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May 1985

DACC Program Cost and Work Breakdown Structure/Dictionary

General Purpose Aft Cargo Carrier Study

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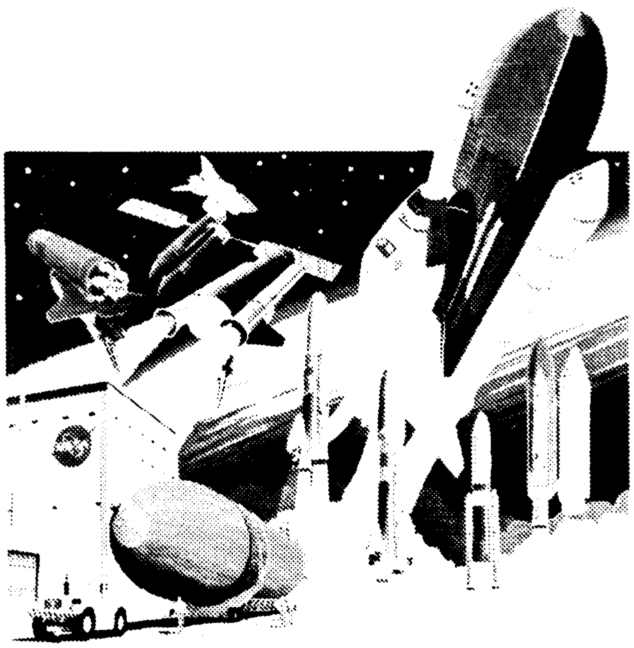

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MICHOUD DIVISION

Contract NAS8-35564

VOLUME II	Final Report	May 1985
DACC Program Cost and Work Breakdown Structure/Dictionary	GENERAL PURPOSE AFT CARGO CARRIER STUDY	

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FOREWORD

This volume is part of the Final Report of the General Purpose Aft Cargo Carrier study extension performed under National Aeronautics and Space Administration (NASA) Contract NAS8-35564, Modification Number 2. The report was prepared by the Michoud Division of Martin Marietta Denver Aerospace, New Orleans, Louisiana, for the NASA/Marshall Space Flight Center (MSFC).

The Contracting Officer Representative at MSFC was James E. Hughes. The Martin Marietta Study Manager was Thomas B. Mobley.

The Final Report is prepared in three volumes:

Volume I - Technical

Volume II - DACC Program Cost and Work Breakdown Structure/Dictionary

Volume III - GPACC Program Cost and Work Breakdown Structure/Dictionary

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FIGURES

TABLES

ACC CONTRACT COST UPDATE/MODEL 201

1.0 INTRODUCTION

This document presents the results of detailed cost estimates and economic analysis performed on the updated 201 configuration of the dedicated Aft Cargo Carrier (DACC).

1.1 Purpose

The objective of this economic analysis is to provide the National Aeronautics and Space Administration (NASA) with information on the economics of using the DACC on the Space Transportation System (STS). The detailed cost estimates for the DACC are presented by a work breakdown structure (WBS) to ensure that all elements of cost are considered in the economic analysis and related subsystem trades. Costs reported by WBS provide NASA with a basis for comparing competing designs and provide detailed cost information that can be used to forecast phase C/D planning for new projects or programs derived from preliminary conceptual design studies.

1.2 Scope

The scope of this document covers all STS and STS/DACC launch vehicle cost impacts for delivering an OTV to a 120 NM low Earth orbit (LEO).

2.0 COSTING APPROACH AND RATIONALE

This section describes the methodology that was necessary to proceed with the economic analysis for the model 201 configuration update.

2.1 Methodology

The key approach to the ACC economic analysis was to develop a WBS that contained all program cost elements to allow consistency in reporting results. The WBS and WBS dictionary were developed early during the Shuttle Derived Vehicle (SDV) Technology Requirements Study Phase I contract with NASA approval to ensure that all program hardware/software design, integration, management, test, operations and facility cost impacts would be estimated and reported on all trade study and economic analysis.

The Martin Marietta LCC methodology is based on independent parametric cost estimates that are developed from the Martin Marietta cost analysis data books. The cost analysis data books contain cost estimating relationships (CERs) for generic hardware/software development and unit cost and are based on historical program cost data. Specific company programs contained in the cost data base were referenced for the cost estimates. For example, an External Tank (ET) CER was used to estimate the ACC Thermal Protection System (TPS) cost.

A detailed analysis was performed by the ET production operations department to determine the tooling impacts for manufacturing the DACC. Recurring labor estimates are based on a bottoms-up estimate, also performed by the ET Production Operations Department.

The cost analysis was prepared using an automated LCC computer model developed by Martin Marietta Corporation with corporate funding. The model calculates all phases of costs by relying on the Martin Marietta cost data base as previously discussed. The model output is designed to report configuration results in a WBS fashion developed from the data requirement (DR-4).

2.2 WBS/WBS Dictionary

The WBS developed during the SDV Technology Requirements Study was utilized for the DACC cost analysis to provide a consistent framework for identifying and reporting all costs associated with the economic life cycle of the DACC. Principle requirements of the WBS were flexibility for a variety of hardware configurations, conformity with the LCC estimating methodology, and the ability to simplistically report the costs of programmatic impacts.

The DACC WBS is illustrated in Figure 2.2-1. The WBS is arranged in a two-dimensional matrix: the columns represent the cost phases identified by function/subfunction and the rows represent the hardware elements and systems. Definitions of the hardware elements and cost phases are provided in the WBS dictionary (Appendix A). The WBS dictionary was developed for a clear understanding of the hardware and function cost shown in the WBS. The DACC WBS dictionary is defined in Appendix A.

The matrix structure of the WBS permits identification and isolation of any hardware element in each LCC phase: design, development, test and evaluation (DDT&E), production and operations. A numbering scheme was established to identify any cost phase relative to any hardware element. The hardware element titles and hardware system titles are defined in a generic fashion to allow flexibility and thereby reduce the size and complexity of the WBS and WBS dictionary.

OF POOR QUALITY

PHASE & FUNCTION DIMENSION

PROJECT: STS PROGRAM 1.000

PHASE: R&T; DDT&E (1.2); PRODUCTION (1.3); OPERATIONS (1.4)

FUNCTION: (1.1) (1.2.1) PGM MGMT; (1.2.2) ENGINEERING; (1.2.3) MANUFACTURING; (1.2.4) TEST; (1.2.5) OPERATIONS; (1.3.1) PGM MGMT; (1.3.2) ENGINEERING; (1.3.3) MANUFACTURING; (1.4.1) OPERATIONS SUPPORT; (1.4.2) LAUNCH SUPPORT

SUB-FUNCTION: SYS ENG & INTEG; DESIGN & DEVELOP; SOFTWARE ENGINEERING; TOOLING & STE; GROUND TEST HDW; FLT TEST HDW; SYS TEST OPS; TEST FIXTURES; OPERATIONS SUPPORT; LAUNCH SUPPORT; SYS ENG & INTEG; DESIGN & DEVELOP; TOOLING & STE; FLIGHT HARDWARE; PROGRAM SUPPORT; REUSABLE HDW SPARES PROCURE.; EXPENDABLE HDW PROCUREMENT; FLIGHT OPS; NETWORK SUPPORT; LAUNCH OPERATIONS; PROPELLANT OPERATIONS

HDW/SW ELEMENT — WBS COLUMN NUMBER

WBS TITLE	WBS ROW #	1.1	1.2.1	1.2.2.1	1.2.2.2	1.2.2.3	1.2.3.1	1.2.3.2	1.2.3.3	1.2.4.1	1.2.4.2	1.2.5.1	1.2.5.2	1.3.1	1.3.2.1	1.3.2.2	1.3.3.1	1.3.3.2	1.4.1.1	1.4.1.2	1.4.1.3	1.4.1.4	1.4.1.5	1.4.2.1	1.4.2.2
STS VEHICLE	1.0.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
VEHICLE INTEGRATED SYSTEM	1.1.0			X								X	X		X							X	X	X	
ORBITER	1.2.0	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X				
INTEGRATED SYSTEM	1.2.1			X			X	X	X	X	X			X	X		X	X	X	X	X				
STRUCTURE	1.2.2				X			X	X							X		X		X					
PROPULSION	1.2.3				X			X	X							X		X		X					
POWER	1.2.4				X			X	X							X		X		X					
AVIONICS	1.2.5				X	X		X	X							X		X		X					
ECLSS	1.2.6				X			X	X							X		X		X					
ENGINES	1.2.7				X			X	X							X		X		X					
ASE	1.2.8				X	X		X	X							X		X		X					
GSE	1.2.9				X			X	X							X		X		X					
PROPELLANT	1.2.10																								X
ET	1.3.0	X	X	X	X		X	X	X	X	X								X		X				
INTEGRATED SYSTEM	1.3.1		X	X			X	X	X	X	X								X		X				
STRUCTURES	1.3.2				X			X	X												X				
PROPULSION	1.3.3				X			X	X												X				
POWER	1.3.4				X			X	X												X				
AVIONICS	1.3.5																								
ENGINES	1.3.6																								
GSE	1.3.7				X			X	X											X					
PROPELLANT	1.3.8																								X
SRB	1.4.0	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X					
INTEGRATED SYSTEM	1.4.1		X	X			X	X	X	X	X			X	X		X	X	X	X					
STRUCTURES	1.4.2				X			X	X							X		X		X					
PROPULSION	1.4.3				X			X	X							X		X		X					
POWER	1.4.4				X			X	X							X		X		X					
AVIONICS	1.4.5				X	X		X	X							X		X		X					
ENGINES	1.4.6				X			X	X							X		X		X					
GSE	1.4.7				X			X	X							X		X		X					
PROPELLANT	1.4.8																								X
ACC	1.5.0	X	X	X	X	X	X	X	X	X	X								X		X				
INTEGRATED SYSTEM	1.5.1		X	X	X			X	X	X	X								X		X				
SHROUD STRUCTURES	1.5.2				X		X	X	X												X				
SHROUD TPS	1.5.3				X			X	X												X				
SHROUD ACOUSTIC BARRIER	1.5.4				X			X	X												X				
SKIRT STRUCTURES	1.5.5				X		X	X	X												X				
SKIRT TPS	1.5.6				X			X	X												X				
SKIRT ACOUSTIC BARRIER	1.5.7				X			X	X												X				
PROPULSION	1.5.8				X			X	X												X				
POWER	1.5.9				X			X	X												X				
AVIONICS	1.5.10				X	X		X	X												X				
GSE	1.5.11				X			X	X												X				
GSE	1.6.0		X	X	X	X	X	X	X	X	X			X	X	X		X		X					
FACILITIES	2.0.0							X	X			X	X					X						X	X
MFG/REFURB	2.1.0							X					X					X				X		X	
TEST	2.2.0								X																
LAUNCH	2.3.0												X											X	
MISSION	2.4.0											X										X			
RECOVERY	2.5.0												X											X	

123.1.85

FIGURE 2.2-1 DACC WBS MATRIX FORMAT

3.0 DACC COST ANALYSIS SUMMARY

The objective of the DACC economic analysis is to provide NASA with an understanding of the costs associated with the development, production and operation of the DACC as an augmentation to the STS.

