Prepared for the
GEORGE C MARSHALL
SPACE FLIGHT CENTER
Huntsville, Alabama

MAY, 1975

Contract No NAS8-31009
IBM No 75W-00072

IUS/TUG ORBITAL OPERATIONS and MISSION SUPPORT STUDY

FINAL REPORT

Vol V of V - Cost Estimates

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Classification and Content Approval ______________________

Data Manager Approval William H McCumber

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FOREWORD

This final report of the IUS/Tug Orbital Operations and Mission Study was prepared for the National Aeronautics and Space Administration, George C Marshall Space Flight Center by the IBM Corporation in accordance with Contract NAS8-31009

The study effort described herein was conducted under the direction of NASA Contract Officer's Representative (COR), Mr. Sidney P Saucier This report was prepared by the IBM Corporation, Federal Systems Division, Huntsville, Alabama, under the direction of Mr Roy E Day, IBM Study Manager Technical support was provided to IBM by the Philco-Ford Corporation, Western Development Laboratories Division, Palo Alto, California, under the direction of Dr W E Waters, Philco-Ford Study Manager The study results were developed during the period from June, 1974, through February, 1975, with the final report being distributed in May, 1975.

The results of this study have been documented in five separate volumes

Volume I	Executive Summary
Volume II	IUS Operations
Volume III	Tug Operations
Volume IV	Project Planning Data
Volume V	Cost Estimates

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ACRONYMS AND ABBREVIATIONS

ACN -	Ascension Island, STDN Ground Station
ACS -	Attitude Control System
ADS -	Advanced Data System
AFSCF -	Air Force Satellite Control Facility
AFSTC -	Air Force Satellite Test Center
AGE -	Automated Ground Equipment
AGO -	Santiago, Chile - STDN Ground Station
AOS -	Acquisition of Signal
AZ-EL -	Azimuth - Elevation
BDA -	Bermuda (U K) - STDN Ground Station
B/U -	Backup
C&D -	Control and Display
C&W -	Caution and Warning
CCTV -	Closed Circuit Television
CMDS -	Command
C/O -	Checkout
CYI -	Canary Island - STDN Ground Station
DFCS -	Digital Flight Control System
DMS -	Data Management System
DoD -	Department of Defense
DSN -	Deep Space Network
EIUS -	Expendable Interim Upper Stage
EVA -	Extravehicular Activity
FPS -	Feet Per Second
GDS -	Goldstone, Calif - STDN Ground Station
GMT -	Greenwich Mean Time
GN&C -	Guidance, Navigation and Control
GND -	Ground
GPCF -	General Purpose Control Facility
GSE -	Ground Support Equipment
GSFC -	Goddard Space Flight Center, Greenbelt, MD
GWM -	Guam Island - STDN Ground Station
HAW -	Hawaii - STDN Ground Station
HSK -	Honeysuckle Creek (Canberra), Australia - STDN Ground Station
IGPS -	Inertial Guidance Power System
IGS -	Inertial Guidance System
IMU -	Inertial Measuring Unit
IUS -	Interim Upper Stage
IUS/OC -	Interim Upper Stage Operations Center

JPL - Jet Propulsion Lab, Pasadena, California
JSC - Johnson Spacecraft Center, Houston, Texas

KADS - Kilo-Add Instruction Executions Per Second
KBPS - Kilobits Per Second
KM - Kilometers
KOPS - Kilo-Operations Per Second
KS - Kick Stage
KSA - Ku-Band Single-Access
KSC - Kennedy Space Center, Cape Canaveral, Florida

LOS - Loss of Signal/Line of Sight
LPS - Launch Processing System

MA - Multiple Access
MAD - Madrid, Spain - STDN Ground Station
M&O - Maintenance and Operations
MBPS - Megabits Per Second
MCC - Mission Control Center
MDM - Multiplexer/Demultiplexer (Orbiter)
MGC - Missile Guidance Computer (IUS)
MHz - Megahertz
MIL - Merritt Island, Florida - STDN Ground Station
MPS - Main Propulsion System
MSFC - Marshall Space Flight Center, Huntsville, Alabama
MSS - Mission Specialist Station (Orbiter)

NASA - National Aeronautics and Space Administration
NASCOM - NASA Communications Network
NOCC - Networks Operations Control Center

ODS - Orbit Determination System
ORR - Orroral, Australia - STDN Ground Station
OS - Operating System (Software)

PCM - Pulse Code Modulation
PDI - Payload Data Interleaver (Orbiter)
PMOCC - Pioneer Mission Operations Control Center
PMS - Performance Monitoring System
PN - Pseudonoise
POCC - Project Operations Control Center
PSP - Payload Signal Processor (Orbiter)
PSS - Payload Specialist Station (Orbiter)
PU - Propellant Utilization

QUI - Quito, Equador - STDN Ground Station

ACRONYMS AND ABBREVIATIONS (Continued)

RCS - Reaction Control System (Orbiter)
RF - Radio Frequency
RFI - Radio Frequency Interference
RIUS - Reusable Interim Upper Stage
RMIS - Remote Multiplexer Instrumentation System (IUS)
RMS - Remote Manipulator System (Orbiter)
RMU - Remote Multiplexer Unit (IUS)
ROS - Rosman, N C - STDN Ground Station
R&RR - Range and Range Rate
RTCC - Real Time Computer Complex
RTS - Remote Tracking Station

SA - Single Access
S/C - Spacecraft
SCF - Satellite Control Facility
SGLS - Space Ground Link System
SIRD - Support Instrumentation Requirements Document
SOC - Spacecraft Operations Center
SPO - Space Project Office
SSA - S-Band Single Access
STDN - Spaceflight Tracking and Data Network

TAN - Tananarive, Malagasy Republic - STDN Ground Station
TBD - To Be Determined
TDRS - Tracking and Data Relay Satellite
TDRSS - Tracking and Data Relay Satellite System
TM - Telemetry
TOC - Tug Operations Center
TTY - Teletype

ULA - Fairbanks, Alaska - STDN Ground Station

Vdc - Direct Current Voltage

ZOE - Zones of Exclusion

ΔV - Delta Velocity

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1 0 COSTING APPROACH, METHODOLOGY AND RATIONALE

This section details the various approaches utilized in generating the cost data for the Composite IUS and Space Tug Orbital Operations and Mission Support program

1 1 IUS/TUG ORBITAL OPERATIONS AND MISSION SUPPORT WORK BREAKDOWN STRUCTURE

When viewed from the standpoint of mission operations, the IUS program and the Space Tug program are a single entity This tends to confound the process of segregating the IUS work breakdown structure from the Space Tug work breakdown structure

The IUS work breakdown structure and the Space Tug work breakdown structure were constructed independently and are presented as Tables 1 1 0-1 and 1 1 0-2 respectively A review of Tables 1 1 0-1 and 1 1 0-2 will indicate that minimum difference exists between the structure developed for IUS and the structure developed for Space Tug. In a practical sense, this means that there is a duplication of work elements between the two programs It is reasonable to make certain assumptions (1) that there will be a single control center build to house both IUS and Space Tug operations, (2) there will be a single computer complex designated to support IUS and Tug operations, (3) certain major blocks of ground software will be common to both the IUS and Space Tug programs.

Table 1 1.0-3 is the combined IUS and Space Tug work breakdown structure In Table 1.1 0-3 the IUS elements have been subordinated to the Space Tug elements where duplication exists Since the Space Tug program is the surviving program, the major hardware and software assets common to both programs have been charged against the Space Tug in the integrated work breakdown structure From the standpoint of overall cost to the government, the integrated work breakdown structure is more pertinent than either the IUS or Space Tug individual work breakdown structure, and will be used through the remainer of this volume as the baseline to which all comments are relevant. Figure 1 1 0-1 illustrates the Space Tug work breakdown structure hierarchy.

The Space Tug orbital operations and mission support work breakdown structure is subordinate to an overall Space Tug project WBS and is designed to be integrated with the basic Space Tug project work breakdown structure The IUS work breakdown structure is similar in form and content to the Space Tug work breakdown structure, thus it is a simple matter to identify the appropriate relationship of IUS elements to an independent IUS program, in the event that funding must be segregated between the programs in the mission operations area

Table 1 1 0-1 IUS WBS Identification Number Sequence

IDENTIFICATION NUMBER	ELEMENT	LEVEL
XXX	IUS PROJECT	3
XXX-01	Project Management	4
XXX-01-01	Cost/Performance Management	5
XXX-01-01-01	Cost Control System	5
XXX-01-01-02	Schedule Control System	6
XXX-01-02	Project Direction	5
XXX-01-02-01	Development Management	6
XXX-01-02-01-01	Contract Software Development	7
XXX-01-02-01-02	Plan Facility Utilization	7
XXX-01-02-01-03	Computer Utilization Plan	7
XXX-01-02-01-04	Maintenance Schedule	7
XXX-01-02-01-05	Hire Control and Support Staff	7
XXX-01-02-01-06	Obtain IUS System Characteristics	7
XXX-01-02-01-07	Prepare IUS Interagency Documents	7
XXX-01-02-01-08	IUS Interagency Coordination	7
XXX-01-02-02	Quality Management	6
XXX-01-02-03	Logistics Management	6
XXX-01-02-04	Engineering Administration	6
XXX-01-03	Information Management	6
XXX-02	Systems Engineering	4
XXX-02-01	IUS Systems Engineering	5
XXX-02-01-01	Master Launch Schedule Analysis	6
XXX-02-01-02	IUS Mission Characterization	6
XXX-02-01-03	Determine IUS Failure Modes	6
XXX-02-02	Shuttle Interface	5
XXX-02-03	Payload Interface	5
XXX-02-04	Sustaining Engineering	5
XXX-02-04-01	Flight Control Engineering	6
XXX-02-04-01-01	Mission Phase Manning Requirements	7
XXX-02-04-01-02	IUS Console Position Guidelines	7
XXX-02-04-01-03	Define IUS Operator Certification/Criteria	7
XXX-02-04-01-04	Validation Test Requirements-Fundamental IUS Ground Programs	7
XXX-02-04-01-05	IUS Ground Validation Test Requirements	7
XXX-02-04-02	Flight Support Engineering	6
XXX-02-04-02-01	Select Operational Data System	7
XXX-02-04-03	Mission Engineering	6
XXX-02-04-03-01	IUS Mission Planning and Optimization	7
XXX-02-04-03-02	IUS Abort Planning	7
XXX-02-04-05	Mission Evaluation Engineering	6
XXX-02-04-05-01	IUS Post Mission Reports	7
XXX-03	IUS Vehicle Main Stage	4
XXX-05	Logistics	4
XXX-05-01	Transportation and Handling	5
XXX-05-02	Training	5

Table 1 1.0-1. IUS WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
XXX-05-02-01	Simulators and Equipment	6
XXX-05-02-02	Ground Crew Training	6
XXX-05-02-03	Flight Operations Crew Training	6
XXX-05-02-03-01	IUS Training Requirement/Criteria/Simsked	7
XXX-05-02-03-02	Develop IUS Training Material	7
XXX-05-02-03-03	Design IUS Mission Simulation	7
XXX-05-02-03-04	IUS Classroom Training	7
XXX-05-02-03-05	IUS Mission Simulation Training	7
XXX-06	Facilities	4
XXX-06-01	Manufacturing	5
XXX-06-02	Test	5
XXX-06-03	Maintenance and Refurbishment	5
XXX-06-04	ETR Launch	5
XXX-06-05	WTR Launch	5
XXX-06-06	Flight Operations Facility	5
XXX-06-06-01	Size Facility/Design Physical Plant	6
XXX-06-06-02	Construct Physical Plant	6
XXX-07	Ground Support Equipment (GSE)	4
XXX-07-01	Manufacturing and Test GSE	5
XXX-07-02	Eastern Test Range GSE	5
XXX-07-03	Western Test Range GSE	5
XXX-07-04	Flight Operations GSE	5
XXX-07-04-01	Install Operational Data System	6
XXX-07-04-02	Install Operational Consoles/Hardware	6
XXX-08	Vehicle Test	4
XXX-09	Launch Operations	4
XXX-10	Flight Operations	4
XXX-10-01	Mission Planning and Documentation	5
XXX-10-01-01	Develop IUS Procedures and Rules	6
XXX-10-01-02	IUS Mission Failure Effects	6
XXX-10-01-03	Analyze IUS Component Characteristics	6
XXX-10-01-04	Flight Control Systems Handbook	6
XXX-10-01-04-01	Prepare IUS Systems Handbook	7
XXX-10-01-04-02	Publish/Update IUS Systems Handbook	7
XXX-10-01-05	IUS Network Interface Documentation	6
XXX-10-01-05-01	Define Network Tracking Requirements	7
XXX-10-01-05-02	Network Tracking Validation Procedures	7
XXX-10-01-05-03	IUS Network Data Handling Pequirements	7
XXX-10-01-05-04	IUS Network Data Validation Procedures	7
XXX-10-02	Operational Preparations	5
XXX-10-02-01	Design Network Interface System	6
XXX-10-02-02	Console Organization	6
XXX-10-02-03	IUS Display Format Design	6
XXX-10-03	Mission Readiness Testing	5
XXX-10-03-01	Network Tracking Validation Tests	6
XXX-10-03-02	IUS Network Validation Tests	6
XXX-10-04	Conduct IUS Mission Operations	5
XXX-11	Refurbishment and Integration	4

Table 1 1 0-1 IUS WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
XXX-15	Software	4
XXX-15-01	Flight Software	5
XXX-15-01-01	Plan Flight Software Development	6
XXX-15-01-02	Baseline Flight Program Development	6
XXX-15-01-02-01	EDD - IUS Flight Program	7
XXX-15-01-02-02	Program IUS Flight Software	7
XXX-15-01-02-03	IUS Flight Program Verification	7
XXX-15-01-03	Mission Specific Program Modification	6
XXX-15-01-03-01	IUS Mission Specific EDD	7
XXX-15-01-03-02	IUS Mission Specific Program	7
XXX-15-01-03-03	IUS Mission Program Verification	7
XXX-15-02	Ground Software	5
XXX-15-02-01	Plan Ground Software Development	6
XXX-15-02-02	Equation Definition	6
XXX-15-02-02-01	EDD - Executive/Tracking/Planning	7
XXX-15-02-02-02	EDD - IUS Dndata/Updata/Sim	7
XXX-15-02-03	Programming	6
XXX-15-02-03-01	Program Ground EX/TK/Planning SW	7
XXX-15-02-03-02	Program IUS Dndata/Updata/Sim	7
XXX-15-02-04	Program Verification	6
XXX-15-02-04-01	Verify Executive/TK/Planning SW	7
XXX-15-02-04-02	Verify IUS Dndata/Updata/Sim	7
XXX-15-02-05	Mission Specific Simulation	6
XXX-15-02-05-01	Program IUS Mission Simulation	7
XXX-15-03	Computer Selection Support	5
XXX-15-03-01	Estimate Ground Software Size	6
XXX-16	Orbiter Interface	4

Table 1 1 0-2 Space Tug WBS Identification Number Sequence

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320	SPACE TUG PROJECT	3
320-01	Project Management	4
320-01-01	Cost/Performance Management	5
320-01-01-01	Cost Control System	5
320-01-01-02	Schedule Control System	6
320-01-02	Project Direction	5
320-01-02-01	Development Management	6
320-01-02-01-01	Contract Software Development	7
320-01-02-01-02	Plan Facility Utilization	7
320-01-02-01-03	Computer Utilization Plan	7
320-01-02-01-04	Maintenance Schedule	7
320-01-02-01-05	Hire Control and Support Staff	7
320-01-02-01-06	Obtain Space Tug System Characteristics	7
320-01-02-01-07	Prepare Tug Interagency Documents	7
320-01-02-01-08	Tug Interagency Coordination	7
320-01-02-02	Quality Management	6
320-01-02-03	Logistics Management	6
320-01-02-04	Engineering Administration	6
320-01-03	Information Management	6
320-02	Systems Engineering	4
320-02-01	Tug Systems Engineering	5
320-02-01-01	Master Launch Schedule Analysis	6
320-02-01-02	Tug Mission Characterization	6
320-02-01-03	Determine Tug Failure Modes	6
320-02-02	Shuttle Interface	5
320-02-03	Payload Interface	5
320-02-04	Sustaining Engineering	5
320-02-04-01	Flight Control Engineering	6
320-02-04-01-01	Mission Phase Manning Requirements	7
320-02-04-01-02	Tug Console Position Guidelines	7
320-02-04-01-03	Define Tug Operator Certification/Criteria	7
320-02-04-01-04	Validation Test Requirements-Fundamental Tug Ground Programs	7
320-02-04-C1-05	Tug Ground Validation Test Requirements	7
320-02-04-02	Flight Support Engineering	6
320-02-04-02-01	Select Operational Data System	7
320-02-04-03	Mission Engineering	6
320-02-04-03-01	Tug Mission Planning and Optimization	7
320-02-04-03-02	Tug Abort Planning	7
320-02-04-05	Mission Evaluation Engineering	6
320-02-04-05-01	Tug Post Mission Reports	7
320-03	Tug Vehicle Main Stage	4
320-05	Logistics	4
320-05-01	Transportation and Handling	5
320-05-02	Training	5

Table 1 1.0-2. Space Tug WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-05-02-01	Simulators and Equipment	6
320-05-02-02	Ground Crew Training	6
320-05-02-03	Flight Operations Crew Training	6
320-05-02-03-01	Tug Training Requirement/Criteria/Simsked	7
320-05-02-03-02	Develop Tug Training Material	7
320-05-02-03-03	Design Tug Mission Simulation	7
320-05-02-03-04	Tug Classroom Training	7
320-05-02-03-05	Tug Mission Simulation Training	7
320-06	Facilities	4
320-06-01	Manufacturing	5
320-06-02	Test	5
320-06-03	Maintenance and Refurbishment	5
320-06-04	ETR Launch	5
320-06-05	WTR Launch	5
320-06-06	Flight Operations Facility	5
320-06-06-01	Size Facility/Design Physical Plant	6
320-06-06-02	Construct Physical Plant	6
320-07	Ground Support Equipment (GSE)	4
320-07-01	Manufacturing and Test GSE	5
320-07-02	Eastern Test Range GSE	5
320-07-03	Western Test Range GSE	5
320-07-04	Flight Operations GSE	5
320-07-04-01	Install Operational Data System	6
320-07-04-02	Install Operational Consoles/Hardware	6
320-08	Vehicle Test	4
320-09	Launch Operations	4
320-10	Flight Operations	4
320-10-01	Mission Planning and Documentation	5
320-10-01-01	Develop Tug Procedures and Rules	6
320-10-01-02	Tug Mission Failure Effects	6
320-10-01-03	Analyze Tug Component Characteristics	6
320-10-01-04	Flight Control Systems Handbook	6
320-10-01-04-01	Prepare Tug Systems Handbook	7
320-10-01-04-02	Publish/Update Tug Systems Handbook	7
320-10-01-05	Tug Network Interface Documentation	6
320-10-01-05-03	Tug Network Data Handling Requirements	7
320-10-01-05-04	Tug Network Data Validation Procedures	7
320-10-02	Operational Preparations	5
320-10-02-01	Design Network Interface System	6
320-10-02-02	Console Organization	6
320-10-02-03	Tug Display Format Design	6
320-10-03	Mission Readiness Testing	5
320-10-03-02	Tug Network Validation Tests	6
320-10-04	Conduct Tug Mission Operations	5
320-11	Refurbishment and Integration	4

Table 1 1 0-2 Space Tug WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-15	Software	4
320-15-01	Flight Software	5
320-15-01-01	Plan Flight Software Development	6
320-15-01-02	Baseline Flight Program Development	6
320-15-01-02-01	EDD - Tug Flight Program	7
320-15-01-02-02	Program Tug Flight Software	7
320-15-01-02-03	Tug Flight Program Verification	7
320-15-01-03	Mission Specific Program Modification	6
320-15-01-03-01	Tug Mission Specific EDD	7
320-15-01-03-02	Tug Mission Specific Program	7
320-15-01-03-03	Tug Mission Program Verification	7
320-15-02	Ground Software	5
320-15-02-01	Plan Ground Software Development	6
320-15-02-02	Equation Definition	6
320-15-02-02-01	EDD - Executive/Planning	7
320-15-02-02-02	EDD - Tug Dndata/Updata/Docking/Sim	7
320-15-02-03	Programming	6
320-15-02-03-01	Program Ground EX/Planning SW	7
320-15-02-03-02	Program Tug Dndata/Updata/Docking/Sim	7
320-15-02-04	Program Verification	6
320-15-02-04-01	Verify Executive/Planning SW	7
320-15-02-04-02	Verify Tug Dndata/Updata/Docking/Sim	7
320-15-02-05	Mission Specific Simulation	6
320-15-02-05-01	Program Tug Mission Simulation	7
320-15-03	Computer Selection Support	5
320-15-03-01	Estimate Ground Software Size	6
320-16	Orbiter Interface	4

Table 1 1 0-3. Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320	SPACE TUG PROJECT	3
320-01	Project Management	4
320-01-01	Cost/Performance Management	5
320-01-01-01	Cost Control System	5
320-01-01-02	Schedule Control System	6
320-01-02	Project Direction	5
320-01-02-01	Development Management	6
320-01-02-01-01	Contract Software Development	7
320-01-02-01-02	Plan Facility Utilization	7
320-01-02-01-03	Computer Utilization Plan	7
320-01-02-01-04	Maintenance Schedule	7
320-01-02-01-05	Hire Control and Support Staff	7
320-01-02-01-06	Obtain Space Tug System Characteristics	7
320-01-02-01-07	Prepare Tug Interagency Documents	7
320-01-02-01-08	Tug Interagency Coordination	7
XXX-01-02-01-06	Obtain IUS System Characteristics	7
XXX-01-02-01-07	Prepare IUS Interagency Documents	7
XXX-01-02-01-08	IUS Interagency Coordination	7
320-01-02-02	Quality Management	6
320-01-02-03	Logistics Management	6
320-01-02-04	Engineering Administration	6
320-01-03	Information Management	6
320-02	Systems Engineering	4
320-02-01	IUS/Tug Systems Engineering	5
320-02-01-01	Master Launch Schedule Analysis	6
320-02-01-02	Tug Mission Characterization	6
320-02-01-03	Determine Tug Failure Modes	6
XXX-02-01-02	IUS Mission Characterization	6
XXX-02-01-03	Determine IUS Failure Modes	6
320-02-02	Shuttle Interface	5
320-02-03	Payload Interface	5
320-02-04	Sustaining Engineering	5
320-02-04-01	Flight Control Engineering	6
320-02-04-01-01	Mission Phase Manning Requirements	7
320-02-04-01-02	Tug Console Position Guidelines	7
320-02-04-01-03	Define Tug Operator Certification/Criteria	7
320-02-04-01-04	Common Ground Software Validation Test Requirements	7
320-02-04-01-05	Tug Ground Validation Test Requirements	7
XXX-02-04-01-05	IUS Ground Validation Test Requirements	7
XXX-02-04-01-02	IUS Console Position Guidelines	7
XXX-02-04-01-03	Define IUS Operator Certification/Criteria	7
320-02-04-02	Flight Support Engineering	6
320-02-04-02-01	Select Operational Data System	7

Table 1 1 0-3 Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-02-04-03	Mission Engineering	6
320-02-04-03-01	Tug Mission Planning and Optimization	7
320-02-04-03-02	Tug Abort Planning	7
XXX-02-04-03-01	IUS Mission Planning and Optimization	7
XXX-02-04-03-02	IUS Abort Planning	7
320-02-04-05	Mission Evaluation Engineering	6
320-02-04-05-01	Tug Post Mission Reports	7
XXX-02-04-05-01	IUS Post Mission Reports	7
320-03	Tug Vehicle Main Stage	4
320-05	Logistics	4
320-05-01	Transportation and Handling	5
320-05-02	Training	5
320-05-02-01	Simulators and Equipment	6
320-05-02-02	Ground Crew Training	6
320-05-02-03	Flight Operations Crew Training	6
320-05-02-03-01	Tug Training Requirement/Criteria/Simsked	7
320-05-02-03-02	Develop Tug Training Material	7
320-05-02-03-03	Design Tug Mission Simulation	7
320-05-02-03-04	Tug Classroom Training	7
320-05-02-03-05	Tug Mission Simulation Training	7
XXX-05-02-03-01	IUS Training Requirement/Criteria/Simsked	7
XXX-05-02-03-02	Develop IUS Training Material	7
XXX-05-02-03-03	Design IUS Mission Simulation	7
XXX-05-02-03-04	IUS Classroom Training	7
XXX-05-02-03-05	IUS Mission Simulation Training	7
320-06	Facilities	4
320-06-01	Manufacturing	5
320-06-02	Test	5
320-06-03	Maintenance and Refurbishment	5
320-06-04	ETR Launch	5
320-06-05	WTR Launch	5
320-06-06	Flight Operations Facility	5
320-06-06-01	Size Facility/Design Physical Plant	6
320-06-06-02	Construct Physical Plant	6
320-07	Ground Support Equipment (GSE)	4
320-07-01	Manufacturing and Test GSE	5
320-07-02	Eastern Test Range GSE	5
320-07-03	Western Test Range GSE	5
320-07-04	Flight Operations GSE	5
320-07-04-01	Install Operational Data System	6
320-07-04-02	Install Operational Consoles/Hardware	6
320-08	Vehicle Test	4
320-09	Launch Operations	4
320-10	Flight Operations	4
320-10-01	Mission Planning and Documentation	5
320-10-01-01	Develop Tug Procedures and Rules	6
XXX-10-01-01	Develop IUS Procedures and Rules	6
320-10-01-02	Tug Mission Failure Effects	6
XXX-10-01-02	IUS Mission Failure Effects	6
320-10-01-03	Analyze Tug Component Characteristics	6
XXX-10-01-03	Analyze IUS Component Characteristics	6

Table 1 1 0-3. Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-10-01-04	Flight Control Systems Handbook	6
320-10-01-04-01	Prepare Tug Systems Handbook	7
320-10-01-04-02	Publish/Update Tug Systems Handbook	7
XXX-10-01-04-01	Prepare IUS Systems Handbook	7
XXX-10-01-04-02	Publish/Update IUS Systems Handbook	7
320-10-01-05	Tug Network Interface Documentation	6
XXX-10-01-05-01	Define Network Tracking Requirements	7
XXX-10-01-05-02	Network Tracking Validation Procedures	7
320-10-01-05-03	Tug Network Data Handling Requirements	7
320-10-01-05-04	Tug Network Data Validation Procedures	7
XXX-10-01-05-03	IUS Network Data Handling Requirements	7
XXX-10-01-05-04	IUS Network Data Validation Procedures	7
320-10-02	Operational Preparations	5
320-10-02-01	Design Network Interface System	6
320-10-02-02	Console Organization	6
320-10-02-03	Tug Display Format Design	6
XXX-10-02-03	IUS Display Format Design	6
320-10-03	Mission Readiness Testing	5
XXX-10-03-01	Network Tracking Validation Tests	6
320-10-03-02	Tug Network Validation Tests	6
XXX-10-03-02	IUS Network Validation Tests	6
320-10-04	Conduct Tug Mission Operations	5
XXX-10-04	Conduct IUS Mission Operations	5
320-11	Refurbishment and Integration	4
320-15	Software	4
320-15-01	Flight Software	5
320-15-01-01	Plan Flight Software Development	6
320-15-01-02	Baseline Flight Program Development	6
320-15-01-02-01	EDD - Tug Flight Program	7
320-15-01-02-02	Program Tug Flight Software	7
320-15-01-02-03	Tug Flight Program Verification	7
XXX-15-01-02-01	EDD - IUS Flight Program	7
XXX-15-01-02-02	Program IUS Flight Software	7
XXX-15-01-02-03	IUS Flight Program Verification	7
320-15-01-03	Mission Specific Program Modification	6
320-15-01-03-01	Tug Mission Specific EDD	7
320-15-01-03-02	Tug Mission Specific Program	7
320-15-01-03-03	Tug Mission Program Verification	7
XXX-15-01-03-01	IUS Mission Specific EDD	7
XXX-15-01-03-02	IUS Mission Specific Program	7
XXX-15-01-03-03	IUS Mission Program Verification	7
320-15-02	Ground Software	5
320-15-02-01	Plan Ground Software Development	6
320-15-02-02	Equation Definition	6
320-15-02-02-01	EDD - Executive/Tracking/Planning	7
320-15-02-02-02	EDD - Tug Dndata/Updata/Docking/Sim	7
XXX-15-02-02-02	EDD - IUS Dndata/Updata/Sim	7
320-15-02-03	Programming	6

Table 1 1 0-3 Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-15-02-03-01	Program Ground EX/TK/Planning SW	7
320-15-02-03-02	Program Tug Dndata/Updata/Docking/Sim	7
XXX-15-02-03-02	Program IUS Dndata/Updata/Sim	7
320-15-02-04	Program Verification	6
320-15-02-04-01	Verify Executive/TK/Planning SW	7
320-15-02-04-02	Verify Tug Dndata/Updata/Docking/Sim	7
XXX-15-02-04-02	Verify IUS Dndata/Updata/Sim	7
320-15-02-05	Mission Specific Simulation	6
320-15-02-05-01	Program Tug Mission Simulation	7
XXX-15-02-05-01	Program IUS Mission Simulation	7
320-15-03	Computer Selection Support	5
320-15-03-01	Estimate Ground Software Size	6
320-16	Orbiter Interface	4

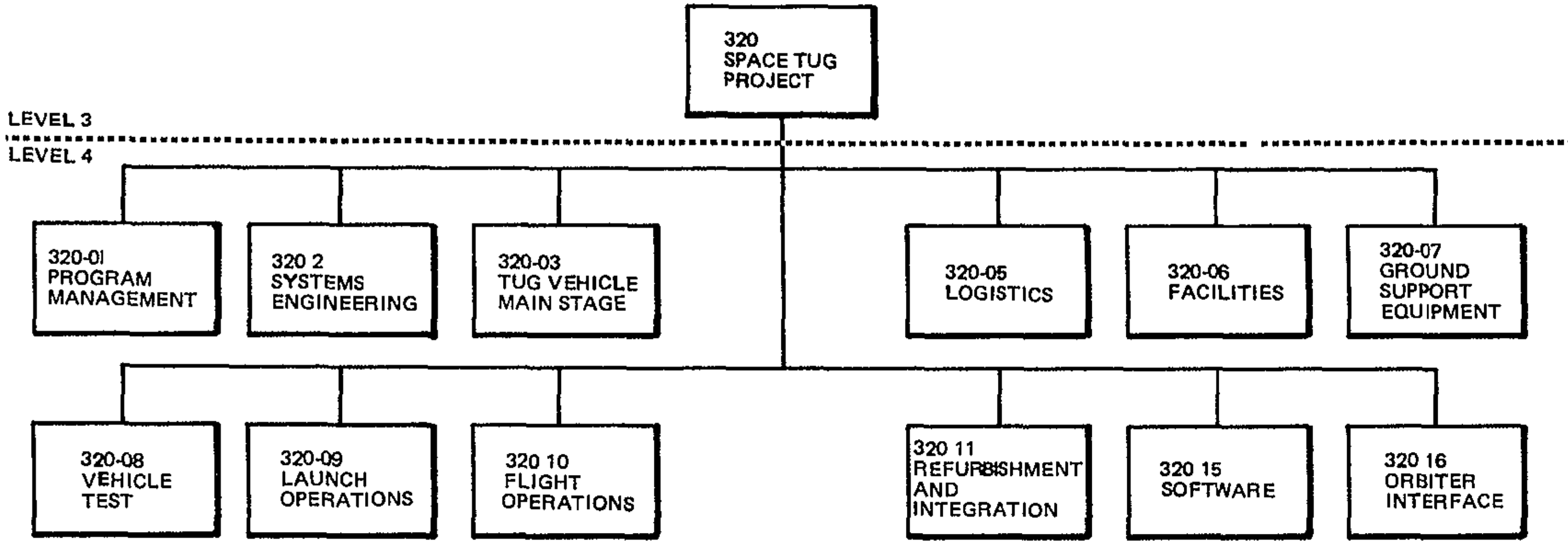

Figure 1 1 0-1 (a) Space Tug Work Breakdown Structure Heirarchy Overview

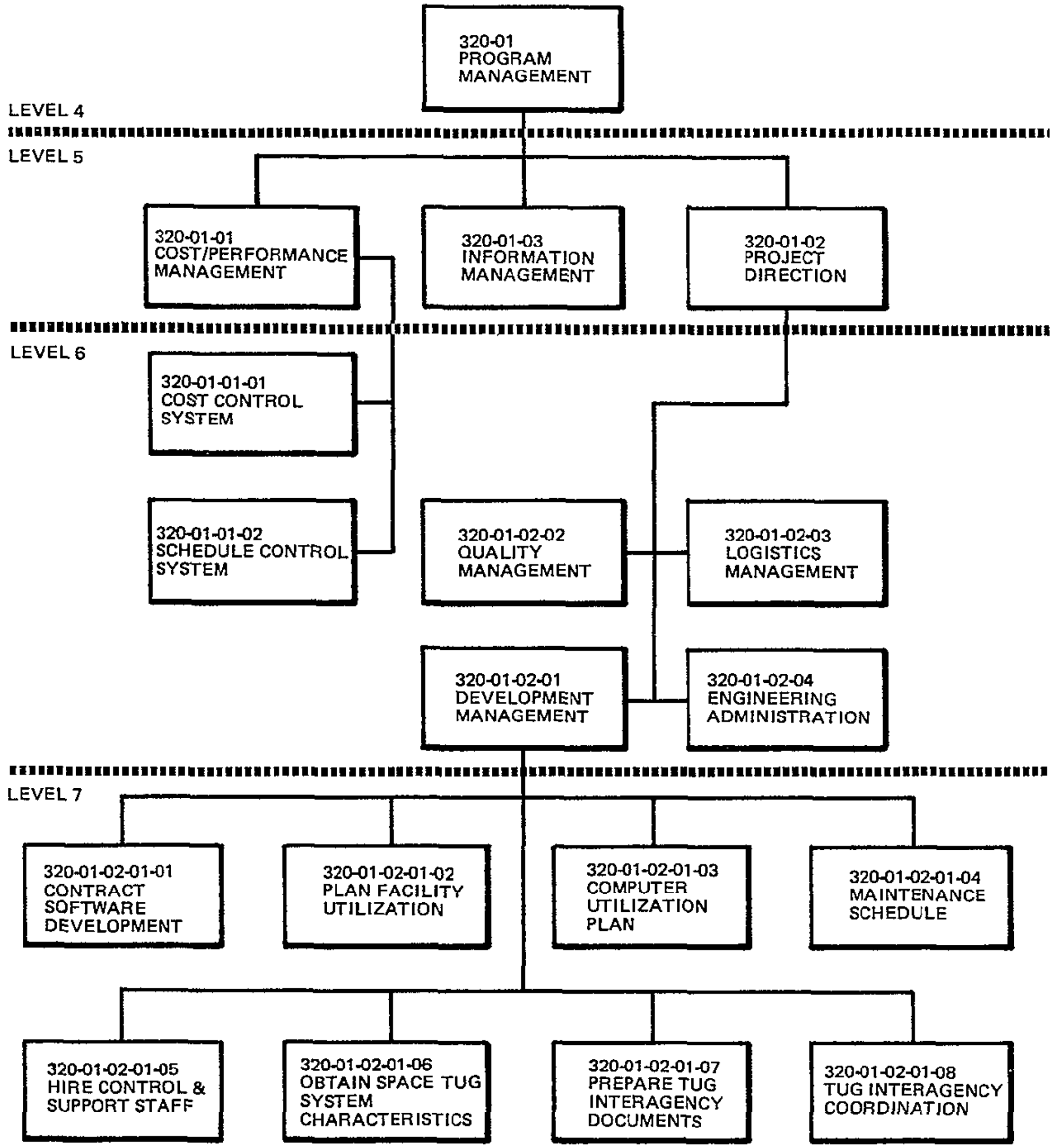

Figure 1 1 0-1(b) OO/MS Program Management NBS

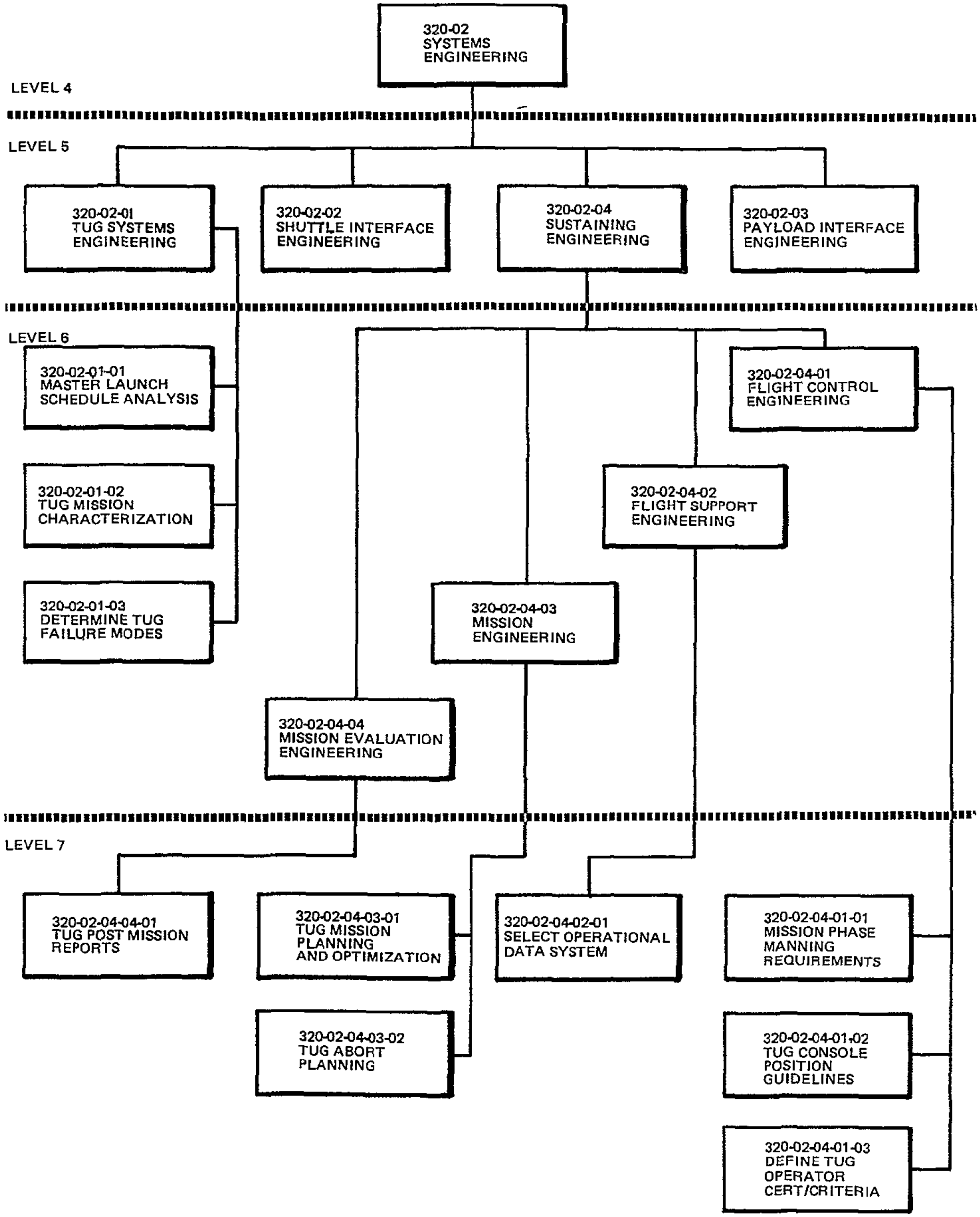

Figure 1 1 0 1 (c) OO/MS Systems Engineering WBS

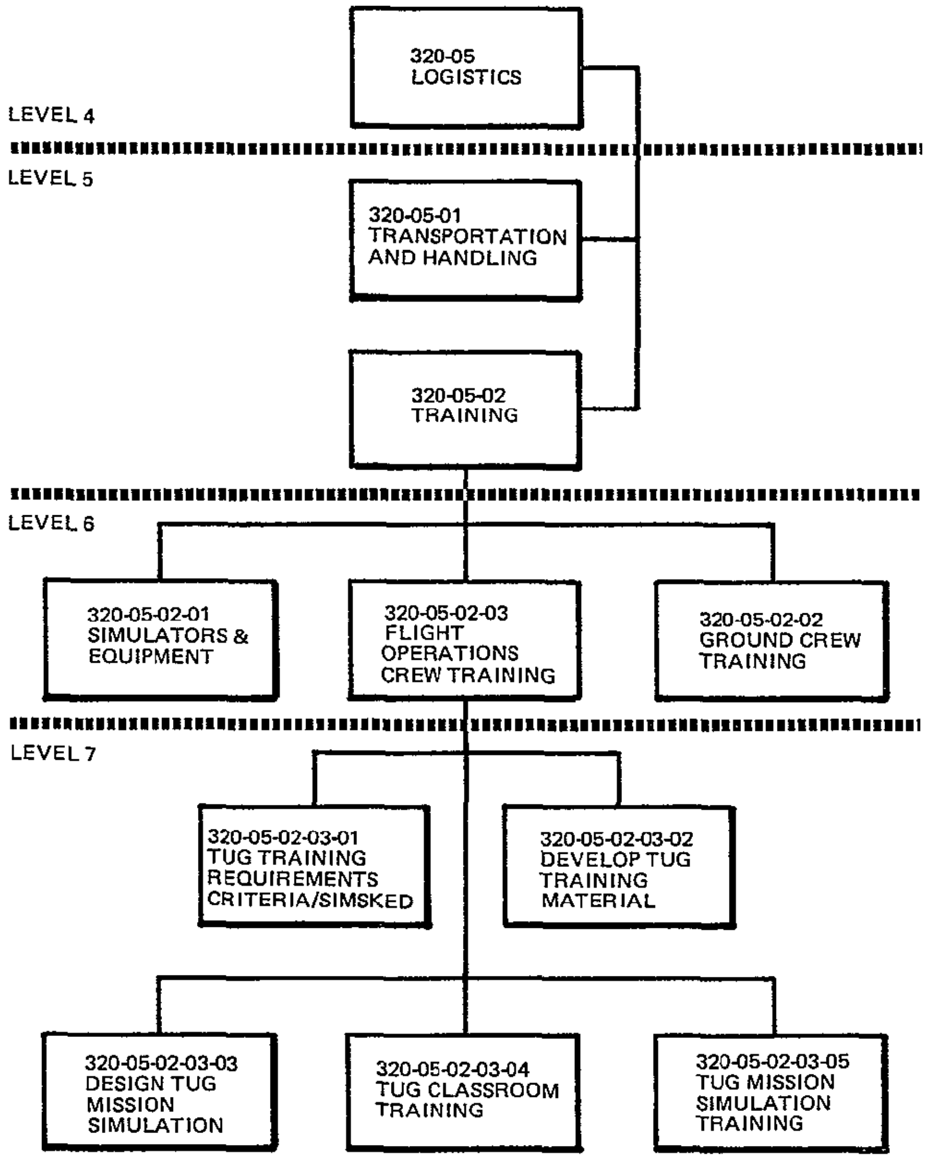

Figure 1 1 0-1 (d) OO/MS Logistics WBS

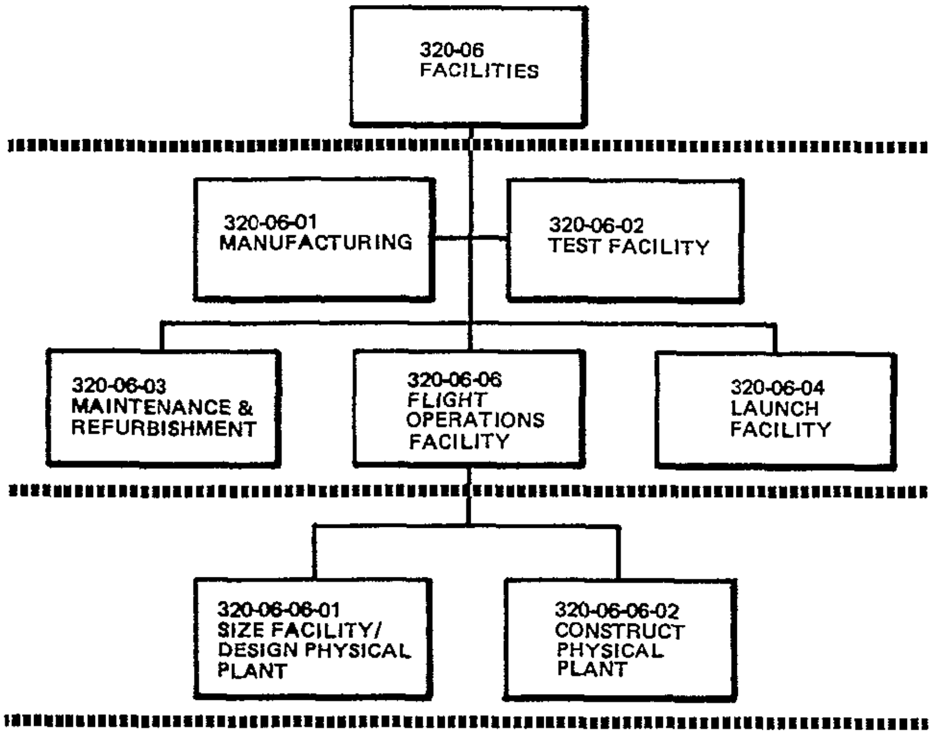

Figure 1 1 0-1 (e) OO/MS Facilities WBS

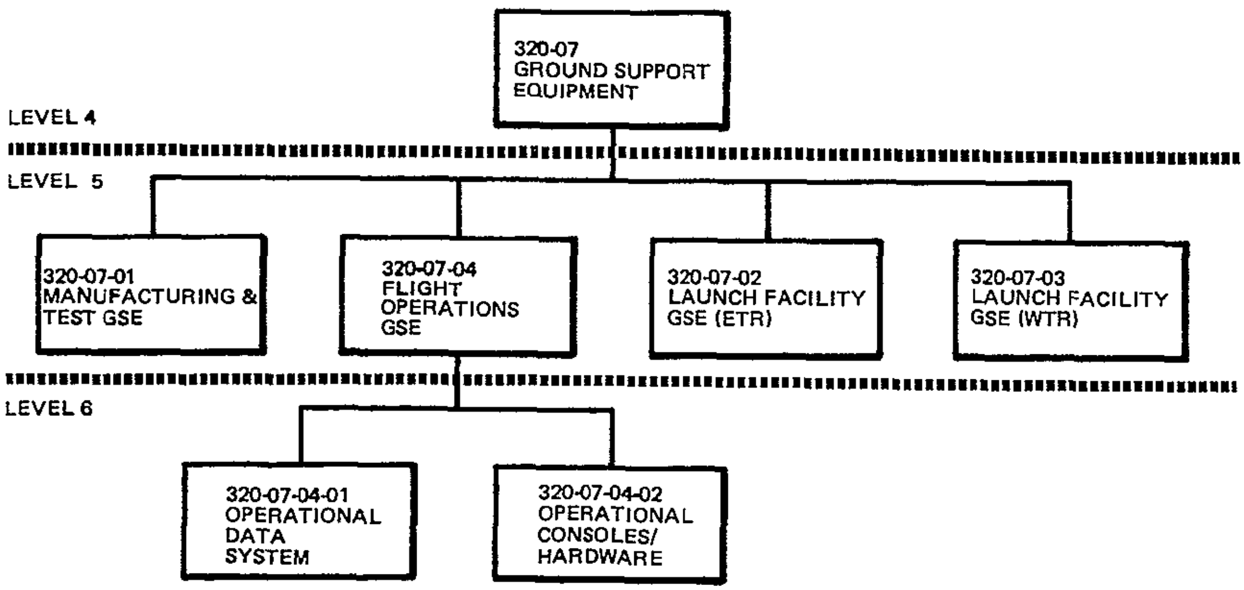

Figure 1 1 0-1 (f) OO/MS Ground Support Equipment WBS

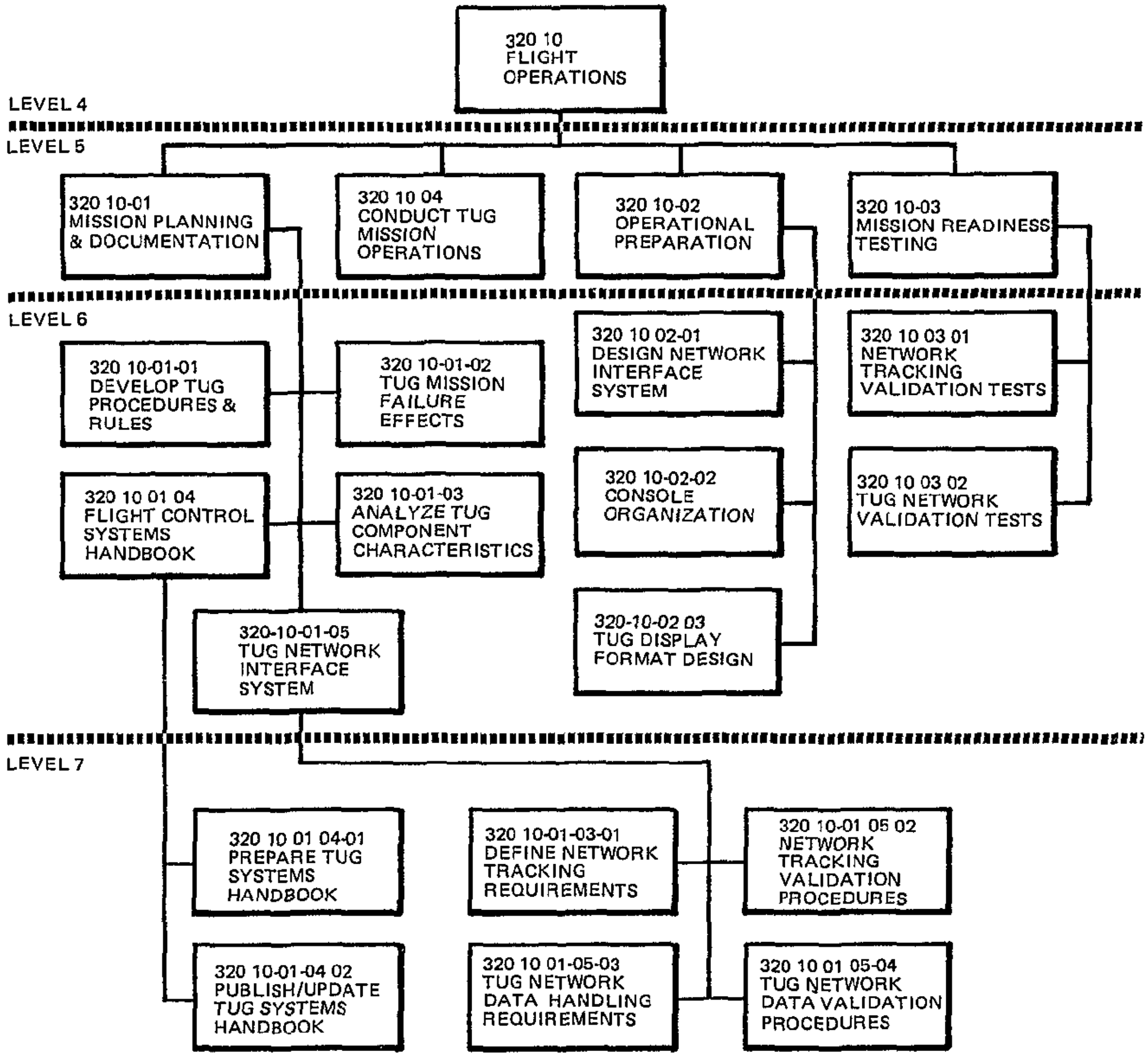

Figure 1 1 0 1 (g) OO/MS Flight Operations WBS

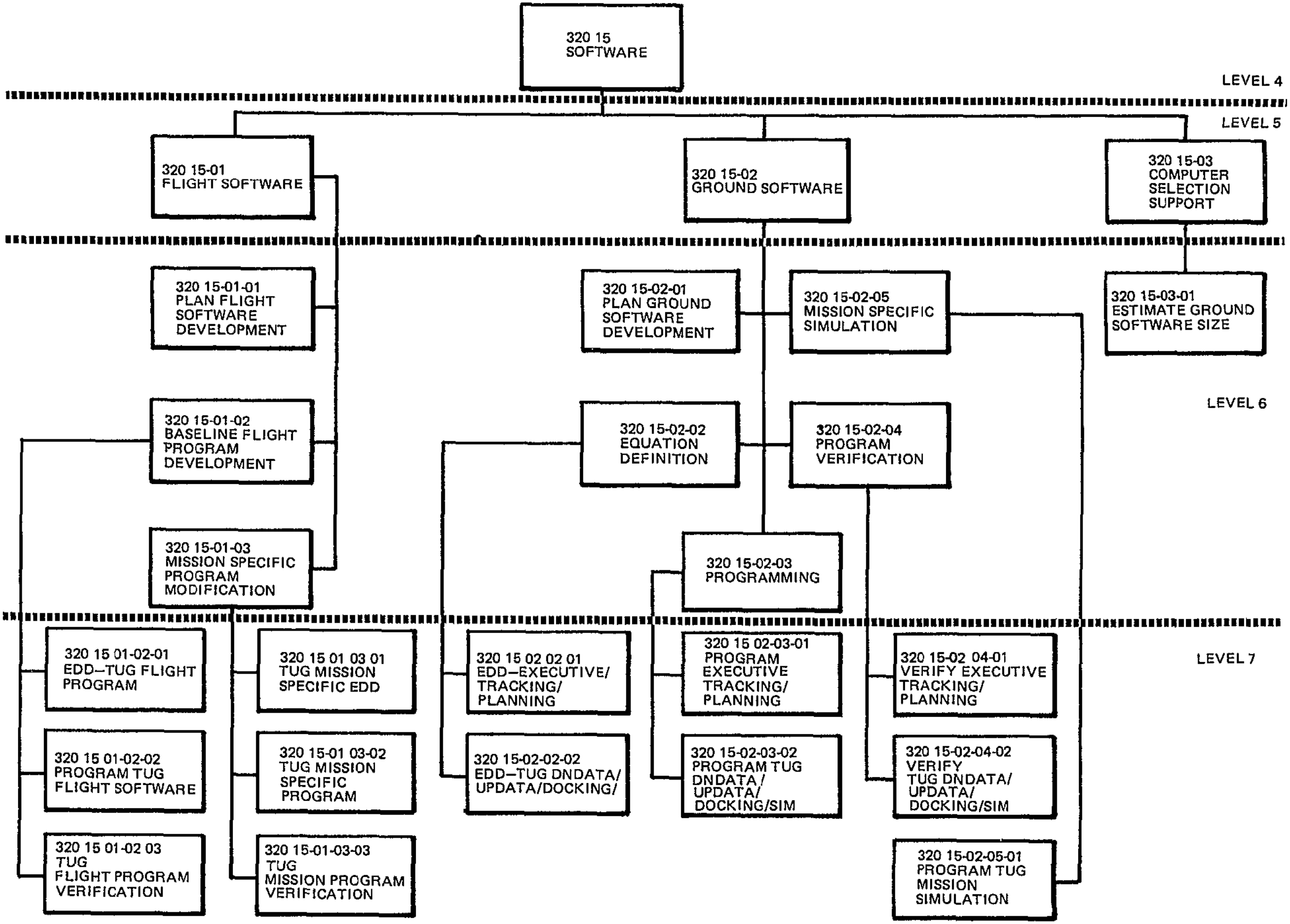

Figure 1 1 0 1 (h) OO/MS Software WBS

1.1 1 DDT&E Elements of the Work Breakdown Structure

The DDT&E portions of this work breakdown structure consists of all tasks, material, hardware and services required to design, develop and test mission operations control center hardware, ground software, flight software, flight operations planning and simulation processes, physical plant design and construction, and data processing capabilities required to implement a concept of mission operations

The point of separation between DDT&E operations and recurring operations has been selected as the termination of the first cycle of mission operations That is, all preparations, design, development, test and checkout have been completed and one IUS mission flown before the IUS DDT&E period is terminated Similarly, all design, development and testing which is peculiar to the Space Tug will have been completed and the first Space Tug mission flown prior to terminating the DDT&E period for the Space Tug program

DDT&E can be said to begin for the IUS program in January, 1977, terminating with conduct of mission operations and post mission reporting in April, 1981 The Space Tug program will begin final DDT&E development in February, 1982, and DDT&E will be considered complete by December, 1983, which terminates the first Space Tug mission cycle It should be emphasized that some portions of the Space Tug DDT&E are included within the IUS DDT&E time period. So, to be completely accurate, the Space Tug mission operations and DDT&E period must also be considered to begin in January, 1977, although minimum activity occurs relevant to Space Tug DDT&E prior to February, 1982 The above times and dates refer to the program development plan presented in Volume IV of this final report.

