DECEMBER 1985

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SSDS

MDAC

Ford IBM RCA

SPACE STATION DATA SYSTEM ANALYSIS/ARCHITECTURE STUDY

Task 5 – Program Plan

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MCDONNELL DOUGLAS CORPORATION

SPACE STATION DATA SYSTEM ANALYSIS/ARCHITECTURE STUDY

Task 5 – Program Plan

DECEMBER 1985

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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY-HUNTINGTON BEACH
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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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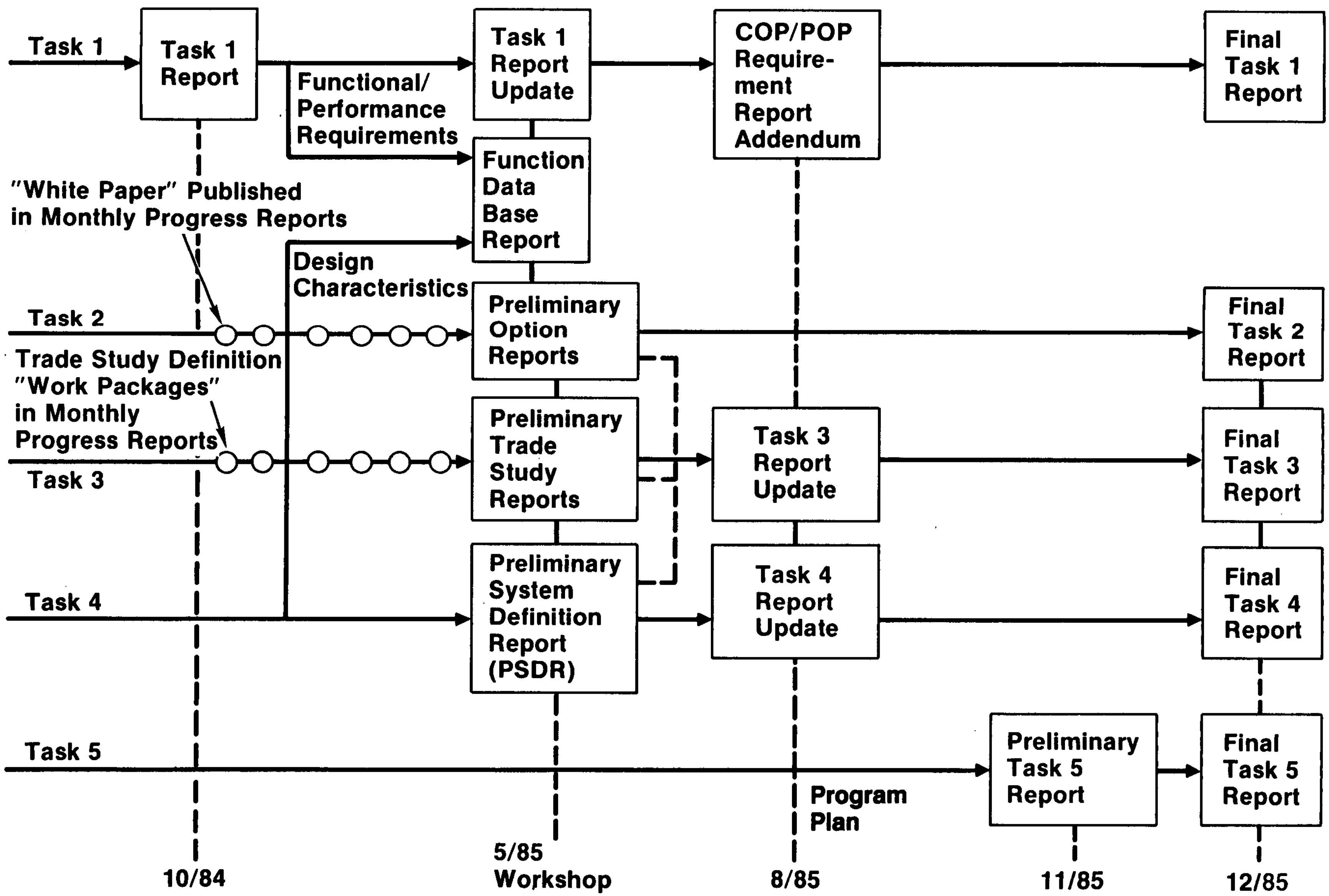
Figure 1

SSDS A/A DOCUMENTATION SCHEDULE

VHG598



CONTENTS

GLOSSARY

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

SSDS A/A STUDY PROGRAM PLAN REPORT

1.0 INTRODUCTION

The McDonnel Douglas Astronautics Company has been engaged in a Space Station Data System (SSDS) Analysis/Architecture A/A Study for the National Aeronautics and Space Administration, Goddard Space Flight Center. This Systems Engineering study which provides SSDS On-Board and Ground segment "strawman" designs within an end-to-end definition is divided into the following six tasks:

Task 1 - Requirements Definition

Task 2 - Options Development

Task 3 - Trade Studies

Task 4 - System Definition

Task 5 - Program Plan

Task 6 - Study Maintenance

The preliminary Task 1 Report was published for NASA review in October, 1984. With the concurrency of the SSDS A/A Study and the Space Station Level B activities in the second quarter of 1985, NASA elected, by Contract Modification, to accelerate the study schedule to deliver preliminary Task 2, 3 and 4 Reports (plus an update to the Task 1 Report) in May, 1985, to support the JSC SSIS Workshop.

The Task 1, 3 and 4 Reports were revised and re-issued in August, 1985 based on comments generated from NASA/Industry review of the preliminary reports and from Quarterly Review presentations. Task 5 preliminary report of October 1985 was reviewed by NASA/Industry, resulting updates and expansions of cost backup have been included in this submittal.

This report contains the final output of the Program Plan (Task 5) effort. The report provides NASA with SSDS Program Schedule, Program Costs, and Advanced Technology Development recommendations as detailed in Sections 2, 3, and 4 respectively.

A summary of the SSDS A/A Study Report publication schedule is provided in Figure 1.1.

FIGURE 1.1

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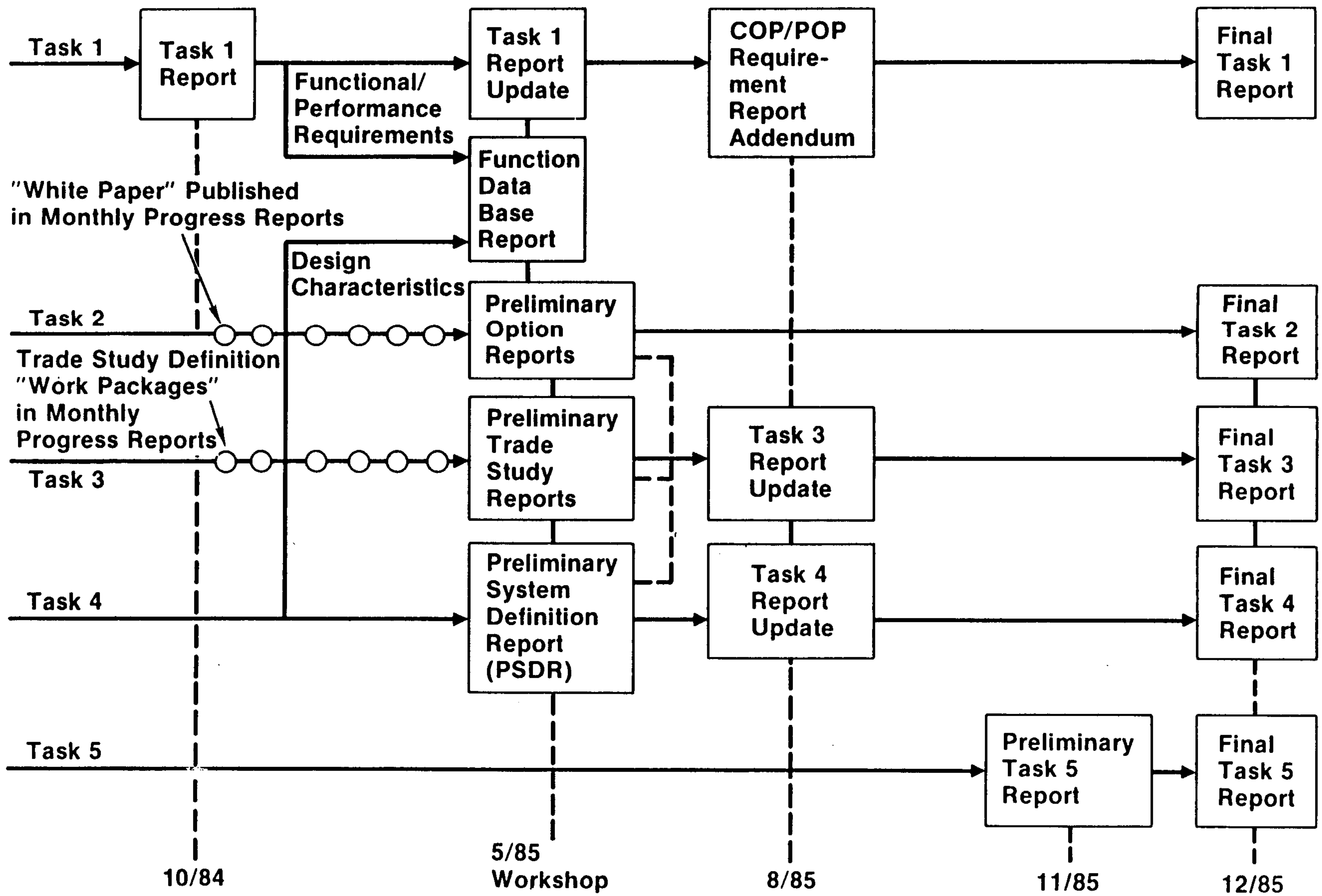
SSDS A/A DOCUMENTATION SCHEDULE



2.0 Executive Summary

2.1 Introduction

The original scope of the Task 5 Program Plan defined in the contractual Statement Of Work included detailed cost estimates and schedules, along with comprehensive program management and procurement strategies for the implementation of the complete system. The Program Plan scope was reduced, however, as part of the over-all study adjustments to accelerate the Task 2, 3, and 4 Reports in support of the Johnson Space Center SSIS Workshop, May 1985. As a result, the Program Plan, was re-defined to consist of the following efforts:

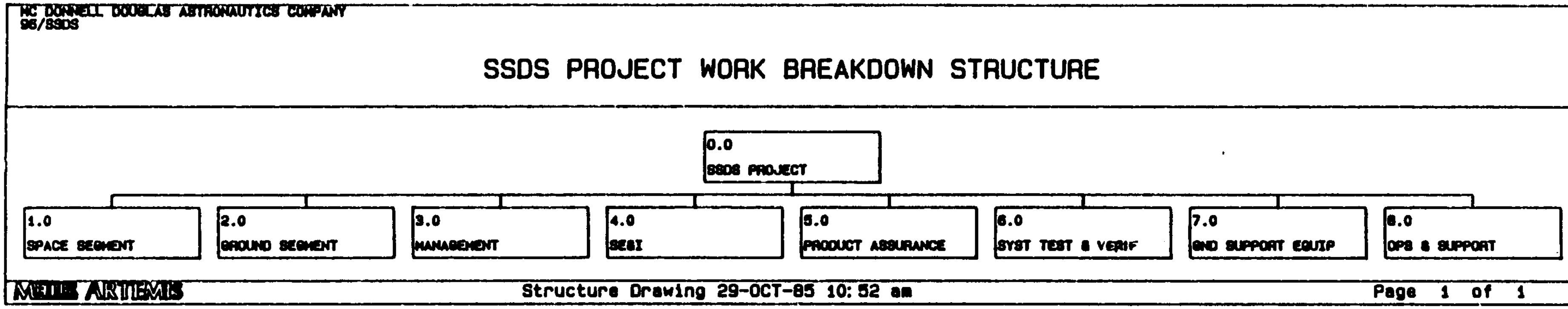
- SSDS cost estimates (both On-Board and Ground segments)
- Summary program schedules
- Advanced Technology Development Recommendations

The SSDS elements addressed within these efforts are the On-Board and Ground system definitions provided within Section 6.0 and 7.0 respectively of the SSDS A/A Study Task 4 Report.

The efforts itemized above are discussed in detail in Sections 3.0, 4.0 and 5.0 of this report; it is the intent of this section to summarize the discussions and conclusions of those sections.

2.2 SSDS Summary Costs

Figure 2.2-1 provides a graphic over-view of the Work Breakdown Structure (WBS) developed for this Program Plan. Costs have been generated to the lower levels of this WBS but a generally reported only at the higher levels. 'Below the line' cost categories, Management, Systems Engineering and Integration SE&I, etc. have been collected against both On-Board and Ground segments and are so reported within the cost summaries.


MC DONNELL DOUGLAS ASTRONAUTICS COMPANY
96/SSDS
SSDS PROJECT WORK BREAKDOWN STRUCTURE
0.0
SSDS PROJECT
1.0
SPACE SEGMENT
2.0
GROUND SEGMENT
3.0
MANAGEMENT
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PRODUCT ASSURANCE
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SYST TEST & VERIF
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GND SUPPORT EQUIP
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Page 1 of 1

Figure 2.2-1

Detailed ground rules and assumptions for the SSDS cost estimates are provided in Section 3.0 and will not be duplicated here except to note that:

- o Implementation/operational costs for the Software Support Environment (SSE) and Development, Simulation, Integration and Training (DSIT) distributed capabilities are not included.

- o Only IOC costs are provided; growth is not addressed.

- o On-Board system implementation costs are provided through integration of SSDS elements into their associated launch packages, but launch and on-orbit 'build-up' support costs are excluded. No operational costs for the On-Orbit elements have been provided.

- o Operational costs for Ground facilities are limited to the staffing required to maintain the facilities; mission unique costs are not included.

- o The platform complement was limited to polar-orbiting platform, launch 1, POP1 deployment concurrent with Station IOC followed by POP2 then co-orbiting platform COP on six month centers.

- o Total hardware commonality was assumed between Station and platforms plus a high degree of software commonality.

- o Cost methodology and cost data provided in this report represent engineering estimates and should not be construed as pricing data or used to develop pricing data.

2.2.1 Space Segment Cost Summaries

Costs for the Space Segment, WBS item 1.0, including H/W and S/W development, integration tests, and the recurring H/W production runs for the Space Station, POP1, POP2, and COP totalled $445.4M; a breakdown of this cost into its component WBS elements is provided in Table 2.2.1-1.

Table 2.2.1-1

Space Segment Cost Summary

Space Element	Hardware Development ($M)	Hardware Recurring ($M)	Software Development ($M)	Integration ($M)	Total ($M)
Space Station	63.2	82.1	145.1	21.5	311.9
POP1	0	32.3	15.4	1.2	48.9
POP2	0	32.3	8.8	1.2	42.3
COP	0	32.3	8.8	1.2	42.3
TOTALS ($M)	63.2	179.0	178.1	25.1	445.4

2.2.2 Ground Segment Cost Summaries

WBS item 2.0 costs for the implementation of the nine ground facilities totalled $402.36M; a breakdown of this cost is provided in Table 2.2.2-1.

2.2.3 Total SSDS Costs

The total SSDS costs, consisting of the all WBS element costs is $1143.58M, representing $339.02M recurring and $804.56M non-recurring effort. A breakdown of these costs into the top level WBS elements is provided in Table 2.2.3-1.

