FR-19691-4
VOLUME III
1 DECEMBER 1989

SPACE TRANSPORTATION BOOSTER ENGINE CONFIGURATION STUDY

FINAL REPORT (DR4)

PROGRAM COST ESTIMATES (DR6)

AND

WORK BREAKDOWN STRUCTURE AND WBS DICTIONARY (DR5)

31 MARCH 1989

CONTRACT NAS8-36857
MODIFICATION NO.10

Pratt & Whitney
Government Engine Business
P.O. Box 109600
West Palm Beach, Florida 33410-9600

Prepared for
Procurement Office
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

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FOREWORD

This study was conducted by the Pratt & Whitney/Government Engine Business (P&W/GEB) of the United Technologies Corporation under NASA/MSFC contract NAS8-36857. The NASA/MSFC program manager was Mr. J. Thomson. The Pratt & Whitney program manager was Mr. W. A. Visek, Jr., and D. R. Connell was the booster engine program manager.

The technical effort started in March 1986 and was completed in March 1989. The study is presented in three volumes.

Volume I — Executive Summary
Volume II — Final Report
Volume III — Program Cost Estimates

Special thanks go to the numerous individuals at NASA, UTC, and the major vehicle contractors who contributed to this study effort.

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SECTION 1.0
INTRODUCTION

The United States is experiencing a critical need to place large payloads in low earth orbit. This need exceeds the capability of current and planned fleets of Titan IV and Space Shuttle launch vehicles, and reflects the requirements of the National Aeronautics and Space Administration (NASA), the U. S. Air Force, the Strategic Defense Initiative Organization (SDIO), and the civilian sector.

The Advanced Launch System (ALS) will provide a low cost, reliable means of satisfying this need. The ALS will enable the United States to meet defense, national, and civil launch requirements, while expending fewer resources on launch vehicles.

The objective of the Space Transportation Booster Engine Configuration Study is to contribute to the ALS development effort by providing highly reliable, low cost booster engine concepts for both expendable and reusable rocket engines.

The objectives of the Space Transportation Booster Engine (STBE) Configuration Study were: (1) to identify engine configurations which enhance vehicle performance and provide operational flexibility at low cost, and (2) to explore innovative approaches to the follow-on Full-Scale Development (FSD) phase for the STBE.

The Pratt & Whitney (P&W) overall technical approach to the study, shown in Figure 1-1, was based on the STBE technical requirements and guidelines presented in the Statement of Work (SOW). These requirements and guidelines were modified continually as the results of the joint NASA/Air Force Space Transportation Architecture Study (STAS), and later the Advanced Launch System (ALS), became available. As a result, the study effort was completely supportive of and interactive with the ALS and other launch vehicle studies. The schedule of the STBE Phase A, including the three extensions and the interim final reporting documentation, is shown in Figure 1-2.

The STBE Configuration Study consisted of six tasks. Task I (SOW Task 5.1) consisted of parametric analyses and trade studies. First, the system design requirements and features were defined, and the information base was established. Second, the STBE configurations that enhance performance and provide operational flexibility at low cost were identified, and the requirements for those engine configurations for the projected missions were defined.

During Task II (SOW Task 5.2), P&W developed a plan to evaluate the STBE configurations identified in Task I and established criteria to select the most promising configurations. The Configuration Evaluation and Criteria Plan used overall system life cycle costs as the figure of merit and included considerations of mission and vehicle requirements, operational flexibility, schedules (along with their risks), required technological advances, and facility requirements. The evaluation and selection criteria were compatible with the NASA requirements and the STAS results.

During Task III (SOW Task 5.3), P&W assessed the STBE configurations and requirements identified during Task I using the Configuration Evaluation and Criteria Plan developed during Task II. This process, based on minimizing life cycle cost (LCC), was used to select the most promising engine candidate as agreed to by NASA and P&W.

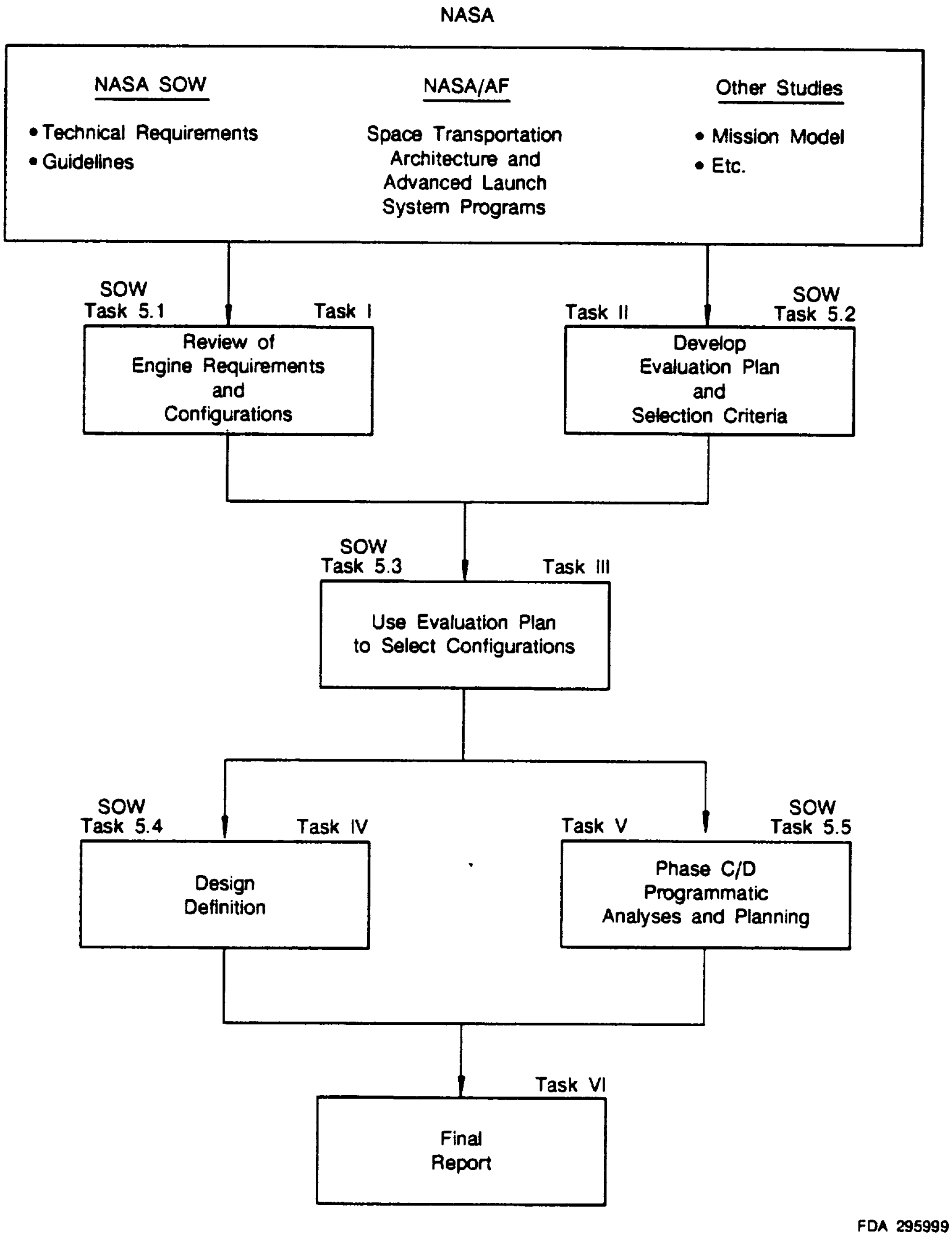


Figure 1-1. Overall Approach to Space Transportation Booster Engine Configuration Study