3.1 Program Cost Analysis - DACC

The DACC is an aluminum structural enclosure that attaches to the aft end of the ET to provide additional cargo volume for the STS. The DACC is specifically designed to accommodate an OTV sized to take advantage of the additional payload bay volume. The two-piece structure consists of a skin/stringer skirt and a riveted hemispherical shroud. Nonrecurring development costs and recurring unit production and operations costs of the DACC are discussed in this Section.

The total cost of the DACC program including all DACC related impacts is $296M. This includes all nonrecurring cost impacts to design the DACC and incorporate it into the STS as well as recurring costs for launch and flight operations and production of the DACC.

The nonrecurring phase of the DACC program includes: the DDT&E of the DACC; design impact to the orbiter; design impact to the ET; and facilities and GSE impacts. The estimated range of DACC program DDT&E costs is from $140M to $170M The cost distribution of the current estimate of $158M (among the DACC, orbiter, ET and facilities/GSE) is shown in Table 3.1-1. The $94M cost estimate for the DACC project DDT&E includes design and development, systems engineering, tooling, manufacture of two test articles, system test operations, and program management. Costs of Level II and Level III systems engineering, system test, and program management are included in the respective DACC DDT&E cost element. The estimated $13M cost impact to the orbiter includes the DDT&E and production impacts for modifying orbiter display panels, cabling, and flight software to accommodate the DACC. Similarly, the estimated $6M cost impact to the ET accounts for design modifications to the LH_2 aft dome, TPS, and ET cable trays to accommodate the DACC interfaces. The $45M estimate for facilities and GSE includes modifications at the launch site and the ET/DACC production facility.

TABLE 3.1-1 DEDICATED ACC PROGRAM COST ESTIMATES

Nonrecurring Program Total			($140M-$170M)
Aft Cargo Carrier		$ 94M	
Design & Development Engineering	$15M		
Systems Engineering & Integration	16M		
Tooling	35M		
Test Hardware	6M		
System Test	11M		
Program Management	11M		
Orbiter Impact		13M	
ET Modification		6M	
Subtotal			113M
Facilities/GSE			45M
Total ACC Nonrecurring			$158M

Recurring Production	First Unit	Average of 64 Units
Shroud	$ 0.9M	0.4M
Skirt	0.7M	0.4M
Propulsion	0.1M	0.0M
Avionics	0.4M	0.2M
Electrical	0.2M	0.1M
A&CO	0.4M	0.3M
SE&I, Program Management	0.8M	0.5M
Total ACC Recurring	$ 3.5M	$1.9M
Range	($3M-4M)	($1M-3M)
ET Modification		$0.04M

Operations	Cost per Flight Increase
Flight Operations	$0.1M
Launch Operations	0.1M
Total Operations Cost/Flight Increase:	$0.2M

The estimated range of the recurring production costs of the DACC is from $3M to $4M for the first unit, and from $1M to $3M for the average of 64 units. The current estimate of the first unit cost is $3.5M; the average unit cost is $1.9M (Table 3.1-1). The cost estimate for the shroud is inclusive of shroud structures and TPS. The skirt cost estimate also includes the cost of structures and TPS. The cost estimates for sustaining engineering and tooling, program management, and final assembly and checkout have also been allocated on a unit basis. ET modification costs are $0.04M per ACC flight for scar and cable tray impacts.

Operational impacts of the DACC on the STS consist of increases in launch and flight operations due to the additional ground processing requirements and on orbit time respectively. The total operations cost per flight increase of $0.2M is distributed between the increase to flight operations of $0.1M and the increase to launch operations of $0.1M (Table 3.1-1).

3.2 Conclusions

The DACC offers a logical extension to STS volume capability for an OTV design having a diameter too large to fit in the orbiter cargo bay. Implementing this program will require a design and development effort of $158M. This cost includes KSC and MAF facilities/GSE impacts as well as STS modifications. Recurring operations costs, including DACC hardware, are expected to increase the STS cost per flight an average of $2.1M over 64 flights ($138M). The total LCC of the DACC program is $296M.

4.0 DACC COST ANALYSIS

The cost estimates that were summarized in Section 3.0 are reported to the DACC WBS in this section.

4.1 Ground Rules and Assumptions

The following ground rules and assumptions were used to proceed with the DACC cost analysis:

A) All costs are expressed in 1984 dollars and are exclusive of fees;

B) The DACC test hardware included in the DDT&E costs consist of one ground test article complete with all hardware systems and one flight test article;

C) The DACC flight test is conducted in conjunction with a scheduled STS flight, i.e., dedicated use of STS hardware and procedures is not required;

D) Operations cost per flight impacts for flight operations and launch operations as a result of introducting the DACC in the STS system are as follows:

   Flight Operations: + $0.1M/Flight

   Launch Operations: + $0.1M/Flight

   The flight operations impact accounts for additional crew training. The launch operations impact consists of additional manpower and expendables required to process the DACC at KSC.

E) The economic analysis of the STS with DACC is based on the OTV flight manifests provided by NASA/MSFC for the 1994-2000 operational time frame.

F) The DACC has an IOC of FY 1994;

G) DACC and ET production improvement is calculated using an 86% Wright learning curve for structural components, and a 95% Wright learning curve for propulsion, power and avionics components.

4.2 Cost Estimates by WBS Elements

The life cycle cost estimate for the DACC configuration is reported to the WBS defined in Section 2.2 to permit visibility of the cost of each hardware element by cost phase and function. The LCC estimate for DACC program DDT&E, orbiter modifications and operations for 64 DACC flights is $296M (Table 4.2-1). Lower level WBS reports (Appendix B) were summarized to generate Table 4.2-1.

<u>DDT&E</u>

The DACC program DDT&E phase consisted of the ACC project, design

SHUTTLE DERIVED VEHICLE COST SUMMARY: AFT CARGO CARRIER

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

64.0 MANIFESTED ACC FLIGHTS

HARDWARE ELEMENTS	RESEARCH & TECHNOLOGY COSTS	DDT&E COSTS	PRODUCTION COSTS	OPERATIONS COSTS	TOTAL COSTS
VEHICLE INTEG. SYS	-	20.4	0.2	14.5	35.1
ORBITER	-	9.5	3.7	-	13.2
ET	-	6.0	-	2.8	8.8
SRB	-	-	-	-	-
ACC	-	72.9	-	121.2	194.1
GSE	-	4.2	-	-	4.2
STS/ACC VEHICLE	-	113.0	3.9	138.5	255.4
FACILITIES	-	41.1	-	-	41.1
*ACC TOTAL	-	154.1	3.9	138.5	296.5

* SHUTTLE DERIVED VEHICLE LCC: 296.5

* INCLUDES HARDWARE ELEMENTS AND FACILITIES

TABLE 4.2-1 DACC WBS COST SUMMARY

modifications to the orbiter and ET, plus facility and GSE impacts. The estimated cost range for the DDT&E phase of the ACC program is $140-170M. The current estimate is $158M (Table 4.2-2).

The DDT&E of the ACC includes design and development of all ACC subsystems, tooling, the manufacture of a complete ground test article and flight test article, system test operations, systems engineering and integration, and program management. Design and development costs are driven by the structural subsystem. At $12.5M the shroud and skirt structures design accounts for approximately 83% of the subsystem design and development effort. The remainder of the subsystem design engineering is largely devoted to the avionics (0.7M) and propulsion ($0.2M). Tooling costs of $35M are based on historical cost data for similar tool design and fabrication for ET production tooling. Ground and flight test articles (one each) amount to $6M and are assumed similar to first production units in cost. Costs of system test operations, systems engineering and integration, and program management were estimated for both Level II and Level III activities and are $11M, $16M, and $11M, respectively. The ACC project DDT&E cost estimate is $94M (Table 4.2-2).

TABLE 4.2-2 DEDICATED ACC PROGRAM DDT&E COST SUMMARY

ACC DDT&E		ACC	Systems Integration
Design & Development:		$15M	
Shroud Structures	$3.6M		
Shroud TPS	0.1M		
Skirt Structures	8.9M		
Skirt TPS	0.1M		
Propulsion	0.2M		
Avionics	0.7M		
Electrical Power	0.1M		
Integrated System	1.3M		
Tooling		35M	
Ground & Flight Test Hardware		6M	
System Test Operations		5M	$ 6M
Systems Engineering & Integration		7M	9M
Program Management		5M	6M
Subtotals		$73M	21M
Total Project ACC DDT&E		$ 94M	
Orbiter Modification		13M	
ET Modification		6M	
Facilities/GSE		45M	
TOTAL ACC PROGRAM DDT&E		$158M	
Range		($140-170M)	

Cost estimates for modifying the orbiter and ET to accommodate the ACC were $13M and $6M, respectively. The modification to the orbiter consisted of design changes to display panels, cabling subsystems and flight software. The modificaton to the ET consisted primarily of design changes to the LH2 aft dome structures and ET cabling interface. All WBS functional costs were included in the respective DDT&E cost estimates.

Facilities/GSE

Nonrecurring facility and GSE impacts (Table 4.2-3) for KSC and MAF were identified by personnel at these locations. Facility costs at KSC and MAF are based on "bottoms up" estimates performed by the MAF facilities department. Costs for the GSE items were developed using appropriate CERs from our historical database.

TABLE 4.2-3 FACILITIES/GSE REQUIREMENTS

KSC Impact	$31M
GSE	
ET Barge Modification	
DACC Towable Transporter	
Protective Covers	
DACC Access Kits	
Test/Checkout Equipment	
OTV/Shroud Hoist/Handling Equipment	
Integrated Test Equipment	
Portable Air Conditioning Unit	
Access Stand - Pad	
Portable Personnel Airlock	
Facilities	
Vehicle Assembly Building	
Mobile Launch Platforms (1, 2 & 3)	
Launch Pads (A & B)	
MAF Impact	$14M
GSE (included in tooling estimates)	
Facilities - Manufacturing Floor Space Mods/Relocations	
Facilities and GSE Total:	$45M

Production

Production costs for the STS with DACC configuration were limited to upgrading of the orbiter fleet to be compatible with ACC interfaces. (The production of DACCs was considered an operations cost per flight item and subsequently reported under operations on the WBS). Cost estimates for orbiter upgrades were estimated based on the design modifications outlined in the DDT&E paragraphs. The upgrades were considered for four orbiters and were reported to the DACC WBS because the modifications were a direct result of the DACC program. Orbiter modification cost estimates were based on ROM cost impacts provided by the Johnson Space Center (JSC) Engineering Cost Group for Orbiter 099 upgrades. The cost of upgrading a four orbiter fleet was estimated to be $3.9M (Table 4.2-1 and Appendix A).