2.2.4 Code S and Code T Funding

As part of the costing effort, NASA requested an estimate of funding responsibilities and associated SSDS costs for the Code S and Code T entities. The funding allocation, derived from NASA inputs and guidelines is summarized in Appendix A. The costs resulting from the allocation is:

Code S: $814.9M   Code T: $328.7M

2.3 Program Schedule

The SSDS program scheduling effort has adopted milestones Contract Start Date (CSD), Preliminary Design Review (PDR), Critical Design Review (CDR), 1st Launch, and Initial Operating Capability (IOC), provided by NASA to the Level C/D activities. The Platform complement and deployment have not been as clearly defined therefore platform schedule assumptions have been made based on the Space Station Level C/D schedule and the Woods Hole update to the Langley Data Base. These assumptions are:

- o POP1 will be operationally deployed concurrent with Space Station IOC.
- o POP2 will be deployed six months after POP1.
- o The COP will be deployed six months after POP2.

Note that POP3, identified in the Langley Data Base, has been associated with the growth period and has not been addressed.

Table 2.2.2-1

Ground System Cost Summary

Facility	Hardware Development ($M)	Hardware Recurring ($M)	Software Development ($M)	Integration ($M)	Total ($M)
Data Handling Ctr.	5	29.4	26	2.2	62.6
Level Zero Proc. Ctr 1	2.5	11.4	9	0.82	23.72
Level Zero Proc. Ctr 2	5	23.4	9	1.5	38.9
Level Zero Proc. Ctr 3	0	8.4	9	0.69	18.09
Ground Service Ctr	.01	2.88	5.59	0.34	8.82
SS Op Cont Ctr	2.5	27.7	49.3	3.08	82.58
SS Engr Data Ctr	1.2	16.9	30.5	1.9	50.57
P/F Cont Ctr	2.8	22.9	37.5	3.32	66.52
PF Engr Data Ctr	1.2	16.9	30.5	1.9	50.57
TOTALS ($M)	20.2	160.02	206.39	15.75	402.36

Table 2.2.3-1

Total SSDS Cost Summary

Segment	H/W Devel ($M)	H/W Recur ($M)	S/W Devel ($M)	Integ. ($M)	Mgmt ($M)	Syst Engr & Integ. ($M)	Product Assoc. ($M)	Syst Test & Verif. ($M)	GSE ($M)	Total ($M)
Space	63.2	179.0	178.1	25.1	82.7	66.2	7.2	12.5	20.6	634.6
Ground	20.2	160.02	206.39	15.75	20.33	29.65	1.87	54.77	0	508.98
TOTALS($M)	83.4	339.02	384.49	40.85	103.03	95.85	9.07	67.27	20.6	1,143.58

Schedules for the Space and Ground segments are provided in Section 4.0. As noted in that section, the schedules are presented in simple bar chart form only; identification of key inter-relationships and critical paths were not addressed.

2.4 Advanced Development Recommendations

As part of the Program Plan, NASA requested advanced technology development recommendations addressing technologies utilized within the study strawman definitions that require advanced development but are not covered adequately within existing NASA sponsored activities. Section 5.4 lists technologies utilized directly within the strawman designs that will require demonstration prior to preliminary design decisions plus those technologies with high potential benefit to the SSDS development but which were discarded because of high development risk.

A compilation of the NASA advanced development plans was obtained from two sources: first and foremost was the Data Management System Advanced Development Project Plan; the second source was the Commerce Business Daily which was surveyed for supplemental NASA sponsored development.

The list of Study technologies was mapped onto the NASA advanced development plans and evaluated. The evaluation led to the recommendations that the following technologies by sponsored in further development:

- Distributed Data Base Management
- End-to-End Protocols/Formats
- Command/Resource Management
- Flight Qualified AI Machines

Additional details of the above subjects are provided in the appropriate section of this report.

3.0 Program Cost Estimates

3.1 Introduction

The SSDS is the combination of hardware and software that provides command and data management services to Space Station/Platform sub-systems and customers, both on orbit and on ground. Both basic segments, On-board and Ground have been addressed within the SSDS A/A Study and both have been cost estimated as discussed in the following sections.

The Work Breakdown Structure defined for the Program Plan is presented and discussed in Section 3.3; estimated costs are consistent with that structure, however cost reporting is generally to the higher levels.

The costing effort Scope, Groundrules and Assumptions, presented in Sections 3.2 and 3.4 respectively, significantly bound and tailor the effort and should be carefully reviewed to fully understand the subsequent cost summaries. Methodologies utilized in Space and Ground segment estimates are provided in Section 3.5.

Finally, the cost summaries are provided in Section 3.6. A sub-section is provided for each segment followed by summaries of the total system. The latter summaries provide traditional 'non-recurring' vs 'recurring' break-out and estimates of NASA Code S and Code T funding responsibilities.

The cost methodology and cost data provided in this section represent 'engineering' estimates and should not be construed as pricing data or be used to develop pricing data.

3.2 Scope

Cost estimates are provided for the implementation (hardware and software) and operation of the SSDS Space and Ground System Definitions as provided in the SSDS A/A Task 4 Report. Elements defined to be outside the contractual scope of the Study, i.e. unique subsystem/user functions, Communications & Tracking, Audio/Video, Ground Distribution Networks, etc. are excluded from this effort.

Growth phase design/implementation was not defined within the Study and will not therefore be estimated. Ground system operation costs and On-Board system spares have been provided for the ten (10) years following IOC and will be based on the IOC configuration.

The platform complement defined within the Woods Hole update to the Langley Mission Data Base provides two (2) polar orbiting platforms (POP's) and one (1) co-orbiting platform (COP) early in the initial operational period of the Space Station Program. A third POP is provided in the 1996 time frame. This last platform is considered to be part of the growth phase and has not been addressed.

The On-Board Systems definition for the cost effort is provided in Figure 3.2-1 and Table 3.2-1; the Ground System definition is provided in Figure 3.2-2 and Table 3.2-2. The facilities included in the pricing and a summary of the hardware items are shown.

The Software Support Environment tools, hardware and operation and the Development, Simulation, Integration & Training capabilities were not included in the cost estimates. These distributed capabilities were not sufficiently defined to be included in the Task 4 Report "strawman" designs and have been left to the Level B Contractor studies to design and cost. Simulation/Training hardware and software elements are also excluded along with ground versions of flight hardware.

The Onboard SSDS hardware and software components represent only a portion of the overall Space Station/Platform entities. It is therefore difficult, if not less than meaningful, to identify unique SSDS costs within the Launch and On-Orbit Assembly/Activation operations. Implementation costs of the On-Board system have been truncated at the completion of the integration of the SSDS elements into their appropriate Launch Packages. Launch and Build-up support on-board operational support and subsystem integration support have not been estimated; the recurring costs are limited to the hardware production run costs.

Space Station - 2nd Quarter FY 1993

- o H/W & S/W to support all sub-systems
  - o SDP's - 2 MIP's/4 MBytes
  - o NIU's - 2 MIP's/4 MBytes
  - o MPAC's - 600 KOP's/16 MBytes/CRT
  - o Bridge - (comparable to NIU)
  - o Mass Store - 256 MBytes/unit (DRAM)
  - o OS, NOS, Application S/W

COP - 2nd Quarter FY 1994

POP 2 - 4th Quarter FY 1993

POP 1 - 2nd Quarter FY 1993

- o H/W & S/W to support all sub-systems

- o 100 Mbps fiber optic global network
- o Core and Payload sub-networks, bridge inter-connects
- o ISO/OSI reference model and CCSDS protocols/formats incorporated
- o Total commonality between Station and Platform H/W
- o High percentage commonality between Station and Platform S/W

Figure 3.2 - 1 On-Board SSDS System Definition

Table 3.2 - 1

On-Board SSDS System Definition (Cost Model)

Space Station

o Hardware Elements:

(Flt Units/Spares)	SDP's	NIU's	MPAC's	BRIDGE's	MASS STOR's
	16/12	38/118	6/5	24/10	5/4

o Software Elements:

o Operating Systems:

(KBytes/SLOC's)	Processor/MPAC OS	N/W OS
	160/40	410/102.5

o Applications:

Application Pgms	Size (KBytes/KSLOC's)
Power	443/111
GN&C	878/220
Thermal	76/19
ECLS	117/29
Struct/Mech	108/27
Crew	210/53
Comm & Track	451/113
Info & Data Mgmt	1628/407
P/L Accom	466/117

Table 3.2 - 1 - Cont'd

On-Board SSDS System Definition (Cost Model)

Platforms

- Hardware Elements:

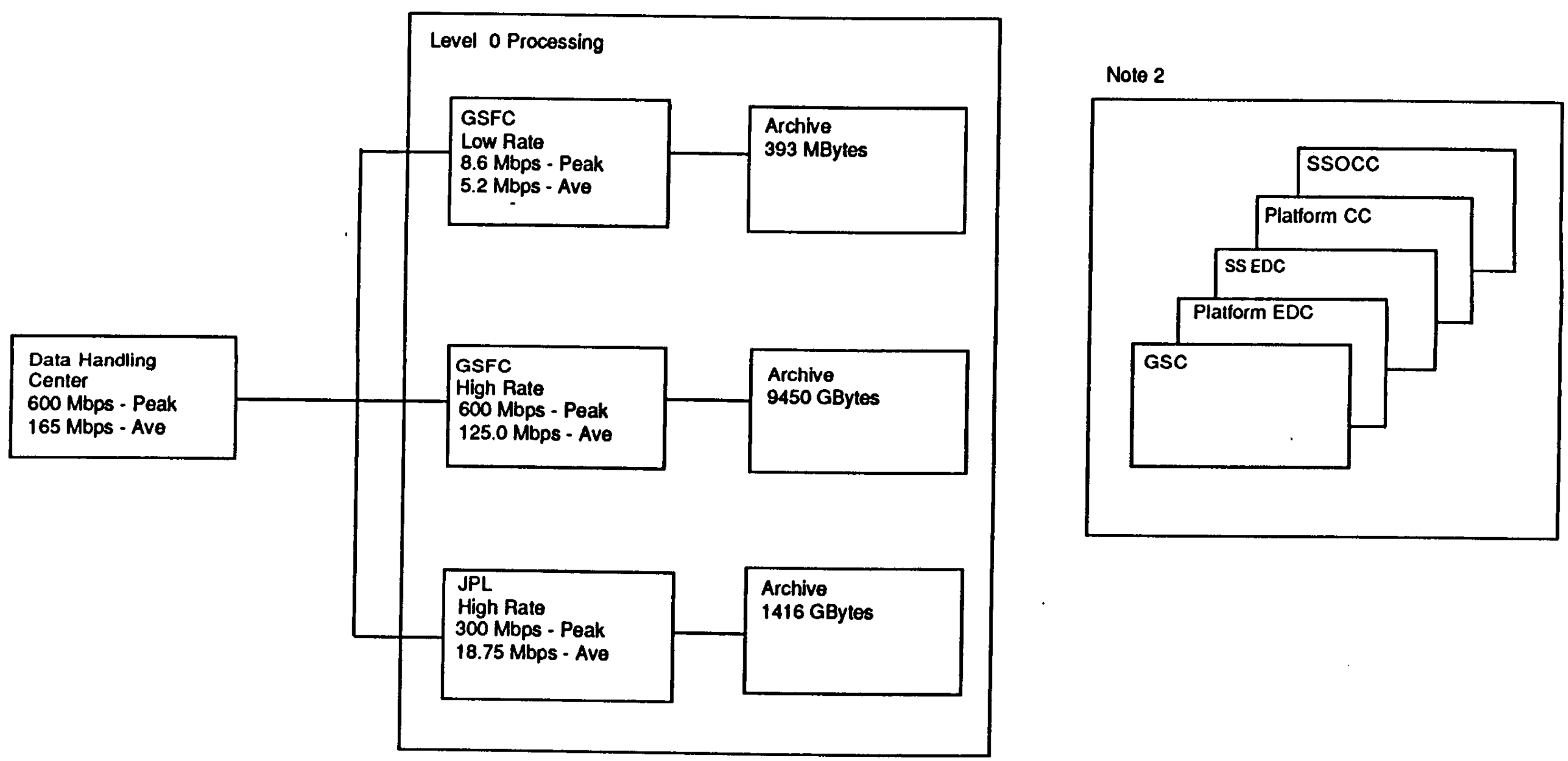
	SDP's	NIU's	BRIDGE's	MASS STOR's
(Flt Units/Spares)	18/6	18/6	2/1	3/1

- Software Elements: Note - Figures represent modification effort of Space Station baseline software

  - Operating Systems:

	SDP OS	N/W OS
(KBytes/KSLOC's)	20/5	50/12.5

  - Applications: 490 KBytes/126 KSLOC's



Note 1 - Ground communications definition and cost not included in SSDS A/A Study
Note 2 - For full Ground SSDS System connectivity, refer to Task 4, Section 7.0

Figure 3.2 - 2 Ground SSDS System Definition (Cost Model)

Table 3.2-2
GROUND SSDS SYSTEM COMPATIBILITY/COST EQUIVALENTS

ITEM ELEMENT	MASS STORE[1]	OPTICAL DISK	MAG. DISK[3]	LAN[5]	LAN[6]	LAN (WS)	LAN (MF)	CONSOL	WORK STATION[4]
DHC	4								
LZPF (GSFC LOW)		1			1				
LZPF (GSFC HI)		1			1				
LZPF (JPL HI)		1			1				
GSC[2]			20	1				1	
SSOCC			3			57	6		55
SS EDC		1	1				8		
POP/COP CC			3			22	6		21
POP/COP EDC		1	1				8		
TOTAL	4	5	28	1	3	79	28	1	76

NOTES:
1 Line outage magnetic tape medium
2 For GSC similar to DEC RA81
3 Disk storage similar to IBM 3880/3380
4 Workstation similar to Masscomp MC550
5 Similar to ETHERNET
6 Similar to Hyperchannel

Table 3.2-2 (cont'd)
GROUND SSDS SYSTEM CAPABILITY/COST EQUIVALENTS

ITEM / ELEMENT	PROCESSOR (4)	PROCESSOR (1)	PROCESSOR (2)	PROCESSOR (3)	BRIDGE (MCC)	GATEWAY (FRONT END)	GATEWAY (LOCAL NET)	GATEWAY (DDN)	GATEWAY (TO EACH ELEMENT)
DHC		3				1		1	
LZPF (GSFC LOW)		4						1	
LZPF (GSFC HI)		4		1				1	
LZPF (JPL HI)		4						1	
GSC		3	1						6
SSOCC	3		7		2	1	2		
SS EDC	4						2		
POP/COP CC	3		5			1	2		
POP/COP EDC	4						2		
TOTAL	14	18	13	1	2	3	8	4	6

NOTES:
1 Similar to VAX 8600 cluster
2 LISP processor similar to Symbolics 3670
3 General processor similar to CYBER or CRAY
4 Similar to IBM 3083

Ground operation costs are limited to the staffing/operations required to maintain each facility; mission unique requirements are not estimated.

Foreign involvment has not been considered in SSDS acquisition and operations costing

Customer generated income from SSDS Services will not be estimated

Periods of performance for the cost estimation have been extracted from the schedules, also based on the WBS, provided in Section 4.0.