The composite DDT&E work breakdown structure elements fall into the following six categories the physical plant, operations center software development, data system procurement and installation, operations staff equipment procurement and installation, IUS software development and Space Tug flight software development.

The physical plant, computer and operations staff equipment will be common to the IUS and Space Tug programs A large part of the software, in the area of operating system and mission planning functions, will be common and shared between the IUS and Space Tug However, the special problems involved in decommutating the telemetry data streams of each vehicle will require additional software over and above the common software, unless there is an effort made early in the program to standardize the telemetry formats and information content of the IUS and Space Tug avionics systems Similarly, the command system may either be unique to the IUS and Space Tug programs or, with proper planning, be a part of the common software package The flight software for IUS and the flight software for Space Tug will be unique The flight software will be developed in two stages First the basic mission types will be programmed (four basic programs have been estimated) and then each successive mission will be programmed as an additive or substitutive module to one of the four basic programs It is this additive module which will be the recurring portion of the flight software task

Items such as the mission peculiar requirements embodied in the flight program are listed as DDT&E items for the first IUS mission and the first Space Tug mission All subsequent flight program module modifications will be chargeable as recurring costs

1 1 2 Recurring Costs Elements

Table 1 1 2-1 is the composite integrated Space Tug/IUS work breakdown structure identification number sequence for the recurring elements of cost These recurring cost elements fall into seven general categories facility maintenance, operation center software maintenance, data system maintenance, sustaining support engineering, sustaining flight control engineering, network utilization expenses and flight software maintenance

The major elements of cost in the recurring cost category are operation center software maintenance, sustaining support engineering, sustaining flight control engineering, and flight software maintenance These are all directly relatable to personnel level of effort type activities The remaining elements facility maintenance, data system maintenance, and network rental are services for which the Tug control agency must pay a fee.

Figure 1.1.2-1 presents a typical operation cycle in terms of launch minus time in weeks Included within the area under the mission operation cycle curve are all activities which are included on the recurring work breakdown structure table It is intended that the maintenance of the operations hardware be performed by the operations support personnel, and that the training for the conduct for operations be conducted by flight control operational personnel, and that the conduct of simulations for flight control operations be handled by flight support personnel Making maximum utilization of the available manpower to accomplish the recurring tasks is cost effective in that the "dead" time between missions is eliminated and the full manpower compliment is engaged actively in support of the operations effort For this reason it is recommended that the operations phase be funded as a level of effort and the recurring cost work breakdown structure be utilized as a guide in directing the activities of permanently assigned mission operations personnel

1.2 COSTING METHODOLOGY - DDT&E

There are 96 individual tasks costed. These tasks fall into five general categories physical plant, ground software development, data system, staff equipment and flight software Those tasks not falling into one of the foregoing general categories are treated as miscellaneous tasks. For the most part, the miscellaneous tasks involve manpower expenditures only

1 2 1 Physical Plant

It has been assumed for the purposes of this study that no existing facilities will be utilized This requires that a separate physical plant be designed to house the flight control, flight support, data system, and ancillary areas required to support the flight control functions

Table 1 1 2-1 Recurring Cost Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320	SPACE TUG PROJECT	3
320-01	Project Management	4
320-01-02	Project Direction	5
320-01-02-01	Development Management	6
320-01-02-01-07	Prepare Tug Interagency Documents	7
320-01-02-01-08	Tug Interagency Coordination	7
320-01-02-01-09	Tug Network Rental	7
XXX-01-02-01-07	Prepare IUS Interagency Documents	7
XXX-01-02-01-08	IUS Interagency Coordination	7
XXX-01-02-01-09	IUS Network Rental	7
320-02	Systems Engineering	4
320-02-04	Sustaining Engineering	5
320-02-04-03	Mission Engineering	6
320-02-04-03-01	Tug Mission Planning and Optimization	7
320-02-04-03-02	Tug Abort Planning	7
XXX-02-04-03-01	IUS Mission Planning and Optimization	7
XXX-02-04-03-02	IUS Abort Planning	7
320-02-04-05	Mission Evaluation Engineering	6
320-02-04-05-01	Tug Post Mission Reports	7
XXX-02-04-05-01	IUS Post Mission Reports	7
320-03	Space Tug Vehicle Mainstage	4
320-05	Logistics	4
320-05-02	Training	5
320-05-02-03	Flight Operations Crew Training	6
320-05-02-03-01	Tug Training Requirement/Criteria/Simsked	7
320-05-02-03-02	Develop Tug Training Material	7
320-05-02-03-03	Design Tug Mission Simulation	7
320-05-02-03-04	Tug Classroom Training	7
320-05-02-03-05	Tug Mission Simulation Training	7
XXX-05-02-03-01	IUS Training Requirement/Criteria/Simsked	7
XXX-05-02-03-02	Develop IUS Training Material	7
XXX-05-02-03-03	Design IUS Mission Simulation	7
XXX-05-02-03-04	IUS Classroom Training	7
XXX-05-02-03-05	IUS Mission Simulation Training	7
320-06	Facilities	4
320-06-06	Flight Operations Facility	5
320-06-06-03	Plant Maintenance	6
320-07	Ground Support Equipment (GSE)	4
320-07-04	Flight Operations GSE	5
320-07-04-03	Data System Maintenance	6
320-08	Vehicle Test	4
320-09	Launch Operations	4

Table 1 1 2-1 Recurring Cost Composite Integrated Space Tug/IUS Work Breakdown Structure WBS Identification Number Sequence (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-10	Flight Operations	4
320-10-01	Mission Planning and Documentation	5
320-10-01-01	Develop Tug Procedures and Rules	6
XXX-10-01-01	Develop IUS Procedures and Rules	6
320-10-01-04	Flight Control Systems Handbook	6
320-10-01-04-01	Prepare Tug Systems Handbook	7
320-10-01-04-02	Publish/Update Tug Systems Handbook	7
XXX-10-01-04-01	Prepare IUS Systems Handbook	7
XXX-10-01-04-02	Publish/Update IUS Systems Handbook	7
320-10-01-05	Network Interface Documentation	6
XXX-10-01-05-01	Define Network Tracking Requirements	7
XXX-10-01-05-02	Network Tracking Validation Procedures	7
320-10-01-05-03	Tug Network Data Handling Requirements	7
320-10-01-05-04	Tug Network Data Validation Procedures	7
XXX-10-01-05-03	IUS Network Data Handling Requirements	7
XXX-10-01-05-04	IUS Network Data Validation Procedures	7
320-10-03	Mission Readiness Testing	5
XXX-10-03-01	Network Tracking Validation Tests	6
320-10-03-02	Tug Network Validation Tests	6
XXX-10-03-02	IUS Network Validation Tests	6
320-10-04	Conduct Tug Mission Operations	5
XXX-10-04	Conduct IUS Mission Operations	5
320-11	Refurbishment and Integration	4
320-15	Software	4
320-15-01	Flight Software	5
320-15-01-03	Mission Specific Program Modification	6
320-15-01-03-01	Tug Mission Specific EDD	7
320-15-01-03-02	Tug Mission Specific Program	7
320-15-01-03-03	Tug Mission Program Verification	7
XXX-15-01-03-01	IUS Mission Specific EDD	7
XXX-15-01-03-02	IUS Mission Specific Program	7
XXX-15-01-03-03	IUS Mission Program Verification	7
XXX15-02	Ground Software	5
320-15-02-05	Mission Specific Simulation	6
320-15-02-05-01	Program Tug Mission Simulation	7
XXX-15-02-05-01	Program IUS Mission Simulation	7
320-15-02-06	Ground Software Maintenance	6
320-16	Orbiter Interface	4

TYPICAL MISSION OPERATIONS CYCLE (SIZED FOR FIRST LAUNCH)

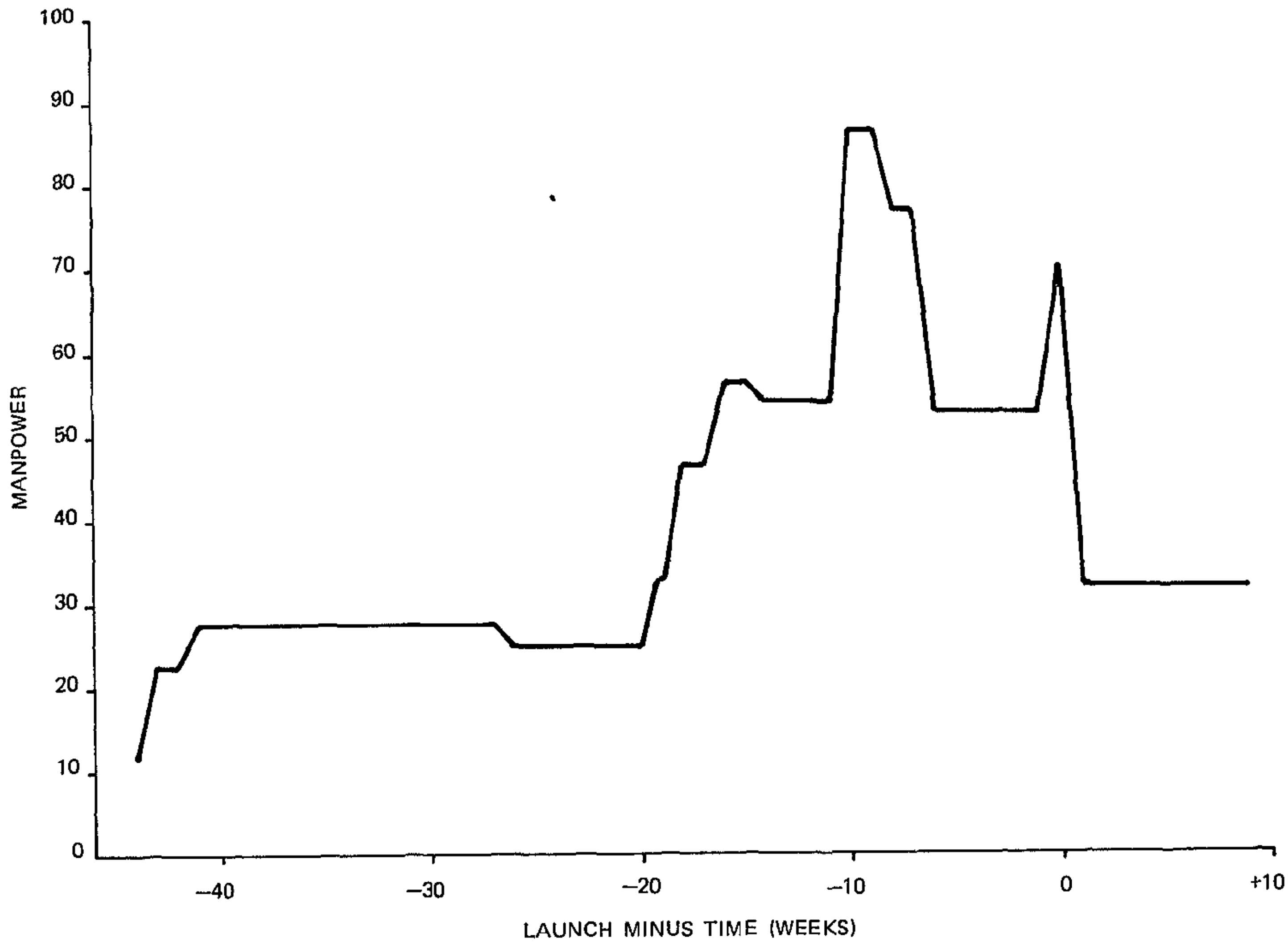

Figure 1 1 2-1 Typical Mission Operation Cycle

The only variable which controls a portion of the physical plant design is the number of consoles required by the flight control personnel and the flight support personnel This parameter varies as a function of the operational philosophy and data display requirements

The Expendable Interim Upper Stage (EIUS) requires 17 consoles for real time operation, while the Level II autonomy Space Tug requires 16 consoles Therefore, the physical plant has been designed to house the 17 consoles required by EIUS Figure 1 2 1-1 is a floor plan of the control center. It is assumed that EIUS and Space Tug will make use of the same physical plant and the same basic console hardware There will be no requirement for additions to the basic physical plant structure as a result of phasing into the Space Tug operations era.

Figure 1 2.1-2 presents an estimated construction schedule for a typical concrete block, slab foundation structure, 114 feet by 90 feet, to house the flight control functions It is assumed that the government will contract the construction of the physical plant and therefore, cost to the government will be in two phases (1) those costs involved in administering and overseeing the contract during the period of its execution, and (2) the procurement cost of the complete building

Procurement costs are estimated on the following basis

Raised floor construction - areas requiring subfloor cabling, air conditioning, etc , will cost $50 00 per square foot to construct.

Ordinary floor construction costs $35 00 per square foot to construct

Table 1 2 1-1 presents the physical plant cost information The physical plant costs were developed on the basis of the floor space required to house the flight control and flight support consoles, data systems and other equipments The total number of square feet required is 9,936 which can be constructed at a cost of $418,620 it will be noted that there is a 324 square foot difference between the floor plan shown in Figure 1 2 1-1 and computer requirements This discrepency should cause no concern since 1 2.1-1 is a representative floor plan and the calculated requirements presents the minimum square footage required to support the minimum interior furnishings

1 2 2 Ground Software Development

Development cost for software is a direct function of program size and complexity Based on IBM's previous experience in the development of JSC ground control center software for the Apollo and Skylab programs, and for JPL, an algorithm has been developed which will give estimated development cost as a function of the size and complexity of software

Before applying the algorithm, it is first necessary to estimate the size and complexity of individual sub-routines within the ground program Table 1.2 2-1 presents the size estimates for a Level II Space Tug vehicle for seventeen defined ground software modules, as derived by proportionally reducing the estimates for twenty-five ground software modules developed to support Level III autonomy

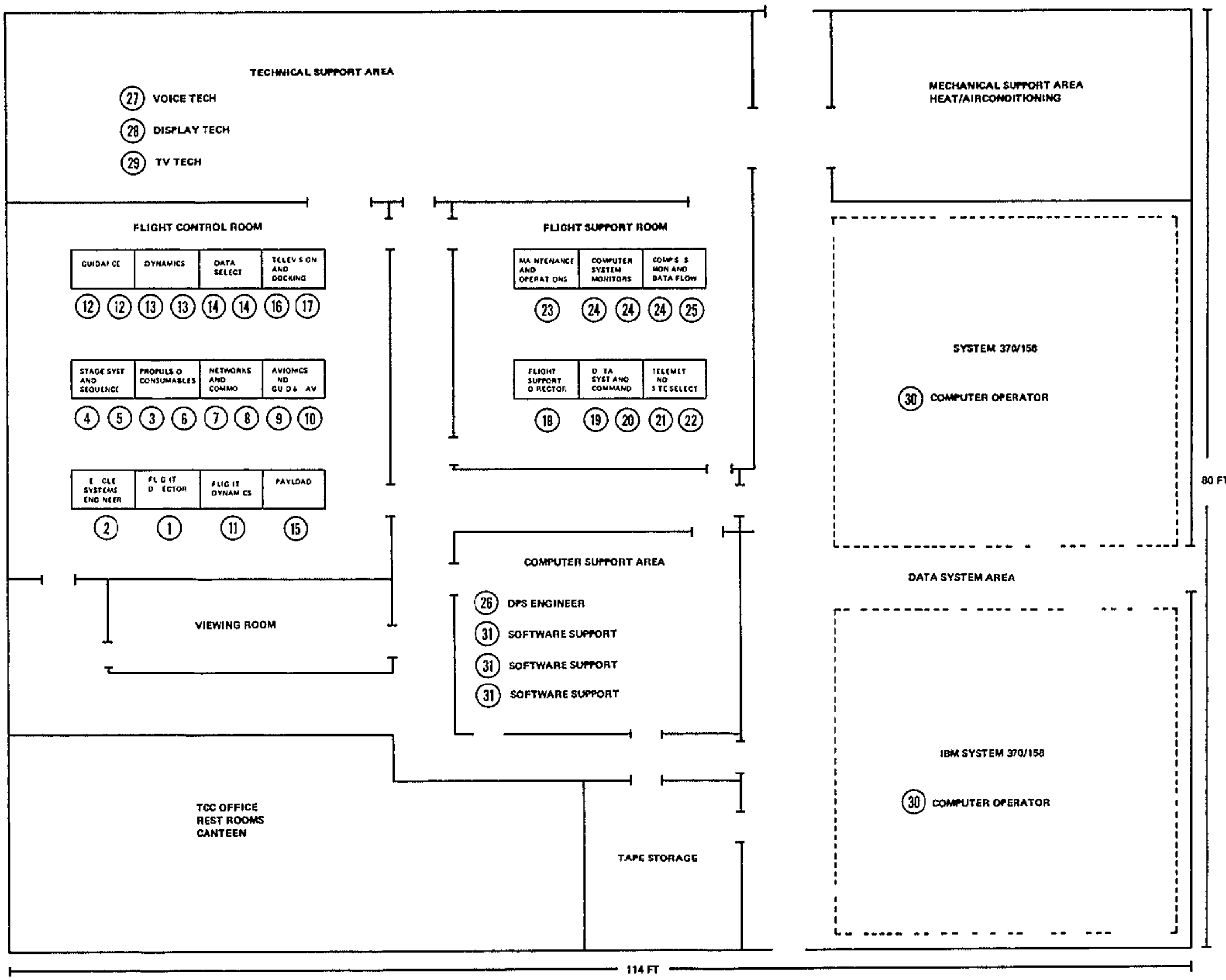

Figure 1 2 1-1 Representative Floor Plan and Support Staff Stations

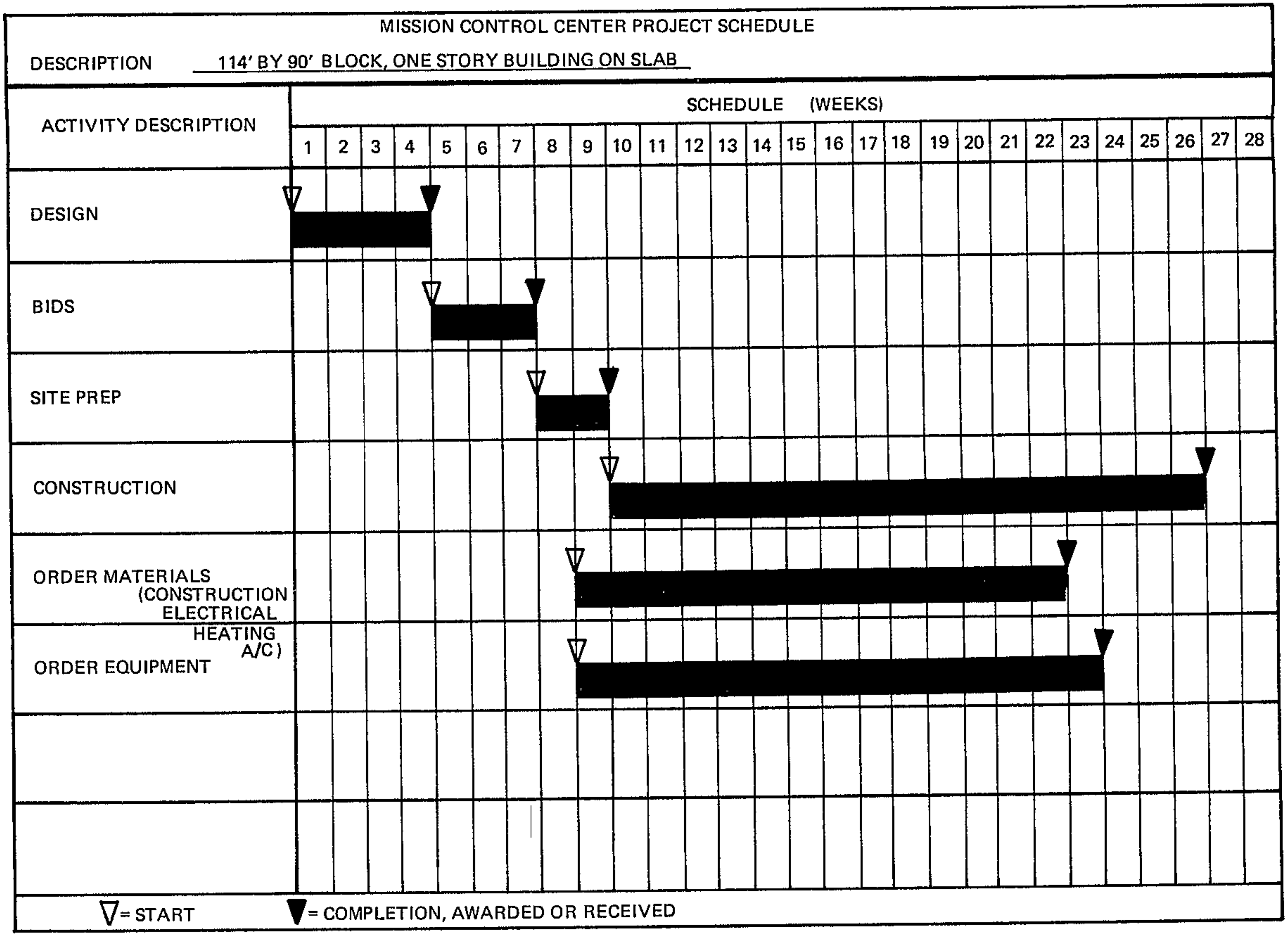

Figure 1 2 1-2 Estimate of Building Construction

Table 1 2 1-1 Physical Plant Cost Breakdown

TOC AREA	SQUARE FEET	D/SQ FT	COST(D)
FLIGHT CONTROL ROOM	1100	50	55000
FLIGHT SUPPORT ROOM	600	50	30000
DATA SYSTEM AREA	3024	35	151200
VIEWING ROOM	243	35	8505
COMPUTER SUPPORT AREA	594	35	20790
TAPE STORAGE	255	35	8925
OFFICES, RESTROOMS, CANTEEN	1080	35	37800
TECHNICAL SUPPORT AREA	1296	35	45360
MECHANICAL SUPPORT AREA	612	35	21420
HALL/LOBBY	1132	35	39620
TOTAL	9936		418620

The cost algorithm takes into account analysis required to produce a program definition document, program design and coding, program testing, system testing, and associated documentation The following equation is utilized to generate the cost numbers

$$\text{COST} = \frac{\text{Instructions}}{(I_1)\ (D)\ (C_1)\ (K)} + \frac{\text{Data}}{(I_d)\ (D)\ (C_d)\ (K)}$$

Where cost equals man-months of effort, I_1 equals the number of computer words per instruction, D equals number of working days per month, C_1 equals number of instructions per day, K equals complexity factor, I_d equals number of computer words per data item, C_d equals number of data words per day

The recommended value for instructions per man day is 14.

The complexity factor (K) varies from 1 to 1 and is inversely porportional to the difficulty of the task.

The recommended value for data words per man day is 30 This appears to be a minimum value

In order to convert from man months to dollars, multiplication by the constant $4,000 per month generates the total cost numbers Table 1 2 2-2 presents the ground software cost as derived for the Space Tug Level II autonomy program Table 1 2 2-3 presents the IUS ground software data.

1 2.3 Data System Selection

The data system, as defined in this report, consists of a computer system, a master clock, network terminal equipment, a teletype printer keyboard, intercommunications equipment, and a video system The dominant cost factor in the data system is the computer and the directly associated peripherals

Table 1 2 2-1 Ground Software Size Estimates

Level III	Instructions (Thousands)	Data Storage (Thousands)	Complexity Factor (1)	Size Required for Level II	
				Instruction (%)	Data (%)
Low Speed Radar	63 5	62.3	75	0	0
High Speed Radar	17.7	8 0	75	0	0
Vector Control	4.6	1 0	.75	0	0
Ephemeris Generation	26.0	8 1	1.00	85%	50%
Maneuver Computations	21 5	1.2	75	0	0
Contact Control (Site Control)	10.8	1 0	75	80%	50%
Mission Planning and Scheduling					
Maneuver Planning and Optimization	55 0	12.5	75	90%	60%
Renedezvous Planning	32.8	3 3	75	90%	60%
Mission Planning Table	0.0	72.0			50%
Docking Control for TV Man-in-Loop	10 8	3 5	.75	0	0
Telemetry Decommutation	5 3	2 6	1 00	95%	60%
Telemetry Conversion	10 9	10.1	1 00	85%	60%
Data Reduction	33 3	4.2	1 00	85%	60%
Data Analysis	30 1	4.0	1 00	85%	60%
Uplink Mode Control (Site Management)	6 8	13 0	1 00	85%	60%
Uplink DCS Processing	32 0	11 4	1 00	85%	60%
Operating System	222.0	33.3	5	95%	88%
Control Center Support/Display	14.1	5.4	.5	90%	60%
Simulation Model of Tug Vehicle	45 0	13 8	.75	125%	120%
Simulation Control/Control Center Interface	7 5	11 3	.75	90%	60%
Ground System Model	55.0	12.5	75	90%	60%
Control Center Model	27 0	27.0	75	90%	60%
Special Telemetry Processing	3 2	1.0	1 00	0	0
Shuttle/Spacecraft Operations Center Data Communications	3 8	2 5	.5	0	0
Laser Radar Interrogator Management	1 0	0.5	75	0	0

(1) The complexity factor is inversely proportional to the complexity of the software

Table 1 2 2-2 Space Tug Ground Software Cost

TCC SOFTWARE COST SUMMARY-AUTONOMY LEVEL 2

PROGRAM	INSTRUCTION SIZE (WORDS)	INSTRUCTION COST (DOLLARS)	DATA SIZE (WORDS)	DATA COST (D)	COMPLEXITY FACTOR	TOTAL (D)
DOWNLINK PROCESSING	68190	927755	12540	19905	1 00	947660
UPLINK PROCESSING	32980	448707	14640	23238	1 00	471946
MISSION PROFILE	109760	1991111	50030	79413	75	2070524
EXECUTIVE	210900	5738776	29304	46514	50	5785290
CONTROL CENTER SUPPORT	12690	345306	3240	5143	50	350449
DATA COMMUNICATIONS	0	0	0	0	50	0
SIMULATION SYSTEM	136800	2481633	47040	74667	.75	2556299
TOTALS		11933288		248879		12182167

Table 1 2 2-3 IUS Ground Software Cost

TOC SOFTWARE COST SUMMARY-AUTONOMY LEVEL B

PROGRAM	INSTRUCTION SIZE (WORDS)	INSTRUCTION COST (DOLLARS)	DATA SIZE (WORDS)	DATA COST (D)	COMPLEXITY FACTOR	TOTAL (D)
DOWNLINK PROCESSING	82800	1126531	21900	34762	1.00	1161293
UPLINK PROCESSING	38800	527891	24400	38730	1 00	566621
MISSION PROFILE	142100	2577778	79000	125397	75	2703175
EXECUTIVE	222000	6040816	33300	52857	50	6093673
CONTROL CENTER SUPPORT	13800	375510	5200	8254	50	383764
DATA COMMUNICATIONS	3800	103401	2500	3968	.50	107370
SIMULATION SYSTEM	132200	2398186	62400	99048	.75	2497234
TOTALS		13150113		363016		13513129

The computer system must be capable of handling mission program development and test, system simulation, scientific computation, training of flight controllers, real-time support of the tug mission, and schedule and control job-shop type work. Because of the criticality of the central computer to the overall operation, it is essential that the computer selected be capable of handling all planned functions

The principal factors in the selection of the computer system are the memory capacity and its central processing unit capabilities The memory capacity is a direct function of the size and complexity of the ground software Since the computer to be chosen must be capable of supporting both the IUS and the Space Tug programs, it is necessary, prior to the selection of the computer, to estimate the maximum load that will be placed upon the computer by either of the two programs. The approach taken in this study was to select a range of computer systems, appropriately configured to provide redundancy and standard peripherals, then to request the cost analysis program to establish which systems from the candidate list are capable of meeting both the memory and the CPU capacity requirements The cost analysis program produces a list of acceptable computer systems in order of ascending installed costs Table 1 2 3-1 and 1 2 3-2 present the Space Tug computer selection and IUS computer selection, respectively.

In each case, the minimum-cost computer was selected Tables 1.2 3-3 and 1 2 3-4 present the total data system cost resulting from adding the selected computer to the master clock, network terminal equipment, teletype printer keyboard, intercom equipment, and video switching equipment costs

1 2 4 Staff Equipment Development

The staff equipment costed consisted of the following hardware items consoles, communications panel, television monitor, event monitor, manual keyboard entry device, command panel, and the display control panel Each operating position will consist of some combination of the listed modules. The actual complement of modules at an operating position is a function of the type of tasks performed at that position

It was assumed, for the purposes of this study, that the equipments involved may be purchased "off the shelf" from a vendor, thus, there are no DDT&E expenses costed to develop special-purpose consoles, communication panels, TV monitors, etc. This assumption is reasonable in view of the fact that there are many agencies currently conducting operations which require similar consoles, and NASA will have access to the vendors of these consoles without necessarily having to enter a new DDT&E cycle for the hardware items Tables 1 2 4-1 and 1 2 4-2 present the Space Tug hardware costs and the IUS hardware costs, respectively It should be noted that in the composite program, only one set of consoles should be purchased.

1 2 5 Flight Software Development

The flight software development expenses are derived in the same manner that the ground software expenses are derived, with the exception that productivity

Table 1 2 3-1 Space Tug Computer Selection

```
THE LIST OF CANDIDATE COMPUTER SYSTEMS (IN ASCENDING ORDER OF
INSTALLED COST) MEETING OR EXCEEDING THE MAIN MEMORY
AND CPU CRITERIA IS
1 3158 MP5 6205376   134458 3024     79   8 70
2 3158 MP6 6711376   138795 3024  1 05    8.70
3 3168 MP3 9811661   276393 3024     79 12 50
4 3168 MP410317601   281730 3024  1 05 12 50
5 3168 MP510931201   291071 3024  1.31 12 50
6 3168 MP611437201   295408 3024  1 57 12 50
7 3168 MP711943201   299745 3024  1  84 12 50
8 3168 MP812449201   304081 3024  2.10 12 50
ENTER THE NUMBER OF THE CANDIDATE SYSTEM YOU SELECT
□
      1
```

Table 1 2 3-2 IUS Computer Selection

```
THE LIST OF CANDIDATE COMPUTER SYSTEMS (IN ASCENDING ORDER OF
INSTALLED COST) MEETING OR EXCEEDING THE MAIN MEMORY
AND CPU CRITERIA IS
1 3158 MP6 6711376   138795 3024  1 05    8 70
2 3168 MP410317601   281730 3024  1 05 12 50
3 3168 MP510931201   291071 3024  1 31 12.50
4 3168 MP611437201   295408 3024  1 57 12 50
5 3168 MP711943201   299745 3024  1  84 12 50
6 3168 MP812449201   304081 3024  2 10 12.50
ENTER THE NUMBER OF THE CANDIDATE SYSTEM YOU SELECT
□
      1
```

Table 1 2 3-3 Space Tug Data System Cost

```
DATA SYSTEM COST
        ITEM                          COST
3158 MP5                           6205376
MASTER CLOCK                         44560
NTWK  TERMINAL EQUIP.                20900
TTY PRINTER KEYBOARD                  3172
INTERCOM  EUIP                      230000
VIDEO SWITCH                          5610
                    TOTAL          6509618
```

Table 1 2 3-4 IUS Data System Cost

DATA SYSTEM COST	
ITEM	COST
3158 MP6	6711376
MASTER CLOCK	44560
NTWK TERMINAL EQUIP	20900
TTY PRINTER KEYBOARD	3172
INTERCOM EUIP	230000
TOTAL	7010008

Table 1 2 4-1 Space Tug Operational Hardware Cost

EQUIPMENT ITEM	QUANTITY	UNIT COST	TOTAL COST
CONSOLE	16	4800	76800
COMMUNICATION PANEL	27	6000	162000
TV MONITOR	32	2000	64000
EVENT MONITOR	62	8000	496000
MED	17	6400	108800
COMMAND PANEL	9	7200	64800
DISPLAY CONTROL PANEL	16	2000	32000
TOTAL			1004400

Table 1 2 4-2 IUS Operation Hardware Cost

EQUIPMENT ITEM	QUANTITY	UNIT COST	TOTAL COST
CONSOLE	17	4800	81600
COMMUNICATION PANEL	28	6000	168000
TV MONITOR	34	2000	68000
EVENT MONITOR	66	8000	528000
MED	18	6400	115200
COMMAND PANEL	8	7200	57600
DISPLAY CONTROL PANEL	17	2000	34000
TOTAL			1052400

is significantly decreased. The decrease in productivity is primarily due to the difficulty involved in limiting the program to fit within the available memory capacity

Flight software falls into the following basic categories the executive, navigation, guidance, attitude control, sequencing, telemetry, uplink processing and inertial measuring unit processing. Table 1 2 5-1 presents the size estimates for a Level II Space Tug flight program

Table 1.2 5-1 Space Tug Level II Flight Software Size

TUG (FLIGHT) SOFTWARE COST SUMMARY-AUTONOMY LEVEL 2

PROGRAM	INSTRUCTION SIZE (WORDS)	DATA SIZE (WORDS)	I+D (WORDS)
DOWNLINK PROCESSING	330	94	424
UPLINK PROCESSING	1822	291	2113
EXECUTIVE	2348	2699	5047
SEQUENCING	517	1769	2286
GUID ,NAV AND CNTL	16788	3422	20210
TOTALS	21805	8275	30080

Two sets of cost numbers were derived during the period of the study The first set was derived based upon the assumption that there would be no changes in the software requirements subsequent to the initial requirement statement Under that assumption, total software development came to approximately $2 5 million However, software requirements have been (historically) significantly gyrated during the period of software development The effect of these gyrations is taken into account by multiplying the minimum number by a factor of 2 27, which is empirically based. Tables 1 2 5-2 and 1 2.5-3 present the Space Tug and IUS flight software cost results, respectively

1 2 6 Miscellaneous DDT&E Expenses

Some tasks, primarily planning and analytical tasks, did not fall into the broad categories which were covered by the automated cost analysis programs These tasks account for approximately 10% of the DDT&E effort Since they are primarily tasks which utilize manpower, they were costed by estimating the man hours to be expended on each task and multiplying by the $48,000 per man-year constant. These tasks appear as line items in the work breakdown structure and on the associated man-loading schedule Table 1 2.6-1 presents the man-hour loading by task and by type of skill required

Table 1 2 5-2 Space Tug Flight Software Cost

TUG (FLIGHT) SOFTWARE COST SUMMARY-AUTONOMY LEVEL 2

PROGRAM	INSTRUCTION SIZE (WORDS)	INSTRUCTION COST (DOLLARS)	DATA SIZE (WORDS)	DATA COST (D)	TOTAL (D)
DOWNLINK PROCESSING	330	34632	94	339	34971
UPLINK PROCESSING	1822	386577	291	1049	387626
EXECUTIVE	2348	728572	2699	9725	738297
SEQUENCING	517	69296	1769	6374	75670
GUID ,NAV AND CNTL	16788	3809795	3422	12330	3822125
TOTALS		5028872		29816	5058689

Table 1 2 5-3 IUS Flight Software Cost

IUS (FLIGHT) SOFTWARE COST SUMMARY-AUTONOMY LEVEL 3

PROGRAM	INSTRUCTION SIZE (WORDS)	INSTRUCTION COST (DOLLARS)	DATA SIZE (WORDS)	DATA COST (D)	TOTAL (D)
DOWNLINK PROCESSING	330	34632	94	339	34971
UPLINK PROCESSING	1622	336446	291	1049	337495
EXECUTIVE	2348	728572	2399	8644	737216
SEQUENCING	517	69296	1069	3852	73148
GUID.,NAV AND CNTL.	8574	1538354	2224	8013	1546367
TOTALS		2707300		21896	2729197

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Table 1 2 6-1 Man-Hour Loading of DDT&E Tasks

CNT	PRED	SUCC	START	FINISH	SA	PM	Y	FP	FC	FS	GP	A	DUR	DESC
1	START	25	6/12/78	7/24/78	240 0	240 0	480 0						6 0	MASTER LAUNCH SCHEDULE ANAL
2	START	3	1/03/77	2/28/77		960 0						320 0	8 0	CONTRACT SOFTWARE DEVELOPME
3	25	6	3/05/79	4/02/79		320 0						80 0	4 0	PLAN FACILITY UTILIZATION
4	3	18	10/30/78	12/11/78	1540 Q			386.0					6.0	PLAN FLIGHT SOFTWARE DEVELO
5	3	7	2/28/77	4/11/77	960 0						240 0		6.0	PLAN GROUND SOFTWARE DEVELO
6	26	27	9/18/78	10/16/78		160 0	320.0						4 0	MISSION PHASE MANNING REQUI
7	26	8	12/25/78	2/19/79	320.0	320 0	320 0			120.0		320 0	8.0	COMPUTER UTILIZATION PLAN
8	26	12	11/12/79	12/24/79		120 0				120 0		120 0	6.0	MAINTENANCE SCHEDULE
9	27	2	10/16/78	11/27/78		60 0	60.0					240.0	6 0	HIRE CONTROL ANS SUPPORT ST
10	2	6	3/05/79	4/02/79					160 0	80 0			4 0	CONSOLE ORGANIZATION
11	4	6	1/08/79	4/02/79					960.0	960 0			12 0	DESIGN NETWORK INTERFACE SY
12	9	8	1/22/79	2/19/79	1600 0		320 0						4.0	ESTIMATE GROUND SOFTWARE SI
13	8	6	2/19/79	4/02/79	120.0	80.0				240 0		240 0	6 0	SELECT OPERATIONAL DATA SYS
14	12	19	12/24/79	5/12/80	120 0					653 0		120.0	20 0	INSTALL OPERATIONAL DATA SY
15	6	10	4/02/79	6/25/79		200 0	160 0			120 0		40 0	12.0	SIZE FACILITY/DESIGN PHYSIC
16	10	12	6/25/79	12/24/79		40 0						160 0	26.0	CONSTRUCT PHYSICAL PLANT
17	12	19	12/24/79	5/12/80					800.0	4000.0			20.0	INSTALL OPERATIONAL CONSOLE
18	7	9	4/11/77	9/11/78	5785 8 0		5786 0		5786 0	5786 0			74 0	EDD-EXECUTIVE/TRACKING/PLAN
19	7	19	3/03/80	5/12/80	4691 0		782.0		782 0	1564 0			10 0	COMMON GND SW VALID TEST RE
20	6	22	10/27/80	11/24/80	160.0	40.0	320 0		160.0	320 0		40 0	4.0	DEFINE NETWORK TRACKING REQ

SA = SYSTEM ANALYSIS
PM = PROGRAM MANAGEMENT
Y = MISSION ENGINEERS
FP = FLIGHT PROGRAMMERS
FC = FLIGHT CONTROLLERS
FS = FLIGHT SUPPORT PERSONNEL
GP = GROUND PROGRAMMERS
A = ADMINISTRATION

Table 1 2 6-1 Man-Hour Loading of DDT&E Tasks (Continued)

CNT	PRED	SUCC	START	FINISH	DUR	DESC	SA	PM	Y	FP	FC	FS	GP	A
21	22	23	11/24/80	1/19/81	8.0	NETWORK TRACKING VALID PROC	320 0				1280 0	640.0		
22	23	IIOC	1/19/81	3/16/81	8.0	NETWORK TRACKING VALID TEST		120 0			320 0	320.0		
23	9	N	9/11/78	9/10/79	52 0	PROGRAM GROUND TK/PLAN/EX S	4106 0		2033 0				265832 0	
24	N	19	9/10/79	5/12/80	35.0	VERIFY EXECUTIVE/TK/PLAN SO	27365 0		2737 0				13682 0	
25	2	4	11/27/78	1/08/79	6.0	OBTAIN SPACE TUG SYSTEM CHA		240.0			720.0	360 0		
26	25	26	7/24/78	9/18/78	8 0	TUG MISSION CHARACTERIZATIO			720.0		240.0	120.0		
27	I1	T1	9/19/80	3/19/82	78 0	EDD-TUG FLIGHT PROGRAM	16948 0		5007 0		5007 0			
28	7	9	4/11/77	9/11/78	74 0	EDD-TUG DOWNDATA/UPDATA/DOC	50977 0		5098.0		5098 0	5098 0		
29	7	19S	8/06/82	10/15/82	10.0	TUG GND SW VALID TEST REQUI	4133 0		689.0		689.0	1378 0		
30	52I	41T	10/15/82	12/10/82	8 0	DETERMINE TUG FAILURE MODES			640 0		6400.0			
31	4	6	2/05/79	4/02/79	8 0	TUG DISPLAY FORMAT DESIGN			320 0		6400 0	3600 0		
32	41T	5T	12/10/82	2/04/83	8.0	TUG MISSION FAILURE EFFECTS	640 0		640 0		6400 0			
33	5T	15T	2/04/83	4/29/83	12 0	DESIGN TUG MISSION SIMULATI	480 0		960 0			960 0		
34	5T	51T	3/18/83	4/29/83	6 0	ANALYZE TUG COMPONENT CHARA			480.0		4800.0	240 0		
35	5T	13T	4/29/83	6/24/83	8 0	TUG TRAINING REQ/CRIT/SIMSK		640 0			320.0	320 0		320 0
36	51T	52T	4/29/83	6/24/83	8 0	PREPARE TUG SYSTEMS HANDBOO			160 0		640 0			320.0
37	52T	16T	6/24/83	9/16/83	12 0	PUBLISH/UPDATE TUG SYSTEMS			480 0		480 0			480 0
38	13T	14T	6/24/83	8/19/83	8 0	DEVELOP TUG TRAINING MATERI		80 0	320.0		1600 0	1600.0		320.0
39	14T	16T	8/19/83	9/16/83	4 0	TUG CLASSROOM TRAINING			160 0		3200.0	3680.0		
40	IIOC	22T	6/10/83	7/08/83	4 0	TUG NETWORK DATA HANDLING R	160 0	40 0	320 0		320.0	320 0		40 0

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Table 1 2 6 1 Man-Hour Loading of DDT&E Tasks (Continued)

CNT	PRED	SUCC	START	FINISH	DUR	DESC	SA	PM	Y	FP	FC	FS	GP	A
41	22T	23T	7/08/83	9/02/83	8 0	TUG NETWORK DATA VALID PROC	320 0				1280 0	640 0		
42	23T	TTOC	9/02/83	10/28/83	8 0	TUG NETWORK VALID TESTS		120 0			320.0	320 0		
43	N	T	6/12/81	2/12/82	35 0	PROGRAM TUG DNDATA/UPDATA/D	2411 0		1171 0				155004 0	
44	T1	T2	3/19/82	10/08/82	29 0	PROGRAM TUG FLIGHT SOFTWARE	3852 0			70618.0	2054.0			
45	T	19S	2/12/82	10/15/82	35.0	VERIFY TUG DNDATA/UPDATA/DO	24112.0		2411 0					
46	27	5T	11/12/82	2/04/83	12 0	TUG CONSOLE POSITION GUIDEL		480 0	960 0		1440.0	1440.0		
47	19S	111T	12/24/82	2/04/83	6 0	TUG MISSION PLANNING AND OP	1920 0		480 0		480.0			
48	19S	5T	10/15/82	2/04/83	16 0	DEVELOP TUG PROCEDURES AND	320 0				3200 0	3200 0		
49	111T	15T	2/04/83	4/29/83	12 0	TUG ABORT PLANNING	960 0		240 0		240 0			
50	21T	TTOC	9/02/83	10/28/83	8 0	TUG INTERAGENCY COORDINATIO		640 0			320.0	320 0		
51	T2	15T	10/08/82	4/29/83	29 0	TUG FLT PROGRAM VERIFICATIO	89877 0		8988 0					
52	15T	21T	7/08/83	9/02/83	8 0	PREPARE TUG INTERAGENCY DOC		320 0	1280 0		640.0	640 0		640 0
53	15T	16T	6/24/83	9/16/83	12.0	PROGRAM TUG MISSION SIMULAT	240 0		240 0				2400.0	
54	15T	151T	4/29/83	5/27/83	4 0	TUG MISSION SPEC EDD	2568 0		257 0		257 0	257 0		
55	151T	152T	5/27/83	7/22/83	8.0	TUG MISSION SPECIFIC PROGRA	1028 0			5136.0	514.0			
56	152T	16T	7/22/83	9/16/83	8.0	TUG MISSION PROGRAM VERIFIC	5136 0		514.0					
57	16T	TTOC	9/16/83	10/28/83	6 0	TUG MISSION SIMULATION TRAI	240 0	240 0	240.0		4800 0	5520.0		
58	TTOC	24T	10/28/83	11/04/83	1.0	CONDUCT TUG MISSION OPERATI	40 0	120.0	40 0		1200.0	1380.0		
59	24T	TCYCL	11/04/83	12/30/83	8 0	TUG POST MISSION REPORTS	320.0	320.0	3200.0		3200.0	3200.0		
60	26	5T	1/07/83	2/04/83	4 0	DEFINE TUG OPERATOR CERT/CR		320.0	800 0		160.0	160 0		

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Table 1 2 6-1 Man Hour Loading of DDT&E Tasks (Continued)

CNT / DUR	PRED / DESC	SUCC	START	FINISH	SA	PM	Y	FP	FC	FS	GP	A
61	25	26	7/24/78	9/18/78			720.0		240 0	120 0		
8 0	IUS MISSION CHARACTERIZATIO											
62	18	I1	12/11/78	12/10/79	9375 0		2679 0		2679 0			
52 0	EDD-IUS FLIGHT PROGRAM											
63	7	9	9/12/77	9/11/78	35189.0		3519.0		3519 0	3519.0		
52 0	EDD-IUS DOWNDATA/UPDATA/SIM											
64	7	19	3/24/80	5/12/80	3284 0		547 0		547 0	1094 0		
7.0	IUS GND SW VALID TEST REQUI											
65	2	4	11/27/78	1/08/79		240 0			720 0			
6 0	OBTAIN IUS SYSTEM CHARACTER											
66	4	41I	3/03/80	4/28/80			640 0		6400.0			
8 0	DETERMINE IUS FAILURE MODES											
67	4	6	2/05/79	4/02/79			320 0		6400.0	3600 0		
8 0	IUS DISPLAY FORMAT DESIGN											
68	41I	5I	4/28/80	6/23/80	640 0		640.0		6400.0			
8 0	IUS MISSION FAILURE EFFECTS											
69	5I	15I	6/23/80	9/15/80	480 0		960 0			960 0		
12 0	DESIGN IUS MISSION SIMULATI											
70	5I	51I	8/04/80	9/15/80			480 0		4800.0	240.0		
6 0	ANALYZE IUS COMPONENT CHARA											
71	5I	13I	9/15/80	11/10/80		640 0				320 0		320 0
8 0	IUS TRAINING REQ/CRIT/SIMSK											
72	51I	52I	9/15/80	11/10/80			160 0		640 0			320.0
8 0	PREPARE IUS SYSTEMS HANDBOO											
73	52I	16I	11/10/80	2/02/81			480 0		480 0			480.0
12 0	PUBLISH/UPDATE IUS HANDBOOK											
74	13I	14I	11/10/80	1/05/81		80 0	320 0		1600 0	1600 0		320.0
8 0	DEVELOP IUS TRAINING MATERI											
75	14I	16I	1/05/81	2/02/81			160 0		3200 0	3680 0		
4.0	IUS CLASSROOM TRAINING											
76	6	22I	10/27/80	11/24/80	160.0	40 0	320 0		320 0	320 0		40.0
4 0	IUS NETWORK DATA HANDLING R											
77	22I	23I	11/24/80	1/19/81	320 0				1280 0	640.0		
8 0	IUS NETWORK DATA VALID PROC											
78	23I	IIOC	1/19/81	3/16/81		120 0			320.0	320.0		
8.0	IUS NETWORK DATA VALID TEST											
79	9	I	4/23/79	12/24/79	2739 0		1329.0				117280.0	
35.0	PROGRAM IUS DNDATA/UPDATA/S											
80	I1	I2	12/10/79	4/28/80	2143 0			38839 0	1125 0			
20 0	PROGRAM IUS FLIGHT SOFTWARE											

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A = ADMINISTRATION

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Table 1 2 6 1 Man Hour Loading of DDT&E Tasks (Continued)

CNT	PRED	SUCC	START	FINISH	SA	PM	Y	FP	FC	FS	GP	A
DUR	DESC											
81	I	19	12/24/79	5/12/80	14660 0		1564 0					
20 0	VERIFY IUS DNDATA/UPDATA/SI											
82	27	5I	3/31/80	6/23/80		480 0	960 0		1440 0	1440 0		
12 0	CONSOLE POSITION GUIDELINES											
83	19	111I	5/12/80	6/23/80	1920 0		480.0		480 0			
6 0	IUS MISSION PLANNING AND OP											
84	19	15I	5/26/80	9/15/80	320 0				3200 0	3200 0		
16 0	DEVELOP IUS PROCEDURES AND											
85	111I	15I	6/23/80	9/15/80	960 0		240 0		240.0			
12 0	IUS ABORT PLANNING											
86	21I	IIOC	1/19/81	3/16/81		640 0			320.0	320 0		
8 0	IUS INTERAGENCY COORDINATIO											
87	I2	15I	4/28/80	9/15/80	42857 0		4286 0					
20 0	IUS FLT PROGRAM VERIFICATIO											
88	15I	21I	11/24/80	1/19/81		320 0	1280 0		640 0	640 0		640 0
8 0	PREPARE IUS INTERAGENCY DOC											
89	15I	16I	11/10/80	2/02/81	240 0		240 0				2400 0	
12 0	PROGRAM IUS MISSION SIMULAT											
90	15I	151I	9/15/80	10/13/80	2143 0		214 0		214 0	214 0		
4 0	IUS MISSION SPEC EDD											
91	151I	152I	10/13/80	12/08/80	857 0			4286 0	429.0			
8.0	IUS MISSION SPEC PROGRAM											
92	152I	16I	12/08/80	2/02/81	4286 0		429.0					
8 0	IUS MISSION PROGRAM VERIFIC											
93	16I	IIOC	2/02/81	3/16/81	240.0	240 0	240.0		4800 0	5520 0		
6 0	IUS MISSION SIMULATION TRAI											
94	IIOC	24I	3/16/81	3/23/81	40 0	120 0	40 0		1200.0	1380.0		
1 0	CONDUCT IUS MISSION OPERATI											
95	24I	ICYCL	3/23/81	5/18/81	320 0	320 0	3200 0		3200 0	3200 0		
8 0	IUS POST MISSION REPORTS											
96	26	5I	5/26/80	6/23/80		320 0	800 0		160 0	160 0		
4 0	DEFINE IUS OPERATOR CERT/CR											
				TOTALS	429255 0	9780 0	77380 0	119265 0	29660 0	82163 0	556838 0	5920 0

SA = SYSTEM ANALYSIS
PM = PROGRAM MANAGEMENT
Y = MISSION ENGINEERS
FP = FLIGHT PROGRAMMERS
FC = FLIGHT CONTROLLERS
FS = FLIGHT SUPPORT PERSONNEL
GP = GROUND PROGRAMMERS
A = ADMINISTRATION

1.3 Costing Methodology - Recurring Cost

The recurring costs incurred in orbital operations and mission support are, in the main, service type costs, since there are no major hardware refurbishment involvements The types of costs included are facility maintenance, ground software update and maintenance, data system maintenance, Space Tug software maintenance, IUS software maintenance, sustaining facilities engineering, sustaining flight control engineering and network rental expenses Of these tasks, facility maintenance and data system maintenance will be contracted to outside agencies. Ground software update and maintenance will be accomplished by the premanently assigned software support team The sustaining facilities engineering and sustaining flight control engineering personnel will perform all pre-mission preparations, training and conduct of mission operations Network rental will be charged to the Operations organization on the basis of the number hours utilized and the type of service rendered The Space Tug software maintenance and IUS software maintenance tasks are those tasks involved in defining, programming and verifying mission specific deviations from the basic four flight programs This is largely a manpower expense Computer time will be provided by the control center computer at no cost

1 3 1 Facility Maintenance

Facility maintenance includes refuse disposal, janitorial services, internal electrical maintenance, internal power and heating maintenance, internal painting, air-conditioning costs, exterior painting, roofing, and parking lot maintenance. Facility maintenance costs commonly are based upon a constant dollar cost per square foot of area maintained This constant is approximately $1.32 for government installations and $2.00 for industrial installations The cost of facility maintenance is computed from the estimated number of square feet required by the operations and support areas multiplied by $2 00 per square foot This expense is approximately $20,000 per year.

