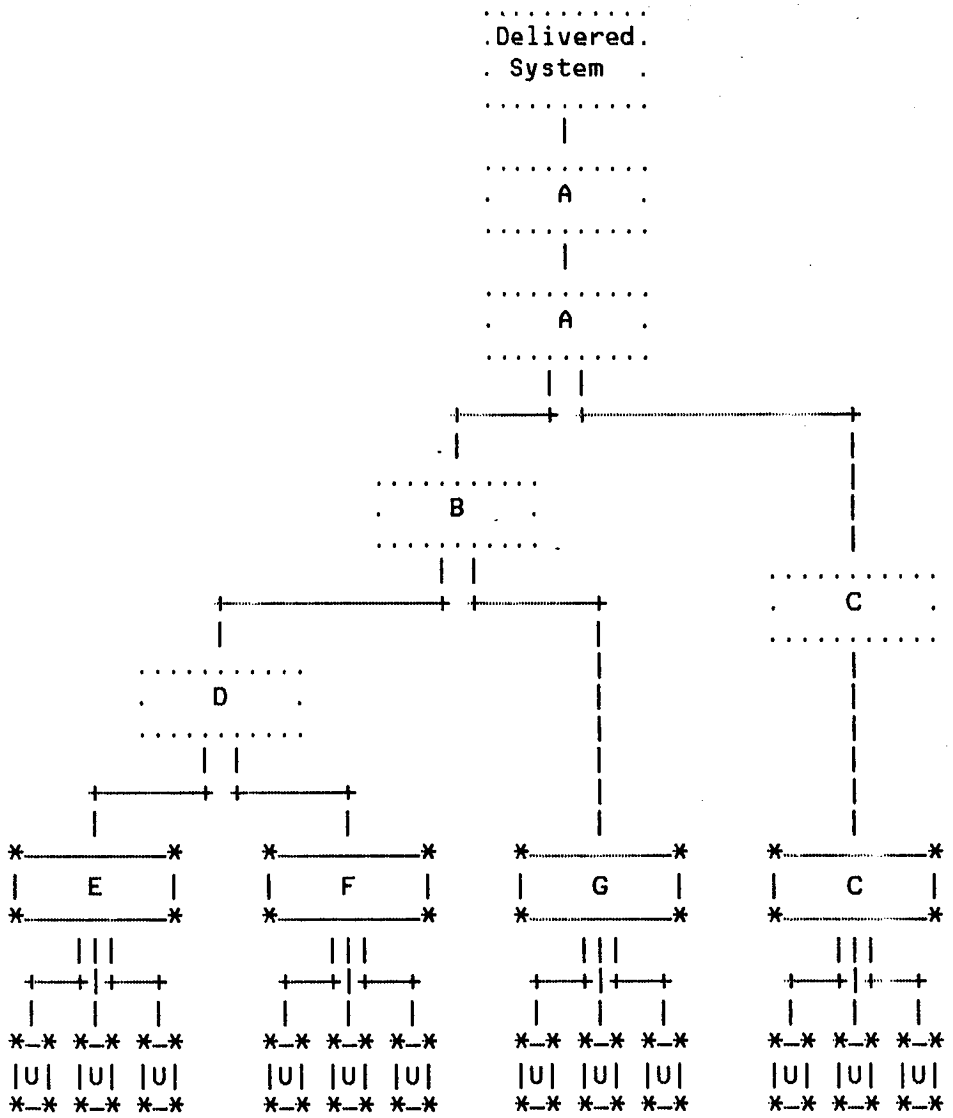


Figure 8.2-7. **Initial Promotion Hierarchy: This is an example of a promotion hierarchy immediately after initial definition. Only the user libraries ("U") and the lowest level subsystems are defined (solid boxes). All other subsystem nodes in the hierarchy are planned (dotted boxes), but do not actually exist.**

Changes to a system are done only to the lowest levels of a hierarchy. When planned change activity and testing for a subsystem is completed, the subsystem is promoted and then removed from the hierarchy. Users who need to make maintenance changes to the subsystem's modules are connected to the higher level subsystem which now contains their module.

Figure 8.2-7 represents a newly-defined hierarchy for system "A". Note that the number of subsystems between the users (programmers) and the delivered system can vary depending on the needs of each subsystem. Also note that multiple levels of integration for a single subsystem can be accommodated (shown by two levels for subsystem "C" and for system "A"). Figure 8.2-8 shows how the system "A" hierarchy looks after some initial baselines have been established for two of the subsystems and Figure 8.2-9 shows how the hierarchy looks when most of the subsystems have been promoted into system "A".

8.2.5.3.3 PROMOTION

Promotion is the way in which a module or subsystem is made available for the next level of integration. A module or subsystem is promoted when the current owner is satisfied that all required testing, inspection, integration, etc. is completed. Promotion can take place only if the appropriate authorization exists in the Configuration Management database. Once promotion takes place, the promoted entity is locked and no more changes can be made to it without the approval of the coordinator for the target subsystem.

Module promotion moves a module from a user library to the collection pool for a subsystem. Module promotion can only be initiated by the responsible programmer defined in the promotion hierarchy for that subsystem. At a minimum, the module source is promoted, but (depending on the rules determined by the subsystem's management) all elements of the module may be promoted.

Subsystem promotion sets up pointers in the collection pool for the subsystem at the next level of the promotion. The rules determined by the next higher level subsystem's coordinator determine whether the promoted subsystem is copied or simply pointed to and whether all elements or only source elements take part in the promotion.

8.2.5.3.4 DELIVERY

When all changes, integration, and testing for a system are completed, the system can be "delivered". This will be the final promotion in a given hierarchy. The system will then either be ready for installation in the final target environment, or it will become a subsystem in a higher-level promotion hierarchy.