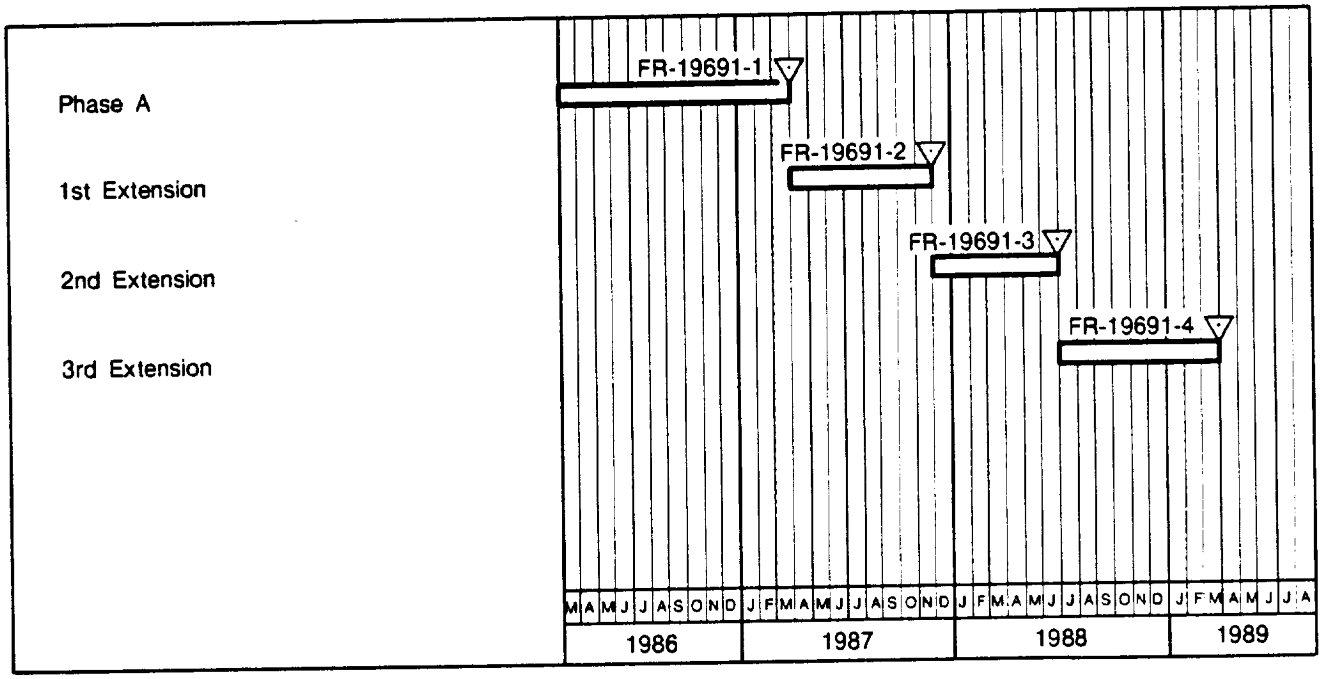


Figure 1-2. STBE Phase A and Extensions

The selected engine candidate was then the subject of Tasks IV and V. During Task IV (SOW Task 5.4), P&W completed the conceptual designs of the selected candidate. Under this task, P&W prepared the Design Definition Document (DR8), including a preliminary Interface Control Document (ICD) and preliminary Contract End Item (CEI) Specification. Task V (SOW Task 5.5) was conducted concurrently with Task IV and provided the plans for Full-Scale Development (FSD). These plans included FSD schedules, facility requirements, and an Environmental Impact Analysis (DR10). In addition, a Work Breakdown Structure (WBS) and dictionary, and program cost estimates were prepared for Phases C, D, and E of the STBE program.

During Task VI, all of the technical reviews, status reports, and the final report were prepared.

The Interim Preliminary Reports were published at the milestones shown in Figure 1-2. The information and studies reported within these documents are referenced but not repeated in this Final Report.

This Volume III of the Final Report presents the STME/Derivative STBE Program Work Breakdown Structure (DR5) and Cost Estimates (DR6) generated as part of Task V (SOW Task 5.5) during the time period July 1, 1988 to March 31,1989. All costs contained in this volume are engineering estimates. These costs should not be considered as contractual commitments and should be used for Life Cycle Cost (LCC) evaluations and planning purposes only.

SECTION 2.0
STME/DERIVATIVE STBE DESCRIPTION

NASA has defined three different ALS program scenarios to be costed as part of the STME and STBE Configuration Studies. Scenario 2 incorporates a methane fuel booster stage and it is the only one of the three applicable to the STBE.

The candidate engine configurations for Scenario 2 are the bipropellant LO_2/LH_2 Gas Generator STME for the core stage and the bipropellant LO_2/CH_4 Gas Generator STBE derived from the STME (Derivative STBE) for the booster stage. This design combination takes advantage of a 72 percent engine cost commonality, without compromising the core engine weight and 580K vacuum thrust level. The booster engine takes advantage of the desirable specific density and combustion stability characteristics of liquid methane while attaining a maximum sea level thrust of 645K lbf. The STME and Derivative STBE engine assemblies and overall engine characteristics are presented in Figure 2-1.

2.1 STME CYCLE

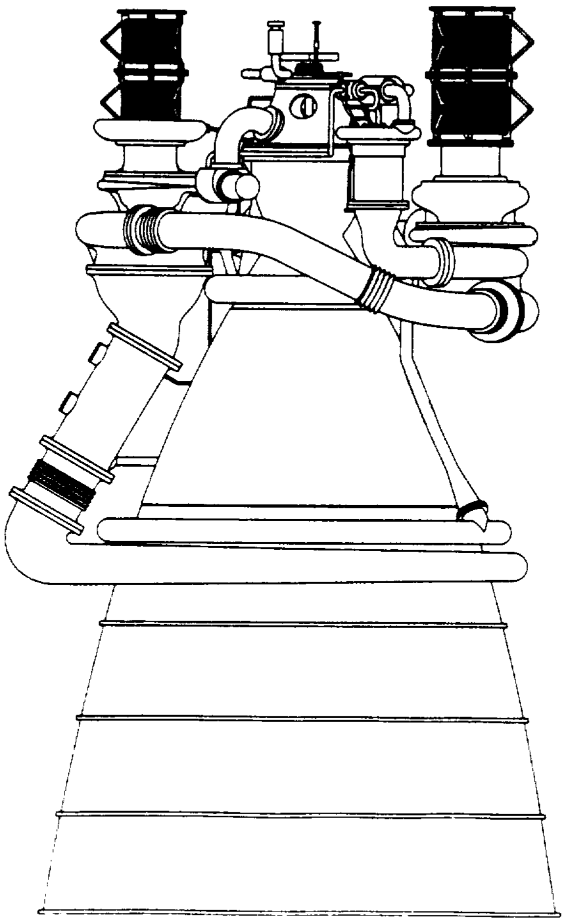
The candidate STME configuration is a gas generator cycle engine which operates at a main chamber pressure of 2250 psia at the rated power level (RPL) of 580K lbf thrust. The engine has a fixed nozzle with an area ratio of 62:1 and delivers 440 seconds of vacuum specific impulse at RPL. Figures 2.1-1 and 2.1-2 are top and side views showing the engine and its major features.

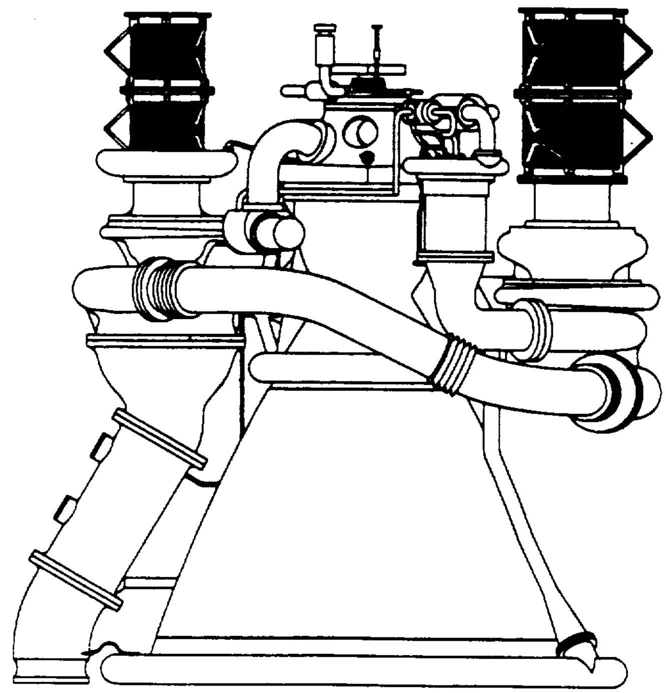
2.2 STME FLOWPATH DESCRIPTION

A flow schematic for the STME is presented in Figure 2.2-1 showing flowpaths and components.

Liquid oxygen enters the engine at a minimum net positive suction pressure (NPSP) level of 28.6 psi supplied by the vehicle. The high-speed, high-pressure oxidizer pump is designed to operate at this minimum NPSP level without a boost pump. Liquid hydrogen enters the engine at a NPSP level of 8.6 psi, again supplied by the vehicle. The high-speed, high-pressure hydrogen pump is also designed to operate without boost pumps.