1 3.2 Ground Software Update and Maintenance

The approach chosen to develop this algorithm divides the software maintenance task into two subtasks. The first subtask consists of finding and fixing software problems, supporting system operation, and installing nominal mission-to-mission program enhancements. The second subtask consists of adding new functions and performing major modifications to the existing software system

The cost of the former can best be sized as a 'level of effort' task Since software problems will probably be discovered throughout the software system, a level of expertise must be maintained thru the availability of personnel familiar with every software area. The number of personnel required for each area is dependent on the size, complexity, criticality, and level of mission-to-mission changes for the programs therein

The level of effort will decrease as a function of time . Saturn Launch Computer Complex data indicates that number of software problems decrease by more than 50% during the first year of system operation. After the first year the number of problems should continue to decrease but at a much slower rate The level of effort cost algorithm is shown in Figure 1 3 2-1

The cost of the second subtask is similar to that of new software development Two offsetting attributes of modification/extension work affect this cost. The first is that adding new functions to an existing working system is easier than new work due to the existence of well defined, operational interfaces and system services. The second attribute applies to modifications

GROUND SOFTWARE
LEVEL OF EFFORT ALGORITHM

$$\text{Area Cost} = \frac{I}{(I_p)\ (K)\ (C)\ (S)}$$

where

Area Cost = Number of personnel required for a software area

I = Number of instructions in the area
I_p = Instructions a programmer can maintain (base number)
K = Area complexity
C = Area criticality
S = Sensitivity to program change

Note The K, C, and S factors range from 1 to 1.

The recommended values are

Area	I_p	K	C	S
Executive/Control Center	120K	5	5	1
Simulation and Training	120K	75	9	.15
Vehicle Systems	120K	1 0	6	7
Mission Profile	120K	75	.8	7

Note The K, C, and S factors range from 1 to 1 and are inversely proportional (e g., 5 is more critcal than 7)

Figure 1 3 2-1 Ground Software Level of Effort Algorithm

Modifications usually require a significantly greater degree of design and system testing than the number of instructions involved would indicate Modifications in inter-program interfaces can spread through larger parts of the system causing subtle problems which require extensive system testing

Given these offsetting factors and assuming a reasonable mixture of the two, we can approximate these costs by using the same cost algorithm as used for new development work

A support staff to handle software maintenance has been established. The cost of this service is 1.2 million dollars per year during the IUS operational phase and 1 0 million dollars per year during the Space Tug operational phase

1 3 3 Data System Maintenance

Standard rate schedules exist for the maintenance of large scale computer systems and the associated peripheral gear. For the data systems chosen, the data system maintenance costs are approximately $139,000 per year for the IUS program and $135,000 per year for the Space Tug program Maintenance of all other equipment will be a responsibility of the sustaining flight support engineering organization.

1 3 4 Sustaining TOC Engineering

A certain minimum staff is required to control and support the control of a Space Tug or IUS vehicle That staff is divided into two major groupings--the flight support group (TOC Sustaining Engineering) and the flight control group. There are 30 to 33 personnel required to staff the flight support organization on a continuing basis These people have been costed at $48,000 per year Table 1 3 4-1 presents the flight support organization

The size of the staff is established by the realtime support requirements However, the staff, during non-mission and non-training periods, is to be utilized to perform mission preparations and maintenance jobs. This multiplexing of personnel is cost-effective in that it spreads the productive work load of the permanently assigned personnel more evenly across the operational periods

The cost of this service is $1 44 million per year for the IUS operational phase and $1.58 million per year for the Space Tug operational phase.

1 3 5 Sustaining Flight Control Engineering

There is a specific minimum staff required to control the Space Tug or the IUS vehicle during mission operational periods For both the IUS and the Space Tug program, that staff requirement is 30 flight control engineers The flight control organization is a required sustaining engineering staff which may be utilized during nonmission periods in performing preparation tasks, such as training, scheduling, and interface type operations As with the flight support staff, the spreading of effort across the period of operations is a cost-effective utilization of the flight control staff Table 1 3 5-1 presents the flight control organization

Table 1 3 4-1 Flight Support Organization

FLIGHT SUPPORT GROUP	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT SUPPORT DIRECTOR	1	1	2	96000
DATA SYSTEM SUPERVISOR	1	1	2	96000
COMMAND	1	0	2	96000
TELEMETRY	1	1	2	96000
SITE SELECT	1	0	2	96000
DATA FLOW	1	1	2	96000
DPS ENGINEER	1	0	2	96000
VOICE TECH	1	0	2	96000
DISPLAY TECH	1	0	2	96000
TV TECH	1	0	2	96000
COMPUTER SYSTEM MONITORS	2	1	2	192000
COMPUTER OPERATIONS	3	0	2	288000
COMPUTER SUPPORT	3	0	1	144000
TOTALS	18	5	33	1584000

(A) SPACE TUG

FLIGHT SUPPORT GROUP	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT SUPPORT DIRECTOR	1	1	2	96000
DATA SYSTEM SUPERVISOR	1	1	2	96000
COMMAND	1	0	2	96000
TELEMETRY	1	1	2	96000
SITE SELECT	1	0	2	96000
MAINTENANCE AND OPERATIONS	1	1	2	96000
DATA FLOW	1	1	2	96000
DPS ENGINEER	1	0	2	96000
VOICE TECH	1	0	2	96000
DISPLAY TECH	1	0	2	96000
COMPUTER SYSTEM MONITORS	2	1	2	192000
COMPUTER OPERATIONS	2	0	2	192000
COMPUTER SUPPORT	2	0	1	96000
TOTALS	16	6	30	1440000

(B) IUS

The cost of the flight control service is $1 44 million per year for both the IUS and the Space Tug programs

1 3 6 Network Rental

In order to arrive at a minimum network rental cost, Philco-Ford designed a system for the transmission of telemetry, command, tracking and television data from six STDN remote sites to the Tug operations control center This network utilized commercial carrier satellite transmission directly from the

Table 1 3 5-1 Flight Control Organization

TUG OPERATIONS CENTER PERSONNEL

POSITION	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT CONTROL GROUP				
TUG OPERATIONS DIRECTOR	1	1	2	96000
VEHICLE SYSTEMS ENGINEER	1	1	2	96000
PROPULSION	1	1	2	96000
STAGE SYSTEMS	1	1	2	96000
CONSUMABLES	1	0	2	96000
NETWORKS	1	1	2	96000
COMMUNICATIONS	1	0	2	96000
AVIONICS	1	1	2	96000
GUID AND NAV.	1	0	2	96000
SEQUENCE	1	0	2	96000
GUIDANCE	1	1	2	96000
DYNAMICS	1	1	2	96000
TV/DOCKING	1	1	2	96000
FLIGHT DYNAMICS OFFICER	1	1	2	96000
SPECIAL FUNCTIONS	1	1	2	96000
TOTALS	15	11	30	1440000

TUG OPERATIONS CENTER PERSONNEL

POSITION	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT CONTROL GROUP				
TUG OPERATIONS DIRECTOR	1	1	2	96000
VEHICLE SYSTEMS ENGINEER	1	1	2	96000
PROPULSION	1	1	2	96000
STAGE SYSTEMS	1	1	2	96000
CONSUMABLES	1	0	2	96000
NETWORKS	1	1	2	96000
COMMUNICATIONS	1	0	2	96000
AVIONICS	1	1	2	96000
GUID AND NAV	1	0	2	96000
SEQUENCE	1	0	2	96000
GUIDANCE	1	1	2	96000
DYNAMICS	1	1	2	96000
DATA SELECTION	1	1	2	96000
FLIGHT DYNAMICS OFFICER	1	1	2	96000
SPECIAL FUNCTIONS	1	1	2	96000
TOTALS	15	11	30	1440000

ground station to the Tug operations control center Figure 1 3 6-1 presents the network and terminal cost data derived by Philco-Ford

To implement the network, each of the remote stations requires a line terminal installation, which creates a recurring cost of $31,700 per month The line terminal equipment at the remote stations feed commercially available common carrier single-sideband data links at a composite leased cost of $284,830 per month The leased lines are demultiplexed at the Tug operations center by three line-terminal stations

It is assumed that no costs will be incurred to rent the ground station equipment itself, that is, the data being fed to the line terminals at the STDN sites are supplied free of charge to the Tug program by Goddard It is also assumed that the terminal stations within the Tug operations center are costed as a portion of the network terminal fees and are not part of the

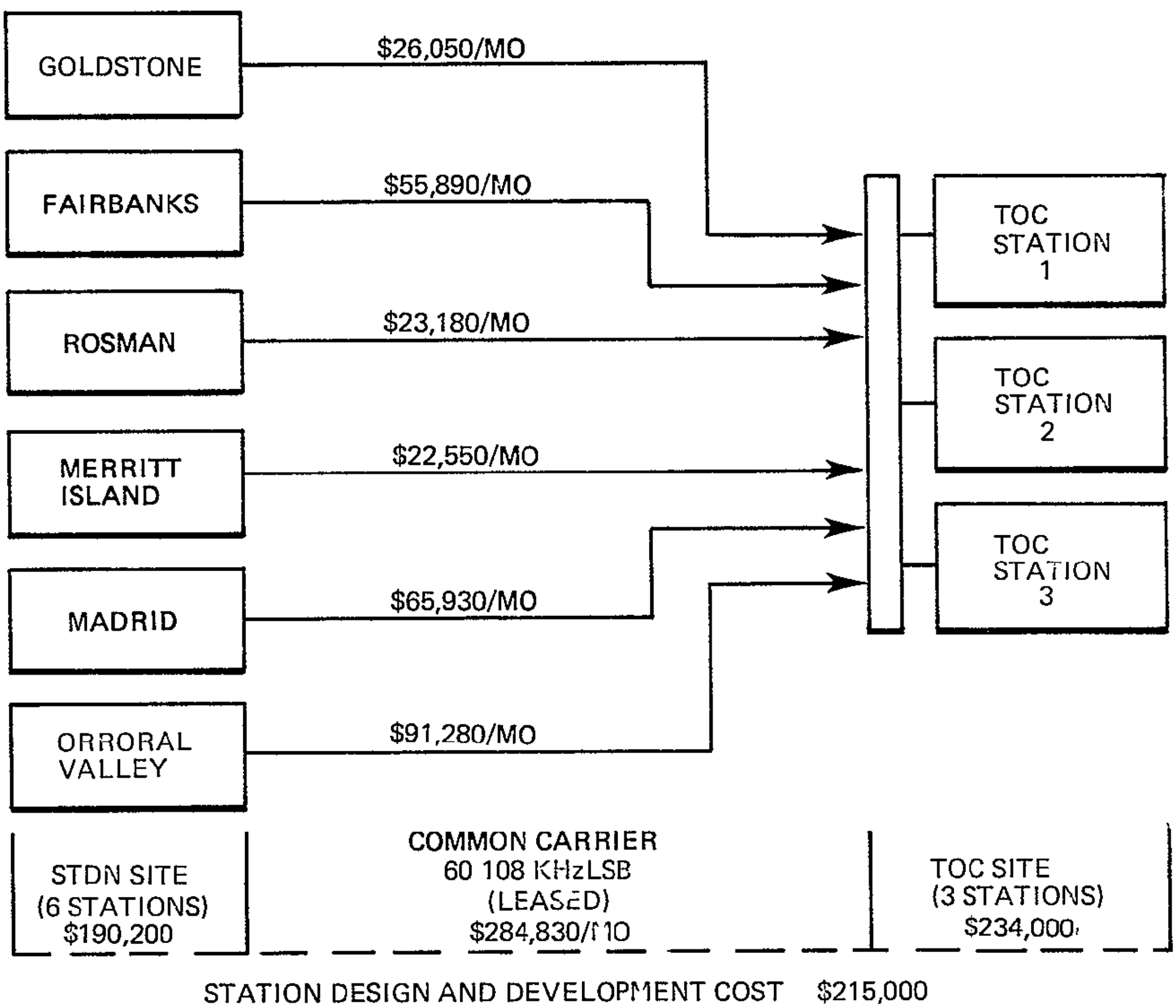

Figure 1 3 6 1 Network and Terminal Cost Data network rental computation The summation of the recurring costs of network leasing per month and the STDN site stations per month are $475,030 To arrive at a minimum cost, the operation of the TDRS system was assumed This reduced the monthly cost of ground station terminal equipment from $190,200 to $31,700. This was derived by assuming the TDRS ground station would be provided with the terminal equipment, and a fee equivalent to the leased line cost from the 6 STDN stations would be imposed

The summation of a single-station line terminal installation and the leased line costs is $316,530. Since these are leased costs, it is assumed that the hourly cost would be equivalent to dividing the summation of leased line cost and ground station recurring cost by the number of hours of operation in a month This gives an hourly rate of $430. Now, the network rental charges will be further based upon the type of service required, since all phases of the missions do not require the entire capability of the leased lines A further division of the $430 per hour fee was made on the basis of bandwidth requirements. The television signal requires 51 kilobits per second, the telemetry signals require 16 kilobits per second, the tracking and command signals require 2 kilobits per second each It was estimated that if a charge were made on the basis of service provided, that charge would be approximately proportional to the bandwidth requirements of the type of signal being processed On that basis, television was rated at $290 per hour, telemetry was rated at $90 per hour, and command and tracking were each rated at $25 per hour Those constants were utilized in arriving at the network rental calculations

The mission density function program within the cost analysis programs calculates the number of hours per year that each of the communications services are required, based upon the launch schedule and mission type established for that year. The baseline mission year chosen for IUS was 1983, and the baseline year chosen for Space Tug was 1984 These two years represent the maximum mission density within a calendar year over the IUS program and Space Tug program durations

Network rental costs are calculated by multiplying the number of hours per year that a service is required by the rental cost per hour. Table 1 3 6-1(a) presents the network rental costs for the IUS program and Table 1.3 6-1(b) presents the network rental costs for the Space Tug program

1 3 7 Space Tug Software Maintenance

A maintenance and support cost algorithm has been developed for flight software This algorithm assumes that the four baseline programs generated in the DDT&E phase will not be subject to major modifications A major modification, should one be required, is to be costed in accordance with the initial software development algorithm Figure 1 3 7-1 presents the maintenance and support algorithm for flight software

The maintenance and support cost algorithm divides the level of effort requirements into manpower required to design the changes, manpower required

Table 1 3 6-1 Network Rental Costs

NETWORK RENTAL COSTS

	HRS	RATE	TOTAL
TM CHANNELS	1 89	90	17004
CMD CHANNELS	1 89	25	4723
TRACKING	1 80	25	4507
TV CHANNELS	0	290	0
GRAND TOTAL			26233

(A) IUS

NETWORK RENTAL COSTS

	HRS	RATE	TOTAL
TM CHANNELS	353	90	31759
CMD CHANNELS	353	25	8822
TRACKING	0	25	0
TV CHANNELS	566	290	164174
GRAND TOTAL			204755

(B) SPACE TUG

MAINTENANCE AND SUPPORT COST ALGORITHM FOR FLIGHT SOFTWARE

- Assume $\leq$ 64K instructions and data
- Assume that major changes are costed by the initial development algorithm

$$\text{Level of effort} = M_D + M_P + M_V$$

$$M_D = 2 + n$$
$$M_P = 1 + n$$
$$M_V = 2 + 2n$$

$$\text{Level of effort} = 5 + 4n \text{ (in men)}$$

where n = number of baseline programs

M_D = Definition and systems analysis/design including change assessment and documentation

M_P = Programming

M_V = Verification including test design and documentation

Figure 1 3 7-1 Maintenance and Support Cost Algorithm for Flight Software to program the changes, and manpower required for flight program verification. For programs less than 64,000 words (instructions and data) the level of effort is a function of the number of programs being maintained. The annual recurring cost for this service is $1.008 million per year for both the Space Tug and IUS flight program maintenance efforts

1 3 8 IUS Software Maintenance

The IUS maintenance and support cost algorithm for flight software, and the rationale for the level of effort requirements are identical to those presented in paragraph 1.3.7 for the Space Tug flight software maintenance efforts

1 3 9 Off-Peak Manpower Utilization

Flight control and flight support are full-time employment for those personnel assigned flight control and flight support duties. There will be no multiplexing between operational and non-operational assignments The time during which operations are not in progress will be utilized by the assigned flight control and flight support personnel in preparation, maintenance and other operations related activities. The frequency and complexity of both IUS and Space Tug missions dictates the assignment of a dedicated staff

1 4 GROUND RULES AND ASSUMPTIONS

This section presents the ground rules and assumptions which are basic to the cost estimation process

1 4.1 STS Launch Schedule and Program Basics

The October, 1973, Mission Model was used to establish the launch schedule and mission type estimates for both the IUS and Space Tug operations The type of mission (Interplanetary, Geosynchronous, etc) is specified in the Mission Model, but the launch schedule is not. It was thus necessary to estimate a launch schedule

The size of a facility dedicated to the support of Space Tug missions and the size of the technical staff required to support the Space Tug missions are functions of the mission schedule and mission content. The equipment utilization factors are derived from an analysis of the overlap between adjacent missions in which the kind and number of equipment necessary to conduct operations when multiple payloads are being simultaneously controlled are determined The number of people, in terms of the number of teams or shifts required, is a direct function of the mission duration It is, therefore, required that the most dense mission year in the NASA traffic model be evaluated in order to determine the mission density load factors

The mission type, the anticipated launch schedule, the maintenance down time required before and after each mission to evaluate the equipment, data flow, etc., the periodic maintenance requirements of the equipment and the remaining available time for mission planning, training and simulation are shown in Figures 1 4 1-1 and 1 4.1-2 for the IUS and Space Tug most dense mission years

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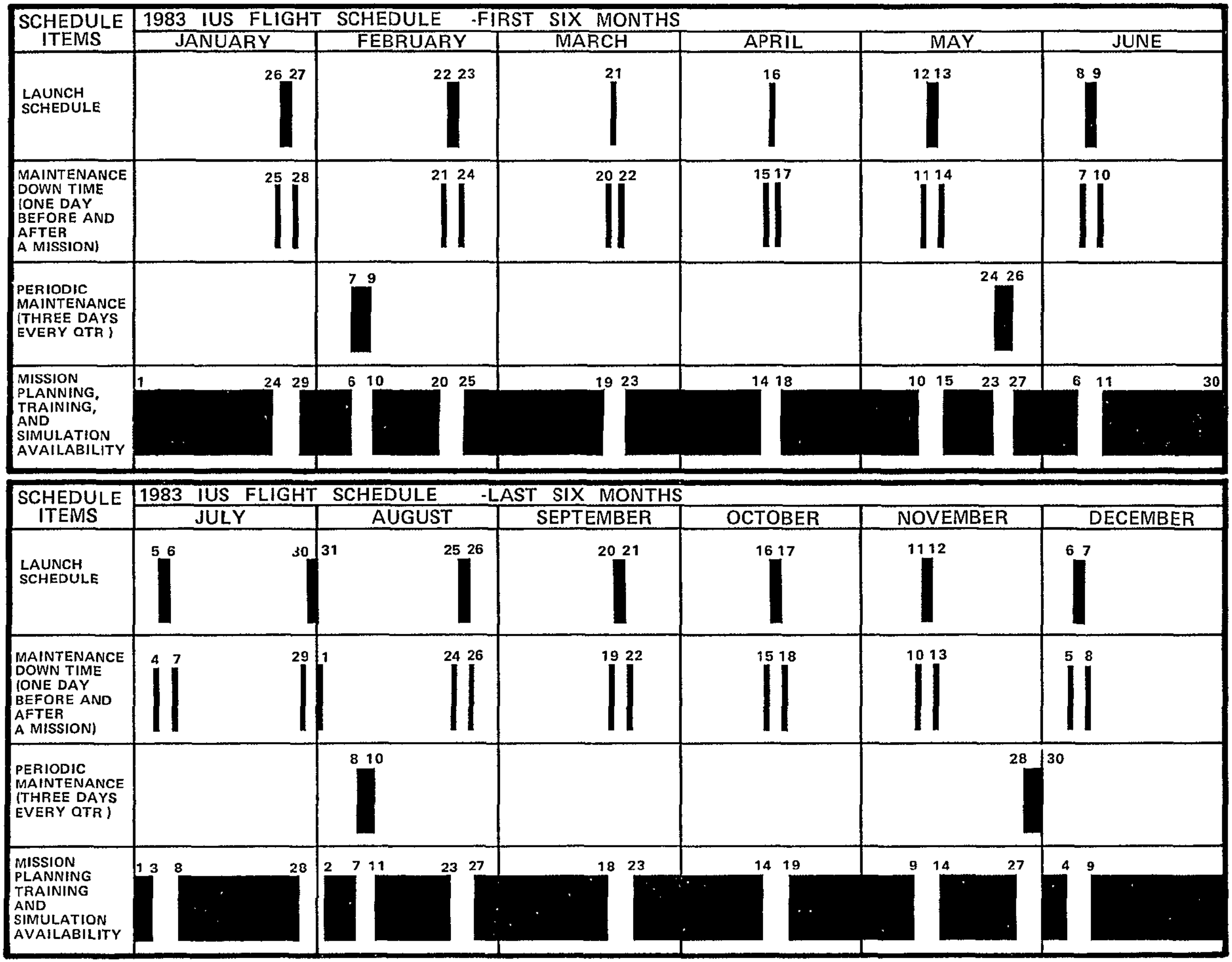

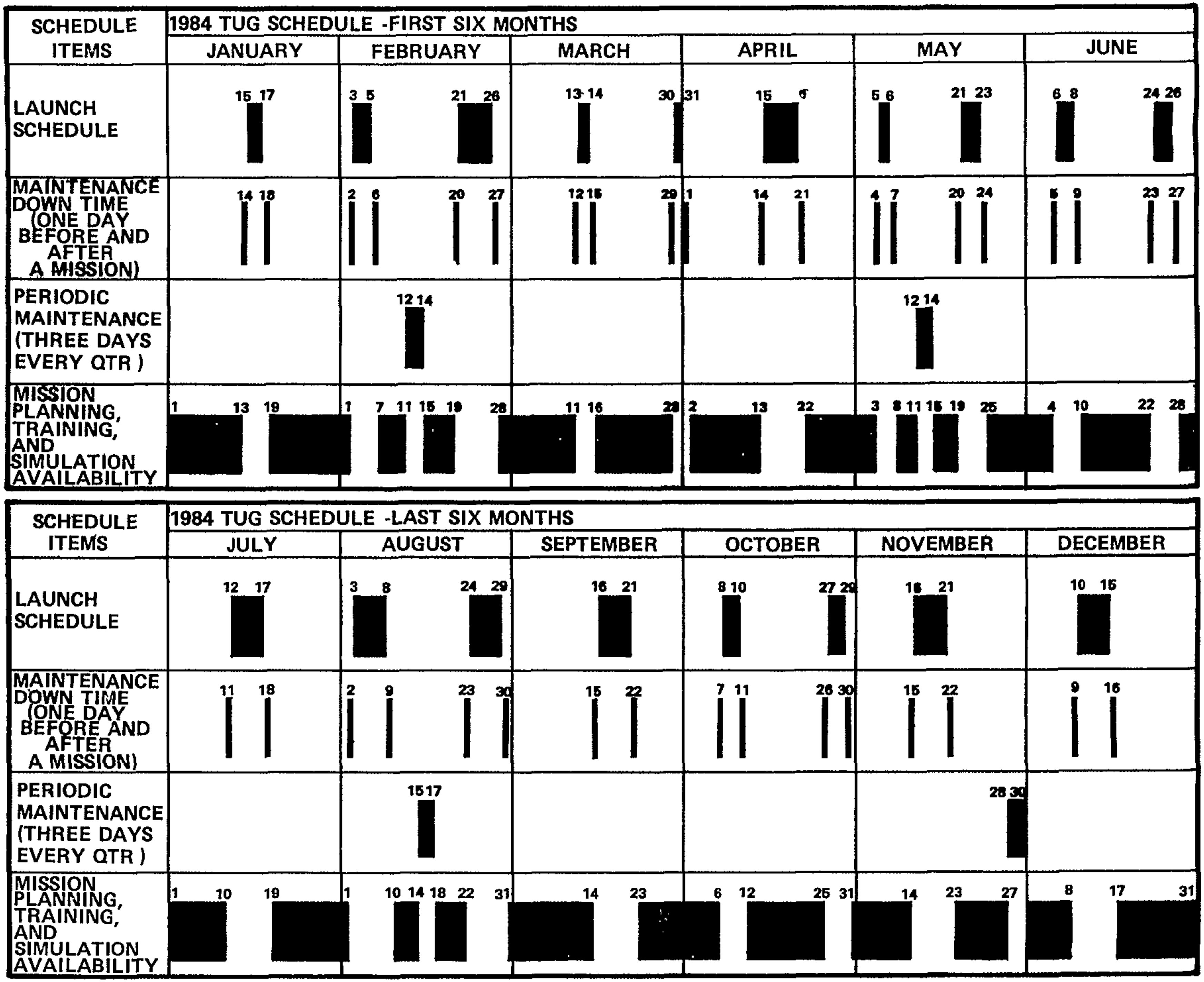

Figure 1 4 1-2 1984 Tug Flight Schedule

Examination of the charts indicate that the most dense year will not involve overlap of missions, and thus will not require additional equipment beyond those which are required to support a single mission Similarly, there appears to be no conflict between specific and periodic maintenance requirements and the launch schedules Finally, there appears to be sufficient uncommitted time to accommodate the training, simulation, and mission planning aspects of the flight control operation

In arriving at the foregoing conclusions it was assumed that the flight control function has pre-emptive authority over the computer complex supporting operations That is, simulation, planning and training, as well as missions, override any other utilization of the computer complex, such as batch processing and administrative utilizations

1 4 2 Tenant Relationship Assumptions

Before discarding the concept of a joint operations center shared with DoD, a series of computations were run based upon various sharing options in which either DoD or NASA would be the host agency with the other being a "tenant" and paying a fee for the services provided by the host

Some portions of the host's expenses incurred in running the operations center are chargeable to the tenant as service and rental fees The service fees are those expenses directly relatable to tenant-peculiar recurring costs Those costs are charged against facility maintenance, ground software maintenance, data system maintenance, sustaining flight control engineering and sustaining flight support engineering

The costs incurred by the host in obtaining additional equipment in the DDT&E phase to handle tenant-peculiar requirements is charged as the differential between the host (alone) and host plus tenant DDT&E expenses amortized over the operational life expectancy of the facility

Table 1 4 2-1 presents a typical tenant cost estimate NASA is assumed to be a tenant on a DoD controlled site during the IUS program

The concept of shared facilities has been discarded as unworkable due to the security requirements of DoD

1 4.3 Ground Software Productivity

The IBM FSD document, "Estimating Resources for Large Programming Systems", indicates a productivity factor of 20 instructions per man-day for the "easy" class of instructions The 20 instruction per man-day figure represents the cost of definition and coding, but excludes the cost of system test

Since the typical ratio of programming to test has been 7 3, the overall cost of program production can be adjusted by multiplying the 20 instructions per man-day by 0 7, which gives the recommended productivity factor of 14 instructions per man-day

Table 1 4 2-1 Typical Tenant Costs

NASA TENANT COSTS-ALTERNATIVE 2

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	5962
TOC SOFTWARE MAINTENANCE	312000
DATA SYSTEM MAINTENANCE	69397
SUSTAINING TOC ENGINEERING	768000
SUSTAINING TOC FLT CNTL ENGINEERING	864000
NETWORK RENTAL	0
IUS SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	38214
DATA SYSTEM	1120563
OPERATIONS STAFF EQUIPMENT	68253
TOTAL	3246389

Applying an average difficulty factor of 0 75, the instructions per man-day becomes 10 5 This figure is in close agreement with the rule-of-thumb figure of 10 end-product instructions per man-day stated in "Estimating Systems Cost", by T A Humphrey

1 4 4 Flight Software Productivity

Flight software productivity is much lower than Ground Software productivity, primarily due to two factors trying to fit a large number of computer functions into a small memory, and the requirement for extensive verification and test efforts demanded by ultra-reliability expectations

The Skylab flight program development history indicates that the recommended value for productivity of the "easy" class of instructions should be 6 9 instructions per man-day Considering an average complexity factor of 25 yields an effective 1 725 instructions per man-day

1 4 5 Hardware Procurement Costs

All hardware procurements have been assumed to be off-the-shelf items There appears to be no necessity for NASA to bear any DDT&E costs for Orbital operations and Mission Support equipment

The data system will be purchased as a unit, installed and checked out Network terminal equipment capable of handling the data flow requirements of the control center are commercially available Consoles are built-up from standard modules similar to those installed in several control centers throughout NASA and DoD

Any minor modifications to the control center hardware, and all maintenance (other than the control computer and peripherals) will be functions of the flight support staff

1 4 6 Physical Plant Area Distribution

The floor plan of the operations control facility was illustrated in Figure 1 2 1-1 This basic layout is functionally derived, but can be modified to suit the needs of NASA

The only variables in the physical plant calculations which affect the distribution of area is the number of consoles to be installed, and whether the consoles are flight control or flight support consoles The constant (non-operational) areas are presented below

TOC AREA	SQUARE FEET	
VIEWING POOM	243	
COMPUTER SUPPORT AREA	594	
TAPE STORAGE	255	
OFFICES, RESTROOMS, CANTEEN	1,080	
TECH SUPPORT AREA	1,296	
MECHANICAL SUPPORT AREA	612	
HALL/LOBBY	1,132	
DATA SYSTEM AREA	3,024	(CONSTANT FOR ALL SYSTEMS IN DATA BANK)
FLIGHT SUPPORT ROOM	600	(VARIABLE)
FLIGHT CONTROL ROOM	1,100	(VARIABLE)

1 4 7 Computer Selection Criteria

The central computer within the Tug control center, through its software, is the focal point for the entire mission support operation The computer must support a myriad of capabilities - examples of which are listed below

- o Mission Program Development and Test
- o System Simulation
- o Scientific Computation
- o Training of Ground Controllers
- o Real-time Support of Tug Mission
- o Schedule and Control Jobshop Work

Because of the criticality of the central computer to the overall operation, it is essential that the computer selected be capable of handling all planned functions in an orderly fashion and also provide sufficient growth capability to support changing requirements as the Tug program matures. The growth factor is particularly significant in view of the fact that the RTCC software required for support of the Apollo Program expanded by approximately 50 percent during that program As a result, the central computer became marginal, in some instances, in its ability to perform the burden of work placed on it.

The principal driving factors in the selection of a computer system are the memory capacity of the computer and its Central Processing Unit (CPU) capabilities The following paragraphs discuss the primary factors of memory capacity and CPU capabilities as they relate to the Tug control center central computer.

It is not necessary for the entire program to continuously reside in main memory. Through a proper structuring of the software system, a significant amount of the program can be placed on auxiliary storage devices to be read into main memory when required This technique will reduce the demand for core-resident programs and therefore reduce the main memory capacity requirements, however, the use of auxiliary storage will require significant input/output operations which may affect the ability of the system to satisfy response time requirements

CPU capability is defined to be the number of operations a computer can perform within a one second interval In selection of the central computer, it is required that the computer have sufficient computational capability to perform all defined functions within the specified time constraints As in the case of memory capacity, CPU growth capability must also exist for additional computational requirements as the Tug Program matures

Within the Tug control center, the principal factors which directly affect the CPU requirements are

- Software execution rates
- Input/output requirements
- Response times to user requests

The determination of CPU execution rates for a proposed computer system is a detailed effort requiring the use of extensive modeling techniques These modeling techniques require a detailed knowledge of software module content and frequency of operation. The preliminary nature of software module definition contained in this study precludes the use of such techniques and therefore an alternate approach was taken.

The functional similarities between the RTCC, JPL, and TCC requirements provide a means whereby an analysis of existing system CPU utilization can establish a baseline for TCC CPU requirements. Because the RTCC is a "man-rated", real-time system, its CPU utilization was selected as an upper bound. A minimum bound was established from the JPL operation, which is a non-man-rated, non-real-time system

TCC execution rates were then assumed to be greater than the JPL operation and less than the RTCC Through comparative statistics, it was established that the maximum case TCC CPU utilization would require 20 percent less than the RTCC maximum

The 75 percent maximum utilization for the TCC, when applied to the 360/75 Model J, results in a maximum CPU utilization of 3 85 X 10^6 operations/second required of the TCC central computer

As has been stated previously, growth capability in both memory capacity and CPU capability must be considered in computer selection IBM's previous experience on similar ground control centers (RTCC and JPL) indicate that growth potential in both areas should be approximately 100 percent to satisfy requirements Failure to provide for this growth can severely restrict the ability of the Tug control center to expand with the increasing requirements placed upon it A major objective in selecting the central computer should be to provide for orderly growth in capability throughout the lifetime of the center

As was developed previously, the main memory capacity must be a minimum of 415,497 words to handle maximum case memory requirements for the IUS program, and the CPU capability provides 3 85 X 10^6 operations/second The additional 100 percent increase in these capabilities to provide the desired growth capacity yields the following characteristics the candidate computer must satisfy

- Memory Capacity - IUS 830,993
  Tug 696,899
- CPU Capability - 7.7 million Operations/Second

The candidate computers, within the IBM 370 line, which should be considered for the ground control center application with the growth capability provided, are shown in Table 1 4 7-1

The automated cost analysis COMPSELECT program lists the computer systems capable of meeting the main memory size and growth requirements and the CPU speed and growth requirements in ascending order of installed cost The operator then elects the computer for the application

The IUS program requires a 370/158-MP6 system, while the Space Tug program requires a 370/158-MP5 system The installed cost differential in price between these two systems is $507,000 dollars

Examination of Table 1 4 7-1 shows that the memory size of the 370/158-MPS computer is the constraint which forced the IUS cost analysis program to eliminate the MP-5 from consideration.

Bearing in mind the facts that 1) the IUS ground computer main memory requirement assumes 100% growth capability, and 2) the IUS program is only three years in duration, it is reasonable to take a calculated risk on IUS growth requirements in order to save a half-million dollars If the 100% growth requirement is relaxed, a computer appropriately sized for Space Tug requirements could be selected and used for both the IUS and Space Tug programs

If the 370/158-MP5 system were selected, the IUS growth factor is reduced from 100% to 89 3%

The cost data presented in this report <u>does not</u> select the 370/158-MP5, but data has been presented which will allow NASA to accept or reject the program risk associated with selecting the 370/158-MP5 at reduced IUS growth potential

Table 1 4 7-1 Candidate Control Center Computers

370/158 SYSTEM

MODEL	WORDS	MEGA OPS	CPU + PERIPHERALS + 1ST YEAR MAINT $	CPU + PERIPHERALS 2ND YEAR MAINT $
MP1	131,072	8 7	4,832,776	117,945
MP2	262,144	8 7	5,085,776	120,113
MP3	393,216	8 7	5,338,776	122,282
MP4	524,288	8 7	5,591,776	124,450
MP5	786,432	8 7	6,205,376	134,458
MP6	1,048,576	8 7	6,711,376	138,795

370/168 SYSTEM

MODEL	WORDS	MEGA OPS	CPU + PERIPHERALS + 1ST YEAR MAINT. $	CPU + PERIPHERALS 2ND YEAR MAINT $
MP1	262,144	12 5	8,777,801	261,547
MP2	524,288	12 5	9,283,801	265,884
MP3	786,432	12.5	9,811,661	276,393
MP4	1,048,576	12 5	10,316,601	281,730
MP5	1,310,720	12.5	10,931,201	291,071
MP6	1,512,864	12 5	11,437,201	295,408
MP7	1,835,008	12 5	11,943,201	299,745
MP8	2,097,152	12 5	12,449,201	304,081

The percentages of the control module, vehicle system module and mission profile module simultaneously resident in main memory are 81 6%, 65% and 34 8%, respectively A growth factor of 100% is assumed

The IUS main memory requirement is calculated to be 830,993 words The Space Tug main memory requirement is calculated to be 696,899 words Each of these figures assume 100% growth factor

1 4.8 Personnel Manning and Shift Density Factors

The console positions were selected based upon the requirements to support the sub-functions within the mission modules For the IUS program 31 positions were identified For the Space Tug program, 33 positions were identified

Analysis of the mission timelines indicated that the missions could be conducted on a two-shift basis, but could not be conducted on a one-shift basis Therefore, any single mission requires at least two times the number of personnel necessary to man a single shift After appropriate adjustment to account for single shift computer support, the total operational manpower requirement of the IUS and Space Tug programs are 60 and 63, respectively.

The most dense NASA Space Tug or IUS mission years do not involve any overlap between mission operations. It is therefore concluded that two shift manning is sufficient to handle the IUS and Space Tug programs An alteration to the traffic model or launch schedule should cue NASA to re-examine the shift density factors. Tables 1 4.8-1 and 1 4 8-2 present the personnel manning requirements for the IUS and Space Tug programs, respectively

Table 1 4 8-1 IUS Operational Personnel

IUS OPERATIONS CENTER PERSONNEL

POSITION	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT CONTROL GROUP				
IUS OPERATIONS DIRECTOR	1	1	2	96000
VEHICLE SYSTEMS ENGINEER	1	1	2	96000
PROPULSION	1	1	2	96000
STAGE SYSTEMS	1	1	2	96000
CONSUMABLES	1	0	2	96000
NETWORKS	1	1	2	96000
COMMUNICATIONS	1	0	2	96000
AVIONICS	1	1	2	96000
GUID AND NAV	1	0	2	96000
SEQUENCE	1	0	2	96000
GUIDANCE	1	1	2	96000
DYNAMICS	1	1	2	96000
DATA SELECTION	1	1	2	96000
FLIGHT DYNAMICS OFFICER	1	1	2	96000
SPECIAL FUNCTIONS	1	1	2	96000
FLIGHT SUPPORT GROUP				
FLIGHT SUPPORT DIRECTOR	1	1	2	96000
DATA SYSTEM SUPERVISOR	1	1	2	96000
COMMAND	1	0	2	96000
TELEMETRY	1	1	2	96000
SITE SELECT	1	0	2	96000
MAINTENANCE AND OPERATIONS	1	1	2	96000
DATA FLOW	1	1	2	96000
DPS ENGINEER	1	0	2	96000
VOICE TECH	1	0	2	96000
DISPLAY TECH	1	0	2	96000
COMPUTER SYSTEM MONITORS	2	1	4	192000
COMPUTER OPERATIONS	2	0	4	192000
COMPUTER SUPPORT	2	0	2	96000
TOTALS	31	17	60	2880000

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Table 1 4 8-2 Space Tug Operations Personnel

TUG OPERATIONS CENTER PERSONNEL

POSITION	MAX MANNING	NUM OF CONSOLES	SHIFT DENSITY	COST
FLIGHT CONTROL GROUP				
TUG OPERATIONS DIRECTOR	1	1	2	96000
VEHICLE SYSTEMS ENGINEER	1	1	2	96000
PROPULSION	1	1	2	96000
STAGE SYSTEMS	1	1	2	96000
CONSUMABLES	1	0	2	96000
NETWORKS	1	1	2	96000
COMMUNICATIONS	1	0	2	96000
AVIONICS	1	1	2	96000
GUID AND NAV	1	0	2	96000
SEQUENCE	1	0	2	96000
GUIDANCE	1	1	2	96000
DYNAMICS	1	1	2	96000
TV/DOCKING	1	1	2	96000
FLIGHT DYNAMICS OFFICER	1	1	2	96000
SPECIAL FUNCTIONS	1	1	2	96000
FLIGHT SUPPORT GROUP				
FLIGHT SUPPORT DIRECTOR	1	1	2	96000
DATA SYSTEM SUPERVISOR	1	1	2	96000
COMMAND	1	0	2	96000
TELEMETRY	1	1	2	96000
SITE SELECT	1	0	2	96000
DATA FLOW	1	1	2	96000
DPS ENGINEER	1	0	2	96000
VOICE TECH	1	0	2	96000
DISPLAY TECH	1	0	2	96000
TV TECH	1	0	2	96000
COMPUTER SYSTEM MONITORS	2	1	4	192000
COMPUTER OPERATIONS	3	0	6	288000
COMPUTER SUPPORT	3	0	3	144000
TOTALS	33	16	63	3024000

1 4.9 Network Utilization Cost Assumptions

The derivation of network utilization cost constraints is presented in paragraph 1 3 6. The derived constants are

Television Data $290/hour
Telemetry Data $ 90/hour
Command Data $ 25/hour
Tracking Data $ 25/hour

1 5 OPERATIONAL PHILOSOPHY

The basic philosophies for performance monitoring, vehicle commanding, contingency support and mission design are presented in this section

1 5 1 Performance Monitoring

The selected IUS and Space Tug systems operate under moderately differing performance monitoring expectations The IUS requires significant ground intervention, monitoring and backup due to the relative lack of sophistication in the onboard avionics The Space Tug is capable of operating with maximum practical autonomy, and thus requires a minimal ground backup capability

In both programs, however, demands for crew safety and protection of the environment require a continual monitoring of the system's performance System performance is monitored in two areas (1) the functional operability of the vehicle systems and (2) the trajectory and orbital mechanics of the vehicle

Systems functional assessments are made in real time by flight control personnel in order to guard against malfunction situations The primary purpose of systems functional assessment is to provide lead time in establishing corrective action and alternate paths for mission continuance A real time operating organization is established which provides a hierarchy and information flow path through which command decisions may be implemented The base of the hierarchy is in the systems analysts, who view the performance of the vehicle and assess the adequacy of the operation of its various systems This information is passed from the systems analyst level to the group overseer level (such as propulsion, avionics, etc) through which it is passed to the central vehicle systems control point Beyond the vehicle systems control point, the information is passed to a mission director who must take into consideration the overall impact of all data input to him from organizations similar to the vehicle systems group The vehicle systems organization is concerned almost exclusively with the operability of the inflight hardware

The basic philosophy of system functional assessment is the same for both IUS and Space Tug programs It is in the implementation of the mission control actions that the two programs deviate

The trajectory and orbital mechanics organization has a hierarchy similar to that defined for the vehicle systems group

At the lowest level in the hierarchy, analysts are responsible for the analysis of the performance of the vehicle. This means that the trajectory is being assessed for the impact of drift in inertial references, necessity for corrective maneuver requirements, and monitored for anomalies.

The IUS program requires ground-based radar to provide trajectory information to a central computer The Space Tug program derives the navigation information from Space Tug mounted sensors. So, there is a major difference between the IUS and Space Tug implementations, although the philosophy of maintaining cognizance of the vehicle trajectory is unchanged.

An organization is required to provide data and computational services to the operational personnel. This is defined as the flight support group. The flight support group is responsible for providing the necessary data, command and network configuration coordination required to support the IUS or the Space Tug missions All scheduling interfaces with network operations will be conducted by this team Additionally, all hardware and software maintenance required in the Tug control center will be supplied by the flight support group.

Under the current operating philosophy, ground-based personnel are required to monitor the functioning of vehicle systems and the vehicle trajectory The basic reason for monitoring trajectory and systems functions is to provide decision support during contingency situations. These decisions are largely thought out in advance of the mission and implemented upon the controller's recognition of a pattern of events indicative of a previously thought out malfunction situation The justification for human interaction with the mission control function is that the human being has a much more perceptive pattern recognition capability than a machine The maintenance of this pattern recognition capability costs the Government almost $3 million annually in recurring personnel expenses

It is within the capability of current computer systems to replace a large portion of the pattern recognition requirements currently supplied by human beings An excellent candidate for future study is the automation of flight control functions This will cause an increase in the cost of ground software and ground software maintenance but should result in a smaller increase than the $3 million currently being spent annually to maintain man-in-the-loop capabilities

1 5 2 Vehicle Command Actions

In the IUS program, ground commands will routinely be issued as a part of nominal operations In the Space Tug program, ground commands will not be issued except in contingency or backup situations.

The IUS will require command capabilities in the following general categories navigation update, target update, attitude update, alternate sequence selection and a generalized capability for the purpose of providing an alternate path for sequential class functions

The Space Tug program will require command intervention only in the event of a systems malfunction or alternate mission requirement The general class of commands to be provided are essentially the same as those required by the IUS program

1 5.3 Contingency Support

The primary purpose of maintaining a ground control organization is to provide support during contingency actions and to protect life, property and the environment

In order to be effective, contingency support must protect against any eventuality To paraphrase a World War II American admiral, "It is more important to be able to defend against what the enemy can do than to defend against what he will probably do " In mission operations, malfunction is the enemy

In the pre-mission period, as many possible malfunctions as can be defined should be investigated and the system response to those malfunctions predicted The documentation resulting from the analysis of potential malfunctions and the prediction of the outcome of those malfunctions is referred to as the Mission Rules Document. The starting point for the generation of such a document should be those failures which have a high probability of occurrence, but should ideally continue throughout all possible failure modes in order to protect against what the malfunctions can possibly do

1 5 4 Mission Design

The mission design function will be accomplished by the computer complex which supports the real-time mission operations This program will also be adaptable for use in real time as a source of trajectory information for building a revised mission time line

1 6 COST COMPRESSION TECHNIQUES

This section presents plans for cost avoidance, equipment multiplexing, personnel multiplexing, program transition, and cost-control management

1 6 1 Cost Avoidance

The cost avoidance technique employed in this study was to lay out a definitive DDT&E plan and to sequence that plan to avoid duplications and wasteful effort

Cost has been avoided in the recurring area by minimizing the number of personnel involved in real-time flight control and flight support operations.

NASA can realize large savings if the IUS and Space Tug avionics interface with the outside world is equal or maximally similar This will permit the specialization of network interface and the control center equipment, thus avoiding the extra expense always incurred when purchasing generalized equipment

1 6.2 Equipment Multiplexing

There is no special-purpose equipment which is unique to either the IUS or the Space Tug program. A single equipment purchase during the IUS program will provide the consoles, data system, and network interface equipment for the entire space transportation system era

1 6.3 Personnel Multiplexing

The IUS program precedes the Space Tug program by three years and overlaps the Space Tug program to a minimum extent. The same personnel should be utilized to control and support the IUS program who are used to control and support the Space Tug program This avoids a dual learning curve and provides for continuity of familiarity with equipment

During the non-operational periods, maximum utilization has been made of flight support personnel and flight control personnel in preparing for subsequent missions and providing planning and maintenance services.

1.6 4 Program Transition Approach

The approach taken to transition between IUS and Space Tug has been to lay out a well defined plan and to sequence and load tasks such that a minimum number of IUS-peculiar activities are taking place during the Space Tug-peculiar DDT&E Transition presents no major problems if it is well planned, and the plan is strictly followed Section 1 4 7 presents a rationale for the selection of a smaller computer than required for the IUS program in order to provide a minimum cost data system for the combined program.

1 6 5 Cost Control Management

Control of cost is best accomplished at the program management level There are relatively few activities in orbital operations and mission support which require close cost control. Among those that do require close cost control are changes to the ground software and flight software The position should be assumed that all change is bad, and changes should be limited to those which are required to make the system work. The program office should establish a cost-control management authority, whose function it would be to review and judge the necessity for all changes in the mission operations area

1 7 COST ESTIMATING RELATIONSHIPS

This section presents the logical flow of information from known (or estimable) parameters to dollar figures. The technique used to illustrate the flow is to present sub-blocks in detail and show the connection to block flows elsewhere in the cost estimating structure. Each sub-block consists of an alphabetic designator, which identifies the block, and numeric designators which identify nodes within the block. For example, the designator UL-3 identifies the third (-3) node of the uplink (UL) processing sub-block All nodes internal to a block are shown in circles, ③ connections between sub-blocks are shown as squares, $\boxed{2}$ (GS), where the alphabetic designator following the square identifies the sub-block to which connection is made. In the example, $\boxed{2}$ (GS) means that the connection is made at the second node of the Ground Software (GS) sub-block Outputs from the cost flow are shown as triangles, △ Inputs to the flow (generally cost constants) are shown as diamonds, ◇ .