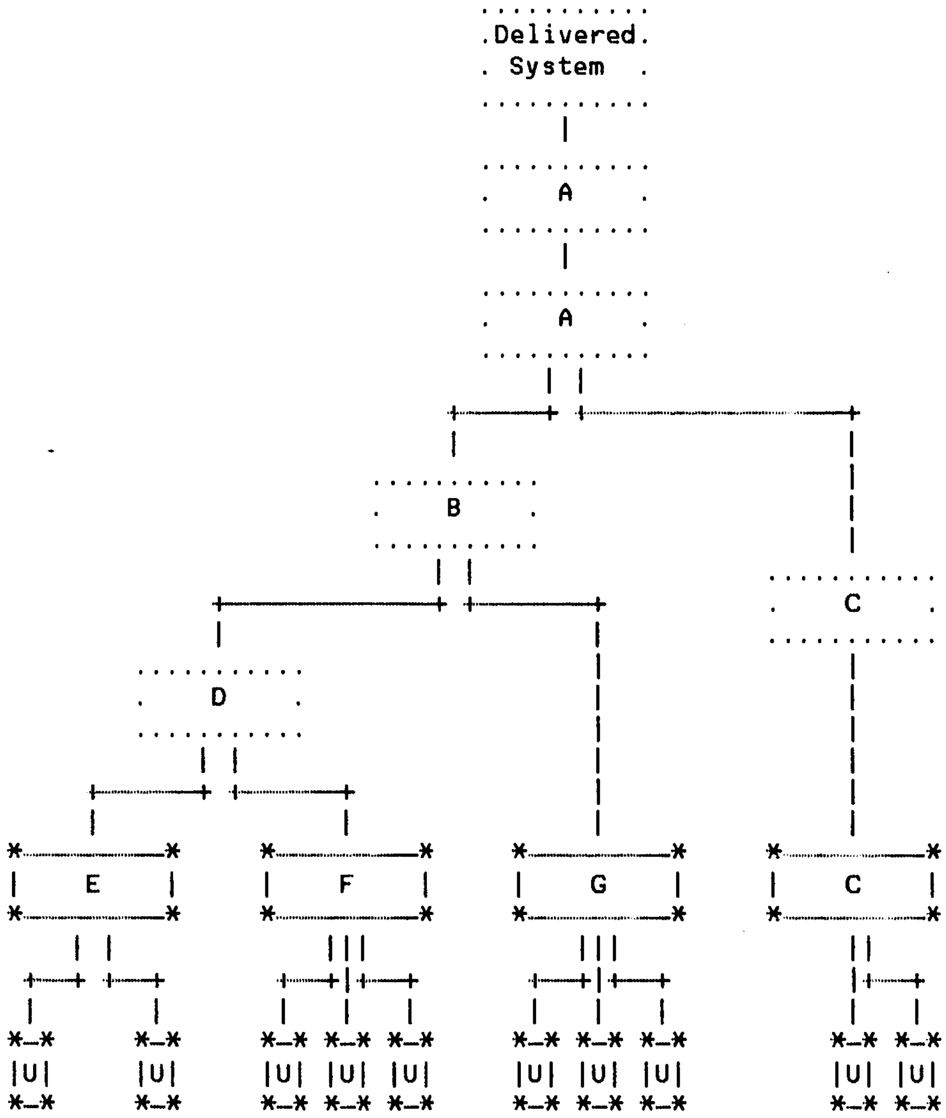


Figure 8.2-8. **Promotion Hierarchy After Initial Builds: This is how the promotion hierarchy for System "A" looks after builds have occurred for the E and C subsystems. Note that users with no more inputs to a subsystem have been removed from the hierarchy.**

8.2.5.3.5 BASELINE

Until the baseline function is performed all modules and subsystems promoted into a subsystem's collection pool are in a pending state. The baseline function takes them out of the collection pool and makes them a permanent part of the subsystem. This involves updates to the subsystem's descriptor and

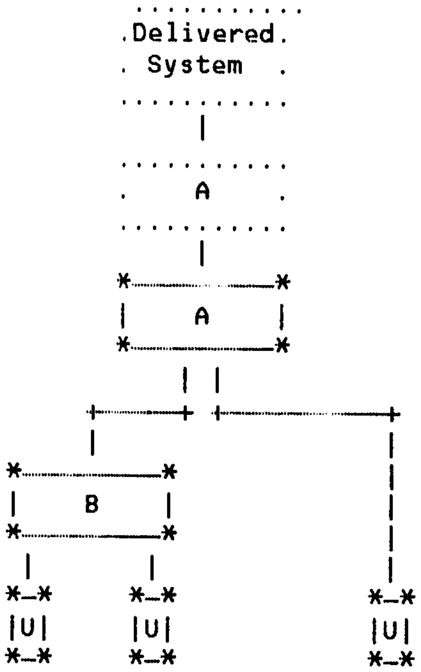


Figure 8.2-9. Promotion Hierarchy During System Integration: This is how the promotion hierarchy looks during system integration. The subsystem nodes have been deleted. Only users who need to make updates to the integrated system are in the hierarchy.

history files and possibly also updates to the subsystem's libraries. The baseline process does not necessarily make copies of the baselined items In many cases (especially when baselining a promoted subsystem), updating the descriptor files is all that is necessary. The baseline process may also copy only certain elements of a module (e.g., source, but not object). Whether to copy and what to copy are options selectable by the subsystem's coordinator. Even though the promotion function checks for proper configuration management authorization, the baseline function checks again and then provides the appropriate feedback to the Configuration Management function.

8.2.5.3.6 SUBSYSTEM INTEGRATION

After the baseline function has been performed on a subsystem it may not be immediately useable. For example, if only source is baselined, modules must be recompiled before subsystem testing can take place. The Subsystem Integration function takes care of any translations or re-formatting which must be done to the contents of the subsystem's libraries to make the subsystem ready for its users.

Subsystem Integration will check dependencies and (based on local options) either flag or automatically re-translate modules which are dependent on modules which have been changed since the last integration. Depending on the content of the External Dependencies portion of the subsystem's Descriptor File and on options set by the subsystem coordinator, Subsystem Integration can use modules from other subsystems to resolve references and produce a useable subsystem.

8.2.5.3.7 TEMPORARY INTEGRATION

Temporary Integration can be done by any user wishing to create a temporary copy of a subsystem for early testing or consistency-checking. Temporary Integration differs from subsystem integration in that it operates outside of configuration control:

1. it does not require any Configuration Management authorization,
2. it does not require a baselined subsystem,
3. it does not update any descriptor or history files,
4. it does not make copies of any of the input libraries.

The user can select any subsystems or user libraries to use as input, select or reject the subsystems' collection pools as input sources, and choose what kind of dependency-checking and re-translations to perform. Depending on the options selected, temporary integration can be used for a wide range of tasks. For example, temporary integration can be used to create a prototype version of a subsystem constructed from existing subsystems and user libraries. It can also be used to verify that the contents of a collection pool will be consistent during system integration before the permanent integration process is executed.

8.2.5.3.8 SUBSYSTEM CONTENTS

Each subsystem in a promotion hierarchy consists of four major elements: a descriptor file, a history file, a set of libraries, and a collection pool (see Figure 8.2-10). The following paragraphs further explain the contents of each of these elements.