Total costs and time-phased distributions (by government fiscal year) are summarized in Section 3.6 in the following formats:

- o On-Board and Ground System costs
- o Full system costs
- o Non-Recurring vs Recurring Costs
- o Code T and Code S cost responsibilities

In all the above costs are provided in 1987 dollars, (escalated from 1985 dollars by a factor of 1.124).

3.3 Work Breakdown Structure (WBS)

The following Work Breakdown Structure has been generated for the SSDS A/A Study Program Plan Cost and Schedule Effort. Table 3.3-1 provides the WBS in tabular form; Figure 3.3-1 provides the WBS in graphic form. Table 3.3-2 provides the WBS Dictionary.

Table 3.3-1

SSDS A/A STUDY PROGRAN PLAN WORK BREAKDOWN STRUCTURE

0.0 SSDS

1.0 SPACE SEGMENT

1.1 SPACE STATION
1.1.1 HARDWARE
1.1.1.1 PROCESSORS
1.1.1.2 NETWORK INTERFACE UNITS (NIU'S)
1.1.1.3 BRIDGES
1.1.1.4 GATEWAYS
1.1.1.5 LOCAL AREA NETWORK
1.1.1.6 MASS STORAGE DEVICES
1.1.1.7 WORKSTATIONS
1.1.2 SOFTWARE
1.1.2.1 OPERATING SYSTEM
1.1.2.2 APPLICATION
1.1.2.3 MAINTENANCE
1.1.3 INTEGRATION

1.2 CO-ORBITING PLATFORM
1.2.1 HARDWARE
1.2.1.1 PROCESSORS
1.2.1.2 NIU'S
1.2.1.3 BRIDGES
1.2.1.4 GATEWAYS
1.2.1.5 LOCAL AREA NETWORK
1.2.1.6 MASS STORAGE DEVICES
1.2.2 SOFTWARE
1.2.2.1 OPERATING SYSTEM
1.2.2.2 APPLICATION
1.2.3 INTEGRATION

1.3 POLAR ORBITING PLATFORM
1.3.1 HARDWARE
1.3.1.1 PROCESSORS
1.3.1.2 NIU'S
1.3.1.3 BRIDGES
1.3.1.4 GATEWAYS
1.3.1.5 LOCAL AREA NETWORK
1.3.1.6 MASS STORAGE DEVICES
1.3.2 SOFTWARE
1.3.2.1 OPERATING SYSTEM
1.3.2.2 APPLICATION
1.3.3 INTEGRATION

Table 3.3-1 (cont'd)

2.0 GROUND SEGMENT

2.1 DATA HANDLING CENTER
2.1.1 HARDWARE
2.1.1.1 PROCESSORS
2.1.1.2 NIU'S
2.1.1.3 BRIDGES
2.1.1.4 GATEWAYS
2.1.1.5 LOCAL AREA NETWORKS
2.1.1.6 LOCAL BUSSES
2.1.1.7 MASS STORAGE DEVICES
2.1.1.8 WORKSTATIONS
2.1.2 SOFTWARE
2.1.2.1 OPERATING SYSTEMS
2.1.2.2 APPLICATION
2.1.3 FACILITY INTEGRATION & ACTIVATION

2.2 LEVEL ZERO PROCESSING FACILITY (LZPF) - GODDARD SPACE FLIGHT CENTER (GSFC) LOW-RATE
2.2.1 HARDWARE
2.2.1.1 PROCESSORS
2.2.1.2 NIU'S
2.2.1.3 BRIDGES
2.2.1.4 GATEWAYS
2.2.1.5 LOCAL AREA NETWORKS
2.2.1.6 LOCAL BUSSES
2.2.1.7 MASS STORAGE DEVICES
2.2.1.8 WORKSTATIONS
2.2.2 SOFTWARE
2.2.2.1 OPERATING SYSTEMS
2.2.2.2 APPLICATION
2.2.3 FACILITY INTEGRATION

2.3 LEVEL ZERO PROCESSING FACILITY - GSFC HIGH-RATE
2.3.1 HARDWARE
2.3.1.1 PROCESSORS
2.3.1.2 NIU'S
2.3.1.3 BRIDGES
2.3.1.4 GATEWAYS
2.3.1.5 LOCAL AREA NETWORKS
2.3.1.6 LOCAL BUSSES
2.3.1.7 MASS STORAGE DEVICES
2.3.1.8 WORKSTATIONS
2.3.2 SOFTWARE
2.3.2.1 OPERATING SYSTEMS
2.3.2.2 APPLICATION
2.3.3 FACILITY INTEGRATION

Table 3.3-1 (cont'd)

2.4 LEVEL ZERO PROCESSING FACILITY - JET PROPULSION LABORATORY (JPL) HIGH-RATE
2.4.1 HARDWARE
2.4.1.1 PROCESSORS
2.4.1.2 NIU'S
2.4.1.3 BRIDGES
2.4.1.4 GATEWAYS
2.4.1.5 LOCAL AREA NETWORKS
2.4.1.6 LOCAL BUSSES
2.4.1.7 MASS STORAGE DEVICES
2.4.1.8 WORKSTATIONS
2.4.2 SOFTWARE
2.4.2.1 OPERATING SYSTEMS
2.4.2.2 APPLICATION
2.4.3 FACILITY INTEGRATION

2.5 GROUND SERVICES CENTER
2.5.1 HARDWARE
2.5.1.1 PROCESSORS
2.5.1.2 NIU'S
2.5.1.3 BRIDGES
2.5.1.4 GATEWAYS
2.5.1.5 LOCAL AREA NETWORKS
2.5.1.6 LOCAL BUSSES
2.4.1.7 MASS STORAGE DEVICES
2.5.1.8 WORKSTATIONS
2.5.2 SOFTWARE
2.5.2.1 OPERATING SYSTEMS
2.5.2.2 APPLICATION
2.5.3 FACILITY INTEGRATION

2.6 SPACE STATION OPERATIONAL CONTROL CENTER
2.6.1 HARDWARE
2.6.1.1 PROCESSORS
2.6.1.2 NIU'S
2.6.1.3 BRIDGES
2.6.1.4 GATEWAYS
2.6.1.5 LOCAL AREA NETWORKS
2.6.1.6 LOCAL BUSSES
2.6.1.7 MASS STORAGE DEVICES
2.6.1.8 WORKSTATIONS
2.6.2 SOFTWARE
2.6.2.1 OPERATING SYSTEMS
2.6.2.2 APPLICATION
2.6.3 FACILITY INTEGRATION

Table 3.3-1 (cont'd)

2.7 SPACE STATION ENGINEERING DATA CENTER
2.7.1 HARDWARE
2.7.1.1 PROCESSORS
2.7.1.2 NIU'S
2.7.1.3 BRIDGES
2.7.1.4 GATEWAYS
2.7.1.5 LOCAL AREA NETWORKS
2.7.1.6 LOCAL BUSSES
2.7.1.7 MASS STORAGE DEVICES
2.7.1.8 WORKSTATIONS
2.7.2 SOFTWARE
2.7.2.1 OPERATING SYSTEMS
2.7.2.2 APPLICATION
2.7.3 FACILITY INTEGRATION

2.8 POP/COP CONTROL CENTER
2.8.1 HARDWARE
2.8.1.1 PROCESSORS
2.8.1.2 NIU'S
2.8.1.3 BRIDGES
2.8.1.4 GATEWAYS
2.8.1.5 LOCAL AREA NETWORKS
2.8.1.6 LOCAL BUSSES
2.8.1.7 MASS STORAGE DEVICES
2.8.1.8 WORKSTATIONS
2.8.2 SOFTWARE
2.8.2.1 OPERATING SYSTEMS
2.8.2.2 APPLICATION
2.8.3 FACILITY INTEGRATION

2.9 POP/COP ENGINEERING DATA CENTER
2.9.1 HARDWARE
2.9.1.1 PROCESSORS
2.9.1.2 NIU'S
2.9.1.3 BRIDGES
2.9.1.4 GATEWAYS
2.9.1.5 LOCAL AREA NETWORKS
2.9.1.6 LOCAL BUSSES
2.9.1.7 MASS STORAGE DEVICES
2.9.1.8 WORKSTATIONS
2.9.2 SOFTWARE
2.9.2.1 OPERATING SYSTEMS
2.9.2.2 APPLICATION
2.9.3 FACILITY INTEGRATION

3.0 MANAGEMENT
3.1 SPACE SEGMENT
3.2 GROUND SEGMENT

Table 3.3-1 (cont'd)

4.0 SYSTEM ENGINEERING & INTEGRATION (SE&I)
4.1 SPACE SEGMENT
4.2 GROUND SEGMENT

5.0 PRODUCT ASSURANCE
5.1 SPACE SEGMENT
5.2 GROUND SEGMENT

6.0 SYSTEM TEST & VERIFICATION
6.1 SPACE SEGMENT
6.2 GROUND SEGMENT

7.0 GROUND SUPPORT EQUIPMENT (GSE)

8.0 OPERATIONS & SUPPORT

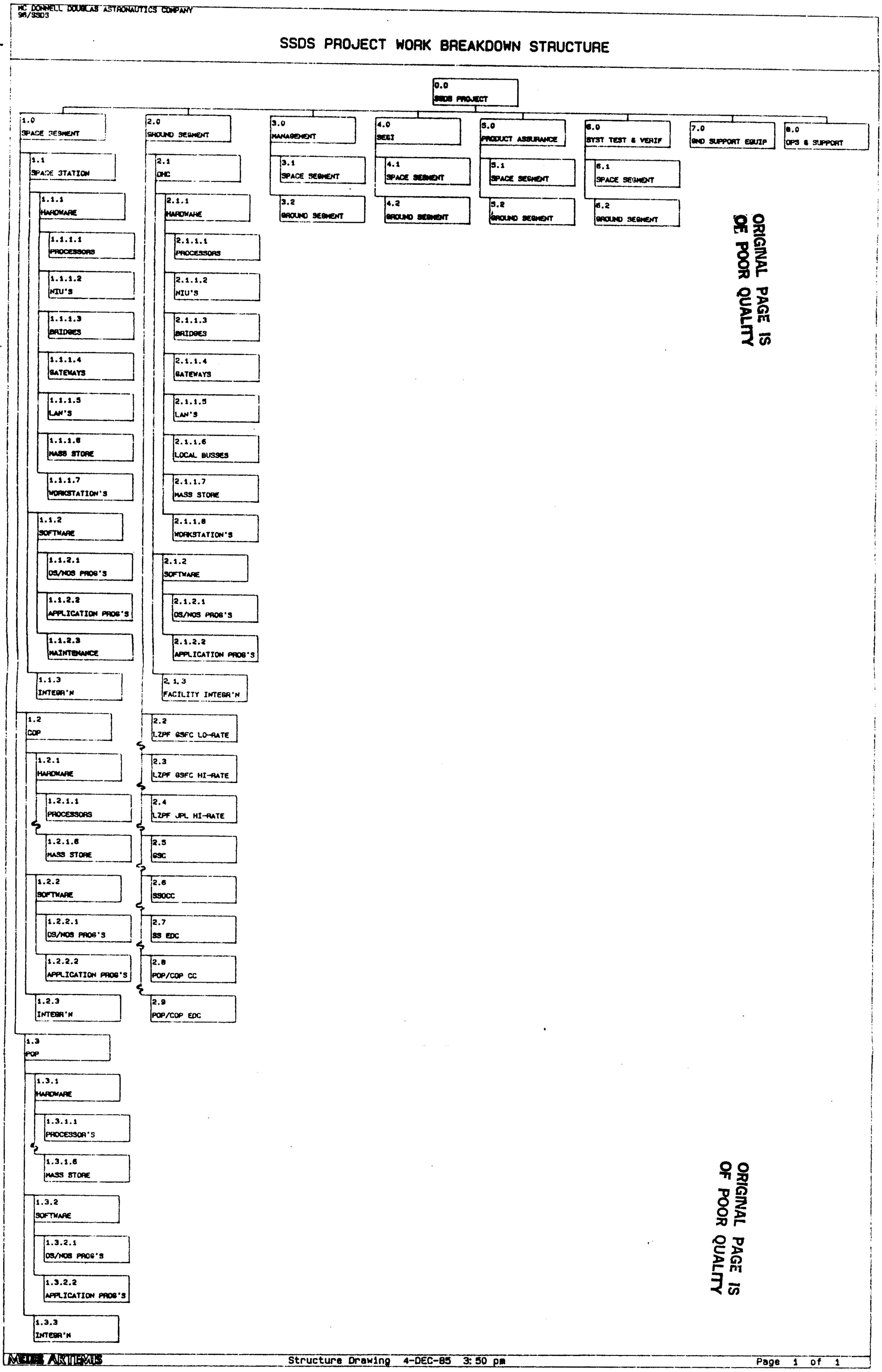


Figure 3.3-1

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Table 3.3-2

WBS DICTIONARY

X.1 HARDWARE (General): Contract End Item (Black Box) costs

Includes:

- o DDT&E Costs
- o Production (& Spares) costs

X.X.1.1 PROCESSORS: All SSDS processors used on-orbit or on-ground

X.X.1.2 NIU's: All network interface units used on-orbit on on-ground

X.X.1.3 BRIDGES: All bridges used to interconnect SSDS Local Area Networks (LAN's)

X.X.1.4 GATEWAYS: All SSDS gateways

X.X.1.5 LOCAL AREA NETWORKS: All hardware associated with the on-board and ground LAN's

X.X.1.6 LOCAL BUSSES: All local (back end) and point-to-point bussing used in on-board and on-ground systems

X.X.1.7 MASS STORAGE DEVICES: All mass storage devices and associated support hardware

X.X.1.8 WORKSTATIONS: All workstations and associated hardware, on-board and on-ground

X.2 SOFTWARE (General): Software costs will include:

- o Design, Development, Coding, Verification & Validation

X.X.2.1 OPERATING SYSTEMS; All Network Operating System (NOS) and Operating Systems (OS) software

X.X.2.2 APPLICATION: All other non-NOS and OS software

X.X.3 INTEGRATION: All efforts to integrate the SSDS within Space Station Program Element (SSPE)

Table 3.3-2 (cont'd)

3.0 MANAGEMENT

The management task consists of Business/Technical Mgmt, Configuration Mgmt, and Data/Information Mgmt. The Business/Technical Mgmt effort is required to provide services of Project Manager's staff, configuration management prepares and maintains the Configuration Management Plan and implementing procedures. The Data/Information Management is that effort required to assure that all responsibilities for preparation of contracturally required deliverable documentation/data/information are defined, assigned, scheduled, and statused; data needs are met.

4.0 SYSTEM ENGINEERING AND INTEGRATION

This task consists of the efforts required to perform and direct the system engineering, analyses, and integration activities in support of the design and development activities.

5.0 PRODUCT ASSURANCE

This element contains the effort required for the planning, conduct and support of the quality assurance, reliability, and safety and maintainability programs for both On-Board and Ground System.

6.0 SYSTEM TEST & VERIFICATION

Includes test equipment and operations by which the prime contractor will integrate, test and verify On-Board and/or Ground segment system level hardware and software.

7.0 GROUND SUPPORT EQUIPMENT

Includes the labor and material required to design, develop, manufacture, procure, assemble, test, checkout and deliver all of the various GSE hardware required for On-Board system checkout and final assembly. The GSE requirements include the equipment needed for test and checkout, fault isolation, handling and transportation.

8.0 OPERATIONS AND SUPPORT

Includes all ground efforts to support core system and maintain facility operations. Includes all non-mission unique activities. Activities include operations planning, scheduling, core systems monitoring, engineering data processing and archiving, etc.