At the rated power level, the hydrogen pump operates at 21,819 rpm to provide the hydrogen pressure level of 3387 psia required by the cycle. From the pump exit, the hydrogen flows through the fuel shutoff valve to a split manifold at the inlet of the chamber/nozzle coolant passages. From the split manifold, 87.4 percent of the hydrogen is used to regeneratively cool the milled channel, copper alloy main chamber from an area ratio of 5.86:1 back to the injector face. This flow is injected into the main chamber to combust with 98.5 percent of the oxygen. The remaining hydrogen flow is used to cool the tubular, stainless steel nozzle from an area ratio of 5.86:1 down to an area ratio of 35:1. This hydrogen then flows through the fuel gas generator control valve and is injected into the gas generator to combust with some of the oxygen to provide high temperature combustion gases to operate the high pressure turbomachinery.





		STME	Derivative STBE
Propellants		H_2/LO_2	CH_4/LO_2
Mixture Ratio		6.0	2.70
Chamber Pressure		2250 psia	2250 psia
Thrust	Vacuum	580,000 lb	711,823 lb
	Sea Level	461,446 lb	644,898 lb
Specific Impulse	Vacuum	440.3 sec	328.4 sec
	Sea Level	350.3 sec	297.5 sec
Nozzle Area Ratio		62	28
Diameter		108 in.	91 in.
Length		175 in.	99 in.
Weight		7981 lb	6960 lb

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Figure 2-1. Gas Generator STME and Derivative STBE Design Characteristics

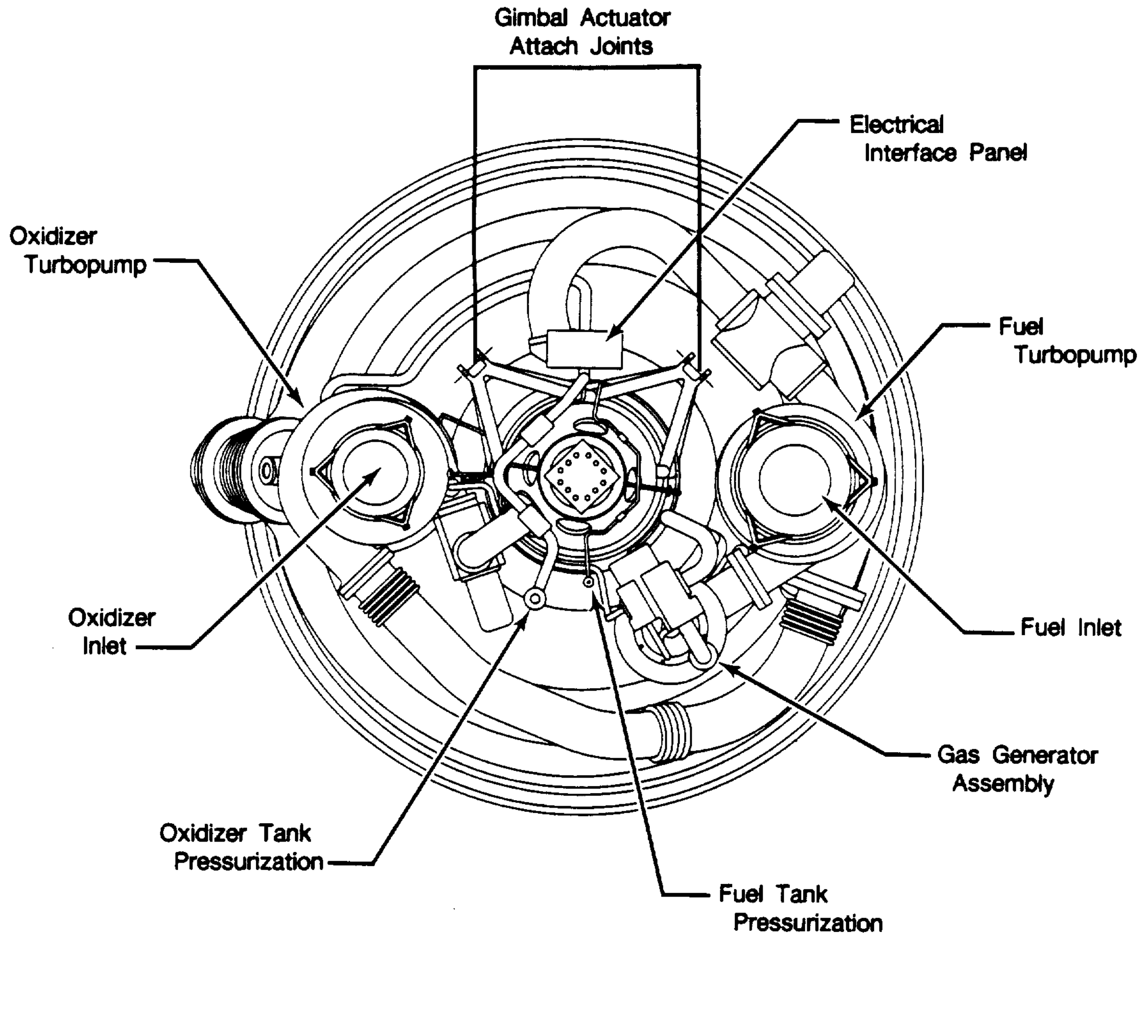


Figure 2.1-1. Gas Generator STME Assembly, Top View

The high-pressure oxidizer pump operates at 8,352 rpm to provide the oxygen pressure level of 2784 psia required by the cycle at the rated power level. From the pump exit, approximately 98.5 percent of the oxygen flow is routed through the main oxidizer control valve and is injected into the main chamber. The remainder of the oxygen flows through the oxygen gas generator control valve before being injected into the gas generator.

The gas generator provides 1688 psia, 1800 R gas to drive the high-pressure propellant pumps. The hot gas is initially expanded through the hydrogen turbine and is subsequently routed to a second turbine which powers the oxygen pump.

A film/radiation cooled nozzle provides the final gas expansion from an area ratio of 35:1 to an area ratio of 62:1 at the exit. Gas generator flow is used for the film cooling.

