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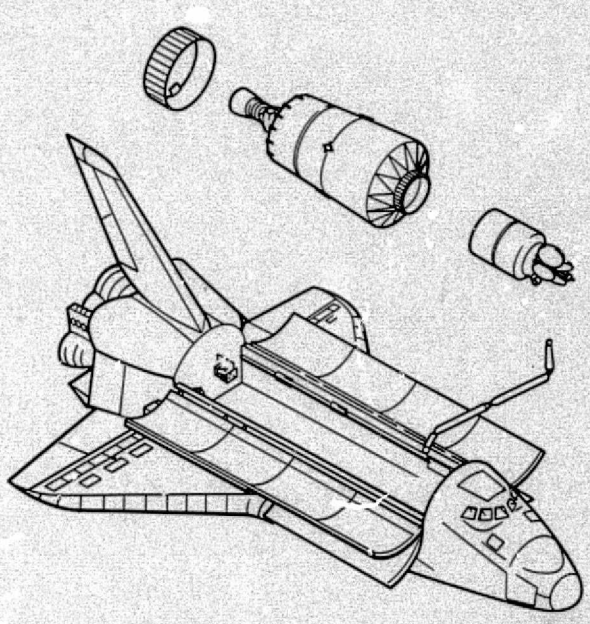

SPACE TUG/SHUTTLE INTERFACE COMPATIBILITY STUDY

FINAL REPORT

VOLUME IV ✦ COST ANALYSIS

GENERAL DYNAMICS
Convair Division

109

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SPACE TUG/SHUTTLE INTERFACE COMPATIBILITY STUDY

FINAL REPORT

VOLUME IV • COST ANALYSIS

June 1975

Prepared for
National Aeronautics and Space Administration
GEORGE C. MARSHALL SPACE FLIGHT CENTER
Huntsville, Alabama

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FOREWORD

This volume describes cost analysis results for a study conducted by Convair Division of General Dynamics Corporation under NASA Contract NAS8-31012. The work was under the management of the NASA Marshall Space Flight Center Tug Task Team in conjunction with four complementary Tug-related study efforts.

The study was conducted between July 1974 and March 1975.

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SUMMARY

The Space Tug/Shuttle interface compatibility study was performed to identify, evaluate, and develop Tug plus payload-to-Orbiter accommodations requirements. The study was the instrument by which design changes to satisfy these requirements were submitted to NASA.

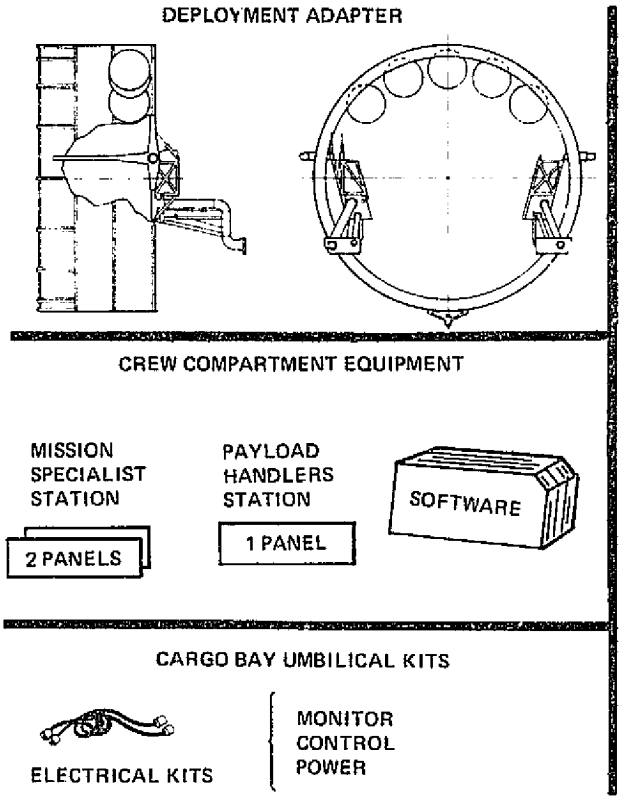
Previously performed Tug-related studies did not specifically address the use or suitability of Orbiter-supplied general-purpose payload support equipment or provide detail description of any Tug-dedicated peripheral equipment. The interface study investigated these areas and supplied the lacking data.

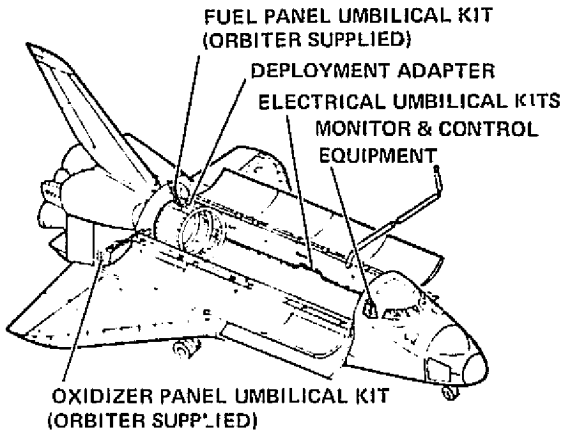
Shuttle interfaces required for Space Tug accommodation are primarily involved with 1) supporting and servicing the Tug during launch, countdown, flight and post landing; 2) deploying and retrieving the Tug on orbit; and 3) maintaining control over the Tug when it is in or near the Orbiter. Each of these interface areas was investigated during the study to determine the best physical and operational method of accomplishing the required functions, with an overriding goal of establishing simple and flexible Orbiter interface requirements suitable for Tug, Tug payloads, and other cargo.

The recommended system concept for supporting and deploying Tug from Orbiter employs a cylindrical load-carrying structure called a deployment adapter. The deployment adapter contains all Tug-peculiar mechanisms required for transfer of Orbiter/ground services and support of deployment, retrieval, and abort operations. Because the deployment adapter is a cylindrical structure to provide efficient axial load distribution, a rotational deployment feature is incorporated to allow Tug removal during deployment without infringing on the Orbiter cargo bay volume available for Tug payloads. By using the deployment adapter concept, Tug umbilical and deployment mechanisms can be attached and checked out before Tug installation into the Orbiter. The entire Tug, adapter, and umbilical support is installed as an autonomous unit into the Orbiter.

Cost details of deployment adapter and other Tug-peculiar peripheral equipment (crew compartment interface panels and cargo bay electrical umbilical kits) were provided as study output.

Total Tug/Shuttle interface equipment DDT&E cost at WBS Levels 5 and 6 is $15.6M as shown. This cost reflects expected value total cost to the government for all phases of Tug/Shuttle interface planning, liaison, development and integration, with estimated cost growth allowances for uncertainties. Interface equipment production cost was estimated at $2.7M per shipset.





EQUIPMENT	COST (1,000$)
ADAPTER STRUCTURE & MECHANISMS	4,270
UMBILICAL SUPPORT & MECHANISMS	1,149
FLUID SYSTEM	2,967
AVIONICS HARDWARE	4,402
INTEGRATION ASSY & C/O	1,606
AVIONICS SOFTWARE	1,260
TOTAL	15,654

In addition to the development and production costs generated for the recommended interface concept, costs were employed in trade study analyses as an important evaluation parameter.

The data contained in this volume describes the methodology used to screen alternative interface candidates and provide the recommended system detailed costs.

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SECTION 1

INTRODUCTION

1.1 STUDY OBJECTIVES

The Space Transportation System flight vehicle, the Space Shuttle, consists of the major segments shown in Figure 1-1. Included as part of this transportation system is a proplusion stage called the Space Tug, depicted in Figure 1-2,which is carried into low-earth orbit by the Space Shuttle in the Orbiter cargo bay. The Tug extends Shuttle capability by placing payloads into higher orbits, such as geosynchronous and interplanetary trajectories,so that more payload users may be accommodated.

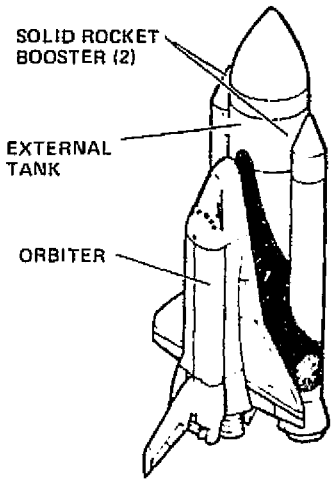


Figure 1-1. Space Shuttle Configuration

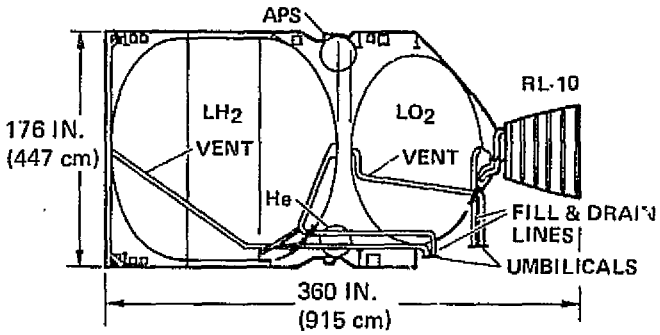


Figure 1-2. MSFC Baseline Tug

Current resource constraints preclude simultaneous development of both Space Shuttle and Tug. The government plans to have the Air Force develop an interim upper stage (IUS), to be followed by a NASA-developed full capability Tug at a later date. The IUS is planned to be operational at or near the Shuttle's initial operational capability (IOC). Although the Space Tug operational date is planned for 1983, it is important that Shuttle/Tug interface requirements be identified early so they can be incorporated into the Shuttle. This advanced planning will prevent having to constrain the Tug design due to prior Shuttle development and will avoid major and costly Shuttle modification when Tug is introduced.

The Space Tug/Shuttle Interface Compatibility Study was structured to compile, screen, evaluate, and recommend suitable Orbiter interface provisions for Space Tug integration.

The Shuttle/Orbiter, as currently configured, includes some general payload accommodations applicable for Space Tug, but a detailed investigation of specific interface requirements had not previously been undertaken. Tug interface requirements needed immediate definition and consideration in conjunction with other payload interface

requirements for incorporation into the Shuttle Orbiter at the earliest possible date. Tug/Shuttle interface compatibility achieved early during Shuttle development will result in lower Space Transportation System program costs.

The purpose of the Space Tug/Shuttle Interface Compatibility Study was to provide 1) timely detailed identification of Tug-related interface requirements, and 2) the instrument by which design changes to satisfy these requirements would be submitted to NASA. Figure 3-1 identifies the Tug-related Orbiter interfaces for the MSFC baseline cryogenic Tug.

The Interface Study was managed by the Tug Task Team at NASA's Marshall Space Flight Center, along with four other parallel Tug-related contracted activities. These other studies, involving ground and flight operations, payload/Tug interfaces, and Tug avionics, supported the Interface Study by generating accommodation requirements within their respective study areas.

The study was arranged into six tasks, which were accomplished sequentially within the eight-month performance period:

Task 1 - Functional Interface Requirements Definition. Tug ground and flight operations were analyzed to obtain a complete accounting of all potential Tug/Orbiter interfaces, their related operations, and safety functional requirements. This analysis was conducted using baseline vehicle and operations definitions supplied by NASA-MSFC at the start of the study effort.

Task 2 - Baseline Tug Interface Analyses. Approved functional interface requirements were systematically evaluated to obtain alternative solutions and determine the optimum interface approach to satisfy each baseline Tug need. Specific payload through Tug and direct to Orbiter service requirements obtained by trade study were included. From these subsystem investigations and trade studies, detailed interface requirements for Tug/Shuttle compatibility were itemized.

Task 3 - Sensitivity Analysis. Using updated subsystem requirements from Task 2, sensitivity analyses were performed to evaluate the effect of Tug operations and design changes on Tug/Orbiter interface requirements.

Task 4 - Tug/Orbiter Interface Requirements. Results from baseline Tug interface analyses (Task 2) were assembled through a total Tug systems interface concept trade study, and a composite set of preliminary Tug/payload/Orbiter interface requirements were submitted for NASA evaluation. These proposed Orbiter accommodation revisions were submitted as recommended Level II changes. The NASA assessment included requirements reviews by MSFC and the Shuttle project.

Task 5 - Interface and Baseline Revisions. Revised interface requirements were prepared in areas where the government disapproved the initial requirements. Revisions

were defined through trade studies of alternative approaches and baseline Tug changes. Since relatively few proposed changes were rejected, unused resources were applied to Tug/Orbiter interface related special emphasis tasks.

Task 6 - IUS/Tug Interface Comparison. Approved Tug requirements from Tasks 4 and 5 were compared with similar IUS requirements. Interface requirement incompatibilities were evaluated to identify and define major problems and recommend compromise solutions.

1.2 REPORT ORGANIZATION

The results of the Space Tug/Shuttle Interface Compatibility Study are contained in the four volumes of the final report. The four volumes are organized as follows:

Volume I Executive Summary - Contains a summary of the objectives, relationship of the Interface Study to other NASA efforts, approach, data generated and significant results, limitations, research implications,

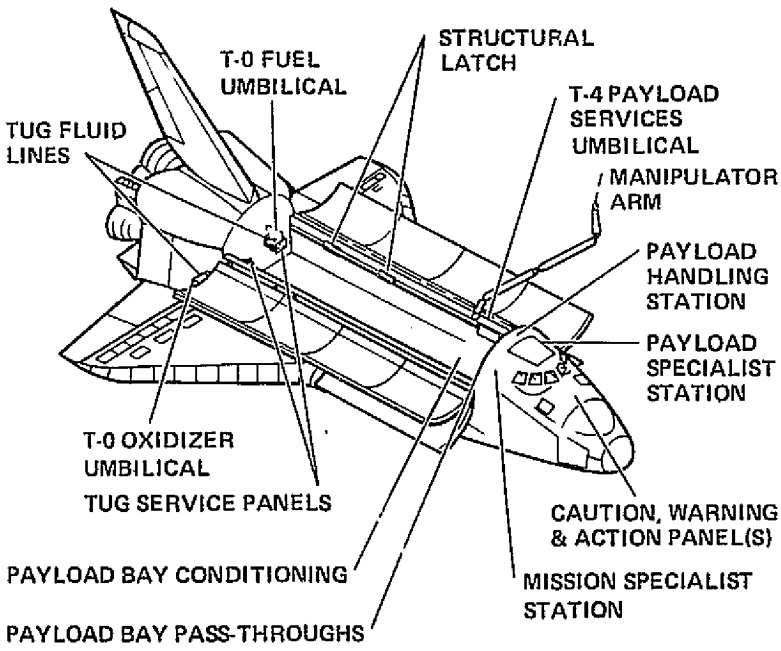


Figure 1-3. Tug-Related Orbiter Interface Provisions

and recommendations for additional effort made as a result of the study.

Volume II — Tug/Payload/Orbiter Interface Analysis — Includes the subsystem technical analysis performed, including the definition of the Tug functional interface requirements and payload service requirements, detailed analyses and trade studies of Tug/Orbiter interfaces, appropriate sensitivity studies, and special emphasis tasks.

Volume III — Tug/Payload/Orbiter Interface Requirement — Contains the system level interface assessment and the operation/physical definition of the recommended Tug/Orbiter interface, plus a description of the Orbiter and baseline Tug changes needed to accommodate the recommended interface. It also includes a comparison of IUS and Tug interface requirements, and recommends interface simulation-demonstration candidates.

Volume IV — Cost Analysis — Provides the detailed study economic analysis approach, methodology, and results.

1.3 VOLUME IV ORGANIZATION

The cost analysis volume presents summary and detailed program costs according to the study Work Breakdown Structure (WBS). This volume consists of four major sections summarizing primary cost analysis results, describing the cost analysis approach and methodology, and presenting cost portions of trade studies. Appendix A to this volume gives detailed descriptions of each WBS category. Appendix B contains the detailed cost and programmatic reporting forms required by DRD MF003M.

SECTION 2

PROGRAM COSTS

2.1 GROUNDRULES AND ASSUMPTIONS

a. Costs are in 1975 dollars, without prime contractor fee/profit.

b. Cost represents the expected value total cost to the Government (less prime contractor fee/profit) at program completion. Therefore, allowances for cost growth are included as discussed in Section 3.2.

c. Costs and funding are predicated upon the program plans described in Section 2.2.

d. Costs are for budgetary and planning purposes. They do not represent a commitment on the part of General Dynamics Corporation, since such a commitment would require more specific contractual arrangements.

e. Costs are those specifically associated with the Tug/Shuttle Interface only. They do not include costs associated with ground checkout and servicing since these areas were a part of the Tug Fleet and Ground Operations Schedules and Control Study.

2.2 PROGRAM PLAN

The Tug/Shuttle Interface Compatibility Study is one of five Space Tug program studies performed during fiscal year 1975. Each of these studies was primarily concerned with subsystem definition. Although no program definition task was included, a study requirement was that costs be presented in accordance with NASA Documentation Requirements Document (DRD) MF003M. To comply with the cost reporting of MF003M, the program plan described here was prepared.

The Tug/Shuttle Interface Compatibility Study program plan and schedule are shown in Figure 2-1. Major milestones are Authority to Proceed (ATP) in Sept. 1978, PDR in August 1979, CDR in Dec. 1980 and Tug IOC in Dec. 1983. This schedule reflects the final development of the Tug/Orbiter interface system and hardware as defined in this study. It includes the timely integration of these systems and hardware assemblies with a full-capability Tug development program, such as outlined in the "Space Tug System Study," Contract NAS8-29676, as Tug Program 2.

The Tug development milestones are shown across the top of this schedule and are significant relative to the scheduling of certain design and engineering events identified under the basic Tug/Orbiter subsystem elements. The individual schedule basis for structure and mechanisms, fluids and avionics denote the basic engineering design and completion events having a significant interface with hardware procurement, subassembly, and subsequent testing as well as with the basic Tug development and flight vehicle integration and assembly.