8.2.5.3.8.1 DESCRIPTOR FILE

The Descriptor File contains two kinds of data. The module descriptor data provides information necessary to retrieve, translate, and integrate the

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```
                Descriptor File                      History File
                *-------------*                      *-------------*
                |             |                      |             |
                | External    |                      | Subsystem   |
                | Dependencies|                      | History     |
                |             |                      |             |
                |-------------|                      |-------------|
                |             |                      |             |
                | Module      |                      | Module      |
                | Descriptors |                      | History     |
                |             |                      |             |
                *-------------*                      *-------------*

          Libraries
          . . . . . . . . . . . . . . . . . . . . . . . . . . .
          .                                                   .      Collection Pool
          .   *--------*   *--------*                         .      *-------------*
          .   |        |   |        |                         .      |             |
          .   | Source |   | Object |                         .      | Promoted    |
          .   |        |   |        |                         .      | Modules     |
          .   *--------*   *--------*                         .      |             |
          .                                                   .      |-------------|
          .   *--------*   *--------*                         .      |             |
          .   |Docu-   |   .        .                         .      | Promoted    |
          .   | ment-  |   . others .                         .      | Subsystems  |
          .   |  ation |   .        .                         .      |             |
          .   *--------*   *--------*                         .      *-------------*
          .                                                   .
          . . . . . . . . . . . . . . . . . . . . . . . . . . .
```

Figure 8.2-10. Contents of a Subsystem

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modules in the subsystem. For each module, this data includes a list of the elements (source, object, design, data) which make up the module, pointers to the libraries in which the elements reside, control data for the translators (compilers, formatters) which operate on the module's elements, and a cross-reference of dependencies between the module and other modules (for use in integration processing).

The external dependency data in the Descriptor File describes how to find external modules (system macros, common subroutines) which are needed by modules in the subsystem. This data includes a list of external modules needed and pointers to the external libraries which contain those modules.

8.2.5.3.8.2 LIBRARIES

The libraries in a subsystem are the files which contain the various elements which make up the subsystem's modules. A library is not any particular type of file. It may be a single physical file, a logically-related collection of physical files, or a logically-related subset of a physical file.

8.2.5.3.8.3 HISTORY FILE

The History File contains a complete record of all changes to a subsystem from some pre-determined base version to the present. This includes change instrument numbers, source lines changed in a module, modules re-translated during integration, and subsystems integrated into the subject subsystem.

8.2.5.3.8.4 COLLECTION POOL

The Collection Pool contains updates to the subsystem which have been promoted, but which have not yet been baselined. These updates include at least the source element of an updated module, but may also include any (or all) of the other elements. Updates to module descriptor data are also promoted to the collection pool to await baselining.

8.2.5.3.9 REUSABLE COMPONENTS

The developers and maintainers of reusable software components will use the same build and integration tools as other users of the SSE. Special functions are provided to notify users of a reusable component of changes to the component in the master component libraries. Tools for the retrieval and tailoring of components are discussed in "Design and Code Generation".

8.2.6.0 TESTING AND ANALYSIS

Testing is the examination of program execution behavior. Testing of the Space Station software will be very important because of its life/mission critical nature. Facilities must be provided in the SDE for testing because of the inability to observe the software in actual use in a safe environment (i.e. on the ground). These test facilities should include a variety of tools that will support cost effective testing of the SSDMS, application software, and payload software.

There are five steps of a test process (see Figure 8.2-11). They are

1. Test Planning
2. Test Design and Development
3. Test Execution and Simulation
4. Data Reduction and Analysis
5. Test Report Generation

The tools and capabilities described in this section represent the full spectrum of test facilities for the project. Subsets may be defined and used to support various levels such as unit testing, performance testing, and independent verification and validation.

8.2.6.1 PLANNING

This involves gathering all data concerning the software to be tested, analyzing it, and deciding what tests need to be performed. The list of tests to be performed and rationale for the tests are put into a test plan. The

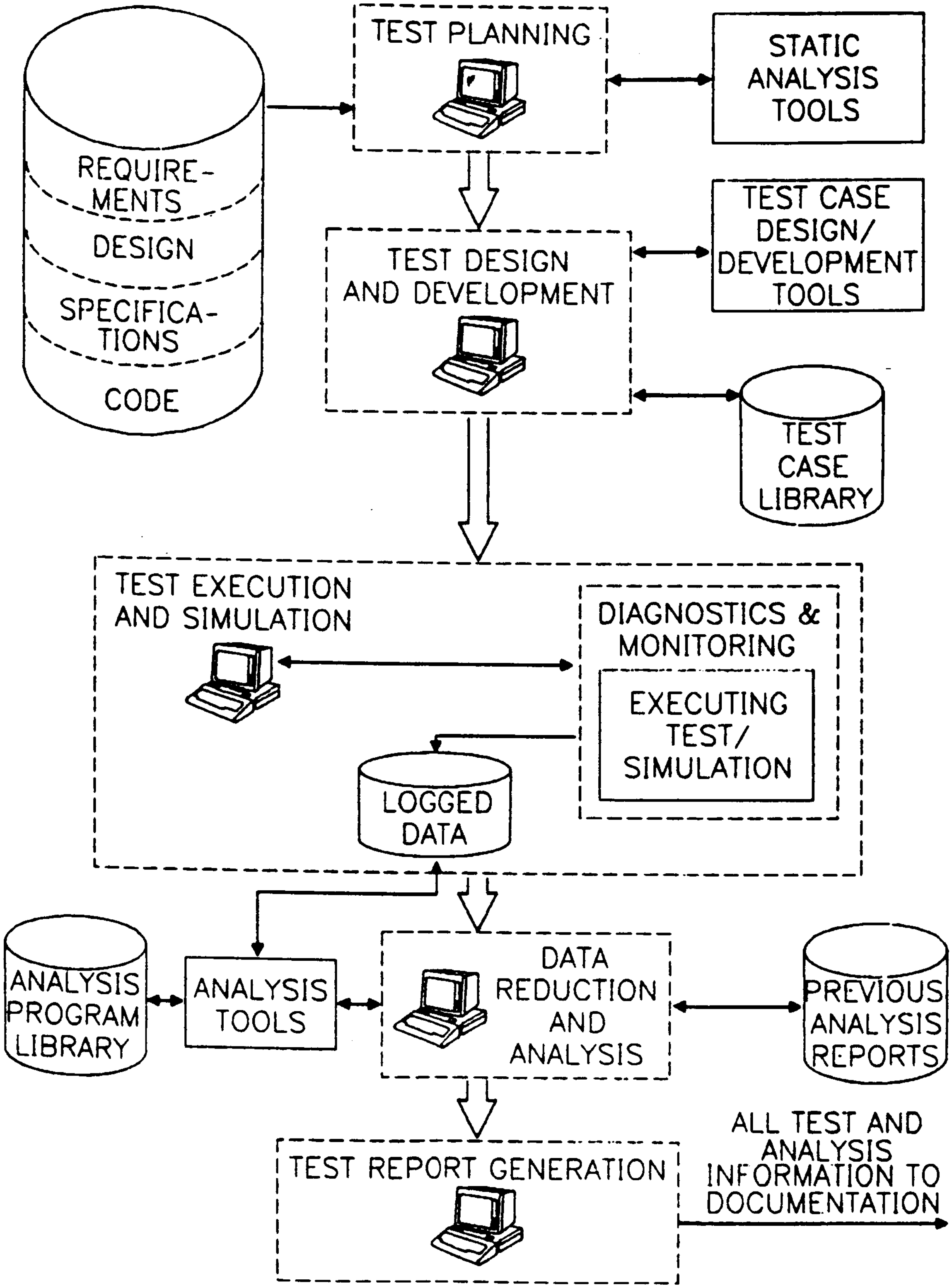

Figure 8.2-11. Steps in the Typical Testing Process

rationale is an explanation for why the specified tests were chosen. Possible explanations are 'to test a specific requirement' or to 'test a high complexity (high risk) section of the code'. The following is a list of possible static analysis tools that could be used to facilitate the planning of tests.

1. Logic Flow Graph Generators

A tool of this type would create a summary of the control flow of the program to be tested. One use of this information is to plan test coverage.

2. Data Flow Graph Generators

A tool of this type would create a summary of the flow of data in the program to be tested. One use of this information is to test for errors in the set/use of variables.

3. Complexity Measuring Tools

A tool of this type would create measures of the complexity of the program to be tested. This information is useful in identifying high risk areas of the code. These areas would require a higher test coverage.

4. Interface analyzers

A tool of this type would create a summary of interface information of the set of modules being tested. This information would be useful for subsystem integration.

8.2.6.2 DESIGN AND DEVELOPMENT

This involves creating test procedures and a test script that will accomplish all the tests and testing goals identified in the test plan. Test procedures will outline the strategy for accomplishing the tests and the test script will contain all necessary details. The test script will be directly executed (i.e. equivalent to code) while the test procedure is the design (i.e. equivalent to program design).

Many of the facilities necessary to support test case design and development are the same tools necessary to support program design and development (see "Design and Code Generation"). These are