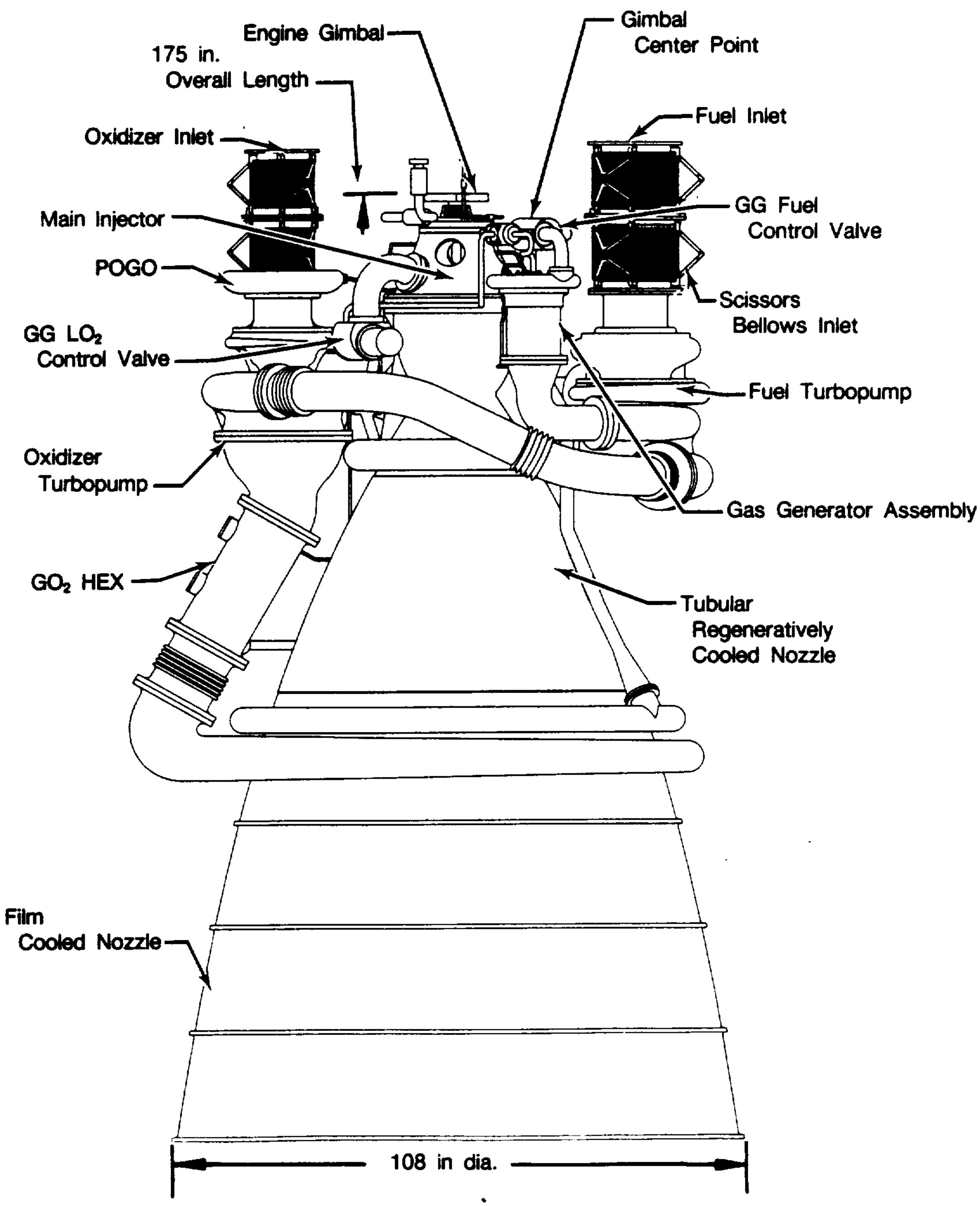
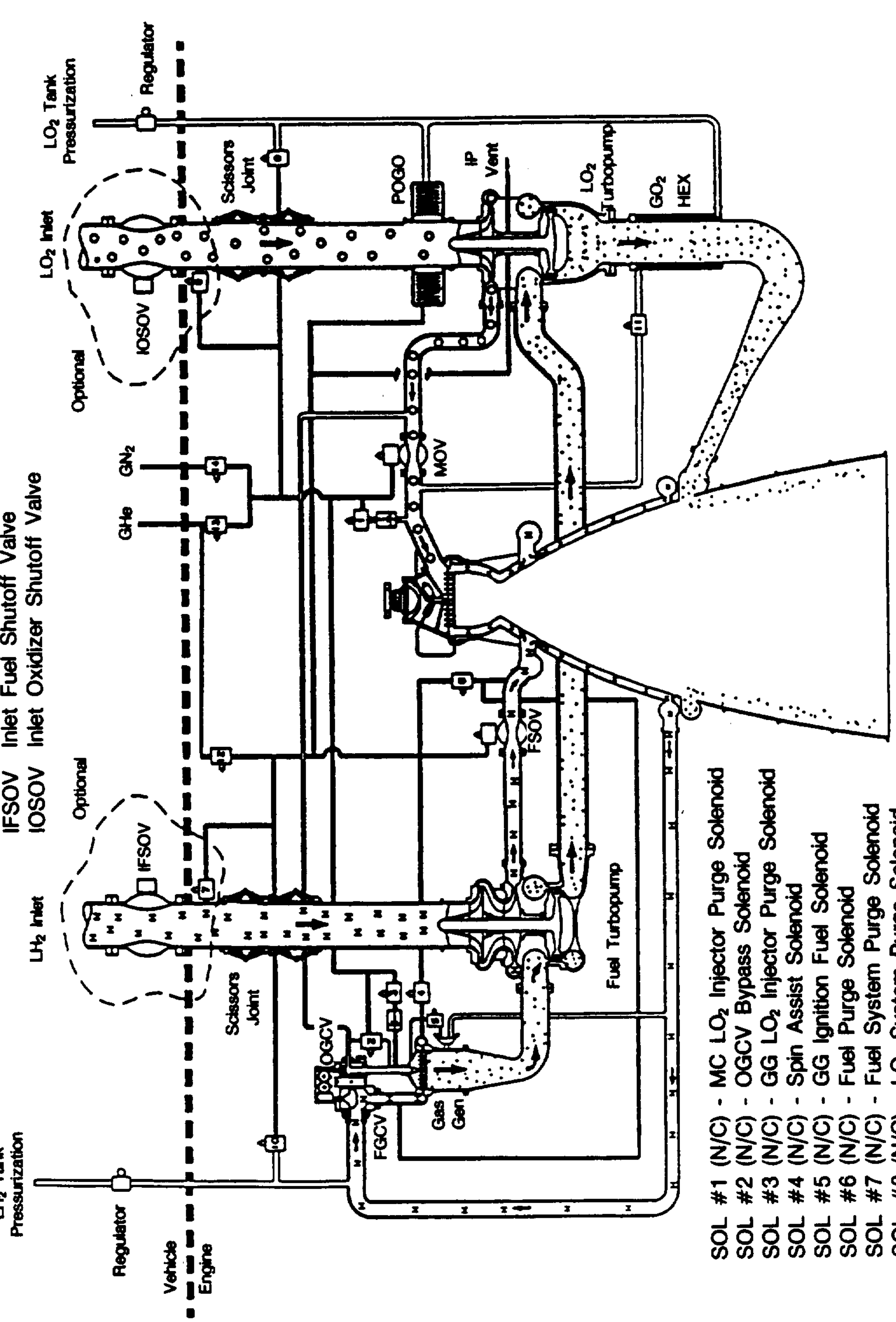


Figure 2.1-2. Gas Generator STME Assembly, Side View

2.3 STME OPERATION

The engine is preconditioned using liquid from the tanks to soak the turbopumps until they are sufficiently cooled. The vehicle inlet valves are opened, thus allowing liquid from the tanks to flow down to the turbopumps, and vapors to percolate back up to the tank to be vented.

FSOV Fuel Shutoff Valve
MOV Main Oxidizer Valve
FGCV GG Fuel Control Valve
OGCV GG Oxidizer Control Valve
IFSOV Inlet Fuel Shutoff Valve
IOSOV Inlet Oxidizer Shutoff Valve



SOL #1 (N/C) - MC LO_2 Injector Purge Solenoid
SOL #2 (N/C) - OGCV Bypass Solenoid
SOL #3 (N/C) - GG LO_2 Injector Purge Solenoid
SOL #4 (N/C) - Spin Assist Solenoid
SOL #5 (N/C) - GG Ignition Fuel Solenoid
SOL #6 (N/C) - Fuel Purge Solenoid
SOL #7 (N/C) - Fuel System Purge Solenoid
SOL #8 (N/C) - LO_2 System Purge Solenoid
SOL #9 (N/O) - LO_2 Pressurization Line Purge
SOL #10 (N/O) - Fuel Pressurization Line Purge
SOL #11 (N/O) - Antiflood Solenoid
SOL #12 (N/C) - GHe Purge (Fuel)
SOL #13 (N/C) - GHe Purge (Oxidizer)
SOL #14 (N/C) - GN_2 Purge

Figure 2.2-1. 580K Gas Generator STME LO_2/H_2 Cycle

The engine start is a timed sequenced process using an oxidizer lead for reliable soft propellant ignition. The oxidizer lead avoids hazardous buildup of unburned fuel in the combustor during the oxygen phase transition from gas to liquid. The transition occurs prior to fuel injection and the fuel is consumed upon injection. Reliability of ignition is enhanced by the LO_2 lead because the transient mixture ratio during propellant filling includes the full excursion of ignitable mixture ratios from greater than 200 to less than one. Pratt & Whitney has had extensive experience with oxidizer leads with the RL10 and XLR-129 engines.

With the oxidizer lead sequence, the gas generator LO_2 injector is cooled and primed prior to opening the fuel shutoff valve to facilitate liquid oxygen flow, minimizing turbine temperature spikes due to oxygen phase change. A helium spin assist is also utilized to initiate turbopump rotation before the fuel is introduced into the gas generator. During the start and shutdown, a small helium purge is used in the gas generator injector and main chamber injector to eliminate the danger of hot gas flow reversals during transient operation. Gas generator and main chamber ignition will be accomplished with dual electrical spark excited, oxygen/hydrogen torch igniters.

Main stage engine operation is controlled by an open-loop control system. The fuel gas generator control valve (FGCV), the oxygen gas generator control valve (OGCV), and the main oxidizer valve (MOV), shown in Figure 2.2-1, are used to set the engine thrust and mixture ratio. Thrust and main chamber mixture ratio are set on the ground by trimming the MOV and OGCV respectively. The gas generator mixture ratio is set using the FGCV.

Engine acceleration is accomplished by a time-based scheduling of the valves to the commanded starting level (~20 percent power level). The acceleration to full thrust is also accomplished with open-loop valve schedules. Engine shutdown is accomplished using a time-based scheduling of the propellant valves. The OGCV is closed first to power down the turbopumps, then the MOV closes, followed by shutting off the hydrogen system.

In addition to a normal operational mode, the engine system is capable of a shutdown resulting from detected problems.

2.4 DERIVATIVE STBE CYCLE

The Derivative STBE is a LO_2/CH_4 gas generator cycle engine adapted from the STME LO_2/LH_2 gas generator cycle engine. The STBE operates at a main chamber pressure of 2250 psia with a sea level thrust of 645K lbf. The nozzle area ratio for this engine is 28:1 and it delivers a sea level specific impulse of 297.5 seconds. Figures 2.4-1 and 2.4-2 show top and side views of the engine and its major features.