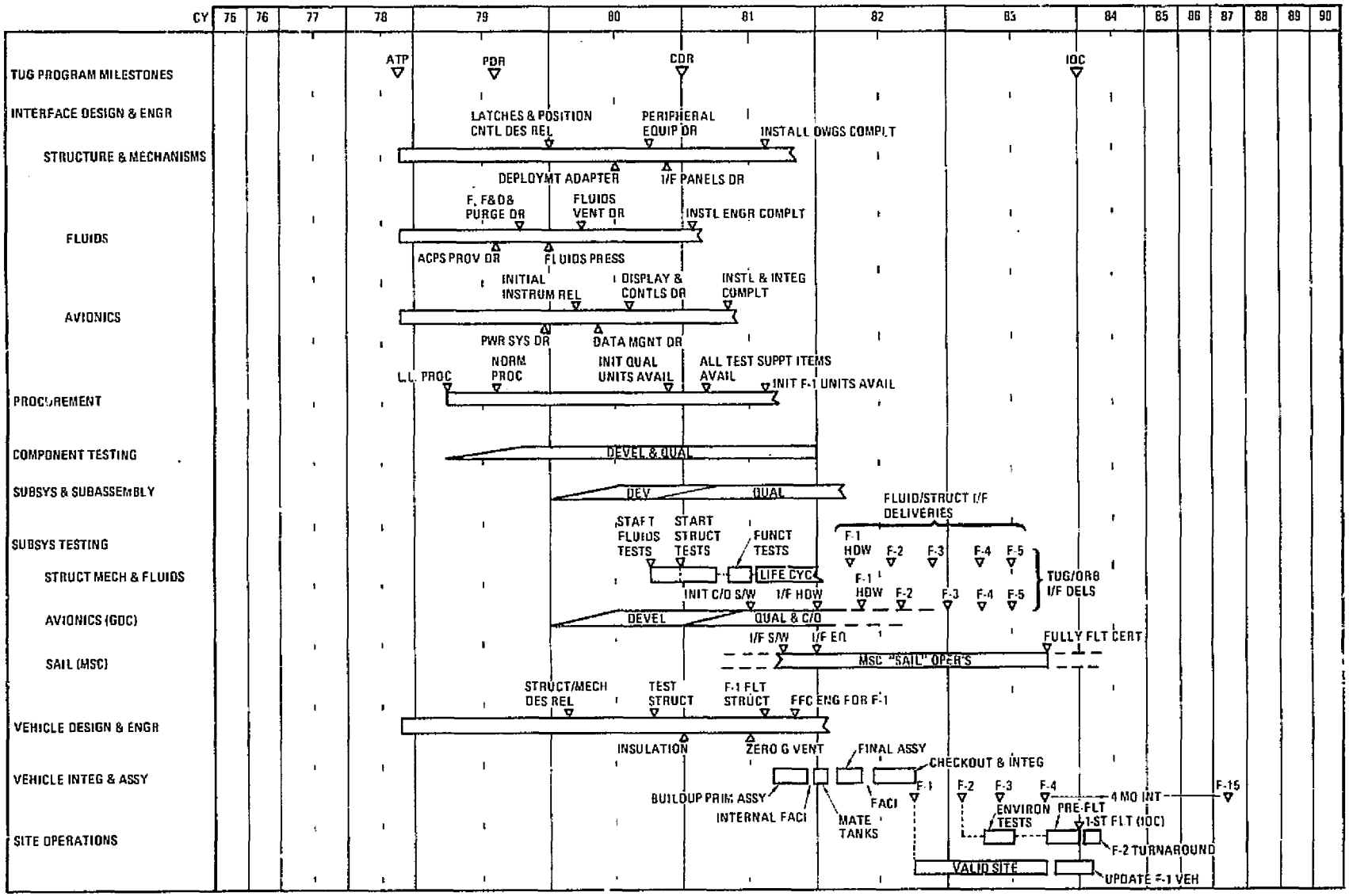


Figure 2-1. Tug/Orbiter Interface Systems Development Plan

Development of the Tug/Orbiter interface systems do not pace the development and assembly of the basic Tug vehicle. For the most part, shorter engineering spans are associated with these tasks; however, critical data exchange interfaces necessitate delayed starts for some of these activities until the appropriate Tug design data is available. The more extensive Tug/Orbiter interface development tasks are associated with the unique deployment adapter design, the airborne support equipment (ASE) data management system and, to some degree, the instrumentation support hardware.

The deployment adapter incorporates a graphite-epoxy sandwich sidewall with composite major frames. Materials and subassembly testing is needed to verify design parameters and assembly procedures. This and other major structural units will have to be structurally qualified under formal testing on preproduction, flight-type hardware. However, these structural test units would not be reused for flight. Functional and fatigue tests of the fully assembled deployment adapter, selected fluid systems, and umbilical panels would also be required before hardware deliveries for flight.

ASE avionics development would progress from the breadboard/brassboard stages in the labs to eventual preproduction hardware integration in the Tug avionics integration lab (TAIL) for ASE system checkout and verification. It would also be verified for compatibility with the Tug avionics and simulated Orbiter interfaces while in the TAIL. The initial ASE avionics set checked out in the TAIL will be delivered to NASA/JSC for Shuttle integration testing in the SAIL.

Subsequent ASE avionics flight hardware will also be verified in the TAIL before final installation with the structural ASE and composite checkout with the completed Tug vehicle, following its final assembly operation.

The initial deployment adapter will be match mated with the initial Tug flight vehicles, then removed and shipped with all other appropriate Tug/Orbiter interface hardware for final assembly and integration with the Orbiter and Tug at the flight operations site.

One set of Tug/Orbiter interface equipment is required for each Orbiter in the inventory plus a predetermined spares requirement by parts. The production rates shown reflect three systems per year without impacting either the Orbiter schedules or the proposed mission traffic model.

The basic Tug vehicle development span is reflected at the bottom of the schedules, showing the basic design and engineering span as well as vehicle assembly and operational site activity schedule. IOC is coincident with the first flight, some 63 months after the Tug program go-ahead (ATP). This is the same Tug development schedule outlined under Program 2 of the Study Contract NAS8-29676. The Tug/Orbiter interface development is not constraining to the vehicle development span; consequently some shortening of the overall Tug program development schedule may be obtained without directly impacting the development of the interface subsystems. Such an

acceleration of the Tug program schedule would likely come from selected, pre-Tug program avionics advanced development in areas such as laser radar for rendezvous, lightweight fuel cells, and redundancy management software.

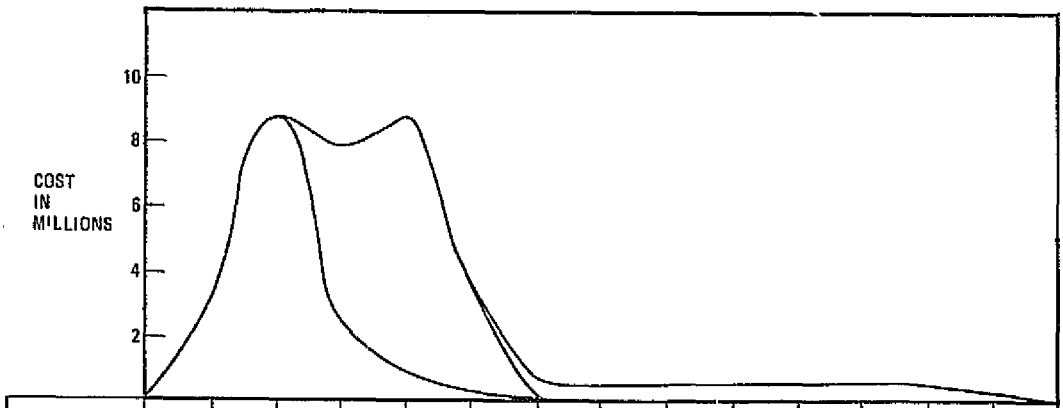
The total Tug vehicle inventory of 15 Tugs (instead of the 17 under Program 2) was derived from the later NASA mission model dated August 1974. The later model shows total payload traffic through 1991 to be 255. These are reduced to 168 Tug flights (considering multipayload flights), including both ETR and WTR launches. Tug attrition is also considered in these totals.

2.3 COST SUMMARY

Total Tug/Shuttle Interface associated costs are:

Item	Cost ($K)
DDT&E	15,655
Production	16,833
Operations	3,220
Total	35,708

Summary annual funding requirements are shown in Figure 2-2.



FY	79	80	81	82	83	84	85	86	87	88	89	90	91	92
DDT&E	3.4	8.7	2.5	0.8	0.2									
PRODUCTION			5.4	7.9	3.5									
OPERATION						0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	
TOTAL	3.4	8.7	7.9	8.7	3.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	

Figure 2-2. Summary of Annual Funding Requirements

2.4 WBS COSTS

DDT&E costs consist of tasks, services, hardware and software costs of performing the Tug/Shuttle interface development tasks described in the WBS (Appendix A). One complete set of hardware is dedicated to TAIL/SAIL and other integration testing. This set of interface hardware constitutes the theoretical first unit (TFU). Therefore, DDT&E costs consist of a subsystem engineering design and development (ED&D), other development and integration tasks, and the one set of integration hardware (one TFU). Space Tug/Shuttle interface DDT&E costs are summarized in Table 2-1. More detailed cost factors and programmatics are shown in Appendix B.

Production costs are for the Tug/Shuttle interface equipment sets required to accomplish the missions in the National Mission Model. Five sets of interface hardware are required for the operational program beginning at IOC in December 1983 and continuing through 1991. Summary production costs by WBS category are shown in Table 2-2. Cost improvement factors, initial spares. and other production cost details are shown in Appendix B.

Operations costs are for the spares and repairable units to maintain and refurbish interface subsystems only during the 1983 through 1991 operational period. Tug/Shuttle interface operations costs are summarized in Table 2-3. Further details are presented in Appendix B.

Table 2-1. DDT&E Costs by WBS Element

WBS Number	Element	TFU*	DDT&E Cost in Thousand Dollars		
			EDD	Other	Total
320-16	Orbiter Interface				
320-16-01	Structural and Mechanical				
320-16-01-01	Deployment, Rendezvous and Docking	218	931		931
320-16-01-02	Tug/Orbiter Supports	631	2,690		2,690
320-16-01-03	Interface Panels	20	538		538
320-16-01-04	Peripheral Equipment	39	352		352
320-16-02	Fluids				
320-16-02-01	Main Propellant Fill, Drain and Dump	96	736		736
320-16-02-02	Vent	59	650		650
320-16-02-03	Purge	83	536		536
320-16-02-04	ACPS Provisions	30	121		121
320-16-02-05	Pressurization	142	515		515
320-16-03	Avionics				
320-16-03-01	Data Management	278	1,365		1,365
320-16-03-05	Instrumentation	494	1,234		1,234
320-16-03-06	Electric Power	342	689		689
320-16-05	Integration Assembly and Checkout	260	1,346		1,346
320-15	On Board Software			1,260	1,260
320-08-01	Ground Test Hardware			2,692	2,692
	Total		11,703	3,952	15,655

*Subsystem breakdown shown for reference only.

Table 2-2. Production Summary Costs by WBS Element

WBS Number	Element	Production Cost ($ K)
320-16	Orbiter Interface	
320-16-01	Structural and Mechanical	(4,914)
320-16-01-01	Deployment, Rendezvous and Docking	1,180
320-16-01-02	Tug/Orbiter Supports	3,415
320-16-01-03	Interface Panels	108
320-16-01-04	Peripheral Equipment	211
320-16-02	Fluids	(3,523)
320-16-02-01	Main Propellant Fill, Drain and Dump	847
320-16-02-02	Vent	520
320-16-02-03	Purge	732
320-16-02-04	ACPS Provisions	171
320-16-02-05	Pressurization	1,253
320-16-03	Avionics	(7,268)
320-16-03-01	Data Management	1,674
320-16-03-05	Instrumentation	2,550
320-16-03-06	Electric Power	3,044
320-16-05	Integration, Assembly and Checkout	(1,128)
	Total	16,833

Table 2-3. Operations Summary Costs by WBS Element

WBS Number	Element	Operations Cost ($ K)
320-16	Orbiter Interface	
320-16-01	Structural and Mechanical	(1,449)
320-16-01-01	Deployment, Rendezvous and Docking	348
320-16-01-02	Tug/Orbiter Supports	1,007
320-16-01-03	Interface Panels	32
320-16-01-04	Peripheral Equipment	62
320-16-02	Fluids	(314)
320-16-02-01	Main Propellant Fill, Drain and Dump	74
320-16-02-02	Vent	46
320-16-02-03	Purge	64
320-16-02-04	ACPS Provisions	20
320-16-02-05	Pressurization	110
320-16-03	Avionics	(1,457)
320-16-03-01	Data Management	110
320-16-03-05	Instrumentation	938
320-16-03-06	Electric Power	379
	Total	3,220

SECTION 3

COST APPROACH AND METHODOLOGY

3.1 DATA BANK

During 1973 General Dynamics Convair Division performed a Centaur cost, technical, and programmatic data study (Contract NAS8-29075) for NASA's Marshall Space Flight Center. This study covered original Centaur development and initial operations through 1966. The approach developed in that study resulted in some improved techniques for advanced system costing. Convair continued these analyses through the latest Centaur D-1A (upper stage with Atlas) and D-1T (upper stage with Titan III). Thus an extensive data bank of historical data has been developed for predicting expected value costs of advanced systems.

In addition to the Centaur cost, technical, and programmatic data bank, Convair obtained cost data from subcontractors/vendors for major components and/or subsystem elements. Specific groundrules and technical guidance were provided so that subcontractor/vendor quotes and technical information would be closely oriented toward Tug/Shuttle interface requirements. Costs of smaller items were obtained from current catalog price data and from recent Convair material buy experience data.

3.2 GROWTH ALLOWANCES

Costs required in this study represent expected value costs to the Government at program completion. Therefore, estimated costs include allowances for program and hardware changes. Three basic uncertainties contribute to cost growth during a program. The first factor is uncertainty in the stated requirements of the system; i.e., Requirements Uncertainty. The second factor is Technology Uncertainty. The third factor is the degree of Concurrency in the development program. In cases where subsystems are being simultaneously developed according to a tight schedule, costs (and schedules) can be severely impacted.

Based upon past studies, particularly in the Centaur program, the range of possible cost uncertainty percentages shown in Figure 3-1 was developed. The results of assessments of technology and requirements uncertainties as well as potential schedule problems were used to develop cost growth factors for each subsystem.

*TYPICAL COST UNCERTAINTY FACTORS	REASON FOR UNCERTAINTY FACTOR
90%	ADVANCED STATE OF ART CONCURRENT DEVELOPMENT & INTEGRATION OF ALL TUG SYSTEMS
30%	MEDIUM/LOW STATE OF ART CONCURRENT DEVELOPMENT & INTEGRATION OF ALL TUG SYSTEMS
10%	OFF THE SHELF COMPONENTS SOME PREVIOUS EXPERIENCE WITH INTEGRATION LOW CONCURRENCY OF TUG SYSTEMS

*BASED ON PAST PROGRAMS. TYPICAL NUMBERS DEVELOPED IN CONTRACTS NAS8 - 29676 & NAS8 - 30290

REASONS FOR UNCERTAINTY – CHANGING REQUIREMENTS, ADVANCED TECHNOLOGY, QUALITY OF COST/SCHEDULE ESTIMATES, & FUNDING CONSTRAINTS

Figure 3-1. Sources of Uncertainty and Their Effects on DDT&E Cost

3.3 COST METHODOLOGY

Subsystem hardware costs were developed using the component cost buildup approach. The cost buildup begins with a tabulation of buy costs (vendor quoted costs and purchased parts/materials) as shown in Table 3-1. The cost growth allowance for uncertainties (see Section 3.2) is added to the buy estimates to get an expected value total buy cost for both the engineering design and development (ED&D) and the theoretical first unit (TFU) costs for subsystems. Next the Convair in-house engineering design is estimated, using Centaur or other analogous task historical cost data, and appropriate cost growth allowances added to get the expected value design cost. The buy ED&D and TFU costs, along with the engineering design estimate are entered on the total subsystem cost worksheet shown in Table 3-1. Total subsystem costs are derived on this worksheet by adding percentages of the design estimate for design supporting functions and progressive percentages to derive estimated costs of other tasks (e.g., tooling, test). The cost buildup add-on percentages shown in Table 3-1 were derived for each subsystem from the most appropriate Centaur experience data. It should be noted that this cost buildup approach assumes a Tug make or buy policy consistent with current Convair practices. Total DDT&E costs of each subsystem were developed by adding one complete shipset of equipment (1 TFU) to the subsystem ED&D cost.

Production costs were developed as shown in Table 3-1, using the required quantities of interface production units and initial spare units times the TFU and times a cost improvement factor. Operational replacement spares costs were determined in a similar manner.

Table 3-1. Cost Analysis — Cost Buildup Approach (Structures Example)

ELEMENT	QTY.	ELEMENT COST ($M)	UNIT COST ($M)	ED&D COST ($M)	VENDOR/SOURCE	SIMILAR TO:
SUPPORT ADAPTER	1	0.220	0.220	0.950	CONVAIR	TITAN/CENTAUR INTERSTAGE ADAPTER
SUBSYSTEM SUPPORTS	1 SET	0.018	0.018	0.140	CONVAIR	CENTAUR VEHICLE SUBSYSTEM SUPPORTS
TUG-TO-ORBITER SUPPORT FITTINGS	4	0.008	0.032	0.055	CONVAIR	CENTAUR HANDLING EQUIP. FITTINGS
INSTALLATION & CHECKOUT			0.022	0.040		
SYSTEM INTEG.				0.115		
TOTAL			0.292	1.300		

THEORETICAL FIRST UNIT (TFU) COST = (UNIT COST) (PRIME CONTRACTOR) (GROWTH) = (0.292) (1.0) (1.1) = 0.321

NONRECURRING (DDT&E)

ED&D = (ELEMENTS ED&D) (PRIME CONTRACTOR) (GROWTH) = (1.300) (1.0) (1.2) = 1.560

MAJOR TEST HARDWARE = (TFU) (NO. UNITS) = (0.321) (2.3) = 0.739

TOTAL 2.299

RECURRING PRODUCTION

PRODUCTION ARTICLES = (NUMBER) (TFU) (COST IMPROVEMENT) = (1.5) (0.321) (0.7) 3.371

TEST ARTICLE CONVERSION = (NUMBER) (TFU) (COST IMPROVEMENT) = (1.0) (0.321) (0.3) 0.096

TOTAL 3.467

RECURRING OPERATIONS

SPARES & REPAIR PARTS = (EQUIV. SETS) (TFU) (COST IMPROVEMENT) = (0.8) (0.321) (0.7) 0.189

TOTAL PROGRAM COST (STRUCTURES) $5.946 M

SECTION 4

TRADE STUDY COSTS

Several key trade studies included costs as one evaluation criteria. Costs of these trades are presented in this section.