Although DACC recurring costs were estimated as a cost per flight item, the estimated range for first unit cost is from $3M to $4M; the estimated range for the average of 64 units is from $1M to $3M. Current estimates are $3.5M and $1.9M for first unit and average unit cost, respectively (Table 4.2-4). The shroud and skirt structures $0.1M and $0.3M (respectively) contribute approximately 35% to the average recurring unit cost of the subsystem hardware. The thermal protection system accounts for an additional 30% ($0.35M). Assembly and checkout of each unit is $0.2M. Systems engineering and program management costs are estimated to be 0.5M.

TABLE 4.2-4 DEDICATED ACC UNIT COST SUMMARY

	First Unit Cost	Average Unit Cost (87)
Flight Hardware:	$2.3	$1.2M
Shroud Structures	$0.3M	$0.1M
Shroud TPS	0.6M	0.2M
Skirt Structures	0.5M	0.3M
Skirt TPS	0.2M	0.1M
Propulsion	0.1M	0.0M
Avionics	0.4M	0.2M
Electrical Power	0.2M	0.1M
Assembly & Checkout	0.4M	0.2M
SE&I, Program Management	0.8M	0.5M
Totals	$ 3.5M	$1.9M
Range	($3M-$4M	($1M-$3M)

Operations

When considered as a cost per flight element, the DACC increased the cost per flight by $2.1M based on 64 DACC flight opportunities. This increase was the sum of: ACC recurring hardware cost ($1.9M), ET modification recurring hardware cost ($0.04M), increased cost for launch operations manpower (0.1M), and increased cost for flight operations manpower ($0.1M).

4.3 Total Program Funding

This section presents the total program funding data for forecasting phase C/D planning for the DACC program presented in this volume. Total program funding includes all program costs for DDT&E, production and a 7 year operational period. The total DACC cost for any fiscal year is the sum of all the phase activities in that year.

4.3.1 Ground Rules and Assumptions

The following ground rules and assumptions were used to develop the DACC funding streams:

A) Program funding is shown for fiscal years 1990-2000;

B) DDT&E and Production funding are based on anticipated hardware development schedules;

C) STS DDT&E is considered complete and is treated as a sunk cost.

D) Hardware salvage value is excluded from the funding operations cost distribution.

E) The following methodology was used for estimating the annual funding distributions:

1) Total funding for each phase is based on the LCC model estimates for the DACC configurations; and

2) Each cost phase was distributed according to a selected distribution type that closely compares to the actual funding distribution. The cost phase total dollars were allocated annually on a percentage basis to provide a smooth funding distribution.

4.3.2 STS/DACC Program Funding

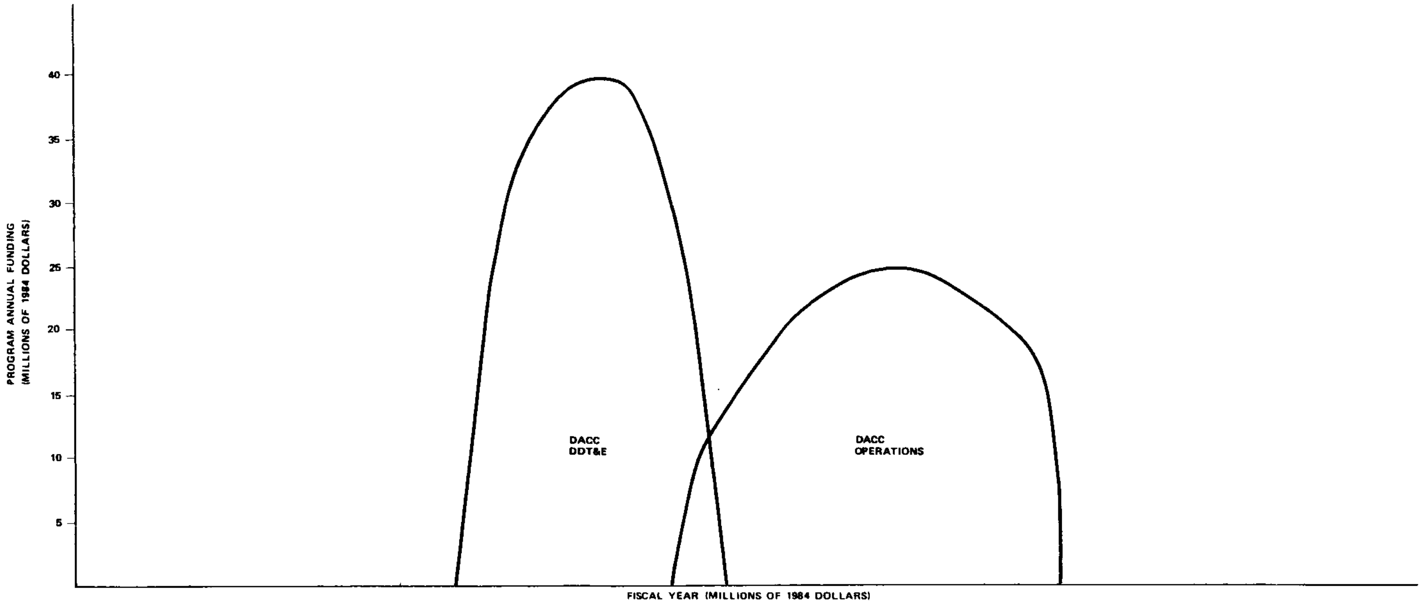
The estimated $158M DACC DDT&E cost is spread over 5 years. The $139M DACC operations cost estimate is spread over 7 fiscal years. Fiscal year 1992 has the maximum funding allocation with $40.5M annually required. Average annual funding equals $27.0M (Figure 4.3.2-1).

4.4 Conclusions

The results of this analysis indicate that the DACC can augment the STS payload carrying capability for an investment of $158M in program development costs.

Recurring operations costs, including the DACC hardware, are projected to increase the STS cost per flight (CPF) an average of $2.1M, or less than 3% of the current STS CPF.

The DACC improves the STS competitive posture by providing volume



DACC — PROGRAM COST PHASE	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTALS
DDT&E								20.8	37.0	40.5	39.0	20.8												158.0
PRODUCTION																								
OPERATIONS												11.1	16.4	21.3	24.0	24.4	22.4	18.8						138.5
DACC ANNUAL TOTALS								20.8	37.0	40.5	39.0	31.9	16.4	21.3	24.0	24.4	22.4	18.8						296.5

PROGRAM COST PHASE	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	TOTALS
PRODUCTION																								
OPERATIONS																								
STS ANNUAL TOTALS																								

PROGRAM ANNUAL TOTALS																								

FIGURE 4.3.2-1 PROGRAM FUNDING FOR DACC (1989-2000)

123.1.85

1 FOLDOUT FRAME

2 FOLDOUT FRAME

capability for OTV configurations that otherwise could not fly on the STS. The DACC is specifically designed to enhance the STS. Therefore, the DACC is expected to minimally impact the operational procedures, launch and production facilities at KSC.

APPENDIX A

DEDICATED ACC WBS DICTIONARY

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

To establish consistency and visibility within the Dedicated Aft Cargo Carrier (DACC) program, a preliminary work breakdown structure (WBS) and dictionary were developed. The dictionary contains definitions of terms to be used in conjunction with the WBS so that a clear understanding of the content of the hardware, function, and cost elements may be established.

The total WBS matrix (Figure 1) is a two-dimensional structure which shows the interrelationship of these dimensions: the hardware elements dimension and the phase and function dimension.

The dimension of time cannot be shown graphically, but must be considered. Each cost entry varies with time so that it is necessary to know these cost values by year for budget planning and approval as well as for establishing cost streams for discounting purposes in the economic analysis.

While a multiple dimensional approach may at first appear complex, it actually provides benefits which outweigh any concern. This structural interrelationship provides the capability to view and analyze the DACC costs from a number of different financial and management aspects. Costs may be summed by hardware groupings, phases, functions, etc. The WBS may be used in a number of dimensional or single listing format applications.