1 7.1 Ground Software Cost Relationships

The technique used to generate a ground software cost is to estimate the number of instruction words (I), the number of data words (D) and a complexity factor (K) for each module The results are then computed through the use of the Ground Software cost algorithm presented in Section 1.2 2

Figure 1.7 1-1 presents the downlink processing sub-block, (a), the uplink processing sub-block, (b), the mission planning sub-block (c), the control software sub-block, (d), and the simulation software sub-block, (e)

The sub-block flows are merged into the ground software block in Figure 1.7 1-2 Outputs from the ground software block go to the memory size (MS) block, the total cost (TC) block and to a summary printout, △1. The conversion from software estimate to dollars is made between GS-15 and GS-16

1.7 2 Computer Selection Cost Relationships

There are two criteria involved in the selection of the Control Center Computer. First, it must satisfy the simultaneous memory requirements of the Ground Software (Figure 1 7 2-1(a)) Second, it must meet or exceed the maximum required CPU execution rate These parametrics are detailed in paragraph 1 4 7

The cost estimating relationship is merely to select an appropriately configured computer Figure 1 7 2-1(b) presents the selection criteria block Figure 1 7 2-1(c) presents the logic leading to selection of a specific computer

The total active memory requirement is derived from percentages of module size, which, in turn, is based upon RTCC and JPL Control Center experience The output from the memory size block establishes one of the two criteria for computer selection

Figure 1 7 2-1(c) requires three inputs a computer system characteristics table which lists the computer system memory size, CPU execution rate, installation area requirement, installed cost, and maintenance cost, a calculated main memory size estimate and a manually entered CPU speed estimate Those factors are integrated at node C-4 to provide a list of computer systems which meet or exceed the memory size and CPU capacity requirements

The actual selection is either made automatically, based on minimum cost, or by manual override The result is an output from SC-3 to C-12 which then distributes the selected computer characteristics to the sub-blocks requiring inputs from C, the data system cost block (DSC), physical plant block (P) and recurring cost block (RC)

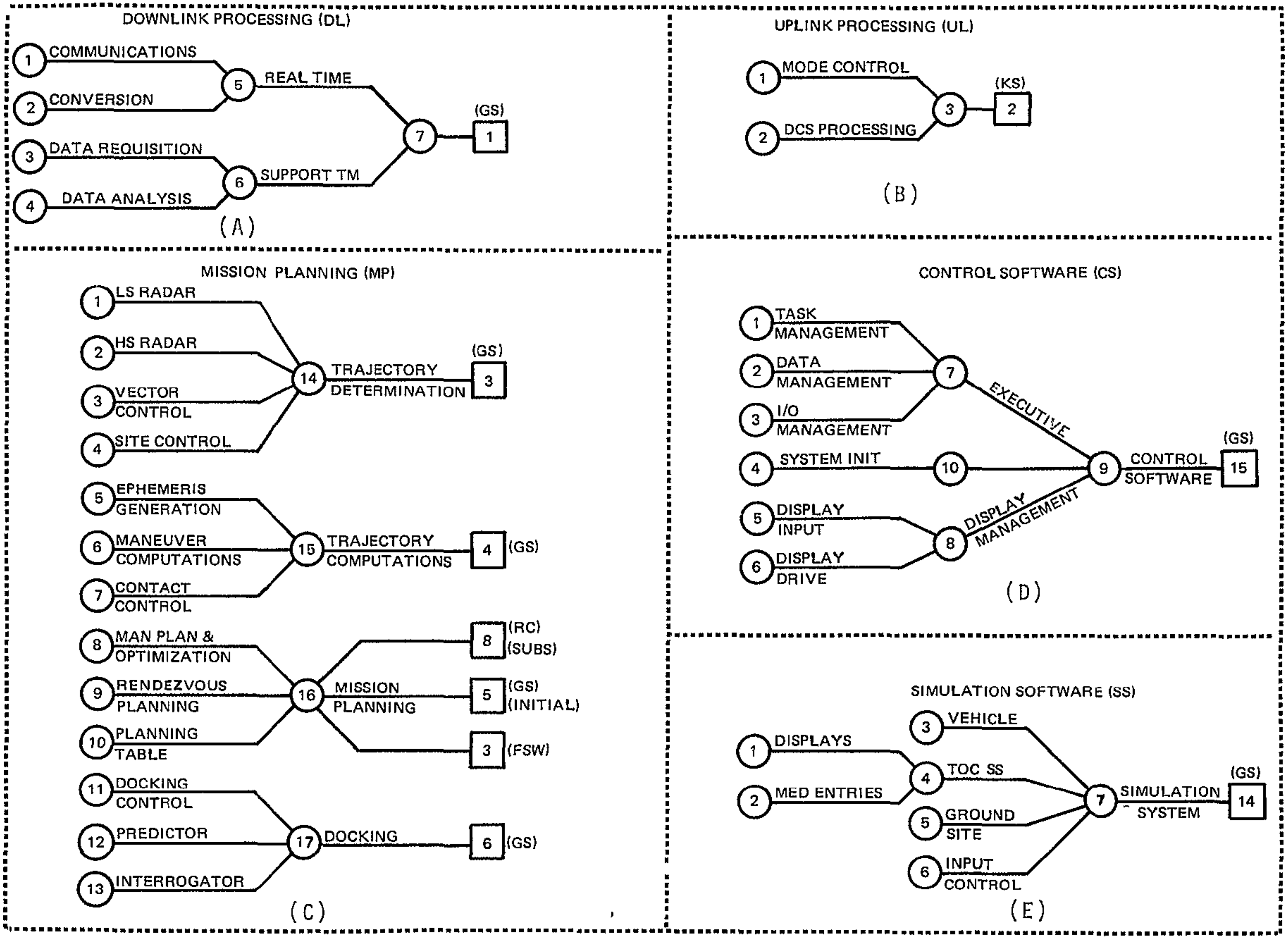


Figure 1 7 1 1 Ground Software Sub-Block Flows

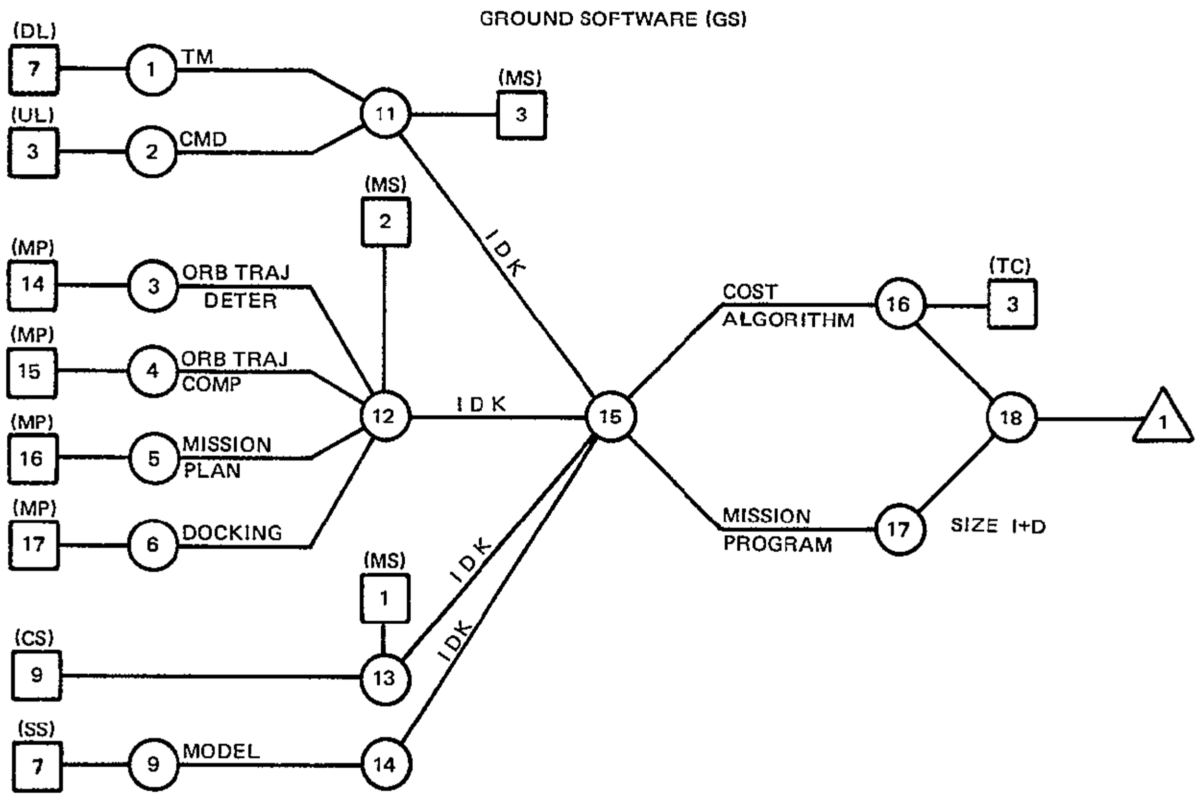


Figure 1 7 1-2 Ground Software Block

1 7 3 Data System Cost Relationships

Figure 1 7 3-1 presents the Data System Cost Relationships

The Data System consists of six sub-systems the computer, which is selected as outlined in the preceeding paragraph, a master timing system, which is priced based upon commercially available equipment, line terminals, which were discussed under paragraph 1 4 9, a teletype system, communications system, and video system

In the initial review of the requirements, it was anticipated that some states of autonomy or vehicle configuration could preclude the need for one or more of the data system elements To accommodate that possibility a "Logic Enable" function, operating upon the involvement matrix was designed into the cost analysis programs This logic enable function "gates" the cost inputs, so that if a "0" appears at a gate, the corresponding data system element is examinated from the cost computations

Output from the DSC block is the total data systen cost, which is input to the total cost (TC) block

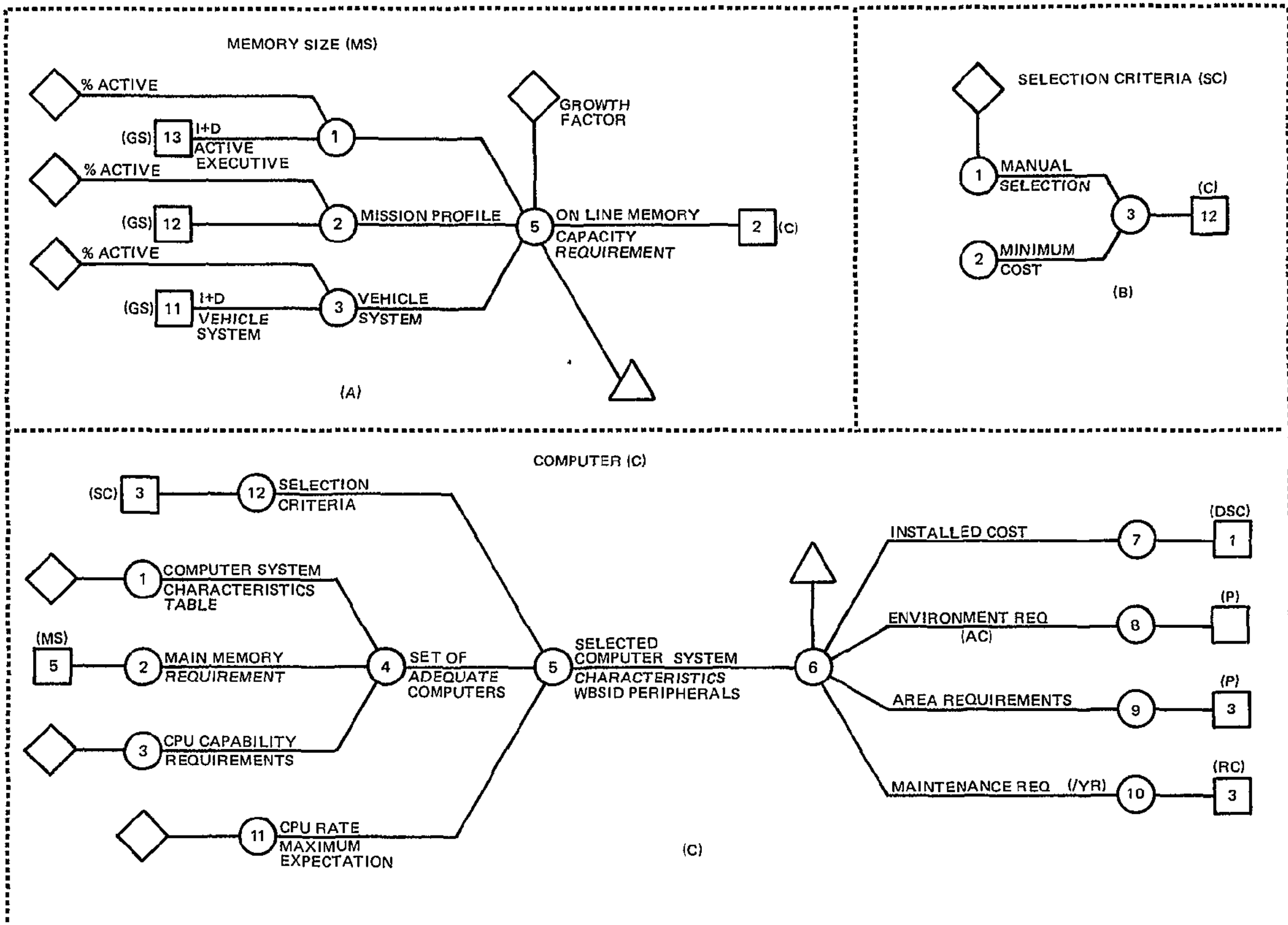


Figure 1 7 2-1 Computer Selection Relationship

DATA SYSTEM COST (DSC)

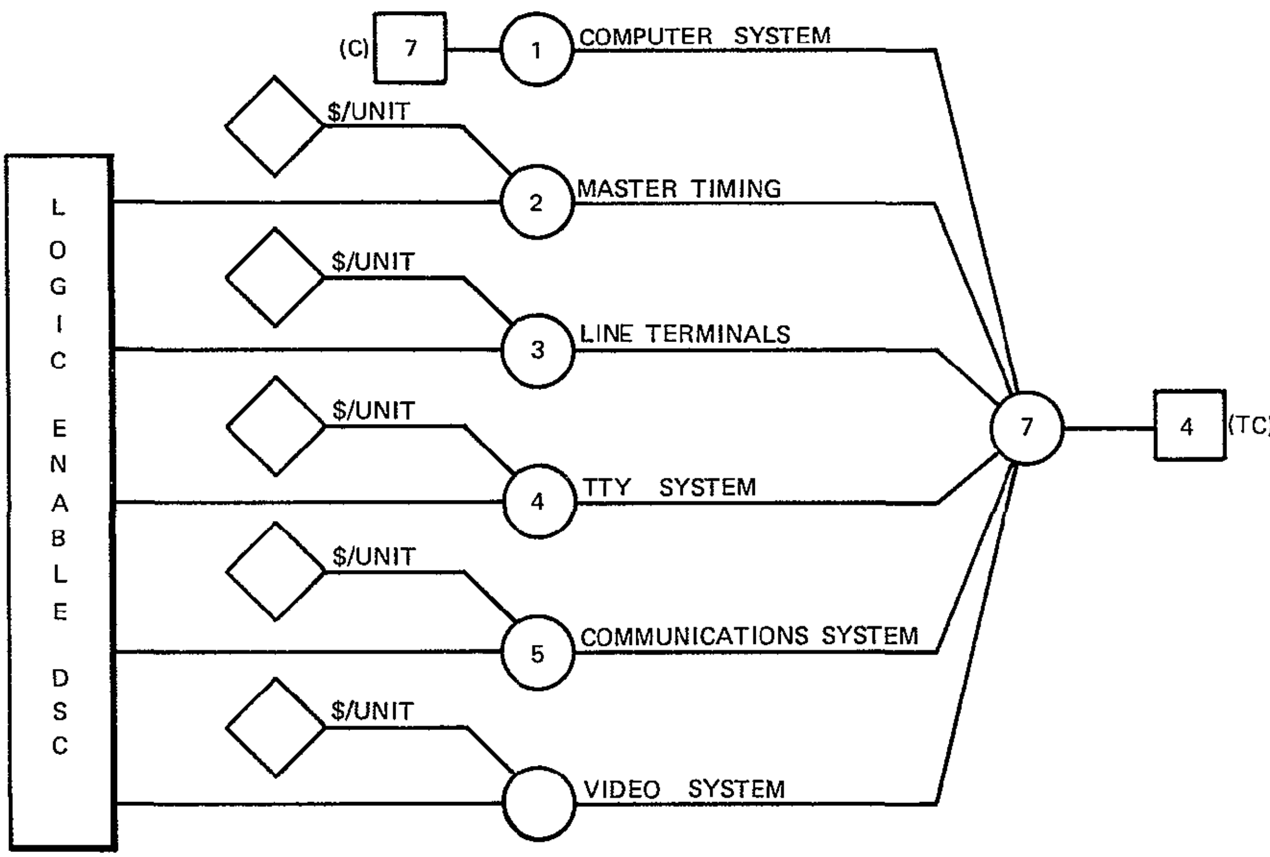


Figure 1 7 3-1 Data System Cost Relationships

1 7 4 Console Cost Relationships

Console types needed to support Orbital operations are related directly to the operational philosophy and vehicle autonomy level Since these parameters are captured in the involvement matrix, a "Logic Enable" function which operates on the involvement matrix was designed into the cost analysis programs

The Logic Enable Function creates a 30 element "CONSOLE CONTROL VECTOR' Each element corresponds to an operating position This vector is used to enable the personnel requirements calculation and the console type calculation

Console types fall into two larger categories, consoles which are used by flight control personnel, and consoles which are used by flight support personnel. These categories also indicate where the consoles are to be installed in the physical plant

Figure 1 7 4-1 presents the flight support console and flight control console relationships The logic enable function selects the consoles from the list The total number of consoles is then supplied to the hardware select block. The number of consoles, multiplied by the number of square feet required by each console, is input to the physical plant block

Provision has been made to accommodate multiple mission impact in the costing scheme. This appears as an input from the mission density block (MDF) to node FCC-17

1 7.5 Hardware Cost Relationships

Figure 1.7.5-1 presents the hardware cost relationships block. The inputs to the block are from the flight support console block and the flight control console block Each console is configured in accordance with the hardware select table, then the accumulated costs are output to the total cost (TC) block

External inputs are required for the module costs These external inputs were derived from a survey of currently available equipment used in similar flight control or real-time operations

Table 1 7.5-1 Console Costs

Item	Quantity	Cost
Console	1	$ 6,000
Comm Panel	2	7,500
TV Monitor	2	2,500
Event Monitor	1	10,000
Manual Entry Keyboard	1	8,000
Command Panel	1	9,000
Display Control Panel	2	2,500

1 7 6 Physical Plant Cost Relationships

The physical plant costs are driven by the floor space required to support the number of consoles calculated by the flight support console and flight control console cost relationship blocks.

Two constants are used 50 dollars per square foot is estimated to be the cost of constructing raised flooring area, 35 dollars per square foot is estimated to be the cost of constructing ordinary flooring areas. These constants oversimplify the problem, but are good "rule-of-thumb" bases for estimating construction of a one-story concrete block structure on slab.

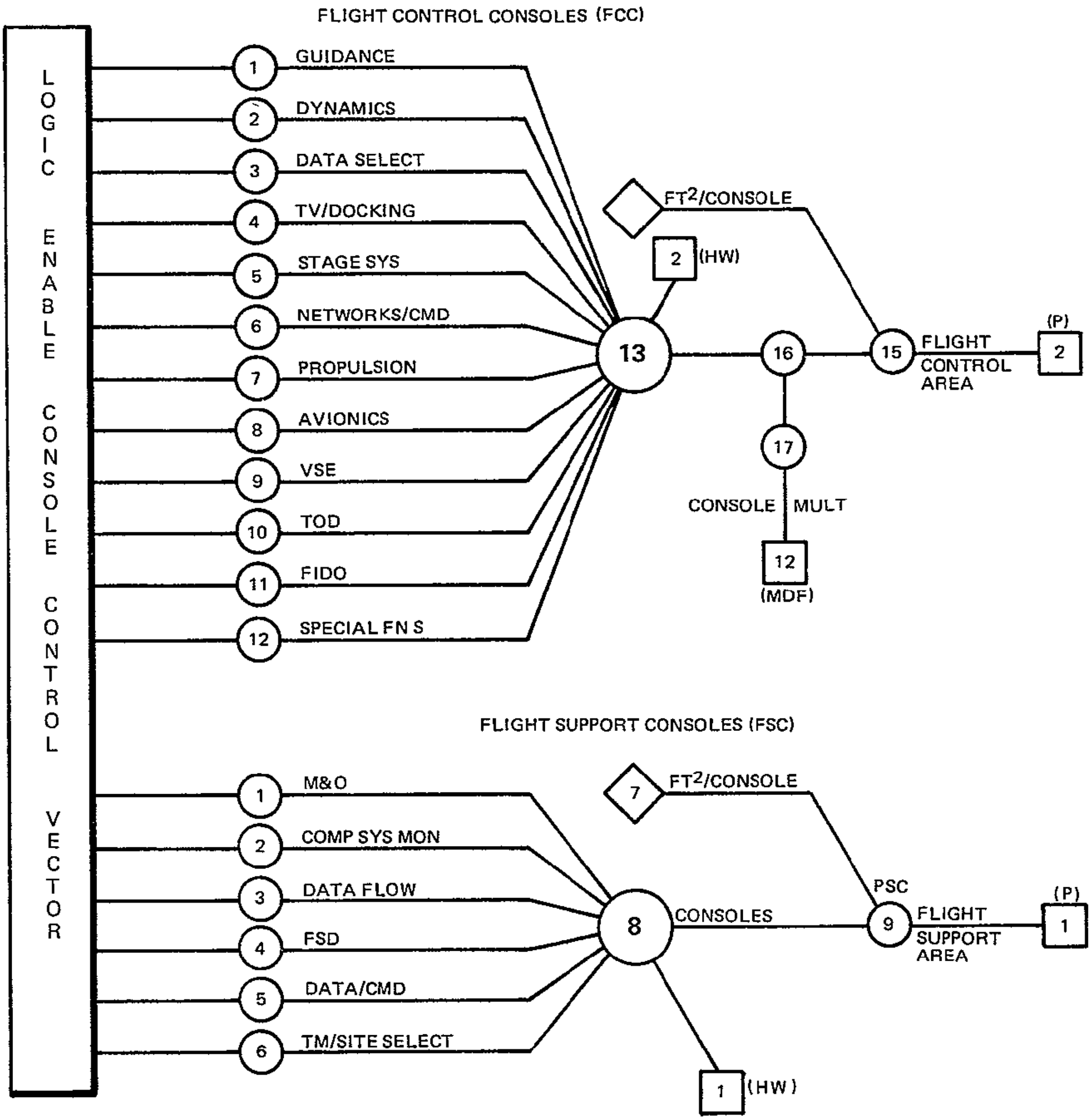


Figure 1 7 4-1 Flight Control Console and Flight Support Console Cost Relationships

HARDWARE SELECT TABLE

POSITIONS		COMM	D/TV	EVENT	MED	CMD	DISPC
M&O FSC	1	1	2	4	1	0	1
CSM	2	3	3	6	1	0	1
DATA FLOW	3	1	1	2	1	0	1
FSD	4	1	2	4	1	1	1
DATA SYS SUP	5	2	2	4	1	1	1
TM/SITE SEL	6	2	2	2	1	0	1
GUID FCC'S	1	2	2	4	1	0	1
DYN	2	2	2	4	1	0	1
DATA SYS	3	2	2	4	1	0	1
T/V	4	2	2	4	1	1	1
STAGE	5	2	2	4	1	0	1
PROP	6	2	2	4	1	1	2
NTWK/CMD	7	2	2	4	2	1	0
AVIONICS	8	2	2	4	1	1	1
VSE	9	1	2	4	1	1	1
TOD	10	1	2	4	1	0	1
FIDO	11	1	2	4	1	1	1
S/F	12	1	2	4	1	1	1

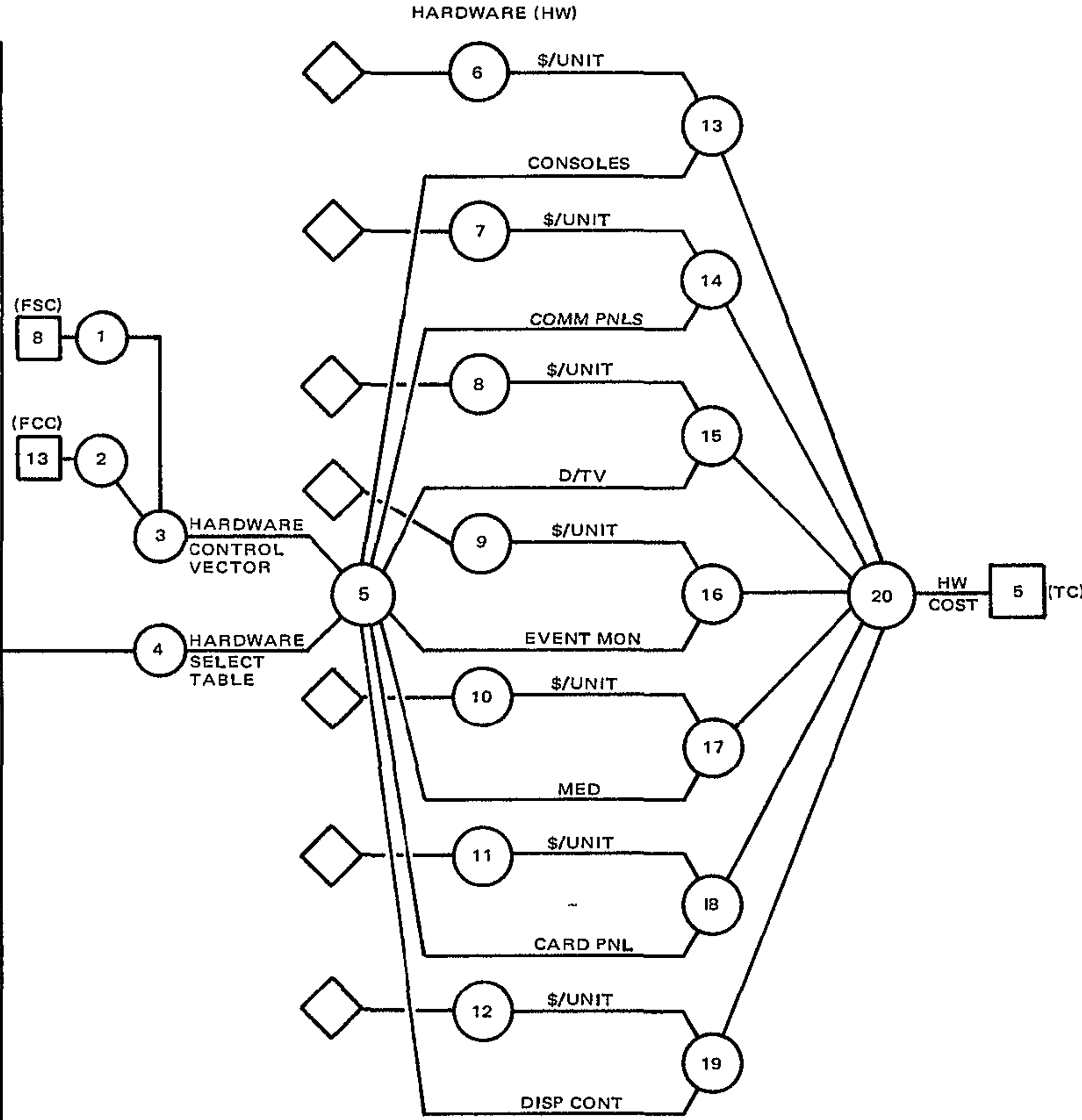


Figure 1 7 5 1 Hardware Cost Relationships

Figure 1 7 6-1 presents the physical plant cost relationship block. Inputs are required from the computer selection block (C), the flight support consoles block (FSC) and the flight control consoles block (FCC) The inputs establish the "raised flooring" area requirements

The normal flooring area requirements are functions of the architectural design, and are left for manual entry

1 7 7 Flight Program Cost Relationships

The technique used to generate a flight software cost estimate is to estimate the number of instruction words (I), the number of data words (D) and a compexity factor (K) for each module The results are then computed through the use of the flight software cost algorithm presented in section 1 2.5

Figure 1 7 7-1 presents the flight software block All terminal nodes in this block are estimates of software size and complexity, based upon IBM's extensive experience in developing flight software for Apollo, Skylab and other programs

The conversion from size estimate to dollar cost is made at node FSW-11 The output of this block feeds the total cost (TC) block

1 7 8 Total DDT&E Cost Relationships

The Total Cost of DDT&E for a single program (IUS or Tug) is developed by summing the outputs from the physical plant block, flight software block, ground software block, data system block and hardware block

Figure 1 7 8-1 presents the total DDT&E cost relationship block

1 7 9 Mission Density Impact on Pecurring Costs

Before arriving at an estimate of recurring costs, it was necessary to investigate the impact of simultaneous missions and mission module overlaps on the level of support required.

Figure 1 7 9-1 presents the logic flow for the mission density factor program This program creates a launch schedule and mission module timing schedule for which the overlap of missions and mission modules is developed At the same time, gaps in the schedule are identified which can be filled by training and simulation tasks

Outputs from the mission density factor block drive the following dependent cost relationships

Computer Support Personnel	- Establishes the hours the computer is committed
Sustaining Flight Control	- Establishes the number of shifts required
	- Establishes the number of personnel required

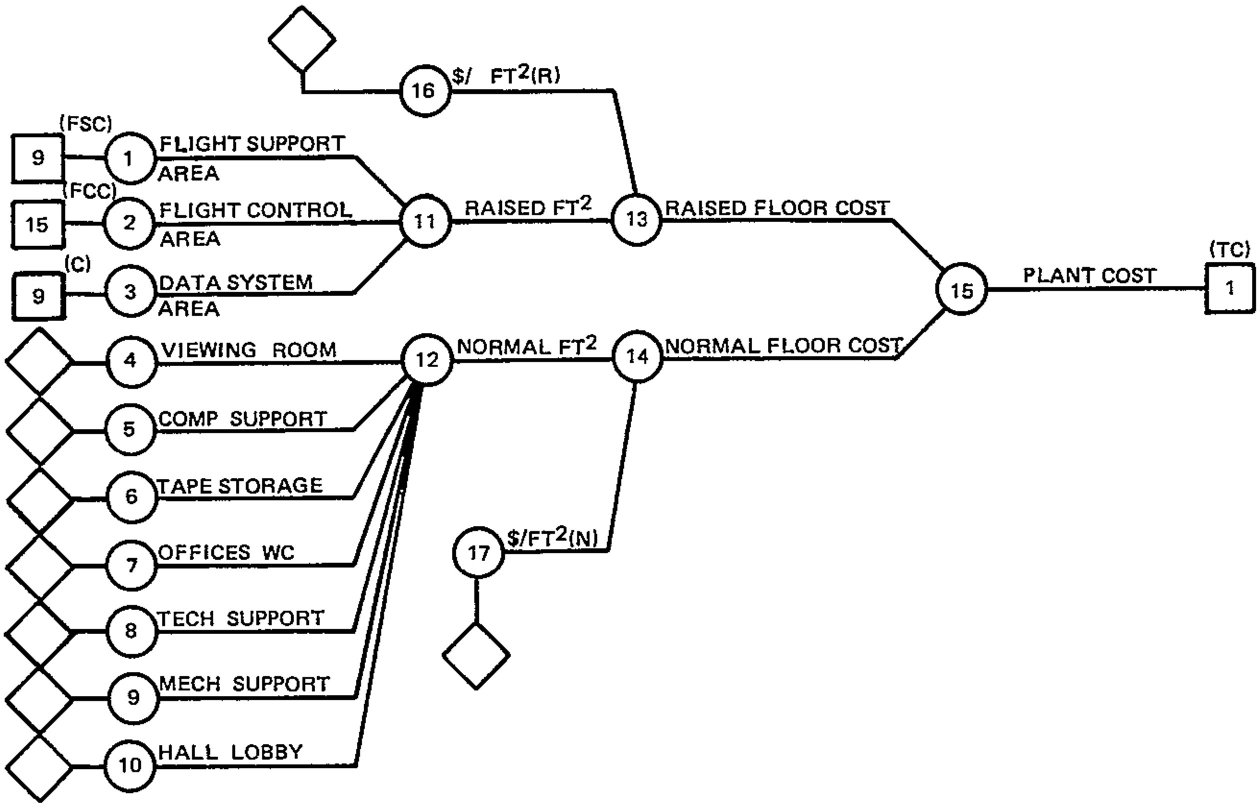


Figure 1 7 6 1 Physical Plant Cost Relationships

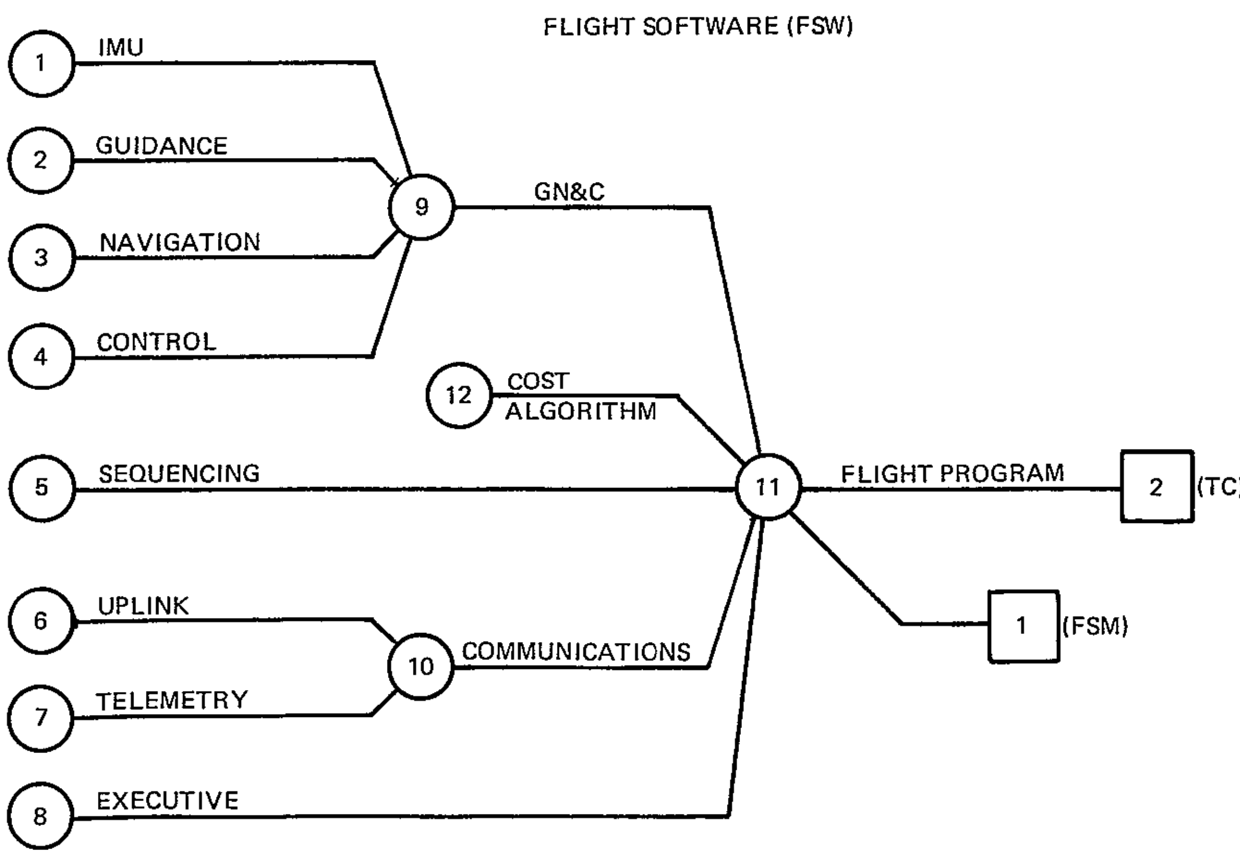


Figure 1 7 7 1 Flight Program Cost Relationships

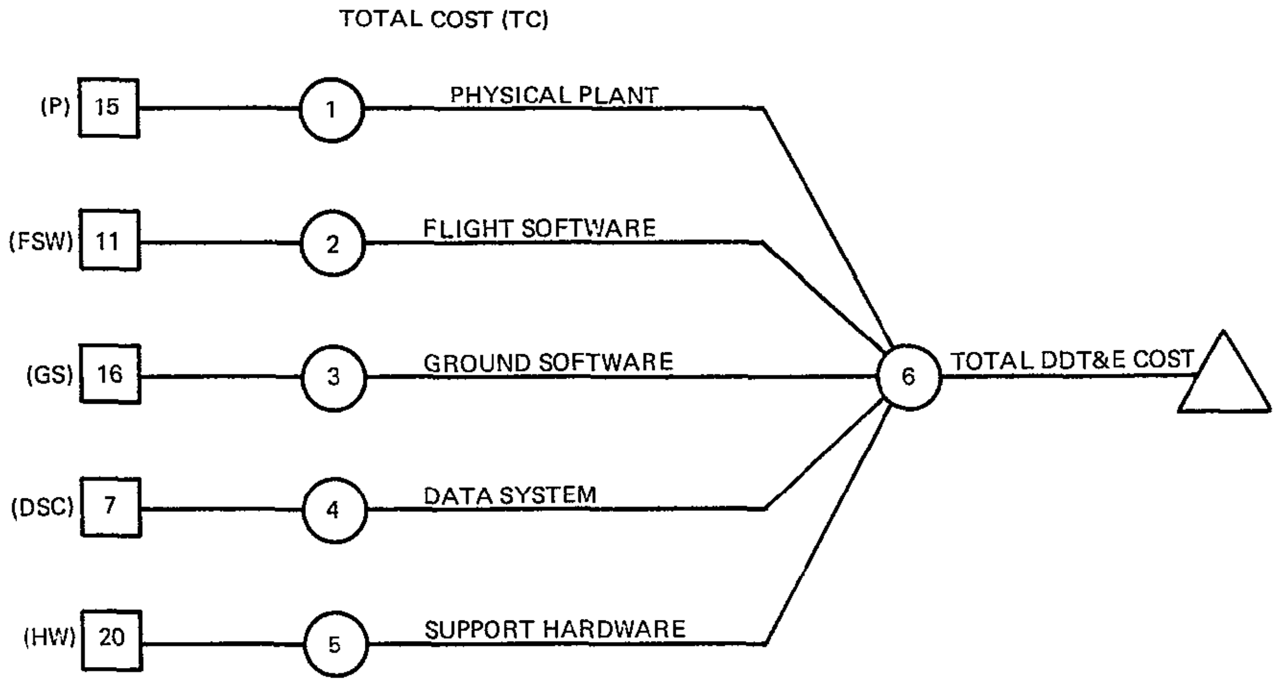


Figure 1 7 8-1 Total DDT&E Cost Relationships

Flight Support Personnel	- Establishes the number of shifts required
Flight Control Consoles	- Establishes the number of consoles required by type
Network Pental	- Establishes the number of hours required in one year of TV, TM, COMMAND and TRACKING service

Statistical outputs are available for inspection

1 7 10 Network Rental

Figure 1 7 10-1 presents the Network Rental Block Inputs are provided by the mission density block, which establishes the network utilization parameters

Manual inputs are provided for the cost per channel-hour constant for Television, telemetry, command and tracking data flow services The cost of network services is derived in paragraph 1 3 6

1 7 11 Facility Maintenance

The facility maintenance recurring cost is based upon the number of square feet to be maintained NASA facility maintenance costs run about $1 32 per square foot per year for the type of installation under consideration Commercial rates for the same service are on the order of $2 00 per square foot per year

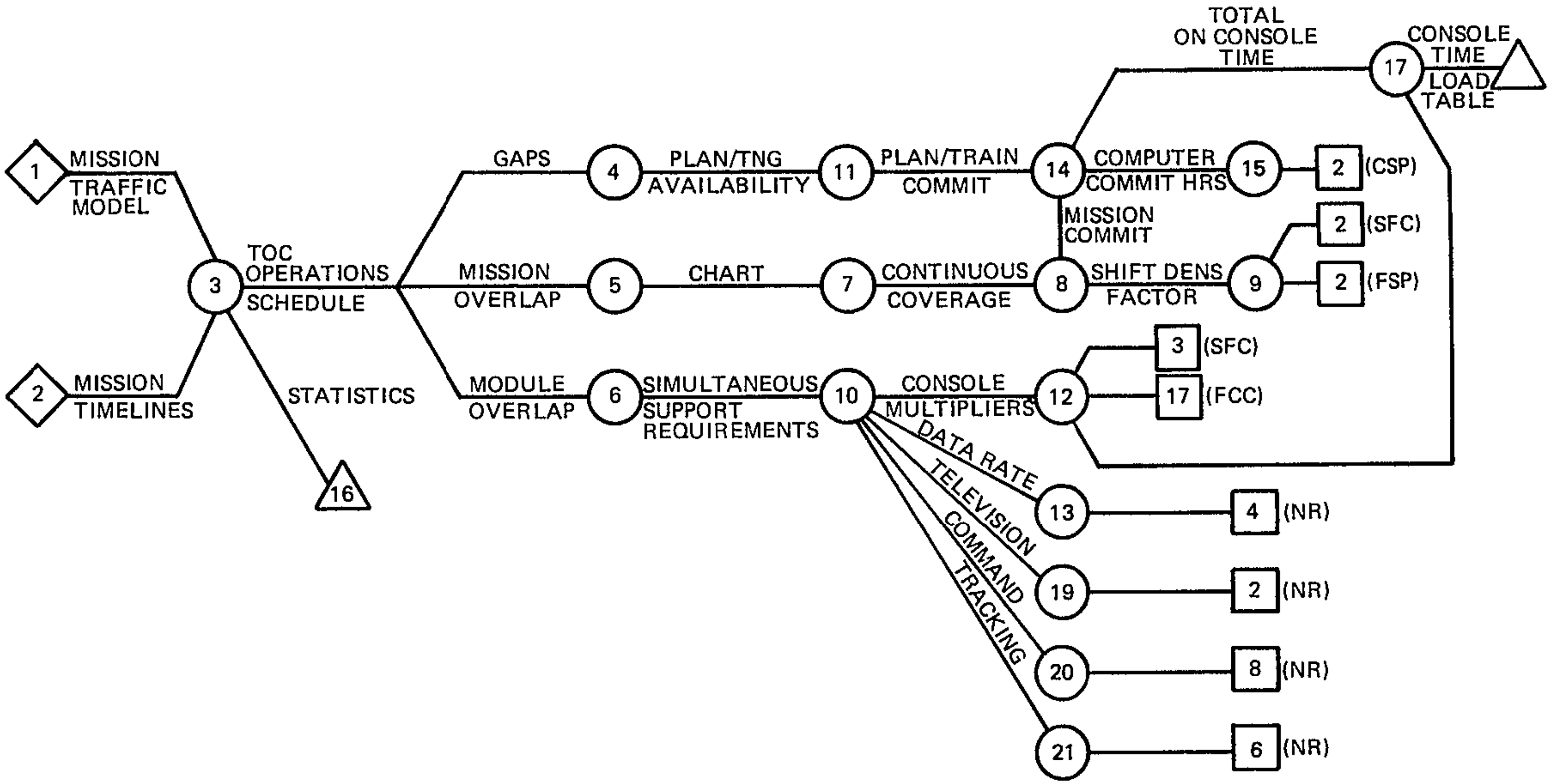


Figure 1 7 9 1 Mission Density Factors

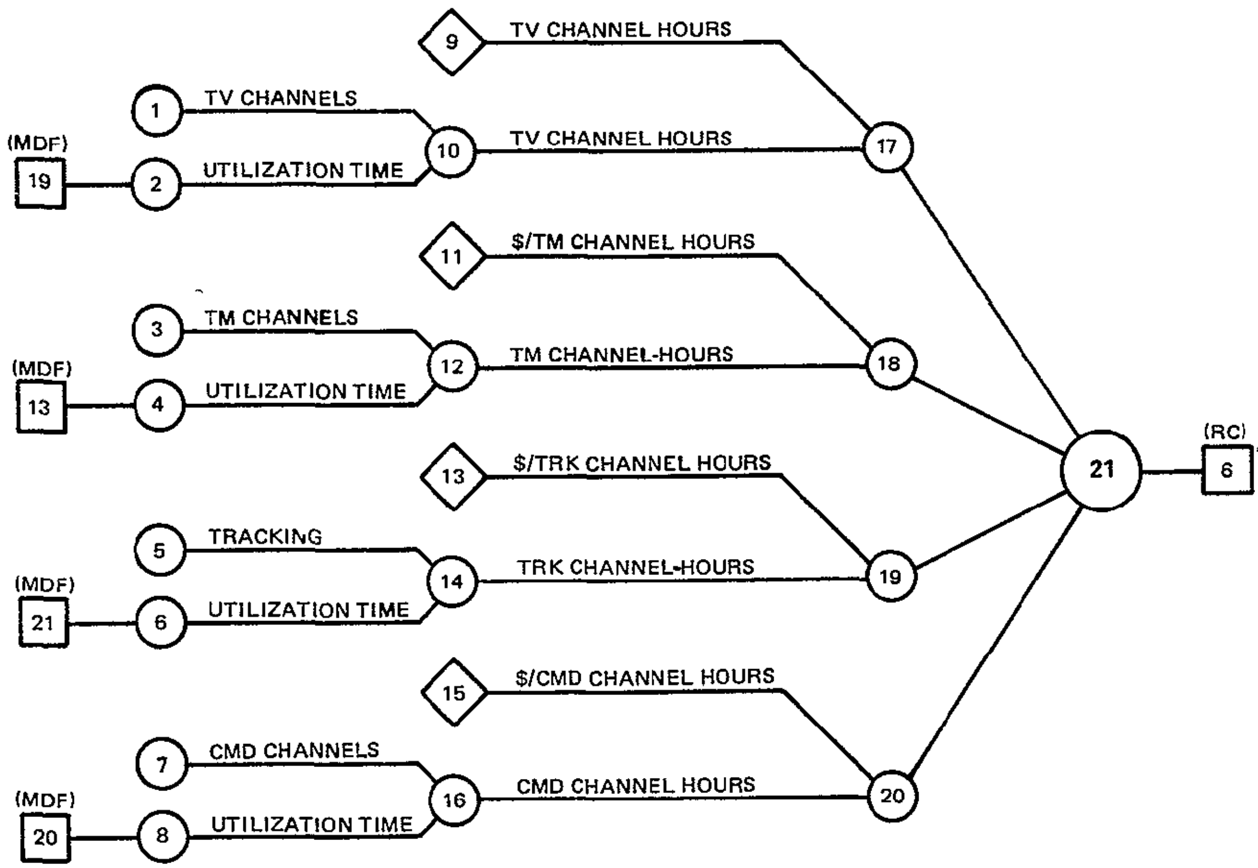


Figure 1 7 10-1 Network Rental Cost Relationships

The cost constants include maintenance and services for refuse disposal, janitorial service, structural maintenance, internal electrical maintenance, internal lighting and heating, internal painting, air conditioning, external painting, roofing and maintenance of a parking lot

Figure 1 7 11-1 presents the Facility Maintenance Block

1 7 12 <u>Ground Software Maintenance</u>

Since software problems will be discovered throughout the entire software module set, it is necessary to provide resident personnel familiar with every area The number of personnel required is dependent upon the size, compexity, criticality and level of mission-to-mission changes for the programs

Figure 1 7 12-1 presents the software maintenance block Inputs are received from the ground software block and processed in nodes SM-1, SM-2, SM-3 and SM-4 to create a manpower level at node SM-5 That level is then multiplied by a manually entered constant ($48,000 per man year) to give the recurring cost of software maintenance

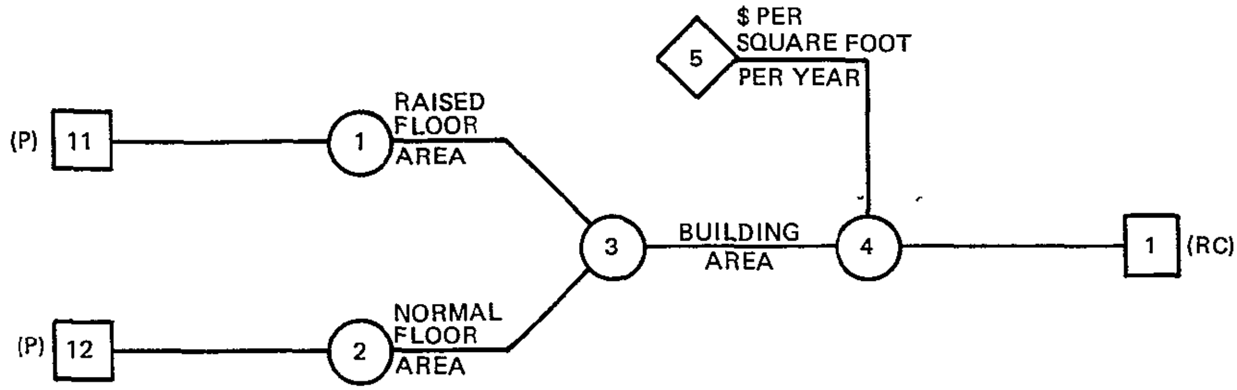


Figure 1 7 11-1 Facility Maintenance

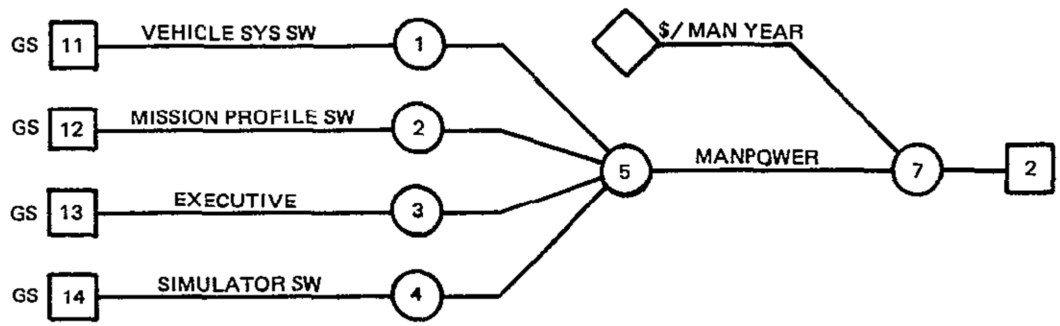


Figure 1 7 12-1 Software Maintenance Cost Relationships

1 7 13 Sustaining Support Personnel

Three blocks contribute to the sustaining support personnel cost relationships These blocks are shown in Figure 1 7 13-1

The mission density function establishes the computer commit hours per year, which then is converted to equivalent men required to provide computer support The output from the computer support block (Figure 1 7 13-1(a)) is fed to the sustaining TOC block as equivalent men per year

The mission density function also establishes the shift density factor for flight support personnel The output of the flight support personnel block is fed to the sustaining TOC block as men per year The level of effort established by the FSP block is constant No provision has been made to assign other duties to the flight support staff

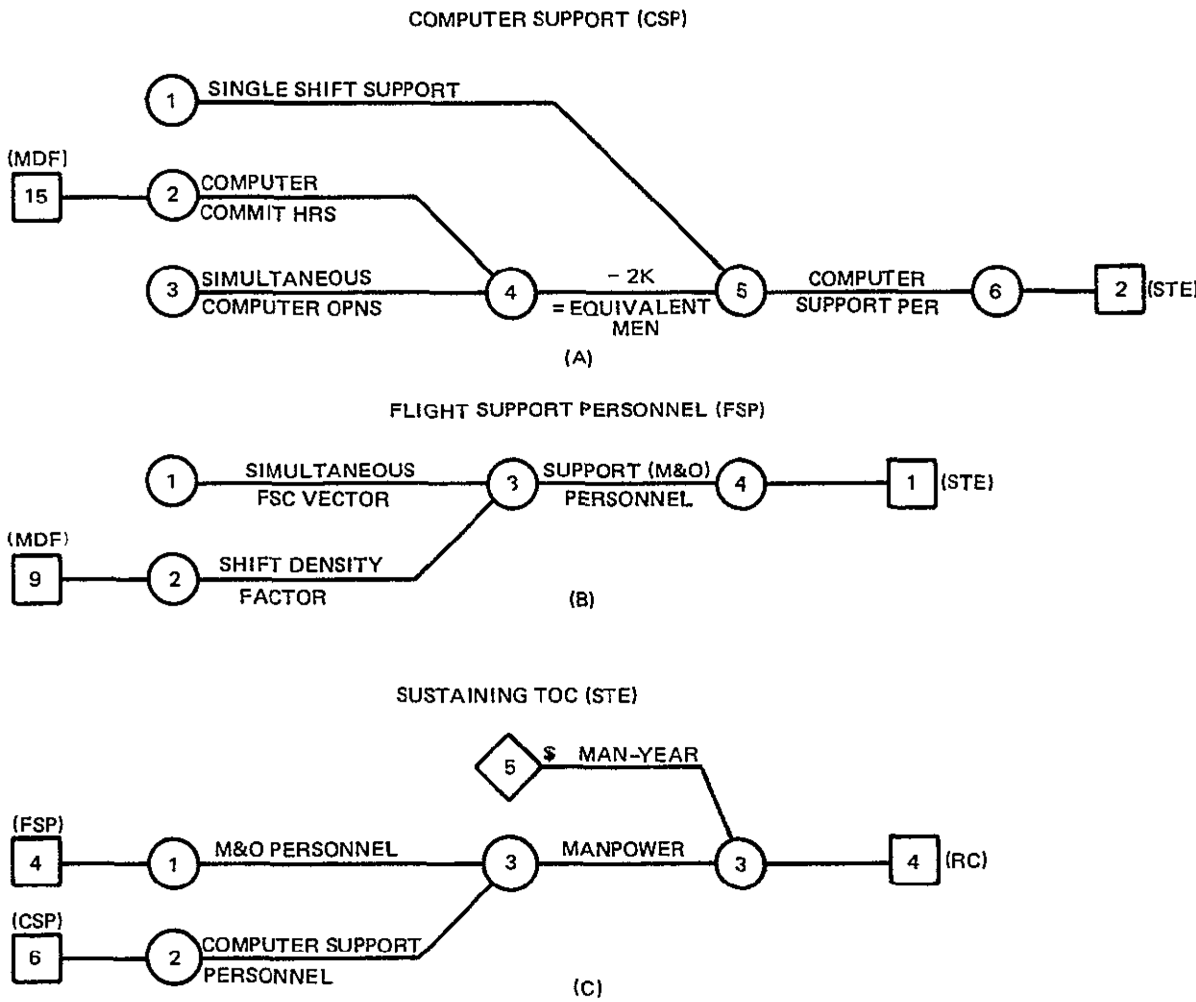


Figure 1 7 13-1 Sustaining Flight Support Personnel Cost Relationships

The sustaining TOC block accepts the manpower and equivalent manpower inputs from the two driver programs and multiplies that output by a dollars per man-year constant

The constant used in $48,000 per man-year The output of the STE program feeds the recurring cost block

1 7 14 Sustaining Flight Control

Figure 1 7 14-1 presents the sustaining Flight Control Block

The mission density function provides a shift density factor and console multiplier which are combined at node SFC-5 to create a manpower requirement estimate At node SFC-6 the manpower estimated is converted to dollars by multiplying by the constant, $48,000 per man-year The cost is passed to the recurring cost program

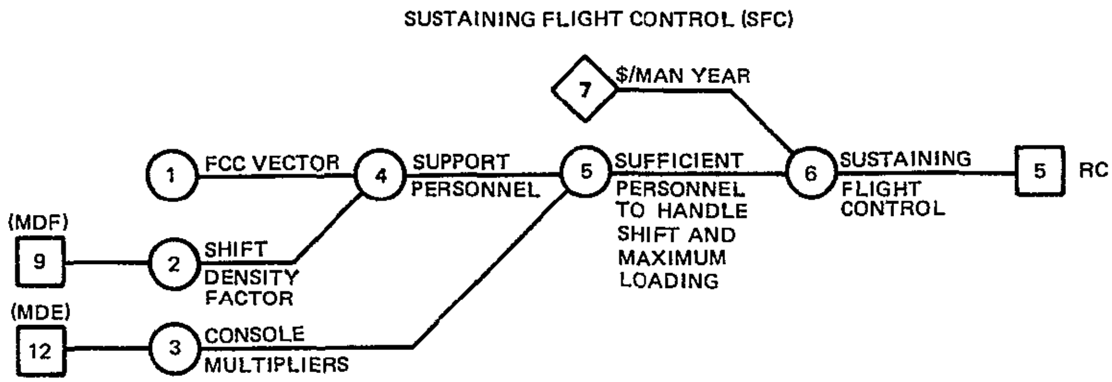


Figure 1 7 14-1 Sustaining Flight Control Personnel Cost Relationship

The level of effort established by the SFC block is constant No provision has been made to assign other duties to the flight control staff

1 7 15 Flight Software Maintenance

Flight software maintenance is similar to ground software maintenance in concept It is necessary to maintain a staff of personnel who are familiar with each of the four basic programs, and to maintain capability to define, code and verify the flight programs

Figure 1 7 15-1 presents the flight software maintenance block Input is received from the flight software block (FSW) and operated on by the flight software maintenance algorithm presented in paragraph 1 3 7

1 7 16 Recurring Costs

The annual recurring cost of the IUS program or the Space Tug program is developed by summing the outputs from the facility maintenance block, the software maintenance block, the contracted maintenance output from the computer select block, the output from the sustaining support engineering block, the sustaining flight control block, the network rental block and the the flight software maintenance block.