4.1 SUPPORT SYSTEMS CONCEPTS

Three alternative Tug/Orbiter interface concepts were analyzed. The baseline adapter rotation concept was compared with direct lateral and direct rotational approaches. Table 4-1 shows summary DDT&E cost differences for alternative support/deployment methods, relative to the baseline deployment adapter rotation concept. The direct lateral support deployment concept gives an 87 thousand dollar DDT&E reduction. The direct rotational concept is 761 thousand dollars below the DDT&E cost of the baseline concept. The primary cost differences are due to the deletion of the adapter structure and mechanisms, which are part of the baseline concept.

Table 4-1. Tug Support Systems Concepts Cost Comparison

	DDT&E Δ Cost ($M)		
Concept/Subsystem	Tug	Interface	Total
Deployment Adapter	Reference Baseline		
Direct Lateral			
Structure/Mech	+0.826	-1.557	-0.731
Fluids	+0.438	+0.849	+1.287
Electrical	-0.884	+0.415	-0.469
	Total Δ Cost		-0.087
Direct Rotational			
Structure	+0.826	-1.557	-0.731
Fluids	—	+0.439	+0.439
Electrical	-0.884	-0.415	-0.469
	Total Δ Cost		-0.761

It should be noted that the baseline deployment adapter approach was retained for reasons other than cost. Details of the trade study are shown in Section 2, Volume III of this report.

4.2 TUG/ORBITER/GROUND OPERATIONS

Three techniques for performing Tug monitor and control were evaluated with respect to the recommended Tug implementation concept to determine interface impacts. These techniques were: 1) increased ground control, 2) high autonomy Tug, and 3) increased Orbiter control. Evaluation criteria consisted of Orbiter and crew safety, Orbiter hardware/software interface complexity, operational complexity, crew effectivity, and cost. For each technique evaluated, a control and monitor allocation plan was established to define primary and backup responsibility for all major Tug flight operational phases involving Tug/Shuttle operations. Concept advantages and penalties were then determined for each technique to allow comparison with the recommended Tug baseline. Cost-related results of the trade are summarized in Table 4-2 in terms of a total program, which includes five years of operations.

Table 4-2. Cost Assessment-Tug Control Methods

		Tug Control Method		
	Baseline	Ground	Autonomous	Orbiter
Requirements				
Hardware Panels	4	2	4	4
Software (Words)				
Orbiter	10,000	3,000	1,200	35,000
Tug	10,000	10,000	32,000	10,000
Ground	43,000	49,000	15,000	15,000
Ground Personnel	81	91	75	75
Cost Difference (thousand dollars)				
Panels	Ref.	-158	0	0
Software				
Airborne	Ref.	-1,780	+3,357	+6,358
Ground	Ref.	+60	-280	-280
Ground Personnel Training		+750	-450	-450
Total DDT&E	Ref.	-1,128	+2,627	+5,628
Total Operations (5 yr)	Ref.	+2,500	-1,500	-1,500
Total Program	Ref.	+1,372	+1,127	+4,128

4.3 TUG SELF CHECKOUT

Three levels of self test were analyzed to determine the best self test method for Tug using low cost, low risk and low complexity as the driving decision criteria. These levels of self test are described below.

Low Self Test. Low self test is basically the method used for D-1 Centaur (mid 60s technology) It was used because computers were large, heavy, and expensive. Large scale integration (LSI) had not come into its own yet (not to mention microprocessors), which forced checkout capabilities to be "stuffed" into one ground computer with costly programming and interfacing required. This concept created a complex of interleaved programs and logic that was very difficult to manage and control. For example, the vent and pressurization engineer was forever concerned that the guidance software change might adversely affect the computer controlled vent and pressurization software system.

Partial Self Test. The partial self test concept as depicted in the Tug baseline indicates that the computer complex is to be broken down into a self test microprocessor for those systems that are localized and the centralized testing kept for those systems that are difficult to design into microprocessor systems in a cost-effective manner. This follows from a conservative prediction of LSI growth through 1978. Therefore, it makes sense to put relatively expensive microprocessors only on complex hardware.

Total Self Test. Total self test is the concept of using microprocessors throughout the Tug vehicle no matter how simple the hardware to be tested. This concept is predicated on LSI growing to the point where microprocessors are small, fast, cheap, and easy to design for special-purpose aerospace applications. This is already the case for commercial applications such as calculators; and in aerospace, the B-1 bomber avionics system design today very closely approaches this concept.

Summary costs for the low and total self test options, relative to the baseline partial self test, are shown in Table 4-3.

4.4 DATA PROCESSOR VS TSS CONCEPT

An analysis was performed to evaluate the use of a separate and unique Tug support station (TSS) deployment adapters (D/A) processor approach to Tug operational control and monitoring operations.

The two concepts, data processor and TSS, are identical with respect to safety. There is no difference in C&W monitoring and safing control implementation. The addition of components in the D/A and crew area results in a net spacecraft weight penalty of 18 pounds for a delivery mission. The Tug Specialist Station would require an additional 200 watts, while the D/A processor and S/C multiplexer-demultiplexer (MDM) would use another 100 watts. The Tug/Orbiter interface would increase by a data link from

Table 4-3. Tug Self Check Trade Cost Summary

Evaluation Criteria		Low Self Test	Partial Self Test	Total Self Test
Weight (lb)		920	923	940
Risk		0.5	0.6	0.7
Speed Reqr. (KOPS)	Checkout	190	13	5
	Tug	65	35	12
Memory (Words)	Checkout	80400	28000	1050
	Tug	3000	8000	5520
Real Time		Fast	Slow	Slow
Interface Complexity	Wires/LRU	15	7	Bus Input
Power (watts)		180	75	35
Operational Complexity		High	Med	Low
Cost Differences ($K)				
DDT&E:	Processing	854	Ref.	7,415
	Memory	369	Ref.	-191
	Wire and Conn.	-99	Ref.	-513
	IACO	144	Ref.	846
	Software	9,197	Ref.	-7,016
Total		+10,465	Baseline	+541

the aft crew station to the D/A and a power connection for the added equipment. No Tug/Orbiter interfaces can be deleted. However, spacecraft control and monitor hard-wires normally routed to the Orbiter would interface in the D/A MDM.

Total program costs, including DDT&E of hardware and software as well as recurring costs, would be increased by 6.1 million dollars.

Crew tasks would be essentially identical, but the mission specialist would be required to interface with two independent computers. This could result in confusion in certain situations.

One contributor to the increased costs is a net increase of 10,000 words, even though Orbiter support would decrease by 5,600 words.

The TSS/deployment adapter processor does, however, have potential benefits that may outweigh the penalties discussed above. If both Tug and Tug payload were to use TSS, the more efficient integration of payload interfaces and operations might result. This is because the integration and interface modifications involved would not significantly impact the Orbiter contractor or NASA/JSC. Table 4-4 presents the cost summary.

Table 4-4. DDT&E Cost Summary — Processor versus TSS

Item	Cost ($K) Data Processor	TSS
DMS (Incl. Displays & Controls)	Ref.	+2,697
Instrumentation	Ref.	-
Electric Power	Ref.	-
Software	Ref.	869
DDT&E Total	Ref.	3,566
Production/Oper (5 yr)	Ref.	2,535
Total Program	Baseline	6,101

APPENDIX A

SPACE TUG PROJECT

WORK BREAKDOWN STRUCTURE AND DICTIONARY

APPENDIX A

SPACE TUG PROJECT

WORK BREAKDOWN STRUCTURE

AND

DICTIONARY

GENERAL DYNAMICS CONVAIR DIVISION

San Diego, California

SPACE TUG PROJECT

WORK BREAKDOWN STRUCTURE

AND

DICTIONARY

TABLE OF CONTENTS

I - INTRODUCTION

The Space Tug Project Work Breakdown Structure (WBS) provides a consistent, subsystem oriented framework for technical, programmatic and cost analyses required by the several Space Tug definition studies. As the Tug project moves into later program phases this WBS will be revised to provide for more detailed or different tasks required in those phases.

The Space Tug Project consists of all tasks, material, hardware and services required to design, develop, test, produce and operate Space Tugs with the Space Shuttle to accomplish NASA and DoD missions. Therefore the project includes Tug/Shuttle interfaces and payload interfaces.

The Tug vehicle is considered as a payload with respect to the Space Shuttle. At the same time the Tug will have its respective payloads (spacecraft) for the several missions. For the purposes of this WBS, payload refers to the Tug payloads.

The following sections present the details of the WBS structure. Section II lists the WBS Identification Number Sequence. This numbering sequence consists of nine digits, which identify the WBS elements to level 6 (Assembly). Section III defines the Subdivisions of Work (SOW) which comprise the basic functional tasks within each WBS element. Section IV consists of definitions for each element displayed in the WBS. Section V consists of a master chart display of the titles of each WBS element and their build up to the total Tug project level.

The level of detail described herein (to level 6) is the minimum required. In specific studies lower level details will be required. For example, a detailed Tug Avionics definition study would require at least the next lower level of detail (level 7).

II - 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
320-01-02	Project Direction	5
320-01-03	Information Management	5
320-02	Systems Engineering and Integration	4
320-02-01	Tug Systems Engineering	5
320-02-02	Shuttle Interface	5
320-02-03	Payload Interface	5
320-02-04	Sustaining Engineering	5
320-03	Tug Vehicle Main Stage	4
320-03-01	Structure and Mechanical	5
320-03-01-01	Fuel Tank and Supports	6
320-03-01-02	Oxydizer Tank and Supports	6
320-03-01-03	Body Structure	6
320-03-01-04	Thrust Structure	6
320-03-01-05	Meteoroid Shield	6
320-03-01-06	Payload Interface	6
320-03-02	Thermal Control	5
320-03-02-01	Fuel Tank Insulation	6
320-03-02-02	Oxydizer Tank Insualtion	6
320-03-02-03	Insulation Purge System	6
320-03-02-04	Thermal Control System	6
320-03-03	Avionics	5
320-03-03-01	Data Management	6
320-03-03-02	Guidance, Navigation and Control	6
320-03-03-03	Rendezvous and Docking	6
320-03-03-04	Communications	6
320-03-03-05	Instrumentation	6
320-03-03-06	Electric Power	6
320-03-03-07	Electric Power Distribution & Control	6
320-03-04	Propulsion	5
320-03-04-01	Main Engine	6
320-03-04-02	Feed, Fill and Drain	6
320-03-04-03	Pressurization, Vent and Purge	6
320-03-04-04	Thrust Vector Control	6
320-03-04-05	Propellant Utilization and Propellant Loading Instrumentation	6
320-03-04-06	ACPS Engine	6
320-03-04-07	ACPS Support	6
320-03-05	Integration Assembly and Checkout	5

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-03-05-01	Final Assembly	6
320-03-05-02	Checkout	6
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	6
320-05-02-03	Flight Operations Crew (NASA)	6
320-05-02-04	Flight Operations Crew (DOD)	6
320-05-03	Logistics Operations	5
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
320-07	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
320-08	Vehicle Test	4
320-08-01	Ground Test Hardware	5
320-08-02	Ground Test Operations	5
320-08-03	Flight Test Hardware	5
320-08-04	Flight Test Operations	5
320-09	Launch Operations	4
320-09-01	Launch Operations, ETR	5
320-09-02	Launch Operations, WTR	5
320-10	Flight Operations	4
320-10-01	Flight Operations, ETR	5
320-10-02	Flight Operations, WTR	5
320-11	Refurbishment and Integration	4
320-11-01	Refurbishment and Integration, ETR	5
320-11-02	Refurbishment and Integration, WTR	5
320-15	Software	4
320-15-01	On Board Software	5
320-15-01-01	Tug	6
320-15-01-02	Shuttle	6
320-15-02	Mission Control Software	5
320-15-03	Ground Support Equipment Software	5

IDENTIFICATION NUMBER	ELEMENT	LEVEL
320-16	Orbiter Interface	4
320-16-01	Structural and Mechanical	5
320-16-01-01	Deployment, Rendezvous and Docking	6
320-16-01-02	Tug/Orbiter Supports	6
320-16-01-03	Interface Panels	6
320-16-01-04	Peripheral Equipment	6
320-16-02	Fluids	5
320-16-02-01	Main Propellant Fill, Drain & Dump	6
320-16-02-02	Vent	6
320-16-02-03	Purge	6
320-16-02-04	ACPS Provisions	6
320-16-02-05	Pressurization	6
320-16-03	Avionics	5
320-16-03-01	Data Management	6
320-16-03-02	Guidance, Navigation & Controls	6
320-16-03-03	Rendezvous and Docking	6
320-16-03-04	Communications	6
320-16-03-05	Instrumentation	6
320-16-03-06	Electrical Power	6
320-16-03-07	Electric Power Distribution & Control	6
320-16-03-08	Peripheral Equipment	6
320-16-04	Environmental	5
320-16-04-01	Thermal Control	6
320-16-04-02	Contamination Control	6
320-16-05	Integration, Assembly and Checkout	5

III - SUBDIVISIONS OF WORK (SOW)

The following definitions apply to the six SOW's. Additional SOW's should be avoided.

1. Engineering is the design, development, analysis, evaluation, and redesign of hardware, GSE, and associated planning and analysis activities. It includes such activities as configuration management, the preparation of specifications, drawings, parts lists, wiring diagrams, technical coordination between engineering and other activities, facilities engineering, vendor coordination, test planning and scheduling, analysis of test results, safety analysis, data reduction and engineering report preparation. It also includes the engineering activities required to support Production and the Operational phases. Materials and subcontracts associated with the above activities are included.

2. Manufacturing includes product and materials receiving, warehousing, fabrication, processing, assembly installation, reworking, modifications, experimental production, shop support to engineering checkout, preparation of hardware for shipping and preparation of necessary manufacturing associated paper work. Includes quality control and inspection activities. This SOW also includes technicians who support various test operations as well as launch operations and refurbishment activities. Materials and subcontracts associated with the above activities are included.

3. Tooling & STE includes planning, design, fabrication, quality control and inspection, modification, maintenance, and rework of all tools, dies, jigs, fixtures, gauges, handling equipment, work platforms, and test equipment and Special Test Equipment (STE) in support of the manufacturing process. It also includes writing and planning tool orders, certification of welding operations, maintaining tool and STE records, preparation of templates, scheduling and controlling all tool and STE orders, programming and preparation of tapes for all numerically controlled machine parts, and calibration and periodic maintenance of production and test tooling. It also includes the necessary tooling maintenance for the Production and Operational phases. Materials and subcontracts associated with the above activities are included.

4. Quality and Reliability Assurance (Q&RA) includes the establishment of Q&RA policies, procedures and requirements; Q&RA review of procurement requests and plans; test plans from a Q&RA standpoint and Q&RA report preparation. Develops Q&RA training plans and certification of quality control personnel. Also includes failure review, analysis and reporting. Materials and subcontracts associated with the above activities are included.

5. Testing involves the investigations on all components, assemblies, subsystems, and systems to determine operational characteristics, verify the suitability in meeting the required criteria, and assure compatibility with the overall system and its intended operational/nonoperational environment. Such tests include design feasibility tests, qualification tests, design verification tests, reliability tests, and

bench functional and environmental tests. Monitoring tests, data reduction, and report preparation are also included. Materials and subcontracts associated with the above activities are included.

6. Management/Other includes all management and administrative effort for planning, organizing, coordinating, directing, controlling, and approving that is required to accomplish the program objectives. Other items not included in the preceding subdivisions should be included in this item where possible. Materials and subcontracts associated with the above activities are included.

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.

320-01-01 COST/PERFORMANCE MANAGEMENT

This element includes those activities which assure the integrated planning, scheduling, budgeting, work authorization and cost accumulation of all tasks performed during the Space Tug Program. Also included are project performance planning, preparation and maintenance of the Project Management Plan, project schedules, resource status reports, change controls, data summary analysis, procurement management, and safety management. This element should implement a low-cost plan to assure adherence to the Government's low-cost Tug philosophy and keyed to the project WBS.

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.

320-01-03 INFORMATION MANAGEMENT

This element refers to the overall management process and activities required to ensure proper information and documentation flow and control. Included are information coordination; identification, control and monitor of the preparation and maintenance of documentation; establishment, implementation and maintenance of the Data Management Plan and Procedures; acquisition of data from subcontractors, vendors and others; preparation, maintenance and submittal of the data, data schedules and accession list; establishment, operation, and maintenance of a project level information file; and public relations.

320-02 SYSTEMS ENGINEERING AND INTEGRATION

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 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.

320-02-02 SHUTTLE INTERFACE

This element provides for that engineering effort required to define and maintain a standard Tug interface with the Shuttle, including analysis and identification of Tug test and checkout operations affecting that interface, analysis and identification of Tug systems configuration changes affecting the interface, and evaluation/coordination of recommended changes to the interface.

320-02-03 PAYLOAD INTERFACE

This element includes all systems engineering and integration effort associated with the Tug/Payload interface. Included are system analysis, design, test, and evaluation to ensure the efficient integration of the Tug to the various payloads of the Mission Model; implementation and maintenance of a system to accomplish the Tug/Payload integration; preparation, submittal and maintenance of Interface Control Documents; studies and analyses for system optimization, cost effectiveness and compatibility; technical risk assessment to identify potential major problems; and failure mode and effect analysis on interface hardware, mechanisms and panels which affect payload delivery, retrieval or mission.