PROJECT		STS PROGRAM 1.000																							
PHASE		R&T	DDT&E (1.2)											PRODUCTION (1.3)					OPERATIONS (1.4)						
PHASE & FUNCTION DIMENSION — FUNCTION		(1.1)	PGM MGMT (1.2.1)	ENGINEERING (1.2.2)			MANUFACTURING (1.2.3)			TEST (1.2.4)		OPERATIONS (1.2.5)		PGM MGMT (1.3.1)	ENGINEERING (1.3.2)		MANUFACTURING (1.3.3)		OPERATIONS SUPPORT (1.4.1)					LAUNCH SUPPORT (1.4.2)	
SUB-FUNCTION				SYS ENG & INTEG	DESIGN & DEVELOP	SOFTWARE ENGINEERING	TOOLING & STE	GROUND TEST HDW	FLT TEST HDW	SYS TEST OPS	TEST FIXTURES	OPERATIONS SUPPORT	LAUNCH SUPPORT		SYS ENG & INTEG	DESIGN & DEVELOP	TOOLING & STE	FLIGHT HARDWARE	PROGRAM SUPPORT	REUSABLE HDW SPARES PROCURE.	EXPENDABLE HDW PROCUREMENT	FLIGHT OPS	NETWORK SUPPORT	LAUNCH OPERATIONS	PROPELLANT OPERATIONS
HDW/SW ELEMENT		WBS COLUMN NUMBER																							
WBS TITLE	WBS ROW #	1.1	1.2.1	1.2.2.1	1.2.2.2	1.2.2.3	1.2.3.1	1.2.3.2	1.2.3.3	1.2.4.1	1.2.4.2	1.2.5.1	1.2.5.2	1.3.1	1.3.2.1	1.3.2.2	1.3.3.1	1.3.3.2	1.4.1.1	1.4.1.2	1.4.1.3	1.4.1.4	1.4.1.5	1.4.2.1	1.4.2.2
STS VEHICLE	1.0.0	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
VEHICLE INTEGRATED SYSTEM	1.1.0			X								X	X		X							X	X	X	
ORBITER	1.2.0	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X	X				
INTEGRATED SYSTEM	1.2.1			X			X	X	X	X	X			X	X		X	X	X	X	X				
STRUCTURE	1.2.2				X			X	X							X		X		X					
PROPULSION	1.2.3				X			X	X							X		X		X					
POWER	1.2.4				X			X	X							X		X		X					
AVIONICS	1.2.5				X	X		X	X							X		X		X					
ECLSS	1.2.6				X			X	X							X		X		X					
ENGINES	1.2.7				X			X	X							X		X		X					
ASE	1.2.8				X	X		X	X							X		X		X					
GSE	1.2.9				X			X	X							X		X		X					
PROPELLANT	1.2.10																								X
ET	1.3.0	X	X	X	X		X	X	X	X	X								X		X				
INTEGRATED SYSTEM	1.3.1		X	X			X	X	X	X	X								X		X				
STRUCTURES	1.3.2				X			X	X												X				
PROPULSION	1.3.3				X			X	X												X				
POWER	1.3.4				X			X	X												X				
AVIONICS	1.3.5																								
ENGINES	1.3.6																								
GSE	1.3.7				X			X	X											X					
PROPELLANT	1.3.8																								X
SRB	1.4.0	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X					
INTEGRATED SYSTEM	1.4.1		X	X			X	X	X	X	X			X	X		X	X	X	X					
STRUCTURES	1.4.2				X			X	X							X		X		X					
PROPULSION	1.4.3				X			X	X							X		X		X					
POWER	1.4.4				X			X	X							X		X		X					
AVIONICS	1.4.5				X	X		X	X							X		X		X					
ENGINES	1.4.6				X			X	X							X		X		X					
GSE	1.4.7				X			X	X							X		X		X					
PROPELLANT	1.4.8																								X
ACC	1.5.0	X	X	X	X	X	X	X	X	X	X								X		X				
INTEGRATED SYSTEM	1.5.1		X	X	X			X	X	X	X								X		X				
SHROUD STRUCTURES	1.5.2				X		X	X	X												X				
SHROUD TPS	1.5.3				X			X	X												X				
SHROUD ACOUSTIC BARRIER	1.5.4				X			X	X												X				
SKIRT STRUCTURES	1.5.5				X		X	X	X												X				
SKIRT TPS	1.5.6				X			X	X												X				
SKIRT ACOUSTIC BARRIER	1.5.7				X			X	X												X				
PROPULSION	1.5.8				X			X	X												X				
POWER	1.5.9				X			X	X												X				
AVIONICS	1.5.10				X	X		X	X												X				
GSE	1.5.11				X			X	X												X				
GSE	1.6.0		X	X	X	X	X	X	X	X	X			X	X	X		X		X					
FACILITIES	2.0.0							X	X			X	X					X						X	X
MFG/REFURB	2.1.0							X					X					X				X		X	
TEST	2.2.0								X																
LAUNCH	2.3.0												X											X	
MISSION	2.4.0											X										X			
RECOVERY	2.5.0												X											X	

123.1.85

FIGURE 1. ACC WBS MATRIX FORMAT

ORIGINAL PAGE IS OF POOR QUALITY

2.0 DICTIONARY ORGANIZATION

The DACC dictionary is divided into:

1) A graphic display of the two-dimensional WBS matrix (Figure 1);
2) The hardware element dimension WBS (Figure 2) and the definition of terms;
3) The phase and function dimensions WBS's phase (Figures 3, 4, 5 and 6) and the definitions of terms.

A systematic numerical coding system coordinates the rows of the hardware element dimension to the columns of the phase and function dimension such that all matrix locations are identifiable by WBS number.

In Figure 1, each mark (X) represents a matrix position that corresponds to an identifiable task that must be completed for the DACC. Each mark (X) also identifies a cost that will occur and must be accounted for.

3.0 HARDWARE ELEMENTS DIMENSION

The hardware elements dimension contains all of the presently defined DACC hardware elements broken out into project, system/subsystem levels. Inherent within this dimension is the capability for further expansion to lower levels such as assemblies, subassemblies, components, etc., limited only by the realism of the requirements. A typical hardware element WBS is shown in Figure 2. Definitions of the individual elements are contained in the following pages.

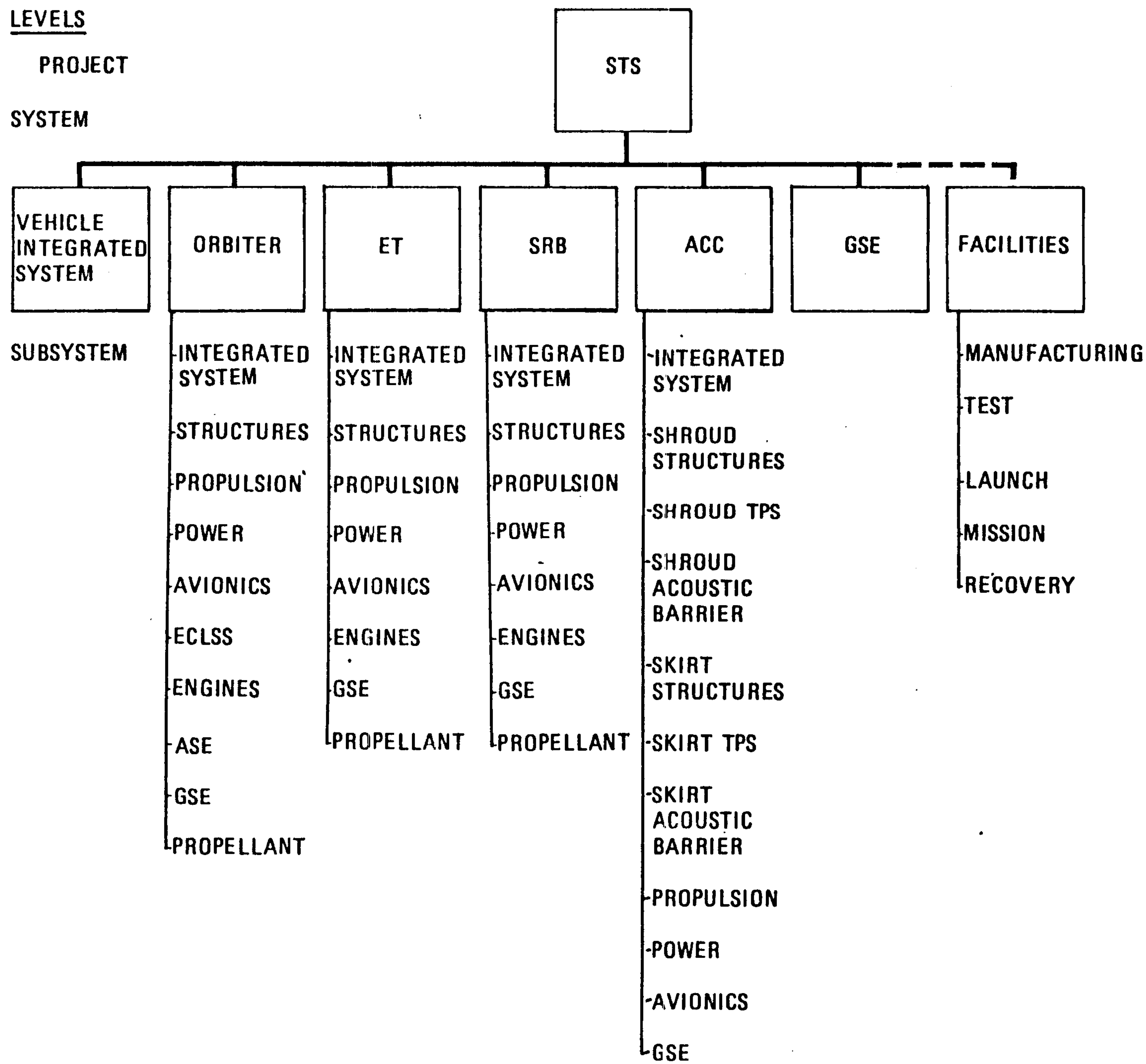


FIGURE 2. HARDWARE ELEMENT WBS - HARDWARE ELEMENT DIVISION

4.0 DEFINITIONS OF HARDWARE ELEMENTS

1.0.0 STS

This hardware element is a summary level element composed of all efforts and materials required for research and technology, design, development, production, and operation of the launch vehicle. This item includes those elements which are combined to provide a total system:

1.1.0 Vehicle Integrated Systems

1.2.0 Orbiter

1.3.0 ET

1.4.0 SRB

1.5.0 DACC

1.6.0 Ground Support Equipment

1.1.0 Vehicle Integrated System

This hardware element contains the hardware related efforts and materials required for research and technology, design, development, production, and operations of the total vehicle which cannot be allocated to individual hardware elements below the vehicle level. It includes elements associated with the integration, test, system engineering, and management of the total launch vehicle.

1.2.0 Orbiter

1.3.0 ET

1.4.0 SRB

1.5.0 DACC

This hardware element sums all the efforts and materials required for research and technology, design, development, production, and operations of the major hardware categories. This element includes all subsystems: Integrated Systems, Structures, Propulsion, Power, Avionics, ECLSS, Engines, GSE, ASE (as applies to orbiter/DACC), Propellant.

1.2.1 Integrated Systems

1.3.1 " "

1.4.1

1.5.1

This hardware element contains the hardware related efforts and materials required for research and technology, design, development, production, and operations of the total hardware category which cannot be allocated to individual hardware elements below the hardware category level. It includes elements associated with integration, test, system engineering, and program management of the total hardware category.

1.2.2 Structures

1.3.2 "

1.4.2

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the structures subsystem. This element includes the frame or body structure, stabilizers, tankage, thermal protection, fins, fairings, intertank, forward and aft skirts, aerodynamic surfaces, tunnels, thrust structure, heat shield, other tank supports, and landing provisions.

1.2.3 Propulsion

1.3.3 "

1.4.3

1.5.8

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the propulsion subsystem. This element includes the propellant feed system elements between the engine interface and the propellant tankage interface, including such items as lines, valves, regulators, controls, tank venting systems, pressurization system, engine pneumatic system, and other engine accessories. Also included are the OMS and RCS tanks, feed system and engines. The main rocket engines are not included (see Engines).

1.2.4 Power

1.3.4 "

1.4.4

1.5.9

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the power system. This element includes the electrical and/or hydraulic power for utilization by all vehicle subsystems. Typical hardware contained in this subsystem are generators, batteries, auxiliary power generators, hydraulic pumps, power converters, power distributors, hydraulic lines, valves, cables and wiring, power conditioners, and lights.