Figure 1 7.16-1 presents the annual recurring cost relationship block

1 7 17 Miscellaneous Costs

It can be seen from the work breakdown structure that a few of the WBS tasks do not fall into the twelve categories presented in this section Those tasks are primarily man-hour consuming tasks in the DDT&E phase which have intermediate or planning products associated with them

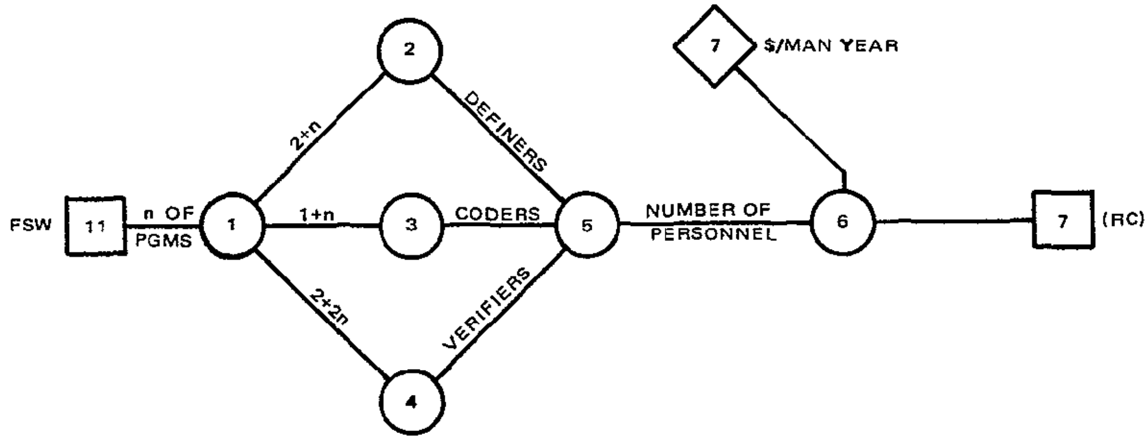


Figure 1 7 15-1 Flight Software Maintenance Cost Relationships

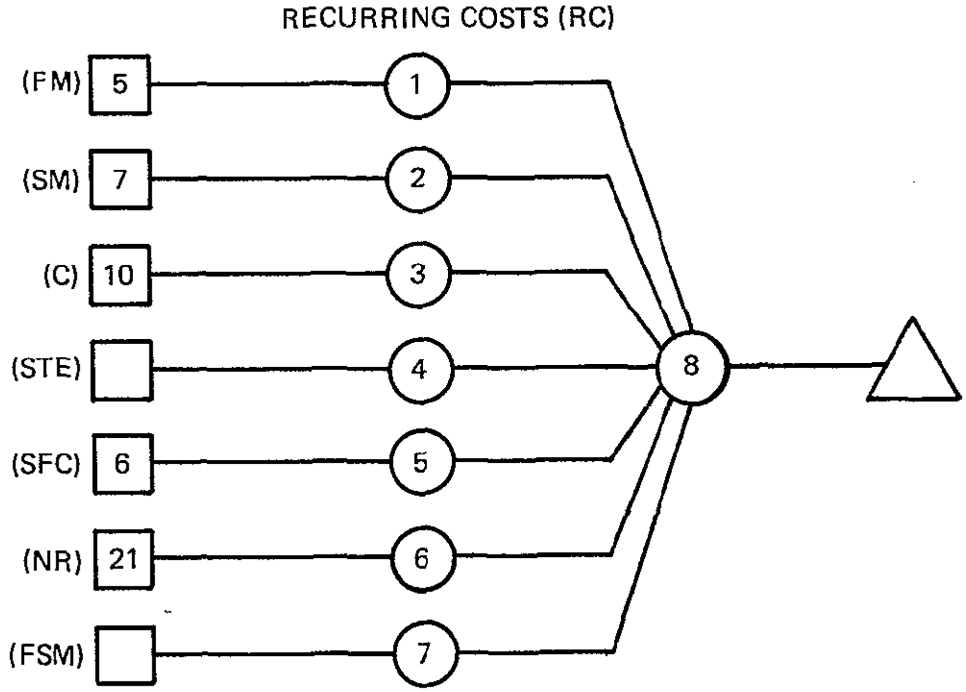


Figure 1 7 16-1 Recurring Cost Relationships

The methodology for assigning cost to tasks falling in this category is to read the man-hours assigned the task from the table, convert to equivalent man-years and multiply by $48,000

In the combined IUS/Space Tug program, tasks falling into the miscellaneous category amount to about 5.3 million dollars over a seven year period

SUMMARY COST PRESENTATION 2

This section presents the summary cost estimates for the composite IUS/Space Tug Orbital operations and mission support program The work breakdown structure from which the composite costs are derived is presented in Section 1, Table 1 1 0-3 These costs refer only to the Orbital Operations and Mission Support elements of the WBS

In addition to presenting the cost summary for the composite program, this section includes cost data initially derived for the IUS program and Space Tug program individually This information is included for comparison and completeness purposes, but does not relate to the data presented in Section 3 directly Therefore, caution should be exercised and context fully understood when referencing Figures 2 3 0-1 through 2 3 0-8

2 1 COMPOSITE IUS/SPACE TUG SUMMARY COST DATA

Figure 2 1 0-1 presents the composite IUS/Space Tug program expenditures for a 180 month program Based on a start date of January 1977, the IUS will become operational in November 1983 The IUS Program is considered to be over at the IOC of the Space Tug Program

The composite IUS/Space Tug Program expenditures exceed $100 million over the program life The curves are derived by adding together the IUS DDT&E expenditures prior to April 1981, the Space Tug DDT&E expenditures prior to November 1983, and the IUS recurring cost expenditures between April 1981 and November 1983, and the Space Tug recurring cost expenditures from November 1983 until the end of the program

Figure 2 1 0-2 presents the IUS Program and Space Tug DDT&E rate of expenditure This is an amplification of the first 86 months of the program In Figure 2 1 0-2 the IUS Program absorbs the hardware, data system, ground software, and physical plant expenditures The actual journaling of those expenditures is a Government decision, since the equipment will belong to the Space Tug Program after the IUS has become non-operational

The average monthly expenditure over the 86 month composite IUS Program and Space Tug DD&TE is approximately $633,000 This includes the major hardware expenditure in the 41st month of $8 04 million

Figure 2 1 0-3 presents the manpower requirements in equivalent man per month based on the composite IUS/Space Tug program schedule This curve represents manpower expended on DDT&E tasks only It does not include any estimate of manpower required to conduct IUS operations over the period from April 1981 through November 1983 In any event, the total man-load over that period should not increase greater than 60 additional men per month, and upon entering the Space Tug operational period at the end of 1983 the total manning will drop to approximately 64

The man-loading curve presents information based upon the assumption that the schedule is loaded such that each task is performed as late as possible without resulting in an overall slip of schedule This results in a net

COMPOSITE IUS/SPACE TUG PROGRAM EXPENDITURES, ORBITAL OPERATIONS AND MISSION SUPPORT

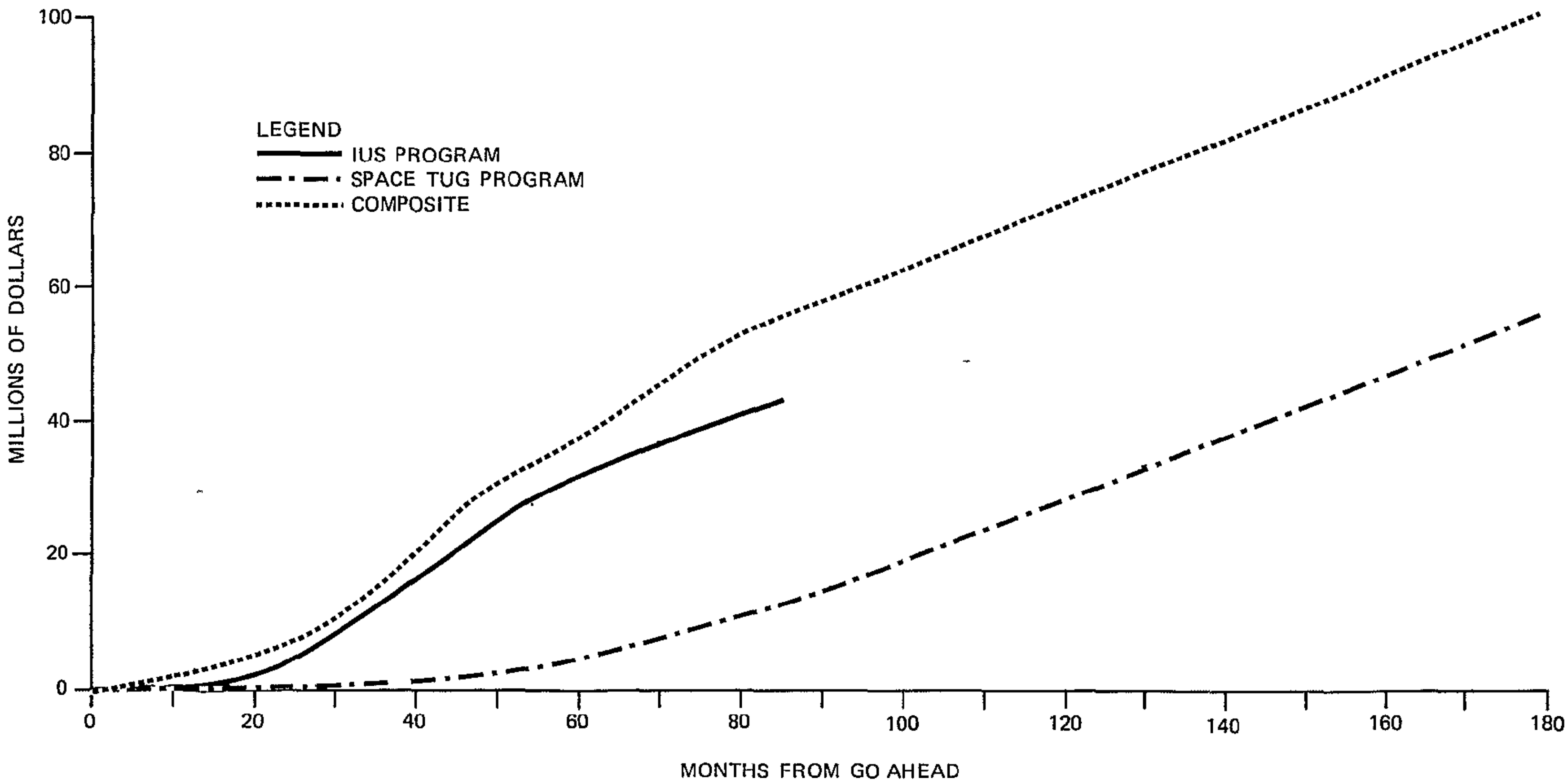


Figure 2 1 0-1 Composite IUS/Space Tug Program Expenditures (OO/MS)

IUS PROGRAM AND SPACE TUG DDT&E RATE OF EXPENDITURE, ORBITAL OPERATIONS AND MISSION SUPPORT

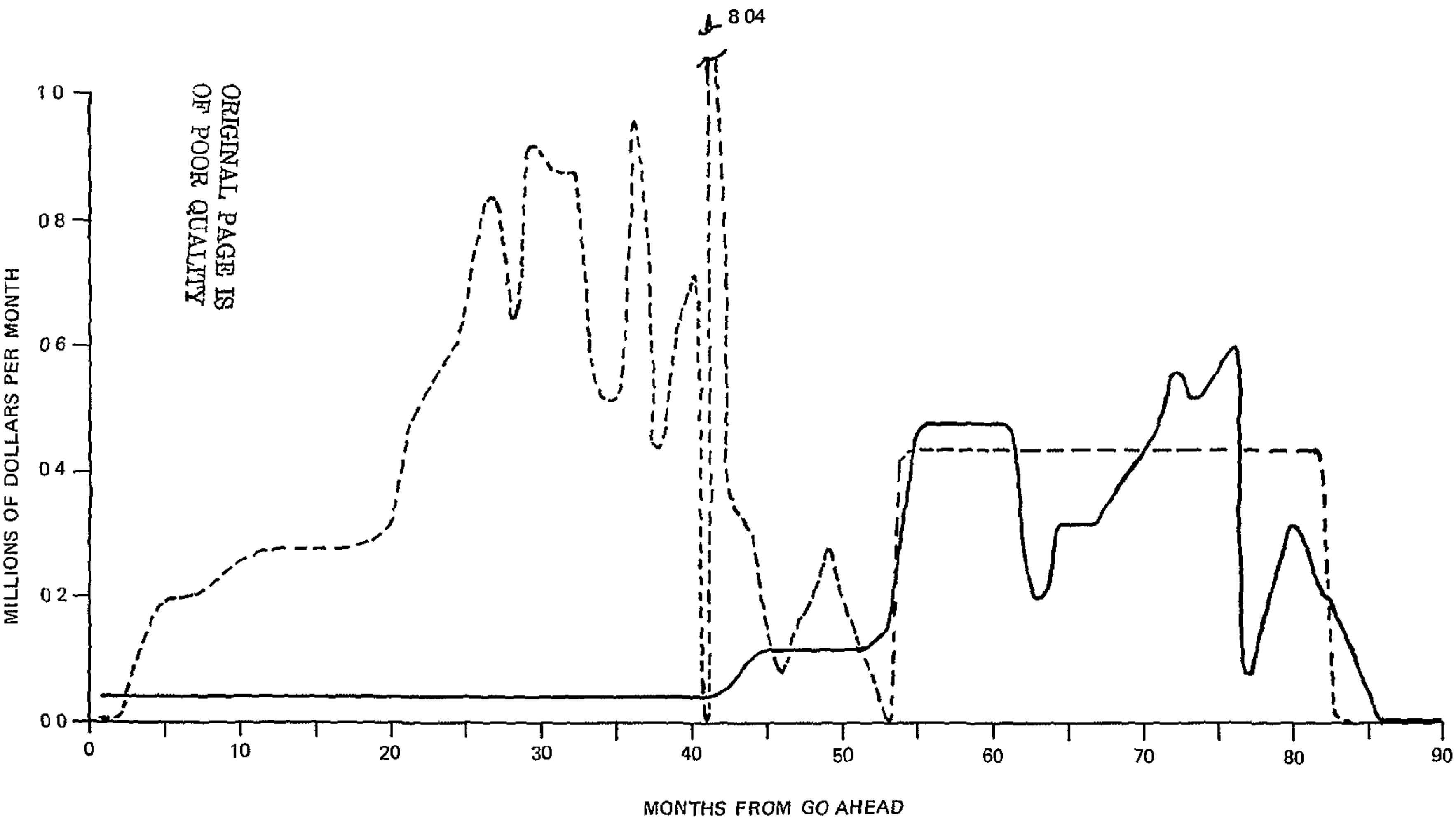
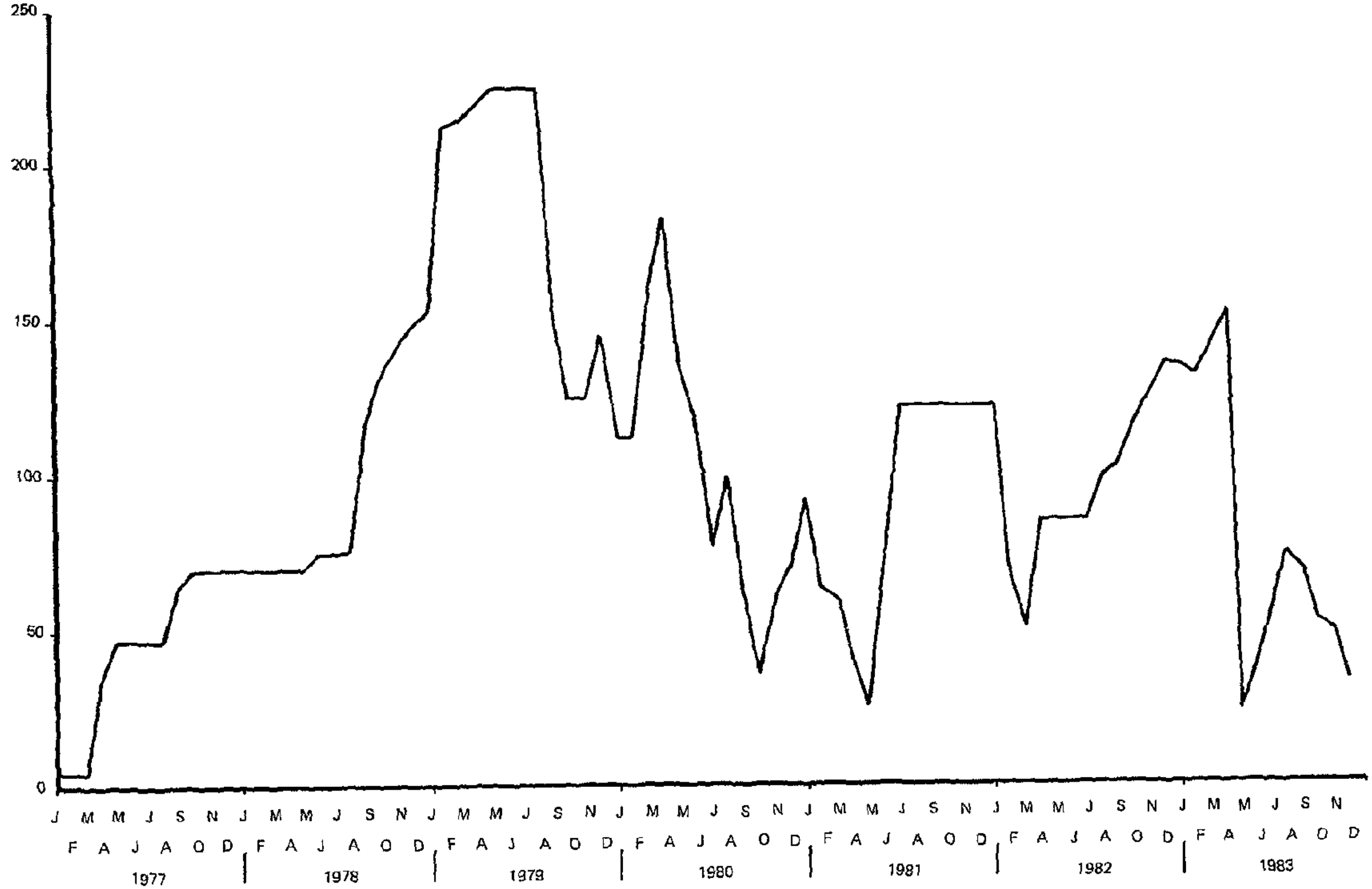


Figure 2 1 0-2 IUS Program and Space Tug DDT&E Rate of Expenditure (OO/MS)

DDT&E MANLOADING CURVE, ORBITAL OPERATIONS AND MISSION SUPPORT



right shift of expenditure, which delays funding to the maximum extent It should be noted that other combinations of tasks and other schedules are possible which can smooth or reduce man-load peaks Volume IV of the Orbital Operations and Mission Support Study final report presents a schedule bar chart which identifies the available rescheduling options to the NASA

Peak loading occurs in May 1979 This is 225 6 equivalent personnel The minimum loading occurs in May 1982 at 23 1 personnel This does not include IUS operational personnel If the IUS operational personnel are included, then the minimum number of personnel applied to the program becomes 83 1 in May 1981

Table 2 1 0-1 presents a cost summary of the composite IUS/Space Tug DDT&E expenditures This summary was derived by adding together the composite program costs, then identifing definable lots of cost, such as physical plant, data system, operations staff equipment, IUS software development, Space Tug software development and ground operation center software development When these definable tasks were subtracted from the composite program costs, a residual of $5 53 million was obtained This residual is composed principally of manpower expenditures for planning and coordination efforts On Table 2 1 0-1 that charge has been identified as service activities

It is of interest to examine net savings resulting from combining the IUS and Space Tug DDT&E expenditures Table 2 1 0-1 demonstrates that $14 56 million are saved by combining IUS and Space Tug orbital operations and mission support functions The major portion of those savings in in ground software development

Figure 2 1 0-4 presents the IUS program cumulative expenditures Bear in mind when examining this curve that the major hardware purchases are incurred during the IUS DDT&E period and thus bias the IUS curve upward

Figure 2 1 0-5 presents the IUS program rate of expenditure curve This curve was shown earlier as the IUS contribution to the IUS program and Space Tug DDT&E rate of expenditure shown in Figure 2 1 0-2

Figure 2.1 0-6 presents the Space Tug DDT&E rate of expenditure curve This curve was shown earlier as the Space Tug DDT&E contribution to Figure 2 1 0-2 The Space Tug DDT&E period may be said to begin in January 1977 along with the IUS program, during which Space Tug peculiar operational problems are being worked in conjunction with the similar operational problems of the IUS The major portion of Space Tug effort is intentionally delayed until the IUS becomes operational in order to avoid excessive overlap of the DDT&E phases

Figure 2 1 0-7 presents the Space Tug program cumulative DDT&E expenditures It should be noted that Space Tug program costs presented on this curve presume the IUS program has borne the expenses of major hardware expenditures and common element costs

2 2 RECURRING COSTS - OPERATIONS

Figure 2 2 0-1 presents a schedule of recurring tasks which will be followed for each flight Man-loading on that schedule is for the first flight operation It is anticipated that the sequence of operations will remain

Table 2 1 0-1 Cost Summary - Composite DDT&E Costs

TOTAL DEVELOPMENT COST

ELEMENT	DOLLARS
PHYSICAL PLANT	418620
TOC SOFTWAPE DEVELOPMENT	18983200
DATA SYSTEM	7010008
OPERATIONS STAFF EQUIPMENT	1052400
IUS SOFTWARE DEVELOPMENT	2729197
TUG SOFTWARE DEVELOPMENT	5058689
SERVICE ACTIVITIES	5533614
TOTAL	40785728
TOTAL IUS DDT&E	27483428
TOTAL TUG DDT&E	27899738
TOTAL COMPOSITE DDT&E	55383136
	(-)40785728
NET SAVINGS	14597438

pretty much the same as the program matures, but that the man loading of each task will be significantly reduced as the program matures

Figure 2 2 0-2 presents a typical mission operations cycle, specifically man-loaded for the initial launch operation On the basis of Figure 2 2 0-2, the first launch should cost NASA $1 887 million The cost of the first launch operation is included in the DDT&E expense presented in Section 2 1 It is included in this section for orientation purposes only The actual cost per flight should be computed by dividing the recurring expenditures over the entire program by the total number of IUS and Space Tug launches This gives an average cost estimate of $375,800 per flight

One is tempted to apply an exponential learning curve to the flight operation effort This should not be done since the flight operations will be handled on a level of effort basis The learning curve could only apply to equivalent man months per month and could never fall below the level of sustaining flight control and flight support engineering personnel costs

Table 2 2 0-1 presents the cost summary for composite recurring IUS and Space Tug expenses Table 2 2 0-1 assumes there is no overlap of IUS and Space Tug operations Costs developed for the IUS program apply from April 1981 to November 1983, and the costs derived for the Space Tug program apply from

IUS PROGRAM CUMULATIVE EXPENDITURE, ORBITAL OPERATIONS AND MISSION SUPPORT

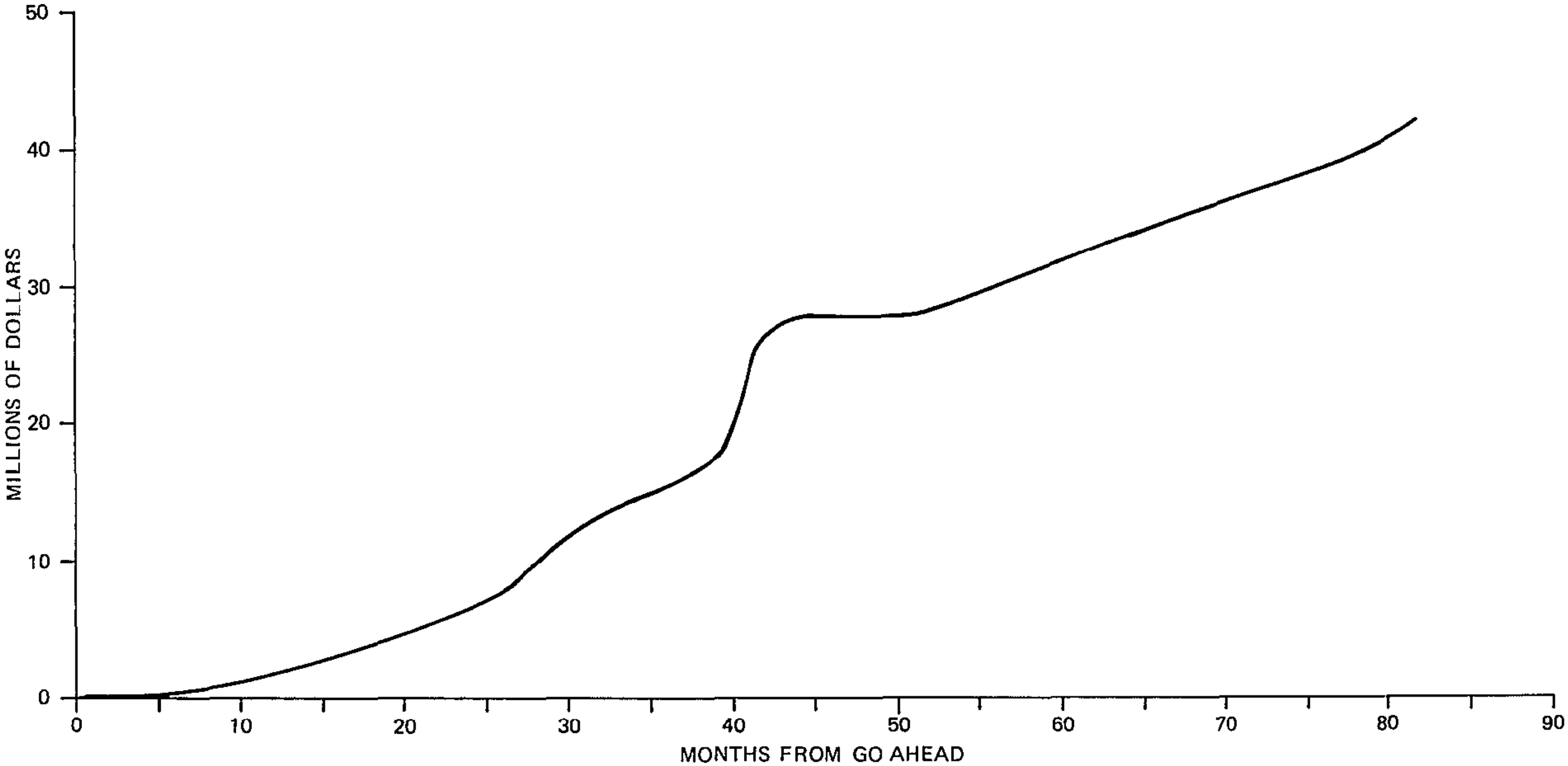


Figure 2 1 0-4 IUS Program Cumulative Expenditures (OO/MS)

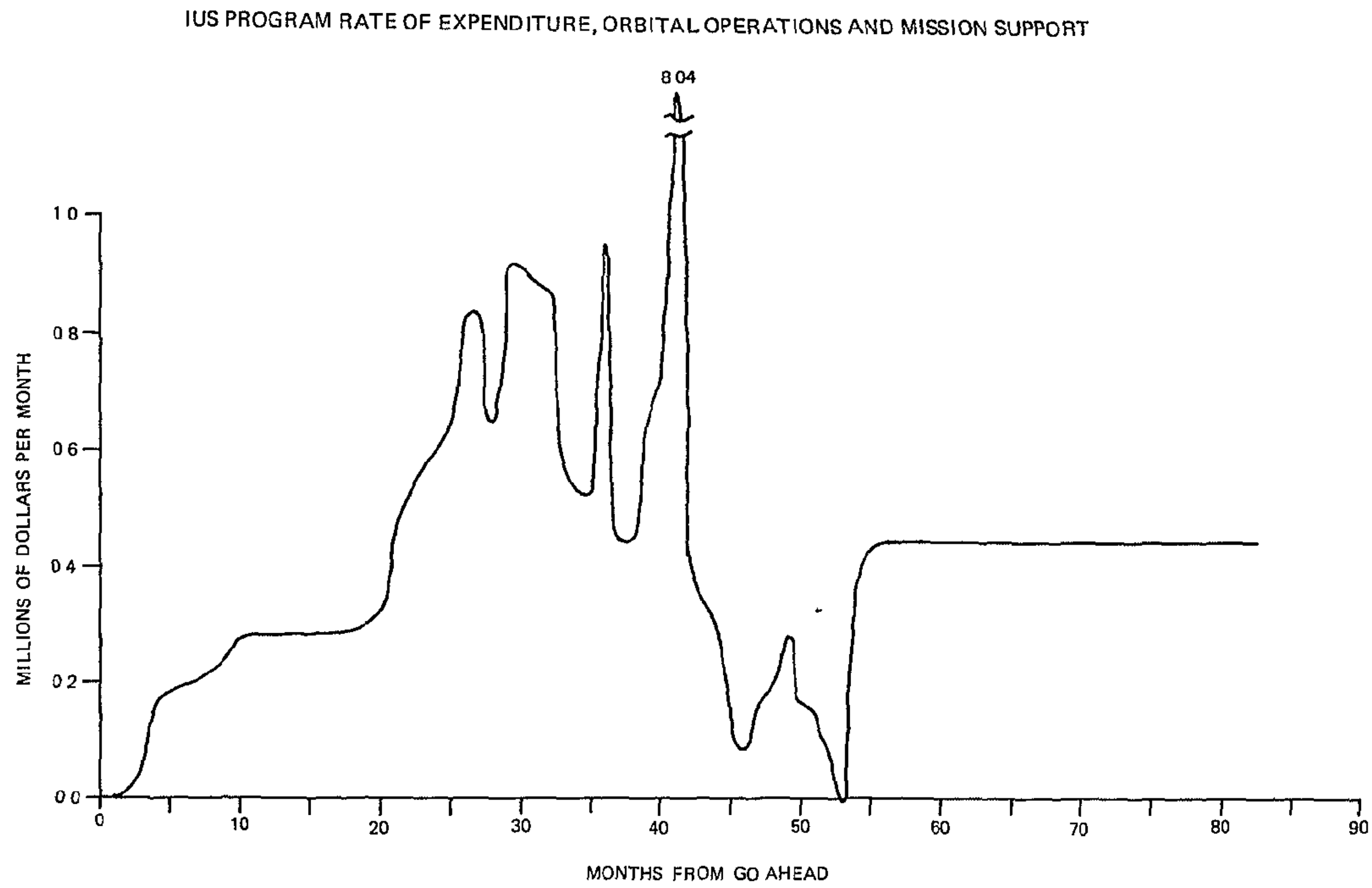


Figure 2 1 0-5 IUS Program Rate of Expenditure Curve (OO/MS)

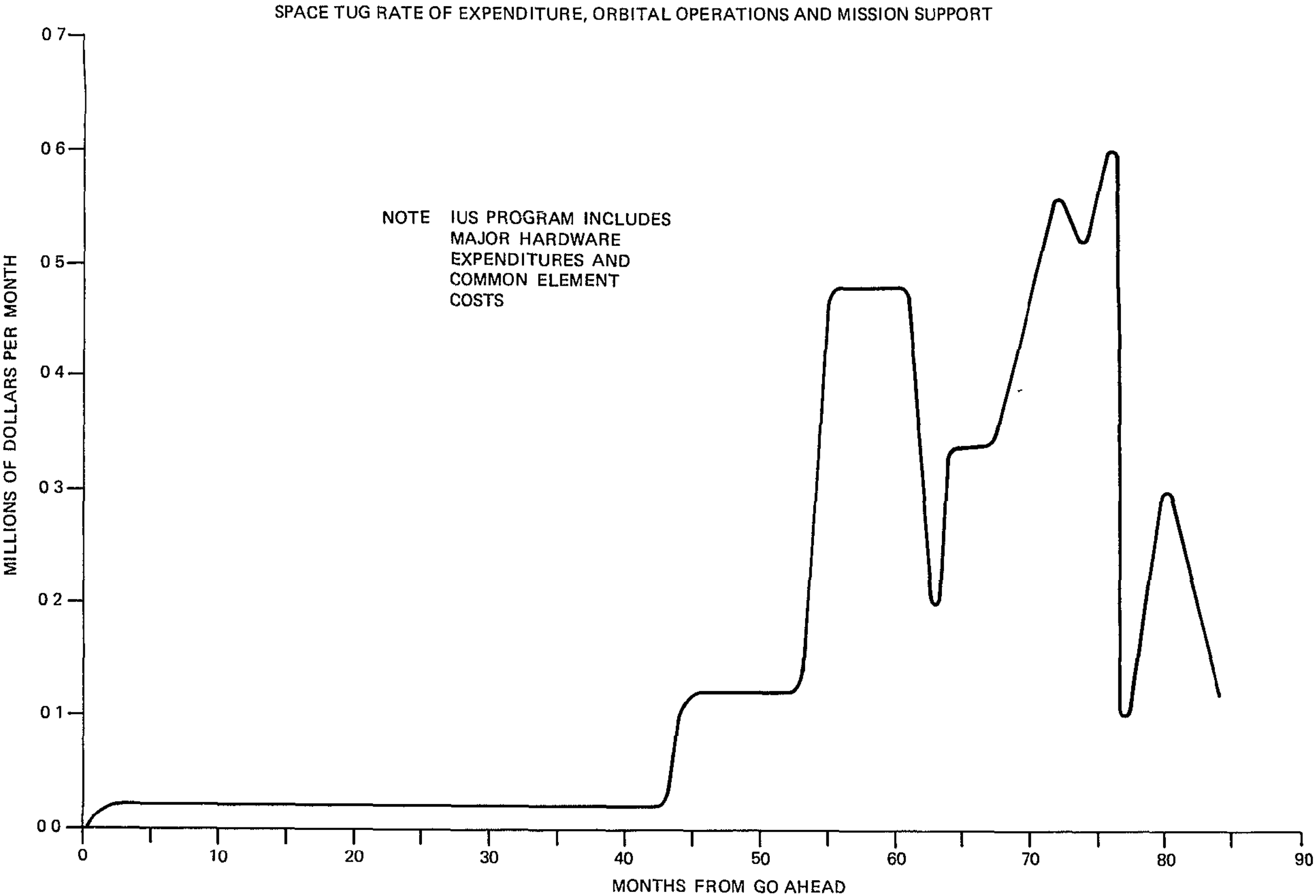


Figure 2 1 0 6 Space Tug DDT&E Rate of Expenditure Curve (OO/MS)

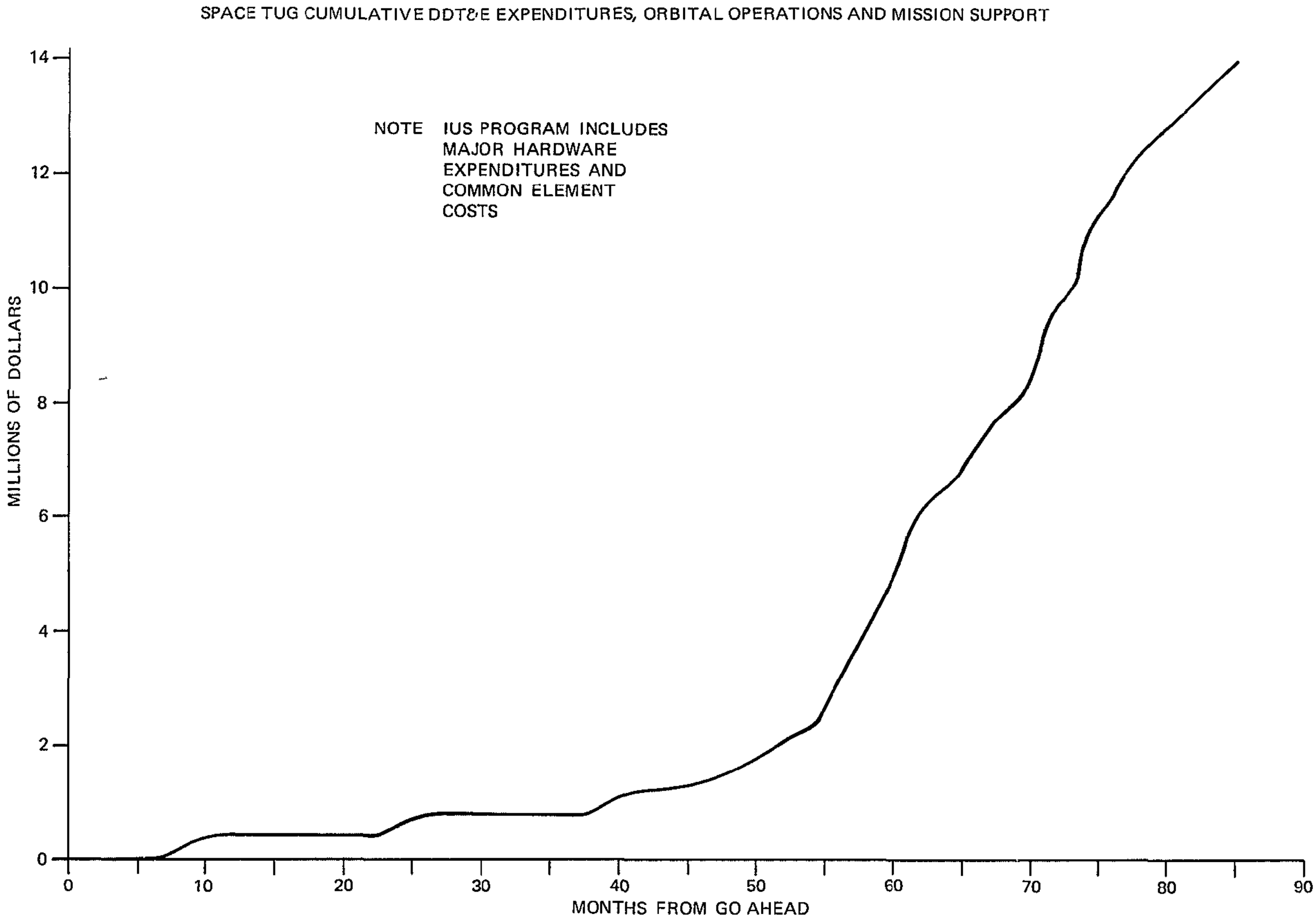


Figure 2 1 0-7 Space Tug Cumulative DDT&E Expenditures (OO/MS)

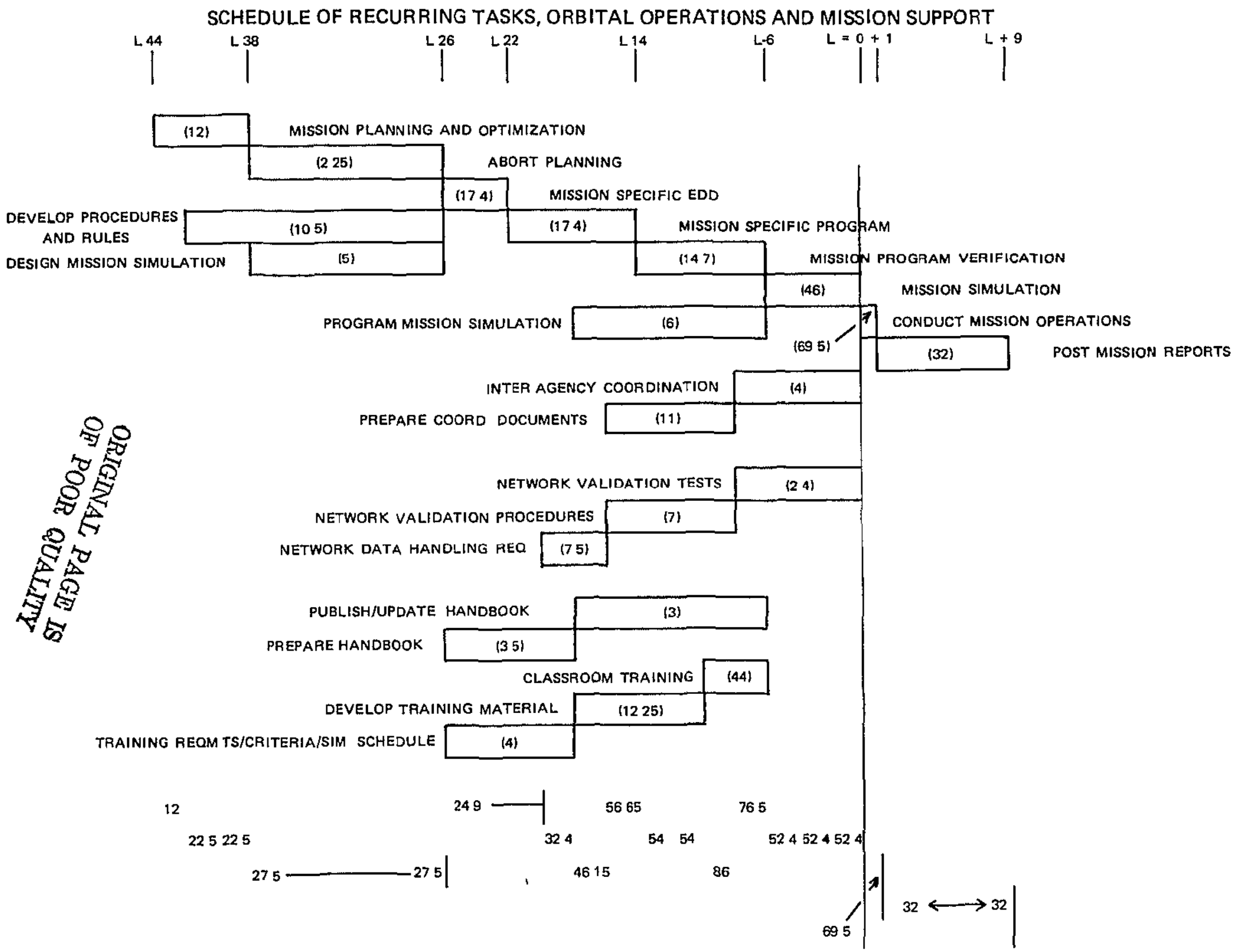


Figure 2 2 0-1 Schedule of Recurring Tasks (OO/MS)

TYPICAL IUS MISSION OPERATIONS CYCLE

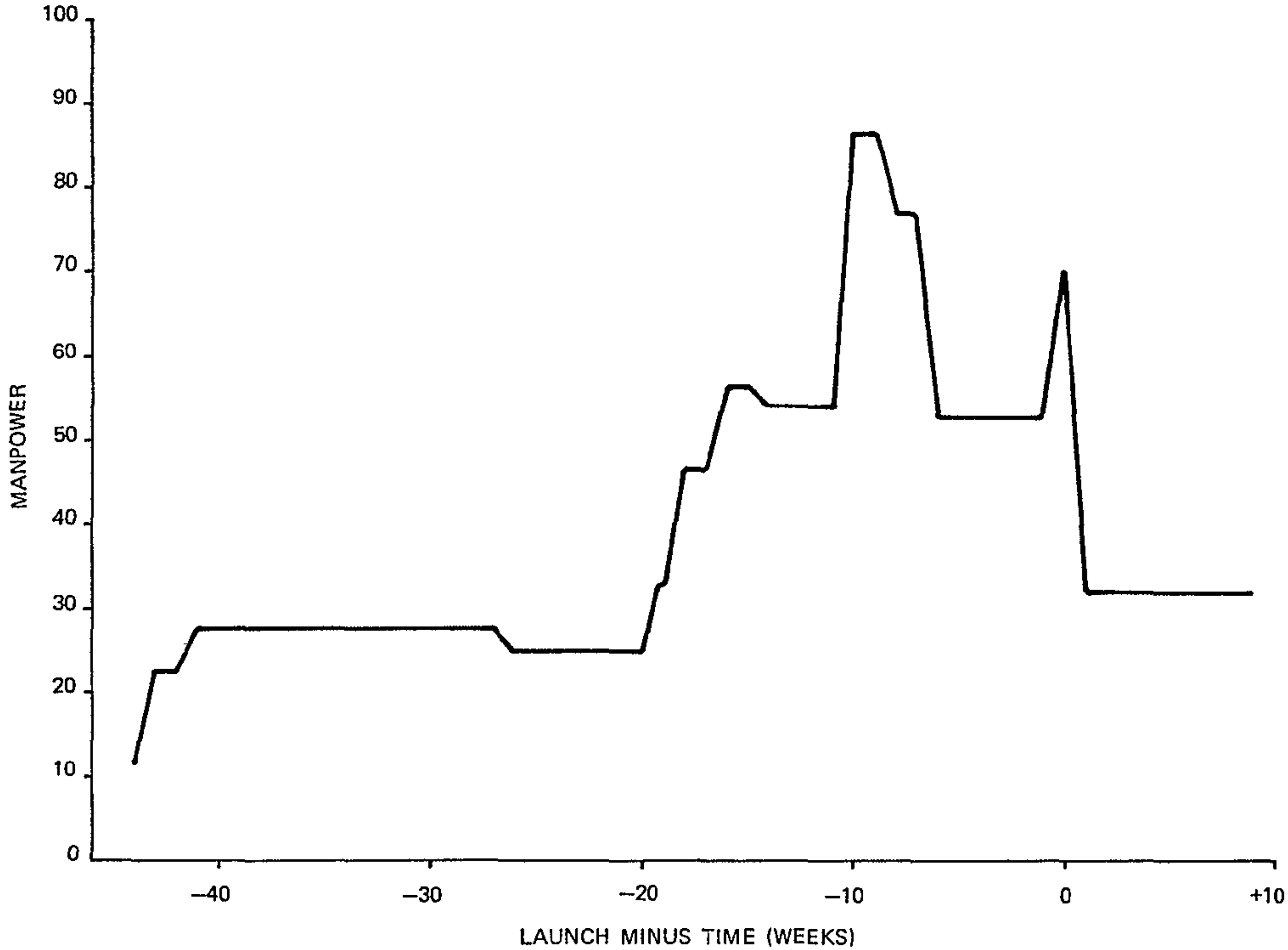


Figure 2 2 0-2 Typical Mission Operations Cycle

Table 2 2 0-1 Composite IUS/Space Tug Recurring Expenses

- NO OVERLAP OF IUS AND SPACE TUG OPERATIONS
  - IUS RECURRING COSTS APPLY FROM APRIL 1981 TO NOVEMBER 1983
  - SPACE TUG RECURRING COSTS APPLY FROM NOVEMBER 1983 TO END OF PROGRAM
- IF IUS OPERATIONS OVERLAP SPACE TUG OPERATIONS,
  - NO INCREASE ABOVE SPACE TUG OPERATIONS COST LEVEL

RECURRING COSTS

ELEMENT	DOLLARS
FACILITY MAINTENANCE	19672
TOC SOFTWARE MAINTENANCE	1104000
DATA SYSTEM MAINTENANCE	134458
SUSTAINING TOC ENGINEERING	1584000
SUSTAINING TOC FLT ON TL ENGINEERING	1440000
NETWORK RENTAL	204755
TUG SOFTWARE MAINTENANCE	1008000
TOTAL	5494885
FACILITY MAINTENANCE	19872
TOC SOFTWARE MAINTENANCE	1200000
DATA SYSTEM MAINTENANCE	138795
SUSTAINING TOC ENGINEERING	1440000
SUSTAINING TOC FLT ON TL ENGINEERING	1440000
NETWORK RENTAL	26233
IUS SOFTWARE MAINTENANCE	1008000
TOTAL	5272900

November 1983 to the end of the program Examination of the mission model indicates a possibility that the IUS may continue to be utilized during a period which is predominately Space Tug oriented If such is the case, there will be no increase in recurring costs over the level required for Space Tug operations, under the assumption that the same personnel will be utilized to control the Space Tug as were utilized to control the IUS, and that the IUS unique ground software is available in off-line storage

2 3 BACKGROUND INFORMATION FROM AUTONOMY VARIATION AND CONCEPT VARIATION INVESTIGATIONS

This section is included for the sake of completeness In Phase 2 and Phase 3 of the Orbital Operations and Mission Support Study, three operations concepts were investigated and two levels of autonomy for each vehicle configuration were investigated and cost figures derived for them This section presents the cost information derived for Autonomy Level II, Concept 1, 2A, and 2B, Autonomy III, Concept 1, Concept 2A, and Concept 2B for the Space Tug Program This section also includes Concept development costs for IUS Level A Expendable Concept 1, Level A Expendable Concept 3, Level A Reusable Concept 1, Level A Reusable Concept 3, Level B Expendable, Concept 1, Level B Expendable Concept 3, Level B Reusable Concept 1, and Level B Reusable Concept 3