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 at the launch sites 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.

320-03 TUG VEHICLE MAIN STAGE

This element summarizes tasks, hardware and services required to design, develop, test, produce, install and checkout all subsystems and the complete Tug vehicle. The subsystems within this element are those that comprise the total Tug and remain with it during all mission phases. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, assembly installation, checkout and procurement efforts required for a completed Space Tug. Production and operational spare for the Tug are included.

320-03-01 STRUCTURE AND MECHANICAL

This element summarizes all work associated with the design, development, test, and production of the Tug structural and mechanical subsystem elements. Included are the initial production and operational spares.

320-03-01-01 FUEL TANK AND SUPPORT

This element covers the structural details, structural subassemblies, brackets and supports of the fuel tank. It encompasses subordinate items such as baffles, level sensors supports, tank supports, basic tank shell, feedline supports, access covers, attachment mechanisms for wiring, etc. Specific inclusions are detail design and analysis; tool engineering and manufacture; procurement of materials and services; development and qualification tests; development and qualification of test fixtures, rigs and set-ups; and manufacture of components, subassemblies, assemblies, and spares.

320-03-01-02 OXIDIZER TANK AND SUPPORT

Same as Fuel Tank and Support (320-03-01-01), plus thrust structure attachment provisions.

320-03-01-03 BODY STRUCTURE

This element is the principal structural entity upon which the propellant tank(s) mount. It consists of the shell structure (comprised of forward skirt, main shell and intertank skirt), forward interface ring, manipulator attach point, access provisions, stage-side umbilicals, and support bracketry for avionics, fuel cell and ACPS components. The portion that remains in the Orbiter is excluded here but included under Orbiter Interface (320-16-01-01).

320-03-01-04 THRUST STRUCTURE

This element is composed of all structural members and subassemblies comprising the interface between the engine and the oxidizer tank.
It includes thrust struts, engine mounting provisions, feed line supports, actuator attach points, and mounting supports for engine fluid and electrical interface lines.

320-03-01-05 METEOROID SHIELD

This item is comprised of any special meteoroid or micrometeoroid protection that may be deemed necessary beyond that provided by the body structure sidewall and the propellant tank insulation.

320-03-01-06 PAYLOAD INTERFACE

This element is comprised of all mechanical devices, electrical power and signal interfaces, pyrotechnics, etc., associated with attachment of the Tug to its payload. The structural interface ring, backup fittings and manipulator attach points are covered in the Body Structure element.

320-03-02 THERMAL CONTROL

This element includes the development, test, fabrication, installation, and checkout of the insulation for the fuel tank, oxidizer tank, and associated bracketry; the insulation purge system; and the vehicle thermal control system. Included are initial production and operational spares.

320-03-02-01 FUEL TANK INSULATION

This element includes the development, test and production of the insulation for the fuel tank. Also included are the procurement and evaluation of mockups and other supporting engineering activities.

320-03-02-02 OXIDIZER TANK INSULATION

Same as Fuel Tank Insulation.

320-03-02-03 INSULATION PURGE SYSTEM

This element includes the insulation purge system including bottles, valves, disconnects, plumbing, regulators, and control provisions.

320-03-02-04 THERMAL CONTROL SYSTEM

This element includes the development, test and production of the vehicle thermal control system. Included are such items as heat pipes, cold plates and active louvres, which are not an inherent part of the components of any subsystem. Thermal control devices or provisions which are an inherent part of a component of another subsystem are included within that subsystem and are excluded from this element.

320-03-03 AVIONICS

This element summarizes tasks, hardware and services to design, develop, test, produce, install and check out the Tug electronic and electrical equipments and the completed avionics subsystems. Tasks include qualification test of components and subsystems, manufacturing and tooling for development, production and operational spares.

320-03-03-01 DATA MANAGEMENT

This element consists of tasks, hardware and services required to provide equipment for the Tug data management subsystem, including data acquisition, computer operation and data processing. Included are such items as central processor, memory units, buffer/formatter, tape recorder and associated interface units. Thermal control provisions are included only if they are inherently part of a component of this subystem. Included are all engineering design and analysis, tooling, manufacturing reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-03-02 GUIDANCE, NAVIGATION AND CONTROL

This element consists of tasks, hardware and services to provide Tug guidance, navigation and electronic/electrical control functions. Included are such items as star trackers, horizon sensors, auto-collimators, IUMs, thermal conditioning systems, rate stabilization systems, and control interfaces for main engine actuators and ACPS actuators. Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-03-03 RENDEZVOUS AND DOCKING

This element consists of tasks, hardware and services required to design, develop, test and produce electronic/electrical Tug equipment necessary to provide Tug/Shuttle and Tug/payload rendezvous and docking functions. Included are items such as a laser radar unit, TV gimbal mounts, camera lights. Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation and associated supporting tasks for this equipment

320-03-03-04 COMMUNICATIONS

This element consists of tasks, hardware and services required to provide Tug communications equipment, such as FM transmitter, PM transponder, antenna, RF multiplexer, power amplifier and associated thermal conditioning. Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are all engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-03-05 INSTRUMENTATION

This element consists of tasks, hardware and services required to provide Tug instrumentation equipment, such as sensors, transducers, signal conditioning and circuitry. Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are all engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-03-06 ELECTRIC POWER

This element consists of tasks, hardware and services to provide Tug electric power sources (e.g., batteries and fuel cells). Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-03-07 ELECTRIC POWER DISTRIBUTION AND CONTROL

This element consists of tasks, hardware and services to provide for the distribution and control of electric power in the Tug. This equipment typically consists of power distribution wiring and connectors, distribution harnesses, power control units, etc. Thermal control provisions are included only when they are an inherent part of a component of this subsystem. Included are engineering design and analysis, tooling, manufacturing reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-03-04 PROPULSION

This element covers the design, development, test, production and maintenance of the main and auxiliary propulsion systems. Included are all propulsion contractor costs incurred in these activities such as direct and indirect labor costs. Integrated testing at the vehicle system level is not included. Initial production and operational spares are also included.

320-03-04-01 MAIN ENGINE (GFE)

This element includes all deliverable main engines required for DDT&E activities, production and operational spare engines. All main engine DDT&E required to modify existing engines are included.

320-03-04-02 FEED, FILL AND DRAIN

This level 6 element is comprised of all lines, valves, ducts, bellows and other components that transfer the main engine oxidizer/fuel from the tanks to the main engine. Also included are all lines, ducts, valves, and other components required to fill and drain the main propellant tanks between the interface panel with the Orbiter or deployment adapter and the main tanks which are filled and drained.

320-03-04-03 PRESSURIZATION, VENT AND PURGE

This level 6 element is composed of all lines, valves, ducts, bellows and other components that take pressurization gases from the engine to the main fuel tank, and the lines, valves, ducts, bellows, storage tank and other components which provide pressurization gas to the oxidizer tanks. It also consists of those components that are required to provide for propellant vent and for carrying pressurization gas for the main oxidizer and main fuel tanks for dumping propellant overboard. Also included are those provisions required to provide gas purge of required vehicle areas.

320-03-04-04 THRUST VECTOR CONTROL

This element consists of the thrust vector control power conversion and distribution system elements and such other mechanisms or components as are required to orient and control the thrust vector of the main engine. It includes engine actuators and the associated valve controls or switches.

320-03-04-05 PROPELLANT UTILIZATION (PU) AND PROPELLANT LOADING INSTRUMENTATION SYSTEM (PLIS)

The PLIS senses liquid level in the propellant tanks and senses propellant mass during tanking and prior to flight. Propellant utilization consists of the controls of propellant use so as to minimize residual weight of one at depletion of the other. It includes the engine mixture ratio controls. Also included are provisions for electric signals of proportional to simulated mass through vehicle umbilicals to ground monitoring equipment.

320-03-04-06 ACPS ENGINE

This element covers tasks, hardware and services necessary to design, develop, test, produce and maintain the entire ACPS except the plumbing and tanks. Included are all test hardware, test operations and test propellants. Installation and testing at the Space Tug vehicle level is not included.

320-03-04-07 ACPS ENGINE SUPPORT

This element covers the tanks (including their internal propellant acquisition devices), propellant and pressurization lines and valves of the ACPS. This element is a separate item due to the large amount of lines included in some Space Tug ACPS concepts. Also included are thermal conditioning provisions.

321-03-05 INTEGRATION, ASSEMBLY AND CHECKOUT

This element consists of tasks, material and services required for integrated Tug subsystems manufacture, and the assembly, checkout and acceptance of these subsystems. Items are included herein only if they are in the nature of overall manufacturing integration of interface WBS elements and/or involve two or more subsystems and hence are not identifiable to a single subsystem WBS element.

320-03-05-01 FINAL ASSEMBLY

This element covers the "prime" contractor activities in integrating and assembling the Space Tug elements and subsystems into an operational vehicle. Included are those activities required for packaging and preparation to ship.

320-03-05-02 CHECKOUT

This element includes all system calibration and checkout, as well as necessary acceptance testing, to validate the vehicle operational capability and readiness.

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.

320-05-01 TRANSPORTATION AND HANDLING

This element refers to the preparation for and transportation of major items of Tug and interface equipment and hardware which have special requirements due to their size, weight, shape, or environmental control. Transportation of items not requiring such special considerations is included within the specific interface or ground subsystem element.

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.

320-05-02-01 SIMULATORS AND EQUIPMENT

This element refers to the cost for the design, development and manufacture of those distinctive end items required specifically to meet training objectives. Included are operational maintenance trainers, cutaways, and models.

320-05-02-02 GROUND CREW

This element includes the cost of instruction, audio-visual teaching aids and accessories required to train the personnel to support and maintain the Tug and Tug/Shuttle interface subsystems. Also included are training information, documentation, and the effort to determine the training requirements.

320-05-02-03 FLIGHT OPERATIONS CREW (NASA)

This element includes the cost of instruction, audio-visual teaching aids and accessories required to train the personnel to operate and/or maintain the Tug and equipment required to support flight operations at tracking stations and flight operations center.

320-05-02-04 FLIGHT OPERATIONS CREW (DOD)

Same as 320-05-02-03, except for DOD.

320-05-03 LOGISTICS OPERATIONS

This element refers to development of integrated logistic support (ILS) of the Tug, and the management of spares and repair parts and other specialized logistics in support of the Tug system during development and operations. This element includes the determination and management of spares quantity, procurement, warehousing, distribution and transportation. It also includes maintenance of spares status and logistics of repairable items to support servicing and maintenance of the Tug Vehicle and Tug support equipment during development. The cost of spares and repair parts (S&RP) and rework costs are not included. S&RP are included under each Tug Subsystem element and the ground support equipment element.

320-06 FACILITIES

This element covers facilities (new or modification to existing) for manufacture, test, maintenance, refurbishment, and launch support of an operational program. Note that the basic launch and operations facilities are charged to the Shuttle. However, those launch site 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.

320-06-01 MANUFACTURING

This element includes all additional and modifications to existing government facilities and private facilities which are needed for Tug and Tug/Shuttle interfaces. It includes new facilities and equipment for the manufacture and checkout of subsystems, and intersite transportation facilities, such as docks, ramps, pads, air strips, etc.

320-06-02 TEST

This element includes all additional or modifications to existing facilities required for testing the Tug and Tug/Shuttle interface subsystems, and major test items as well as those required for development of new technology.

320-06-03 MAINTENANCE AND REFURBISHMENT

This element includes all additional or modifications to existing facilities required for maintenance and refurbishment of the operational Tug and Tug/Shuttle interface subsystems. Maintenance and refurbishment facilities include those necessary to accomplish on-site maintenance and repair, field site modifications, post-maintenance checkout, refurbishment, and equipment storage.

320-06-04 ETR LAUNCH

This element includes all additional or modification to existing launch facilities at the Eastern Test Range for the Tug and Tug/Shuttle interface equipments. Only the additional facilities built or modified specifically to configure the launch facilities for Tug/Shuttle interface acceptance are included.

320-06-05 WTR LAUNCH

This element includes all additions or modifications to existing launch facilities at the Western Test Range for Tug and Tug/Shuttle interface equipment. Only the additional facilities built or modified specifically to configure the launch facilities for interface acceptance are included.

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 activation, and maintenance peculiar to interface ground operations for manufacturing and launch. All common DDT&E GSE costs will be charged to ETR since it will be the first activated. Therefore, the only DDT&E charged to WTR will be that for GSE which is peculiar to WTR. GSE spares are also included.

320-07-01 MANUFACTURING AND TEST GSE

This element is composed of all factory support equipment required to support the Tug system manufacturing operations and checkout, and the peculiar GSE which is required only for the R&D test program. This element also includes design, fabrication, integration, documentation, and qualification of all ground support equipment for manufacturing and test. Items included are hardware, site activation of GSE, maintenance, and any non-deliverable support equipment as well as associated spares.

320-07-02 EASTERN TEST RANGE GSE

This element includes all ground-based equipment required to support launch, flight, recovery and maintenance of the Space Tugs during both flight tests and operations. This element also includes design, modification, fabrication, integration, documentation, and qualification of the launch site and Tug GSE associated with flight hardware. Items included are hardware, site activation of GSE, and maintenance. The first set of launch site GSE produced can be used during the vehicle test program (Element #320-08).

320-07-03 WESTERN TEST RANGE GSE

Same as 320-07-02

320-08 VEHICLE TEST

This element includes the effort to plan and perform integrated system and subsystem level tests on the Tug and Tug/Shuttle interface equipment for both ground and flight testing. Included are ground test hardware, ground test operations, flight test hardware, and flight test operations. Included are major hardware articles such as fuel tank, oxidizer tank, thrust structure, battleship vehicle, flight test vehicles, mockups, etc. Hardware for subsystem test and qualification is excluded from this element, but is included with their design and development cost. Propellants and gases are included under the appropriate test operations.

320-08-01 GROUND TEST HARDWARE

This element includes the fabrication, assembly, installation, quality assurance, and checkout of major test articles, and mockups. The subsystem hardware installed on the test articles is included.

320-08-02 GROUND TEST OPERATIONS

This element includes the test management, requirements development and test planning activities for the vehicle level test programs. The preparation of the test articles for test; design of test fixtures; set-up, performance of tests and teardown; and data reduction/analysis and report generation are included. Propellants and gases required for ground test activities are also included.

320-08-03 FLIGHT TEST HARDWARE

This element includes the fabrication, assembly, installation, quality assurance, and checkout of all test hardware used for flight tests. Refurbishment of test articles for another major test is also included.

320-08-04 FLIGHT TEST OPERATIONS

This element includes dedicated vehicle test flights and associated activities only. A dedicated test flight is a vehicle flight for test purposes only and does not carry an operational payload. It includes all activities that support such test flight programs from the planning to launch, actual flight and return. All Tug and Tug/Shuttle interface systems launch support, operations support (i.e., countdown, tracking, etc.) data analysis and evaluation are included. Propellants and gases are also included. Excluded are activities associated with flights that carry an operational payload. These are to be included under the appropriate operational elements even though the flight may, as a secondary purpose, serve as a test flight.

320-09 LAUNCH OPERATIONS

This element summarizes services and operations required to perform those activities that comprise pre-launch and launch tasks for Tug and Tug/Shuttle interface elements. These activities include launch site services/support, mating and checkout, propellants and gases, pre-launch checkout, countdown, and post flight safing.

320-09-01 LAUNCH OPERATIONS, EASTERN TEST RANGE

This element consists of services and launch tasks which support Tug and Tug/Shuttle interface subsystems during pre-launch and launch operations.

320-09-02 LAUNCH OPERATIONS, WESTERN TEST RANGE

Same as 320-09-01

320-10 FLIGHT OPERATIONS

This element summarizes flight operations tasks and services directly related to Tug and Tug/Shuttle interface equipment aspects of missions. These activities include mission planning, flight control and flight evaluation related to interface subsystems.

320-10-01 FLIGHT OPERATIONS, EASTERN TEST RANGE

This element consists of tasks and services required to support Tug and Tug/Shuttle interface aspects of flight operations.

320-10-02 FLIGHT OPERATIONS, WESTERN TEST RANGE

Same as 320-10-01

320-11 REFURBISHMENT AND INTEGRATION

This element summarizes efforts for restoring the reusable Tug and Tug/Shuttle interface subsystems after each mission to a readiness condition for subsequent missions. This activity is completed when the Tug and interface equipment are ready for launch operations. It includes both refurbishment and normal turnaround maintenance and checkout between flights, both scheduled and unscheduled. Also included are preflight requirement planning efforts, such as inspection requirements, reliability vs. refurbishment trade offs, Tug-to-Payload mating and checkout. Hardware costs for spares are excluded from this element but are included under interface subsystem elements.

320-11-01 REFURBISHMENT AND INTEGRATION, EASTERN TEST RANGE

This element consists of refurbishment and integration tasks to make Tug and Tug/Shuttle interface equipment used for one mission fully ready for the subsequent mission at ETR.

320-11-02 REFURBISHMENT AND INTEGRATION, WESTERN TEST RANGE

Same as 320-11-01, except at WTR.

320-15 SOFTWARE

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

320-15-01 ONBOARD SOFTWARE

This element consists of tasks and services required to analyze, design, develop, simulate, verify, and maintain software for use onboard the Shuttle or Tug to support Tug and Tug/Shuttle interface requirements.

320-15-01-01 TUG ONBOARD SOFTWARE

This element consists of tasks and services for software which is required for Tug onboard subsystems.

320-15-01-02 SHUTTLE ONBOARD SOFTWARE

This element consists of tasks and services for software which are generated by Tug requirements, but which is for Shuttle subsystems or subsystems which remain with the Shuttle during the Tug flight portion of the missions.

320-15-02 MISSION CONTROL SOFTWARE

This element consists of tasks and services required to analyze, design, develop, simulate, verify, and maintain Tug and Tug/Shuttle interface software used in ground mission control systems.