Components of the Derivative STBE that will be common with the STME are the main injector, gas generator, tubular nozzle, engine controller, igniters, GO_2 HEX, POGO suppressor, instrumentation, vehicle interfaces, and 80 percent of the ducting. Items that will be redesigned for the STBE derivative are the combustion chamber, oxidizer pump, oxidizer turbine, fuel turbine, GG oxidizer valve, GG fuel valve, and the gimbal. Table 2.4-1 summarizes the common hardware components between the STME and Derivative STBE gas generator engines.

2.5 DERIVATIVE STBE FLOWPATH DESCRIPTION

A simplified flow schematic for the Derivative STBE is presented in Figure 2.5-1 showing the major components and flowpaths. Liquid methane and liquid oxygen enter the engine at NPSP levels, supplied by the vehicle, sufficient for the high-speed, high-pressure pumps to operate with no boost pumps required.

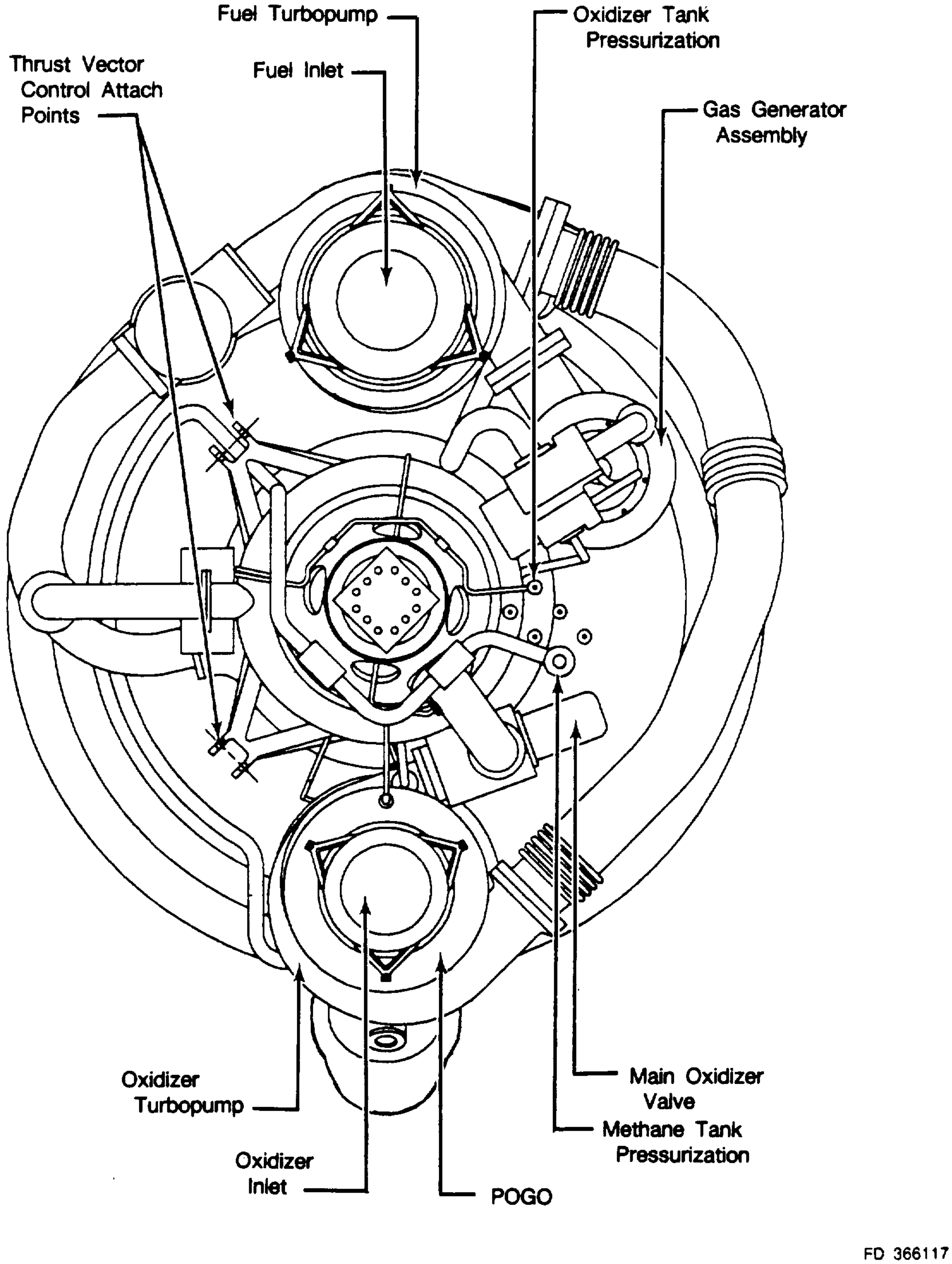


Figure 2.4-1. Gas Generator Derivative STBE Assembly, Top view

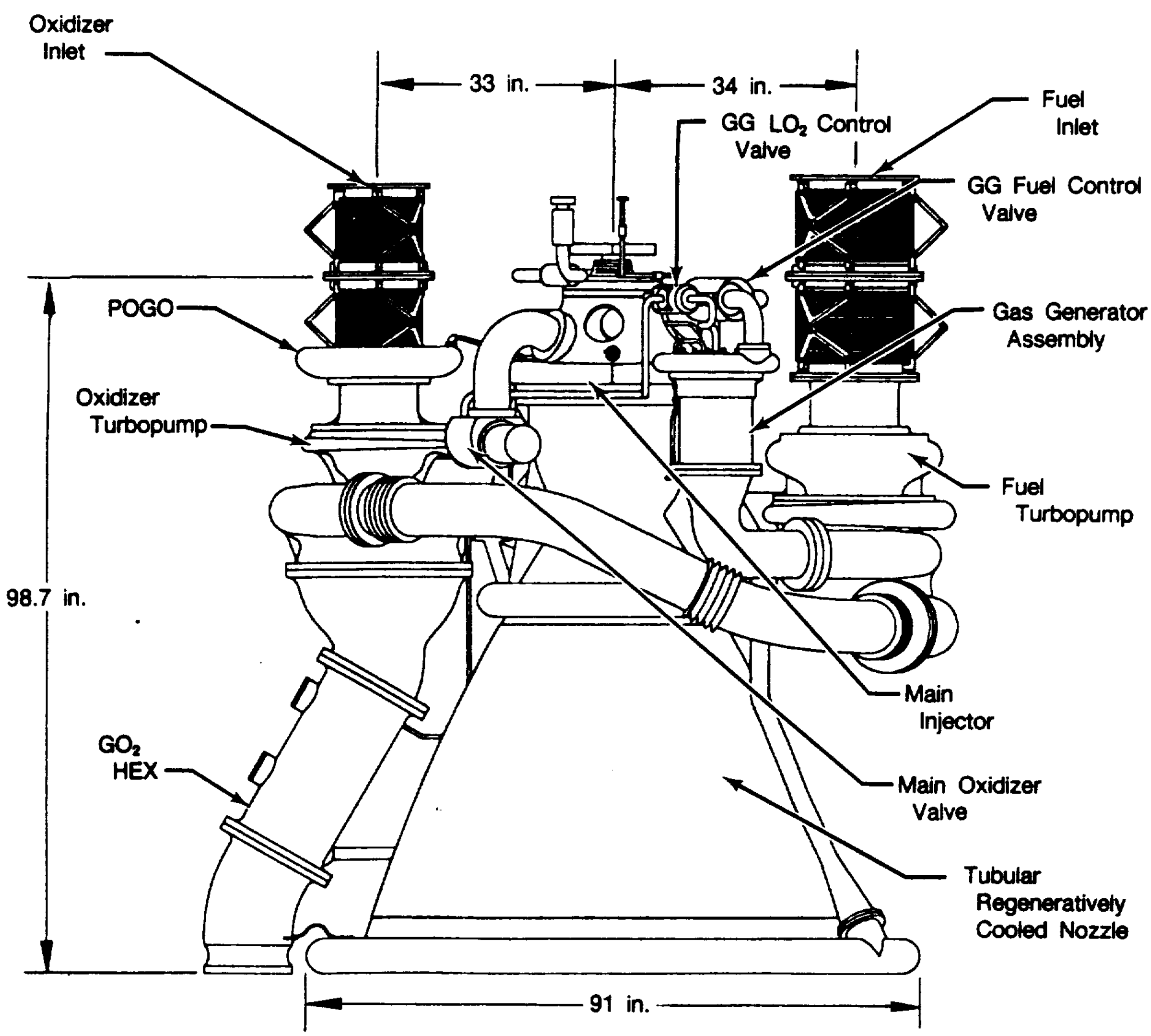


Figure 2.4-2. Gas Generator Derivative STBE Gas Generator

The two-stage methane pump operates at 10673 rpm to deliver fuel at the required pressure of 4621 psia. From the pump exit the fuel flows through the fuel shutoff valve (FSOV) and to the chamber/nozzle cooling jacket manifold where the flow splits so that 25 percent goes to the regenerative nozzle cooling jacket and 75 percent goes to the regeneratively cooled main chamber jacket. The nozzle cooling flow is used entirely to fuel the gas generator while the chamber coolant flow is discharged at 409 R directly into the main chamber injector.