Following the completion of Phase 2 and Phase 3 of this study, a selection was made of a single IUS concept and a single Space Tug concept to be carried forward into detailed program costing and transition analysis This section also includes rationale for the selection of Level II Autonomy, Concept 1 for Space Tug, and Level B Autonomy, Concept 1 for the IUS

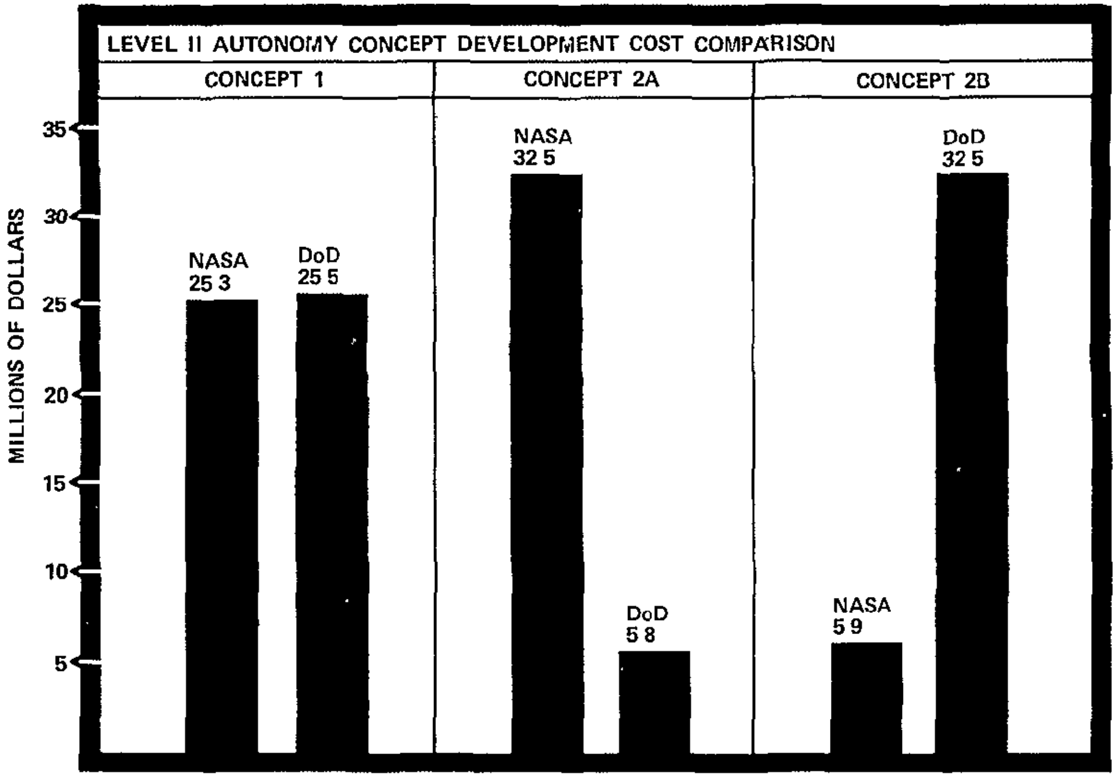
Figure 2 3 0-1 presents the Level II Space Tug autonomy concept development cost comparison The similarity of NASA and DoD costs for Concept 1 is the result of the assumption that DoD operates in a manner similar to NASA and that DoD costs are comparable to NASA costs

The cost distribution in Concept 2A and 2B shift the higher portion of the cost to the Control Center host This does not mean the tenant will not pay his share of the combined cost burden, but reflects the actual responsibility relationship between host and tenant

Figure 2 3 0-2 presents the Level 2 Autonomy annual recurring cost comparison For the recurring costs, it was assumed that the host would require tenant fees from the tenant agency and would retain all program assets at the end of the program Tenant income and tenant fees paid are identified on the histogram Selected computer printouts have been provided to allow analysis of the distribution of costs within the recurring cost figures

Figure 2 3 0-3 and Figure 2 3 0-4 present the Level III Autonomy Concept DDT&E comparison and the Level III Autonomy Annual Recurring Cost Comparison These figures represent identical information to that appearing on Figure 2 3 0-1 and Figure 2 3 0-2, except this information is relevant to Level III autonomy

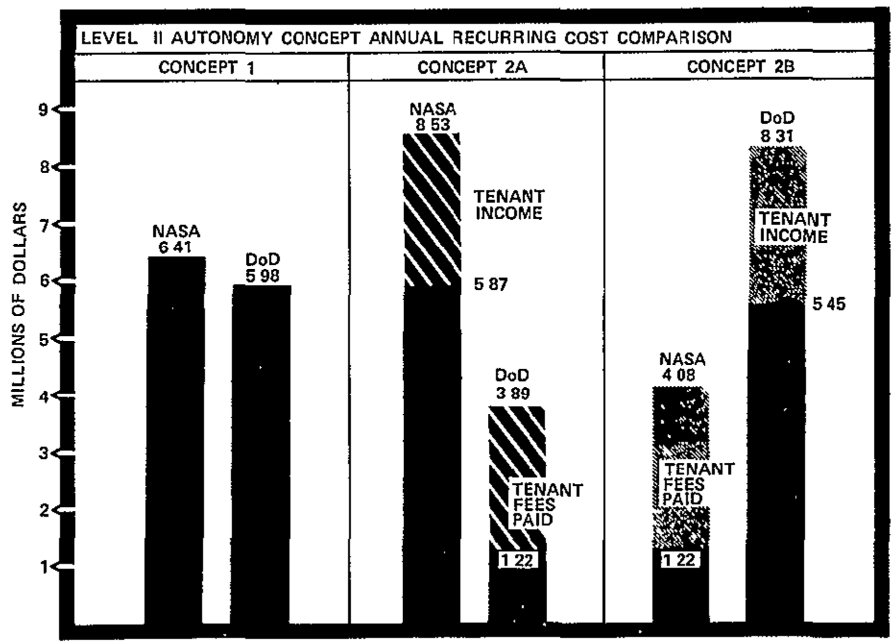
Before beginning analysis of the transition and programmatics of the combined IUS/Space Tug program it was necessary to reduce the number of configurations under consideration The Concept 1 Level II Autonomy Space Tug was selected because Concepts 2A and 2B involve sharing hardware, software and facilities with DoD This was felt to be a serious problem in that DoD has security restrictions on Space Tug operations, and the probability of successfully operating a joint facility by two agencies having diverse missions was considered very low The Level II Autonomy Space Tug design was selected because trend in the technology makes high autonomy feasible within the development cycle of Space Tug The ground support software cost is minimized in Level II by maximizing the number of functions performed in the onboard software



TOTAL ALTERNATIVE DEVELOPMENT COSTS

	ALTERNATIVE 1		ALTERNATIVE 2A		ALTERNATIVE 2B	
ELEMENT	NASA	DOD	NASA	DOD	NASA	DOD
PHYSICAL PLANT	423620	465982	563414	0	0	563523
TOC SOFTWARE DEVELOPMENT	12262924	12262924	15040932	773051	875605	15040932
DATA SYSTEM	6509618	6509618	9764427	0	0	9764427
OPERATIONS STAFF EQUIPMENT	1120800	1232880	2107104	0	0	2129520
TUG SOFTWARE DEVELOPMENT	5058689	5058689	5058689	5058689	5058689	5058689
TOTALS	25375650	25530092	32534565	5831739	5934294	32557090

Figure 2 3 0-1 Level II Autonomy Concept DDT&E Comparison



TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 2A NASA	ALTERNATIVE 2A DOD	ALTERNATIVE 2B NASA	ALTERNATIVE 2B DOD
FACILITY MAINTENANCE	20072	22079	25696	0	0	28101
TOC SOFTWARE MAINTENANCE	1104000	1104000	1391040	0	0	1391040
DATA SYSTEM MAINTENANCE	134458	134458	201687	0	0	201687
SUSTAINING TOC ENGINEERING	2016000	1794240	2913120	0	0	2802240
SUSTAINING TOC FLT CNTL ENGINEERING	1920000	1708800	2774400	0	0	2668800
NETWORK RENTAL	212772	212772	212772	212772	212772	212772
TUG SOFTWARE MAINTENANCE	1008000	1008000	1008000	1008000	1008000	1008000
TOTALS	6415302	5984349	8527714	1220772	1220772	8312639

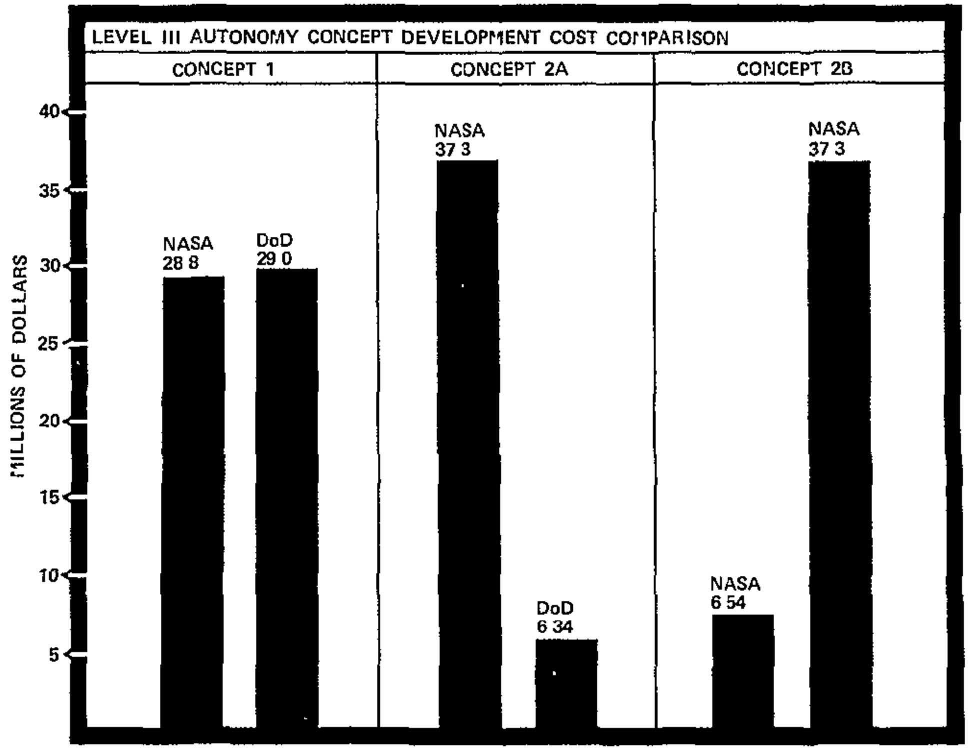
DOD TENANT COSTS ALTERNATIVE 2A

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	6624
TOC SOFTWARE MAINTENANCE	287040
DATA SYSTEM MAINTENANCE	67229
SUSTAINING TOC ENGINEERING	897120
SUSTAINING TOC FLT CNTL ENGINEERING	854400
NETWORK RENTAL	0
TUG SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	15969
DATA SYSTEM	406851
OPERATIONS STAFF EQUIPMENT	123288
TOTAL	2658521

NASA TENANT COSTS ALTERNATIVE 2B

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	6022
TOC SOFTWARE MAINTENANCE	287040
DATA SYSTEM MAINTENANCE	67229
SUSTAINING TOC ENGINEERING	1008000
SUSTAINING TOC FLT CNTL ENGINEERING	960000
NETWORK RENTAL	0
TUG SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	14518
DATA SYSTEM	406851
OPERATIONS STAFF EQUIPMENT	112080
TOTAL	2861739

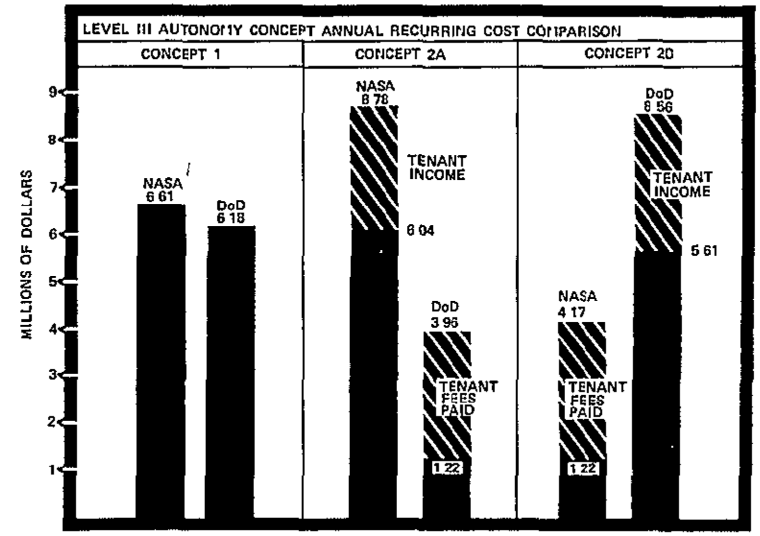
Figure 2 3 0-2 Level II Autonomy Annual Recurring Cost Comparison



TOTAL ALTERNATIVE DEVELOPMENT COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 2A NASA	ALTERNATIVE 2A DOD	ALTERNATIVE 2B NASA	ALTERNATIVE 2B DOD
PHYSICAL PLANT	423620	465 892	563 41 4	0	0	563523
TOC SOFTWARE DEVELOPMENT	15559751	15559751	193 807 83	157 8037	17 80921	193 807 83
DATA SYSTEM	7015618	7015618	10523427	0	0	10523427
OPERATIONS STAFF EQUIPMENT	1120 800	1232 880	2107104	0	0	2129520
TUG SOFTWARE DEVELOPMENT	4757902	4757902	4757902	4757902	4757902	4757902
TOTALS	28877690	290320 42	37305630	6335939	653 8823	37355155

Figure 2 3 0-3 Level III Autonomy Concept DDT&E Comparison



TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 2A NASA	ALTERNATIVE 2A DOD	ALTERNATIVE 2B NASA	ALTERNATIVE 2B DOD
FACILITY MAINTENANCE	20072	22079	26696	0	0	28101
TOC SOFTWARE MAINTENANCE	1296000	1296000	1632960	0	0	1632960
DATA SYSTEM MAINTENANCE	138795	138795	208192	0	0	208192
SUSTAINING TOC ENGINEERING	2016000	1794240	2913120	0	0	2802240
SUSTAINING TOC FLT CNTL ENGINEERING	1920000	1708800	2774400	0	0	2668800
NETWORK RENTAL	212772	212772	212772	212772	212772	212772
TUG SOFTWARE MAINTENANCE	1008000	1008000	1008000	1008000	1008000	1008000
TOTALS	6611638	6180686	8776140	1220772	1220772	8561065

NASA TENANT COSTS ALTERNATIVE 2 A

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	6022
TOC SOFTWARE MAINTENANCE	336960
DATA SYSTEM MAINTENANCE	69397
SUSTAINING TOC ENGINEERING	1008000
SUSTAINING TOC FLT CNTL ENGINEERING	960000
NETWORK RENTAL	0
TUG SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	14518
DATA SYSTEM	438476
OPERATIONS STAFF EQUIPMENT	112080
TOTAL	2945453

DOD TENANT COSTS ALTERNATIVE 2 A

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	6624
TOC SOFTWARE MAINTENANCE	336960
DATA SYSTEM MAINTENANCE	69397
SUSTAINING TOC ENGINEERING	897120
SUSTAINING TOC FLT CNTL ENGINEERING	854400
NETWORK RENTAL	0
TUG SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	15960
DATA SYSTEM	438476
OPERATIONS STAFF EQUIPMENT	123288
TOTAL	2742235

Figure 2 3 0-4 Level III Autonomy Annual Recurring Cost Comparison

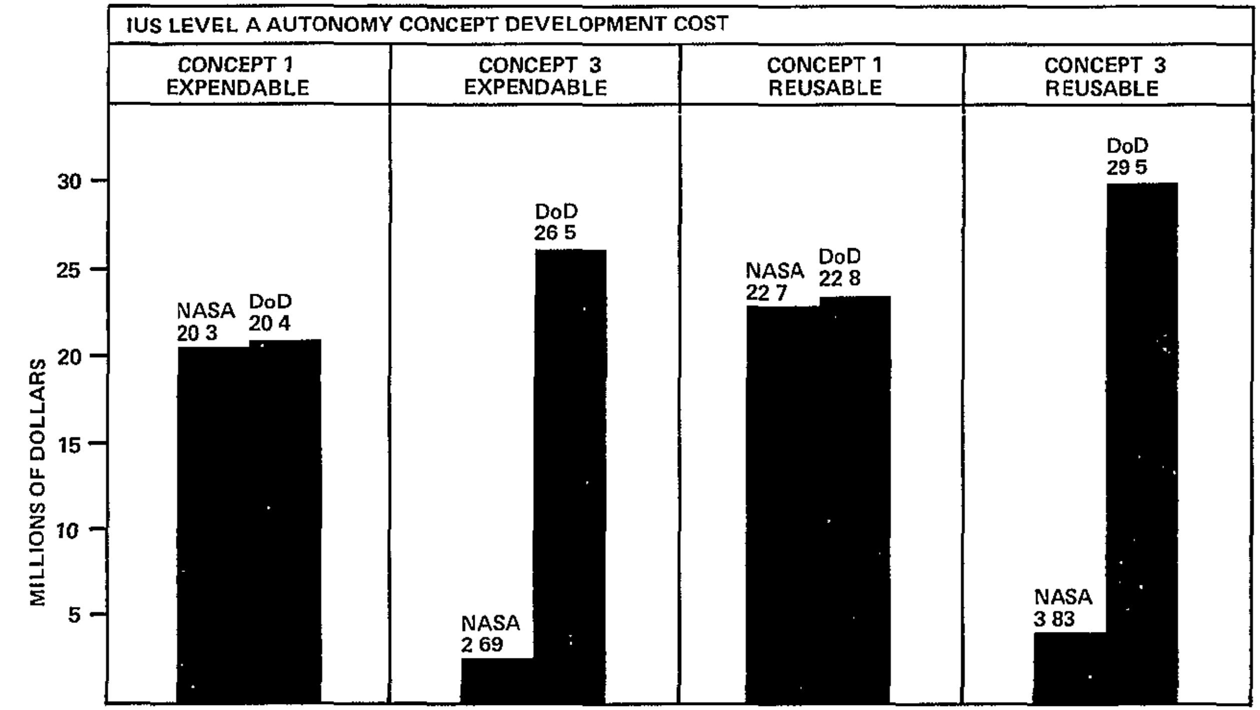
Maximizing onboard software functions, although more expensive a per-word basis, is less expensive overall than implementing equivalent functions on the ground And finally, the selection was made because ground support recurring costs are minimized for Level II autonomy Space Tug design

The IUS was analyzed from the standpoint of four configurations (Expendable, Autonomy A, Expendable, Autonomy B, Reusable, Autonomy A, and Reusable, Autonomy B) Each of these configurations were analyzed in two mission operations concepts, Concept 1 - Separate, but equivalent NASA and DoD facilities, Concept 3 - DoD facility upon which NASA is a tenant Figure 2 3 0-5 and Figure 2 3 0-6 present the IUS Level A Autonomy concept DDT&E cost summary and the IUS Level A Autonomy annual recurring cost summary, respectively.

Figure 2 3 0-7 and Figure 2 3 0-8 present the IUS Level B Autonomy concept DDT&E cost and IUS Level B Autonomy annual recurring cost, respectively.

Before entering Phase 4 of the Orbital Operations and Missions Support Study, wherein a Space Tug concept and IUS concept are merged during a transition phase to produce an overall program, it was necessary to select one of the eight configurations of IUS to be analyzed further The Reusable Interim Upper Stage was ruled out by customer direction Analysis had shown that the only retrieval capability the Reusable IUS would have, is to return itself to the Space Tug orbit It was not felt that the Reusable IUS would be an cost effective design Level A expendable IUS was ruled out because the design was unable to meet NASA placement accuracy constraints and the command system was limited to two on/off commands This allowed no capability for real time navigation update, target update, alternate mission selection or malfunction corrective action The Expendable Level B IUS replaces the command system of the Expendable Level A IUS with a generalized command system capable of providing navigation updates, target updates, alternate mission selection and generalized sequential override The addition of navigation update and target update capabilities eliminates the problem of meeting NASA placement accuracy constraints Therefore, the Expendable Level B IUS was selected Concept 1 was selected because Concept 3 involves NASA tenancy on a DoD facility, and DoD security must be considered prominently in any tenant relationship NASA might assume with DoD Under these conditions, it was decided that the probability of successfully operating a joint facility is low, and therefore NASA should develop its own control capability for the IUS Program

Entering the transitional phase of the study, the Level II Space Tug, operated under Concept 1, and the Level B Expendable IUS, operating under Concept 1 were selected



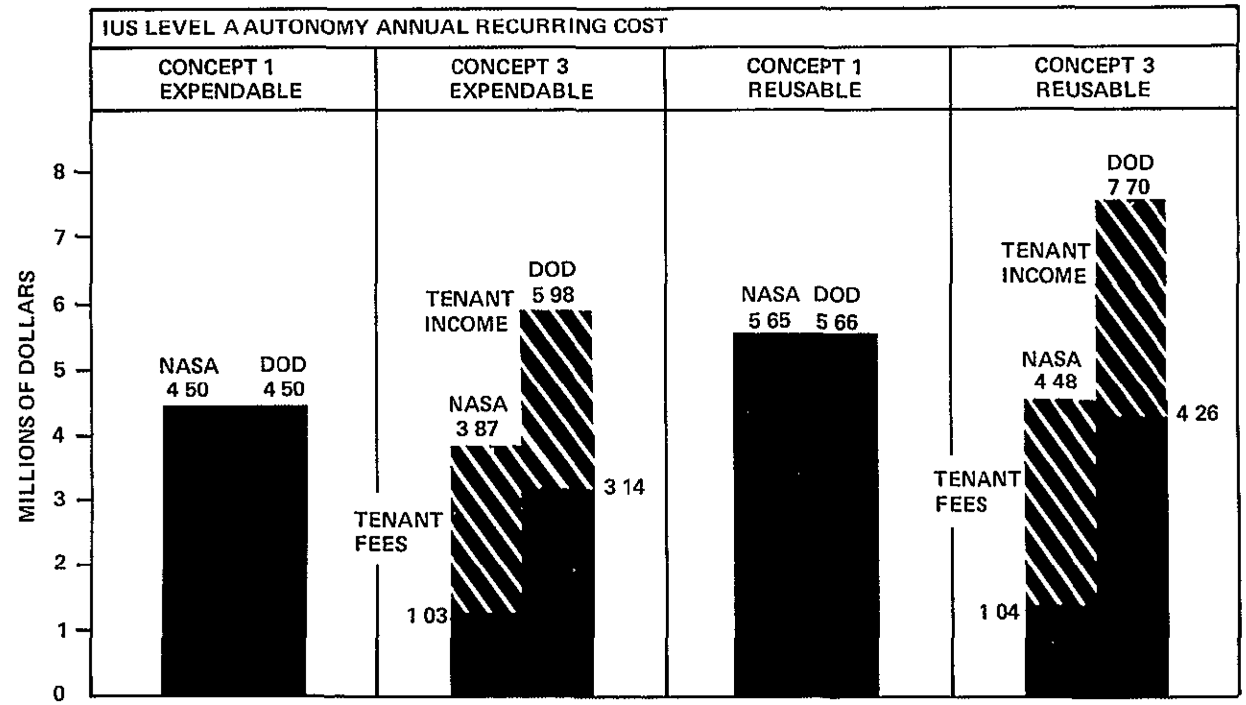
TOTAL ALTERNATIVE DEVELOPMENT COSTS

	ALTERNATIVE 1		ALTERNATIVE 3	
ELEMENT	NASA	DOD	NASA	DOD
PHYSICAL PLANT	372136	409350	0	520990
TOC SOFTWARE DEVELOPMENT	10112000	10112000	299347	12143040
DATA SYSTEM	6504008	6504008	0	9756012
OPERATIONS STAFF EQUIPMENT	884400	972840	0	1680360
IUS SOFTWARE DEVELOPMENT	2391702	2391702	2391702	2391702
TOTALS	20264245	20389899	2691049	26492104

TOTAL ALTERNATIVE DEVELOPMENT COSTS

	ALTERNATIVE 1		ALTERNATIVE 3	
ELEMENT	NASA	DOD	NASA	DOD
PHYSICAL PLANT	382136	420350	0	534990
TOC SOFTWARE DEVELOPMENT	11515093	11515093	624062	14041256
DATA SYSTEM	6504008	6504008	0	9756012
OPERATIONS STAFF EQUIPMENT	1052400	1157640	0	1999560
IUS SOFTWARE DEVELOPMENT	3203274	3203274	3203274	3203274
TOTALS	22656910	22800364	3827336	29535093

Figure 2 3 0-5 IUS Level A Autonomy Concept DDT&E Cost



TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
FACILITY MAINTENANCE	19472	21419	0	27261
TOC SOFTWARE MAINTENANCE	1008000	1008000	0	1270080
DATA SYSTEM MAINTENANCE	134458	134458	0	201687
SUSTAINING TOC ENGINEERING	1440000	1440000	0	2160000
SUSTAINING TOC FLT CNTL ENGINEERING	864000	864000	0	1296000
NETWORK RENTAL	21510	21510	21510	21510
IUS SOFTWARE MAINTENANCE	1008000	1008000	1008000	1008000
TOTALS	4495440	4497387	1029510	5984538

NASA TENANT COSTS-ALTERNATIVE 3

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	5842
TOC SOFTWARE MAINTENANCE	262080
DATA SYSTEM MAINTENANCE	67229
SUSTAINING TOC ENGINEERING	720000
SUSTAINING TOC FLT CNTL ENGINEERING	432000
NETWORK RENTAL	0
IUS SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	37214
DATA SYSTEM	1084001
OPERATIONS STAFF EQUIPMENT	235840
TOTAL	2644205

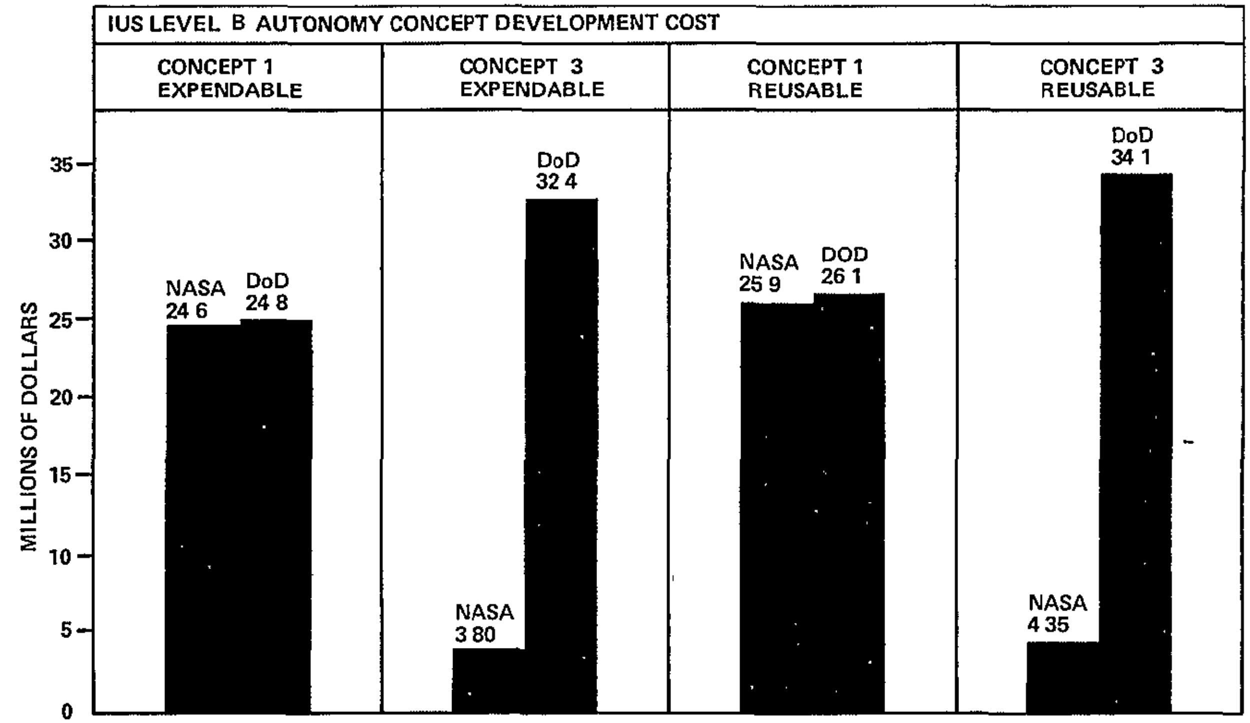
TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
FACILITY MAINTENANCE	19872	21859	0	27821
TOC SOFTWARE MAINTENANCE	1104000	1104000	0	1391040
DATA SYSTEM MAINTENANCE	134458	134458	0	201687
SUSTAINING TOC ENGINEERING	1632000	1632000	0	2448000
SUSTAINING TOC FLT CNTL ENGINEERING	1728000	1728000	0	2592000
NETWORK RENTAL	27953	27953	27953	27953
IUS SOFTWARE MAINTENANCE	1008000	1008000	1008000	1008000
TOTALS	5654283	5656270	1035953	7696501

NASA TENANT COSTS ALTERNATIVE 3

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	5962
TOC SOFTWARE MAINTENANCE	287040
DATA SYSTEM MAINTENANCE	67229
SUSTAINING TOC ENGINEERING	816000
SUSTAINING TOC FLT CNTL ENGINEERING	864000
NETWORK RENTAL	0
IUS SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	38214
DATA SYSTEM	1084001
OPERATIONS STAFF EQUIPMENT	280640
TOTAL	344308 5

Figure 2 3 0 6 IUS Level A Autonomy Annual Recurring Costs



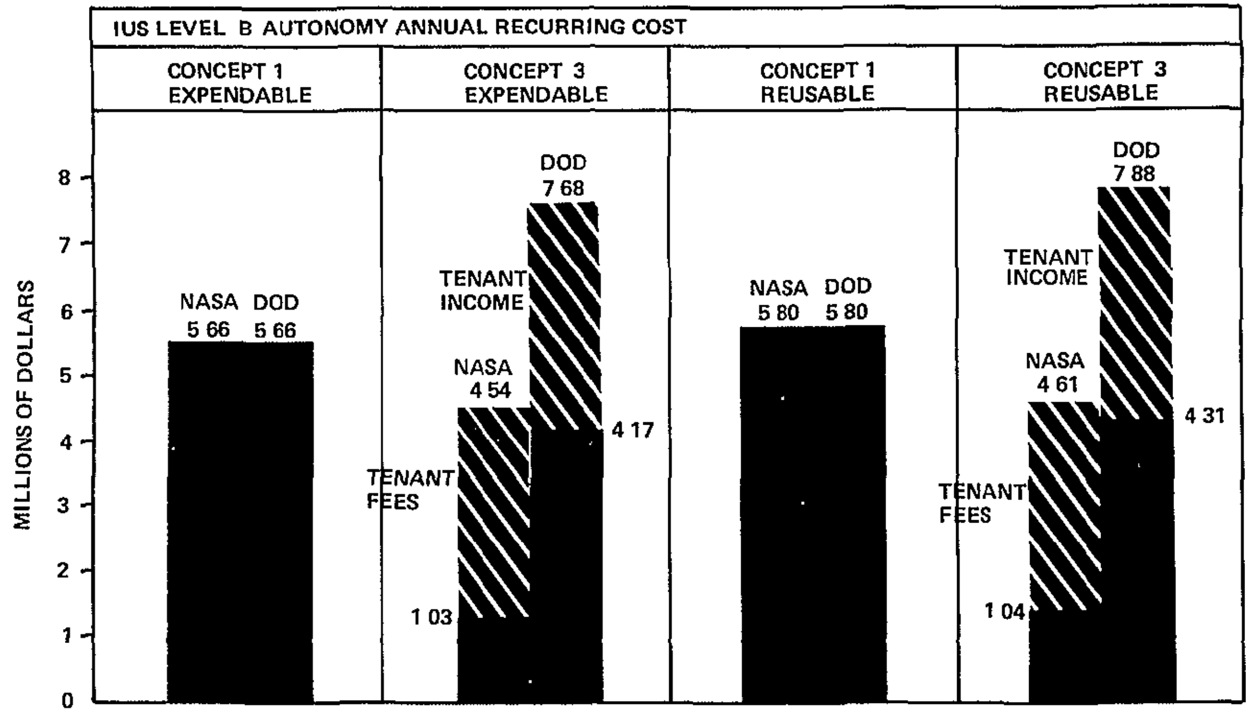
TOTAL ALTERNATIVE DEVELOPMENT COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
PHYSICAL PLANT	382136	420350	0	534990
TOC SOFTWARE DEVELOPMENT	13513129	13513129	1072753	16627057
DATA SYSTEM	7010008	7010008	0	10515012
OPERATIONS STAFF EQUIPMENT	1052400	1157640	0	1999560
IUS SOFTWARE DEVELOPMENT	2729197	2729197	2729197	2729197
TOTALS	24686870	24830323	3801950	32405816

TOTAL ALTERNATIVE DEVELOPMENT COSTS '

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
PHYSICAL PLANT	382136	420350	0	534990
TOC SOFTWARE DEVELOPMENT	14605147	14605147	1454023	18100747
DATA SYSTEM	7010008	7010008	0	10515012
OPERATIONS STAFF EQUIPMENT	1052400	1157640	0	1999560
IUS SOFTWARE DEVELOPMENT	2902487	2902487	2902487	2902487
TOTALS	25952178	26095632	4356510	34052796

Figure 2 3 0-7 IUS Level B Autonomy Concept DDT&E Cost



TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
FACILITY MAINTENANCE	19872	21 859	0	27 821
TOC SOFTWARE MAINTENANCE	1200000	1200000	0	1512000
DATA SYSTEM MAINTENANCE	13 8795	13 8795	0	20 8192
SUSTAINING TOC ENGINEERING	1536000	1536000	0	2304000
SUSTAINING TOC FLT CNTL ENGINEERING	172 8000	172 8000	0	2592000
NETWORK RENTAL	26233	26233	26233	26233
IUS SOFTWARE MAINTENANCE	100 8000	100 8000	100 8000	100 8000
TOTALS	5656000	565 8887	1034233	767 8246

NASA TENANT COSTS ALTERANTIVE 3

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	5962
TOC SOFTWARE MAINTENANCE	312000
DATA SYSTEM MAINTENANCE	69397
SUSTAINING TOC ENGINEERING	76 8000
SUSTAINING TOC FLT CNTL ENGINEERING	86 4000
NETWORK RENTAL	0
IUS SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	3 8214
DATA SYSTEM	116 8335
OPERATIONS STAFF EQUIPMENT	2 806 40
TOTAL	3506547

TOTAL ALTERNATIVE RECURRING COSTS

ELEMENT	ALTERNATIVE 1 NASA	ALTERNATIVE 1 DOD	ALTERNATIVE 3 NASA	ALTERNATIVE 3 DOD
FACILITY MAINTENANCE	19872	21 859	0	27 821
TOC SOFTWARE MAINTENANCE	1248000	1248000	0	1572480
DATA SYSTEM MAINTENANCE	13 8795	13 8795	0	20 8192
SUSTAINING TOC ENGINEERING	1632000	1632000	0	2448000
SUSTAINING TOC FLT CNTL ENGINEERING	172 8000	172 8000	0	2592000
NETWORK RENTAL	27953	27953	27953	27953
IUS SOFTWARE MAINTENANCE	100 8000	100 8000	100 8000	100 8000
TOTALS	5 802620	5 80 4607	1035953	7 88446

NASA TENANT COSTS ALTERNATIVE 3

ELEMENT	COST PER YEAR
SERVICE FEES	
FACILITY MAINTENANCE	5962
TOC SOFTWARE MAINTENANCE	3244 80
DATA SYSTEM MAINTENANCE	69397
SUSTAINING TOC ENGINEERING	816000
SUSTAINING TOC FLT CNTL ENGINEERING	86 4000
NETWORK RENTAL	0
IUS SOFTWARE MAINTENANCE	0
RENTAL FEES	
PHYSICAL PLANT	3 8214
DATA SYSTEM	116 8335
OPERATIONS STAFF EQUIPMENT	2 806 40
TOTAL	3567027

Figure 2 3 0 8 IUS Level B Autonomy Annual Recurring Costs

COST ESTIMATES 3

This section presents the cost estimates for each work breakdown structure element contained on the WBS presented in Table 1 1 0-3

3 1 COMPOSITE PROGRAM RATIONALE

Independent work breakdown structures were developed for the Space Tug program and the IUS program under the concepts of operation and autonomy discussed in Section 2 0 of this report Upon integrating the two work breakdown structures, it was found that a significant percentage of the tasks were structurally identical This allowed the combining of common operational elements such that one element of the composite program takes the place of two elements in the disjoint programs

The common operational elements are presented in Table 3 1 0-1 These elements are in the general categories of program planning and schedule analysis, console hardware design requirements and selection, network interface design requirements and equipment selection, operational data system, physical plant, and ground software in the areas of operating system and mission planning Table 3 1 0-2 presents those operational elements which are unique to the IUS, having no counterpart in the elements in the Space Tug work breakdown structure Those elements are related to the IUS unique requirement for ground tracking of the vehicle. Tracking is not required for Space Tug The IUS is required to define ground network tracking requirements, provide network tracking validation procedures and to execute network tracking validation tests

Table 3 1 0-3 presents unique but comparable operational elements That is, the elements are similar in content but different in execution These operational elements involve the following general categories, mission design, flight program design, development and verification, training and training criteria, ground software in the areas of down data processing, up data processing and vehicle specific simulation, inter-agency relationships with DoD and other NASA centers, flight program mission specific elements, and post-mission analysis

Table 3 1 0-4 presents those IUS elements which are initially required by the IUS and are then modified to meet the Space Tug operations requirements These elements include maintenance schedule, network interface design, and console position guidelines

3 2 COST DATA FORMS A(1) - NON-RECURRING COSTS (DDT&E)

The following Cost Data Forms present the "one-time" cost of Designing, Developing, Testing and Evaluating (DDT&E) the Orbital operations and Mission Support Hardware and Software This includes the cost of preparing for, and executing the first mission of the IUS, and the first mission of the Space Tug The DDT&E cycle for the IUS and the Space Tug is considered over whenever the first mission cycle is complete The first mission cycle is included in the DDT&E costs in order to capture the transient expenses involved in establishing repetitive activities

Table 3 1 0-1 Common Space Tug and IUS Operational Elements

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
02-01-01	Master Launch Schedule Analysis	✓				This task may be shared by enlarging the scope of work - no unique factors
01-02-01-01	Contract Software Development	✓				Mission timing and common utilization of data processing equipment make combining of software under one contractor attractively cost-effective.
01-02-01-02	Plan Facility Utilization	✓				A single facility for both IUS and Tug mission control makes this a common task
15-01-01	Plan Flight Software Development	✓				Total IUS/Tug program cost can be minimized by integrating flight software development techniques, simulator, etc.
15-02-01	Plan Ground Software Development	✓				Ground software will be driven by 1) IUS TM and CMD configuration, 2) Tug TM and CMD configuration, and 3) Ground system (network) configuration A unified plan will save double development costs for 3)
02-04-01-01	Mission Phase Manning Requirements	✓				Common disciplines are required, although mission structure may be significantly different This task can be combined and enlarged to include cross-training.
01-02-01-03	Computer Utilization Plan	✓				Basic ground rules for computer utilization should apply to both programs

Table 3 1 0-1 Common Space Tug and IUS Operational Elements (Continued)

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
01-02-01-04	Maintenance Schedule	√			√	General maintenance policy will be a shared task. Maintenance of Tug-unique hardware (e g , television equipments) will require modification of the plan
01-02-01-05	Hire Control and Support Staff	√				The same staff should be utilized by both IUS and Space Tug programs
10-02-02	Console Organization	√				Console organization should be frozen early and carried through Tug.
10-02-01	Design Network Interface	√			√	Equipment selected should be sufficiently flexible to encompass both IUS and Space Tug interface constraints.
15-03-01	Estimate Ground Software Size	√				This task must size for the maximum memory and speed load on the Data Processing system. Thus must analyze both IUS and Tug programs
02-04-02-01	Select Operational Data System	√				The data processing system should be common to both programs
07-04-01	Install Operational Data System	√				Same as above
06-06-01	Size Facility/Design Physical Plant	√				The physical plant should be designed to incorporate both program requirements without subsequent modification
06-06-02	Construct Physical Plant	√				A single plant construction is desirable and cost-effective

Table 3.10-1 Common Space Tug and IUS Operational Elements (Continued)

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
07-04-02	Install Operational Consoles	✓				Consoles should be flexible enough to incorporate both IUS and Tug requirements with only minor modification.
15-02-02-01	Equation Defining Document Executive/Tracking/Planning Software	✓		✓		The functions of the executive and mission planning software are independent of the flight vehicle Tracking is IUS-peculiar
02-04-01-04	Validation Test Requirements Fundamental IUS [Tug] Ground Programs	✓				This task establishes test requirements against common software and thus may be merged between both programs.
01-02-01-07	Prepare IUS [Tug] Interagency Documentation	✓	✓	✓		This task continues from IUS through Space Tug operations and involves program support documentation
01-02-01-08	IUS [Space Tug] Interagency Coordination	✓	✓	✓		This task continues from IUS through Space Tug operations and involves program support documentation.
02-04-01-03	Define IUS [Tug] Operation Certification Criteria	✓	✓	✓		This task is mission and vehicle dependent, but also involves underlying common human factors considerations.
05-02-03-01	IUS [Tug] Training Requirements, Evaluation Criteria and Simulation Schedule	✓	✓	✓		These tasks are vehicle and mission configuration dependent, but have common underlying human factor considerations
15-02-03-01	Program Ground Tracking, Planning and Executive Routines	✓		✓		This program implements the software which will be common to both IUS and Space Tug and the IUS tracking software
15-02-04-01	Verify Executive, Tracking and Planning Software	✓		✓		This task verifies the common aspects of the ground software and the IUS-peculiar tracking software

Table 3 1 0-2 Unique IUS Operational Elements

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
10-01-05-01	Define Ground Network Tracking Requirements			✓		Tracking will be an IUS function. Space Tug navigation will be autonomous
10-01-05-02	Network Tracking Validation Procedures			✓		Procedures to test the tracking function are required
10-03-01	Network Tracking Validation Tests			✓		The test is unique to the IUS program

Table 3 1 0-3 Unique Comparable Operational Elements

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
01-02-01-06	Obtain the IUS [Space Tug] System Characteristics		✓	✓		These tasks are independent, but both must be accomplished prior to the design of common network equipment and common console utilization.
02-01-02	IUS [Tug] Mission Characterization		✓	✓		These tasks are independent, but both must be accomplished prior to major planning activities
15-01-02-01	Equation Defining Document IUS [Space Tug] Flight Program		✓	✓		All tasks relative to flight software design, development, programming and verification are vehicle - driven
15-02-02-02	IUS [Tug] Downdata/Updata/ [Docking] and Simulation Ground		✓	✓		These tasks are vehicle updata, downdata and configuration dependent
02-04-01-05	IUS [Tug] Ground Validation Test Requirements		✓	✓		These tasks are vehicle updata, downdata and configuration dependent
02-01-03	Determine IUS [Tug] Failure Modes		✓	✓		These tasks are vehicle configuration dependent
10-02-03	IUS [Tug] Display Format Design		✓	✓	✓	These tasks are vehicle updata, downdata and configuration dependent except in the flight dynamics discipline
10-01-02	IUS [Tug] Mission Failure Effects Analysis		✓	✓		These tasks are vehicle and mission configuration dependent

Table 3 1 0 3 Unique Comparable Operational Elements (Continued)

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
05-02-03-03	Design IUS [Tug] Mission Simulation		✓	✓		These tasks are vehicle and mission configuration dependent.
10-01-03	Analyze IUS [Tug] Component Characteristics		✓	✓		These tasks are vehicle configuration dependent
05-02-03-01	IUS [Tug] Training Requirements, Evaluation Criteria and Simulation Schedule	✓	✓	✓		These tasks are vehicle and mission configuration dependent, but have common underlying human factor considerations
10-01-04-01	Prepare IUS [Tug] System Handbook		✓	✓		These tasks are vehicle configuration and performance dependent
10-01-04-02	Publish and Update IUS [Tug] System Handbook		✓	✓		These tasks are vehicle configuration and performance dependent
05-02-03-02	Develop IUS [Space Tug] Training Material		✓	✓		These tasks are vehicle downdata, updata, configuration and mission dependent
05-02-03-04	IUS [Space Tug] Classroom Training		✓	✓		These tasks are vehicle downdata, updata, configuration and mission dependent
10-01-05-03	IUS [Space Tug] Network Data Handling Requirements		✓	✓		These tasks are vehicle updata and downdata dependent.
10-01-05-04	IUS [Tug] Network Data Validation Procedures		✓	✓		These tasks are vehicle updata and downdata dependent.
10-03-02	IUS [Space Tug] Network Validation Tests		✓	✓		These tasks are vehicle updata and downdata dependent

Table 3 1 0-3 Unique Comparable Operational Elements (Continued)

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
15-02-03-02	Program IUS [Space Tug] Downdata/Updata/[Docking]/Simulation System		✓	✓		These tasks are vehicle updata, downdata and configuration dependent
15-02-04-02	Verify IUS [Tug] Downdata/Updata/[Docking]/Simulation Programs		✓	✓		These tasks are vehicle updata, downdata and configuration dependent
02-04-01-02	IUS [Tug] Console Position Guide-lines				✓	This task will be executed once for the IUS program, then modified for Space Tug implementation, based upon IUS experience
02-04-03-01	IUS [Tug] Mission Planning and Optimization		✓	✓		This task is unique for each mission flown by both IUS and Tug
10-01-01	Develop IUS [Tug] Procedures and Rules		✓	✓		These tasks are vehicle and mission dependent
02-04-03-02	IUS [Tug] Abort Planning		✓	✓		This task is unique for each mission
01-02-01-08	IUS [Space Tug] Interagency Coordination	✓	✓	✓		This task continues from IUS through Space Tug operations and involves program support documentation
15-01-02-03	IUS [Space Tug] Flight Program Verification		✓	✓		This task is vehicle and mission dependent
01-02-01-07	Prepare IUS [Tug] Interagency Documentation	✓	✓	✓		This task continues from IUS through Space Tug operations and involves program support documentation.
15-02-05-01	Program IUS [Tug] Mission Simulation		✓	✓		This task is unique for each mission flown by both IUS and Tug

Table 3 1 0-3 Unique Comparable Operational Elements (Continued)

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
15-01-03-01	IUS [Tug] Mission Specific Equation Defining Document (EDD)		✓	✓		This task is unique for each mission flown by both IUS and Tug
15-01-03-02	IUS [Tug] Mission Specific Programming		✓	✓		This task is unique for each mission flown by both IUS and Tug
15-01-03-03	IUS [Tug] Mission Program Verification		✓	✓		This task is unique for each mission flown by both IUS and Tug
05-02-03-05	IUS [Tug] Mission Simulation Training		✓	✓		This task is unique for each mission flown by both IUS and Tug
10-04	Conduct IUS [Space Tug] Mission Operations		✓	✓		This task is unique for each mission flown by both IUS and Tug
02-04-05-01	IUS [Space Tug] Post Mission Reports		✓	✓		This task is unique for each mission flown by both IUS and Tug
02-04-01-03	Define IUS [Tug] Operation Certification Criteria	✓	✓	✓		This task is mission and vehicle dependent, but also involves underlying common human factors considerations.