1. High level languages to facilitate the design and development of test cases. This language(s) will support design of the test procedures and the development of the test script.

2. Syntax Directed Editor

This type of editor would directly support the development of test cases in the high level test language by providing skeletons of all structures in the language.

3. Test Script Static Analysis Aids

Tools of this type will analyze the test script for potential development errors. Some examples of potential errors are

a. Incorrect use of the simulator capabilities
b. Incorrect use of the Space Station system capabilities
c. Incorrect references to program variables and locations
d. Incorrect test facility or simulator configuration

Detecting these errors in test cases before the tests are executed will help eliminate may wasted test executions (which may be expensive) and will help eliminate analysis of errors that were due to an incorrect test script.

4. Test Libraries and Reusability

To promote Reusability in test cases there should be tools to encourage and facilitate the use of test case components. The tools will of the same ones used for software development (see "Design and Code Generation"). These tools should support the maintenance and use of libraries of test case components.

5. Stub/Driver Generator

A tool of this type would generate skeleton stubs and drivers necessary for execution of the program being tested. This would need to be done, for example, when the module calls another procedure that has not yet been coded.

6. Test Data Generators

A tool of this type would generate test data to be used to test the program. The test data will be generated to accomplish a specific test goal such as forcing execution down a specific path or testing boundary conditions.

8.2.6.3 EXECUTION AND SIMULATION

This involves applying the test scripts to the software being tested and creating a set of test results. To support the actual execution of the test cases a dynamic test facility must provide the following

1. Diagnostic capabilities

The required capabilities vary from unit test to system testing. Unit testing will require more detailed diagnostics such as traces, stop on address compare, variable altering, variable snapping, etc. These diagnostic capabilities allow the programmer to effectively test and debug his software module. Since it is much cheaper to catch errors in the unit testing process than it to catch the same errors later in the testing process, it is important to provide these detailed diagnostics to encourage and facilitate early error detection. System testing will not require diagnostic capabilities as detailed as unit testing will.

2. Performance monitors

These are necessary to monitor performance characteristics of the system such as CPU utilization, timing/synchronization, and bus traffic throughput.

3. Simulation

To model unavailable parts of the system and environmental effects, a set of simulation models must be provided. The amount and fidelity required will vary from unit testing to system testing with system testing having the most stringent requirements. High fidelity simulation resources will be limited and a simulator scheduling facility will be provided to optimize use of these resources.

4. Data Logging

Sampling of many different items will occur during test case executions. Often, much of this data will need to be analyzed after the tests. Adequate facilities must be provided for short and long term storage of this data.

8.2.6.4 DATA REDUCTION AND ANALYSIS

This involves formatting and summarizing the test results obtained from the Test Execution and analyzing the results to determine success/failure of the software to pass the tests applied. The data logged during the test execution should be reduced, summarized and formatted into two different possible formats. The first format will be a report suitable for human viewing and analysis. This would include a variety of graphical and text formats. The second format would be one that is suitable for input to a program to perform some automated analysis.

8.2.6.5 REPORT GENERATION

This involves assembling all work products generated during previous steps of the test process into a report. The format and the content of the test reports will vary across different test groups. They may contain any of the possible work products generated during testing. These include the test plan, test design, test procedures, test execution configuration, analysis results, and problems and/or anomalies found. These work products will be automatically formatted into a preliminary version of the test report. Then the report can be completed manually.

8.2.7.0 DOCUMENTATION

The documentation function will provide online documentation facilities to create a minimum paper environment with hard copying capability. This function will be used for viewing as well as creating the online documents. There will be a capability to assign access levels for security of nonpublic documents. Examples of document types are: requirements, user's guides, instruction manuals, test specifications, program test reports, software build reports, status reports, and working papers.

Working papers are lost, historically, in most long-lived projects as the designers move on to newer tasks. The documentation capabilities will support the archiving of background information, such as design rationale and justification, etc.

8.2.7.1 SUBFUNCTIONS

8.2.7.1.1 PROVIDE ONLINE DOCUMENTATION FACILITIES

Online documentation facilities must be provided to all SSE users. This includes the ability to create and maintain document source online and the ability to access formatted documents online. Multiple versions of documents will be maintained to reflect the multiple versions of software being used and developed at a time. The users will be able to obtain hard copies of selected documents.

8.2.7.1.2 PROVIDE MEANS TO "REDLINE" DOCUMENTS ONLINE

With electronic transmissions of review documents, a means will be provided to facilitate "redlining" a document to indicate desired changes.

8.2.7.1.3 PROVIDE CROSS REFERENCE CAPABILITY WITH ONLINE RETRIEVAL

A means for users to cross reference topics between the books and volumes, such as a trace from requirements to a users guide must be provided. It will enable users to relate the software development phases to categories of documents to ease the documenting and retrieval tasks. An information retrieval system would provide an efficient means to locate information by subject or keywords.

8.2.7.1.4 PROVIDE INTEGRATED TEXT/GRAPHICS SUPPORT

This function will provide integrated document text and graphics support with a means for identifying revision levels.

8.2.7.1.5 CONFIGURATION MANAGEMENT

An interface the the configuration control and management support system (see "Configuration Control and Management Support") system must be provided to support configuration of documents.

8.2.7.2 CHARACTERISTICS

The documentation function will encourage thorough documentation by being easy to learn and use.

Some uses for the tools, e.g., maintaining working papers, do not require configuration control and users should be able to perform these tasks exclusive of the control functions.

8.2.8.0 COMMUNICATION

The communication function will provide the means to make the SSE appear as a single facility to each user, regardless of site location. It will enable a user to send and receive data, e.g., documents, messages, or software to other users or functions of the SSE. This function will field requests from other functions to transfer data between functions and to users.

8.2.8.1 SUBFUNCTIONS

8.2.8.1.1 MESSAGES BETWEEN USERS