Table 2.4-1. *STME and Derivative STBE Gas Generator Engines — Common Hardware Components*

Turbomachinery / Engine Controls	Combustion Devices / Engine Assembly
Turbomachinery	*Combustion Devices*
• Fuel Pump Housing Flow Paths	• Gas Generator Injector Interpropellant Plate
• Fuel Pump Impeller Flow Path	• Gas Generator Injector Housing
• Ball and Roller Bearings	• Gas Generator Combustion Chamber
• Turbine Outer Seals	• Gas Generator Combustion Chamber Liner
• Tiebolt Shaft and Disks (Modified Blade Attachments)	• Tubular Nozzle
• Internal Labyrinth Seals	• Nozzle Inlet Manifold
• Major Flange Seals	• Nozzle Discharge Manifold
• Bolts, Nuts, Studs, Washers, Pins	• Main Injector Interpropellant Plate
• 1st and 2nd-Stage Impeller Castings	• Main Injector Housing
• Uniform Cross Section Static Housing Seals	• Main Injector Faceplate
• Inducer Retaining Bolts	• Igniter Assembly — Main Injector
• Blade Retaining Rings, Tip Seals	• Igniter Assembly — Gas Generator Main Chamber to Injector Flange, Seals, Fasteners
• Spacers, Bearing Sleeves, Wave Washers Made from Same Forging or Identical Hardware	
Engine Controls	*Engine Assembly*
• Engine Controller	• Ducting 80% Small Lines 80% Large Lines
• Engine and Component Instrumentation	• GO_2 HEX
	• POGO Suppressor
	• Fuel Inlet Flex Joints
	• Fasteners, Seals

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The high-pressure oxidizer pump operates at 7601 rpm to provide the oxygen pressure level of 3338 psia required by the cycle. From the pump exit, approximately three percent of the LO_2 flow is diverted to the gas generator oxidizer control valve and subsequently to the gas generator. The bulk of the LO_2 flow (97 percent) flows through the main oxidizer control valve and directly to the main chamber injector.

The high-pressure, high-temperature (1688 psia/1800 R) gas from the gas generator provides the power to drive the high-pressure propellant pumps. The hot gas flow is initially expanded through the methane turbine and is subsequently routed to a second turbine which powers the oxidizer pump. The turbine exhaust gas is then diverted through the gaseous oxygen heat exchanger (to heat LO_2 for tank pressurization) and then discharged through a nozzle with an area ratio of 5.0 to produce thrust.

2.6 DERIVATIVE STBE OPERATION

The engine is preconditioned using liquid propellants from the tanks to soak the turbopumps until they are sufficiently cooled. The inlet valves will be opened, allowing liquid from the tanks to flow down to the turbopumps and letting vapors percolate back up to the tanks to be vented.

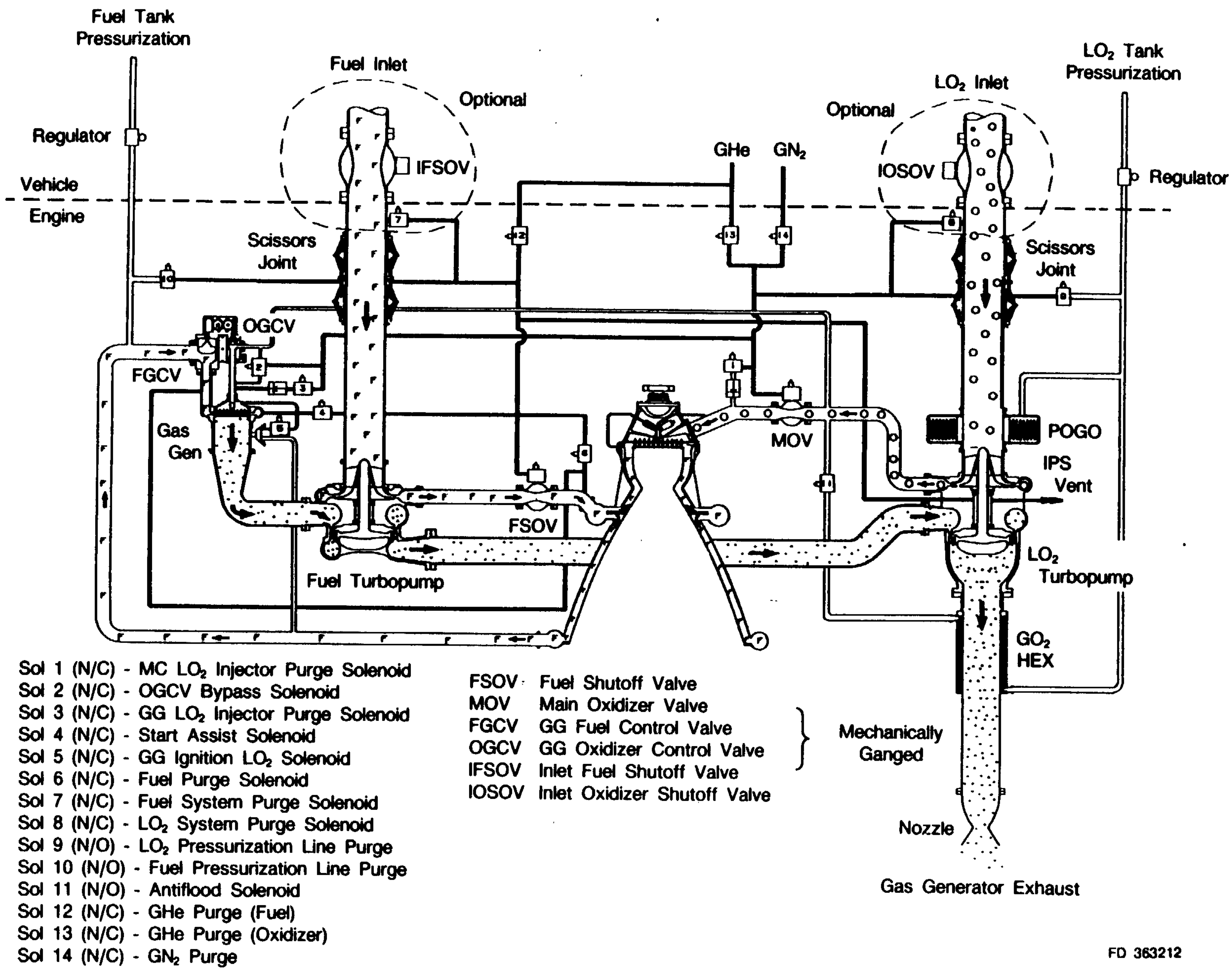

Figure 2.5-1. Simplified Flow Schematic for Derivative STBE Gas Generator Cycle Engine

The engine start is a timed sequence process using an oxidizer lead for reliable soft propellant ignition. The oxidizer lead avoids hazardous buildup of unburned fuel in the combustor or on the pad, because all fuel is consumed immediately upon injection. Reliability of ignition is enhanced by the LO_2 lead because the transient mixture ratio during propellant filling includes the full excursion of ignitable mixture ratios from greater than 200 to less than one.

With the oxidizer lead start sequence, the GG LO_2 injector is primed prior to opening the GG fuel valve to assure liquid oxidizer flow, thus eliminating turbine temperature spikes due to oxidizer phase change. After the GG LO_2 valve is opened, the main oxidizer valve (MOV) is opened followed by both the fuel GG valve and the fuel shutoff valve (FSOV). Helium spin assist is provided to the gas generator to help start the turbopump rotating and is discontinued early in the engine acceleration. Gas generator and main chamber ignition is accomplished with common design dual electrical spark-excited, oxygen/methane torch igniters. Engine acceleration is accomplished by open-loop scheduling of the gas generator oxidizer control valve.

Main stage thrust control is provided through open loop control of the GG oxidizer valve. Engine mixture ratio is preset by trim of the main oxidizer valve.

Engine shutdown is accomplished using a time based scheduling of the propellant valves. The gas generator oxidizer valve is closed first to power down the turbopumps, then the GG fuel valve is shut along with the MOV. The FSOV is closed when the pump is at low rpm. Provisions for post shutdown purging of propellants are provided.