320-15-03 GROUND SUPPORT EQUIPMENT SOFTWARE

This element consists of tasks and services required to analyze, design, develop, simulate, verify and maintain Tug and Tug/Shuttle interface software for GSE at the manufacturing, refurbishment and launch site.

320-16 ORBITER INTERFACE

This element summarizes tasks and services required to design, develop, test, produce, install and checkout all hardware required to mate the Tug with the Shuttle, link with and separate from it. Hardware includes that which remains in the Shuttle during the Tug flight portion of the mission. Included is the equipments for operational docking/undocking of the Tug and Shuttle, abort provisions, alignment and energy absorption, retraction/extension support, reentry purge, avionics interface, and umbilical disconnects in the fluid/electrical interface. Initial production and operational spares are included.

320-16-01 STRUCTURE AND MECHANICAL

This element summarizes tasks, hardware and services required to design, develop, test, produce, install and checkout structural and mechanical Tug/Shuttle interface equipments. These equipments consist of structural/mechanical portions of items required for Tug deployment, rendezvous and docking; interface panels, Tug/Orbiter supports, and supports for interfacing subsystems. Tasks include qualification test of components and subsystems, manufacturing and tooling for development, production and operational spares.

320-16-01-01 DEPLOYMENT, RENDEZVOUS AND DOCKING

This element consists of tasks, hardware and services required to design, develop, test and produce structural and mechanical hardware for Tug/Shuttle deployment, rendezvous and docking interfaces. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment within this element may consist of such items as deployment position control mechanisms and locks, Tug/adapter alignment/attenuation provisions, Tug/adapter separation latches and actuators. attachment fittings for Orbiter Remote Manipulation System, and deployment adapter structure.

320-16-01-02 INTERFACE PANELS

This element consists of tasks, hardware and services required to design, develop, test and produce structural and mechanical interface panels for the Tug/Shuttle interfaces. Engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated support for structural and mechanical interface panels is included. Interface panels typically consist of such items as electrical, fuel and oxydizer umbilical panels; and panel position control mechanisms.

320-16-01-03 TUG/ORBITER SUPPORTS

This element consists of tasks, hardware and services required to design, develop, test and produce structural and mechanical supports for the Tug/Orbiter interface. Engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated support for Tug/Orbiter supports are included. These supports typically consist of structural interface fittings, load balancing system elements, and deployment adapter.

320-16-01-04 PERIPHERAL EQUIPMENT

This element consists of tasks, hardware and services required to design, develop, test and produce structural and mechanical items required for Tug/Shuttle interface, but which may not be included in other structure/mechanical elements. Typical of this element are the various structural and mechanical support provisions required by other interface subsystems (e.g., fluids, avionics, etc.).

320-16-02 FLUIDS

This element summarizes tasks, hardware and services required to design, develop, test, produce, install and checkout Tug/Shuttle interface fluid subsystems. These items consist of main propellant fill, drain, dump, vent and purge provisions between the Tug and Shuttle and through the Shuttle and similar Attitude Control propellant provisions as required. Tasks include qualification test of components and subsystems, manufacturing and tooling for development, production and operational spares.

320-16-02-01 MAIN PROPELLANT FILL, DRAIN AND DUMP

This element consists of tasks, hardware and services required to design, develop, test and produce Tug/Shuttle main propellant fill, drain and dump interface equipments. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment within this element typically consists of lines, valves, ducts, bellows and other components between the Tug and Orbiter and within the Orbiter that are required to fill, drain and dump Tug main propellants from Tug tanks overboard through the Orbiter. Also included are special propulsion interfaces of those types necessary to mate/demate fill and drain functions when the Tug is entering or leaving the payload bay.

320-16-02-02 VENT

This element consists of tasks, hardware and services required to design, develop, test and produce Tug/Shuttle interface equipments for venting of Tug propellants and/or gases overboard through the Orbiter. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment within this element typically consists of lines, valves, ducts, bellows, and other components required between the Tug and Orbiter and within the Orbiter to provide for carrying pressurization gas from Tug main propellant tanks for dumping propellants overboard. Also included are special vent interface provisions of the above types to accomplish mate/demate when the Tug is entering or leaving the Orbiter payload bay.

320-16-02-03 PURGE

This element consists of tasks, hardware and services required to design, develop, test and produce Tug/Shuttle equipments for purging propellants and gases from Tug tanks and lines overboard through the Orbiter. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment within this element typically consists of lines, valves, ducts, bellows, storage tank and other components installed between the Tug and Orbiter and within the Orbiter to provide gas purge of required vehicle areas. Also included are the provisions for purge required for mate/demate when the Tug is leaving and/or entering the Orbiter payload bay.

320-16-02-04 ATTITUDE CONTROL PROPULSION SYSTEM (ACPS) PROVISIONS

This element consists of tasks, hardware and services required to design, develop, test and produce Tug/Shuttle interface equipment to accommodate the Tug ACPS within the Orbiter and while linking with or separating from it during the mission. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment within this element typically consists of lines, valves, flex joints, couplings, etc., installed between Tug and Orbiter and within the Orbiter to provide for fill and drain of Tug ACPS propellants and gases when the Tug is in the Orbiter payload bay. Also included are interfaces for handling ACPS propellants and gases mate/demate when the Tug is entering or leaving the payload bay.

320-16-02-05 PRESSURIZATION

This element consists of tasks, hardware and services required to design, develop, test and produce Tug/Shuttle interface equipment to provide for pressurization of Tug main propellant tanks and/or vehicle areas while the Tug is within the Orbiter and for mate/demate during the mission. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment. Equipment in this element typically consists of lines, valves, ducts, bellows and other components between the Tug and Orbiter and within the Orbiter that provide pressurization gas to Tug tanks and vehicle areas while the Tug is in the Orbiter. Also included are these items required for mate/demate when the Tug is entering or leaving the Orbiter payload bay.

320-16-03 AVIONICS

This element summarizes tasks, hardware and services to design, develop, test, produce, install and check out the electronic and electrical equipments that provide Tug/Shuttle interfaces while the Tug is in the Orbiter payload bay and while it is entering or leaving it during a mission. Tasks include qualification test of components and subsystems, manufacturing and tooling for development, production and operational spares.

320-16-03-01 DATA MANAGEMENT

This element consists of tasks, hardware and services required to provide equipment for Tug/Shuttle hardware data exchange and processing while the Tug is in the Orbiter bay and when it is entering or leaving it during a mission. Included are all engineering design and analysis, tooling, manufacturing reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-03-02 GUIDANCE, NAVIGATION AND CONTROL

This element consists of tasks, hardware and services to provide guidance, navigation and electronic/electrical control functions between the Tug and Shuttle while the Tug is in the Orbiter payload bay and while it is leaving or entering the bay during a mission. Included are engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-03-03 RENDEZVOUS AND DOCKING

This element consists of tasks, hardware and services required to design, develop, test and produce electronic/electrical interface equipment necessary to provide Tug/Shuttle and Tug/Payload rendezvous and docking functions in addition to the functions provided by standard on board Shuttle and Tug equipments. Included are engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation and associated tasks for this equipment.

320-16-03-04 COMMUNICATIONS

This element consists of tasks, hardware and services required to provide communications equipment for the Tug/Shuttle interface during all launch and flight mission phases. Included are all engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-03-05 INSTRUMENTATION

This element consists of tasks, hardware and services required to provide instrumentation equipment for the Tug/Shuttle interface provisions. Included are all engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-03-06 ELECTRIC POWER

This element consists of hardware, tasks and services to design, develop, test and produce electrical power sources (e.g., batteries and fuel cells) and/or associated provisions within the Tug/Shuttle interface. In the case of a fuel cell the associated reactant supply and storage, venting, product water, purge, and thermal control provisions are included. Included are the associated Tug/Orbiter mate/demate provisions.

320-16-03-07 ELECTRIC POWER DISTRIBUTION AND CONTROL

This element consists of tasks, hardware and services to provide for the distribution and control of electric power in the Tug/Shuttle interface. This equipment typically consists of power distribution wiring and connectors, distribution harnesses, etc. Included are engineering design and analysis, tooling, manufacturing reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-03-08 PERIPHERAL EQUIPMENT

This element consists of tasks, hardware and services required to design, develop, test and produce electronic and electrical equipments required for Tug/Shuttle interface, but which may not be included in other avionics elements.

320-16-04 ENVIRONMENTAL

This element summarizes tasks, hardware and services required to design, develop, test, produce, install and checkout Tug/Shuttle interface environmental control equipment. This equipment typically includes thermal control items, such as heat dissipation devices and insulation, and equipment required to control/prevent contamination in critical areas of the vehicle. Tasks include qualification test of components and subsystems, manufacturing and tooling for development, production, and operational spares.

320-16-04-01 THERMAL CONTROL

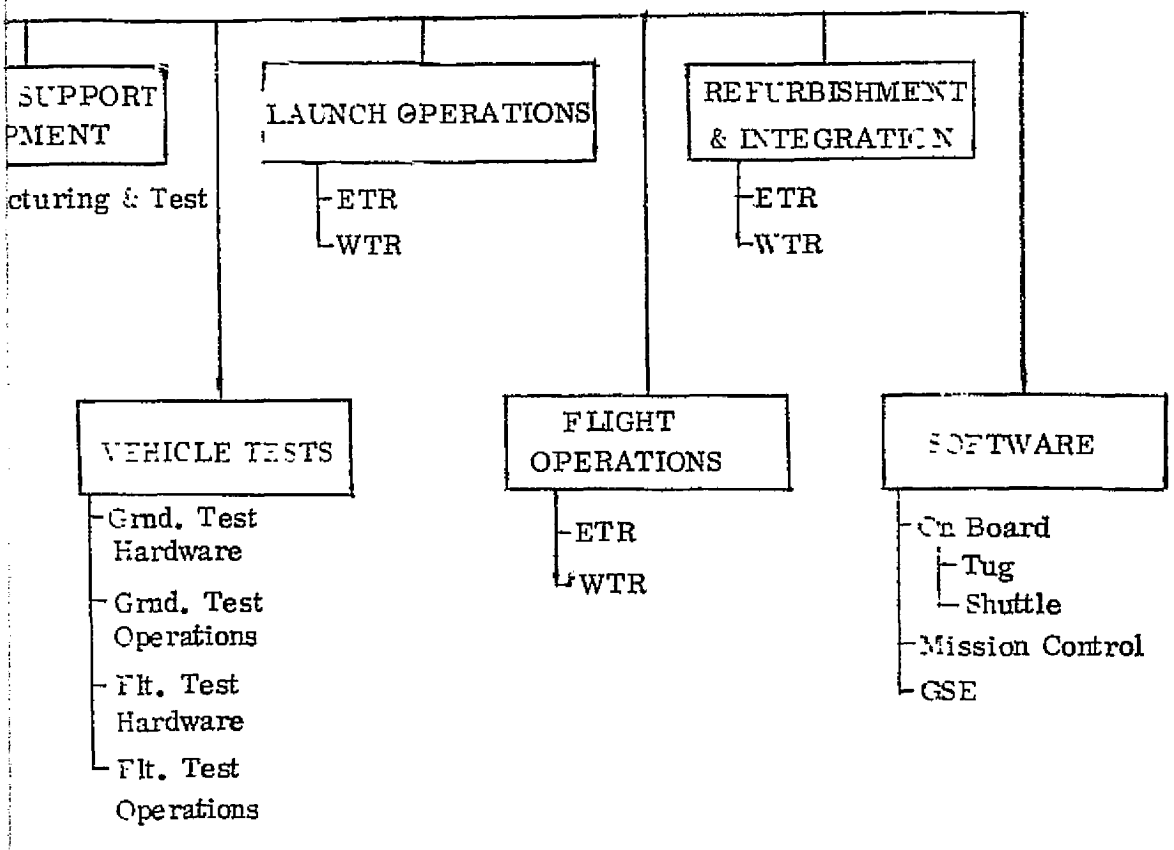
This element consists of active subsystems hardware and passive (e.g., insulation) provision for control of temperature in critical Tug/Shuttle interface areas. Thermal control devices or provisions which are an inherent part of a component of another subsystem are included within that subsystem element and are excluded from this element. Included are all engineering design and analysis, tooling, manufacture, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

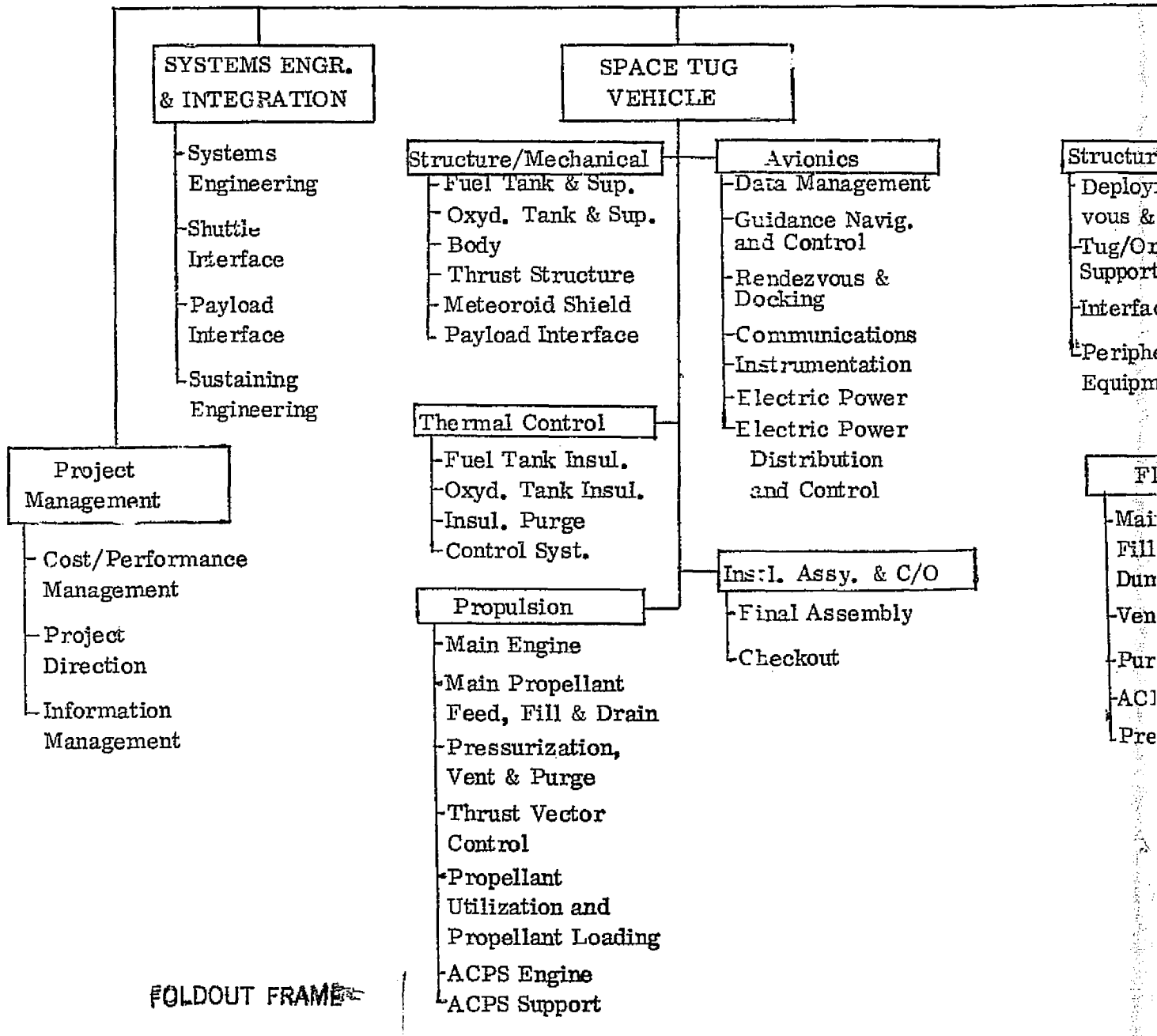
320-16-04-02 CONTAMINATION CONTROL

This element consists of tasks, hardware and services required to provide subsystems for control of contamination in critical vehicle areas of the Tug/Shuttle interface. Included are engineering design and analysis, tooling, manufacturing, reliability and quality assurance, test and evaluation, and associated supporting tasks for this equipment.

320-16-05 INTEGRATION, ASSEMBLY AND CHECKOUT

This element consists of tasks, material and services required to integrated Tug/Shuttle interface subsystems manufacture, and the assembly, checkout and acceptance of these subsystems. Items are included herein only if they are in the nature of overall manufacturing integration of interface WBS elements and/or involve two or more subsystems and hence are not identifiable to a single subsystem WBS element.