3.4 Cost Estimation Ground Rules and Assumptions

In developing detailed and summary costs, the following ground-rules and assumptions have been adopted.

- o Contractor fees and NASA "wrap" costs have not been estimated.

- o Acquisition, modification, and operational costs for Institutional Facilities outside the SSDS boundaries are excluded.

- o Operational costs for existing and/or currently planned NASA Test Beds, Simulation Systems and Facilities are excluded.

- o H/W and S/W products have been considered as new development for the On-Board segment.

- o All costs are expressed in FY 1987 dollars.

- o Facility brick and mortar costs are excluded.

- o Application software for both Space and Ground segments will be estimated.

- o Hardware has been assumed to be common between Space Station and platforms (both COP and POP), thus eliminating development costs for platform equipment. Radiation hardening costs for the polar platform were not considered.

- o Operational (Ground segment) costs are provided in man-years/year.

- o Recurring hardware (flight units/spares production) will be produced at cost effective production rate.

3.5 Costing Methodologies

As noted in the introduction to Section 3.0, the cost estimations provided here-in have been somewhat coarse due to schedule and resource limitations. Costs have been generally based on empirical approximations, end-item comparisons, and engineering estimates. Identified methodologies are listed in the following two sections addressing Space segment and Ground segment estimates respectively.

3.5.1 Space Segment Methodologies

o Spares Requirements: The required number of spares was computed by assuming:

1) a re-supply interval of 3 months for the Space Station and a 6 month interval for the platforms.

2) a unit MTBF of 10,000 hours when powered and 100,000 when not powered.

3) redundant platform elements are powered off until needed.

4) a 99% probability that the minimum required hardware complement is available.

o Software Sizing: Memory sizing was ignored when identified as buffer storage (C&T-400 KBytes, IDMS-950 KBytes, Cust. P/L-2MBytes). Bytes were converted to source lines of code (SLOC) by the factor 4 bytes/SLOC. Because of the enforcement of commonality, the size of the unique S/W for POP1 was assumed to be 10% of the Space Station S/W size and 5% was assumed for POP2 and COP.

o System Test and Verification: Costed as a 10 man level of effort (LOE) for each STS launch package; 3 concurrent events for the Space Station and 1 event for each platform. Application S/W support was assumed to be provided by the subsystem contractor.

o Hardware Elements: The Subsystem data Processor (SDP), Network Interface Unit (NIU), and Bridge (B) elements were considered to be of equal complexity and cost; their cost was based on the Orbiter upgrade computer. The non-recurring cost for these components was based on the modification effort for a comparable unit being developed for another program. The Workstation (WS) and Mass Storage (MS) costs were based on Orbiter and other current program experience.

o Ground Support Equipment: The GSE requirements were based on the need to support four facilities and production simultaneously. Unique equipment was assumed for each hardware element with a total of 8 each for the SDP, NIU and B, and 6 each for the MS and WS.

o Software Development/Maintenance: OS and NOS software development was costed using a 65 SLOC/man-month productivity factor over a three year period. Follow-on maintenance until launch utilized a productivity of 6000 SLOC/man-month LOE. Development and maintenance factors utilized for application software were 110 SLOC/man-month and 15000 SLOC/man-month LOE respectively. These factors are based on STS program experience.

o Labor: Labor was estimated at $105,000/yr-man, (1985).

o Data Management System (DMS) Integration: DMS integration costs for the Space Station include a facilities cost of $16M (1985) and a 20 man LOE; each platform cost consisted only of a 10 man LOE.

o Product Assurance: Product Assurance was estimated as 4% of the recurring hardware cost. Software QA costs are included in the productivity factors.

o System Engineering and Integration/Management: SE&I costs were estimated as 15% of the S/W, H/W and GSE costs; management (includes project and line management) costs were estimated as 15% of all other costs.

3.5.2 Ground Segment Methodologies

o Design, development, testing and engineering (DDT&E): DDT&E for Commercial Off-The-Shelf (COTS) equipment are zero; DDT&E costs for special-build hardware were not shared between facilities for similar equipment.

o Hardware Procurement: All hardware was considered to be purchased, not leased; no volume purchase discounts were considered.

o Application Software: Application software costs are 3 to 4 times the cost of the associated processor hardware.

o Software Commonality: The re-use of applications software between a Space Station and a Platform facility was not assumed.

o Application Software Maintenance: Annual applications software maintenance costs are 20% of the development costs and are not shown.

o Facility Integration: Facility Activation and System Integration were estimated as 15% of the total H/W and S/W costs for the facility.

o Facility Operational Staffing: It was assumed that key facility positions were continuously manned. It is recognized that if scheduling of mission activities was optimized with respect to the ground controller crew, the number of controllers could be reduced. This was not considered likely or desirable however, due to scheduling complications and the requirement for contingency support.

3.6 Cost Summaries

3.6.1 Space Segment

The total cost for implementation of the Space Segment, as bounded by the estimation scope, ground rules and assumptions is $634.6M. In summary this figure represents the implementation cost to develop and support the SSDS Space Segment through integration into the appropriate launch packages; costs beyond that point, i.e. for support of launch, build-up support and subsequent operations are not included. It is noted, however, that some (pre-IOC) software maintenance for both OS/NOS and application programs is included in these estimates.

These costs are all non-recurring with the exception of hardware production run costs. Summation of these costs yields a distribution of $160.1M Recurring, and $474.5M Non-Recurring.

Cost estimates for the individual WBS elements are provided in Table 3.6.1-1.

Details of the hardware development/recurring costs and software sizing/development costs for both the Space Station and platform(s) are provided in Figures 3.6.1-1 through 3.6.1-6.

Time-phased distributions of these elements are provided in Figures 3.6.1-7 through 3.6.1-15.

Table 3.6.1-1

SPACE SEGMENT SUMMARY COSTS

WBS	DESCRIPTION	RECURRING ($M)	NON-RECURRING ($M)
1.1	Space Station	63.2	248.7
1.2	COP	32.3	10.6
1.3	POP 1	32.3	16.6
1.3	POP 2	32.3	10.0
3.1	Management	0	82.7
4.1	SE&I	0	66.2
5.1	Product Assurance	0	7.2
6.1	System Test & Verif	0	12.5
7.1	Ground Support Equipment	0	20.6
	TOTALS:	160.1	474.5

Figure 3.6.1-1

SPACE STATION HARDWARE COSTS

HARDWARE ELEMENTS	Development Cost ($M)	Recurring Cost($M)/ Flight Unit	Total Flight Units	Fl.Units Recurring Cost($M)	Total Spare Units	Spares Recurring Cost($M)	Total Recurring Cost($M)	Total Cost($M)
SUBSYS.DATA PROC	22.5	0.562	16	9.0	12	6.7	15.7	38.2
NETWORK INT.UNIT	22.5	0.562	38	21.4	18	10.1	31.5	54.0
WORKSTATION	7.0	0.703	6	4.2	5	3.5	7.7	14.8
MASS STORAGE	5.6	0.899	5	4.2	4	3.6	8.1	13.7
BRIDGE	5.6	0.562	24	13.5	10	5.6	19.1	24.7
TOTALS	63.2		89	52.5	49	29.6	82.1	145.4

Figure 3.6.1-2

SPACE STATION SOFTWARE COSTS

FUNCTION	Memory Size (K Bytes)	Software Size (K SLOC)	Development Cost ($M)	Maintenance Cost ($M)	Total ($M)
OPERATING SYSTEM	160	40	6.1	2.4	8.4
NETWORK OPERATING SYSTEM	410	102.5	15.5	6.0	21.6
TOTALS	570	142.5	21.6	8.4	30.0

Figure 3.6.1-3

SPACE STATION - APPLICATION SOFTWARE COSTS

FUNCTION	Memory (K Bytes)	Software Sizing (K SLOC)	Development Cost ($M)	Maintenance Cost ($M)	Total ($M)
ELECTRIC POWER	443	111	9.9	1.7	11.6
GN&C	878	220	19.6	3.5	23.1
THERMAL CONTROL	76	19	1.7	0.3	2.0
ECLS	117	29	2.6	0.5	3.1
STRUCTURES/MECHANISMS	108	27	2.4	0.4	2.8
CREW SYSTEMS	210	53	4.7	0.8	5.5
COMM & TRACKING	451	113	10.1	1.8	11.9
INFO & DATA MANAGEMENT	1628	407	36.4	6.4	42.8
PL & SERVICING ACCOM.	466	117	10.4	1.8	12.2
TOTALS	4377	1094	97.8	17.2	115.1

Figure 3.6.1-4

SPACE PLATFORM HARDWARE COSTS

HARDWARE ELEMENTS	Recurring Cost($M)/ Flight Unit	Total Flight Units	Fl.Units Recurring Cost($M)	Total Spare Units	Spares Recurring Cost($M)	Total Recurring Cost($M)
SUBSYS.DATA PROC	0.562	18	10.1	6	3.4	13.5
NETWORK INT.UNIT	0.562	18	10.1	6	3.4	13.5
MASS STORAGE	0.899	3	2.7	1	0.9	3.6
BRIDGE	0.562	2	1.1	1	0.6	1.7
TOTALS		41	24.1	14	8.2	32.3

Figure 3.6.1-5

SPACE PLATFORM SOFTWARE COSTS
(FIRST PLATFORM)

FUNCTION	Memory Size (K Bytes)	Software Size (K SLOC)	Development Cost ($M)	Maintenance Cost ($M)	Total ($M)
OPERATING SYSTEM	20	5	0.8	0.2	1.0
NETWORK OPERATING SYSTEM	50	12.5	1.9	0.6	2.5
TOTALS	70	17.5	2.7	0.8	3.5

Figure 3.6.1-6

SPACE PLATFORM - APPLICATION SOFTWARE COSTS
(FIRST PLATFORM)

FUNCTION	Memory Size (K Bytes)	Software Size (K SLOC)	Development Cost ($M)	Maintenance Cost ($M)	Total ($M)
ELECTRIC POWER	50	13	1.1	0.10	1.2
GN&C	90	23	2.0	0.18	2.2
THERMAL CONTROL	10	3	0.2	0.02	0.2
ECLSS	20	5	0.4	0.04	0.5
STRUCTURES/MECHANISMS	20	5	0.4	0.04	0.5
CREW SYSTEMS	30	8	0.7	0.06	0.7
COMM & TRACKING	50	13	1.1	0.10	1.2
INFO & DATA MANAGEMENT (IDM)	170	43	3.8	0.33	4.1
PL & SERVICING ACCOM. (PL&SA)	50	13	1.1	0.10	1.2
TOTALS	490	123	11.0	0.96	11.9

NOTE: This figure represents the effort to modify the Space Station baseline software for platform utilization.

Figure 3.6.1-7. Space Station Cost Summary

WBS NO.	DESCRIPTION	FY 1987 3Q	FY 1987 4Q	FY 1988 1Q	FY 1988 2Q	FY 1988 3Q	FY 1988 4Q	FY 1989 1Q	FY 1989 2Q	FY 1989 3Q	FY 1989 4Q	FY 1990 1Q	FY 1990 2Q	FY 1990 3Q	FY 1990 4Q
	MILESTONES	♦ CSD													
1.1.1	STATION HARDWARE														
	-NON-RECURRING	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9						
	-RECURRING		2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	2.76	5.22	5.22
1.1.2	STATION SOFTWARE	1.79	1.79	1.79	1.79	9.94	9.94	9.94	9.94	9.94	9.94	9.94	9.94	8.85	8.85
1.1.3	INTEGRATION							3.58	3.58	3.58	3.58	3.58	3.58		
	TOTALS BY FY QUARTER	9.69	12.4	12.4	12.4	20.6	20.6	24.1	24.1	16.2	16.2	16.2	16.2	14.0	14.0

WBS NO.	DESCRIPTION	FY 1991 1Q	FY 1991 2Q	FY 1991 3Q	FY 1991 4Q	FY 1992 1Q	FY 1992 2Q	FY 1992 3Q	FY 1992 4Q	FY 1993 1Q	FY 1993 2Q	FY 1993 3Q	FY 1993 4Q	FY 1994 1Q	FY 1994 2Q	FY 1994 3Q	FY 1994 4Q	TOTAL ($M)
	MILESTONES							♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP		
1.1.1	STATION HARDWARE																	
	-NON-RECURRING																	63.2
	-RECURRING	5.22	5.22	5.22	5.22	5.22	5.22	2.46	2.46	2.46	2.48							82.1
1.1.2	STATION SOFTWARE	8.85	8.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85	2.85							145.1
1.1.3	INTEGRATION																	21.5
	TOTALS BY FY QUARTER	14.0	14.0	8.07	8.07	8.07	8.07	5.31	5.31	5.31	5.33	0	0	0	0	0	0	311.9

Figure 3.6.1-8. POP1 Cost Summary

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTAL ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	♦ CSD																				♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP		
1.3.1	POP HARDWARE (RECURRING ONLY)							1.71	1.71	1.71	1.71	1.71	1.71	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	0.68	0.68	0.68	0.68							32.3
1.3.2	POP SOFTWARE							0.33	0.33	1.24	1.24	1.24	1.24	1.24	1.24	0.99	0.99	0.99	0.99	0.99	0.99	0.32	0.32	0.32	0.32							15.4
1.3.3	INTEGRATION													0.29	0.29	0.29	0.29															1.2
TOTALS BY FY QUARTER		0	0	0	0	0	0	2.04	2.04	2.95	2.95	2.95	2.95	3.92	3.92	3.67	3.67	3.38	3.38	3.38	3.38	1	1	1	1	0	0	0	0	0	0	48.9

Figure 3.6.1-9. POP2 Cost Summary

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTAL ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
1.3.1	POP HARDWARE (RECURRING ONLY)									1.71	1.71	1.71	1.71	1.71	1.71	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	0.68	0.68	0.68	0.68					32.3
1.3.2	POP SOFTWARE									0.18	0.18	0.7	0.7	0.7	0.7	0.7	0.7	0.56	0.56	0.56	0.56	0.56	0.56	0.17	0.17	0.17	0.17					8.8
1.3.3	INTEGRATION															0.29	0.29	0.29	0.29													1.2
TOTALS BY FY QUARTER		0	0	0	0	0	0	0	0	1.89	1.89	2.41	2.41	2.41	2.41	3.38	3.38	3.24	3.24	2.95	2.95	2.95	2.95	0.85	0.85	0.85	0.85	0	0	0	0	42.3

Figure 3.6.1-10. COP Cost Summary

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	TOTAL ($M)
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
1.2.1	COP HARDWARE (RECURRING ONLY)											1.71	1.71	1.71	1.71	1.71	1.71	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39	0.68	0.68	0.68	0.68			32.3
1.2.2	COP SOFTWARE											0.18	0.18	0.7	0.7	0.7	0.7	0.7	0.7	0.56	0.56	0.56	0.56	0.56	0.56	0.17	0.17	0.17	0.17			8.8
1.2.3	INTEGRATION																	0.29	0.29	0.29	0.29											1.2
TOTALS BY FY QUARTER		0	0	0	0	0	0	0	0	0	0	1.89	1.89	2.41	2.41	2.41	2.41	3.38	3.38	3.24	3.24	2.95	2.95	2.95	2.95	0.85	0.85	0.85	0.85	0	0	42.3