SECTION 3.0
COSTING APPROACH, METHODOLOGY AND RATIONALE

3.1 PROGRAMMATIC AND COST GROUND RULES

3.1.1 General Ground Rules

Ground rules and assumptions have a significant impact on the magnitude of program costs. P&W used the Space Transportation Engine Program ground rules and work breakdown structure (WBS) provided by NASA/MSFC for program costing and for structuring its cost reporting. When items were not specified, ground rules which are consistent with those being used by the ALS vehicle contractors were selected.

The general ground rules and assumptions used for the STME/Derivative STBE Gas Generator program cost estimate are summarized in Table 3.1.1-1. All costs are in constant FY87 dollars. The total period covered in the program cost estimate is 32½ years, which includes Phases C and D (DDT&E Phase) for 7½ years and Phase E (Operations Phase) for 27 years. Operational Production which overlaps the latter part of DDT&E and the first 22 years of Operations occurs for 24 years while Operations occurs for 25 years. The use of one launch site (ESMC) for the ALS flight tests and operational flight program was assumed.

The vehicle configuration used for the STME/Derivative STBE cost estimate, as specified by the NASA ground rules, is shown in Figure 3.1.1-1. It is a two-stage vehicle using liquid methane and oxygen propellants for the booster stage, and liquid hydrogen and oxygen propellants for the core stage.

The core stage consists of three STME's, each designed to deliver a maximum vacuum thrust of 580,000 pounds at an inlet mixture ratio of 6.0. The engine operates at a combustion chamber pressure of 2250 psia and has a nozzle area ratio of 62:1.

The booster stage consists of seven Derivative STBE's, each designed to deliver a maximum sea level thrust of 645,000 pounds at an inlet mixture ratio of 2.7. The engine operates at a combustion chamber pressure of 2250 psia and has a nozzle area ratio of 28:1.

The Derivative STBE gas generator engine has been designed to use as many STME parts as possible and it has 72% cost commonality with the STME. Table 3.1.1-2 shows the common/uncommon hardware by component.

3.1.2 Design and Development Phase

The STME/Derivative STBE design and development phase starts in October 1991 and extends until March 1999, a 7½ year (90-month) period. The DDT&E program includes a 78-month engine development period prior to the first vehicle flight test, scheduled for April 1998. The development program includes both STME and STBE component and engine tests with completion of Final Flight Certification for both engines occurring in March 1999. The STBE design, fabrication and testing tasks are scheduled to start slightly behind the STME tasks so that the STBE can take advantage of lessons learned from the STME portion of the program.

Table 3.1.1-1. *General Cost Ground Rules and Assumptions*

Dollars	FY87	
Life Cycle Period-Years (Phases C, D, and E)	32¼ (FY92 thru 2023)	
Phases C and D (DDT&E Phase) — years	7¼ (FY92 thru 1999)	
Phase E (Operations Phase) — years	27 (FY97 thru 2023)	
Operational Production — years	24 (FY97 thru 2020)	
Operations — years	25 (FY99 thru 2023)	
Number Operational Flights per year	See Tables 3.1.3-1 thru 3.1.3-3	
Total Number Operational Flights (Scenario 2)		
Nominal	300	
Maximum	625	
Minimum	250	
	STME	Derivative STBE
Number of Equivalent Development Engines	28.5	16.0
Number MPTA Engines	4 (3 installed + 1 spare)	9 (7 installed + 2 spares)
Number Flight Test Engines	8 (6 installed + 2 spares)	19 (14 installed + 5 spares)
Number Engines per Vehicle	3	7
Total Production Buy (Scenario 2)		
Nominal	175	425
Maximum	350	850
Minimum	100	275
Engine Refurishment	By Contractor	
Number of Launch Sites	1 (ESMC)	
Start Phase C and D (DDT&E)	1992	
First R&D Flight	1998	
Second R&D Flight	1999	
First Operational Flight	FY99	
Number of Flight Tests	2	

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The ground rules associated with the design and development phase are listed in Table 3.1.2-1. Table 3.1.2-2 presents key milestones in the design and development program schedule.

The schedule used for the STME/Derivative STBE development cost estimate is shown in Figure 3.1.2-1. The first scheduled tests in the STME/Derivative STBE development program are component tests of the gas generator and thrust chamber assembly which start in January 1994. The fuel turbopump, oxidizer turbopump and controls component tests start in March 1994.The first engine test occurs in May 1994 while MPTA stage cluster testing starts in September 1996.

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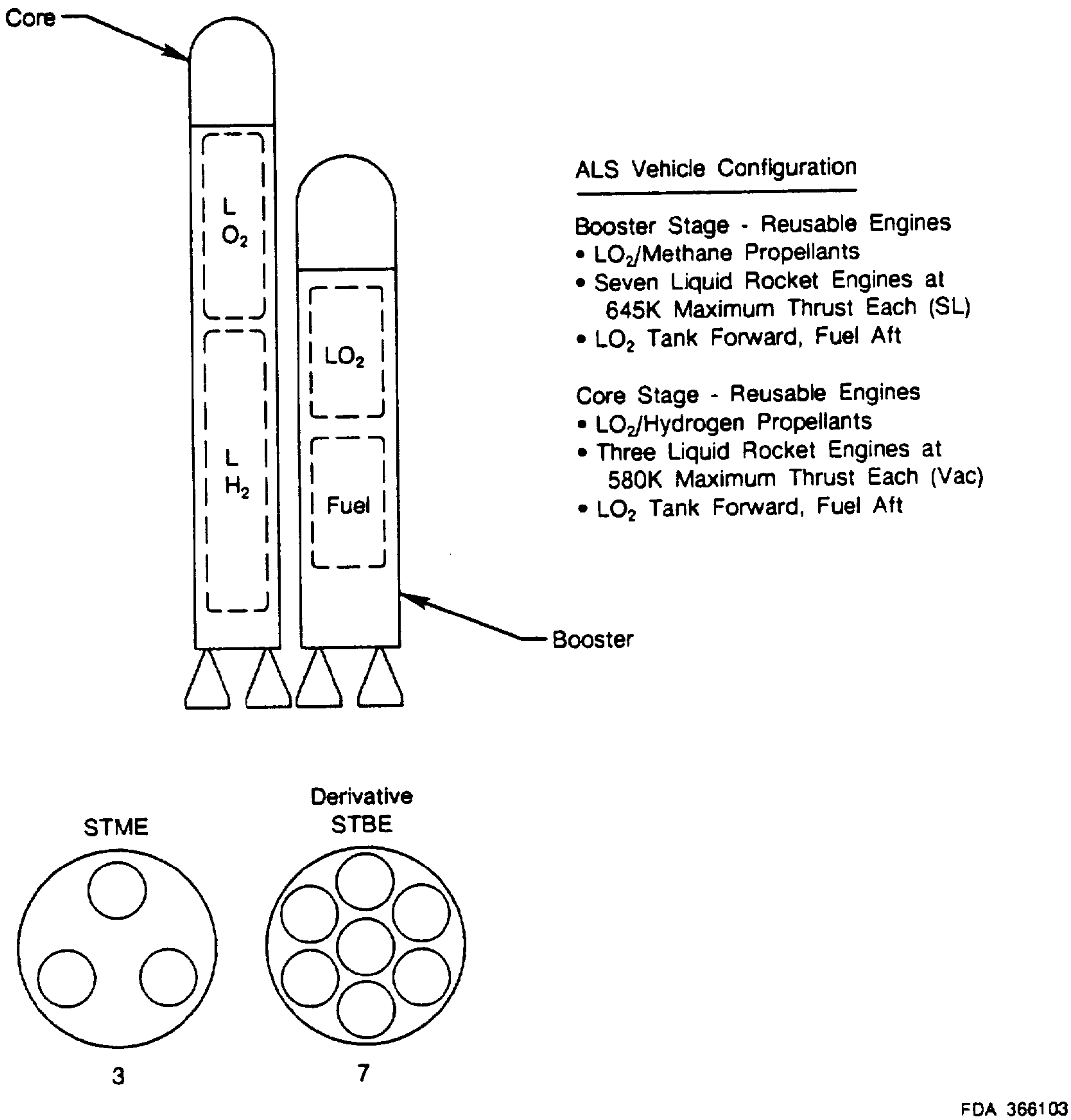

Figure 3.1.1-1. ALS Vehicle Configuration

Pratt & Whitney will conduct the large component and engine tests using government-provided test facilities at Stennis Space Center. The controls and small component laboratory tests will be conducted by P&W using test facilities at P&W.