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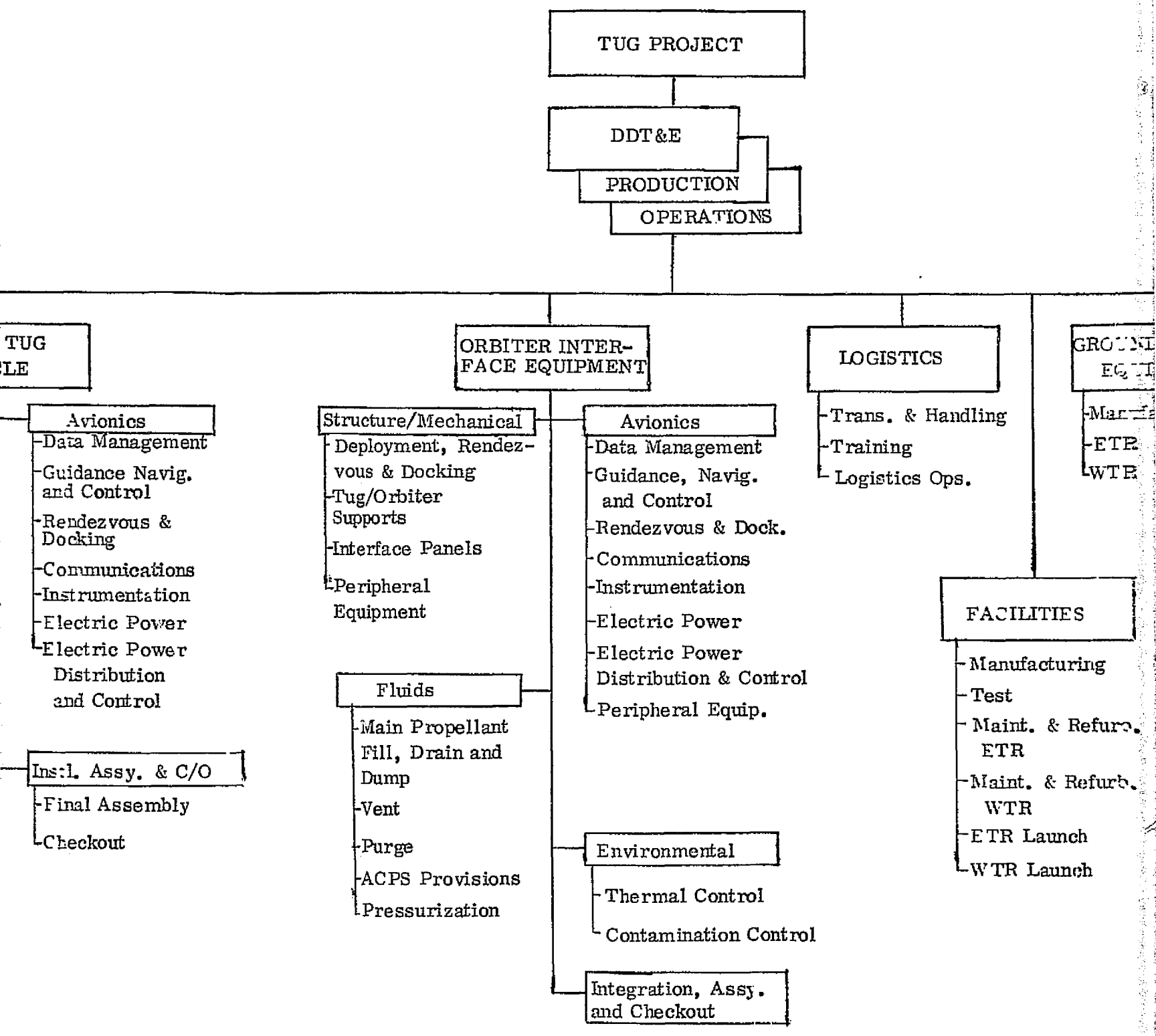

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APPENDIX B

NASA DETAILED COST REPORT FORMS

CONTENTS

SPACE TUG/SHUTTLE INTERFACE DEFINITION STUDY

CONTRACT NAS8-31012

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

DATE 5/5/75

PAGE 1 OF 1

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	EXPECT. COST	CONFID. RATING	T_d	T_s	SPREAD FUNCT.
320-16	Orbiter Interface	4	((11,703))				
320-16-01	Structure/Mechanical	5	(4,511)				
320-16-01-01	Deployment, RDVU & Docking	6	931	3	34	12/78	3
320-16-01-02	Tug/Orbiter Supports	6	2,690	3	30	12/78	3
320-16-01-03	Interface Panels	6	538	3	24	12/78	4
320-16-01-04	Peripheral Equipment	6	352	3	24	12/78	3
320-16-02	Fluids	5	(2,558)				
320-16-02-01	Main Propellant Feed, Fill, Drain	6	736	3	26	12/78	4
320-16-02-02	Vent	6	650	3	26	12/78	4
320-16-02-03	Purge	6	536	3	24	12/78	3
320-16-02-04	ACPS Provisions	6	121	3	18	12/78	3
320-16-02-05	Pressurization	6	515	3	24	12/78	4
320-16-03	Avionics	5	(3,288)				
320-16-03-01	Data Management	6	1,365	3	22	12/78	3
320-16-03-05	Instrumentation	6	1,234	3	18	12/78	3
320-16-03-06	Electric Power	6	689	3	18	12/78	3
320-16-05	Integration, Assembly & Checkout	5	1,346	3	12	1/80	4
320-15-01-01	On Board Software	6	1,260	3	30	1/81	3
320-06-01	Ground Test Hardware	5	2,692	3	18	1/80	3

SPACE TUG/SHUTTLE INTERFACE DEFINITION STUDY

CONTRACT NUMBER – NAS8-31012

COST DATA FORM – A(2)
RECURRING (PRODUCTION)

DATE 5/5/75

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	1st UNIT COST T_1	EXPECTED COST	REF. UNIT*	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT.	LEARN INDEX
320-16	Orb. Interface	4			((16, 833))							
320-16-01	Structure/ Mechanical	5			(4, 914)							
320-16-01-01	Depl., RDVU, & Docking	6	5	218	1, 016	1		3	26	1/ 81	6	.95
320-S16-01-01	Depl., RDVU, & Docking Spares	6	0.75	218	164	1						1.00
320-16-01-02	Tug/Orb. Supports	6	5	631	2, 942	1		3	26	1/ 81	6	.95
320-S16-01-02	Tug/Orb. Supports Spares	6	0.75	631	473	1						1.00
320-16-01-03	Interface Panels	6	5	20	93	1		3	26	1/ 81	6	.95
320-S16-01-03	Interface Panels Spares	6	0.75	20	15	1						1.00
320-16-01-04	Peripheral Equip.	6	5	39	182	1		3	26	1/ 81	6	.95
320-S16-01-04	Peripheral Equip. Spares	6	0.75	39	29	1						1.00
320-16-02	Fluids	5			(3, 523)							
320-16-02-01	Main Prop. F. F. &D.	6	5	96	448	1		3	26	1/ 81	6	.95
320-S16-02-01	Main Prop. F. F. &D. Spares	6	4.16	96	399	1						1.00
320-16-02-02	Vent	6	5	59	275	1		3	26	1/ 81	6	.95
320-S16-02-02	Vent Spares	6	4.16	59	245	1						1.00
320-16-02-03	Purge	6	5	83	387	1		3	26	1/ 81	6	.95
320-S16-02-03	Purge Spares	6	4.16	83	345	1						1.00
320-16-02-04	ACPS Provisions	6	5	30	140	1		3	26	1/ 81	6	.95
320-S16-02-04	ACPS Provisions Spares	6	1.02	30	31	1						1.00
320-16-02-05	Pressurization	6	5	142	662	1		3	26	1/ 81	6	.95
320-S16-02-05	Pressurization Spares	6	4.16	142	591	1						1.00
320-16-03	Avionics	5			(7, 268)							
320-16-03-01	Data Management	6	5	278	1, 296	1		3	26	1/ 81	6	.95
320-S16-03-01	Data Management Spares	6	1.36	278	378	1						1.00
320-16-03-04	Instrumentation	6	5	494	2, 303	1		3	26	1/ 81	6	.95
320-S16-03-05	Instrumentation Spares	6	0.5	494	247	1						1.00
320-16-03-06	Electric Power	6	5	342	1, 594	1		3	26	1/ 81	6	.95
320-S16-03-06	Electric Power Spares	6	4.24	342	1, 450	1						1.00
320-16-05	Integ., Assy. & C	5	5	260	1, 128			3	20	11/ 81	6	.90
			* See Column Titled 1st Unit Cost T_1									

See Column Titled 1st Unit Cost T_1

SPACE TUG/SHUTTLE INTERFACE DEFINITION STUDY
CONTRACT NUMBER – NAS8-31012

COST DATA FROM – A(3)
RECURRING (OPERATIONS)

DATA 5/5/75
PAGE 1 OF 1

IDENTIFICATION NUMBER	WBS IDENTIFICATION	WBS LEVEL	NO. OF UNITS	EXPECT COST	REF. UNIT	REF. UNIT COST	CONFID. RATING	T_d	T_S	SPREAD FUNCT.	LEARN INDEX
320-16	Orbiter Interface	4		((3,220))							
320-16-01	Structure/Mechanical	5		(1,449)							
320-16-01-01	Deployment,RDVU. & Docking	6	1.5960	348	1	218	3	93	10/83	6	1.00
320-16-01-02	Tug/Orbiter Supports	6	1.5960	1,007	1	631	3	93	10/83	6	1.00
320-16-01-03	Interface Panels	6	1.5960	32	1	20	3	93	10/83	6	1.00
320-16-01-04	Peripheral Equipment	6	1.5960	62	1	39	3	93	10/83	6	1.00
320-16-02	Fluids	5		(314)							
320-16-02-01	Main Propellant FF&D	6	.7728	74	1	96	3	93	10/83	6	1.00
320-16-02-02	Vent	6	.7728	46	1	59	3	93	10/83	6	1.00
320-16-02-03	Purge	6	.7728	64	1	83	3	93	10/83	6	1.00
320-16-02-04	ACPS Provisions	6	.6720	20	1	30	3	93	10/83	6	1.00
320-16-02-05	Pressurization	6	.7728	110	1	142	3	93	10/83	6	1.00
320-16-03	Avionics	5		(1,457)							
320-16-03-01	Data Management	6	.5040	140	1	278	3	93	10/83	6	1.00
320-16-03-05	Instrumentation	6	1.8984	938	1	494	3	93	10/83	6	1.00
320-16-03-06	Electric Power	6	1.1088	379	1	342	3	93	10/83	6	1.00

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatability

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-01	Deploy, Rendezvous and Docking				
	Position Control and Alignment				
	Actuators			Commercial Aircraft Type	
		2	Each	Quantity	
		22 (10)	Lb (Kg)	Weight	
	Support Fittings			Machined Aluminum	
		4	Each	Quantity	
		39 (17.7)	Lb (Kg)	Weight	
	Guide Fittings			Machined Aluminum	
		2	Each	Quantity	
		20 (9.1)	Lb (Kg)	Weight	
	Structural Latches				
	Actuators, Mechanisms & Supports				
		11	Each	Quantity	
		117 (53)	Lb (Kg)	Weight	

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-02	Interface Panels:				
	Electrical Panels	22 (10)	Lb (Kg)	Weight	
	Basic Panel			Machined Aluminum	
		2	Each	Quantity	
	Supports/Guides			Machined Aluminum	
		6	Each	Quantity	
	Oxidizer Panels	25 (11.3)	Lb (Kg)	Weight	
	Basic Panels			Machined Aluminum	
		1	Each	Quantity	
	Supports/Guides			Aluminum	
		3	Each	Quantity	
	Fuel Panels	25 (11.3)	Lb (Kg)	Weight	
	Basic Panel			Machined Aluminum	
		1	Each	Quantity	
	Supports/Guides			Aluminum	
		3	Each	Quantity	

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-03	Tug-Orbiter Supports			DESIGN CRITERIA	
		1.4 (Ult); 1.1 (Yield)	-	Safety factors	
		70 (294)	°F (°K)	Datum temp or strength allowables	
		-200 to +250 (144 to 394)	°F (°K)	Operating temp range	
				SUPPORT/DEPLOYMENT ADAPTER	
				Geometry	
		74.60 (189.5)	in. (cm)	Length	
		176.0 (447.0)	in. (cm)	Diameter (outside)	
				Structural Description	
		Frame Stabilized Sandwich	-	Sidewall concept	
		Graphite/epoxy	-	Facing material	
		.012-.038 (.030-.097)	in. (cm)	Thickness range	
		HRP	-	Core material	
		0.615 (1.56)	in. (cm)	Depth	
		4.0 (10.2)	lb/ft^3 (g/cm^3)	Density	
		Scrim-reinforced	-	Adhesive Type	
		220.0 (99.9)	lb_m (Kg)	Weight	
		Machined, tapered	-	Latch longeron type	
		Aluminum	-	Material	
		11	-	Quantity	
		22.3 (10.1)	lb_m (Kg)	Weight (total)	
		X_o 1172.9	-	Fwd ring station	
		Angle		Cross-section config.	
		Aluminum	-	Material	
		13.0 (5.9)	lb_m (Kg)	Weight	

TECHNICAL CHARACTERISTICS DATA FORM B

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-03 (Continued)	Tug-Orbiter Supports (Cont)	X_o 1181.0	-	"Kick" frame station	
		J	-	Cross-section config.	
		6.0 (15.2)	in (cm)	Depth	
		Solid laminate caps, sandwich web	-	Design concept	
		Graphite/epoxy	-	Cap, web facing material	
		HRP	-	Web core material	
		26.2 (11.9)	lb_m (Kg)	Weight	
		X_o 1202.7 1224.3	-	Stabilizing frame stations	
		I	-	Cross-section config.	
		2.5 (6.4)	in. (cm)	Depth	
		Co-cured solid laminate	-	Design concept	
		Graphite/epoxy	-	Material	
		9.8 (4.4)	lb_m (Kg)	Unit weight	
		X_o 1246.0	-	Aft frame station	
		I	-	Cross-section config.	
		8.0 (20.3)	in. (cm)	Depth	
		Solid laminate caps sandwich web	-	Design concept	
		Graphite/epoxy	-	Cap, web facing material	
		HRP		Web core material	
		60.4 (27.4)	lb_m (Kg)	Weight	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-03 (Continued)	Tug-Orbiter Supports (Cont)			STRUCTURAL INTERFACE DR-1 FITTINGS	
		Z-only	-	Support reaction component	
		X_o 951	-	Orbiter station location	
		2	-	Quantity of fittings	
		45.2 (192.2)	klb_f (kN)	Max. limit reaction	
		Turned shaft in machined, welded hub	-	Design concept	
		≥260 (1793)	ksi (mPa)	Shaft ultimate strength	
		Titanium	-	Hub material	
		28.9 (13.1)	lb_m (Kg)	Unit weight	
		Y-only	-	Support reaction component	
		X_o 951; X_o 1181	-	Orbiter station locations	
		1; 1	-	Quantity	
		27.6 (122.8); 30.0 (133.4)	klb_f (kN)	Max limit reaction	
		Machined beam with local bearing cap	-	Design concept	
		Aluminum	-	Beam material	
		Steel	-	Cap material	
		16.9 (7.7); 13.1 (5.9)	lb_m (Kg)	Weight	
		X/Z	-	Support reaction component	
		X_o 1246	-	Orbiter station location	
		2	-	Quantity of fittings	
		101.4 (451.0)	klb_f (kN)	Max limit X-reaction	

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Study Title - Space Tug/Shuttle Interface Compatibility

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-03 (Continued)	Tug-Orbiter Supports (Cont)	X/Z (Cont)			
		42.9 (190.8)	klb_f (kN)	Max limit Z-reaction	
		Turned shaft in machined, welded hub & longeron assy	-	Design concept	
		≥260 (1793)	ksi (mPa)	Shaft ultimate strength	
		Titanium	-	Hub, longeron material	
		64.9 (29.5)	lb_m (Kg)	Unit weight	

TECHNICAL CHARACTERISTICS DATA FORM B

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-01-04	Peripheral Equipment	Misc. Brackets, Clips, etc.	-	Subsystem Support Provisions	
		Aluminum	-	Material	
		37.0 (16.8)	lb_m (Kg)	Weight	

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-01	Main Propellant, Fill, Drain, and Dump	Liquid Oxygen System	-	DESIGN CRITERIA	
		Liquid Oxygen	-	Fluid contained	
		163 (91)	°R (K)	Minimum temperature	
		560 (311)	°R (K)	Maximum temperature	
		28.5 (20)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
			lb/sec (Kg/sec)	Design flow rate	
		30 (14)		Fill	
		30 (14)		Drain	
		147 (67)		Dump	
				LINE DESCRIPTION	
		Uninsulated	-	Type	
		4.0 (10.2)	in. (cm)	Diameter	
		301 (765)	in. (cm)	Length	
		7	number	Flex joints	
		4	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		Aluminum Alloy	-	Material	
			lb (Kg)	Weights	
		54 (25)		Line	
		8 (3.6)		Values	
		7 (3)		Disconnects	
		69 (31.6)		Total	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-01 (Continued)	Main Propellant Fill, Drain, and Dump (Cont)	Liquid Oxygen Topping Line	-	DESIGN CRITERIA	
		Liquid Oxygen	-	Fluid contained	
		164 (91)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		35 (24)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
			lb/sec(Kg/sec	Design Flow rate	
		0.15 (0.07)		Minimum	
		0.2 (0.09)		Nominal	
		2.0 (0.9)		Maximum	
				LINE DESCRIPTION	
		Vacuum Jacketed	-	Type	
		55 (16)	Btu/hr(watts)	Maximum heat leak	
		0.75	in. (cm)	Diameter	
		301	in. (cm)	Length	
		7	number	Flex joints	
		3	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		CRES	-	Material	
			lb (Kg)	Weights	
		29 (13)		Line	
		2.2 (1)		Valves	
		2.2 (1)		Disconnects	
		33.4 (15)		Total	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-01 (Continued)	Main Propellant Fill, Drain, and Dump (Cont)	Liquid Hydrogen System	-	DESIGN CRITERIA	
		Liquid Hydrogen	-	Fluid contained	
		36 (20)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		24 (17)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
			lb/sec(Kg/sec)	Design Flow Rate	
		4.15		Fill	
		4.15		Drain	
		25.0		Dump	
		0.15		Topping	
				LINE DESCRIPTION	
		Vacuum Jacketed	-	Type	
		350 (103)	Btu/hr(watts)	Maximum heat leak	
		5.0 (12.7)	in. (cm)	Diameter	
		300 (762)	in. (cm)	Length	
		7	number	Flex joints	
		4	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		CRES	-	Material	
			lb (Kg)	Weights	
		202 (92)		Line	
		34 (15)		Valves	
		34 (15)		Disconnects	
		210 (122)		Total	