Table 3 1 0-4 IUS Elements Modifiable for Space Tug Operations

WBS 320- OR XXX-	TITLE	C	TU	IU	M	COMMENTS
01-02-01-04	Maintenance Schedule	✓			✓	General maintenance policy will be a shared task Maintenance of Tug-unique hardware (i e , television equipments) will require modification of the plan
02-04-01-02	IUS [Tug] Console Position Guidelines				✓	This task will be executed once for the IUS program, then modified for Space Tug implementation, based upon IUS experience
10-02-01	Design Network Interface	✓			✓	Equipment selected should be sufficiently flexible to encompass both IUS and Space Tug interface constraints
10-02-03	IUS [Tug] Display Format Design		✓	✓	✓	These tasks are vehicle updata, downdata and configuration dependent except in the flight dynamics discipline

Mission cycles subsequent to the first are costed as recurring (operations) expenses

Costs are spread at the lowest level of the WBS (7) and folded into successively higher levels The spread function used was flat (F) indicating a constant rate of expenditure over the task execution period

3 3 IUS RECURRING (OPERATIONS) COST DATA FORMS (A-3)

The following cost data forms present the recurring costs associated with mission operations This includes the cost of mission control mission planning, flight controller training, simulator modification, mission specific flight program development, on-going ground software maintenance and support hardware maintenance

The cyclic mission operations elements are presented on Figure 2.2 0-1 "Schedule of Recurring Tasks (OO/MS)"

3 4 SPACE TUG RECURRING (OPERATIONS) COST DATA FORMS (A-3)

The following Cost Data Forms present the recurring costs associated with Mission Operations This includes the cost of mission control, mission planning, flight controller training, simulator modification, mission specific flight program development, on-going ground software maintenance and support hardware maintenance

The cyclic mission operations elements are presented in Figure 2 2 0-1 "Schedule of Recurring Tasks (OO/MS)"

Table 3 2 0-1

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320	Space Tug Project	3	40,917,951				
320-01	Project Management	4	361,560				
320-01-01	Cost/Performance Management	5					
320-01-01-01	Cost Control System	6					
320-01-01-02	Schedule Control System	6					
320-01-02	Project Direction	5	361,560				
320-01-02-01	Development Management	6	361,560				
320-01-02-01-01	Contract Software Development	7	29,440	3	2 0	I-51	F
320-01-02-01-02	Plan Facility Utilization	7	9,200	3	1.0	I-23	F
320-01-02-01-03	Computer Utilization Plan	7	32,200	3	2 0	I-27	F
320-01-02-01-04	Maintenance Schedule	7	8,280	3	1 5	I-17	F
320-01-02-01-05	Hire Control and Support St	7	8,280	3	1 5	I-30	F
320-01-02-01-06	Obtain Tug System Char	7	30,360	3	1.5	T-59	F
320-01-02-01-07	Prepare Tug Interagency Docs	7	81,880	3	2 0	T-4	F
320-01-02-01-08	Tug Interagency Coordination	7	29,440	3	2 0	T-2	F
XXX-01-02-01-06	Obtain IUS System Char	7	22,080	3	1.5	I-28	F
XXX-01-02-01-07	Prepare IUS Interagency Docs	7	80,960	3	2 0	I-4	F
XXX-01-02-01-08	IUS Interagency Coordination	7	29,440	3	2 0	I-2	F
320-01-02-02	Quality Management	6					

Table 3 2 0-1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320-01-02-03	Logistics Management	6					
320-01-02-04	Engineering Administration	6					
320-01-03	Information Management	5					
320-02	Systems Engineering	4	1,821,140				
320-02-01	IUS/Tug Systems Engineering	5	395,600				
320-02-01-01	Master Launch Schedule Analy.	6	22,080	3	1 5	I-34	F
320-02-01-02	Tug Mission Characterization	6	24,840	3	2 0	T-63	F
320-02-01-03	Determine Tug Failure Modes	6	161,920	3	2 0	T-13	F
XXX-02-01-02	IUS Mission Characterization	6	24,840	3	2 0	I-32	F
XXX-02-01-03	Determine IUS Failure Modes	6	161,920	3	2 0	I-13	F
320-02-02	Shuttle Interface	5					
320-02-03	Payload Interface	5					
320-02-04	Sustaining Engineering	5	1,425,540				
320-02-04-01	Flight Control Engineering	6	740,140				
320-02-04-01-01	Mission Phase Manning Req	7	11,040	3	1 0	I-31	F
320-02-04-01-02	Tug Console Position Guide	7	99,360	3	3 0	T-12	F
320-02-04-01-03	Define Tug Opr Cert /Crit	7	33,120	3	1 0	T-10	F
320-02-04-01-04	Common Gnd S/W Valid'n Test R	7	179,837	3	2 5	I-13	F
320-02-04-01-05	Tug Gnd Valid'n Test Req	7	158,447	3	2 5	T-15	F

Table 3 2 0-1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
XXX-02-04-01-05	IUS Gnd Valid'n Test Req	7	125,856	3	1 75	I-12	F
XXX-02-04-01-02	IUS Console Position Guides	7	99,360	3	4 0	I-12	F
XXX-02-04-01-03	Define IUS Opr Cert /Crit	7	33,120	3	1 0	I-11	F
320-02-04-02	Flight Support Engineering	6	15,640				
320-02-04-02-01	Select Operational Data Sys	7	15,640	3	1 5	I-26	F
320-02-04-03	Mission Engineering	6	198,720				
320-02-04-03-01	Tug Mission Planning & Opt'n	7	66,240	3	1 5	T-11	F
320-02-04-03-02	Tug Abort Planning	7	33,120	3	3 0	T-9	F
XXX-02-04-03-01	IUS Mission Planning & Opt'n	7	66,240	3	1 5	I-11	F
XXX-02-04-03-02	IUS Abort Planning	7	33,120	3	3 0	I-9	F
320-02-04-05	Mission Evaluation Engr	6	471,040				
320-02-04-05-01	Tug Post - Mission Reports	7	235,520	3	2 0	T-0	F
XXX-02-04-05-01	IUS Post - Mission Reports	7	235,520	3	2 0	I-0	F
320-03	Tug Vehicle Mainstage	4					
320-05	Logistics	4	1,188,640				
320-05-01	Transportation and Handling	5					
320-05-02	Training	5	1,188,640				
320-05-02-01	Simulators and Equipment	6					
320-05-02-02	Ground Crew Training	6					

Table 3 2 0-1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320-05-02-03	Flight Operations Crew Trng	6	1,188,640				
320-05-02-03-01	Tug Trng Peq/Crit/Schedule	7	36,800	3	2 0	T-6	F
320-05-02-03-02	Develop Tug Trng Materials	7	90,160	3	2 0	T-5	F
320-05-02-03-03	Design Tug Mission Simulation	7	55,200	3	3 0	T-9	F
320-05-02-03-04	Tug Classroom Training	7	161,920	3	1 0	T-3	F
320-05-02-03-05	Tug Mission Simulation Trng	7	253,920	3	1 5	T-2	F
XXX-05-02-03-01	IUS Trng Req/Crit/Schedule	7	29,440	3	2 0	I-7	F
XXX-05-02-03-02	Develop IUS Trng. Materials	7	90,160	3	2.0	I-5	F
XXX-05-02-03-03	Design IUS Mission Simulation	7	55,200	3	3 0	I-9	F
XXX-05-02-03-04	IUS Classroom Training	7	161,920	3	1 0	I-3	F
XXX-05-02-03-05	IUS Mission Simulation Trng	7	253,920	3	1 5	I-2	F
320-06	Facilities	4	435,180				
320-06-01	Manufacturing	5					
320-06-02	Test	5					
320-06-03	Maintenance & Refurbishment	5					
320-06-04	ETR Launch	5					
320-06-05	WTR Launch	5					
320-06-06	Flight Operations Facility	5	435,180				
320-06-06-01	Size Facility/Design Phy Plant	6	11,960	3	3 0	I-24	F

Table 3 2 0 1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320-06-06-02	Construct Physical Plant	6	423,220	3	6 0	I-20	F
320-07	Ground Support Equipment	4	8,193,347				
320-07-01	Manufacturing and Test	5					
320-07-02	Eastern Test Pange GSE	5					
320-07-03	Western Test Range GSE	5					
320-07-04	Flight Operations GSE	5	8,193,347				
320-07-04-01	Install Operational Data Sys.	6	7,030,547	3	5 0	I-15	F
320-07-04-02	Install Opn'l Consoles/Hdw	6	1,162,800	3	5 0	I-15	F
320-08	Vehicle Test	4					
320-09	Launch Operations	4					
320-10	Flight Operations	4	1,972,480				
320-10-01	Mission Planning & Documen	5	1,267,760				
320-10-01-01	Develop Tug Procedures & Rules	6	154,560	3	4 0	T-13	F
XXX-10-01-01	Develop IUS Procedures & Rules	6	154,560	3	4 0	I-10	F
320-10-01-02	Tug Mission Failure Effects	6	176,640	3	2 0	T-11	F
XXX-10-01-02	IUS Mission Failure Effects	6	176,640	3	2 0	I-11	F
320-10-01-03	Analyze Tug Component Ch	6	126,960	3	1 5	T-8	F
XXX-10-01-03	Analyze IUS Component Ch	6	126,960	3	1.5	I-8	F
320-10-01-04	Flt Control Systems Handbook	6	117,760				

Table 3 2 0 1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320-10-01-04-01	Prepare Tug Systems Handbook	7	25,760	3	2 0	T-6	F
320-10-01-04-02	Pub/Update Tug Sys. Handbook	7	33,120	3	3 0	T-5	F
XXX-10-01-04-01	Prepare IUS Systems Handbook	7	25,760	3	2 0	I-7	F
XXX-10-01-04-02	Pub/Update IUS Sys Handbook	7	33,120	3	3 0	I-5	F
320-10-01-05	Tug Network Interface Doc.	6	233,680				
XXX-10-01-05-01	Define N/W Tracking Req	7	23,920	3	1 0	I-5	F
XXX-10-01-05-02	Network Tracking Val Proc	7	51,520	3	2 0	I-4	F
320-10-01-05-03	Tug N/W Data Handling Peq	7	27,600	3	1 0	T-5	F
320-10-01-05-04	Tug N/W Data Val Proc	7	51,520	3	2 0	T-4	F
XXX-10-01-05-03	IUS N/W Data Handling Req	7	27,600	3	1 0	I-5	F
XXX-10-01-05-04	IUS N/W Data Val Proc	7	51,520	3	2.0	I-4	F
320-10-02	Operational Preparations	5	524,400				
320-10-02-01	Design Network Interface	6	44,160	3	3 0	I-27	F
320-10-02-02	Console Organization	6	5,520	3	1 0	I-25	F
320-10-02-03	Tug Display Format Design	6	237,360	3	2 0	T-57	F
XXX-10-02-03	IUS Display Format Design	6	237,360	3	2 0	I-26	F
320-10-03	Mission Readiness Testing	5	52,440				
XXX-10-03-01	N/W Tracking Validation Tests	6	17,480	3	2.0	I-2	F
320-10-03-02	Tug N/W Validation Tests	6	17,480	3	2 0	T-2	F

Table 3 2 0 1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
XXX-10-03-02	IUS N/W Validation Tests	6	17,480	3	2 0	I-2	F
320-10-04	Conduct Tug Mission Opns	5	63,940	3	25	T-0	F
XXX-10-04	Conduct IUS Mission Opns	5	63,940	3	25	I-0	F
320-11	Refurbishment and Integration	4					
320-15	Software	4	26,945,604				
320-15-01	Flight Software	5	7,750,977				
320-15-01-01	Plan Flight S/W Development	6	44,298	4	1 5	I-29	F
320-15-01-02	Baseline Flt Program Dev	6	7,045,682	4	18.0	T-38	F
320-15-01-02-01	EDD-Tug Flight Program	7	620,126				
320-15-01-02-02	Program Tug Flt Software	7	1,760,052	4	6.5	T-20	F
320-15-01-02-03	Tug Flt Program Verification	7	2,273,895	4	6 5	T-13	F
XXX-15-01-02-01	EDD-IUS Flight Program	7	338,860	4	12 0	I-28	F
XXX-15-01-02-02	Program IUS Flt Software	7	968,461	4	5 0	I-16	F
XXX-15-01-02-03	IUS Flt Program Verification	7	1,084,289	4	5 0	I-11	F
320-15-01-03	Mission Specific Program Mods	6	660,997				
320-15-01-03-01	Tug Mission Specific EDD	7	76,797	4	1 0	T-6	F
320-15-01-03-02	Tug Mission Specific Program	7	153,594	4	2 0	T-5	F
320-15-01-03-03	Tug Mission Pgm Verification	7	129,950	4	2.0	T-3	F
XXX-15-01-03-01	IUS Mission Specific EDD	7	64,055	4	1 0	I-7	F

Table 3 2 0-1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
XXX-15-01-03-02	IUS Mission Specific Program	7	128,156	4	2 0	I-6	F
XXX-15-01-03-03	IUS Msn Program Verification	7	108,445	4	2.0	I-4	F
320-15-02	Ground Software	5	19,150,467				
320-15-02-01	Plan Ground S/W Development	6	27,600	4	1 5	I-49	F
320-15-02-02	Equation Definition	6	4,306,359				
320-15-02-02-01	EDD-Exec /Track/Planning	7	1,729,969	4	17 0	I-48	F
320-15-02-02-02	EDD-Tug Dndata/Updata/Sim	7	1,524,233	4	17 0	T-79	F
XXX-15-02-02-02	EDD-IUS Dndata/Updata/Sim	7	1,052,158	4	12 0	I-43	F
320-15-02-03	Programming	6	12,693,815				
320-15-02-03-01	Pgm Gnd Exec/Track/Planning	7	6,255,333	4	12 0	I-31	F
320-15-02-03-02	Pgm Tug Dndata/Updata/Sim	7	3,647,478	4	8 0	T-29	F
XXX-15-02-03-02	Pgm IUS Dndata/Updata/Sim	7	2,791,004	4	8.0	I-23	F
320-15-02-04	Program Verification	6	1,990,213				
320-15-02-04-01	Verify Exec/Track/Planning	7	1,007,032	4	8.0	I-19	F
320-15-02-04-02	Verify Tug Dndata/Updata/Sim	7	610,029	4	8 0	T-21	F
XXX-15-02-04-02	Verify IUS Dndata/Updata/Sim	7	373,152	4	5 0	I-15	F
320-15-02-05	Mission Specific Simulation	6	132,480				
320-15-02-05-01	Program Tug Mission Sim	7	66,240	4	3 0	T-5	F
XXX-15-02-05-01	Program IUS Mission Sim	7	66,240	4	3 0	I-5	F

Table 3 2 0-1 (Continued)

COST DATA FORM – A(1)
NON–RECURRING (DDT&E)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT COST	CONFID RATING	T_d	T_s	SPREAD FUNCT
320-15-03	Computer Selection Support	5	44,160				
320-15-03-01	Estimate Gnd Software Size	6	44,160	4	1 0	I-26	F

Table 3 3 0 1

COST DATA FORM — A(3)

RECURRING IUS (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	T_s	SPREAD FUNCT	LEARN INDEX
XXX	IUS Project	3		15,818,738							
XXX-01	Project Management	4		387,662							
XXX-01-02	Project Direction	5		387,622							
XXX-01-02-01	Development Mgt	6		387,622							
XXX-01-02-01-07	Prepare Interagcy Docs	7	40	66,630	2	1,666	3	0 2	I-2 25	F	
XXX-01-02-01-08	Interagency Coordin.	7	40	242,293	2	6,057	3	2 0	I-2	F	
XXX-01-02-01-09	Network Rental	7	40	78,699	2	1,967	2	12	LOE	F	
XXX-02	Systems Engineering	4		2,756,077							
XXX-02-04	Sustaining Engineering	5		2,756,077							
XXX-02-04-03	Mission Engineering	6		817,737							
XXX-02-04-03-01	Mission Planning & Opt	7	40	545,158	2	13,629	3	1 5	I-11	F	
XXX-02-04-03-02	Abort Planning	7	40	272,579	2	6,814	3	3 0	I-9	F	
XXX-02-04-05	Mission Eval Engr	6		1,938,340							
XXX-02-04-05-01	Post Mission Reports	7	40	1,938,340	2	48,459	3	2 0	I-0	F	
XXX-05	Logistics	4		3,566,243							
XXX-05-02	Training	5		3,566,243							
XXX-05-02-03	Flt Opns Crew Trng	6		3,566,243							
XXX-05-02-03-01	Trng Req/Crit/Sched	7	40	24,229	2	605	3	0 2	I-3 4	F	
XXX-05-02-03-02	Develop Ing Mat'l	7	40	74,202	2	1,855	3	0 2	I-3 2	F	
XXX-05-02-03-03	Design Mission Sim	7	40	45,430	2	1,136	3	0 3	I-7 3	F	

Table 3 3 0-1 (Continued)

COST DATA FORM – A(3)
RECURRING IUS (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	T_s	SPREAD FUNCT	LEARN INDEX
XXX-05-02-03-04	Classroom Training	7	40	1,332,609	2	33,315	3.0	1.0	I-3	F	
XXX-05-02-03-05	Mission Sim Training	7	40	2,089,773	2	52,244	3	1 5	I-2	F	
XXX-06	Facilities	4		59,616							
XXX-06-06	Maintenance & Refurb	5		59,616							
XXX-06-06-03	Facility Maintenance	6	3	59,616	1	19,872	3	12	LOE	F	
XXX-07	Ground Support Equip	4		416,385							
XXX-07-04	Flight Opns GSE	5		416,385							
XXX-07-04-03	Data System Maint	6	3	416,385	1	138,795	3	12	LOE	F	
XXX-10	Flight Operations	4		2,008,755							
XXX-10-01	Mission Plan & Doc'n	5		302,866							
XXX-10-01-01	Develop Procedures	6	40	127,204	2	3,180	3	0 4	I-7 4	F	
XXX-10-01-04	F/C Systems Handbook	6		48,459							
XXX-10-01-04-01	Prepare Sys Handbook	7	40	21,201	2	530	3	0 2	I-2 5	F	
XXX-10-01-04-02	Pub/Update Sys Handbook	7	40	27,258	2	681	3	0 3	I-2 3	F	
XXX-10-01-05	Network Interface Doc	6		127,203							
XXX-10-01-05-01	Define N/W Track Req	7	40	19,686	2	492	3	0 1	I-2.3	F	
XXX-10-01-05-02	N/W Track Valid Proc	7	40	42,401	2	1,060	3	0 2	I-2.2	F	
XXX-10-01-05-03	N/W Data Hand. Req	7	40	22,715	2	568	3	0 1	I-2 3	F	
XXX-10-01-05-04	N/W Data Valid Proc	7	40	42,401	2	1,060	3	0 2	I-2 2	F	
XXX-10-03	Mission Readiness Testg	5		1,179,660							

Table 3 3 0-1 (Continued)

COST DATA FORM – A(3)

RECURRING IUS (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	T_s	SPREAD FUNCT	LEARN INDEX
XXX-10-03-01	N/W Track Valid Tests	6	40	143,861	2	3,597	3	2.0	I-2	F	
XXX-10-3-02	N/W (Data) Valid. Tests	6	40	1,035,800	2	25,895	3	2 0	I-2	F	
XXX-10-04	Conduct Mission Opns	5	40	526,229	2	13,156	3	0.25	I-0	F	
XXX-15	Software	4		6,624,000							
XXX-15-01	Flight Software	5		3,024,000							
XXX-15-01-03	MSN Spec Prog Mod	6		3,024,000							
XXX-15-01-03-01	Mission Spec EDD	7	40	644,266	2	16,107	3	1 0	I-7	F	
XXX-15-01-03-02	Mission Spec Program	7	40	1,288,994	2	32,225	3	2 0	I-6	F	
XXX-15-01-03-03	Mission Prog Ver	7	40	1,090,740	2	27,269	3	2 0	I-4	F	
XXX-15-02	Ground Software	5		3,600,000							
XXX-15-02-05	Mission Spec Simulation	6		152,352							
XXX-15-02-05-01	program MSN Sim	7	40	152,352	2	3,809	3	0 3	I-2 3	F	
XXX-15-02-06	Ground S/W Maint	6	3	3,447,648	1	1,159,216	3	12	LOE	F	

COST DATA FORM — A(3)

RECURRING TUG (OPERATIONS)

Table 3 4 0-1

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	Ts	SPREAD FUNCT	LEARN INDEX
320	Space Tug Project	3		43,959,127							
320-01	Project Management	4		2,628,103							
320-01-02	Project Direction	5		2,628,103							
320-01-02-01	Development Mgt	6		2,628,103							
320-01-02-01-07	Prepare Interagcy Docs	7	118	213,512	2	1,809	3	0.2	T-2 25	F	
320-01-02-01-08	Interagency Coordin	7	118	776,551	2	6,581	3	2 0	T-2	F	
320-01-02-01-09	Network Rental	7	118	1,638,040	2	13,882	2	12	LOE	F	
320-02	Systems Engineering	4		8,833,270							
320-02-04	Sustaining Engineering	5		8,833,270							
320-02-04-03	Mission Engineering	6		2,620,860							
320-02-04-03-01	Mission Planning & Opt	7	118	1,747,240	2	14,807	3	1 5	T-11	F	
320-02-04-03-02	Abort Planning	7	118	873,620	2	7,404	3	3 0	T-9	F	
320-02-04-05	Mission Eval Engr	6		6,212,410							
320-02-04-05-01	Post Mission Reports	7	118	6,212,410	2	52,648	3	2 0	T-0	F	
320-05	Logistics	4		11,449,278							
320-05-02	Training	5		11,449,278							
320-05-02-03	Flt Opns Crew Trng	6		11,449,278							
320-05-02-03-01	Trng Req/Crit/Sched	7	118	97,069	2	823	3	0 2	T-3 4	F	
320-05-02-03-02	Develop Ing Mat'l	7	118	237,819	2	2,015	3	0 2	T-3 2	F	
320-05-02-03-03	Design Mission Sim	7	118	145,603	2	1,234	3	0 3	T-7.3	F	

COST DATA FORM – A(3)

RECURRING TUG (OPERATIONS)

Table 3 4 0-1 (Contınued)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	T_s	SPREAD FUNCT	LEARN INDEX
320-05-02-03-04	Classroom Traınıng	7	118	4,271,032	2	36,195	3	1 0	T-3	F	
320-05-02-03-05	Mıssıon Sım Traınıng	7	118	6,697,755	2	56,761	3	1 5	T-2	F	
320-06	Facılıtıes	4		157,376							
320-06-06	Maıntenance & Refurb	5		157,376							
320-06-06-03	Facılıty Maıntenance	6	8	157,376	1	19,672	3	12	LOE	F	
320-07	Ground Support Eq	4	8	1,075,664							
320-07-04	Flıght Opn'l GSE	5	8	1,075,664							
320-07-04-03	Data System Maınt	6	8	1,075,664	1	134,458	3	12	LOF	F	
320-10	Flıght Operatıons	4		2,919,346							
320-10-01	Mıssıon Plan & Doc'n	5		771,697							
320-10-01-01	Develop Procedures	6	118	407,689	2	3,455	3	0.4	T-7 4	F	
320-10-01-04	F/C Systems Handbook	6		155,310							
320-10-01-04-01	Prepare Sys Handbook	7	118	67,948	2	576	3	0 2	T-2 5	F	
320-10-01-04-02	Pub/Update Sys Handbook	7	118	87,362	2	740	3	0 3	T-2 3	F	
320-10-01-05	Network Interface Doc	6		208,698							
320-10-01-05-03	N/W Data Hand Req	7	118	72,802	2	642	3	0 1	T-2 3	F	
320-10-01-05-04	N/W Data Valıd Proc	7	118	135,896	2	1,152	3	0 2	T-2 2	F	
320-10-03	Mıssıon Readıness Tests	5		461,077							
320-10-03-02	N/W (Data) Valıd Tests	6	118	461,077	2	3,907	3	2 0	T-2	F	
320-10-04	Conduct Mıssıon Opns	5	118	1,686,572	2	14,293	3	0 25	T-0	F	

Table 3 4 0-1 (Continued)

COST DATA FORM – A(3)
RECURRING TUG (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO OF UNITS	EXPECT COST	REF UNIT	REF COST UNIT	CONFID RATING	Td	T_s	SPREAD FUNCT	LEARN INDEX
320-15	Software	4		16,896,000							
320-15-01	Flight Software	5		8,064,000							
320-15-01-03	MSN Spec Prog Mod	6		8,064,000							
320-15-01-03-01	Mission Spec EDD	7	118	1,718,625	2	14,565	3	1 0	T-7	F	
320-15-01-03-02	Mission Spec Program	7	118	3,437,250	2	29,129	3	2 0	T-6	F	
320-15-01-03-03	Mission Prog Ver	7	118	2,908,125	2	24,645	3	2 0	T-4	F	
320-15-02	Ground Software	5		8,832,000							
320-15-02-05	Mission Spec Simulation	6		449,438							
320-15-02-05-01	Program MSN Sim	7	118	449,438	2	3,809	3	0 3	T-2 3	F	
320-15-02-06	Ground S/W Maint	6	8	8,382,562	1	1,047,820	3	12	LOE	F	

TECHNICAL CHARACTERISTICS DATA 4

The following forms present the technical, physical and mission characteristics which have a significant effect on the cost of the WBS elements listed

Table 4 0 0-1

TECHNICAL CHARACTERISTICS DATA FORM B

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
320-06-06-01	Size Facility/Design Physical Plant	10260	Square Feet	Area Acquired to House Operational Data System and Control Consoles	Design Depends upon Arrangement of Equipment
320-06-06-02	Construct Physical Plant	10,260	Square Feet	Concrete Block on Slab	
320-06-06-03	Facility Maintenance	10,260	Square Feet	Maintenance Cost ~ $2/Sq Ft/Year	Recurring Cost
320-07-04-01	Install Operational Data System	830,993	Words	Simultaneous Memory Capacity	Computer Selection is Driven by and Software Size
		7 70	MEGAOPS	CPU Speed	
320-07-04-02	Install Operational Consoles/Hardware	17	Each	Configuration and Quantity Depend upon End Utilization	
320-10-02-03	Tug Display Format Design	50	Formats	Parameter Size, Scaling and Organization	Quantity Should be Minimized
XXX-10-02-03	IUS Display Format Design	50	Formats	Parameter Size Scaling and Organization	Quantity Should be Minimized

Table 4 0 0-1 (Continued)

TECHNICAL CHARACTERISTICS DATA FORM B

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
320-10-04	Conduct Tug Mission Operations	118	Missions	Sizing Assumes Launch Frequency Less than 30/Yr	Launch Frequency Greater than 30/Year will Force Doubling of Facility Capability and Manpower Req
XXX-10-04	Conduct IUS Mission Operations	40	Missions	Sizing Assumes Launch Frequency Less than 30/Yr	
320-15-01-01	Baseline Flight Program Development	4 4	Tug Programs IUS Programs	Four Mission Types	Proportional Increase if More than Four Baseline Programs are Specified
320-15-01-02-01	EDD - Tug Flight Program	500	Equations	Number of Algorithms to be Designed	Equations Consist Primarily of 3rd Order Matrix Equations
320-15-01-02-02	Program Tug Flight Software	30,080	Words	Size of Flight Program	Complexity Ranges from 0 1 to 1
320-15-01-02-03	Verify Tug Flight Program	2,000	Cases	Simulated Flight Responses & Analysis	Requires Simulator
XXX-15-01-02-01	EDD - IUS Flight Program	300	Equations	Number of Algorithms to be Designed	Equations Consist Primarily of 3rd Order Matrix Equations

Table 4 0 0-1 (Continued)

TECHNICAL CHARACTERISTICS DATA FORM B

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
XXX-15-01-02-02	Program IUS Flight Software	19,468	Words	Size of Flight Program	Complexity Ranges from 0 1 to 1
XXX-15-01-02-03	Verify IUS Flight Program	1,500	Cases	Simulations of Flight Responses	Requires Simulator
320-15-02-02-01	EDD - Executive/ Tracking/Planning	7,500	Equations	Number of Algorithms to be Designed	Equations Consist Primarily of 3rd Order Matrix Manipulations
320-15-02-02-02	EDD - Tug DnData/Up-Data/Docking/Sim	4,700	Equations	Number of Algorithms to be Designed	Control Logic to be Adapted from Operating System Supplied
XXX-15-02-02-02	EDD - IUS DnData/Up-Data/Simulation	5,000	Equations	Number of Algorithms to be Designed	
320-15-02-03-01	Program Ground Exec / Tracking/Planning	495,400	Words	Size of Modules	Complexity Ranges from 0 25 to 1
320-15-02-03-02	Program Tug Gnd DnData/ UpData/Docking/ Simulation	312,190	Words	Size of Modules	Complexity Ranges from 0 25 to 1
XXX-15-02-03-02	Program IUS Gnd DnData/ UpData/Sim	383,130	Words	Size of Modules	Complexity Ranges from 0 25 to 1
320-15-01-03-01	Tug Mission Specific EDD	150	Equations	Number of Algorithms to be Designed	Primarily Guidance Pre-Settings

Table 4 0 0-1 (Continued)

TECHNICAL CHARACTERISTICS DATA FORM B

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
320-15-01-03-02	Tug Mission Specific Program	150	Words	Size of Mission Specific Module	
320-15-01-03-03	Tug Mission Program Verification	200	Cases	Simulations of Flight Responses	200 Cases for Partial Verification (Changes Only)
XXX-15-01-03-01	IUS Mission Specific EDD	150	Equations	Number of Algorithms to be Designed	Primarily Guidance Presettings
XXX-15-01-03-02	IUS Mission Specific Program	150	Words	Size of Mission Specific Module	
XXX-15-01-03-03	IUS Mission Program Verification	200	Cases	Simulations of Flight Responses	200 Cases for Partial Verification (Changes Only)
320-15-02-04-01	Verify Exec/Track/ Planning Programs	1,000	Cases	Simulation of Real-Time Operations/ Diagnosis	Ground Control Computer System Proof-of-Performance
320-15-02-04-02	Verify Tug DnData/ UpData/Docking/Sim	1,000	Cases	Simulation of Real-Time Operations/ Diagnosis	Ground Control Computer System Proof-of-Performance
XXX-15-02-04-02	Verify IUS DnData/Up-Data/Simulation	1,000	Cases	Simulation of Real-Time Opoerations/ Diagnosis	Ground Control Computer System Proof-of-Performance

Table 4 0.0-1. (Continued)

TECHNICAL CHARACTERISTICS DATA FORM B

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
320-15-02-05-01	Program Tug Mission Simulation	45,960	Words	Special Training Simulation	Math Model of Vehicle, Control Center, Data Network, etc Simulated Malfunctions to Test Operator Response to Real-Time Contingencys
XXX-15-02-05-01	Program IUS Mission Simulation	48,650	Words	Special Training Simulation	

TOTAL PROGRAM FUNDING SCHEDULES 5

This section includes the DDT&E and recurring cost funding schedules by fiscal year

5 1 DDT&E FUNDING SCHEDULE

The man-hour loading of DDT&E tasks presented in Table 1 7 8-1 was spread in accordance with the IUS/TUG Systems Development Schedule presented in Volume IV (Figure B-3), then grouped by fiscal year and augmented with one-time hardware purchases to present the following funding schedules

5 2 IUS RECURRING COST FUNDING SCHEDULE

The IUS Recurring Costs are spread over the three-year operational period of the IUS (1982 - 1984) Cost has been proportionally distributed in accordance with the IUS Elements of the Recurring Cost WBS presented in Table 1 1 2-1

5 3 SPACE TUG RECURRING COST FUNDING SCHEDULE

The Space Tug Recurring Costs are spread over the operational lifetime of the vehicle Cost has been proportionally distributed in accordance with the Space Tug Elements of the Recurring Cost WBS presented in Table 1 1 2-1.

Table 5 1 0-1˜ Funding Schedule - Composite DDT&E

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
320	Space Tug Project	3	599,406	2,969,627	7,198,361	16,041,186
320-01	Project Management	4	29,440		102,120	8,280
320-01-01	Cost/Performance Management	5				
320-01-01-01	Cost Control System	6				
320-01-01-02	Schedule Control System	6				
320-01-02	Project Direction	5	29,440		102,120	8,280
320-01-02-01	Development Management	6	29,440		102,120	8,280
320-01-02-01-01	Contract Software Development	7	29,440			
320-01-02-01-02	Plan Facility Utilization	7			9,200	
320-01-02-01-03	Computer Utilization Plan	7			32,200	
320-01-02-01-04	Maintenance Schedule	7				8,280
320-01-02-01-05	Hire Control and Support Per	7			8,280	
320-01-02-01-06	Obtain Tug System Char	7			30,360	
320-01-02-01-07	Prepare Tug Interagency Docs	7				
320-01-02-01-08	Tug Interagency Coordination	7				
XXX-01-02-01-06	Obtain IUS System Char	7			22,080	
XXX-01-02-01-07	Prepare IUS Interagency Docs	7				
XXX-01-02-01-08	IUS Interagency Coordination	7				
320-01-02-03	Quality Management	6				
320-01-02-03	Logistic Management	6				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
320-01-02-04	Engineering Administration	6				
320-01-03	Information Management	5				
320-02	Systems Engineering	4		11,040	87,400	666,333
320-02-01	IUS/Tug Systems Engineering	5		11,040	60,720	161,920
320-02-01-01	Master Launch Schedule Analy	6		11,040	11,040	
320-02-01-02	Tug Mission Characterization	6			24,840	
320-02-01-03	Determine Tug Failure Modes	6				
XXX-02-01-02	IUS Mission Characterization	6			24,840	
XXX-02-01-03	Determine IUS Failure Modes	6				161,920
320-02-02	Shuttle Interface	5				
320-02-03	Payload Interface	5				
320-02-04	Sustaining Engineering	5			26,680	504,413
320-02-04-01	Flight Control Engineering	6			11,040	438,173
320-02-04-01-01	Mission Phase Manning Req	7			11,040	
320-02-04-01-02	Tug Console Position Guides	7				
320-02-04-01-03	Define Tug Opr Cert /Crit	7				
320-02-04-01-04	Common Gnd S/W Valid'n Test R	7				179,837
320-02-04-01-05	Tug Gnd Valid'n Test Req	7				
XXX-02-04-01-05	IUS Gnd Valid'n Test Req	7				125,856
XXX-02-04-01-02	IUS Console Position Guides	7				99,360

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
XXX-02-04-01-03	Define IUS Opr Cert /Crit	7				33,120
320-02-04-02	Flight Support Engineering	6			15,640	
320-02-04-02-01	Select Operational Data Sys.	7			15,640	
320-02-04-03	Mission Engineering	6				66,240
320-02-04-03-01	Tug Mission Planning & Opt'n	7				
320-02-04-03-02	Tug Abort Planning	7				
XXX-02-04-03-01	IUS Mission Planning & Opt'n	7				66,240
XXX-02-04-03-02	IUS Abort Planning	7				
320-02-04-05	Mission Evaluation Engineering	6				
320-02-04-05-01	Tug Post-Mission Reports	7				
XXX-02-04-05-01	IUS Post-Mission Reports	7				
320-03	Tug Vehicle Mainstage	4				
320-05	Logistics	4				
320-05-01	Transportation & Handling	5				
320-05-02	Training	5				
320-05-02-01	Simulators and Equipment	6				
320-05-02-02	Ground Crew Training	6				
320-05-02-03	Flight Operations Crew Trng	6				
320-05-02-03-01	Tug Trng Req/Crit/Schedule	7				
320-05-02-03-02	Develop Tug Trng Materials	7				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
320-05-02-03-03	Design Tug Mission Simul	7				
320-05-02-03-04	Tug Classroom Training	7				
320-05-02-03-05	Tug Mission Simulation	7				
XXX-05-02-03-01	IUS Trng Req/Crit/Schedule	7				
XXX-05-02-03-02	Develop IUS Trng Materials	7				
XXX-05-02-03-03	Design IUS Mission Simul	7				
XXX-05-02-03-04	IUS Classroom Training	7				
XXX-05-02-03-05	IUS Mission Simulation Trng	7				
320-06	Facilities	4			11,960	423,220
320-06-01	Manufacturing	5				
320-06-02	Test	5				
320-06-03	Maintenance and Refurbishment	5				
320-06-04	ETR Launch	5				
320-06-05	WTR Launch	5				
320-06-06	Flight Operations Facility	5			11,960	423,220
320-06-06-01	Size Facility/Design Phy Plant	6			11,960	
320-06-06-02	Construct Physical Plant	6				423,220
320-07	Ground Support Equipment	4				8,193,347
320-07-01	Manufacturing and Tests	5				
320-07-02	Eastern Test Range GSE	5				

Table 5 1 0 1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
320-07-03	Western Test Range GSE	5				
320-07-04	Flight Operations GSE	5				8,193,347
320-07-04-01	Install Operational Data Sys	6				7,030,547
320-07-04-02	Install Opn'l Consoles/Hdw	6				1,162,800
320-08	Vehicle Test	4				
320-09	Launch Operations	4				
320-10	Flight Operations	4			524,400	215,280
320-10-01	Mission Planning & Docking	5				215,280
320-10-01-01	Develop Tug Procedures & Rules	6				
XXX-10-01-01	Develop IUS Procedures & Rules	6				38,640
320-10-01-02	Tug Mission Failure Effects	6				
XXX-10-01-02	IUS Mission Failure Effects	6				176,640
320-10-01-03	Analyze Tug Component Ch	6				
XXX-10-01-03	Analyze IUS Component Ch	6				
320-10-01-04	Flt Control System Handbook	6				
320-10-01-04-01	Prepare Tug Systems Handbook	7				
320-10-01-04-02	Pub/Update Tug Sys Handbook	7				
XXX-10-01-04-01	Prepare IUS Systems Handbook	7				
XXX-10-01-04-02	Pub/Update IUS Sys Handbook	7				
320-10-01-05	Tug Network Interface Doc	6				

Table 5 1 0 1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
XXX-10-01-05-01	Define N/W Tracking Req	7				
XXX-10-01-05-02	Network Tracking Vali'd Proc.	7				
320-10-01-05-03	Tug N/W Data Handling Req	7				
320-10-01-05-04	Tug N/W Data Vali'd Proc.	7				
XXX-10-01-05-03	IUS N/W Data Handling Peq	7				
XXX-10-01-05-04	IUS N/W Data Vali'd Proc	7				
320-10-02	Operational Preparations	5			524,400	
320-10-02-01	Design Network Interface	6			44,160	
320-10-02-02	Console Organization	6			5,520	
320-10-02-03	Tug Display Format Design	6			237,360	
XXX-10-02-03	IUS Display Format Design	6			237,360	
320-10-03	Mission Readiness Testing	5				
XXX-10-03-01	N/W Tracking Validation Tests	6				
320-10-03-02	Tug N/W Validation Tests	6				
XXX-10-03-02	IUS N/W Validation Tests	6				
320-10-04	Conduct Tug Mission Opns	5				
XXX-10-04	Conduct IUS Mission Opns	5				
320-11	Refurbishment and Integration	4				
320-15	Software	4	569,966	2,958,587	6,472,481	6,534,726
320-15-01	Flight Software	5			213,728	1,517,392

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
320-15-01-01	Plan Flight Sim Development	6			44,298	
320-15-01-02	Baseline Flt Program Dev	6			169,430	1,517,392
320-15-01-02-01	EDD-Tug Flight Program	7				
320-15-01-02-02	Program Tug Flt Software	7				
320-15-01-02-03	Tug Flt Pgm Verification	7				
XXX-15-01-02-01	EDD-IUS Flight Program	7			169,430	169,430
XXX-15-01-02-02	Program Tug Flt Software	7				968,461
XXX-15-01-02-02	IUS Flt. Pgm Verification	7				379,501
320-15-01-03	Mission Spec Flt Pgm Mods	6				
320-15-01-03-01	Tug Msn Specific EDD	7				
320-15-01-03-02	Tug Msn. Specific Program	7				
320-15-01-03-03	Tug Msn. Pgm Verification	7				
XXX-15-01-03-01	IUS Msn Specific EDD	7				
XXX-15-01-03-02	IUS Msn Specific Program	7				
XXX-15-01-03-03	IUS Msn Pgm Verification	7				
320-15-02	Ground Software	5	569,966	2,958,587	6,214,593	5,017,334
320-15-02-01	Plan Ground S/W Development	6	27,600			
320-15-02-02	Equation Definition	6	542,366	2,958,586	805,406	
320-15-02-02-01	EDD-Exec/Tracking Planning	7	288,328	1,153,312	288,328	
320-15-02-02-02	EDD-Tug Dndata/Updata/Sim	7	254,038	1,016,157	254,038	

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1977	FY 1978	FY 1979	FY 1980
XXX-15-02-02-02	EDD - IUS DnData/UpData/Sim	7		789,118	263,040	
320-15-02-03	Programming	6			5,409,187	3,637,150
320-15-02-03-01	Pgm Ground Exec/Track/Plan	7			4,691,500	1,563,833
320-15-02-03-02	Pgm Tug DnData/UpData/Sim	7				
XXX-15-02-03-02	Pgm IUS DnData/Updata/Sim	7			717,687	2,073,317
320-15-02-04	Program Verification	6				1,380,184
320-15-02-04-01	Verify Exec/Track/Planning	7				1,007,032
320-15-02-04-02	Verify Tug DnData/UpData/Sim	7				
XXX-15-02-04-02	Verify IUS DnData/UpData/Sim	7				373,152
320-15-02-05	Mission Specific Simulation	6				
320-15-02-05-01	Program Tug Mission Sim	7				
XXX-15-02-05-01	Program IUS Mission Sim	7				
320-15-03	Computer Selection Support	5			44,160	
320-15-03-01	Estimate and SW Size	6			44,160	

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
320	Space Tug Project	3	3,115,074	4,977,728	4,724,683	1,291,887
320-01	Project Management	4	110,400			111,320
320-01-01	Cost/Performance Mgt	5				
320-01-01-01	Cost Control System	6				
320-01-01-02	Schedule Control System	6				
320-01-02	Project Direction	5	110,400			111,320
320-01-02-01	Development Management	6	110,400			111,320
320-01-02-01-01	Contract Software Dev	7				
320-01-02-01-02	Plan Facility Utilization	7				
320-01-02-01-03	Computer Utilization Plan	7				
320-01-02-01-04	Maintenance Schedule	7				
320-01-02-01-05	Hire Control and Support	7				
320-01-02-01-06	Obtain Tug System Char	7				
320-01-02-01-07	Prepare Tug Inter-Agy Docs	7				81,880
320-01-02-01-08	Tug Inter-Agency Coord	7				29,440
XXX-01-02-01-06	Obtain IUS System Char	7				
XXX-01-02-01-07	Prepare IUS Inter-Agy Docs	7	80,960			
XXX-01-02-01-08	IUS Inter-Agency Coord	7	29,440			
320-01-02-02	Quality Management	6				
320-01-02-03	Logistic Management	6				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
320-01-02-04	Engineering Administation	6				
320-01-03	Information Management	5				
320-02	Systems Engineering	4	268,640		552,207	235,520
320-02-01	IUS/Tug Systems Engineering	5			161,920	
320-02-01-01	Master Launch Schedule Analy	6				
320-02-01-02	Tug Mission Characterization	6				
320-02-01-03	Determine Tug Failure Modes	6				
XXX-02-01-02	IUS Mission Characterization	6				
XXX-02-01-03	Determine IUS Failure Modes	6			161,920	
320-02-02	Shuttle Interface	5				
320-02-03	Payload Interface	5				
320-02-04	Sustaining Engineering	5	268,640		390,287	235,520
320-02-04-01	Flight Control Engineering	6			290,927	
320-02-04-01-01	Mission Phase Manning Req	7				
320-02-04-01-02	Tug Console Position Guide	7			99,360	
320-02-04-01-03	Define Tug Opr Cert /Cont	7			33,120	
320-02-04-01-04	Common and S/W Valid'n Test	7				
320-02-04-01-05	Tug and Valid'n Test Req	7			158,447	
XXX-02-04-01-05	IUS and Valid'n Test Req	7				
XXX-02-04-01-02	IUS Console Position Guides	7				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX-02-04-01-03	Define IUS Opp Cert/Cert	7				
320-02-04-02	Flight Support Engineering	6				
320-02-04-02-01	Select Operational Data Sys	7				
320-02-04-03	Mission Engineering	6	33,120		99,360	
320-02-04-03-01	Tug Mission Planning Fort'n	7			66,240	
320-02-04-03-02	Tug Abort Planning	7			33,120	
XXX-02-04-03-01	IUS Mission Planning & Option	7				
XXX-02-04-03-02	IUS Abort Planning	7	33,120			
320-02-04-05	Mission Evaluation Engr	6	235,520			235,520
320-02-04-05-01	Tug Post-Mission Reports	7				235,520
XXX-02-04-05-01	IUS Post-Mission Reports	7	235,520			
320-03	Tug Vehicle Main Stage	4				
320-05	Logistics	4	590,640		92,000	506,000
320-05-01	Transfortation and Handling	5				
320-05-02	Training	5	590,640		92,000	506,000
320-05-02-01	Simulators and Equipment	6				
320-05-02-02	Ground Crew Training	6				
320-05-02-03	Flight Operations Crew Trng	6	590,640		92,000	506,000
320-05-02-03-01	Tug Trng Req/Crit/Schedule	7			36,800	
320-05-02-03-02	Develop Tug Trng Materials	7				90,160

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
320-05-02-03-03	Design Tug Mission Simulation	7			55,200	
320-05-02-03-04	Tug Classroom Training	7				161,920
320-05-02-03-05	Tug Mission Simulation Trng	7				253,920
XXX-05-02-03-01	IUS Trng Req/Crit/Schedule	7	29,440			
XXX-05-02-03-02	Develop IUS Trng Materials	7	90,160			
XXX-05-02-03-03	Design IUS Mission Simulation	7	55,200			
XXX-05-02-03-04	IUS Classroom Training	7	161,920			
XXX-05-02-03-05	IUS Mission Simulation Trng	7	253,920			
320-06	Facilities	4				
320-06-01	Manufacturing	5				
320-06-02	Test	5				
320-06-03	Maintenance and Refurbishmant	5				
320-06-04	ETR Launch	5				
320-06-05	WTR Launch	5				
320-06-06	Flight Operations Facility	5				
320-06-06-01	Size Facility/Design Phy Plant	6				
320-06-06-02	Construct Physical Plant	6				
320-07	Ground Support Equipment	4				
320-07-01	Manufacturing and Test	5				
320-07-02	Eastern Test Range GSE	5				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
320-07-03	Western Test Range GSE	5				
320-07-04	Flight Operations GSE	5				
320-07-04-01	Install Operational Data Sys	6				
320-07-04-02	Install Opn'l Consoles/Hdw	6				
320-08	Vehicle Test	4				
320-09	Launch Operations	4				
320-10	Flight Operations	4	555,220		511,520	166,060
320-10-01	Mission Planning & Doc'n	5	456,320		511,520	84,640
320-10-01-01	Develop Tug Procedures - Rules	6			154,560	
XXX-10-01-01	Develop IUS Procedures - Rules	6	115,920			
320-10-01-02	Tug Mission Failure Effects	6			176,640	
XXX-10-01-02	IUS Mission Failure Effects	6				
320-10-01-03	Analyze Tug Component Ch	6			126,960	
XXX-10-01-03	Analyze IUS Component Ch	6	126,960			
320-10-01-04	Flt Control Systems H'Book	6	58,880		25,760	33,120
320-10-01-04-01	Prepare Tug Systems H'Book	7			25,760	
320-10-01-04-02	Pub/Update Tug Syst H'Book	7				33,120
XXX-10-01-04-01	Prepare IUS Systems H'Book	7	25,760			
XXX-10-01-04-02	Pub/Update IUS Syst H'Book	7	33,120			
320-10-01-05	Tug Network Interface Doc	6	154,560		27,600	51,520

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX-10-01-05-01	Define N/W Tracking Req	7	23,920			
XXX-10-01-05-02	Network Tracking Val Proc	7	51,520			
320-10-01-05-03	Tug N/W Data Handling Req	7			27,600	
320-10-01-05-04	Tug N/W Data Val Proc	7				51,520
XXX-10-01-05-03	IUS N/W Data Handling Req	7	27,600			
XXX-10-01-05-04	TUS N/W Data Val Proc	7	51,520			
320-10-02	Operational Preparations	5				
320-10-02-01	Design Network Interface	6				
320-10-02-02	Console Organization	6				
320-10-02-03	Tug Display Format Design	6				
XXX-10-02-03	IUS Display Format Design	6				
320-10-03	Mission Readiness Testing	5	34,960			17,480
XXX-10-03-01	N/W Tracking Validation Tests	6	17,480			
320-10-03-02	Tug N/W Validation Tests	6				17,480
XXX-10-03-02	IUS N/W Validation Tests	6	17,480			
320-10-04	Conduct Tug Mission Opns	5				63,940
XXX-10-04	Conduct IUS Mission Opns	5	63,940			
320-11	Refurbishment and Integration	4				
320-15	Software	4	1,590,174	4,977,728	3,568,956	272,987
320-15-01	Flight Software	5	1,315,507	1,190,089	3,307,515	206,747

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
320-15-01-01	Plan Flight S/W Development	6				
320-15-01-02	Baseline Flt Program Develop	6	1,014,851	1,190,089	3,153,921	
320-15-01-02-01	EDD-Tug Flight Program	7	310,063	310,063		
320-15-01-02-02	Program Tug Flt Software	7		880,026	880,026	
320-15-01-02-03	Tug Flt Pgm Verification	7			2,273,895	
XXX-15-01-02-01	EDD-IUS Flight Program	7				
XXX-15-01-02-02	Program TUS Flt Software	7				
XXX-15-01-02-03	IUS Flt Prog Verification	7	704,788			
320-15-01-03	Mission Specific Prog Mods	6	300,656		153,594	206,747
320-15-01-03-01	Tug MSN Specific EDD	7			76,797	
320-15-01-03-02	Tug MSN Specific Program	7			76,797	76,797
320-15-01-03-03	Tug MSN Prog Verification	7				129,950
XXX-15-01-03-01	IUS MSN Specific EDD	7	64,055			
XXX-15-01-03-02	IUS MSN Specific Program	7	128,156			
XXX-15-01-03-03	IUS MSN Prog Verification	7	108,445			
320-15-02	Ground Software	5	274,667	3,787,639	261,441	66,240
320-15-02-01	Plan Ground S/W Develop	6				
320-15-02-02	Equation Definition	6				
320-15-02-02-01	EDD-Exec/Track/Planning	7				
320-15-02-02-02	EDD-Tug DnData/UpData/Sim	7				

Table 5 1 0-1 Funding Schedule - Composite DDT&E (Continued)

FUNDING SCHEDULE DATA FORM C

X NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX-15-02-02-02	EDD-IUS DnData/UpData/Sim	7				
320-15-02-03	Programming	6	208,427	3,439,051		
320-15-02-03-01	Pgm and Exec/Track/Plan	7				
320-15-02-03-02	Pgm Tug DnData/UpData/Sim	7	208,427	3,439,051		
XXX-15-02-03-02	Pgm IUS DnData/UpData/Sim	7				
320-15-02-04	Program Verification	6		348,588	261,441	
320-15-02-04-01	Verify Exec/Track/Planning	7				
320-15-02-04-02	Verify Tug DnData/UpData/Sim	7		348,588	261,441	
XXX-15-02-04-02	Verify IUS DnData/UpData/Sim	7				
320-15-02-05	Mission Specific Simulation	6	66,240			66,240
320-15-02-05-01	Program Tug Mission Sim	7				66,240
XXX-15-02-05-01	Program IUS Mission Sim	7	66,240			
320-15-03	Computer Selection Support	5				
320-15-03-01	Estimate Ground SW Size	6				

Table 5 2 0 1 Funding Schedule - IUS Recurring Cost

FUNDING SCHEDULE DATA FORM C

____ NON-RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
__X__ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX	IUS Project	3		5,272,912	5,272,912	5,272,912
XXX-01	Project Management	4		129,221	129,221	129,220
XXX-01-02	Project Direction	5		129,221	129,221	129,220
XXX-01-02-01	Development Management	6		129,221	129,221	129,220
XXX-01-02-01-07	Prepare Interagency Docs	7		22,210	22,210	22,210
XXX-01-02-01-08	Interagency Coordination	7		80,767	80,767	80,767
XXX-01-02-01-09	Network Rental	7		26,233	26,233	26,233
XXX-02	Systems Engineering	4		918,692	918,692	918,693
XXX-02-04	Sustaining Engineering	5		918,692	918,692	918,693
XXX-02-04-03	Mission Engineering	6		272,579	272,579	272,579
XXX-02-04-03-01	Mission Planning & Opt	7		181,719	181,719	181,720
XXX-02-04-03-03	Abort Planning	7		90,860	90,860	90,859
XXX-02-04-05	Mission Evaluation Eng	6		646,113	646,113	646,114
XXX-02-04-05-01	Post Mission Reports	7		646,113	646,113	646,114
XXX-05	Logistics	5		1,188,747	1,188,747	1,188,748
XXX-05-02	Training	5		1,188,747	1,188,747	1,188,748
XXX-05-02-03	Flight Opns Crew Trng	6		1,188,747	1,188,747	1,188,748
XXX-05-02-03-02	Trng Req/Crit/Schedule	7		8,076	8,076	8,076
XXX-05-02-03-02	Develop Tng Materials	7		24,734	24,734	24,734
XXX-05-02-03-03	Design Mission Sim	7		15,143	15,143	15,143

Table 5 2 0-1 Funding Schedule - IUS Recurring Cost (Continued)

FUNDING SCHEDULE DATA FORM C

____ NON–RECURRING (DDT&E)
____ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX-05-02-03-04	Classroom Training	7		444,203	444,203	444,203
XXX-05-02-03-05	Mission Sim Training	7		696,591	696,591	696,591
XXX-06	Facilities	4		19,872	19,872	19,872
XXX-06-06	Maintenance - Refurbishment	5		19,872	19,872	19,872
XXX-06-06-03	Facility Maintenance	6		19,872	19,872	19,872
XXX-07	Ground Support Equip	4		138,795	138,795	138,795
XXX-07-04	Flight Opns GSE	5		138,795	138,795	138,795
XXX-07-04-03	Data System Maintenance	6		138,795	138,795	138,795
XXX-10	Flight Operations	4		669,585	669,585	669,585
XXX-10-01	Mission Plan & Documentation	5		100,955	100,955	100,956
XXX-10-01-01	Develop Procedures & Rules	6		42,401	42,401	42,402
XXX-10-01-04	F/C System Handbook	6		16,153	16,153	16,153
XXX-10-01-04-01	Prepare Sys Handbook	7		7,067	7,067	7,067
XXX-10-01-04-02	Publish/Update Sys Handbook	7		9,086	9,086	9,086
XXX-10-01-05	Network Interface Doc	6		42,401	42,401	42,401
XXX-10-01-05-01	Define N/W Track	7		6,562	6,562	6,562
XXX-10-01-05-02	N/W Track Valid Proc	7		14,133	14,133	14,134
XXX-10-01-05-03	N/W Data Hand Req	7		7,571	7,571	7,572
XXX-10-01-05-04	N/W Data Valid Proc	7		14,135	14,135	14,133
XXX-10-03	Mission Readiness Tests	5		393,220	393,220	393,220

Table 5 2 6-1 Funding Schedule -
IUS Recurring Cost (Continued)

FUNDING SCHEDULE DATA FORM C

___ NON–RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
X RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1981	FY 1982	FY 1983	FY 1984
XXX-10-03-01	N/W Train Valid Test	6		47,954	47,954	47,953
XXX-10-03-02	N/W (Data) Valid Tests	6		345,266	345,266	345,267
XXX-10-04	Conduct Mission Operations	5		175,410	175,410	175,409
XXX-15	Software	4		2,208,000	2,208,000	2,208,000
XXX-15-01	Flight software	5		1,008,000	1,008,000	1,008,000
XXX-15-01-03	Mission Specific Pgm Mod	6		1,008,000	1,008,000	1,008,000
XXX-15-01-03-01	Mission Spec EDD	7		214,755	214,755	214,756
XXX-15-01-03-02	Mission Spec Program	7		429,664	429,664	429,663
XXX-15-01-03-03	Mission Prog Verification	7		363,581	363,581	363,581
XXX-15-02	Ground Software	5		1,200,000	1,200,000	1,200,000
XXX-15-02-05	Mission Spec Simulation	6		50,784	50,784	50,784
XXX-15-02-05-01	Program MSN Simulation	7		50,784	50,784	50,784
XXX-15-02-06	Ground Sim Maintenance	6		1,149,216	1,149,216	1,149,216

Table 5 3 0 1 Funding Schedule - Space Tug Recurring Costs

FUNDING SCHEDULE DATA FORM C

_____ NON–RECURRING (DDT&E)
_____ RECURRING (PRODUCTION)
__X__ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1984	FY 1985 & Subs	FY ___	FY ___
320	Space Tug Project	3	2,747,439	5,494,878		
320-01	Project Management	4	164,257	328,513		
320-01-02	Project Direction	5	164,257	328,513		
320-01-02-01	Development Management	6	164,257	328,513		
320-01-02-01-07	Prepare Intergency Data	7	13,344	26,689		
320-01-02-01-08	Interagency Coordination	7	48,534	97,069		
320-01-02-01-09	Network Rental	7	102,379	204,755		
320-02	Systems Engineering	4	552,079	1,104,158		
320-02-04	Sustaining Engineering	5	552,079	1,104,158		
320-02-04-03	Mission Engineering	6	163,803	327,607		
320-02-04-03-01	Mission Planning Optimization	7	109,202	218,405		
320-02-04-03-02	Abort Planning	7	54,601	109,202		
320-02-04-05	Mission Evaluation Eng	6	388,275	776,551		
320-02-04-05-01	Post Mission Reports	7	388,275	776,551		
320-05	Logistics	4	715,560	1,431,159		
320-05-02	Training	5	715,560	1,431,159		
320-05-02-03	Flight Opns Crew Trng	6	715,560	1,431,159		
320-05-02-03-01	Trng Req/Crit/Schedule	7	6,067	12,134		
320-05-02-03-02	Develop Tng Mat'l	7	14,863	29,727		
320-05-02-03-03	Design Mission Sim	7	9,100	18,200		