1. Facilitate inter and intra user group communication

User groups will be conducting reviews of all types (e.g., requirements review, design/code review, test specification/procedure review). The reviews require communications between the groups for the scheduling of reviews, and resolution of review comments.

2. Provide means for users to schedule resources

Users will be able to communicate between sites to coordinate resources for things such as integrated testing.

8.2.8.1.2 DATA TRANSFER BETWEEN USERS OR SSE FUNCTIONS

1. Support transfer of software between SSE and contractors

This function of the SSE will provide a method for both simulator models and application software to be transmitted between the SSE and the contractor sites for review (source) or execution (modules).

2. Interface with TMIS

Many of the SSE functions will send or receive data (e.g., plans, schedules, documents, status) to the TMIS for Space Station program management. This function will provide the interface with the TMIS system.

3. Provide interface to all SSE functions

All other SSE functions use this function to communicate status, schedules, product dependencies, configuration control instrument status, and to transmit program software products with other functions.

4. Provide means for document transfer

Users will be able to transfer documents between sites.

5. Provide interface to reusable software library

To promote software commonality, it is envisioned that a reusable software library will be a part of the SSE. Users will be able to send and retrieve elements to and from this library.

8.2.8.2 CHARACTERISTICS

For the other SSE functions to be used effectively, communications between these functions and the users is essential. Therefore, the communications function must operate in a straight-forward and easy-to-use manner to encourage such use.

8.2.9.0 RECONFIGURATION

The software on the Space Station will be required to interface with a vast number of hardware components (e.g. IMUs, rate gyros, etc.). During the life time of the station, it will be necessary to integrate, test, operate, and replace hardware components. Each component has specific characteristics which must be provided for within the software. Reconfiguration data is that set of data values required to tailor the application software and UIL interface environments to be compatible with a specific hardware configuration. The process of managing the reconfiguration data and incorporating updates into the target system (e.g. onboard DMS, integration test sets) is called reconfiguration. The SSE must support this activity.

8.2.9.1 SUBFUNCTIONS

8.2.9.1.1 DATA COLLECTION AND MAINTENANCE

Data pertaining to each hardware unit which will interface with the application software must be available in the SSE. Data representative of actual flight hardware components (e.g. IMUs, Rate Gyros) will come from the TMIS. Other data, for example test unique data, will originate in the SSE. This data will be maintained in a data base and interfaces must be provided for the user to update and review the data.

8.2.9.1.2 DATA SELECTION

The data base will contain data for many hardware components, not all of which will coexist in a single configuration. By identifying a subset which could coexist, a specific configuration is defined. The ability to define configurations and subsets of configurations will be provided through the use of interactive menues and commands. The ability to to define and store configurations will also be provided.

8.2.9.1.3 DELIVERY

Data from the data base will be extracted and delivered to target environments. (See "Hardware Interface".) Thre target operating system will then use the data base to provide the hardware interface services for both the application and the user interface environments.

8.2.9.2 CHARACTERISTICS

An interface with the configuration control system will be provided to support configuration control of data representing onboard hardware and some of the testing configurations. The ability will also exist for users to define data and configurations for testing without requiring configuration control. After IOC, a representation of the actual onboard configuration, as well as test and development configurations, will always be maintained within the system.

8.2.10.0 ON-BOARD DATA MANAGEMENT SYSTEM (DMS)

The On-board Data Management System will consist of the software and hardware to support crew control of the Space Station (SS) structure and other SS subsystems. These systems include a set of "core elements" such as housekeeping data (e.g., time), a data storage system, a Crew Interface system, a network for support of a distributed processing system, and an operating system which supports many core and payload systems. The software and hardware of the DMS will be configured into a network of **Subsystem** Data Processors (SDP's), Network Interface Units (NIU's), and data buses connecting sensors/effectors into a network(s). The SSE will provide the environment for development of the DMS. Once developed, the DMS will be made available in the SSE for application software/hardware development and verification.

8.2.10.1 SUBFUNCTIONS

8.2.10.1.1 SOFTWARE SYSTEMS

8.2.10.1.1.1 NETWORK OPERATING SYSTEM (NOS)

The Network Operating System will support process/data distribution and data base interfaces as a service to the application development. Within the SSE, the NOS will provide applications with the capability to configure software into a network compatible to the on-board system for development and test.

8.2.10.1.1.2 DISPLAY GENERATION/SUPPORT

The principal interface of the SS crew will be the display unit (MultiPurpose Application Console (or MPAC)). The DMS display generation/support software will be provided in the SSE to support the generation and test of displays. The display generation function will provide the options for diagnostics sufficient to guide the development and verification of display(s).

8.2.10.1.1.3 REAL TIME OPERATING SYSTEM (RTOS)

The Real Time Operating System in conjunction with the NOS provides for a complete application support environment.

8.2.10.1.1.4 DATA BASE MANAGEMENT SYSTEM (DBMS)

The Data Base Management System will provide the data storage and retrieval necessary (in conjunction with the NOS) to support application archiveing of data for trend analysis or for transmission via the Tracking Data Relay Satelite (TDRS) or other Radio Freqrency (RF) means to the ground.

8.2.10.1.1.5 HARDWARE INTERFACE

The DMS must provide the application software and user interface environments with an interface to the hardware sensors and effectors with which they will be communicating. This service is necessary to isolate the application and user interface environments from changes in hardware configurations. This will be accomplished by maintaining a data base in the target environments which contains a representation of the current configuration and data unique to each hardware component present. The data in the data base will be used by the DMS to provide addressing, scaling and formating of hardware data. Data base maintenance will be dictated by changes in the configuration. The DMS will provide an interface for users to indicate modifications to the current configuration (e.g. replacing one component with another). When new hardware is delivered to the station, associated data will be delivered from the SSE and will be processed and stored in the data base by the DMS. An interface will be provided to enter hardware components that are being discarded so that the corresponding data in the data base will be deleted.