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-02	Vent	Liquid Hydrogen Vent	-	DESIGN CRITERIA	
		Gaseous Hydrogen	-	Fluid contained	
		40 (22)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		23 (15.9)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.25 (0.11)	lb/sec (Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Vacuum Jacketed	-	Type	
		3.0 (7.62)	in. (cm)	Diameter	
		300 (7.62)	in. (cm)	Length	
		7	Number	Flex joints	
		4	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		CRES		Material	
			lb (Kg)	Weights	
		104 (47.2)		Line	
		16 (7.3)		Valves	
		16 (7.3)		Disconnects	
		134 (61.8)		Total	

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-02 (Continued)	Vent (Cont)	Liquid Hydrogen Relief	-	DESIGN CRITERIA	
		Gaseous Hydrogen	-	Fluid contained	
		40 (22)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		20 (13.8)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.144 (0.065)	lb/sec (Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Vacuum Jacketed	-	Type	
		2.0 (5.1)	in. (cm)	Diameter	
		516 (13.10)	in. (cm)	Length	
		7	Number	Flex joints	
		4	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		CRES	-	Material	
			lb (Kg)	Weights	
		103 (46.7)		Line	
		9 (4.1)		Valves	
		4 (1.8)		Disconnects	
		116 (52.6)		Total	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-02 (Continued)	Vent (Cont)	Liquid Oxygen Vent (Cont)	-	DESIGN CRITERIA	
		Gaseous Oxygen	-	Fluid contained	
		170 (94)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		20 (138)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.2 (0.09)		Design flow rate	
				LINE DESCRIPTION	
		Uninsulated		Type	
		2.0 (5.1)	in. (cm)	Diameter	
		100 (254)	in. (cm)	Length	
		3	number	Flex joints	
		2	"	Flanges	
		1	"	Valves	
		1	"	Disconnects	
		Aluminum Alloy	-	Material	
			lb (Kg)	Weights	
		6.9 (3.1)		Line	
		6.0 (2.7)		Valves	
		3.0 (1.35)		Disconnects	
		15.9 (7.15)		Total	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-02 (Continued)	Vent (Cont)	Disconnect Panel Purges			
		O_2	-	DESIGN CRITERIA	
		GO_2/HE	-	Fluid contained	
		170 (94)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		20 (13.8)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.00065 (0.0003)	lb/sec (Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		2	-	Number	
		Uninsulated	-	Type	
		0.375 (.095)	in. (cm)	Diameter	
		18 (45.7)	in. (cm)	Length	
		-	Number	Flex joints	
		0	"	Flanges	
		1	"	Check valves	
		0	-	Disconnects	
		Aluminum Alloy	-	Material	
				Weights	
		0.4 (.18)		Line	
		0.6 (.27)		Valves	
		0		Disconnects	
		1.0 (.45)		Total	

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
		H_2	-		
		GH_2/HE	-		
		40 (22)	°R (°K)		
		500 (278)	°R (°K)		
		20 (13.8)	psia (N/cm^2)		
		0 (0)	psia (N/cm^2)		
		0.00065 (0.0003)	lb/sec (Kg/sec)		
		2	-		
		Uninsulated	-		
		0.375 (.095)	in. (cm)		
		18 (45.7)	in. (cm)		
		-	Number		
		0	"		
		1	"		
		0	-		
		Aluminum Alloy	-		
		0.4 (.18)			
		0.6 (.27)			
		0			
		1.0 (.45)			

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-03	Purge	Leakage Containment Vent Assembly			
		O_2 H_2	-	DESIGN CRITERIA	
		Helium Helium	-	Fluid contained	
		40 (22) 170 (94)	°R (°K)	Minimum temperature	
		560 (311) 560 (311)	°R (°K)	Maximum temperature	
		15 (10.3) 15 (10.3)	psia (N/cm^2)	Maximum pressure	
		0 (0) 0 (0)	psia (N/cm^2)	Minimum pressure	
		.08 (.036) .08 (.036)	lb/sec (Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Uninsulated Uninsulated	-	Type	
		0.75 (1.9) 0.75 (1.9)	in. (cm)	Diameter	
		300 (762) 300 (762)	in. (cm)	Length	
		0 0	Number	Flex joints	
		0 0	"	Flanges	
		1 1	"	Check valves	
		1 1	"	Disconnects	
		Aluminum Alloy	-	Material	
			lb (Kg)	Weights	
		5.0 (2.3) 5.0 (2.3)		Line	
		1.0 (.45) 1.0 (.45)		Valves	
		1.0 (.45) 1.0 (.45)		Disconnects	
		7.0 (3.2) 7.0 (3.2)		Total	

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320-16-02-03 (Continued)	Purge (Cont)	Deployment Adapter Purge/ Control Assembly	-	DESIGN CRITERIA	
		Helium	-	Fluid contained	
		500 (278)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		20 (13.8)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.01 (.0045)	lb/min(Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Uninsulated	-	Type	
		0.25 (.635)	in. (cm)	Diameter	
		300 (762)	in. (cm)	Length	
		2	Number	Regulators	
		14	"	Valves	
		Aluminum Alloy	-	Material	
			lb (Kg)	Weights	
		4.4 (2.0)		Line	
		8.0 (3.6)		Valves	
		2.0 (0.9)		Disconnects	
		14.4 (6.5)		Total	

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-04	ACPS Provisions	N_2H_4 Relief Assembly	-	DESIGN CRITERIA	
		N_2H_4	-	Fluid contained	
		500 (278)	°R (°K)	Minimum temperature	
		600 (333)	°R (°K)	Maximum temperature	
		300 (207)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.05 (0.023)	lb/sec(Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Uninsulated	-	Type	
		0.375 (0.95)	in. (cm)	Diameter	
		300 (962)	in. (cm)	Length	
		0	Number	Flex joints	
		0	"	Flanges	
		0	"	Valves	
		1	"	Disconnects	
		CRES	-	Material	
			lb (Kg)	Weights	
		6.7 (3.04)		Line	
		0.5 (.23)		Valves	
				Disconnects	
		7.2 (3.27)		Total	

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WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-05	Pressurization	Helium Storage Bottles			
		6	Number	Bottles	
		4.5 (.127) each	ft^3 (m^3)	Capacity	
		10.33 (4.68) each	lb(Kg) Helium	Capacity	
		3200 (2205)	psia (N/cm^2)	Pressure	
		Titanium	-	Material	
		90 (41)	lb (Kg)	Weight, Instl. each	
		540 (245)	lb (Kg)	Total	

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Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-02-05 (Continued)	Pressurization (Cont)	Helium Charge Line Assy.	-	DESIGN CRITERIA	
		Helium	-	Fluid contained	
		500 (278)	°R (°K)	Minimum temperature	
		560 (311)	°R (°K)	Maximum temperature	
		3200 (2206)	psia (N/cm^2)	Maximum pressure	
		0 (0)	psia (N/cm^2)	Minimum pressure	
		0.022 (0.01)	lb/sec (Kg/sec)	Design flow rate	
				LINE DESCRIPTION	
		Uninsulated	-	Type	
		0.375 (0.095)	in. (cm)	Diameter	
		240 (610)	in. (cm)	Length	
		0	Number	Flex joints	
		0	"	Flanges	
		4	"	Valves	
		1	"	Disconnects	
		CRES	-	Material	
			lb (Kg)	Weights	
		9.8 (4.4)		Line	
		2.2 (1.0)		Valves	
		0.5 (.23)		Disconnects	
		12.5 (5.63)		Total	

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-03-01	Data Management				
	Deployment Adapter Interface Unit (DIU)	50 (22.7)	Lb (Kg)	Weight	Redundant
		50	Watts	Power	
	Command Decoder	2	KBPS	Input BI-Ø-L	NASA
		2	KBPS	Input FSK/AM	
	Command Distributor	100	Number	Outputs @ +28 VDC	
	Downlink	16	KBPS	Data Rate	To PDI
	Wiring & Connectors				
	Cables	4	Each	Quantity	
		44 (20)	Lb (Kg)	Weight	
	D/A Junction Box	1	Each	Quantity	
		30 (13.6)	Lb (Kg)	Weight	

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-03-05	Instrumentation				
	Tug Abort Panel	23 (148)	in^3 (cc)	Volume/size	At
		4 (1.8)	Lb (Kg)	Weight	Orbiter
		20	Watts	Power	Mission
		10	Each	No. of Switches	Specialist
		20	Each	No. of Lights	Station
	Tug Deployment Panel	23 (148)	in^2 (cc)	Volume/size	At
		4 (1.8)	Lb (Kg)	Weight	Orbiter
		20	Watts	Power	Payload
		7	Each	No. of Switches	Handling
		14	Each	No. of Lights	Station
	Tug Checkout, Initialization and Safing Panel	48 (310)	in^2 (cc)	Volume/size	At
		6 (2.7)	Lb (Kg)	Weight	Orbiter
		20	Watts	Power	Mission
		14	Each	No. of Switches	Specialist
		28	Each	No. of Lights	Station

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-03-05	Instrumentation (Cont'd.)				
	Tug Panel Control Electronics	5 (23) 30	Lb (Kg) Watts	Weight Power	At Orbiter Mission Specialist Station
	Tug Master Caution & Warning Lights	2 1 (.45) 3 (20) 10	Each Lb (Kg) in^2 (cc) Watts	Quantity Weight Volume/size Power	
	Tug Control Panel Harness	10 (4.54)	Lb (Kg)	Weight	
	Tug Control Panel Elect. Power	6 (2.72)	Lb (Kg)	Weight	
	Remote Multiplexer	75 10 (.45)	Watts Lb (Kg)	Power Weight	
	Measurement Devices	100	Each	Quality	

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-16-03-07	Electric Power				
	Power Control Unit	12 (5.4) 224	Lb (Kg) Watts	Weight Power (Peak)	In Deployment Adapter
	Power Cables	2 90 (40.1)	Each Lb (Kg)	Quantity Weight	In Cargo Bay and Deployment Adapter

TECHNICAL CHARACTERISTICS DATA FORM B

Study Title - Space Tug/Shuttle Interface Compatibility

Date 5 May 1975

Contract Number - NAS8-31012

WBS IDENTIFICATION NUMBER	WBS IDENTIFICATION	VALUE	UNIT OF MEASURE	CHARACTERISTICS	NOTES
320-15-01	On Board Software (GPC/Tug Support)	850	Words	Memory - Tug Real Time Monitor	16 Bit Words
		4,890	Words	Memory - Tug Instrumentation Status	
		200	Words	Memory - Tug Deployment/Capture	
		2,225	Words	Memory - Tug RF Control	
		505	Words	Memory - Tug Utility & Control	
		1,500	Words	Memory - Common, Storage	
		10,170	Words	Total	

FUNDING SCHEDULE DATA FORM C

SPACE TUG/SHUTTLE INTERFACE
DEFINITION STUDY

TUG/SHUTTLE INTERFACE SUBSYSTEMS COSTS (1975 $)

(ALL COSTS SHOWN IN THOUSANDS OF DOLLARS)

SUBSYSTEMS	TOTAL	FY78	FY79	FY80	FY81	FY82	FY83
NON-RECURRING (DDT+E)							
DDT+E							
DEPL.,ROVU.,+DOCKING	931.000	0.000	144.664	563.126	223.211	0.000	0.000
TUG/ORBITER SUPPORTS	2690.000	0.000	564.568	1797.605	327.827	0.000	0.000
INTERFACE PANELS	638.100	0.000	144.104	381.950	11.946	0.000	0.000
PERIPHERAL EQUIPMENT	352.000	0.000	122.010	228.199	1.791	0.000	0.000
MAIN PROP. FEED,FILL,DRN	736.000	0.000	163.596	517.646	54.758	0.000	0.000
VENT	650.000	0.000	144.471	457.160	48.368	0.000	0.000
PURGE	536.000	0.000	185.788	347.485	2.727	0.000	0.000
ACPS PROVISIONS	121.000	0.000	73.001	47.999	0.000	0.000	0.000
PRESSURIZATION	515.000	0.000	137.943	365.621	11.435	0.000	0.000
DATA MANAGEMENT	1355.000	0.000	566.404	788.196	0.000	0.000	0.000
INSTRUMENTATION	1234.000	0.000	744.488	489.512	0.000	0.000	0.000
ELECTRIC POWER	884.110	0.000	415.692	273.318	0.000	0.000	0.000
INTEG.,ASSY.,+CHECKOUT	1346.000	0.000	0.000	1093.099	252.9 1	0.000	0.000
ONBOARD SOFTWARE	1250.000	0.000	0.000	0.000	205.481	949.038	205.481
GROUND TEST HARDWARE	2632.100	0.000	0.000	1346.000	1346.000	0.000	0.000
TUG/SHUTTLE DDT+E	15675.000	0.000	3407.110	8706.917	2486.454	949.038	205.481

FUNDING SCHEDULE DATA FORM C

SPACE TUG/TUG INTERFACE
DEFINITION STUDY

TUG/SHUTTLE INTERFACE SUBSYSTEMS COSTS (1975 $)

(ALL COSTS SHOWN IN THOUSANDS OF DOLLARS)

SUBSYSTEMS	TOTAL	FY78	FY79	FY80	FY81	FY82	FY83
RECURRING PRODUCTION							
DEPL.,ROVU.,+DOCKING	1130.000	0.000	0.000	0.000	408.462	544.615	226.923
TUG/ORBITER SUPPORTS	3415.000	0.000	0.000	0.000	1182.115	1576.154	656.731
INTERFACE PANELS	106.000	0.000	0.000	0.000	37.385	49.846	20.769
PERIPHERAL EQUIPMENT	211.110	0.000	0.000	0.000	73.038	97.385	40.577
MAIN PROP. FILL,FEED,+DR	847.000	0.000	0.000	0.000	293.192	390.923	162.885
VENT	520.000	0.000	0.000	0.000	180.000	240.000	100.000
PURGE	732.000	0.000	0.000	0.000	253.385	337.846	140.769
ACPS PROVISIONS	171.000	0.000	0.000	0.000	59.192	78.923	32.885
PRESSURIZATION	1253.000	0.000	0.000	0.000	433.731	578.308	240.962
DATA MANAGEMENT	1674.000	0.000	0.000	0.000	579.462	772.615	321.923
INSTRUMENTATION	2550.000	0.000	0.000	0.000	882.692	1176.923	490.385
ELECTRIC POWER	3044.000	0.000	0.000	0.000	1053.692	1404.923	585.385
INTEG.,ASSY.,+CHECKOUT	1128.000	0.000	0.000	0.000	0.000	620.400	507.600
TUG/ORB REC. PROD.	16933.000	0.000	0.000	0.000	5436.346	7968.852	3527.732

SPACE TUG/SHUTTLE INTERFACE
DEFINITION STUDY

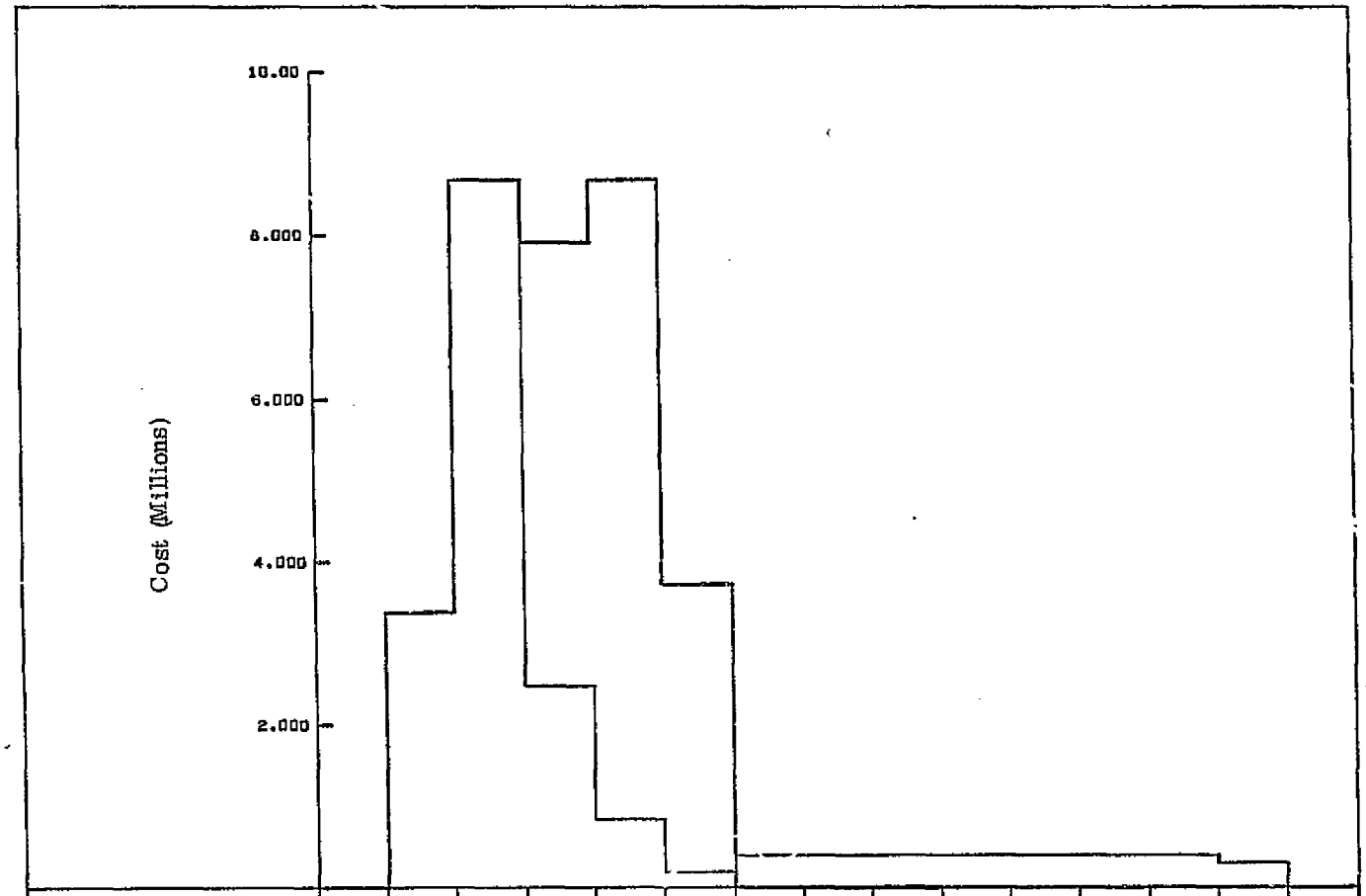
TUG/SHUTTLE INTERFACE SUBSYSTEMS COSTS (1975 $)