Table 5 3 0 1 Funding Schedule -

Space Tug Recurring Costs (Continued)

FUNDING SCHEDULE DATA FORM C

____ NON-RECURRING (DDT&E)

____ RECURRING (PRODUCTION)

__X__ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1984	FY 1985 & Subs	FY ____	FY ____
320-05-02-03-04	Classroom Training	7	266,940	533,879		
320-05-02-03-05	Mission Sim Training	7	418,610	837,219		
320-06	Facilities	4	9,836	19,672		
320-06-06	Maintenance & Refurbishment	5	9,836	19,672		
320-06-06-03	Facility Maintenance	6	9,836	19,672		
320-07	Ground Support Equipment	4	67,229	134,458		
320-07-04	Flight Operations GSE	5	67,229	134,458		
320-07-04-03	Data System Maintenance	6	67,229	134,458		
320-10	Flight Operations	4	182,459	364,918		
320-10-01	Mission Plan &-Documentation	5	48,231	96,462		
320-10-01-01	Develop Procedures & Rules	6	25,480	50,960		
320-10-01-04	F/C System Handbook	6	9,707	19,414		
320-10-01-04-01	Prepare Sys Handbook	7	4,247	8,494		
320-10-02-04-02	Pub/Update Sys Handbook	7	5,460	10,920		
320-10-01-05	Network Interface Doc	6	13,044	26,087		
320-10-01-05-03	N/W Data Hand Req	7	4,550	9,100		
320-10-01-05-04	N/W Data Valid Proc	7	8,494	16,987		
320-10-03	Mission Readiness Tests	5	28,818	57,635		
320-10-03-02	N/W (Data) Valid Tests	6	28,818	57,635		
320-10-04	Conduct Mission Operations	5	105,411	210,822		

Table 5 3 0 1 Funding Schedule - Space Tug Recurring Costs (Continued)

FUNDING SCHEDULE DATA FORM C

_____ NON–RECURRING (DDT&E)
_____ RECURRING (PRODUCTION)
__X__ RECURRING (OPERATIONS)

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	FY 1984	FY 1985 & Subs	FY	FY
320-15	Software	4	1,056,000	2,112,000		
320-15-01	Flight Software	5	504,000	1,008,000		
320-15-01-03	Mission Specific Pgm Mod	6	504,000	1,008,000		
320-15-01-03-01	Mission Spec EDD	7	107,414	214,828		
320-15-01-03-02	Mission Spec Program	7	214,828	429,656		
320-15-01-03-03	Mission Program Verification	7	181,758	363,516		
320-15-02	Ground Software	5	552,000	1,104,000		
320-15-02-05	Mission Spec Simulation	6	28,090	56,180		
320-15-02-05-01	Program MSN Simulation	7	28,090	56,180		
320-15-02-06	Ground S/W Maintenance	6	523,910	1,047,820		

WBS DICTIONARY 6

Table 6 0 0-1 presents the Index of Relevant WBS items which apply to the Orbital Operations and Mission Support efforts of the Composite Integrated IUS/Space Tug program

The WBS definitions are keyed to the structure presented in Table 6 0 0-1 This WBS dictionary only presents those WBS items which are costed in this report, and are relevant to Orbital Operations and Mission Support

Table 6 0 0-1 Composite Integrated Space Tug/IUS Work Breakdown Structure
WBS Identification Number Sequence

(INDEX OF WBS ITEMS RELEVANT TO OO/MS)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320	SPACE TUG PROJECT	3
320-01	Project Management	4
320-01-02	Project Direction	5
320-01-02-01	Development Management	6
320-01-02-01-01	Contract Software Development	7
320-01-02-01-02	Plan Facility Utilization	7
320-01-02-01-03	Computer Utilization Plan	7
320-01-02-01-04	Maintenance Schedule	7
320-01-02-01-05	Hire Control and Support Staff	7
320-01-02-01-06	Obtain Space Tug System Characteristics	7
320-01-02-01-07	Prepare Tug Interagency Documents	7
320-01-02-01-08	Tug Interagency Coordination	7
320-01-02-01-09	Tug Network Rental	7
XXX-01-02-01-06	Obtain IUS System Characteristics	7
XXX-01-02-01-07	Prepare IUS Interagency Documents	7
XXX-01-02-01-08	IUS Interagency Coordination	7
XXX-01-02-01-09	IUS Network Rental	7
320-02	Systems Engineering	4
320-02-01	IUS/Tug Systems Engineering	5
320-02-01-01	Master Launch Schedule Analysis	6
320-02-01-02	Tug Mission Characterization	6
320-02-01-03	Determine Tug Failure Modes	6
XXX-02-01-02	IUS Mission Characterization	6
XXX-02-01-03	Determine IUS Failure Modes	6
320-02-04	Sustaining Engineering	5
320-02-04-01	Flight Control Engineering	6
320-02-04-01-01	Mission Phase Manning Requirements	7
320-02-04-01-02	Tug Console Position Guidelines	7
320-02-04-01-03	Define Tug Operator Certification/Criteria	7
320-02-04-01-04	Common Ground Software Validation Test Requirements	7
320-02-04-01-05	Tug Ground Validation Test Requirements	7
XXX-02-04-01-05	IUS Ground Validation Test Requirements	7
XXX-02-04-01-02	IUS Console Position Guidelines	7
XXX-02-04-01-03	Define IUS Operator Certification/Criteria	7
320-02-04-02	Flight Support Engineering	6
320-02-04-02-01	Select Operational Data System	7
320-02-04-03	Mission Engineering	6
320-02-04-03-01	Tug Mission Planning and Optimization	7
320-02-04-03-02	Tug Abort Planning	7
XXX-02-04-03-01	IUS Mission Planning and Optimization	7
XXX-02-04-03-02	IUS Abort Planning	7

Table 6 0 0-1 (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-02-04-05	Mission Evaluation Engineering	6
320-02-04-05-01	Tug Post Mission Reports	7
XXX-02-04-05-01	IUS Post Mission Reports	7
320-05	Logistics	4
320-05-02	Training	5
320-05-02-03	Flight Operations Crew Training	6
320-05-02-03-01	Tug Training Requirement/Criteria/Simsked	7
320-05-02-03-02	Develop Tug Training Material	7
320-05-02-03-03	Design Tug Mission Simulation	7
320-05-02-03-04	Tug Classroom Training	7
320-05-02-03-05	Tug Mission Simulation Training	7
XXX-05-02-03-01	IUS Training Requirement/Criteria/Simsked	7
XXX-05-02-03-02	Develop IUS Training Material	7
XXX-05-02-03-03	Design IUS Mission Simulation	7
XXX-05-02-03-04	IUS Classroom Training	7
XXX-05-02-03-05	IUS Mission Simulation Training	7
320-06	Facilities	4
320-06-06	Flight Operations Facility	5
320-06-06-01	Size Facility/Design Physical Plant	6
320-06-06-02	Construct Physical Plant	6
320-06-06-03	Plant Maintenance	6
320-07	Ground Support Equipment (GSE)	4
320-07-04	Flight Operations GSE	5
320-07-04-01	Install Operational Data System	6
320-07-04-02	Install Operational Consoles/Hardware	6
320-07-04-03	Data System Maintenance	6
320-10	Flight Operations	4
320-10-01	Mission Planning and Documentation	5
320-10-01-01	Develop Tug Procedures and Rules	6
XXX-10-01-01	Develop IUS Procedures and Rules	6
320-10-01-02	Tug Mission Failure Effects	6
XXX-10-01-02	IUS Mission Failure Effects	6
320-10-01-03	Analyze Tug Component Characteristics	6
XXX-10-01-03	Analyze IUS Component Characteristics	6
320-10-01-04	Flight Control Systems Handbook	6
320-10-01-04-01	Prepare Tug Systems Handbook	7
320-10-01-04-02	Publish/Update Tug Systems Handbook	7
XXX-10-01-04-01	Prepare IUS Systems Handbook	7
XXX-10-01-04-02	Publish/Update IUS Systems Handbook	7
320-10-01-05	Network Interface Documentation	6
XXX-10-01-05-01	Define Network Tracking Requirements	7
XXX-10-01-05-02	Network Tracking Validation Procedures	7
320-10-01-05-03	Tug Network Data Handling Requirements	7
320-10-01-05-04	Tug Network Data Validation Procedures	7
XXX-10-01-05-03	IUS Network Data Handling Requirements	7
XXX-10-01-05-04	IUS Network Data Validation Procedures	7
320-10-02	Operational Preparations	5
320-10-02-01	Design Network Interface System	6

Table 6 0 0-1 (Continued)

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-10-02-02	Console Organization	6
320-10-02-03	Tug Display Format Design	6
XXX-10-02-03	IUS Display Format Design	6
320-10-03	Mission Readiness Testing	5
XXX-10-03-01	Network Tracking Validation Tests	6
320-10-03-02	Tug Network Validation Tests	6
XXX-10-03-02	IUS Network Validation Tests	6
320-10-04	Conduct Tug Mission Operations	5
XXX-10-04	Conduct IUS Mission Operations	5
320-15	Software	4
320-15-01	Flight Software	5
320-15-01-01	Plan Flight Software Development	6
320-15-01-02	Baseline Flight Program Development	6
320-15-01-02-01	EDD - Tug Flight Program	7
320-15-01-02-02	Program Tug Flight Software	7
320-15-01-02-03	Tug Flight Program Verification	7
XXX-15-01-02-01	EDD - IUS Flight Program	7
XXX-15-01-02-02	Program IUS Flight Software	7
XXX-15-01-02-03	IUS Flight Program Verification	7
320-15-01-03	Mission Specific Program Modification	6
320-15-01-03-01	Tug Mission Specific EDD	7
320-15-01-03-02	Tug Mission Specific Program	7
320-15-01-03-03	Tug Mission Program Verification	7
XXX-15-01-03-01	IUS Mission Specific EDD	7
XXX-15-01-03-02	IUS Mission Specific Program	7
XXX-15-01-03-03	IUS Mission Program Verification	7
320-15-02	Ground Software	5
320-15-02-01	Plan Ground Software Development	6
320-15-02-02	Equation Definition	6
320-15-02-02-01	EDD - Executive/Tracking/Planning	7
320-15-02-02-02	EDD - Tug DnData/UpData/Docking Sim	7
XXX-15-02-02-02	EDD - IUS DnData/UpData/Sim	7
320-15-02-03	Programming	6
320-15-02-03-01	Program Ground Ex/TK/Planning SW	7
320-15-02-03-02	Program Tug DnData/UpData/Docking/Sim	7
XXX-15-02-03-02	Program IUS DnData/UpData/Sim	7
320-15-02-04	Program Verification	6
320-15-02-04-01	Verify Executive/TK/Planning SW	7
320-15-02-04-02	Verify Tug DnData/UpData/Docking/Sim	7
XXX-15-02-04-02	Verify IUS DnData/UpData/Sim	7
320-15-02-05	Mission Specific Simulation	6
320-15-02-05-01	Program Tug Mission Simulation	7
XXX-15-02-05-01	Program IUS Mission Simulation	7
320-15-02-06	Ground Software Maintenance	6
320-15-03	Computer Selection Support	5
320-15-03-01	Estimate Ground Software Size	6

WBS DEFINITIONS

320 SPACE TUG PROJECT

This element summarizes the direct and indirect (G&A and burden) effort to provide hardware, software, services, and facilities that are required to develop, produce, operate, and maintain a Space Tug Project, including the associated Tug/Shuttle interfaces

320-01 PROJECT MANAGEMENT

This element summarizes the management activities of planning, organizing, directing, coordinating, controlling and approval actions required to accomplish overall Space Tug Project objectives which are not associated with specific hardware elements

320-01-02 PROJECT DIRECTION

This element pertains to the continuous monitoring of all functional management disciplines to provide central direction and control of the overall project Included are the decision making for management, timely resolution of problem areas to meet established schedules, and overall surveillance of project progress and goals

320-01-02-01 DEVELOPMENT MANAGEMENT

This element includes those tasks which require external contractual interfaces, interagency interfaces and inter-center interfaces to be accomplished It also includes direction of sensitive development tasks which require project level stature to insure proper execution

320-01-02-01-01 CONTRACT SOFTWARE DEVELOPMENT

This task includes all effort necessary to prepare a Statement of Work, evaluate proposals and provide financial, contracting and procurement support in order to place an outside contractor under contract for development of ground and flight software

320-01-02-01-02 PLAN FACILITY UTILIZATION

This task includes all efforts involved in establishing a coherent plan for the utilization of a Mission Control facility This will include such things as scheduling of activities, program sharing, office, canteen, technical support area and other generic requirements which impact facility design

320-01-02-01-03 COMPUTER UTILIZATION PLAN

This task includes all efforts required to develop and enforce a plan to maximize the utilization of the computational facility incorporated in the IUS/Tug ground control complex This will include a pre-emption hierarchy, mission planning schedule, mission operation schedule, batch processing schedule, etc

320-01-02-01-04 MAINTENANCE SCHEDULE

This task establishes the housekeeping and periodic maintenance requirements of the control center and associated equipments This task includes the contracting for, and administration of, specific external maintenance of the data system, plant environmental control mechanisms, and janitorial services Periodic and specific maintenance of the flight control and flight support console items will be conducted by the permanent party flight support staff

320-01-02-01-05 HIRE CONTROL AND SUPPORT STAFF

This task includes all efforts required to procure competent personnel to perform flight control tasks in the technical disciplines of propulsion, avionics, networks, communication, guidance, dynamics, data selection, television, and docking It also includes the efforts required to hire flight support personnel in the technical disciplines of facility supervisor, data systems, maintenance operations and software support

320-01-02-01-06 OBTAIN SPACE TUG SYSTEM CHARACTERISTICS

This task includes all efforts necessary to acquire, catalog, define and analyze the operational characteristics of the Space Tug system The output of this task is utilized in the development of flight controller display designs, network telemetry and updata interface systems design, and as primary input into the determination of operational failure modes

XXX-01-02-01-06 OBTAIN IUS SYSTEM CHARACTERISTICS

This task includes all efforts necessary to acquire, catalog, define and analyze the operational characteristics of the IUS system The output of this task is utilized in the development of flight controller display designs, network telemetry and updata interface system design, and as primary input into the determination of operational failure modes

320-01-02-01-07 PREPARE TUG INTERAGENCY DOCUMENTATION

This task includes all efforts required to prepare interagency and intercenter coordination documents, a ground support plan and documents which levy requirements on other government agencies or other NASA centers The output of this task is required for the interagency coordination task

320-01-02-01-08 SPACE TUG INTERAGENCY COORDINATION

This task includes all efforts required to establish mutual agreements with DoD and NASA centers supporting Space Tug mission operations This includes the coordination of program support requirements and ground support planning

XXX-01-02-01-08 IUS INTERAGENCY COORDINATION

This task includes all efforts required to establish mutual agreements with DoD and NASA centers supporting the IUS mission operations This includes the coordination of program support requirement and ground support planning

320-01-02-01-09 SPACE TUG NETWORK RENTAL

This element includes the cost of purchasing network services (Telemetry Data, Command Data, Television Image) from the data support network

XXX-01-02-01-09 IUS NETWORK RENTAL

This element includes the cost of purchasing network servcies (Telemetry Data, Command Data, Tracking Data) from the data support network

320-02 SYSTEMS ENGINEERING

This element summarizes the Space Tug systems engineering task of directing and controlling a totally integrated engineering effort, including requirements analysis and integration, system definition, system test definition, interfaces, safety, reliability, maintainability, configuration management, quality engineering, technology utilization and logistics support analysis

320-02-01 IUS/TUG SYSTEMS ENGINEERING

This element consists of the systems engineering and integration effort to design, develop, produce and test the Space Tug and associated Tug/Shuttle interfaces Included are analyses required to verify compatibility of designs with requirements, to meet mission model requirements, to control and direct the engineering activities, to assure proper Space Tug systems integration with both the Shuttle and spacecraft, and to make cost/performance tradeoffs Also included are engineering planning, studies, technology utilization, technical risk assessment, reliability engineering, safety engineering, quality control, configuration requirements analysis, and associated support required to perform the Tug systems engineering task Logistics planning and management are also included

320-02-01-01 MASTER LAUNCH SCHEDULE ANALYSIS

The master Launch Schedule will be analyzed to determine the type, spacing, and frequency of both IUS and Space Tug flight This task will establish the range of mission types, trajectories, payload accommodations and control facility utilization requirements across the IUS/Space Tug operational period This task is a predecessor to the establishment of Tug mission characteristics, IUS mission characteristics and control facility utilization planning

320-02-01-02 TUG MISSION CHARACTERIZATION

This task accepts the output of the master launch schedule analysis task and operates on that output in order to determine the specific characteristics of all defined Space Tug missions The output of this task is utilized in the determination of mission phase manning requirements, definition of Space Tug operator certification (and criteria for certification), a computer utilization plan for the Space Tug portion of the Shuttle era and the associated maintenance schedule

XXX-02-01-02 IUS MISSION CHARACTERIZATION

This task accepts the output of the master launch schedule analysis tasks and operates on that output in order to determine the specific characteristics of all defined IUS missions The output of this task is utilized in the determination of mission phase manning requirements, definition of IUS operator certification (and criteria for certification), a computer utilization plan for the IUS portion of the Shuttle era and the associated maintenance schedule

320-02-01-03 DETERMINE TUG FAILURE MODES

After the Space Tug system characteristics have been obtained, categorized and defined, the systems will be analyzed for high probability failure modes The output of this task will be a list of potential failures, which can impact the operational performance of the vehicle Failures of a cosmetic nature will not be considered The output of this task is a list of high probability failure modes which will then be analyzed for the overall mission effect of that failure

XXX-02-01-03 DETERMINE IUS FAILURE MODES

After the IUS system characteristics have been obtained, categorized and defined, the systems will be analyzed for high-probability failure modes The output of this task will be a list of potential failures which can impact the operational performance of the vehicle Failures of a cosmetic nature will not be considered The output of this task is a list of high probability failure modes which will then be analyzed for the overall mission effort of that failure

320-02-04 SUSTAINING ENGINEERING

This element consists of sustaining engineering effort required for the Space Tug and associated Tug/Shuttle interfaces after the completed, assembled Tug and interface subsystems have been checked out for full flight certification and delivered A principal effort includes normal product improvement and engineering changes that may occur as a result of user recommendations and/or operational experience Also included are in-plant engineering liaison support of operational activities and the sustaining engineering support required during the operations phase Activities would include further allocation of performance requirements for the vehicle into subsystem requirements, evaluation of vehicle and GSE performance, maintainability analysis, etc Excluded are those activities that pertain to major hardware modification required to meet new performance specifications

320-02-04-01 FLIGHT CONTROL ENGINEERING

This task includes all efforts required to provide real-time assessment of systems status, formulation and issuance of command actions, pre-mission preparation, training and operator certification

320-02-04-01-01 MISSION PHASE MANNING REQUIREMENTS

This task includes all efforts required to establish the types and quantity of personnel required to support both IUS and Space Tug flight control and flight support activities It will include an analysis of the mission density, the overlap between adjacent modules in the mission structure and will establish the control and support personnel necessary to accomplish the IUS and Space Tug missions with a minimum loss of productive man hours This task will also include the plan for cross-training mission support personnel as the IUS phases into the Space Tug era

320-02-04-01-02 TUG CONSOLE POSITION GUIDELINES

This task includes all activities required to establish generic position responsibilities as a function of console and technical discipline This activity is based upon the mission phase manning requirements The output is utilized as one input to the mission simulation design and to the Space Tug requirements criteria, simulation and schedule tasks The output of this task establishes the organizational reporting tree and authority for both technical and hierarchial relationships

XXX-02-04-01-02 IUS CONSOLE POSITION GUIDELINES

This task includes all activities required to establish generic position responsibilities as a function of console and technical discipline This activity is based upon the mission phase manning requirements The output is utilized as one input to the mission simulation design and to the IUS requirements criteria, simulation and schedule tasks The output of this task establishes the organizational reporting tree authority for both technical and hierarchial relationships.

320-02-04-01-03 DEFINE SPACE TUG OPERATOR CERTIFICATION/CRITERIA

This task includes all efforts required to analyze the functions of the consoles and to establish appraisal criteria by which the operator's performance may be evaluated As with all real time operations, console operators must demonstrate the ability to perform well under stress This task analyzes the stress situations which the operator will face and establishes the criteria by which the operator's performance and technical adequacy are to be judged

XXX-02-04-01-03 DEFINE IUS OPERATOR CERTIFICATION/CRITERIA

This task includes all efforts required to analyze the functions of the consoles and to establish appraisal criteria by which the operator's performance may be evaluated As with all real time operations, console operators must demonstrate the ability to perform well under stress This task analyzes the stress situations which the operator will face and establishes the criteria by which the operator's performance and technical adequacy are to be judged

320-02-04-01-04 COMMON GROUND VALIDATION TEST REQUIREMENTS

This task includes the establishment of proof-of-performance parameters for the software which is common to both the IUS ground operations and the Space Tug operations This task establishes the vital criteria against which the program performance is to be evaluated, and should be conducted independently of the Equation Definition generation

320-02-04-01-05 TUG GROUND VALIDATION TEST REQUIREMENTS

This task includes all efforts required to establish the criteria for acceptance or rejection of Space Tug peculiar ground software This task is performed independently of the programming effort and is specifically to establish proof-of-performance standards against which the program will be judged

XXX-02-01-05 IUS GROUND VALIDATION TEST REQUIREMENTS

This task includes all efforts required to establish the criteria for acceptance or rejection of IUS-peculiar ground software This task is performed independently of the programming effort and is specifically to establish proof-of-performance standards against which the program will be judged

320-02-04-02 FLIGHT SUPPORT ENGINEERING

This task includes all efforts required to provide real-time support to Flight Control personnel, maintain operational hardware in operable condition, provide network interface and alternate support capability.

320-02-04-02-01 SELECT OPERATIONAL DATA SYSTEM

This task includes all efforts required to establish the integrated requirements of an operational data system and takes into account the ground software size estimate, the computer utilization plan, and growth factors This task also includes all procurement and purchase operations necessary in the buy of an operational data system, and the engineering of the data system configuration

320-02-04-03 MISSION ENGINEERING

This task includes all efforts to plan and optimize the Space Tug or IUS trajectory under nominal mission and abort conditions

320-02-04-03-01 TUG MISSION PLANNING AND OPTIMIZATION

This task is iterative and includes the basic design of trajectory, timing of burns, and error propagation analysis leading to the design of the mission flight plan This task will be performed on the operational computer utilizing software specially developed for the purpose The output of this task, and the output from the associated Space Tug abort planning task are utilized to establish the mission specific deviations from the Space Tug flight program baseline, and to provide an input to the mission specific simulation development

XXX-02-04-03-01 IUS MISSION PLANNING AND OPTIMIZATION

This task includes the basic design of trajectory, timing of burns, and error propagation analysis leading to the design of the mission flight plan This task will be performed on the operational computer utilizing software specially developed for the purpose The output of this task, and the output from the associated IUS abort planning task are utilized to establish the mission specific deviations from the IUS flight program baseline, and to provide an input to the mission specific simulation development

320-02-04-03-02 TUG ABORT PLANNING

After the basic mission planning and optimization has been completed, certain off-nominal malfunction, abort and contingency conditions must be investigated and contingency operational procedures developed to handle those situations This task utilizes special software programmed into the operational computer system and is iterated for each mission The output of this task includes alternative mission definitions, abort profiles, and degraded mission plans This task is conducted roughly in parallel with the development of Tug procedures and mission rules in order that cross feed between the abort planning and contingency operational planning may take place

XXX-20-04-03-02 IUS ABORT PLANNING

After the basic mission planning and optimization has been completed, certain off-nominal malfunction, abort and contingency conditions must be investigated and contingency operational procedures developed to handle those situations This task utilizes special software programmed into the operational computer system and is iterated for each mission The output of this task includes alternative mission definitions, abort profiles, and degraded mission plans This task is conducted roughly in parallel with the development of IUS procedures and mission rules in order that cross-feed between the abort planning and contingency operational planning may take place

320-02-04-05 MISSION EVALUATION ENGINEERING

This task includes all efforts required to evaluate vehicle performance-to-design analysis, and to provide comprehensive feed-back into the design modification and maintenance programs of the vehicles

320-02-04-05-01 SPACE TUG POST MISSION REPORTS

This task includes all efforts required to generate three post mission reports an evaluation and critique report prepared by the flight controllers which define the performance of the vehicle as viewed from the position of a real time console operator, a maintenance interface report prepared by the flight control personnel which summarizes the observations made in real time which imply maintenance requirements against the flight stage, (this report is forwarded to the launch center for incorporation in the Specific Vehicle Maintenance Plan), a maintenance and operations interface report which evaluates the performance of the data gathering and tracking network during the mission

XXX-02-04-05-01 IUS POST MISSION REPORTS

This task includes all efforts required to generate two post mission reports an evaluation and critique report is prepared by the flight controllers which define the performance of the vehicle as viewed from the positions of a real time console operator and a maintenance and operations interface report which evaluates the performance of the data gathering and tracking network during the mission

320-05 LOGISTICS

This element provides the effort to implement, operate, and maintain a logistics management for support of the Tug and Tug/Shuttle interfaces and related ground support equipment, including transportation, handling, factory warehousing, and inventories, systems orientation, and familiarization, training of ground and flight crew personnel and the design, development and manufacture of those distinctive end-items required specifically to meet the training objectives Included are operational maintenance trainers, cutaways, models and any facilities constructed or modified for training purposes

320-05-02 TRAINING

This element consists of training services, training materials, training aids and training equipment required for Tug factory, technical, flight and ground crew training It includes instructor and student services, and the development and maintenance of lesson plans, study guides, training manuals, and training aids for classroom and trainer instruction in preparation for and during the Tug test and operations program phases

320-05-02-03 FLIGHT OPERATIONS CREW TRAINING

This element includes the cost of instruction, audio-visual teaching aids and accessories required to train the personnel to operate the Tug and equipment required to support flight operations at a flight operations center

320-05-02-03-01 TUG TRAINING REQUIREMENTS, EVALUATION CRITERIA AND SIMULATION SCHEDULE

This task accepts as inputs the Space Tug console position guidelines, operator certification criteria, procedures and mission rules and from that information creates a requirement for training criteria against which successful training is judged, a definition of kind and content of simulations and a schedule for classroom, and simulation training for a particular mission This task is a recurring task

XXX-05-02-03-01 IUS TRAINING REQUIREMENTS, EVALUATION CRITERIA AND SIMULATION SCHEDULE

This task accepts as input the IUS console position guidelines, operator certification criteria, procedures and mission rules and from that information creates a requirement for training criteria against which successful training is judged, definition of kind and content of simulations and a schedule for classroom, and simulation training for a particular mission This task is a recurring task.

320-05-02-03-02 DEVELOP SPACE TUG TRAINING MATERIAL

This task includes the development and preparation of all materials required for classroom training of flight controllers and flight support personnel This includes text books, handouts, view graphs, reference material, etc

XXX-05-02-03-02 DEVELOP IUS TRAINING MATERIAL

This task includes the development and preparation of all materials required for classroom training of flight controllers and flight support personnel This includes text books, handouts, view graphs, reference material, etc

320-05-02-03-03 DESIGN TUG MISSION SIMULATION

This task includes all efforts required to integrate the results of the Space Tug procedures and rules, the optimum and abort mission timelines, and operator training criteria into a Tug mission specific simulation design This task will be accomplished both in the DDT&E phase and in the recurring phase of the Space Tug program A specific simulation design will be formulated for each mission The flight controller and flight support personnel will be trained against the mission specific simulation in preparation for their operational roles. the output of this task is a set of malfunctions, predicted responses and operator performance evaluation criteria

XXX-05-02-03-03 DESIGN IUS MISSION SIMULATION

This task includes all efforts required to integrate the results of the IUS procedures and rules, the optimum and abort mission timelines, and operator training criteria into an IUS mission specific simulation design This task will be accomplished both in the DDT&E phase and in the recurring phase of the IUS program A specific simulation design will be formulated for each mission The flight control and flight support personnel will be trained against the mission specific simulation in preparation for their operational roles The output of this task is a set of malfunctions, predicted responses and operator performance evaluation criteria

320-05-02-03-04 SPACE TUG CLASSROOM TRAINING

This task includes the instructor's time, student's time, and the facilities required for conducting classroom training in the characteristics of a Space Tug vehicle, the mission, and support networks. Training will be conducted by flight control and flight support personnel in addition to their normal operational tasks

XXX-05-02-03-04 IUS CLASSROOM TRAINING

This task includes the instructor's time, student's time, and the facilities required for conducting classroom training in the characteristics of an IUS vehicle, the mission, and support networks Training will be conducted by flight control and flight support personnel in addition to their normal operational tasks

320-05-02-03-05 TUG MISSION SIMULATION TRAINING

This task includes the simulation of the specific Space Tug mission for nominal and contingency performance cases wherein the flight support personnel conduct the simulation and the flight control personnel are judged on their ability to respond to contingency situations and to recognize nominal vehicle performance This task is iterative and must be repeated prior to each flight

XXX-05-02-03-05 IUS MISSION SIMULATION TRAINING

This task includes the simulation of the specific IUS mission for nominal and contingency performance cases wherein the flight support personnel conduct the simulation and the flight control personnel are judged on their ability to respond to contingency situations and to recognize nominal vehicle performance This task is iterative and must be repeated prior to each flight

320-06 FACILITIES

This element covers facilities (new or modification to existing) for manufacture, test, maintenance, refurbishment, and support of an operational program Note that the basic launch and operations facilities are charged to the Shuttle However, those facilities built specifically for Tug and Tug/Shuttle interfaces are included here This effort includes facilities planning, acquisition or modification, and maintenance Amortization of adequate existing facilities will not be included

320-06-06 FLIGHT OPERATIONS FACILITY

This element covers development of a new facility for flight control support of the IUS and Space Tug programs. This effort includes facility planning, acquisition, modification and maintenance

320-06-06-01 SIZE FACILITY/DESIGN PHYSICAL PLANT

Prior to beginning this task, the operational data system will have been selected, the network interface design will have been completed and equipment selected, and the console equipment designed and ordered This task includes the architectural design of the facility

320-06-06-02 CONSTRUCT PHYSICAL PLANT

This task includes the effort involved by a building contractor to perform site preparation, construction of a physical plant, environmental control and electrical installations on the structure

320-06-06-03 PLANT MAINTENANCE

This task includes all contracted services for the maintenance of the facility interior and exterior, including refuse, janitorial services, structural, electrical, mechanical and paint maintenance Also included are utility costs

320-07 GROUND SUPPORT EQUIPMENT (GSE)

This element includes all GSE required for the Tug and Tug/Shuttle interface subsystems test and operations Included are all ground-based equipment required to support the ground test program and launch, recovery and maintenance phases during flight test operations and flight operations The GSE element includes design, fabrication, documentation, and qualification of Tug and Tug/Shuttle interface peculiar test and operational GSE GSE items included are hardware, site activiation, and maintenance peculiar to interface ground operations for manufacturing and launch

320-07-04 FLIGHT OPERATIONS GSE

This element includes all ground-based equipment required to support flight control of the Space Tug during both flight tests and operations This element also includes design, modification, fabrication, integration, documentation, and qualification of the site Items included are hardware, site activiation, and maintenance

320-07-04-01 INSTALL OPERATIONAL DATA SYSTEM

This task includes all efforts by the data system contractor to install, diagnose and checkout the completed data system installation At the end of this task, the data processing system will be on-line and operational, ready to support future data processing activities

320-07-04-02 INSTALL OPERATIONAL CONSOLES

This task includes the installation of the console hardware and associated interface equipments This task presumes that the consoles will be delivered to the finished physical plant by a vendor and then will be installed by flight support technicians

320-07-04-03 DATA SYSTEM MAINTENANCE

This task includes contracted services for the maintenance, diagnosis and repair of the operational data system and associated peripheral equipment This service is contracted on an annual basis

320-10 FLIGHT OPERATIONS

This element includes flight operations tasks and services directly related to the post-launch real-time operational control of the Space Tug and IUS vehicles These activities include mission planning and Documentation, Operational preparations, Flight Readiness Testing and Real-Time Flight Control

320-10-01 MISSION PLANNING AND DOCUMENTATION

This task includes efforts to develop and document mission rules and flight control procedures, analyze mission effects of system malfunction, analyse vehicle component characteristics, preparation and update of reference documents, documentation of requirements on and procedures for testing support network interface

320-10-01-01 DEVELOP TUG PROCEDURES AND RULES

The specific rules and procedures utilized during the mission will consist of a fundamental set of procedures and rules which are applicable across all Tug missions, and a mission specific set of rules and procedures The output of this task is a document containing all predefined mission decisions, a document containing basic step-by-step implementation procedures, a set of predefined contingency procedures and a vehicle command listing

XXX-10-01-01 DEVELOP IUS PROCEDURES AND RULES

The specific rules and procedures utilized during the mission will consist of a fundamental set of procedures and rules which are applicable across all IUS missions, and a mission specific set of rules and procedures The output of this task is a document containing all predefined mission decisions, a document containing basic step-by-step implementation procecures, a set of predefined contingency procedures and a vehicle command listing

XXX-10-01-02 IUS MISSION FAILURE EFFECTS ANALYSIS

Once the IUS failure modes have been identified and categorized, the occurrence of these failures at various points in the flight must be evaluated for overall mission effect The output of this task will be a series of scenarios against which pre-thought decisions may be constructed

320-10-01-02 TUG MISSION FAILURE EFFECTS ANALYSIS

Once the Space Tug failure modes have been identified and categorized, the occurrence of these failures at various points in the flight must be evaluated for overall mission effect The output of this task will be a series of scenarios against which pre-thought decisions may be constructed

320-10-01-03 ANALYZE TUG COMPONENT CHARACTERISTICS

This task includes all efforts required to assemble basic operational information describing the characteristics of the operationally significant components of the Tug vehicle The output of this task is a compendium of nominal operational performance, characteristic performance curves, expectations of behavior, etc This output will be utilized in the preparation of training material and a reference handbook.

XXX-10-01-03 ANALYZE IUS COMPONENT CHARACTERISTICS

This task includes all efforts required to assemble basic operational information describing the characteristics of the operationally significant components of the IUS vehicles The output of this task is a compendium of nominal operational performance, characteristic performance curves, expectations of behavior, etc This output will be utilized in the preparation of training material and a reference handbook

320-10-01-04 FLIGHT CONTROL SYSTEMS HANDBOOK

This task includes the acquisition, assembly and preparation of Space Tug or IUS vehicle systems data in a form which is readily accessible to real-time operational personnel This includes schematic diagrams, performance characteristics, component characteristics and inherent constraints and limitations on vehicle operations.

320-10-01-04-01 PREPARE TUG SYSTEM HANDBOOK

This task includes all efforts required to generate simplified schematic diagrams, simplified interface connections, a summary of component characteristics, prediction of mission events and performance curves, and inherent Space Tug constraints and limitations

XXX-10-01-04-01 PREPARE IUS SYSTEM HANDBOOK

This task includes all efforts required to generate simplified schematic diagrams, simplified interface connections, a summary of component characteristics, prediction of mission events and performance curves, and inherent IUS constraints and limitations.

320-10-01-04-02 PUBLISH AND UPDATE SPACE TUG SYSTEM HANDBOOK

The basic publication of a Space Tug system handbook will incorporate the information prepared for that purpose under one cover The updating of a system handbook will be on a by-mission, and as required, basis, and thus, is an iterative task Major updates and changes to the Space Tug baseline design must be incorporated into the systems handbook prior to the utilization of that vehicle for a mission

XXX-10-01-04-02 PUBLISH AND UPDATE IUS SYSTEM HANDBOOK

The basic publication of a Space Tug system handbook will incorporate the information prepared for that purpose under one cover The updating of a system handbook will be on a by-mission, and as required, basis, and thus, is an iterative task. Major updates and changes to the IUS baseline design must be incorporated into the systems handbook prior to the utilization of that vehicle for a mission

320-10-01-05 NETWORK INTERFACE DOCUMENTATION

This element includes efforts required to establish performance requirements on the data network feeding the Flight Operations control center, and to generate proof-of-performance test procedures for the network

XXX-10-01-05-01 DEFINE GROUND NETWORK TRACKING REQUIREMENTS

This task includes those systems analyses, mission engineering, flight control and flight support efforts required to develop a checkout procedure which will exercise the tracking capabilities of the support network from the flight control and flight support consoles in the Mission Control Center The output of this task will be a procedural checklist which will be followed in the actual testing of the network proof-of-performance

XXX-10-01-05-02 NETWORK TRACKING VALIDATION PROCEDURES

This task includes those systems analyses, mission engineering, flight control and flight support efforts required to develop a checkout procedure which will exercise the tracking capabilities of the support network from the flight control and flight support consoles in the Mission Control Center The output of this task will be a procedural checklist which will be followed in the actual testing of the network proof-of-performance

320-10-01-05-03 SPACE TUG NETWORK DATA HANDLING REQUIREMENTS

This task includes all efforts required to produce a document levying specific data handling, processing, and special requirements on the supporting network This includes both updata and downdata processing

XXX-10-01-05-03 IUS NETWORK DATA HANDLING REQUIREMENTS

This task includes all efforts required to produce a document levying specific data handling, processing, and special requirements on the supporting network This includes both updata and downdata processing

320-10-01-05-04 TUG NETWORK DATA VALIDATION PROCEDURES

This task includes all efforts required to establish proof-of-performance criteria for the acceptance test of Tug-peculiar ground software

XXX-10-01-05-04 IUS NETWORK DATA VALIDATION PROCEDURES

This task includes all efforts required to establish proof-of-performance criteria for the acceptance test of IUS-peculiar ground software

320-10-02 OPERATIONAL PREPARATIONS

This element includes efforts to establish the interface with the data acquisition network; to design the basic layout of flight control consoles and flight support consoles, and to establish the display format, engineering units and special processing requirements for data display to flight control and flight support personnel

320-10-02-01 DESIGN NETWORK INTERFACE

This task includes the engineering effort necessary to establish the interface with the data acquisition network It specifically includes telemetry decommutation and special processing, command processing, television, and tracking format and processing requirements. The output of this task will be the operational requirements for a network interface system design which will include suggested hardware items

320-10-02-02 CONSOLE ORGANIZATION

This task includes all efforts necessary to establish the requirements for location of console display and control devices to the satisfaction of the console operating personnel

320-10-02-03 <u>TUG DISPLAY FORMAT DESIGN</u>

This task includes all efforts required to establish the organizational, display format and engineering units for flight control and flight support personnel digital TV presentation This task also includes all efforts directed toward the definition of the special processing requirements, remote site and control center logical operations, limit sensing, event light triggering, etc

XXX-10-02-03 <u>IUS DISPLAY FORMAT DESIGN</u>

This task includes all efforts required to establish the organization, display format and engineering units for flight control and flight support personnel digital TV presentation. This task also includes all efforts directed toward the definition of the special processing requirements, remote site and control center logical operations, limit sensing, event light triggering, etc

320-10-03 <u>MISSION READINESS TESTING</u>

This element includes all efforts required to set-up and conduct pre-mission proof-of-performance tests on the flow of data into the control center from the ground site(s) of the data acquisition network

XXX-10-03-01 <u>NETWORK TRACKING VALIDATION TESTS</u>

This task includes all efforts required to set up and conduct specific pre-mission tests of the tracking capabilities and tracking accuracies of the support network This will involve the generation of tapes to simulate over-flying vehicles and ground receiving tracking stations, the distribution and execution of procedures previously prepared and the evaluation of test results

320-10-03-02 <u>SPACE TUG NETWORK VALIDATION TESTS</u>

This task includes all efforts required to conduct tests of the network handling of Space Tug peculiar software, including the providing of vehicle simulation tapes to remote sites of the ground data acquisition network, providing the procedures to remote operations, and providing personnel to conduct these tests

XXX-10-03-02 <u>IUS NETWORK VALIDATION TESTS</u>

This task includes all efforts required to conduct tests of the network handling of IUS-peculiar software, including the providing of vehicle simulation tapes to remote sites of the ground data acquisition network, providing the procedures to remote operators, and providing personnel to conduct these tests

320-10-04 <u>CONDUCT SPACE TUG MISSION OPERATIONS</u>

This task includes all efforts necessary to provide control and support to the Space Tug vehicle in prelaunch, orbital operations, placement, retrieval and landing phases This task requires the total attention of the flight control team, the flight support team, and other personnel This task is the culmination of all prior efforts

XXX-10-04 CONDUCT IUS MISSION OPERATIONS

This task includes all efforts necessary to provide control and support to the IUS vehicle in prelaunch, orbital operations and placement mission phases This task requires the total attention of the flight control team, the flight support team, and other personnel This task is the culmination of all prior efforts

320-15 SOFTWARE

This element summarizes all tasks and services required to analyze, develop, verify and implement Tug and IUS software It includes design, processing and implementation of software (computer languages, computer programs, program verification, debugging, etc) for ground and airborne subsystems

320-15-01 FLIGHT SOFTWARE

This element consists of task and services required to analyze, design, develop, simulate, verify and maintain software for use onboard the IUS or Tug to support IUS and Tug requirements

320-15-01-01 PLAN FLIGHT SOFTWARE DEVELOPMENT

This task includes all efforts required to establish a schedule for development of the flight software, establish design concept validation procedures, establish the necessity for, and required characteristics of, hybrid and interpretive simulators, establishing a plan for the integration of the IUS and Space Tug flight software development to minimize cost, and establishing controls and feedback to insure customer requirements on the IUS and Space Tug flight software are fulfilled

320-15-01-02 BASELINE FLIGHT PROGRAM DEVELOPMENT

This element includes the creation of an Equation Defining Document (EDD), programming and verification of four basic flight programs for the IUS and four basic flight programs for the Space Tug

320-15-01-02-01 EQUATION DEFINING DOCUMENT - SPACE TUG FLIGHT PROGRAM

This task includes basic conceptual work on the requirements for flight software, customer support and flight software definition, definitions of equations pertaining to vehicle dynamics, design of algorithm techniques and the associated simulation equipments, the generation of a program requirements document known as the Equation Defining Document (EDD), control of requirements, performance of software implementation studies, analysis of sample calculations, definition of flight control functional interfaces, definition of hardware interfaces, and miscellaneous preliminary analysis

XXX-15-01-02-01 EQUATION DEFINING DOCUMENT - IUS FLIGHT PROGRAM

This task includes basic conceptual work on the requirements for flight software, customer support and flight software definition, definitions of equations pertaining to vehicle dynamics, a design of algorithm techniques and the associated simulation equipments, the generation of a program requirements document known as the Equation Defining Document (EDD), control of requirements, performance of software implementation studies, analysis of sample calculations, definition of flight control functional interfaces, definition of hardware interfaces, and miscellaneous preliminary analysis.

320-15-01-02-02 PROGRAM TUG FLIGHT SOFTWARE

This task includes all efforts required to develop preflight and flight software to satisfy baseline requirements Included are performance of overall software system design based on execution rates, input/output requirements, and response time restrictions, design and develop documentation, participate in design reviews, perform systematic integration testing of software, update software as a result of change activity, participate in configuration control, and perform program delivery generation and validation

XXX-15-01-02-02 PROGRAM IUS FLIGHT SOFTWARE

This task includes all efforts required to develop preflight and flight software to satisfy baseline requirements Included are performance of overall software system design based on execution rates, input/output requirements, and response time restrictions, design and develop executive and application program modules, generate detailed software design documentation, participate in design reviews, perform systematic integration testings of software, update software as a result of change activity, participate in configuration control, and perform program delivery generation and validation

320-15-01-02-03 SPACE TUG FLIGHT PROGRAM VERIFICATION

The objective of program verification is to insure, thru systematic testing by a independent functional area, that the flight software satisfies all requirements levied on it by the Equation Defining Document To accomplish this objective, the following activities are performed analysis of software reqirements, generation of a detailed testing plan, performance of systematic tests, analysis of software listings, comparison of flight software derived results with independently generated results, analysis of hardware/software compatability, reverification of all changes made to the software and generation of documented test results

XXX-15-01-02-03 IUS FLIGHT PROGRAM VERIFICATION

The objective of program verification is to insure, thru systematic testing by an independent functional area, that the flight software satisfies all requirements levied on it by the Equation Defining Document To accomplish this objective, the following activities are performed analysis of software requirements, generation of a detailed testing plan, performance of systematic tests, analysis of software listings, comparison of flight software derived results with independently generated results, analysis of hardware/software compatibility, reverification of all changes made to the software and generation of documented test results

320-15-01-03 MISSION SPECIFIC PROGRAM MODIFICATION

This element includes all efforts required to modify the baseline flight programs to perform specific IUS or Space Tug missions This includes the EDD, programming and verification of mission specific "application modules"

320-15-01-03-01 TUG MISSION SPECIFIC EQUATION DEFINING DOCUMENT (EDD)

This task includes all efforts required to modify the definition of the baseline Space Tug flight program to incorporate mission specific peculiarities This task is iterative and must be repeated prior to each flight

XXX-15-01-03-01 IUS MISSION SPECIFIC EQUATION DEFINING DOCUMENT (EDD)

This task includes all efforts required to modify the definition of the baseline IUS flight program to incorporate mission specific pecularities This task is iterative and must be repeated prior to each flight

320-15-01-03-02 TUG MISSION SPECIFIC PROGRAMMING

This task develops the "application module" which incorporates the specific deviations from the baseline program required by the subject Space Tug mission This task is iterative and must be repeated prior to each flight

XXX-15-01-03-02 IUS MISSION SPECIFIC PROGRAMMING

This task develops the "application Module" which incorporates specific deviations from the baseline program required by the subject IUS mission This task is iterative and must be repeated prior to each flight

320-15-01-03-03 TUG MISSION PROGRAM VERIFICATION

This task includes efforts necessary to analyze flight program implementation of the Equation Defining Document for this "application module". The task includes generation of a detailed testing plan to insure that all requirements are satisfied, the performance of systematic tests, and generation of a test results document

XXX-15-01-03-03 IUS MISSION PROGRAM VERIFICATION

This task includes efforts necessary to analyze flight program implementation of the Equation Defining Document for this "application module" The task includes generation of a detailed testing plan to insure that all requirements are satisfied, the performance of systematic tests, and generation of a test results document

320-15-02 GROUND SOFTWARE

This element consists of tasks and services required to analyze, design, develop, simulate, verify and maintain software used in the IUS/Space Tug Mission control center

320-15-02-01 PLAN GROUND SOFTWARE DEVELOPMENT

This task includes all efforts necessary to establish a plan for the development of IUS and Space Tug ground software Included will be the advisability of transforming software modules from existing ground control systems, establishment of the basic data processing techniques, planning the use of existing ground system simulators, and establishing ground program organization and source strings, and establishing a maximum transfer capability between IUS and Space Tug ground support software.

320-15-02-02 EQUATION DEFINITION

This element consists of all efforts in equation definition and algorithm development for Space Tug and IUS ground programs

320-15-02-02-01 EQUATION DEFINING DOCUMENT - EXECUTIVE/TRACKING/ PLANNING SOFTWARE

This task includes those efforts from the definition and analysis to the development of the equations and algorithms to be utilized in the Space Tug and IUS ground programs It is limited to those equations and algorithms which will not change during transition from IUS operations to Space Tug operations, with the exception of the IUS-peculiar tracking requirements, which will be phased out when the IUS becomes non-operational

320-15-02-02-02 TUG DOWN DATA/UP DATA AND DOCKING GROUND SOFTWARE

This task includes all efforts required to create an Equation Defining Document (EDD) for those ground software modules which are specifically oriented to the Space Tug The output of this task is an Equation Defining Document against which the ground Tug-peculiar software will be programmed

XXX-15-02-02-02 IUS DOWN DATA/UP DATA AND SIMULATION GROUND SOFTWARE

This task includes all efforts required to create an Equation Defining Document (EDD) for those ground software modules which are specifically oriented to the IUS The output of this task is an Equation Defining Document against which the ground IUS-peculiar software will be programmed

320-15-02-03 PROGRAMMING

This element includes the coding of all equations and algorithms specified for the IUS and Space Tug Ground programs.

320-15-02-03-01 PROGRAM GROUND TRACKING, PLANNING AND EXECUTIVE ROUTINES

This task depends on the generation of an adequate Equation Defining Document at a prior time, and includes the programming of all fundamental routines

320-15-02-03-02 PROGRAM SPACE TUG DOWN DATA/UP DATA AND SIMULATION SYSTEM

This task includes all efforts required to design an overall software system based on execution rates, input/output requirements, and response restrictions, design and develop Tug specific program modules, generating a detailed software design document, participation in design reviews, perform software integration testing, participate in change reviews and update software, provide configuration control and perform program generation, delivery and validation

XXX-15-02-03-02 PROGRAM IUS DOWN DATA, UP DATA AND SIMULATION SYSTEM

This task includes all efforts required to design an overall software system based on execution rates, input/output requirements, and response restrictions, design and develop IUS specific program modules, generating a detailed software design document, participation in design reviews, perform software integration testing, participate in change reviews and update software, provide configuration control and perform program generation, delivery and validation

320-15-02-04 PROGRAM VERIFICATION

This task includes all activities required to insure, through systematic testing by an independent functional area, that the ground software developed meets the intent of the Equation Defining Documents

320-15-02-04-01 VERIFY EXECUTIVE TRACKING AND PLANNING SOFTWARE

This task verifies that the intent of the Equation Defining Document has been implemented in the developed programs by testing the coded program under critical operational situations and includes the development of any special tools or simulators necessary in the accomplishment of this task

320-15-02-04-02 VERIFY TUG DOWN DATA/UP DATA AND SIMULATION PROGRAMMING

This task includes all activities involved to insure, thru systematic testing by an independent functional area, that the Tug peculiar ground software satisfies all requirements levied upon it by the Equation Defining Document This includes analysis of software requirements to insure accuracy, adequacy, and completeness, generation of a detailed testing plan, performance of systematic tests utilizing interpretive simulators, analysis of software listings, analysis of hardware/software compatibility and validation of all changes made to the basic software package

XXX-15-02-04-02 VERIFY IUS DOWN DATA/UP DATA AND SIMULATION PROGRAMMING

This task includes all activities involved to insure, thru systematic testing by an independent functional area, that the IUS-peculiar ground software satifies all requirements levied upon it by the Equation Defining Document This includes analysis of software requirements to insure accuracy, adequacy, and completeness, generation of a detailed testing plan, performance of systematic tests utilizing interpretive simulators, analysis of software listings, analysis of hardware/software compatibility and validation of all changes made to the basic software package

320-15-02-05 MISSION SPECIFIC SIMULATION

This element includes all efforts in equation definition, programming and verification required to incorporate specific mission profiles and contingency cases into the basic IUS or Space Tug simulation

320-15-02-05-01 PROGRAM TUG MISSION SIMULATION

This task includes all efforts required to modify the baseline Tug simulator to incorporate mission specific profiles and contingency cases This task accepts as inputs the output from the Space Tug mission planning and optimization task, and the Space Tug abort planning task, as well as outputs from Space Tug basic simulation design This task is iterative and must be repeated for each flight This task is, in a sense, a mission specific simulation application module.

XXX-15-02-05-01 PROGRAM IUS MISSION SIMULATION

This task includes all efforts required to modify the baseline IUS simulator to incorporate mission specific profiles and contingency cases This task accepts as inputs the output from the IUS mission planning and optimization task, and the IUS abort planning task, as well as outputs from IUS basic simulation design This task is iterative and must be repeated for each flight This task is in a sense a mission simulation application module

320-15-02-06 GROUND SOFTWARE MAINTENANCE

This element includes efforts required to maintain the ground software in operable condition and to incorporate modification and enhancements to the ground programs This is a level of effort task

320-15-03 COMPUTER SELECTION SUPPORT

This element includes all analytical tasks involved in the selection of the optimum operational data system for the IUS/Space Tug Control Center

320-15-03-01 ESTIMATE GROUND SOFTWARE SIZE

This task analyzes the Equation Defining Document for ground software and establishes a lower boundary upon the data system memory size and central processor unit speed requirements For maximum cost-effectiveness this task should be completed prior to the selection of an operational data system