1.2.5 Avionics

1.3.5 "

1.4.5

1.5.10

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the avionics subsystem. This element includes guidance, navigation and control, data management, flight instrumentation, communications and air traffic control and displays and controls. Typical hardware utilized by this subsystem are: computer complex, recorder and storage units, data bus interface, inertial measurement unit, rate gyro package, signal conditioner, caution and warning, measuring equipment, antenna system, tracking and command, telemetry, flight sensors, and switching networks.

1.2.6 ECLSS

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the environmental control and life support subsystem. This element contains the ECLSS equipment required to provide for a shirt sleeve environment for booster crew and passengers. Some of the functions the equipment must perform are heating and cooling, water and waste management, flight environmental control, electronic thermal control, consumable storage and supply, cabin pressurization, portable oxygen supply, fire fighting equipment, and a vehicle free volume purge system which controls fuel oxidizers and tank temperatures.

1.2.7 Engines

1.3.6 "

1.4.6

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the engine subsystem. This element contains the primary rocket engine only.

1.2.8 ASE

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the airborne support equipment. This element includes those STS hardware items required to mate the payload (i.e., Upper Stages) with the STS, link with and separate from it. Included are such items as structural, mechanical equipment, fluid systems, electrical, and avionics equipment that provide STS/payload interfaces while the payload is in the payload bay and while it is entering or leaving it during a mission.

1.2.9 GSE

1.3.7 "

1.4.7

1.5.11

This hardware element sums all efforts and materials required for research and technology, design, development, production, and operations of the ground support equipment. This element includes those hardware items used to perform ground tests on the system and/or subsystem items and those used during the operational phase (spares).

1.2.10 Propellant

1.3.8 "

1.4.8

This hardware element includes all flight propellants, all power systems fuels and oxidizers, pressurants, purging gases, and fluids. Propellant totals support annual base requirements plus total flight requirements. Included are LO_2, LH_2, N_2H_4, N_2O_4, etc.

1.5.2 Shroud Structures

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC shroud structure. This element includes the frame structure, separation mechanisms, staging rails and muffler vent assembly.

1.5.3 Shroud TPS

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC shroud thermal protection system. This element includes the SLA and CPR covering the jettisoned shroud.

1.5.4 Shroud Acoustic Barrier

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC shroud acoustic barrier.

1.5.5 Skirt Structures

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC skirt structures. This element includes the payload support structures.

1.5.6 Skirt TPS

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC skirt TPS.

1.5.7 Skirt Acoustic Barrier

This hardware element sums all the efforts required for research and technology, design, development, production and operations of the DACC skirt acoustic barrier.

1.6.0 GSE

This hardware element sums all the efforts and materials required for research and tecnology, design, development, production, and operations of the GSE for the total launch vehicle. This element includes all hardware items used to perform ground tests on the system/subsystem and simulations.

2.0.0 Facilities

This hardware element sums all effort and materials required for research and technology, design, development, construction/modification and activation of the facilities. This element is subdivided into the following:

- 2.1.0 Manufacturing/Refurbish
- 2.2.0 Test
- 2.3.0 Launch
- 2.4.0 Mission
- 2.5.0 Recovery

2.1.0 Manufacturing/Refurbishment

This hardware element sums all efforts and materials required for research and technology, design, development, construction/modification and activation of the manufacturing and refurbishment facilities. This element includes manufacturing and refurbishment facilities for the launch vehicle hardware elements and propellants.

2.2.0 Test

This hardware element sums all efforts and materials required for research and technology, design, development, construction/modification and activation of the test facilities.

2.3.0 Launch

This hardware element includes all efforts and materials required for research and technology, design, development, construction/modification and activation of the launch facilities. This element includes transportation equipment, stage processing facilities, vehicle integration facilities, launch servicing facilities, etc.

2.4.0 Mission

This hardware element sums all efforts and materials required for the research and technology, design, development, construction/ modification and activation of the mission control facilities. This element includes facilities required to monitor the mission at the various operational levels and provides information required to control, direct, and evaluate the mission from prelaunch checkout through recovery. Facilities required include a central flight control facility, a worldwide network of monitoring stations, and real time display system.

2.5.0 Recovery

This hardware element sums all efforts and materials required for the research and technology, design, development, construction/modification and activation of the recovery facilities. This element includes the surface transportation equipment, tracking equipment, etc. required at the termination of a mission.

5.0 PHASE AND FUNCTION DIMENSION

The phase dimension is divided into four major phases: research and technology (R&T); design, development, test, and evaluation (DDT&E); production; and operations. The R&T phase is not subdivided but includes top level estimates of the efforts and materials required to establish new technology. The remaining phases are subsequently subdivided into subfunctions such as systems engineering and integration, design and development, tooling, flight hardware, program support, etc. An illustration of a typical WBS for each phase is shown in Figures 3, 4, 5 and 6. Definitions of the individual elements are contained in the following pages.