(ALL COSTS SHOWN IN THOUSANDS OF DOLLARS)

SUBSYSTEMS	TOTAL	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87
RECURRING OPERATIONS											
DEPL.,RDVU.,+DOCKING	349.000							44.903	44.903	44.903	44.903
TUG/ORBITER SUPPORTS	1007.000							129.935	129.935	129.935	129.935
INTERFACE PANELS	32.000							4.129	4.129	4.129	4.129
PERIPHERAL EQUIPMENT	62.000							8.000	8.000	8.000	8.000
MAIN PROP. FEED,FILL,+DR	74.000							9.548	9.548	9.548	9.548
VENT	46.000							5.935	5.935	5.935	5.935
PURGE	64.000							8.258	8.258	8.258	8.258
ACPS PROVISIONS	20.000							2.581	2.581	2.581	2.581
PRESSURIZATION	110.000							14.194	14.194	14.194	14.194
DATA MANAGEMENT	140.000							18.065	18.065	18.065	18.065
INSTRUMENTATION	938.000							121.032	121.032	121.032	121.032
ELECTRIC POWER	379.000							48.903	48.903	48.903	48.903
TUG/ORB REC. OPNS.	3220.000							415.484	415.484	415.484	415.484
DEPL.,RDVU.,+DOCKING	348.000	44.903	44.903	44.903	33.677	0.000					
TUG/ORBITER SUPPORTS	1007.000	129.935	129.935	129.935	97.452	0.000					
INTERFACE PANELS	32.000	4.129	4.129	4.129	3.097	0.000					
PERIPHERAL EQUIPMENT	62.000	8.000	8.000	8.000	6.000	0.000					
MAIN PROP. FEED,FILL,+DR	74.000	9.548	9.548	9.548	7.161	0.000					
VENT	46.000	5.935	5.935	5.935	4.452	0.000					
PURGE	64.000	8.258	8.258	8.258	6.194	0.000					
ACPS PROVISIONS	20.000	2.581	2.581	2.581	1.935	0.000					
PRESSURIZATION	110.000	14.194	14.194	14.194	10.645	0.000					
DATA MANAGEMENT	140.000	18.065	18.065	18.065	13.548	0.000					
INSTRUMENTATION	938.000	121.032	121.032	121.032	90.774	0.000					
ELECTRIC POWER	379.000	48.903	48.903	48.903	36.677	0.000					
TUG/ORB REC. OPNS.	3220.000	415.484	415.484	415.484	311.613	0.000					

FUNDING SCHEDULE DATA FORM C

ANNUAL EXPENDITURE PROFILE



SUBSYSTEMS	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92
TUG/SHUTTLE DDT+E		3.407	8.707	2.486	.8490	.2055									
TUG/ORB REC. PROD.				5.436	7.869	3.528									
TUG/ORB REC. OPNS.							.4155	.4155	.4155	.4155	.4155	.4155	.4155	.3116	
TOTAL		3.407	8.707	7.923	8.718	3.733	.4155	.4155	.4155	.4155	.4155	.4155	.4155	.3116	

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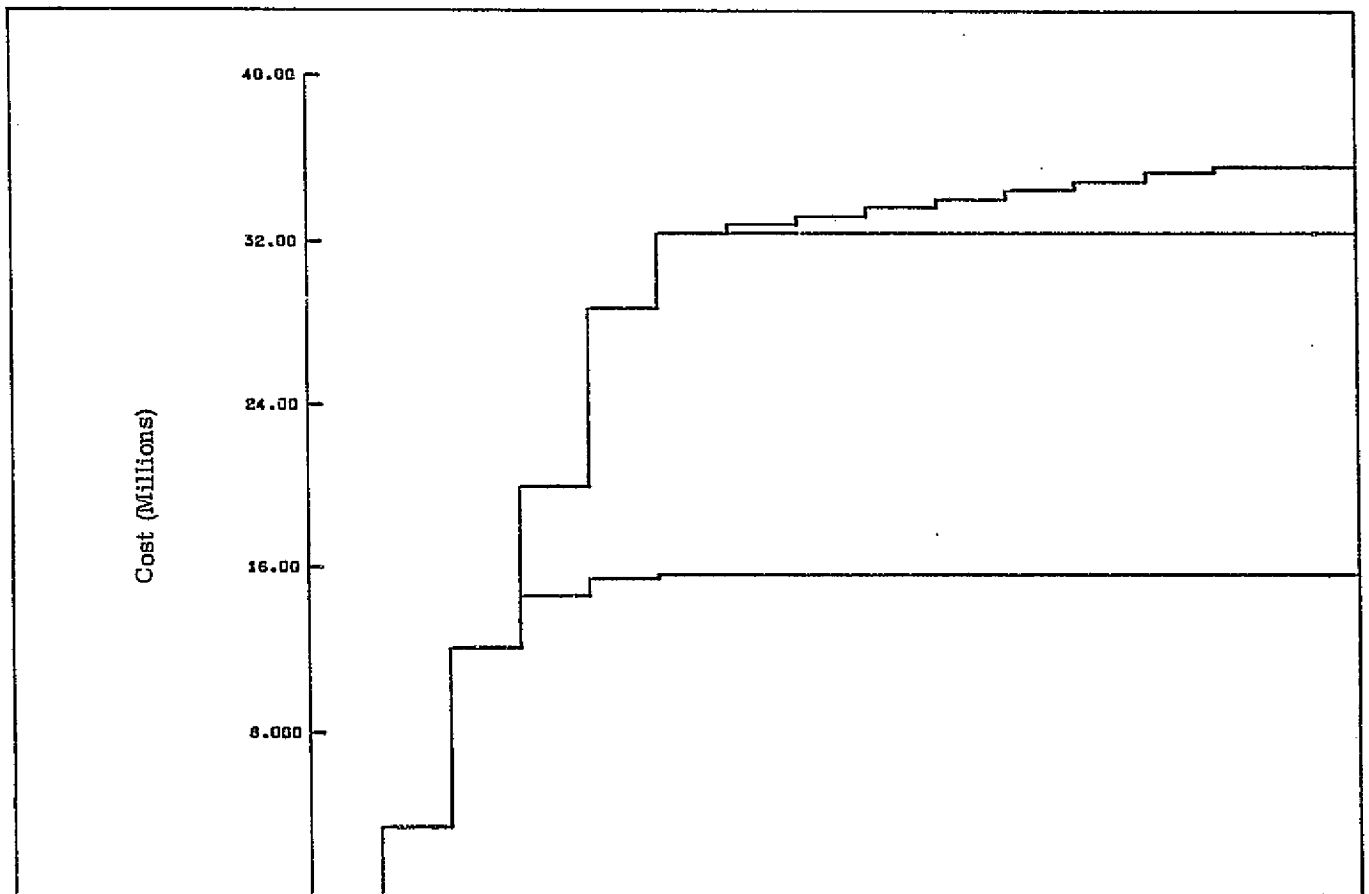
FUNDING SCHEDULE DATA FORM C

CUMULATIVE EXPENDITURE PROFILE



SUBSYSTEMS	FY78	FY79	FY80	FY81	FY82	FY83	FY84	FY85	FY86	FY87	FY88	FY89	FY90	FY91	FY92
TUG/SHUTTLE DDT+E		3.407	12.11	14.60	15.45	15.65	15.65	15.65	15.65	15.65	15.65	15.65	15.65	15.65	15.65
TUG/ORB REC. PROD.				5.436	13.31	16.83	16.83	16.83	16.83	16.83	16.83	16.83	16.83	16.83	16.83
TUG/ORB REC. OPNS.							.4155	.8310	1.246	1.662	2.077	2.493	2.908	3.220	3.220
TOTAL		3.407	12.11	20.04	28.75	32.49	32.90	33.32	33.73	34.15	34.57	34.98	35.40	35.71	35.71

04/09/78

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-01 WBS NAME Structure, Deployment RDVU & Docking

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	22,658	415
INTEGRATION	125	2
TOOLING	18,438	276
PRODUCTION		
TEST & EVALUATION	11,926	204
RELIABILITY & QUALITY	53	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	8	33
TOTAL	53,208	931

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-02 WBS NAME Structure, Tug/Orbiter Supports

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	73,514	1,678
INTEGRATION	996	16
TOOLING	60,737	905
PRODUCTION	20	1
TEST & EVALUATION	202	3
RELIABILITY & QUALITY	44	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	5	86
TOTAL	135,516	2,690

COST ESTIMATE
DATA FORM T

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PROGRAM PHASE Nonrecurring DDT&E

CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-03 WBS NAME Structure Interface Panels

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	13,068	240
INTEGRATION	71	1
TOOLING	10,634	160
PRODUCTION		
TEST & EVALUATION	6,878	118
RELIABILITY & QUALITY	32	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	5	18
TOTAL	30,688	538

COST ESTIMATE
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PROGRAM PHASE Nonrecurring DDT&E

CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-04 WBS NAME Structure Peripheral Equipment

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	8,550	157
INTEGRATION	48	1
TOOLING	6,958	105
PRODUCTION		
TEST & EVALUATION	4,500	77
RELIABILITY & QUALITY	20	-
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	3	12
TOTAL	20,079	352

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-01 WBS NAME Main Propellant Fill, Drain, Dump

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	32,130	594
INTEGRATION	64	1
TOOLING	7,222	113
PRODUCTION		
TEST & EVALUATION	16	1
RELIABILITY & QUALITY	32	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		26
TOTAL	39,464	736

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-02 WBS NAME Vent

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	16,136	293
INTEGRATION	32	1
TOOLING	8,779	133
PRODUCTION	1,088	83
TEST & EVALUATION	6,460	119
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		21
TOTAL	32,495	650

COST ESTIMATE
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PROGRAM PHASE Nonrecurring DDT&E

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-03 WBS NAME Purge

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	18,419	334
INTEGRATION	785	14
TOOLING	6,062	90
PRODUCTION		
TEST & EVALUATION	2,994	77
RELIABILITY & QUALITY	13	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		20
TOTAL	28,273	536

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-04 WBS NAME ACPS Provisions

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	3,808	76
INTEGRATION	218	4
TOOLING	1,674	25
PRODUCTION		
TEST & EVALUATION	398	11
RELIABILITY & QUALITY	64	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		4
TOTAL	6,162	121

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-05 WBS NAME Pressurization

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	17,698	330
INTEGRATION	755	13
TOOLING	5,824	92
PRODUCTION		
TEST & EVALUATION	2,877	58
RELIABILITY & QUALITY	12	2
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		20
TOTAL	27,166	515

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-01 WBS NAME Data Management

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	29,010	516
INTEGRATION	28	1
TOOLING	9,790	170
PRODUCTION	1,412	58
TEST & EVALUATION	18,673	546
RELIABILITY & QUALITY	1,858	39
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	85	35
TOTAL	60,856	1,365

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-05 WBS NAME Instrumentation

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	34,979	631
INTEGRATION	2,847	40
TOOLING	7,237	123
PRODUCTION	364	14
TEST & EVALUATION	16,143	368
RELIABILITY & QUALITY	1,016	21
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		37
TOTAL	62,586	1,234

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-03-06 WBS NAME Electric Power

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	17,369	352
INTEGRATION	3,818	65
TOOLING	8,551	136
PRODUCTION	260	5
TEST & EVALUATION	3,394	98
RELIABILITY & QUALITY	585	10
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	20	23
TOTAL	33.997	689

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-05 WBS NAME Integration, Assembly & Checkout

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	15,509	321
TOOLING	45,483	750
PRODUCTION	5,063	75
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		200
TOTAL	66,055	1,346

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
PAGE 14 OF 40

CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-15 WBS NAME Software

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING	52,416	1,021
INTEGRATION		
TOOLING		
PRODUCTION		
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		239
OTHER		
TOTAL	52,416	1,260

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Nonrecurring DDT&E

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-08-01 WBS NAME Ground Test Hardware

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	21,014	395
TOOLING	903	25
PRODUCTION	89,548	2,153
TEST & EVALUATION	1,555	34
RELIABILITY & QUALITY	148	23
TRANSPORTATION	567	9
PROGRAM MANAGEMENT		
OTHER	23	53
TOTAL	113,758	2,692

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Recurring Production

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-01 WBS NAME Structure, Deployment RDVU & Docking

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	14,419	274
TOOLING	450	6
PRODUCTION	28,664	877
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		23
TOTAL	43,533	1,180

COST ESTIMATE
DATA FORM T

PROGRAM PHASE Recurring Production

DATE 5/5/75
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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-02 WBS NAME Structure, Tug/Orbiter Supports

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	11,088	218
TOOLING	1,035	15
PRODUCTION	214,487	3,078
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		104
TOTAL	226,610	3,415

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-03 WBS NAME Structure Interface Panels

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	1,320	25
TOOLING	41	1
PRODUCTION	2,623	80
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		2
TOTAL	3,984	108

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-04 WBS NAME Structure Peripheral Equipment

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	2,578	49
TOOLING	81	1
PRODUCTION	5,125	157
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		4
TOTAL	7,784	211

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-1 WBS NAME Main Propellant Fill, Drain, Dump

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	7,103	138
TOOLING	47	1
PRODUCTION	49,706	681
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		27
TOTAL	56,856	847

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-02 WBS NAME Vent

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	3,526	74
TOOLING	372	6
PRODUCTION	15,868	383
TEST & EVALUATION	2,190	43
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		14
TOTAL	21,956	520

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 210-16-02-03 WBS NAME Purge

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	6,276	115
TOOLING	104	2
PRODUCTION	26,630	594
TEST & EVALUATION	14	1
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	68	20
TOTAL	33,092	732

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-04 WBS NAME ACPS Provisions

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	933	19
TOOLING	57	1
PRODUCTION	1,959	149
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		2
TOTAL	2,949	171

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CONTRACT NA8-31012 STUDY Tug/Snuttle Interface Definition

WBS NO. 320-16-02-05 WBS NAME Pressurization

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	10,743	197
TOOLING	177	3
PRODUCTION	45,585	1,017
TEST & EVALUATION	24	1
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	118	35
TOTAL	56,647	1,253

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-01 WBS NAME Data Management

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	15,336	283
TOOLING	113	2
PRODUCTION	14,386	1,362
TEST & EVALUATION		1
RELIABILITY & QUALITY	340	8
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		18
TOTAL	30,175	1,674

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-05 WBS NAME Instrumentation

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	26,091	504
TOOLING		43
PRODUCTION	32,082	1,764
TEST & EVALUATION	5,990	126
RELIABILITY & QUALITY	145	100
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		13
TOTAL	64,308	2,550

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-08-06 WBS NAME Electric Power

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	24,251	435
TOOLING	3,690	52
PRODUCTION	91,347	2,497
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		0
TOTAL	119,288	3,044

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-05 WBS NAME Integration Assembly & Checkout

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	6,391	126
TOOLING	3,330	47
PRODUCTION	19,423	370
TEST & EVALUATION	24,850	348
RELIABILITY & QUALITY	217	3
TRANSPORTATION	2,228	34
PROGRAM MANAGEMENT		
OTHER	7,020	200
TOTAL	63,459	1,128

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-01 WBS NAME Structure, Deployment RDVU & Docking

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	4,252	81
TOOLING	133	2
PRODUCTION	8,454	258
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		7
TOTAL	12,839	348

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-02 WBS NAME Structure, Tug/Orbiter Supports

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	3,270	64
TOOLING	305	4
PRODUCTION	63,247	909
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		30
TOTAL	66,822	1,007

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-03 WBS NAME Structure Interface Panels

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	391	7
TOOLING	12	1
PRODUCTION	777	24
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		
TOTAL	1,180	32

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-01-04 WBS NAME Structure Peripheral Equipment

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	757	14
TOOLING	24	1
PRODUCTION	1,506	46
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		1
TOTAL	2,287	62

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-01 WBS NAME Main Propellant Fill, Drain, Dump

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	620	12
TOOLING	4	1
PRODUCTION	4,337	59
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		2
TOTAL	4,961	74

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-02 WBS NAME Vent

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	312	7
TOOLING	33	1
PRODUCTION	1,402	34
TEST & EVALUATION	193	4
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		
TOTAL	1,940	46

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-03 WBS NAME Purge

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	549	10
TOOLING	9	1
PRODUCTION	2,328	52
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	7	2
TOTAL	2,893	64

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-04 WBS NAME ACPS Provisions

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	109	2
TOOLING	7	1
PRODUCTION	230	17
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		
TOTAL	346	20

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-02-05 WBS NAME Pressurization

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	943	17
TOOLING	16	1
PRODUCTION	4,000	89
TEST & EVALUATION	2	1
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER	10	2
TOTAL	4,971	110

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-01 WBS NAME Data Management

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	1,282	24
TOOLING		
PRODUCTION	1,203	114
TEST & EVALUATION		
RELIABILITY & QUALITY	28	1
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		1
TOTAL	2,513	140

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-16-03-05 WBS NAME Instrumentation

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	9,597	185
TOOLING		16
PRODUCTION	11,801	649
TEST & EVALUATION	2,203	46
RELIABILITY & QUALITY	53	37
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		5
TOTAL	23,654	938

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CONTRACT NA8-31012 STUDY Tug/Shuttle Interface Definition

WBS NO. 320-03-06 WBS NAME Electric Power

SUBDIVISION OF WORK	LABOR HOURS	TOTAL COST ($1,000)
ENGINEERING		
INTEGRATION	3,019	55
TOOLING	459	6
PRODUCTION	11,373	311
TEST & EVALUATION		
RELIABILITY & QUALITY		
TRANSPORTATION		
PROGRAM MANAGEMENT		
OTHER		7
TOTAL	14,851	379