8.2.10.1.2 DMS HARDWARE SYSTEMS

The DMS hardware must be capable of supporting the functional requirements as required by the on-board systems (both core systems and application systems). It is assumed that the On-Board software functions will be a distributed system sharing data over a data link or "BUS". The DMS/SSE will provide the hardware necessary for application development and test.

8.2.10.1.2.1 STANDARD DATA PROCESSOR (SDP)

The primary application processor will be a Standard Data Processor. The SSE will provide one or more SDP's for execution of applications in the SS target language.

8.2.10.1.2.2 NETWORK INTERFACE UNIT (NIU)

The Network Interface Unit will be the standard hardware unit which will connect all SDP's to the network of SDP's and sensors/effectors. The SSE will provide for the NIU's just as it will with the SDP's above.

8.2.10.1.2.3 NETWORK BUS

The processor network will be interconnected with a bus or ring. In the SSE, the bus(es) necessary for the formation of a net for application testing will be provided. The make up of this bus and the network as a whole must be transparent to the user.

8.2.10.1.2.4 MASS STORAGE

The On-Board systems require a mass storage device(s) for software systems such as the NOS, RTOS, Display generation and other software elements in support of the SS and to support data archival for trend analysis or for retransmission to ground systems when RF transmission is more readily available. Mass storage sufficient for application development will be provided in the SSE.

8.2.10.1.3 DMS/SSE SOFTWARE TOOLS

There is a set of software programs which support any software development which is normally thought of as being resident in a host environment such as in the SSE. Because of the nature of the Space Station, a subset of development tools must be resident on-board. The Display Generation/Support could be considered as in this categorary. Other tools include compilers, linkers, debug, diagnostics, deloggers. This is not a complete list of such tools. The allocation of these tools to DMS on-board or SSE will be determined. Both the on-Board DMS and the SSE must support the upload and download of programs and data. In the life time of the Space Station, a large range of software and hardware and software upgrades must be supported.

8.2.10.2 DMS CHARACTERISTICS

The Data Management System must be flexible to support an environment where the nature of the support is critical (involve life support systems, SS attitude control, etc.) to very simple functions such as providing time and other parameters to payload customers. Some of the critical systems such as GN&C must not only be redundant but must be restartable in case of a bus, SDP, or other failure situation in which the critical functions are terminated. The following are other generic requirements of the DMS.

- Software/Hardware interfaces must be well definded, simple and stable.
- The user (crew) interfaces must be easy to use and provide a step by step method (e.g. menus) for the inexperienced user and a short cut for experienced user.
- All crew actions must be logged on-board or ground for historical processing in the SSE.
- Where possible, routine actions must be automated to support a mantended environment as well as allowing the crew to pursue other tasks. This automation must also be provided with crew override.
- On-board to ground and ground to on-board communications must be minimized to conserve RF bandwidth.

8.3 SYSTEM TEST, INTEGRATION & VERIFICATION (STIV)

Previous sections of this report have addressed the various aspects of the SSDS definition process. This section will discuss concepts associated with the major steps in the STIV process that can influence key design and programmatic decisions.

Task 2 (options development) identified and characterized several options available in the STIV process that provide the opportunity for meaningful cost and schedule savings throughout the evolutionary lifetime of the SSDS. These options are being assessed as part of a major trade study (Task 3) to define preferred techniques, methodologies, facilities and resources required for STIV.

8.3.1 Test

SSDS testing definition and policies planning will be an integration of Level SE&I direction and the preferred options identified in associated trade studies. This integration will be structured around the scheduled availabilities of SSDS elements. Cost will be a primary driver in structuring the test program.

Early decisions are required in several areas (as discussed later) to identify and schedule long lead time facilities and resources for integration with fiscal year funding contraints into DTC/LCC planning.

Hardware should be designed to maximize the use of commercially available test equipment for both acceptance and qualification tests.

8.3.1.1 Development Tests

Development tests are engineering evaluation tests to minimize technical risks and to provide proof of design concepts. They may include material selection, failure modes and effects, design/operating tolerances, etc.

For those elements judged to require engineering development testing, long lead time requirements must be identified very early in the program. Hardware development will utilize NASA testbeds, or similar facilities at the developing contractors location. For software, the long lead items required first are those development tools for the Software Support Environment (SSE). These include the Higher Order Programming Languages, Support Software, Operating Systems, Users Interface Language, and the Network Operating System.

8.3.1.2 Qualification Tests

Qualification testing, from both the functional requirements and the environmental requirements viewpoint, can be one of the most costly items of a large space program. The protoflight concept must be considered for application to all elements of the SSDS system to reduce costs.

The most cost-effective method of utilizing qualification units for flight must be determined in each case. The protoflight concept can be implemented by: increased design margins to arrive at a "no-test" or "qualification by analysis" situation; the use of additional inspection techniques after the qualification test, such as open box inspections or X-ray examinations; refurbishment or replacement of critical components in the assembly. Other cost avoidance techniques are: deferred module testing, i.e., qualification at the highest assembly level practical; selective environmental qualification (all assemblies need not be qualified to the same level depending on location, shielding, etc.); modified qualification levels, considering the criticality of the assembly. These techniques will be examined early in the design phase of all hardware assemblies requiring qualification testing.

In parallel with the development of the SSDS system definition, Phase B Space Station Systems Engineering will be defining the environmental levels for the various hardware applications. Qualification testing planning will then move into a more detailed phase with early emphasis on accommodating the protoflight concept. Qualification testing should utilize acceptance test software whereever possible to minimize costs.

8.3.1.3 System Tests

The anticipated SSDS testing will follow a sequence of ground segment activation and checkout, integration and test of space segment elements assigned to modules/launch packages, and integration of those elements within the module. Some limited end-to-end testing possibly utilizing TDRSS may occur during pre-launch integration efforts; final testing will occur during on-orbit assembly/activation of station and platform(s).