Figure 3.6.1-11. Management

WBS NO.	DESCRIPTION	FY 1987 3Q	FY 1987 4Q	FY 1988 1Q	FY 1988 2Q	FY 1988 3Q	FY 1988 4Q	FY 1989 1Q	FY 1989 2Q	FY 1989 3Q	FY 1989 4Q	FY 1990 1Q	FY 1990 2Q	FY 1990 3Q	FY 1990 4Q	FY 1991 1Q	FY 1991 2Q
	MILESTONES	+ CSD															
3.1.1	SPACE STATION	1.91	17.8	2.84	2.84	4.06	4.06	4.6	4.6	2.9	2.9	2.9	2.9	2.7	2.7	2.7	2.7
3.1.2	POP 1							0.39	0.39	0.53	0.53	0.53	0.53	0.67	0.67	0.68	0.68
3.1.3	POP 2									0.36	0.36	0.44	0.44	0.44	0.44	0.58	0.58
3.1.4	COP											0.36	0.36	0.44	0.44	0.44	0.44
TOTALS BY FY QUARTER		1.91	17.8	2.84	2.84	4.06	4.06	4.99	4.99	3.79	3.79	4.23	4.23	4.25	4.25	4.4	4.4

WBS NO.	DESCRIPTION	FY 1991 3Q	FY 1991 4Q	FY 1992 1Q	FY 1992 2Q	FY 1992 3Q	FY 1992 4Q	FY 1993 1Q	FY 1993 2Q	FY 1993 3Q	FY 1993 4Q	FY 1994 1Q	FY 1994 2Q	FY 1994 3Q	FY 1994 4Q	TOTALS ($M)
	MILESTONES					+ 1st Launch					+ IOC,POP1	+ POP2		+ COP		
3.1.1	SPACE STATION	1.36	1.36	1.36	1.36	0.81	0.81	0.81	0.81							58.4
3.1.2	POP 1	0.64	0.64	0.64	0.64	0.16	0.16	0.16	0.16							8.9
3.1.3	POP 2	0.56	0.61	0.56	0.56	0.56	0.56	0.18	0.14	0.14	0.14					7.7
3.1.4	COP	0.58	0.58	0.61	0.61	0.56	0.56	0.56	0.56	0.14	0.14	0.14	0.14			7.7
TOTALS BY FY QUARTER		3.14	3.19	3.17	3.17	2.09	2.09	1.71	1.67	0.28	0.28	0.14	0.14	0	0	82.7

Figure 3.6.1-12. System Engineering and Integration

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
4.1.1	SPACE STATION	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91	2.91															46.6
4.1.2	POP 1							0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51	0.51											7.2
4.1.3	POP 2									0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44									6.2
4.1.4	COP											0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44							6.2
TOTALS BY FY QUARTER		2.91	2.91	2.91	2.91	2.91	2.91	3.42	3.42	3.86	3.86	4.3	4.3	4.3	4.3	4.3	4.3	1.39	1.39	1.39	1.39	0.88	0.88	0.44	0.44	0	0	0	0	0	0	66.2

Figure 3.6.1-13. Product Assurance

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
5.1.1	SPACE STATION	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13							3.3
5.1.2	POP 1							0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07							1.3
5.1.3	POP 2										0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07					1.3
5.1.4	COP											0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07			1.3
TOTALS BY FY QUARTER		0.13	0.13	0.13	0.13	0.13	0.13	0.2	0.2	0.2	0.27	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.14	0.14	0.07	0.07	0	0	7.2

Figure 3.6.1-14. System Test and Verification

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
6.1.1	SPACE STATION													0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88											7.1
6.1.2	POP 1															0.29	0.29	0.29	0.29	0.29	0.29											1.8
6.1.3	POP 2																		0.29	0.29	0.29	0.29	0.29	0.29								1.8
6.1.4	COP																			0.29	0.29	0.29	0.29	0.29	0.29							1.8
TOTALS BY FY QUARTER		0	0	0	0	0	0	0	0	0	0	0	0	0.88	0.88	1.17	1.17	1.17	1.46	1.75	1.75	0.58	0.58	0.58	0.29	0	0	0	0	0	0	12.5

Figure 3.6.1-15. Ground Support Equipment

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	($M)
	MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1		+ POP2		+ COP		
7.1.1	SPACE STATION			3.42	3.42	3.42	3.42	3.42	3.42																							20.6
7.1.2	POP 1																															
7.1.3	POP 2																															
7.1.4	COP																															
TOTALS BY FY QUARTER		0	0	3.42	3.42	3.42	3.42	3.42	3.42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20.6

3.6.2 Ground Segment Costs

3.6.2.1 Implementation Costs

The implementation cost for the Ground Segment, again as bounded by the estimation scope, ground rules and assumptions, is $509.01M. This figure represents the full development and integration costs for ground system readiness to support IOC. The estimates utilized a large percentage of Commercial-Off-The-Shelf (COTS) hardware which is categorized as "recurrent" costs; the total implementation cost breaks down to $160.05M Recurring and $348.96M Non-Recurring.

Costs for the individual WBS elements are provided in Table 3.6.2-1. Time-phased distributions are provided in Figure 3.6.2-1 through 3.6.2-22.

Table 3.6.2-1

Ground Segment Summary Costs

WBS	DESCRIPTION	RECURRING ($M)	NON-RECURRING ($M)
2.1	DATA HANDLING CENTER	29.4	33.2
2.2	LZPF GSFC LO-RATE	11.4	12.3
2.3	LZPF GSFC HI-RATE	23.4	15.5
2.4	LZPF JPL HI-RATE	8.4	9.7
2.5	GROUND SERVICES CENTER	2.88	5.94
2.6	SPACE STATION OPERATION CONTROL CENTER	27.73	54.88
2.7	SPACE STATION ENGINEERING DATA CENTER	16.97	33.60
2.8	PLATFORM CONTROL CENTER	22.9	43.62
2.9	POP/COP ENGINEERING DATA CENTER	16.97	33.60
3.2	MANAGEMENT	0	20.33
4.2	SE&I	0	29.65
5.2	PRODUCT ASSURANCE	0	1.865
6.2	SYSTEM TEST & VERIF	0	54.77
	TOTALS ($M)	160.05	348.96

Figure 3.6.2-1. Data Handling Facility

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.1.1	HARDWARE																															
	-NON-RECURRING	0.5	2	1.5	1																											5
	-RECURRING	1.47	2.94	2.94	2.94	4.41	4.41	4.41	2.94	2.94																						29.4
2.1.2	SOFTWARE			1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52	1.52												26
2.1.3	FAC. INTEGR'N					0.22	0.33	0.33	0.33	0.33	0.22	0.22	0.22																			2.2
TOTALS BY FY QUARTER		1.97	4.94	5.96	5.46	6.15	6.26	6.26	4.79	4.79	1.74	1.74	1.74	1.52	1.52	1.52	1.52	1.52	1.52	1.52	0	0	0	0	0	0	0	0	0	0	0	62.6

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Figure 3.6.2-2. Data Handler Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Proc. (VAX 8500 Cluster)	3	800	2400		9600
Gateway (Data Dist. Net)	1	5000	5000	1000	5400
Gateway (Front End TLM)	1	10000	10000	4000	10000
Mass Stor. (L. O. Mag.T)	4	3000	12000		
TOTALS:			29400	5000	25000

Figure 3.6.2-3. Level Zero Processing Facility -- GSFC Low Rate

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	TOTALS ($M)
	MILESTONES	♦ CSD																			♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP			
2.2.1	HARDWARE																															
	-NON-RECURRING	0.5	1	1																												2.5
	-RECURRING	0.57	1.14	1.14	1.14	1.71	1.71	1.71	1.14	1.14																						11.4
2.2.2	SOFTWARE			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40							9
2.2.3	FAC. INTEGR'N				0.08	0.12	0.12	0.12	0.12	0.08	0.08	0.08																				0.816
TOTALS BY FY QUARTER		1.07	2.14	2.54	1.62	2.23	2.23	2.23	1.66	1.62	0.48	0.48	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40							23.71

Figure 3.6.2-4. LZPF (GSFC Low Rate)

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Proc. (VAX 8600 Cluster)	4	800	3200		9000
Gateway (to Network)	1	5000	5000	1000	
LAN (Hyperchannel)	1	200	200		
Mass Store (Eras. Disk)	1	3000	3000	1500	
TOTALS:			11400	2500	9000

Figure 3.6.2-5. Level Zero Processing Facility -- GSFC High Rate

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.3.1	HARDWARE																															
	-NON-RECURRING	0.5	0.75	1.5	1.25	0.5	0.5																									5
	-RECURRING	1.17	2.34	2.34	2.34	3.51	3.51	3.51	2.34	2.34																						23.4
2.3.2	SOFTWARE			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40							9
2.3.3	FAC. INTEGR'N				0.15	0.22	0.22	0.22	0.22	0.15	0.15	0.15																				1.5
TOTALS BY FY QUARTER		1.67	3.09	4.24	4.14	4.64	4.64	4.14	2.97	2.89	0.55	0.55	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40							38.9

Figure 3.6.2-6. LZPF (GSFC High Rate)

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Proc. (VAX 8600 Cluster)	4	800	3200		9000
Proc. (Cyber, CRAY)	1	15000	15000	5000	
Gateway (to Network)	1	2000	2000		
LAN (Hyperchannel)	1	200	200		
Mass Storage (Eras. Disk)	1	3000	3000		
TOTALS:			23400	5000	9000

Figure 3.6.2-7. Level Zero Processing Facility -- JPL High Rate

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.4.1	HARDWARE -NON-RECURRING -RECURRING	0.42	0.84	0.84	0.84	1.26	1.26	1.26	0.84	0.84																						8.4
2.4.2	SOFTWARE			0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40							9
2.4.3	FAC. INTEGR'N				0.07	0.10	0.10	0.10	0.10	0.07	0.07	0.07																				0.69
TOTALS BY FY QUARTER		0.42	0.84	1.24	1.31	1.76	1.76	1.76	1.34	1.31	0.47	0.47	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0	0	0	0	0	0	18.09

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Figure 3.6.2-8. LZPF (JPL High Rate)

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Proc. (VAX 8600 Cluster)	4	800	3200		9000
Gateway (to Network)	1	2000	2000		
LAN (Hyperchannel)	1	200	200		
Mass Storage (Eras. Disk)	1	3000	3000		
TOTALS:			8400		9000

Figure 3.6.2-9. Ground Service Center

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.5.1	HARDWARE																															
	-NON-RECURRING		0.01																													0.012
	-RECURRING	0.14	0.28	0.28	0.28	0.43	0.43	0.43	0.28	0.28																						2.88
2.5.2	SOFTWARE	.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28											5.59
2.5.3	FAC. INTEGR'N				0.03	0.05	0.05	0.05	0.05	0.03	0.03	0.03																				0.338
TOTALS BY FY QUARTER		0.42	0.58	0.56	0.60	0.76	0.76	0.76	0.61	0.60	0.31	0.31	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28	0.28											8.82

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Figure 3.6.2-10. Ground Service Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Proc. (VAX 8600 Cluster)	3	550	1650		4950
LISP Proc. (Symb. 3670)	1	160	160		540
Gateways (to ea. Element)	6	50	300	10	
LAN (Ethernet)	1	15	15		
Mass Storage (DEC RA81)	20	37	740		
Network Console	1	8	8	2	
TOTALS:			2873	12	5500

Figure 3.6.2-11. Space Station Operational Control Center

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	TOTALS ($M)
	MILESTONES	+ CSB																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.6.1	HARDWARE																															
	-NON-RECURRING	0.21	0.21	0.21	0.42	0.42	0.42	0.21	0.21	0.21																						2.5
	-RECURRING	1.39	2.77	2.77	2.77	4.16	4.16	4.16	2.77	2.77																						27.73
2.6.2	SOFTWARE			2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9												49.3
2.6.3	FAC. INTEGR'N					0.62	0.62	0.62	0.62	0.62																						3.08
TOTALS BY FY QUARTER		1.6	2.98	5.88	6.09	8.1	8.1	7.89	6.5	6.5	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9	0	0	0	0	0	0	0	0	0	0	0	82.61

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Figure 3.6.2-12. Space Station Operational Control Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Processor (IBM 3083)	3	2500	7500		22500
LISP Proc. (Symb. 3670)	7	160	1120		4480
MCC Bridge	2	50	100		300
JSC Gateway	1	10000	10000	2000	5000
Core Gateway	2	80	160	100	480
LANs, Worksta. Connect.	57	30	1710	100	
LAN, Mainframe Con.	6	45	270	100	
Library (DS.IBM 3880/3380)	3	456	1368		
Worksta. (Masscomp MC550)	55	100	5500	500	16500
TOTALS:			27728	2800	49260

Figure 3.6.2-13. Space Station Engineering Data Center

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	♦ CSD																			♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP			
2.7.1	HARDWARE																															
	-NON-RECURRING	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1																						1.2
	-RECURRING	0.85	1.7	1.7	1.7	2.55	2.55	2.55	1.7	1.7																						16.97
2.7.2	SOFTWARE			1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39							30.5
2.7.3	FAC. INTEGR'N					0.38	0.38	0.38	0.38	0.38																						1.9
TOTALS BY FY QUARTER		0.95	1.8	3.19	3.29	4.52	4.52	4.42	3.57	3.57	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39							50.57

Figure 3.6.2-14. Space Station Engineering Data Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Processor (IBM 3083)	4	2500	10000		30000
Gateway (to JSC Net.)	2	80	160	100	480
LAN, Mainframe Con.	8	45	360	100	
Mag. Disk (IBM 3880/3380)	1	456	456		
Optical Disk	1	6000	6000	1000	
TOTALS:			16976	1200	30480

Figure 3.6.2-15. Platform Control Center

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.8.1	HARDWARE																															
	-NON-RECURRING	0.23	0.23	0.23	0.46	0.46	0.46	0.23	0.23	0.23																						2.8
	-RECURRING	1.15	2.29	2.29	2.29	3.44	3.44	3.44	2.29	2.29																						22.9
2.8.2	SOFTWARE			1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63						37.5
2.8.3	FAC. INTEGR'N					0.66	0.66	0.66	0.66	0.66																						3.32
TOTALS BY FY QUARTER		1.38	2.52	4.15	4.38	6.2	6.2	5.96	4.81	4.81	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63	1.63						66.52

Figure 3.6.2-16 . Platform Control Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Processor (IBM 3083)	3	2500	7500		22500
LISP Proc. (Symb. 3670)	5	160	800		3200
GSFC Gateway	1	10000	10000	2000	5000
Core Gateway	2	80	160	100	400
LANs, Worksta. Con.	22	30	660	100	
LAN, Mainframe Con.	6	45	270	100	
Library (DS, IBM 3880/3380)	3	456	1368		
Worksta. (Masscomp MC550)	21	100	2100	500	6300
TOTALS			22858	2300	37490

Figure 3.6.2-17. POP/COP Engineering Data Center

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
2.9.1	HARDWARE																															
	-NON-RECURRING	0.1	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1																						1.2
	-RECURRING	0.85	1.7	1.7	1.7	2.55	2.55	2.55	1.7	1.7																						16.97
2.9.2	SOFTWARE			1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39							30.5
2.9.3	FAC. INTEGR'N					0.38	0.38	0.38	0.38	0.38																						1.9
TOTALS BY FY QUARTER		0.95	1.8	3.19	3.29	4.52	4.52	4.42	3.57	3.57	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39							50.57

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Figure 3.6.2-18. POP/COP Engineering Data Center