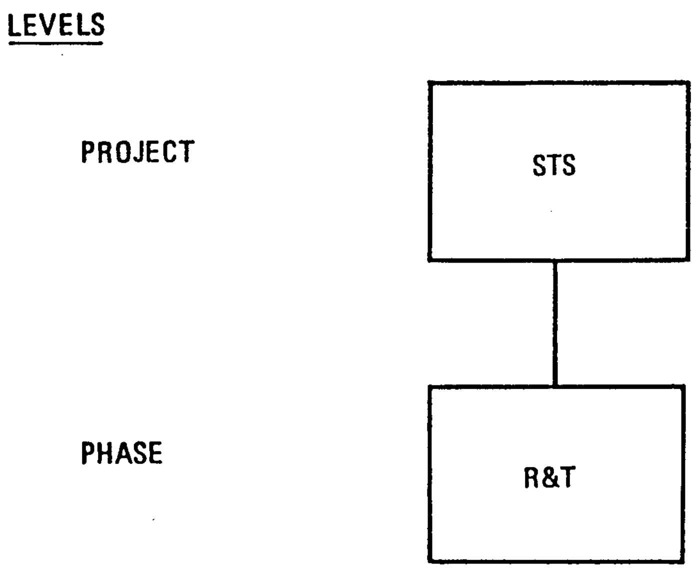


FIGURE 3. RESEARCH & TECHNOLOGY PHASE

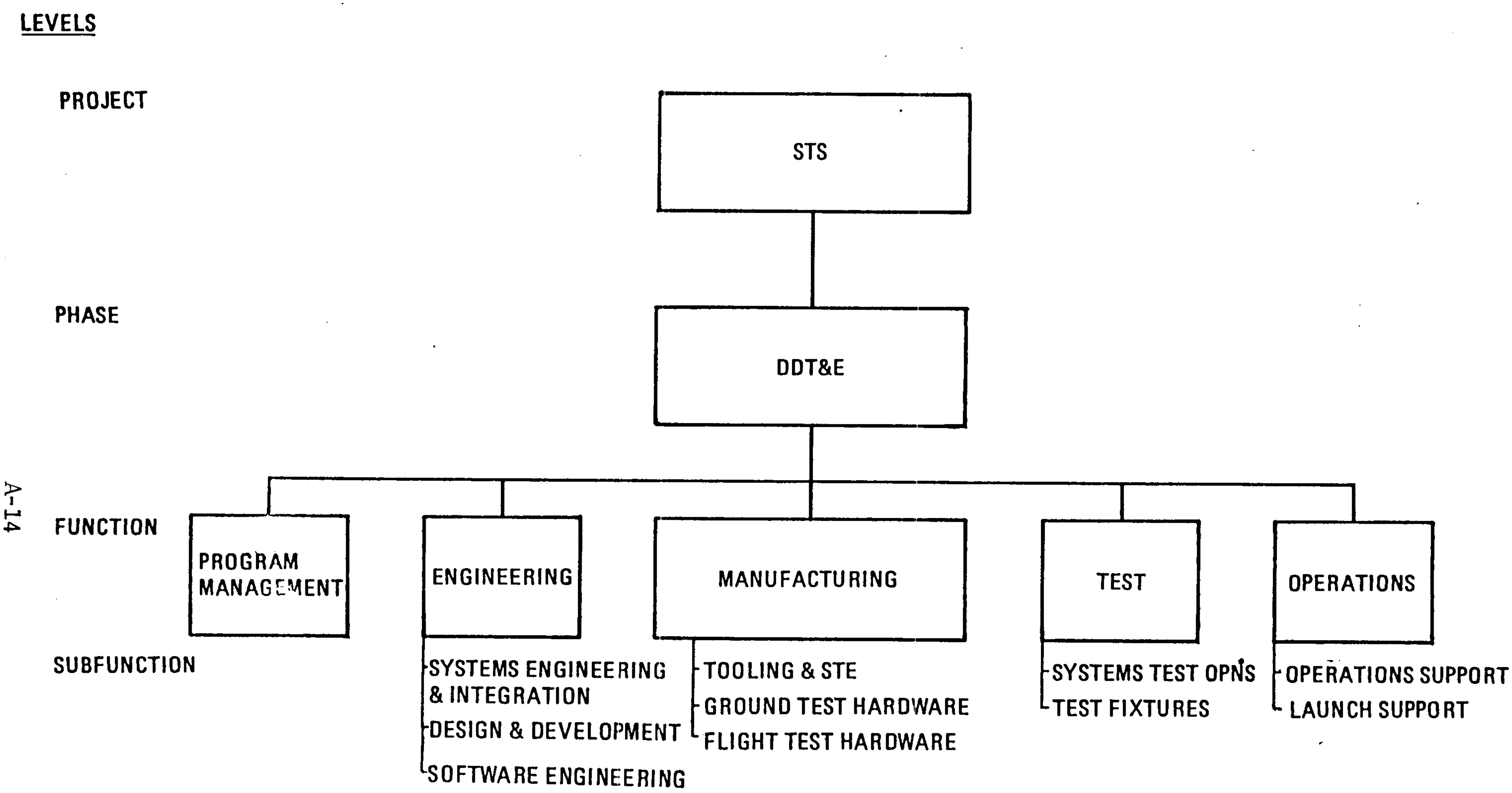


FIGURE 4. DESIGN, DEVELOPMENT, TEST, & EVALUATION (DDT&E) WBS PHASE & FUNCTION DIMENSION

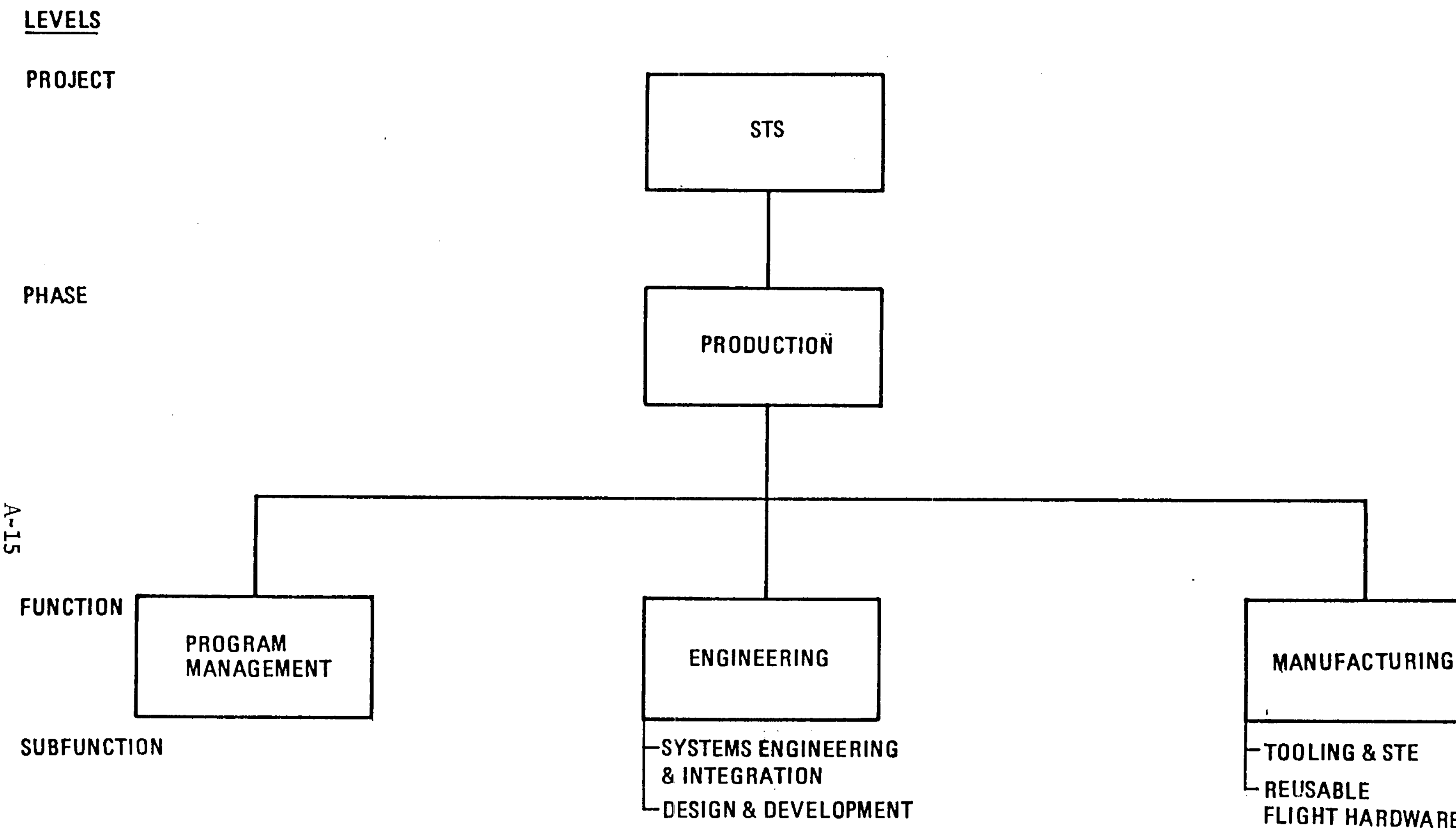


FIGURE 5. PRODUCTION WBS PHASE & FUNCTION DIMENSION

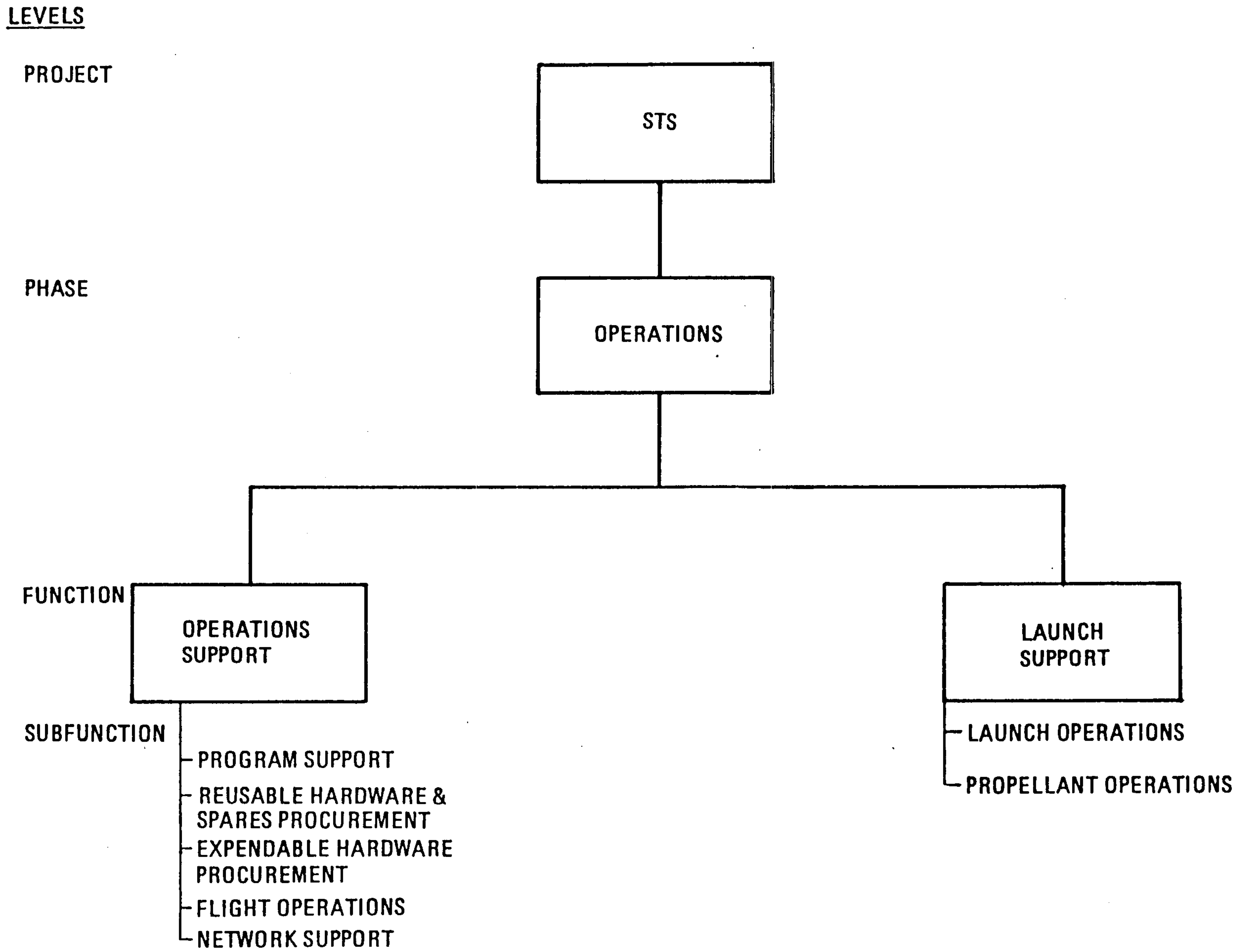


FIGURE 6. OPERATIONS WBS PHASE AND FUNCTION DIMENSION

6.0 DEFINITIONS OF PHASES AND FUNCTIONS

1.0.0.0 STS Program

This element sums all efforts and materials required for research and technology, development, production, and operations of the total STS program.

1.1.0.0 R&T - R&T Phase

This phase includes all efforts and materials required to advance the state-of-the-art in selected technologies. Areas of emphasis will include, but are not limited to, the following:

- Manufacturing
- TPS
- Composite Materials
- Hardware Recovery

1.2.0.0 DDT&E - DDT&E Phase

This phase encompasses those tasks associated with the DDT&E phase of the vehicle and with the requirement for demonstrating the vehicle's performance capabilities.

- 1.2.1.0 Program Management
- 1.2.2.0 Engineering
- 1.2.3.0 Manufacturing
- 1.2.4.0 Test
- 1.2.5.0 Operations

Specifically, it includes: mission analysis and requirements definition; mission and support hardware functional definition and design specification; design support; test hardware manufacture; functional, qualification and flight test effort. Also included are special test equipment and development tooling; mission control and/or launch site activation (if required); logistics, training (that is not covered in operations), developmental spares and other program peculiar costs not associated with repetitive production.

1.2.1.0 Program Management - DDT&E Phase

This DDT&E element includes all efforts and materials required for management and fundamental direction to ensure that a quality product is produced and delivered on schedule and within budget. Specific lower level items that are included are:

Program Administration

Program Planning and Control

Contracts Administration

Engineering Management

Manufacturing Management

Support Management

Quality Assurance Management

Configuration Management

Data Management

These items sum all efforts required to provide direction and control of the development of the system, including the efforts required for planning, organizing, directing, coordination, and controlling the project to ensure that overall project objectives are accomplished.

1.2.2.0 Engineering - DDT&E Phase

This DDT&E element includes all efforts and materials associated with analysis, design, development, evaluation, and redesign for specified hardware element items. This element is subdivided into the following lower elements:

1.2.2.1 Systems Engineering and Integration

1.2.2.2 Design and Development Engineering

1.2.2.3 Software Engineering

1.2.2.1 Systems Engineering and Integration - DDT&E Phase

This DDT&E element includes the engineering efforts related to the establishment of a technical baseline for a system by generation of system configuration parameters, criteria, and requirements. Specifically included are:

Engineering Analysis and Systems Integration

Human and Value Engineering

Logistics and Training

Safety, Reliability, Maintainability and Quality Assurance Requirements

1.2.2.2 Design and Development Engineering - DDT&E Phase

This DDT&E element includes all efforts associated with analysis, design, development, evaluation, and redesign necessary to translate a performance specification into a design. Specifically included are the preparation of specification and fabrication drawings, parts lists, wiring diagrams, technical coordination between engineering and manufacturing, vendor coordination, data reduction, and engineering related report preparation. This element can be further subdivided into the following:

Structures
Mechanical
Electrical
Propulsion
Aerodynamics

1.2.2.3 Software Engineering - DDT&E Phase

This DDT&E element includes the cost of the design, development, production, checkout, maintenance and delivery of computer software. Included are ground test, on-board and mission or flight software.