Early planning will incorporate NASA SE&I defined policies and preferred test options identified during trade activities. Key outputs of this planning will be:

a. definition of simulators and the degree of fidelity required.

b. definition of SDE support requirements.

c. definition of test sequence, (to be coordinated with development/production scheduling).

8.3.2 Integration

The methods and degree of, both hardware/software integration, will be identified initially by trade studies early in the program and refined as the system matures. Both hardware and software will be under development by several different contractors at several different locations, and this will occur over a significant span of time. Therefore, a well conceived integration plan must be available early in the program to identify GSE, facilities, and other resources, including provisions for growth, so that integration tasks and schedules are not impacted by lack of definition or appropriate support.

The following sections discuss selected integration activities peculiar to hardware and to software.

8.3.2.1 Hardware Integration

Integration of the hardware components of the SSDS/SSIS will depend on several factors. The protoflight concept dictates that all hardware, in so far as possible, will be designed and built with the end purpose of being usable as flight hardware. This concept implies that the hardware will not be continuously available in a development/integration facility, but rather, may cycle through such a facility as it progresses to a launch package onboard the NSTS. Obviously, enough flight-type hardware must be available at some point in the development phase to prove out critical issues such as data rates, processing throughput, standardized payload interfaces, etc.

A policy for the degree of standardization/commonality of the processors for Bus Interface Units, Common Data Processors, etc. must be established as this will have an influence on the integration tasks by determining how many units must cycle through the integration process.

Along with standardization/commonality, elements should be designed such that commercially available test equipment can be used. The "golden box" laboratory test approach should be used where practical to reduce GSE and formal test procedure requirements. This is justified for small production quantity elements. However for elements to be produced in quantities and whose interfacing inputs are likely to have significant excursions, then a more rigorous text approach will be required. This is based on the premise that for more applications/users, more design margin will be required.

The prelaunch readiness testing at KSC will be limited to that necessary to confirm no degradation from shipping, depending on integration strategies implemented. Each package to be delivered on orbit will receive a functional checkout before installation in the NSTS, including verification of NSTS interfaces, as required.

8.3.2.2 Software Integration

The software integration process takes place at many different levels throughout the system. Starting with the software unit or module level, the modules will be successively integrated into increasingly larger and multi-level packages.

To insure that all contractors/subcontractors generate compatible applications software for their subsystem the SSE will provide a standard set of tools and resources for general use. The Higher Order Programming Languages. Support Software, Operating Systems, and the Users Interface Language (UIL), will all be standardized.

8.3.3 Verification

Verification is the total process of planning and implementing a comprehensive program to demonstrate that the SSDS satisfies all design, performance, and safety requirements. The verification process will be an integration of certification, development testing, acceptance testing, integration, final on orbit checkout and supplemental analysis to support the total verification program.

While the final verification of the System will not be established until the IOC configuration is in place and operating in the space environment, much of the verification effort will have been accomplished in NASA testbeds and other development facilities.

The SSE will play a key role in this verification effort in supporting and furnishing time critical, long lead time items such as operating systems, and other software development tools which are essential to the timely and cost effective usage of the SSE for development, integration/verification, and continued support.

Based on the SSDS functional requirements defined in Task 1, and the System Definition of Task 4, all contractors will identify their best estimate of requirements for the SSE including language processors, simulations, diagnostic routines, and sizing and loading requirements. These requirements will be refined and updated as the SSDS system evolves.

9.0 TECHNOLOGY RECOMMENDATIONS

The objective of this section is to identify and justify (provide supporting rationale) those technology advancement items that represent a significant "payoff" to the SSDS. This assessment will consider both SSDS architectural needs as well as ongoing research and technology development activities (NASA, DoD, Industry, Academia). The intent is to provide the basis for technology development planning that will enhance cost-effective capabilities for IOC and/or growth opportunities.

Technology items that were potentially beneficial to the SSDS were initially identified and characterized during the options development (Task 2) activities. Since this effort included the development of projected capabilities, many advanced and immature technologies were considered. As the system definition process evolved (supported by trade studies), preferred technologies were identified based on their availability for IOC or growth. In addition, an analysis was performed to identify those technologies that would have been selected for IOC except for uncertainties in their maturity levels. As a result, they may not have been selected due to an unacceptable risk element. These items were then examined to determine the payoff for continuing, accelerating or initiating NASA-sponsored research and technology development efforts.

Table 9-1 lists the recommended technology advancement candidates that are considered to have the highest priority. This assessment is based on the following generic factors.

a. Benefit/Cost Ratio - Benefits include enhanced performance, lower risk, improved crew productivity/safety and customer accommodation. These are then compared to estimated cost at IOC and growth.

b. Leverage - The opportunity to capture a substantial technology base from other programs (i.e., VHSIC, etc.) with minimal investment.

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Table 9-1
KEY TECHNOLOGY DESIGN/COST DRIVERS

TECHNOLOGY	RATIONALE
REAL-TIME EXPERT SYSTEMS	° INCREASES CAPABILITIES OF EXPERT SYSTEMS AND BROADENS THE RANGE OF THEIR SS APPLICATIONS. MAY REDUCE SS OPERATING COSTS AND IMPROVE PRODUCTIVITY BY RELIEVING FLIGHT AND GROUND CREW FROM ROUTINE TASKS.
ADVANCED SOFTWARE DEVELOPMENT/MGT TOOLS & TECHNIQUES	° REDUCE THE CHANCE OF SCHEDULE SLIPS AND COST OVERRUNS COMMON IN MANY LARGE SOFTWARE INTENSIVE PROJECTS. ° IMPROVE SOFTWARE DEVELOPMENT PRODUCTIVITY
ONBOARD AI MACHINES	° IMPROVE SUBSYSTEM AUTONOMY AND PERFORMANCE ° ENHANCE AUTOMATION GROWTH POTENTIAL
FAULT TOLERANT FLIGHT COMPUTERS	° IMPROVE DATA SYSTEM RELIABILITY/AVAILABILITY/MAINTAINABILITY.
SMART ADAPTABLE BUS INTERFACE UNITS	° IMPROVES DATA SYSTEM ARCHITECTURE FLEXIBILITY AND WILL IMPROVE OVERALL NETWORK PERFORMANCE