ITEM - (Similar To)	QUANTITY	PER UNIT ($K)	TOTAL H/W ($K)	DDT&E ($K)	S/W DEVELOPMENT ($K)
Processor (IBM 3083)	4	2500	10000		30000
Gateway (to GSFC)	2	80	160	100	480
LAN/Mainframe I/F	8	45	360	100	
Mag Disks (IBM 3880/3380)	1	456	456		
Optical Disk Unit	1	6000	6000	1000	
TOTALS:			16976	1200	30480

Figure 3.6.2-19. Management

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	♦ CSD																			♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP			
3.2.1	DATA HANDLING CENTER	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15											3
3.2.2	LZPF - GSFC LOW RATE	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04							1.1
3.2.3	LZPF - GSFC HIGH RATE	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08							2.05
3.2.4	LZPF - JPL HIGH RATE	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04							0.957
3.2.5	GROUND SERVICE CENTER	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02											0.465
3.2.6	SS OP. CONTROL CENTER	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.2	0.22	0.22	0.22	0.22	0.22												4.24
3.2.7	SS ENGR. DATA CENTER	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10							2.6
3.2.8	P/F CONTROL CENTER	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13						3.32
3.2.9	POP/COP ENG. DATA CTR.	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.1	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10							2.6
TOTALS BY FY QUARTER		0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.90	0.89	0.91	0.91	0.91	0.91	0.91	0.69	0.52	0.52	0.52	0.52	0.13	0	0	0	0		20.33

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Figure 3.6.2-20. System Engineering and Integration

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
4.2.1	DATA HANDLING CENTER	0.44	0.44	0.44	0.44	0.26	0.26	0.26	0.22	0.17	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13											4.4
4.2.2	LZPF - GSFC LOW RATE	0.16	0.16	0.16	0.16	0.08	0.08	0.08	0.08	0.08	0.08	0.06	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03							1.6
4.2.3	LZPF - GSFC HIGH RATE	0.29	0.29	0.29	0.29	0.15	0.15	0.15	0.15	0.15	0.15	0.12	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06							2.99
4.2.4	LZPF - JPL HIGH RATE	0.14	0.14	0.14	0.14	0.07	0.07	0.07	0.07	0.07	0.07	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02							1.4
4.2.5	GROUND SERVICE CENTER	0.06	0.06	0.06	0.06	0.04	0.04	0.04	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02											0.678
4.2.6	SS OP. CONTROL CENTER	0.51	0.51	0.51	0.51	0.51	0.51	0.31	0.31	0.31	0.31	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21	0.21												6.16
4.2.7	SS ENGR. DATA CENTER	0.31	0.31	0.31	0.31	0.31	0.31	0.12	0.12	0.12	0.12	0.12	0.12	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09							3.8
4.2.8	F/F CONTROL CENTER	0.4	0.4	0.4	0.4	0.4	0.4	0.16	0.16	0.16	0.16	0.16	0.16	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11						4.83
4.2.9	POP/COP ENG. DATA CTR.	0.31	0.31	0.31	0.31	0.31	0.31	0.12	0.12	0.12	0.12	0.12	0.12	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09							3.8
TOTALS BY FY QUARTER		2.65	2.65	2.65	2.65	2.14	2.14	1.32	1.27	1.22	1.17	1.01	0.89	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.57	0.42	0.42	0.42	0.42	0.11	0	0	0	0	0	29.65

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Figure 3.6.2-21. Product Assurance

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	+ CSD																			+ 1st Launch				+ IOC,POP1		+ POP2		+ COP			
5.2.1	DATA HANDLING CENTER	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01											0.277
5.2.2	L2PF - GSFC LOW RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											0.102
5.2.3	L2PF - GSFC HIGH RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							0.187
5.2.4	L2PF - JPL HIGH RATE	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							0.087
5.2.5	GROUND SERVICE CENTER	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00											0.042
5.2.6	SS OP. CONTROL CENTER	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02												0.39
5.2.7	SS ENGR. DATA CENTER	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							0.24
5.2.8	P/F CONTROL CENTER	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01						0.3
5.2.9	POP/COP ENG. DATA CTR.	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01							0.24
	TOTALS BY FY QUARTER	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.08	0.08	0.08	0.06	0.04	0.04	0.04	0.04	0.01	0	0	0	0		1.865

Figure 3.6.2-22. System Test and Verification

WBS NO.	DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				TOTALS ($M)
		3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	
	MILESTONES	♦ CSD																			♦ 1st Launch				♦ IOC,POP1		♦ POP2		♦ COP			
6.2.1	DATA HANDLING CENTER						0.33	0.33	0.33	0.33	0.49	0.49	0.49	0.49	0.49	0.49	0.66	0.83	0.83	0.83	0.83											8.3
6.2.2	L2PF - GSFC LOW RATE								0.12	0.12	0.12	0.12	0.12	0.12	0.18	0.18	0.18	0.18	0.18	0.18	0.24	0.24	0.24	0.24	0.24							3
6.2.3	L2PF - GSFC HIGH RATE								0.19	0.19	0.19	0.19	0.19	0.19	0.28	0.28	0.28	0.28	0.28	0.28	0.38	0.38	0.38	0.38	0.38							4.8
6.2.4	L2PF - JPL HIGH RATE								0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.15	0.15	0.15	0.15	0.15	0.20	0.20	0.20	0.20	0.20							2.6
6.2.5	GROUND SERVICE CENTER						0.05	0.05	0.05	0.05	0.07	0.07	0.07	0.07	0.07	0.07	0.10	0.12	0.12	0.12	0.12											1.27
6.2.6	SS OP. CONTROL CENTER							0.46	0.46	0.46	0.46	0.98	0.98	0.98	0.98	1.16	1.16	1.16	1.16	1.16												11.5
6.2.7	SS ENGR. DATA CENTER							0.22	0.22	0.22	0.22	0.22	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.59	0.59	0.59	0.59	0.59	0.59							7.12
6.2.8	P/F CONTROL CENTER							0.29	0.29	0.29	0.29	0.29	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.64	0.64	0.64	0.64	0.64	0.64	0.64						9.06
6.2.9	POP/COP ENG. DATA CTR.							0.28	0.28	0.28	0.28	0.28	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.57	0.57	0.57	0.57	0.57							7.12
TOTALS BY FY QUARTER		0	0	0	0	0	0.38	1.64	2.06	2.06	2.25	2.77	3.11	3.11	3.32	3.5	3.69	3.88	3.88	4.33	3.59	2.64	2.64	2.64	2.64	0.64	0	0	0	0	0	54.77

3.6.2.2 Operational Costs

Operational staffing for each of the ground facilities was estimated in this costing effort. As noted in the ground rules and assumptions, it was difficult to separate generic staffing from mission unique requirements therefore that visibility is not provided. In addition, the staffing is provided based on 24-hour coverage. These operational costs in man-years per year are provided in Table 3.6.2-2.

Table 3.6.2-2

GROUND SEGMENT OPERATIONAL COSTS

FACILITY	STAFFING (MANYEARS/YEAR)
DHC	36
LZPF GSFC LO-RATE	52
LZPF GSFC HI-RATE	52
LZPF JPL HI-RATE	28
GSC	32
SSOCC	276
SSEDC	4
P/F CC	136
POP/COPEDC	36

3.6.3 Total SSDS Implementation Costs

The total implementation costs for the SSDS is simply the summation of the Onboard and Ground Systems costs provided in sections 3.6.1 and 3.6.2. This total is $1,143.58M and consists of $339.02M Recurring plus $804.56M Non-Recurring. Distribution of these costs across the WBS elements is provided in Table 3.6.3-1.

3.6.4 Code S/Code T Estimated Funding Responsibilities

As part of the costing estimation effort, NASA requested estimates of the Code S and Code T element funding responsibilities. The first effort was to develop an allocation of Onboard and Ground System components to a Code S/Code T implementation/operation responsibility matrix. This matrix, provided as Appendix A to this report, was generated based on NASA provided inputs and guidelines.

Based on the allocation matrix, the total element costs are:

Code S: $814.9M   Code T: $328.7M

Time-phased cost distributions of the allocated costs are provided in Figure 3.6.4-1.

Table 3.6.3-1

DISTRIBUTION OF COSTS ACROSS WBS

Segment	H/W Devel ($M)	H/W Recur ($M)	S/W Devel ($M)	Integ. ($M)	Mgmt ($M)	Syst Engr & Integ. ($M)	Product Assoc. ($M)	Syst Test & Verif. ($M)	GSE ($M)	Total ($M)
Space	63.2	179.0	178.1	25.1	82.7	66.2	7.2	12.5	20.6	634.6
Ground	20.2	160.02	206.39	15.75	20.33	29.65	1.87	54.77	0	508.98
TOTALS($M)	83.4	339.02	384.49	40.85	103.03	95.85	9.07	67.27	20.6	1,143.58

Figure 3.6.4-1. Time-Phased Cost Distributions

NASA CODE S

WBS NO. DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				
	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	TOTALS ($M)
MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1	+ POP2		+ COP			
GROUND SEGM'T ALLOC'N	5.64	8.87	14.5	14.9	19.5	19.6	19.3	16.1	16.0	7.86	8.20	8.37	8.29	8.20	8.49	8.51	8.54	8.54	8.80	4.29	3.84	3.84	3.84	3.84	0	0	0	0	0	0	180.3
SPACE SEGM'T ALLOC'N	14.6	33.2	21.7	21.7	31.1	31.1	38.2	38.2	28.9	29	32.4	32.4	9.77	32.5	33.7	33.7	24.1	24.4	24.2	24.2	16.1	16.1	13.1	12.8	2.12	2.12	1.06	1.06	0	0	634.6
CODE S TOTALS BY FY QUARTER	20.2	42.0	36.2	36.6	50.6	50.7	57.5	54.3	44.9	36.8	40.6	40.7	18.0	40.7	42.1	42.2	32.6	32.9	33.0	28.4	19.9	19.9	16.9	16.6	2.12	2.12	1.06	1.06	0	0	814.9

NASA CODE T

WBS NO. DESCRIPTION	FY 1987		FY 1988				FY 1989				FY 1990				FY 1991				FY 1992				FY 1993				FY 1994				
	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	TOTALS ($M)
MILESTONES	+ CSD																				+ 1st Launch				+ IOC,POP1	+ POP2		+ COP			
TOTAL GND SEGM'T COSTS	8.95	13.3	20.6	21.3	27.2	27.6	27.4	23.4	23.3	12.0	12.4	12.5	12.4	12.6	12.8	13.0	13.2	13.2	13.7	9.62	8.03	8.03	8.03	8.03	2.53	0	0	0	0	0	509
CODE S ALLOC'N	5.64	8.87	14.5	14.9	19.5	19.6	19.3	16.1	16.0	7.86	8.20	8.37	8.29	8.20	8.49	8.51	8.54	8.54	8.80	4.29	3.84	3.84	3.84	3.84	0	0	0	0	0	0	180.3
CODE T TOTALS BY FY QUARTER	3.31	4.45	6.08	6.32	7.66	7.99	8.07	7.30	7.25	4.19	4.13	4.22	4.17	4.30	4.30	4.55	4.71	4.71	4.90	5.32	4.19	4.19	4.19	4.19	2.53	0	0	0	0	0	328.7

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4.0 SSDS Program Schedules

Program scheduling is necessarily the fundamental effort of any successful Program Plan. It provides the time-lines and key project milestones against which the cost and man-power resources must be metered. It allows over-view of critical task phasing in supporting initial feasibility determinations against project milestones and provides an on-going tool to evaluate effects of program perturbations.

4.1 Introduction

The intent of this section is to provide over-view schedules of the SSDS implementation efforts. The schedules are consistent with the Work Breakdown Structure (WBS) of Section 3.3 although scheduling resolution is only to the third level (X.X.X) WBS elements. Separate schedules are provided for the On-Board and Ground Systems primarily to maintain manageable presentations.

4.2 Scope

The schedules provided are limited to the SSDS On-Board and Ground Systems as basically defined in the Task 4 Report, Sections 6.0 and 7.0 respectively. The schedule provided are in the form of simple bar charts. Gantt or Pert chart formats identifying the underlying complexities, critical paths, etc., are beyond the remaining resource capability of the study.

As in the case of the costing effort, the SSE and DSIT elements of the SSDS have not been addressed.

4.3 Ground-Rules and Assumptions

The following represent the significant ground-rules and assumptions utilized in developing the schedules.

1. Major program milestones have been adopted from those of the current Level C/D planning

2. The first platform, defined by the Langley Data Base as POP 1 will be deployed coincident with Station IOC; POP 2 and then the COP will follow on 6-month intervals. POP 3, also identified in the Langley Data Base has not been addressed.

3. The 'core support' elements of the SSDS Ground System must be in place and operational to support the first launch.

4.4 Methodology

The methodologies utilized for the schedule development have been engineering estimations based on insight and experience with prior programs.

4.5 Schedules

The On-Board system schedule and required WBS defined support item and Ground Systems schedule and required WBS defined support items are provided in Figures 4.5.1 and 4.5.2 respectively.