1.2.3.0 Manufacturing - DDT&E Phase

This DDT&E element includes the efforts and materials required to produce the various items of test hardware required by the program which include inspection assembly and checkout of tools, parts, material, subassemblies, and assemblies. The testing of this hardware is accomplished under system test operations. The test articles considered under this element include development models, engineering models, design verification units, qualifications models, structural test units, thermal models, mechanical models, and prototypes. Also included are the design and construction of DDT&E manufacturing facilities. This element is further subdivided into the following:

1.2.3.1 Tooling and STE
1.2.3.2 Ground Test Hardware
1.2.3.3 Flight Test Hardware

1.2.3.1 Tooling and STE - DDT&E Phase

This DDT&E element includes all efforts and materials associated with the planning, design, fabrication, assembly, inspection, installation, modification, maintenance, and rework of all tools, dies, jigs, fixtures, guages, handling equipment, work platforms, and special test equipment necessary for manufacture of the DDT&E vehicles.

1.2.3.2 Ground Test Hardware - DDT&E Phase

This DDT&E element includes all efforts and materials required to produce the various items of required ground test hardware. This element includes processing, subassembly, final assembly, reworking, and modification and installation of parts and equipment. Ground test hardware includes such items as static and dynamic test models, thermal and (if required) firing test articles and the qualification test unit. Also included are those costs chargeable to the acceptance testing, quality control program, and assembly as related to ground test hardware. In addition, the design and construction of manufacturing facilities for DDT&E vehicles are included.

1.2.3.3 Flight Test Hardware - DDT&E Phase

This DDT&E element includes all efforts and materials required to produce the various items of flight test hardware. This element includes the same basic operations as defined in WBS item number 1.2.3.2 (Ground Test Hardware).

1.2.4.0 Test - DDT&E Phase

This DDT&E element includes all efforts and materials required for qualifications, integration, and system/subsystem development tests, including the design and fabrication of test facilities and fixtures. This element is further subdivided into the following:

1.2.4.1 Systems Test Operations

1.2.4.2 Test Fixtures

1.2.4.1 Systems Test Operations - DDT&E Phase

This DDT&E element includes all efforts and materials required for assemblies, subsystems, and systems to determine operational characteristics and compatibility with the overall system and its intended operational/non-operational environment. Such tests include design feasibility tests, design and integrated systems to verify whether they are unconditionally suitable for their intended use. These tests are conducted on hardware that have been produced, inspected, and assembled by established methods. Tests performed by two or more contractors to substantiate the feasibility compatibility are also included as well as test planning and scheduling, data reduction and report preparation. In addition, the design and construction of DDT&E test facilities are included.

1.2.4.2 Test Fixtures - DDT&E Phase

This DDT&E element includes all the efforts and materials required for the design and fabrication of the unique test fixtures required to support a given system/subsystem test.

1.2.5.0 Operations - DDT&E Phase

This DDT&E element includes all efforts and materials required to operate the hardware defined in the corresponding hardware elements during flight test operations. Also included are the design, construction, and operation of the launch, mission, and recovery facilities required for DDT&E test flights. This element further subdivides into the following:

1.2.5.1 Operations Support

1.2.5.2 Launch Support

1.2.5.1 Operations Support - DDT&E Phase

This element includes all efforts and materials required to support the DDT&E flight test program. This item includes the operation of the mission control facilities and equipment. Included is mission control monitoring which provides the information required to control, direct, and evaluate the mission from prelaunch through recovery. In addition, the design and construction of the DDT&E mission control facilities are included.

1.2.5.2 Launch Support - DDT&E Phase

This operations element includes all efforts and materials required to support launch and recovery operations during the DDT&E flight test program. Included are those efforts and materials associated with the receipt of the major hardware categories of the mission hardware. This element does not include payload integration. Included are subelements such as ground operations (including recovery) and propellant operations. In addition, the design and construction of DDT&E launch and recovery facilities are included.

1.3.0.0 Production - Production Phase

This phase includes all efforts and materials required for the production of the reusable flight hardware to meet the total operational requirements. This includes the production of initial spares, but excludes the operational spares as they are included under the operations phase. Specifically this phase includes the following functions:

1.3.1.0 Program Management
1.3.2.0 Engineering
1.3.3.0 Manufacturing

1.3.1.0 Program Management - Production Phase

This element includes all efforts and materials required to ensure fundamental direction, and to make decisions to ensure that a quality product is produced and delivered on schedule and within budget. Specifically included are program administration, program planning and control, contracts administration, engineering management, manufacturing management, project management, and documentation. This item sums all efforts required to provide direction and control of the production of the system, including the efforts required for planning, organizing, direction, coordination, and controlling the project to ensure that overall project objectives are accomplished. These efforts overlay the other functional categories and assure that they are properly integrated.

1.3.2.0 Engineering - Production Phase

This element includes those sustaining engineering efforts and materials necessary to facilitate production and to resolve day-to-day production problems. This element includes the following:

1.3.2.1 Systems Engineering and Integration

1.3.2.2 Design and Development Engineering

1.3.2.1 Systems Engineering and Integration - Production Phase

This element includes the recurring engineering efforts related to the maintenance of a technical baseline for systems configuration parameters, criteria, and requirements. This baseline may include specifications, procedures, reports, technical evaluation, software, and interface definition. This element also includes those efforts required to monitor the system during production to ensure that the hardware conforms to the baseline specifications.

1.3.2.2 Design and Development Engineering - Production Phase

This element includes all recurring efforts and materials associated with sustaining engineering required during the production of the reusable flight hardware and initial spares.

1.3.3.0 Manufacturing - Production Phase

This element includes all recurring efforts and materials associated with the production of reusable flight hardware, initial spares, tooling, and special test equipment (STE). Also included are the design and construction of additional manufacturing facilities during the production phase. This element includes:

1.3.3.1 Tooling and STE

1.3.3.2 Reusable Flight Hardware

1.3.3.1 Tooling and STE - Production Phase

This element includes the fabrication of production tooling and those sustaining efforts necessary to facilitate production and to resolve production problems involving tooling and STE. This element also includes the production and/or procurement of replacement parts and spares.

1.3.3.2 Reusable Flight Hardware - Production Phase

This element includes all efforts and materials required to produce production flight units. This item includes time expended on, or chargeable to, such operations as fabrication processing, subassembly, final assembly, reworking, modification, and installation of parts and equipment (including Government furnished equipment). Included are those costs chargeable to the acceptance testing, quality control program, and assembly as related to flight units. The design and construction of additional manufacturing facilities required during the production phase are also included.

1.4.0.0 Operations - Operations Phase

This phase includes those efforts and materials associated with the receipt of the stages, shrouds, etc. at the launch site and the processing, testing, and integration required to prepare for and launch the mission hardware and recovery. This phase also includes reusable hardware spares procurement to support hardware refurbishment and replenishment operations, expendable hardware and initial spares procurement and GSE maintenance. Additional facilities required to meet updated mission requirements are also included. This element is subdivided into the following:

1.4.1.0 Operations Support

1.4.2.0 Launch Support

1.4.1.0 Operations Support - Operations Phase

This operations element includes the efforts and materials required to support the operational program. This item includes the operations and program support of the mission control facilities and equipment. It includes reusable hardware spares procurement to support hardware refurbishment and replenishment operations, expendable hardware procurement and GSE Maintenance. This element is subdivided into the following:

1.4.1.1 Program Support

1.4.1.2 Reusable Hardware and Spares Procurement

1.4.1.3 Expendable Hardware Procurement

1.4.1.4 Flight Operations

1.4.1.5 Network Support

1.4.1.1 Program Support - Operations

This operations element includes efforts and materials required to support the operational program. Included are the hardware/mission control center effort and the associated contractor effort to support the operations phase of the program. Mission planning, mission control, sustaining engineering and program management activities for hardware delivery in direct support of the program are included as well as the indirect effort required to support the program or provide multi-program support which must be pro-rated to the program. Both civil service and support contractor effort at the hardware/mission control centers are included. This item includes such functions as:

Management Systems
Operations and Maintenance of Computers and Terminals
Systems Engineering Support Requirements
Documents
Flight Planning Support
National Weather Service
Sustaining Engineering

Also, any additional mission control facility design and construction required in the operational phase are included here.

1.4.1.2 Reusable Hardware Spares Procurement - Operations Phase

This operations element includes all production, refurbishment and spares cost of the reusable SRB and orbiter in the operational phase of the program.

1.4.1.3 Expendable Hardware Procurement - Operations Phase

This operations element includes all the production and spares costs of the external tank and DACC hardware that is expended in the operational phase of the program.

1.4.1.4 Flight Operations - Operations Phase

This operations element includes all efforts and materials required to support the mission hardware after launch. This effort includes the following:

- o Mission control operations, simulator operations, software production facility, orbiter flight software and flight design.
- o Crew operations such as: T-38 aircraft operations, shuttle carrier aircraft operations, shuttle training aircraft operations, crew procedures and flight control.
- o Engineering support to include crew systems lab, data processing system maintenance, shuttle avionics lab, mockups/trainers, simulator software support and other engineering support function.
- o Program Management and Support

1.4.1.5 Network Support - Operations Phase

This operations element includes the operations and maintenance of the NASCOM communication links.

1.4.2.0 Launch Support - Operations Phase

This operations element includes all the efforts and materials required for launch support. This element includes those efforts and materials associated with the receipt of the major hardware elements at the launch site and the processing, testing, and integration required for preparation and launch of the mission hardware. This element does not include payload integration. The design and construction of operational launch and recovery facilities above those provided in the DDT&E phase are included in this item. Further sub elements are:

1.4.2.1 Launch Operations

1.4.2.2 Propellant Operations

1.4.2.1 Launch Operations - Operations Phase

This operations element includes all the effort and materials required for the receipt of the vehicle hardware at the launch site and the processing, testing, and integration required to prepare for launching of the mission hardware. This effort includes the manpower associated with the:

- Processing, testing, and integration of the flight hardware
- Operation and maintenance of launch related ground support equipment
- Offline ground systems activities (shops, labs, etc.) required to support the vehicle turnaround activities
- GSE sustaining engineering effort to support modification design and configuration control of all launch site related ground support equipment
- Direct and indirect civil service effort for program management of all prelaunch and launch site activities
- Direct and indirect contractor activities at the launch site including a prorata share of the base support functions
- Production and inventory/control of the launch site related ground support equipment replenishment/ refurbishment spares.

Any additional launch or recovery facilities required for the operational phase are included in this event, as well as landing and recovery operations.

1.4.2.2 Propellant Operations - Operations Phase

This operations element includes all flight propellant costs at the launch site such as all fuel and oxidizers, pressurants, purging gases and fluids to support the operational phase of the program. These costs reflect annual base requirements in addition to total flight requirements. Also included are any additional manufacturing facilities required above those provided in the DDT&E phase.