READ/WRITE OPTICAL DISK	° REDUCE DATA ARCHIVAL COSTS, AFFECTS DATA BASE MANAGEMENT DESIGN, MAY ALLOW DATA CAPTURE OF HIGH DATA RATE PAYLOADS WHEN OUT OF CONTACT WITH GROUND
USER TEST AND CONTROL LANGUAGE	° REDUCE PAYLOAD AND CORE SYSTEM INTEGRATION AND CHECKOUT COSTS ° INCREASE CREW PRODUCTIVITY ° GIVE USERS MORE FLEXIBILITY AND CAPABILITY TO MANAGE THEIR PAYLOADS AND SUBSYTEMS
COLOR FLAT PANEL DISPLAYS	° IMPROVE CREW WORKSTATION "FRIENDLINESS" AND EXPAND CAPABILITIES WITH LOWER POWER, WEIGHT, AND VOLUME
DISTRIBUTED DATA BASE MANAGEMENT TECHNIQUES	° AFFECTS THE NUMBER, AND PERFORMANCE REQUIREMENTS OF MASS STORAGE AND BUFFER MEMORY DEVICES AND THEIR LOCATION WITHIN THE DATA NETWORK ARCHITECTURE - GROUND AND SPACE ° IMPROVES USER ACCESS TO STORED DATA

c. General Utility - The extent to which a technology can be applied within the SSDS, the Space Station Program, or other NASA space applications. In some cases (i.e., AI technology, etc.), the extent to which the technology can be applied beyond NASA may also be a major consideration.

d. Schedule - The urgency of starting an advancement effort to meet desired use data. Includes benefit of accelerating schedule to be consistent with IOC, thus eliminating costs associated with later technology accommodation. Also minimizes schedule risk.

Table 9-1 also identifies the rationale and key benefits associated with each recommendation. Table 9-2 summarizes the evaluation of each recommendation in terms of the above factors.

Table 9-2
TECHNOLOGY CANDIDATE EVALUATION

	Benefit/Cost Ratio	Leverage	General Utility	Schedule
REAL-TIME EXPERT SYSTEMS	High	° Commercial ° DOD ° Other NASA	Yes	IOC/Growth
ADVANCED SOFTWARE DEVELOPMENT/MGT TOOLS & TECHNIQUES	Medium-to-High	° Primarily DOD ° Commercial	Yes	IOC/Growth
ONBOARD AI MACHINES	High	° Ground AI Hardware ° Other NASA ° DOD	Yes	IOC (Maybe) Growth
FAULT TOLERANT FLIGHT COMPUTERS	Medium-to-High	° Other NASA ° DoD ° Commercial	Yes	IOC
SMART ADAPTABLE BUS INTERFACE UNITS	High	° Other NASA ° DOD	Perhaps	IOC
READ/WRITE OPTICAL DISK	High	° Commercial ° DoD	Yes	IOC (if feasible) Growth
USER TEST AND CONTROL LANGUAGE	Medium	° Other NASA	Perhaps - depending on generality of design	IOC
COLOR FLAT PANEL DISPLAYS	High	° Commercial ° DoD	Yes	IOC
DISTRIBUTED DATA BASE MANAGEMENT TECHNIQUES	High	° DOD ° Commercial	Yes	IOC/Growth

10.0 ISSUES AND RECOMMENDATIONS

As a preliminary result of the SSDS Analysis/Architecture study a set of issues has been identified that need to have continuing attention in the remainder of this study as well as in the Space Station Definition and Preliminary Design studies and related activities. These issues are listed below and (in some cases) contain recommendations for action that would lead to resolution.

1) Accuracy and completeness of the Mission Requirements Data Base is not adequate for use as a firm basis for SSDS architectural decisions. Correlation and elimination of redundancy of nearly identical proposed missions is still needed; complete, consistent and accurately timelined mission data is also required. These conditions are not expected to change in the near-term. Consequently, we have accepted this data base as a "prototype" and have attempted to speculate on reasonable excursions for key architectural decisions.

2) The quality, connectivity, and duty cycle requirements for video data communications requirements have large excursions based on NASA and contractor analyses information.

3) The operational relationship between the Space Station manned base and the Co-orbiting Platform needs to be clarified so that the communications network requirements and SS data management support for COP can be established. The decision as to whether the COP and Space Station will be at the same, or different, altitudes,hence affecting line-of-sight connectivity, needs resolution.

4) The impact of design-to-cost (DTC) goals has not been factored into the study and relative cost data has been used in our design analyses. The DTC allocation could have major impacts on level of IOC automation, use of advanced technology, system flexibility, degree of system redundancy, and growth capability. The DTC allocation must be developed and established as a key design decision criteria.

5) The need for security provisions has not been fully explored, especially with regard to potential DOD use, and the potential mixing of commercial, foreign, scientific, and DOD users. Our study considerations have been limited to commercial and scientific users. Foreign users with technology transfer implications and DoD users have not been considered.

6) Growth goals are only speculative. A quantification of growth goals is needed to provide some consistency and discipline across the various elements, systems, and technologies in the SS program. For example, the decisions as to whether NASA will implement TDAS and continue to support ACTS type technology affect SS program growth planning. Realistic SSDS growth goals need to be established by NASA.

7) The tradeoff between subsystem autonomy and system flexibility/expandability for onboard architecture configurations has a wide range of possible solutions. Specific NASA feedback on our proposed architecture is needed to guide future study activities.

8) The ability of key technologies to support the IOC goals is not firmly established in certain areas; e.g., expert system planners and schedulers, space-qualified AI hardware, high rate data capture and routing technologies, reliable, cost-effective large volume data storage technologies. Realistic "selection freeze" dates need to be established as a basis for IOC recognizing the need to minimize the "technology gap." We expect that there will be a range of freeze date because of different technical and programmatic factors for different components.

9) The nature and degree of foreign involvement in the program needs better definition. This involvement has potential widespread effects on the SSDS architecture. Will NASA be required to capture and distribute foreign data? What degree of monitoring and safety assurance will NASA have regarding foreign module operations cojoined

to the Space Station? Do foreign users need real-time interaction from their home facilities? Future study activities should ensure the accommodation of foreign users when their needs and operating modes are defined.

10) The degree of commitment by NASA to provide special purpose data routing and processing facilities for the few proposed very high data rate experiments can greatly affect the rest of the SSDS ground network sizing and capabilities. We recommend a specified range and cost bogey for this service be developed for customers to evaluate. Any further analyses should be deferred pending customer community assessment.

11) The extent to which the ISO/OSI upper layers should be strictly applied in the onboard LAN, especially the Specific Application Service Elements (SASE), needs additional evaluation before firm design decisions are established.

12) The division of the OSI layers between the NIU and the SDP has not been completely resolved and is a key design decision requiring further tradeoff analyses. Our current recommendations are included in section 6.

13) There is still some uncertainty about the extent to which hardware commonality should be applied across SSP space elements due to significant variations in operating environments. This will be further evaluated as COP/POP requirements are developed and SS architectural concepts are applied and evaluated.

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