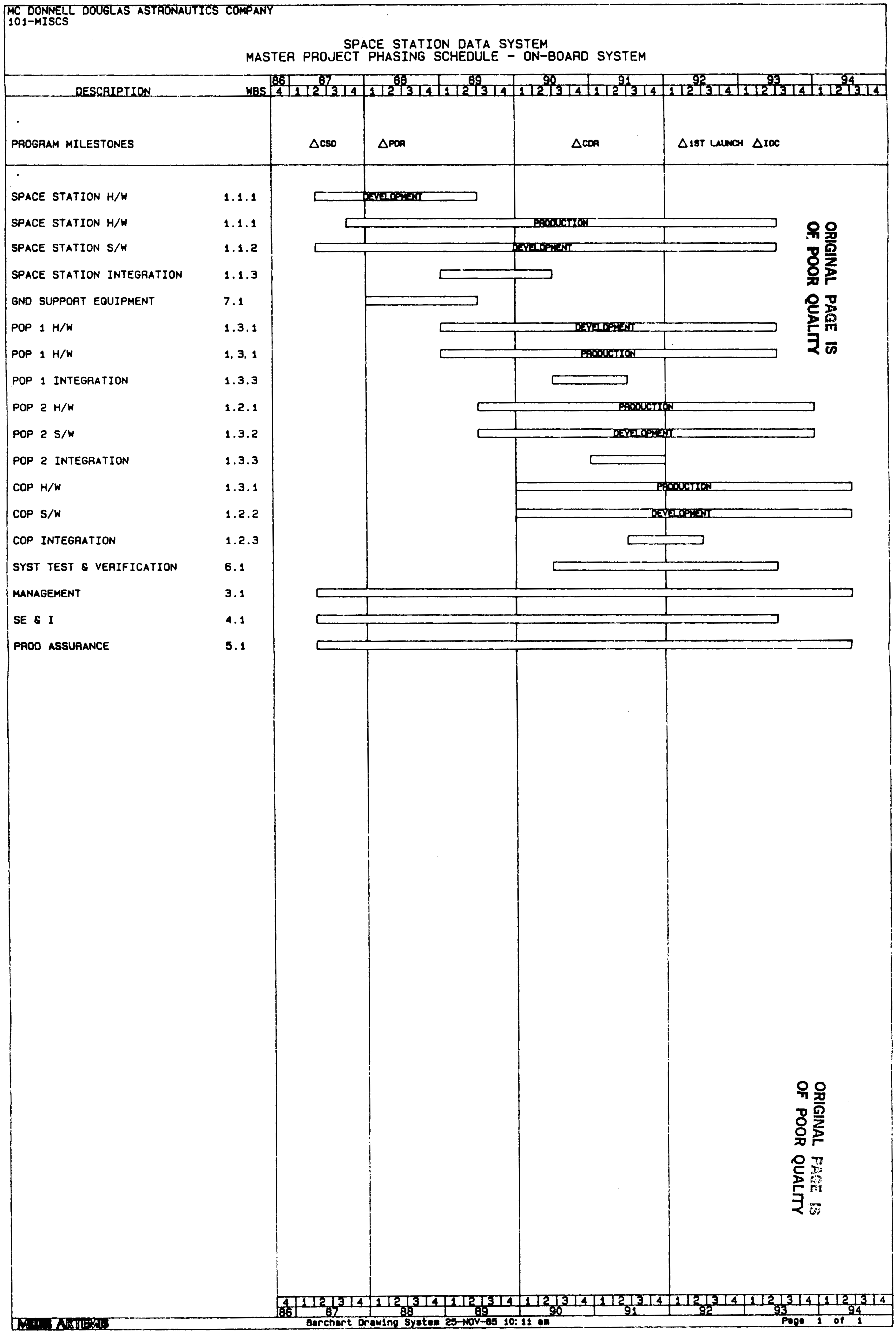

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Figure 4.5-1

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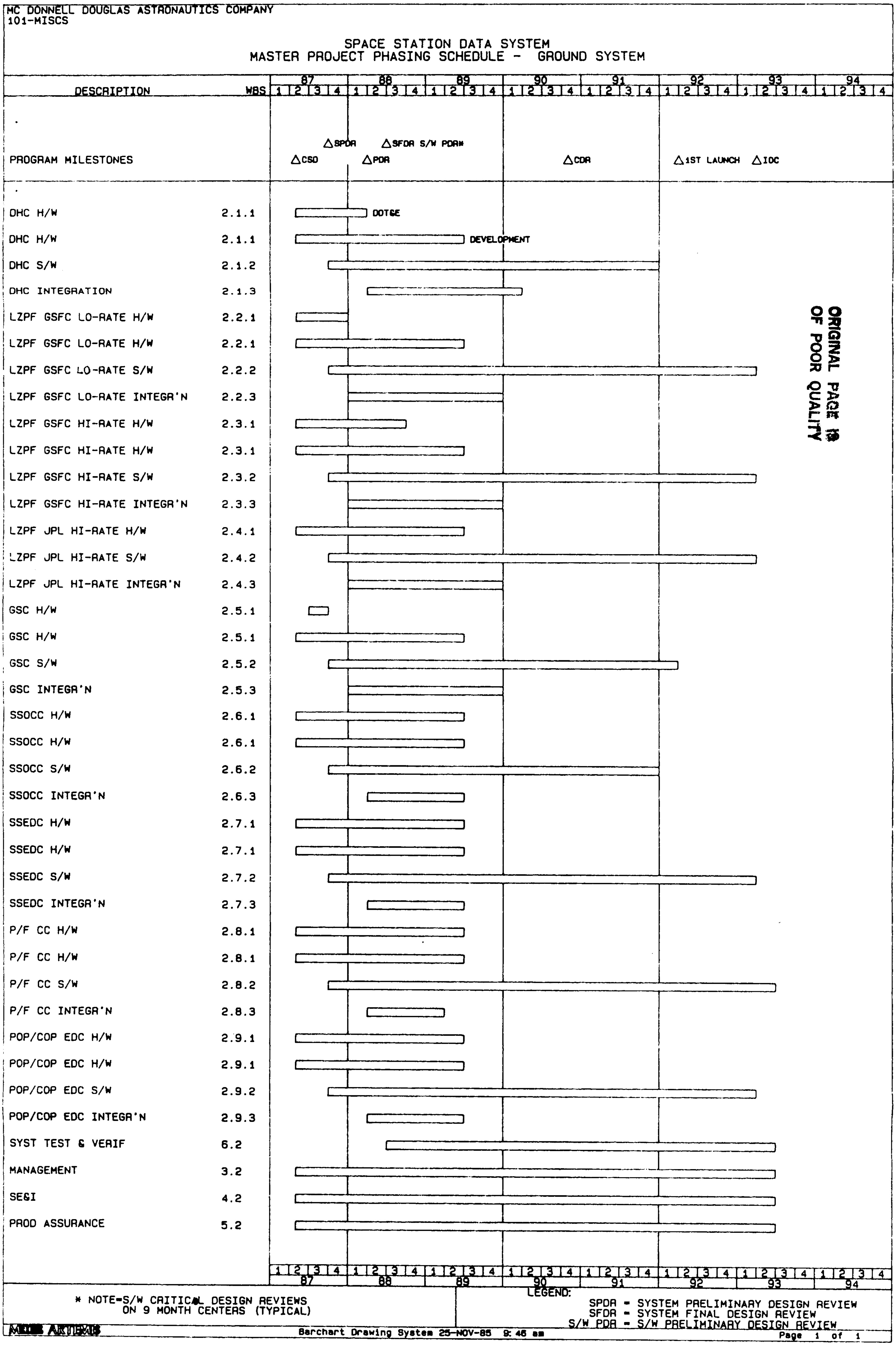

Figure 4.5-2

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5.0 ADVANCED TECHNOLOGY DEVELOPMENT RECOMMENDATIONS

5.1 INTRODUCTION

NASA has forecast technology development requirements for the Space Station Program based on earlier studies/analysis of the developing design requirements, and is supporting/funding those technologies through advanced development (A/D) project plans. It is the intent of this section to evaluate technology issues identified by the MDAC SSDS A/A Study against these NASA advanced development plans.

A summary of the NASA SSDS applicable advanced development tasks is provided in Section 5.3. Advanced Technology Development candidates identified by the Study are provided in Section 5.4 and the conclusions/recommendations resulting from the evaluation is provided in Section 5.5.

5.2 SCOPE

This effort will be limited to an assessment of those technologies directly utilized by the MDAC Study Task 4 System Definitions and to technologies that were discounted during the Task 3 trade studies because of "development risk". By NASA direction, only NASA sponsored development activities will be addressed; current/proposed industry IR&D activities have not been considered and were not factored into the Section 5.5 recommendations.

5.3 NASA ADVANCED TECHNOLOGY DEVELOPMENT SUMMARY

The NASA advanced development summary provided in this section is an extraction from two basic sources. The first is the "Space Station Data Management Advanced Development Project Plan" provided directly by NASA; the second source is the Commerce Business Daily which was surveyed for additional NASA sponsored activities in the SSDS technology areas.

The items in this section represent the study team assessment of the over-all NASA SSDS oriented advanced development plans.

o SSE Development Activities - JSC: Development of direct analytical support required for synthesis of SSE requirements in coherent formulations suitable for end-item management products. JSC also to provide a prototyping (SSE Computer) capability for evaluation of SSE software.

o ADA Evaluation/Implementation - JSC, Marshall Space Flight Center (MSFC), National Space Technology Laboratory (NSTL): JSC to develop guidelines for use of Ada for SSE and to evaluate detailed implications of Ada applied to 'real time' applications requiring rigorous verification. NSTL to code the Payload Simulator (Ref. Task 40) in Ada.

o Network/Bus Interface Units - JSC, GSFC: GSFC to design/prototype a hardware BIU for testing the GSFC Star Bus system. JSC to produce a commercially-derived "Multi-compatible Network Interface Unit", consistent with the OSI model, to support differing topologies.

o Gateway Development - GSFC: Development and prototyping of a gateway to couple the networks being developed at JSC and GSFC.

o Workstation Development - LARC: Development of a state-of-the-art flight type workstation for evaluation in the Test Bed. Will incorporate findings from 'User Interface' tasks.

o Space Qualified Computers - JPL: An assessment of VHSIC technology and its impact/applicability to IOC. Also includes development of steps required to harden candidate processors against SEU and total dose affects.

o User Accommodation/Interface Definition - GSFC, JSC: GSFC to prototype actual 'tail circuit' designs suitable for interface with representative payloads and for use in conjunction with DMS Test Bed. GSFC to define access protocols/techniques for user interface to DMS services. GSFC to develop a set of candidate techniques for payload command and control scenarios to be evaluated on the DMS Test Bed. GSFC, JSC to define requirements for standard user interface capability for on-board and ground access to DMS services.

o DMS Simulator - MSFC: Development of a rudimentary DMS Simulator to be used by the ACS Test Bed.

o End-to-end Activity - JSC: The merging of the DMS Test Bed in an end-to-end sense with customer (GSFC), C & T, and JSC Ground Support Operations Center Test Beds. Planning and conduct of specific end-to-end testing using prototype ground workstations to establish ground flight controller interface requirements is also included.

o Color Flat Panel Display LaRC: In conjunction with the Navy, and Army (ERADCOM), NASA is funding/managing a 2-phase contract with Planar Systems to develop a full color, electro-eluminescent display panel. Phase 1 is the development of thin film primary phosphor technique; the phase 2 goal is the development of a 6" diagonal, 240 X 320 pixel, full color display.

5.3.1 Space Station Data Management Advanced Development Project Plan

The "Space Station Data Management System Advanced Development Project Plan" consists of 42 separable tasks assigned to various NASA Centers to provide a coherent program for the development of tools and technologies targeted to the On-Board Data Management and the Software Support Environment. A complete summary of the project plan tasks is provided in Appendix D.

A number of the tasks are dedicated to the development/implementation of an operational Data Management System Test Bed. The remaining tasks are summarized by general subject below:

o Network Evaluation - Ames Research Center (ARC): An ongoing capability to comprehensively evaluate the Goddard Space Flight Center (GSFC) Fiber Optics Data System (FODS) network (Task 7); this capability is being expanded to model the Johnson Space Center (JSC) Fiber Distributed Data Interface (FDDI) Token Ring system (Task 13) and the IBM unique network in development (IR&D).

o Network Operating System - JSC, GSFC: Both centers are to develop and prototype complementary NOS segments, derived from commercial products, compatible with the Open Systems Interconnections (OSI) Model. The two segments are to be combined into one NOS for use on either the GSFC or JSC network topologies.

o International Standards Organization (ISO/OSI) Model Implementations: Commercial implementations and evolving industry standards are being comprehensively evaluated.

o LISP Processor/Expert Systems - JSC: Implementation of a LISP processor capability to host contractor developed "expert systems".

5.3.2 Survey Of Commerce Business Daily (CBD)

Two entries in the CBD were identified as independent from and supplemental to the activities of Section 5.3.1. These entry/activities are:

1. Non-Volatile Solid State Memory - LaRC (CBD Pub. Date 9/7/84): Demonstration of a high data rate, non-volatile solid state memory. The scope of work encompasses definition of two functional models using Metal Nitride Oxide Semiconductor (MNOS) and Silicon Nitride oxide Semiconductor (SNOS) devices.

2. Optical Disk Recorder (10 Gigabit) - GSFC (CBD Pub. Date 1/17/85): Development of ruggedized versions of commercially available technology. The initial phase will utilize available "write-once" devices then will address eraseable disk technology.

5.4 SSDS A/A Study Technology Development Candidates

In the course of the SSDS A/A Study, options developed in support of the functional requirements were evaluated within associated Task 3 Trade Studies to determine the preferred approach/technologies. In these trade studies, projected availability/development risk was a primary evaluation parameter. Consequently, the Task 4 system definitions include some "fall-back" solutions in cases where technically superior technologies were discounted because of development risk. To support a more comprehensive evaluation of the NASA plans, the set of advanced development candidates provided here includes not only technologies used directly in the Study system definitions but also those that, with intensive development, would provide a significant payoff for the Space Station Program. The total candidate list therefore consists of the following:

o Fiber Optic Network: The ANSI X3T9.5, a 100Mbps, ring topology, token access format network was selected for the On-Board local area network (LAN) design. This emerging standard must be prototyped/evaluated in support of preliminary SSDS design decisions.

o NIU: The Network Interface Unit for the On-Board system has been functionally defined to support OSI layer 1 through layer 4 services, and defined protocols, while satisfying the 100Mbps network data rate. This device must be prototyped and evaluated in terms of functionality and performance (throughput) in support of preliminary design decisions. Comparable devices being developed on DoD programs have demonstrated the NIU device to be in the critical path of the data processing system development. Hardware complexity is a design concern. This is reflected in terms of overall high parts count, high speed requirements related to the 100 Mbps fiber optic interface, a necessity for extensive built-in fault detection to maintain bus topology fault tolerance, and a layered design to accommodate technology insertion for post IOC.

o SDP: The standard data processor for the On-Board system was defined with a performance of 2MIPS and a 4MByte memory. Fault tolerance will be a requirement. VHSIC technology is anticipated with its performance and potential total dose radiation advantages. However the probability of a VHSIC SDP design to support IOC is questionable. Single event upset phenomenon will also remain an issue.

It is currently anticipated that the selection of an instruction set architecture must be made essentially at Space Station phase C/D contract start date. Since the onboard Data Management Subsystem must lend the other subsystem development, an off-the-shelf SDP might be a necessity. This implies that flight qualifiable a 2 MIP-4Mbyte design must exist within the next two years. If this is the case, then NASA must initiate near term activity related to the SDP.

o Protocols/Formats: Of the ISO/OSI for the LAN's and the CCSDS definitions for the Space-Space, and Space-Ground communication links is a essentially a Program given. End-to-end design, in terms of coherent packet formats, packet switching and data distribution, will result in additional evolution of at least the CCSDS formats/structures. However, in order to meet space station requirements some changes to the detailed CCSDS formats must be made. Overt action is requested on NASA's part to cause this to occur.

o Distributed Network Operating System: For the On-Board System, a networking, distributed processing architecture was defined supported by a distributed operating system. The DOS was functionally defined at a relatively high level and represents a significant development risk. A DOS of the space station complexity has never been designed and built before. Several systems in DoD programs have developed requirements and initiated breadboard level testing but none have been successful to-date. Partitioning of DOS functions between the SDP and the NIU along with what level of dynamic reconfiguration which can be allowed at the network level pose considerable alternatives. Network level redundancy management schemes may or may not be integral to the DOS design. Early function allocation and designs should be prototyped and exercised in a test bed environment.

o Distributed Data Base Management System (DBMS): The extensive amount of On-Board and On-Ground data must be updated and manipulated with a defined data consistency and minimal query response times. A distributed DBMS was selected for the On-Board design but represents a development risk. Commercial developments of distributed DBMS's have been under development for several years but no significant capability releases are in use to date. The ability to maintain a real time distributed data base and concurrently to provide application software a reasonable quantity of historical snapshots of the same data as well as other correlatable data poses a challenging DBMS design.

o Command/Resource Management: Allocation of resources to full payload complements and insuring that payload commands do not jeopardize the Station/Platform health and welfare or data quality of other payloads all while supporting telescience concept, is a major development item. The MDAC study made some in-roads on the subject but the concepts and methodologies were not completed. This subject, in conjunction with mission scheduling is pivotal to the customer utility. To complicate matters further the considerations of privacy and security provide other constraints in the command management implementation. The dynamics of the onboard core and payload state makes for a tremendous bookkeeping problem along with convenient methods for predictability of resource utilization.