APPENDIX B

DEDICATED ACC COST ESTIMATES BY WBS

SHUTTLE DERIVED VEHICLE COST SUMMARY: AFT CARGO CARRIER

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

64.0 MANIFESTED ACC FLIGHTS

HARDWARE ELEMENTS	RESEARCH & TECHNOLOGY COSTS	DDT&E COSTS	PRODUCTION COSTS	OPERATIONS COSTS	TOTAL COSTS
VEHICLE INTEG. SYS	-	20.4	0.2	14.5	35.1
ORBITER	-	9.5	3.7	-	13.2
ET	-	6.0	-	2.8	8.8
SRB	-	-	-	-	-
ACC	-	72.9	-	121.2	194.1
GSE	-	4.2	-	-	4.2
STS/ACC VEHICLE	-	113.0	3.9	138.5	255.4
FACILITIES	-	41.1	-	-	41.1
*ACC TOTAL	-	154.1	3.9	138.5	296.5

* SHUTTLE DERIVED VEHICLE LCC: 296.5

* INCLUDES HARDWARE ELEMENTS AND FACILITIES

HARDWARE ELEMENT SUMMARY: DDT&E

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PROGRAM MANAGEMENT	ENGINEERING			MANUFACTURING			TEST		OPERATIONS	
DDT&E 113.0	11.8	45.2			44.4			10.7		1.0	
		SYS ENG & INTEG	DESIGN & DEVELMNT	SOFTWARE ENGINEER	TOOLING & STE	GND TEST HARDWARE	FLT TEST HARDWARE	SYS TEST OPER	TEST FIXTURE	OPER. SUPP.	LAUNCH SUPP.
VEHICLE INTEG. SYS	5.6	9.3	-	-	-	-	-	4.6	-	0.8	0.1
ORBITER	0.5	1.7	2.1	3.4	-	0.8	0.8	0.2	0.0	-	-
E T	0.4	1.3	1.8	-	1.8	0.0	0.0	0.7	0.1	-	-
S R B	-	-	-	-	-	-	-	-	-	-	-
A C C	5.4	6.6	15.1	-	35.1	2.7	3.1	4.4	0.7	-	-
G S E	-	-	4.2	-	-	-	-	-	-	-	-
STS/ACC VEHICLE	11.8	18.8	23.0	3.4	36.9	3.5	4.0	9.9	0.8	0.8	0.1

HARDWARE ELEMENT SUMMARY: PRODUCTION

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PRODUCTION 3.9				
	PROGRAM MANAGEMENT	ENGINEERING		MANUFACTURING	
	0.1	1.0		2.8	
		SYSTEM ENGINEER AND INTEGRATION	DESIGN AND DEVELOPMENT	TOOLING AND STE	REUSABLE FLIGHT HARD
VEHICLE INTEG. SYS	0.0	0.1	-	-	-
ORBITER	0.0	0.2	0.7	0.4	2.5
E T	-	-	-	-	-
S R B	-	-	-	-	-
A C C	-	-	-	-	-
G S E	-	-	-	-	-
STS/ACC VEHICLE	0.1	0.4	0.7	0.4	2.5

HARDWARE ELEMENT SUMMARY: DDT&E

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PROGRAM MANAGEMENT	ENGINEERING			MANUFACTURING			TEST		OPERATIONS	
DDT&E 9.5	0.5	7.1			1.6			0.3		0.0	
		SYS ENG & INTEG	DESIGN & DEVELMNT	SOFTWARE ENGINEER	TOOLING & STE	GND TEST HARDWARE	FLT TEST HARDWARE	SYS TEST OPER	TEST FIXTURE	OPER. SUPP.	LAUNCH SUPP.
ORBITER	0.5	1.7	2.1	3.4	-	0.8	0.8	0.2	0.0	-	-
INTEGRATED SYSTEM	0.5	1.7	-	-	-	-	-	0.2	0.0	-	-
STRUCTURE	-	-	-	-	-	-	-	-	-	-	-
PROPULSION	-	-	-	-	-	-	-	-	-	-	-
POWER	-	-	0.4	-	-	0.1	0.1	-	-	-	-
AVIONICS	-	-	1.6	3.4	-	0.7	0.7	-	-	-	-
ECLSS	-	-	-	-	-	-	-	-	-	-	-
ENGINES	-	-	-	-	-	-	-	-	-	-	-
ASE	-	-	-	-	-	-	-	-	-	-	-
GSE	-	-	-	-	-	-	-	-	-	-	-
PROPELLANT	-	-	-	-	-	-	-	-	-	-	-

HARDWARE ELEMENT SUMMARY: DDT&E

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PROGRAM MANAGEMENT	E N G I N E E R I N G			M A N U F A C T U R I N G			T E S T		O P E R A T I O N S	
D D T & E 6.0	0.4	3.0			1.9			0.8		0.0	
		SYS ENG & INTEG	DESIGN & DEVELMNT	SOFTWARE ENGINEER	TOOLING & STE	GND TEST HARDWARE	FLT TEST HARDWARE	SYS TEST OPER	TEST FIXTURE	OPER. SUPP.	LAUNCH SUPP.
E T	0.4	1.3	1.8	-	1.8	0.0	0.0	0.7	0.1	-	-
INTEGRATED SYSTEM	0.4	1.3	0.0	-	-	-	-	0.7	0.1	-	-
STRUCTURES	-	-	1.7	-	1.8	0.0	0.0	-	-	-	-
PROPULSION	-	-	-	-	-	-	-	-	-	-	-
POWER	-	-	-	-	-	-	-	-	-	-	-
AVIONICS	-	-	-	-	-	-	-	-	-	-	-
ENGINES	-	-	-	-	-	-	-	-	-	-	-
GSE	-	-	-	-	-	-	-	-	-	-	-
PROPELLANT	-	-	-	-	-	-	-	-	-	-	-

HARDWARE ELEMENT SUMMARY: DDT&E

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PROGRAM MANAGEMENT	ENGINEERING			MANUFACTURING			TEST		OPERATIONS	
DDT&E 72.9	5.4	21.6			40.9			5.1		0.0	
		SYS ENG & INTEG	DESIGN & DEVELMNT	SOFTWARE ENGINEER	TOOLING & STE	GND TEST HARDWARE	FLT TEST HARDWARE	SYS TEST OPER	TEST FIXTURE	OPER. SUPP.	LAUNCH SUPP.
A C C	5.4	6.6	15.1	-	35.1	2.7	3.1	4.4	0.7	-	-
INTEGRATED SYSTEM	5.4	6.6	1.3	-	-	0.4	0.5	4.4	0.7	-	-
SHROUD STRUCTURES	-	-	3.6	-	14.2	0.3	0.3	-	-	-	-
SHROUD TPS	-	-	0.1	-	-	0.6	0.6	-	-	-	-
SHROUD AC. BARR.	-	-	-	-	-	-	-	-	-	-	-
SKIRT STRUCTURES	-	-	8.9	-	20.9	0.5	0.5	-	-	-	-
SKIRT TPS	-	-	0.1	-	-	0.2	0.2	-	-	-	-
SKIRT AC. BARR.	-	-	-	-	-	-	-	-	-	-	-
PROPULSION	-	-	0.2	-	-	0.1	0.1	-	-	-	-
POWER	-	-	0.1	-	-	0.2	0.2	-	-	-	-
AVIONICS	-	-	0.7	-	-	0.4	0.8	-	-	-	-
GSE	-	-	-	-	-	-	-	-	-	-	-

HARDWARE ELEMENT SUMMARY: DDT&E

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

D D T & E

41.1

	PROGRAM MANAGEMENT	E N G I N E E R I N G			M A N U F A C T U R I N G			T E S T		O P E R A T I O N S	
	0.0		41.1			0.0		0.0		0.0	
		SYS ENG & INTEG	DESIGN & DEVELMNT	SOFTWARE ENGINEER	TOOLING & STE	GND TEST HARDWARE	FLT TEST HARDWARE	SYS TEST OPER	TEST FIXTURE	OPER. SUPP.	LAUNCH SUPP.
F A C I L I T I E S	-	-	41.1	-	-	-	-	-	-	-	-
MFG / REFURB	-	-	14.6	-	-	-	-	-	-	-	-
TEST	-	-	-	-	-	-	-	-	-	-	-
LAUNCH	-	-	26.5	-	-	-	-	-	-	-	-
MISSION	-	-	-	-	-	-	-	-	-	-	-
RECOVERY	-	-	-	-	-	-	-	-	-	-	-

HARDWARE ELEMENT SUMMARY: PRODUCTION

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	PROGRAM MANAGEMENT	PRODUCTION 3.7 — ENGINEERING 0.9		MANUFACTURING 2.8	
	0.0	SYSTEM ENGINEER AND INTEGRATION	DESIGN AND DEVELOPMENT	TOOLING AND STE	REUSABLE FLIGHT HARD
ORBITER	0.0	0.2	0.7	0.4	2.5
INTEGRATED SYSTEM	0.0	0.2	-	-	-
STRUCTURE	-	-	-	-	-
PROPULSION	-	-	-	-	-
POWER	-	-	0.0	0.1	0.4
AVIONICS	-	-	0.6	0.3	2.1
ECLSS	-	-	-	-	-
ENGINES	-	-	-	-	-
ASE	-	-	-	-	-
GSE	-	-	-	-	-
PROPELLANT	-	-	-	-	-

HARDWARE ELEMENT SUMMARY: OPERATIONS

DATE : MON, APR 22 1985
MILLIONS OF 1984 DOLLARS

	OPERATIONS 121.2					LAUNCH SUPPORT 0.0	
	OPERATIONS SUPPORT 121.2						
	PROGRAM SUPPORT	REUS HARD & SPARES	EXPNDABLE HARD PROC	FLIGHT OPS	NETWORK SUPPORT	LAUNCH OPS	PROPELLANT OPS
A C C	28.9	-	92.3	-	-	-	-
INTEGRATED SYSTEM	28.9	-	15.7	-	-	-	-
SHROUD STRUCTURES	-	-	8.5	-	-	-	-
SHROUD TPS	-	-	14.3	-	-	-	-
SHROUD AC. BARR.	-	-	-	-	-	-	-
SKIRT STRUCTURES	-	-	18.6	-	-	-	-
SKIRT TPS	-	-	8.3	-	-	-	-
SKIRT AC. BARR.	-	-	-	-	-	-	-
PROPULSION	-	-	2.4	-	-	-	-
POWER	-	-	8.9	-	-	-	-
AVIONICS	-	-	15.6	-	-	-	-
GSE	-	-	-	-	-	-	-