Both commands and resource definition require large amounts of data. However, the most difficult thing to cope with is the development of the algorithms to use this data in a predictive and deterministic manner. Prototyping of these algorithms should be initiated as soon as possible in order to develop implementation options. Telescience transparency of commands and actual command delays need to be determined in order to assess computing requirements in terms of throughput, local memory and mass memory requirements. The questions of what level of parallelism can be achieved because of a distributed processor architecture must be analyzed and options developed. This also could have distributed operating system requirements implications.

o Read/Write Optical Disk: Re-writeable high speed, random access, high volume, mass storage is a fundamental requirement for the On-Orbit elements. The optical disk technology is being strongly supported based on government/industry needs however there remains some IOC readiness risk. Key application areas benefiting from this capability are the following:

A. Buffering of delayable payload data both in space
B. On-board space station data base.

Buffering requirements for payload data ranges from $2x10^{11}$ bits for the space base to $5x10^{11}$ bits for the POP. Typical on-board space station data base mass storage includes manuals and procedures, software and scheduling information with requirements has been estimated to be in the order of $2x10^{9}$ bits.

Eraseable optical disk is a relatively new technology that has the high capacity and transfer rate characteristics that make it a potential candidate for both On-Board and Ground data buffer/storage applications. With proper funding this device can be developed and ready for use in the 1992 timeframe.

o User Test and Control (Interface) Language: Development of a high level control language is key to the user friendliness, productivity, and telescience drivers. Experience with the Launch Procession System (LPS) goal language usage has shown too much tight coupling of the use of the language with the details of the LPS hardware architecture. The MDAC team has had similar experiences with supposed generic commercial test systems. The ability to develop a space station test and control language, its attendant preprocessors and architecture dependant execution restrictions and further without requiring the user to emulate computer programmer thought processes is a real challenge. To achieve the desire implementation goals will be a development process requiring user participation and feedback. Rapid prototyping of many of the desirable language features should be initiated immediately in order for the evolving requirements to be developed. The design of the language has to accommodate a large spectrum of users encompassing software developers, test engineers, scientists and ground controllers. While this may suggest many subsets, the ability to integrate these subsets into cost effective and practical size wise software implementation will require innovative designs.

o Flight Qualified AI Processors/Expert Systems: These elements were not selected for the MDAC System Definitions however they represent significant gains in meeting productivity, and autonomy drivers in the areas of scheduling, maintenance (and trouble-shooting), etc. Expert systems have emerged in the commercial world to a degree that several implementations are being use in a highly improved productivity applications. However, the implementations have been accomplished using small 6-10 engineer/programmer teams. Several applications for the space station promise significant productivity improvements if both the algorithms/inference engine designs can be developed. One such candidate is scheduling of space station resources, whether it be for power, thermal control or crew time. Of significance is the size of the development team required for this design. It certainly is an order of magnitude greater than has been done to date. To implement such a system onboard the space station would very likely require a flight qualified special purpose AI processor. While it is not expected that such processor will be available for IOC it is anticipated that they would be available shortly after IOC. Consequently, the significant increase in productivity and hence cost reduction is attractive enough for NASA to consider funding some development in this area.

o Color Flat Panel Displays: This technology, targetted primarily for On-Board workstations/displays, provides a distinct advantage over monochromatic displays which would result in gains in user/operator productivity. Color provides the potential for greatly increasing information coding capability and flexibility, as well as for reducing visual search time on complex displays. Secondly, luminance requirements can be reduced without a reduction in visibility of displayed information because of the addition of chromatic contrast. Color also provides for a greater degree of user productivity because of the aesthetic preference for working with color displays.

This technology is at an immature level. The advantages of brightness, contrast ratio, and viewing angle of thin film electro-illuminescent (TFEL) technology over the more mature color LCD technology dictate that advanced development effort be devoted to color TFEL. TFEL phosphors for red, blue, and green colors have been successfully developed, but have yet to reach performance levels obtained by manganese-doped zinc sulphide, the material used to produce yellow panels. Research effort needs to be directed toward development of new phosphors, and in particular, for the development of an efficient blue phosphor.

5.5 <u>Conclusions and Recommendations</u>

Evaluation of the NASA advanced development (A/D) plans against the candidate list provided in Section 5.4 led to the conclusion that a number of technologies need additional special emphasis and that the NASA A/D plans should be so adjusted. These technologies, with the A/D adjustment recommendations, are identified below.

1. Distributed Data Base Management - This technology must be pursued by NASA to insure that some level of maturity is available for On-Board and Ground system utilization. It is recommended that an A/D Task be established to evaluate available commercial systems and develop a prototype system for evaluation on the JSC DMS Test Bed.

2. End-to-end protocols/formats - Formats/protocols have a significant effect on efficiency, reliability and response times. It is recommended that Task 32 of the DMS A/D Project Plan be expanded to explicitly address evaluation of JPL/Contractor developed protocols/formats.

3. Command/Resource Management - The approach to this technology in Section 5.0 the Task 4 Report represents a preliminary attempt to meet the necessary payload resource allocation and the system safety requirements while satisfying the telescience concept requirements. A considerable amount of work/definition was provided on the subject however the concept must be developed further to not only satisfy customer needs but also the operator/core system needs. It is recommended that two efforts be initiated to develop this technology. First develop a simulation test bed to evaluate command management algorithms. Once an algorithm or set of algorithms have been developed, then use these algorithms in an end-to-end functional simulation of the commanding process. This functional simulation would then be exercised in a telescience mode to provide the human interface design performance. Programmed delays in this simulation would be used to modify algorithms and iterate until an acceptable end-to-end design or concept is achieved. A second effort would be to develop and evaluate time critical command/resource management design options on the (end-to-end) DMS test bed.

4. Flight Qualified AI Machines - On-Board AI (Lisp) machines to host 'expert system' applications represent significant potential autonomy/productivity increases. It is recommended that an A/D Task be established to sponsor this effort.

APPENDIX A
CODE S/CODE T ALLOCATION

		Implementation	Operation
I.	ONBOARD SSDS		
	o Space Station	Code S	Code S
	o POP1	Code S	Code S
	o POP2	Code S	Code S
	o COP	Code S	Code S
II.	GROUND SSDS		
	o DHC	Code T	Code T
	o LZPF's	Code T	Code T
	o GSC	Code S	Code S
	o SSOCC	Code S	Code S
	o SSEDC	Code S	Code S
	o P/F CC	Code T	Code T
	o P/F EDC	Code S	Code S

APPENDIX B
NASA DMS TEST BED ADVANCED DEVELOPMENT
PROJECT PLAN TASKS

NETWORK EVALUATION:

Task 1 - Extended Network Analysis - ARC

An ongoing network analysis capability that is being expanded to evaluate the performance of the GSFC FODS network being developed under Task 7. The ARC simulation is being expanded to model the FDDI Token Ring System under development by JSC (Task 13) as well as the IBM-unique network currently being developed under IR&D funding. It provides a NASA capability to conduct relevant, comparable analytical evaluations of candidate network configurations arising from Phase B. The ARC simulation will also provide the basis for a "calibrated" analysis tool which can be refined as Phase C/D progresses with the end result being a valuable verification capability to support post-IOC performance analyses as additional demands are made of the DMS Network.

DMS TEST BED:

Coordinated tasks to fund engineering and operation activities required to put the "test environment" in place and/or operate equipment supporting that environment.

Task 18 - DMS Test Bed Engineering - JSC

Task 19 - DMS Test Bed Operations - JSC

Task 27 - S/W Test Bed Operations - JSC

END-TO-END TEST BED:

Task 32 - End-to-End Test Bed JSC

Merges the DMS Test Bed in an end-to-end sense with customer (GSFC) and the Communication and Tracking, and JSC Ground Support Operations Center Test Beds. Also covers planning and conduct of specific end-to-end testing using prototype ground workstations to establish ground flight controller interface requirements.

DMS SIMULATION:

Task 38 - Data Subsystem Network Technology - MSFC

Provides funds for completion of a rudimentary DMS Simulator to be used by the Attitude Control System (ACS) Test Bed. The DMS/User ICD presently used for the DMS Test Bed is being provided MSFC for guidance in structuring a representative interface between the simulator and ACS.

NETWORK OPERATING SYSTEM:

Complementary segments from JSC and GSFC for the study and prototyping of Network Operating Systems derived from commercial products that accomplish the software functions of the ISO model. The intent is to segment those tasks such that each center "delivers" complementary elements of a standard NOS with the further requirement the the two products combine, consistent with the appropriate ISO layering, to form one NOS for use on either the GSFC or JSC network topologies.

Task 8 - GSFC NOS (ISO Layers 3 & 4)

Task 29 - JSC NOS (ISO Layers 5, 6 & 7)

Task 23 - SSE System Software Studies - JSC

JSC to perform study/prototyping activity investigating the applicability of commercially available O/S to on-board O/S and NOS requirements.

NETWORK/BUS INTERFACE UNITS:

Task 7 - Optical BIU - GSFC

GSFC to design/prototype a hardware BIU required for FY-86 testing of the GSFC Star Bus system. That BIU is being effectively used as a "pathfinder" for specific study activities conducted under Tasks 8, 13, and 29.

Task 12 - MCNIU - JSC

JSC to produce a commercially-derived device, referred to as the Multi-compatible Network Interface Unit (MCNIU) which will provide potential Test Bed users with multiple options for transparent interfacing with different topologies and/or differing degrees of computational support consistent with accepted layering defined by the ISO/OSI model.

GATEWAY:

Task 9 - Star to Ring Gateway - GSFC

GSFC to develop and provide a prototype gateway to effectively couple the 'star' and 'ring' networks being developed at GSFC and JSC respectively. Will offer an opportunity for both centers to utilize the gateway in support of the DMS Test Bed end-to-end evaluations and to explore some specific issues known to exist relative to gateway implementation.

ISO/OSI MODEL IMPLEMENTATION:

Task 13 - DMS Interface Standards - JSC

JSC to perform the study and prototyping activity to define actual electronic implementations of the lower two layers of the MCNIU. Commercial implementations and evolving industry standards are being comprehensively evaluated for applicability to the required designs.

AI/EXPERT SYSTEMS:

Task 15 - DMS Expert Systems - JSC

Investigation of expert system technology for applicabiity to Automated Fault Detection and Isolation system.

Task 25 - Expert Systems - JSC

Develop and prototype an expert system of the type anticipated for use on Space Station.

SPACE QUALIFIED COMPUTERS:

Task 14 - Processor Technology - JSC

Essentially a VHSIC technology assessment with a final report advising NASA of the anticipated impact and applicability of VHSIC technology to IOC. This (FY-87 funded only) task takes advantage of the unique expertise of JPL in the area of Space Radiation effects on electronic devices. The intent is to have JPL provide a detailed definition of any steps required to harden a candidate processor against single event upset (SEU) and total dose effects.

Task 41 - Flight Processor Space Qualification Definition - JPL

Develop a program development plan for space qualifying a specific processor based on Level B analysis.

HOL/ADA ACTIVITIES:

Task 31 - Ada Target and Benchmark - JSC

Provides results such that the SSE designers are given a set of guidelines relative to the use of Ada for specific purposes. This task continues with increased focus on the very detailed implications of actually using Ada in real-time applications requiring rigorous verification techniques.

Task 39 - Ada Development Tools - MSFC

Procures development tools (cross-compilers, editors, etc.). Also supplements MSFC's capability to implement the ACS applications code in Ada.

Task 40 - Payload Simulator - NSTL

Payload simulator will be designed from information provided by GSFC, MSFC, and JSC, and will provide the end-to-end Test Bed with capability for conducting representative "closed loop" operations studies as well as assessing the interaction of various types of payloads on the onboard DMS elements. Task 40 is augmented with sufficient funds to allow NSTL to code the P/L Simulator using Ada.

Task 21 - Ada Evaluation - JPL

JPL support to JSC in evaluation of Ada as a Space Station High-Order Language (HOL). Task will develop a set of metrics and a decision matrix for the evaluation process.

Task 10 - Evaluation of Ada For Users - GSFC

The objective of the task is to acquire advanced software support environments related to Ada for evaluation. Ada application will be evaluated through the use of selected pilot applications for GSFC SS functions.

USER ACCOMMODATION/INTERFACE DEFINITION:

Task 3 - Customer Interface Adapter - GSFC

Prototypes actual "end-circuit" designs suitable for interfacing with representative payloads GSFC has identified. Will provide the DMS Test Bed with the capability early in phase C to actually accommodate selected real payload electrical interfaces for "high-fidelity" point design trade studies.

Task 4 - User Data Flow Management - GSFC

Produces and evaluates user access protocols/techniques for the (user transparent) management, storage and retrieval of payload, engineering, and ancillary data from distributed data bases.

Task 5 - User Interface Technology - GSFC

A coordinated effort with Tasks 6, 33, and 34 to support the SSE RFP with definition of requirements for a standard user interface capability suitable for onboard and ground access to DMS services. Encompasses the total spectrum of "users" from on-board system and payload control to ground telescience operations as well as ground pre-launch checkout operations.

Task 6 - P/L Cmmd and Control Techniques - GSFC

Produces a set of candidate techniques for P/L Command and Control scenarios that will be eventually evaluated in the end-to-end test bed environment.

Task 33 - User Interface Studies - JSC

Develops a common user interface to access On-Board/Ground SSDS segments. Integrates GSFC, KSC and JSC user interface language (UIL) tasks.

Task 34 - SS Operations Language - KSC

Specifies operations language and associated utilities in support of test and integration community.

WORKSTATIONS/DISPLAYS:

Task 16 - Displays & Controls - JSC

Provides a set of requirements for SS Displays and Controls and evaluates commercially available D & C devices.

Task 37 - Control/Display Interface Technology - LaRC

Provides a state-of-the-art flight-type workstation for evaluation in the Test Bed environment with the implicit acceptance that the device should evolve into an actual part of the Test Bed environment by supporting detailed development of operational scenarios during the early Phase C design phase. Its design will incorporate recommendations and lessons learned from Tasks 3, 4, 33, and 34.

SSE ACTIVITIES:

Task 22 - S/W Engineering Support - JSC

Provides direct analytical support required for synthesis of SSE requirements into coherent formulations suitable for end-item products.

Task 26 - S/W Test Bed (SSE Computer) - JSC

Procures a host mainframe computer for the Test Bed to provide a prototyping capability for the evaluation of SSE S/W.

MISCELLANEOUS:

Task 2 - Enhanced Telemetry - GSFC

This task will evaluate high rate Data Handling Center requirements. An SS requirements analysis with DHC options mapped to the requirements/assumptions plus a modular architecture design derivation will be performed as the first two sub-tasks. Expansion methodology and technology drivers will be identified to weigh the On-Board vs Ground data handling options, (packetization, calibrations, etc.).

Task 11 - Subsystem Test and Checkout - JSC

This task will investigate techniques and procedures for monitoring and evaluating the performance of spacecraft subsystems. Areas of investigation include automated fault detection and isolation, data base design, data management systems and crew interfaces.

Task 28 - SIB Development - JSC

Prototypes a Simulation Interface Buffer (SIB).

Task 35 - Software Reliability Technology - LaRC

This task will supplement on-going research to establish the reliability effectiveness of software fault-tolerance techniques.

Task 36 - Optical Transceiver Module - LaRC

Funds the development of a fiber optic transmitter/receiver to satisfy a common set of requirements for both NASA and DoD. The transceiver will cover the data range from 200 to 1000Mbps.