The component test program listed in Table 3.1.2-3 shows the total number of runs/firings for each component for both the STME and the Derivative STBE. Engine tests are also included, showing the total number of firings, test objectives and the number of accountable engine firings prior to first flight. Figure 3.1.2-2 is a graphic projection of the scheduled engine test firings. The DDT&E costs for the STME/Derivative STBE are based on this test program.

Table 3.1.1-2. *Common Hardware for STME and Derivative STBE Gas Generator Engines*

Common Hardware Components	
Turbomachinery	*Combustion Devices*
Fuel Pump Housing Flow Paths	Gas Generator Injector
Fuel Pump Impeller Flow Paths	Interpropellant Plate
Ball and Roller Bearings	Gas Generator Injector Housing
Turbine Outer Seals	Gas Generator Combustion Chamber
Tiebolt Shaft and Disks (Modified Blade Attachments	Gas Generator Combustion Chamber Liner
Internal Labyrinth Seals	Tubular Nozzle
Major Flange Seals	Nozzle Inlet Manifold
Bolts, Nuts, Studs, Washers, Pins	Nozzle Discharge Manifold
1st and 2nd Stage Impeller Castings	Main Injector Interpropellant Plate
Uniform Cross Section Static Housing Seals	Main Injector Housing
Inducer Retaining Bolts	Main Injector Faceplate
Blade Retaining Rings, Tip Seals	Igniter Assembly — Main Injector
Spacers, Bearing Sleeves, Wave Washers Made From Same Forging or Identical Hardware	Igniter Assembly — Gas Generator Main Chamber to Injector Flange, Seals, Fasteners
Engine Controls	*Engine Assembly*
Engine Controller	Ducting
Engine and Component Instrumentation	80% Small Lines
	80% Large Lines
	GO_2 HEX
	POGO Suppressor
	Fuel Inlet Flex Joints
	Fasteners, Seals
Partial Commonality and New Design Components	
Components That Utilize Same Internal Flow Path Geometry, But Operate at a Higher Pressure	*Components That Will Be New Design*
Fuel Pump Impeller and Housings	Main Combustion Chamber
Fuel Shutoff Valve	Oxidizer Pump Impeller and Housings
	Oxidizer Turbine Blading
	Fuel Turbine Blading
	GG Oxidizer Valve
	GG Fuel Valve
	Main Oxidizer Valve
	Gimbal

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The test schedule has been structured to demonstrate at least 0.99 engine reliability with 90% confidence prior to first flight. This requires 230 accountable engine firings with no engine chargeable premature shutdowns. For the STME and Derivative STBE, P&W has scheduled 414 and 264 accountable firings, respectively, thus exceeding the required 230 accountable engine firings and providing margin for demonstrating the 0.99 reliability.

Table 3.1.2-4 shows test facility usage rates for the STME and Derivative STBE test program. The DDT&E engine test operation and support costs are based on these levels of test facility usage.

Table 3.1.2-1. *Gas Generator STME/Derivative STBE DDT&E Program Ground Rules*

90-Month Phases C/D Program through Final Flight Certification (FFC)
October 1991 Phases C/D Start
Reusable Engine — 15-Mission Capability
960 STME Engine Firings
488 Derivative STBE Firings
0.99 Minimum Demonstrated Reliability at 90% Confidence on Both Engines Prior to First Flight
STME Design, Fabrication and Testing Leads Derivative STBE — Benefits Cost
Design Verification Tests Conducted on Same or Similar Components Using Highest Load Set
Verification Tests Conducted with CH_4 on Common Parts
Government Supplied Propellants and Test, Engine Assembly, and Launch Site Facilities
Development Engines and Components Refurbished after 30 Firings at 50% Cost of New Development Engine or Component. Development Engines and Components Replaced 100% after 60 Total Firings.
P&W to Conduct Large Component and Engine Tests on Government Facilities Located at Stennis Space Center (SSC). Small Component and Rig Tests to be Conducted by P&W at P&W Site.
Booster and Core MPTA Tests to be Conducted by Vehicle Contractors at SSC. P&W to Provide Engine Support.
Flight Tests From Eastern Space and Missile Center (ESMC) with Booster Engine Recovery and Refurbishment Following Flights.

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Table 3.1.2-2. *Gas Generator STME/Derivative STBE DDT&E Program Schedule Milestones*

Oct 1991	—	Start Program
Oct 1993	—	Component and Subsystem Development Test Facility Available
June 1994	—	First LO_2/LH_2 Engine Stand Available — 2 Positions
Oct 1994	—	Second and Third LO_2/LH_2 Engine Stands Available — 2 Positions Each
Sept 1996	—	MPTA Stand Available at SSC
July 1997	—	Deliver First Flight Engine Set With Spares
Jan 1998	—	Deliver Second Flight Engine Set With Spares
April 1998	—	First Flight
March 1999	—	Complete DDT&E and Flight Testing. Submit Final Report.

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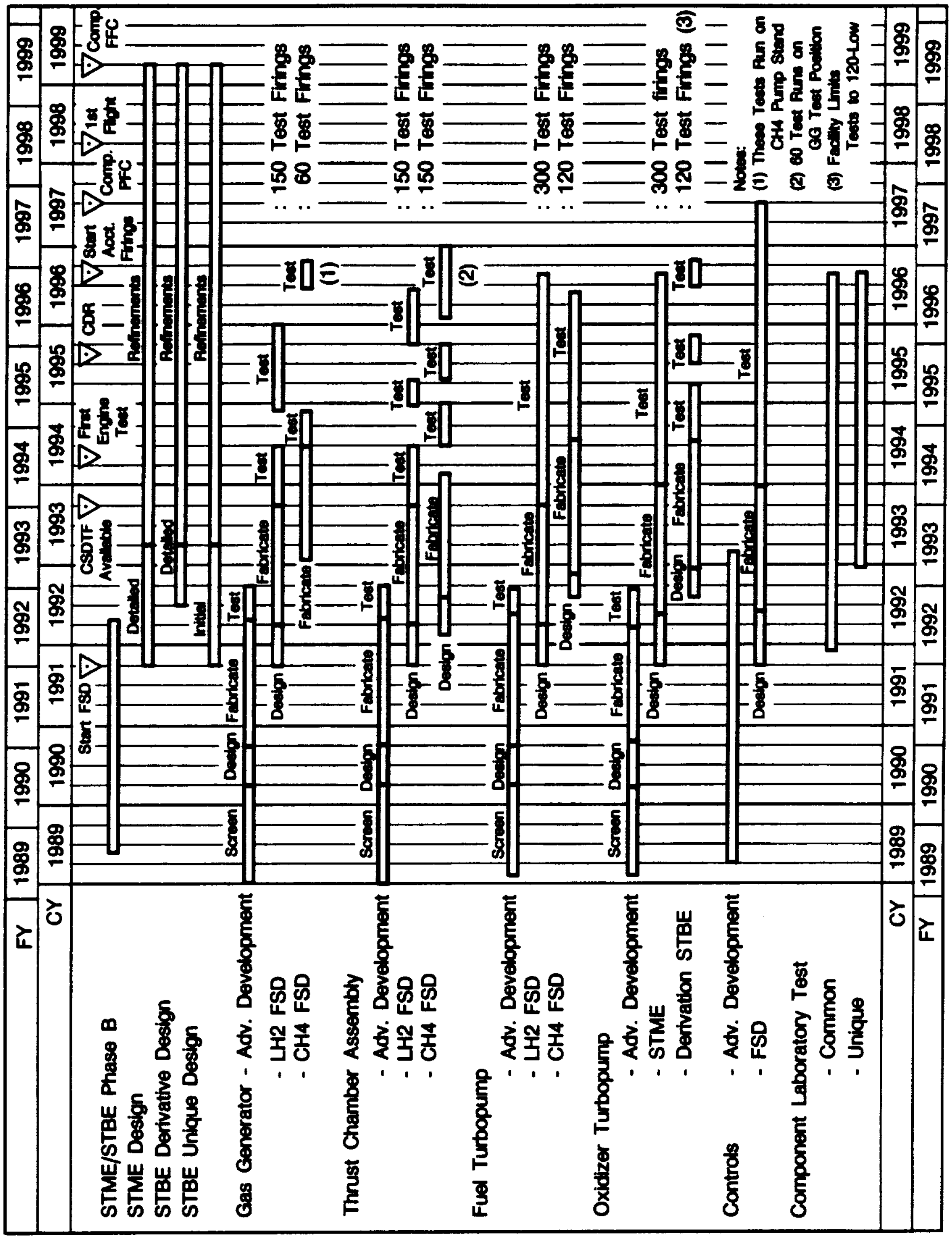

Figure 3.1.2-1. Schedule Used for the STME/STBE Development Cost Estimate (Sheet 1 of 2)

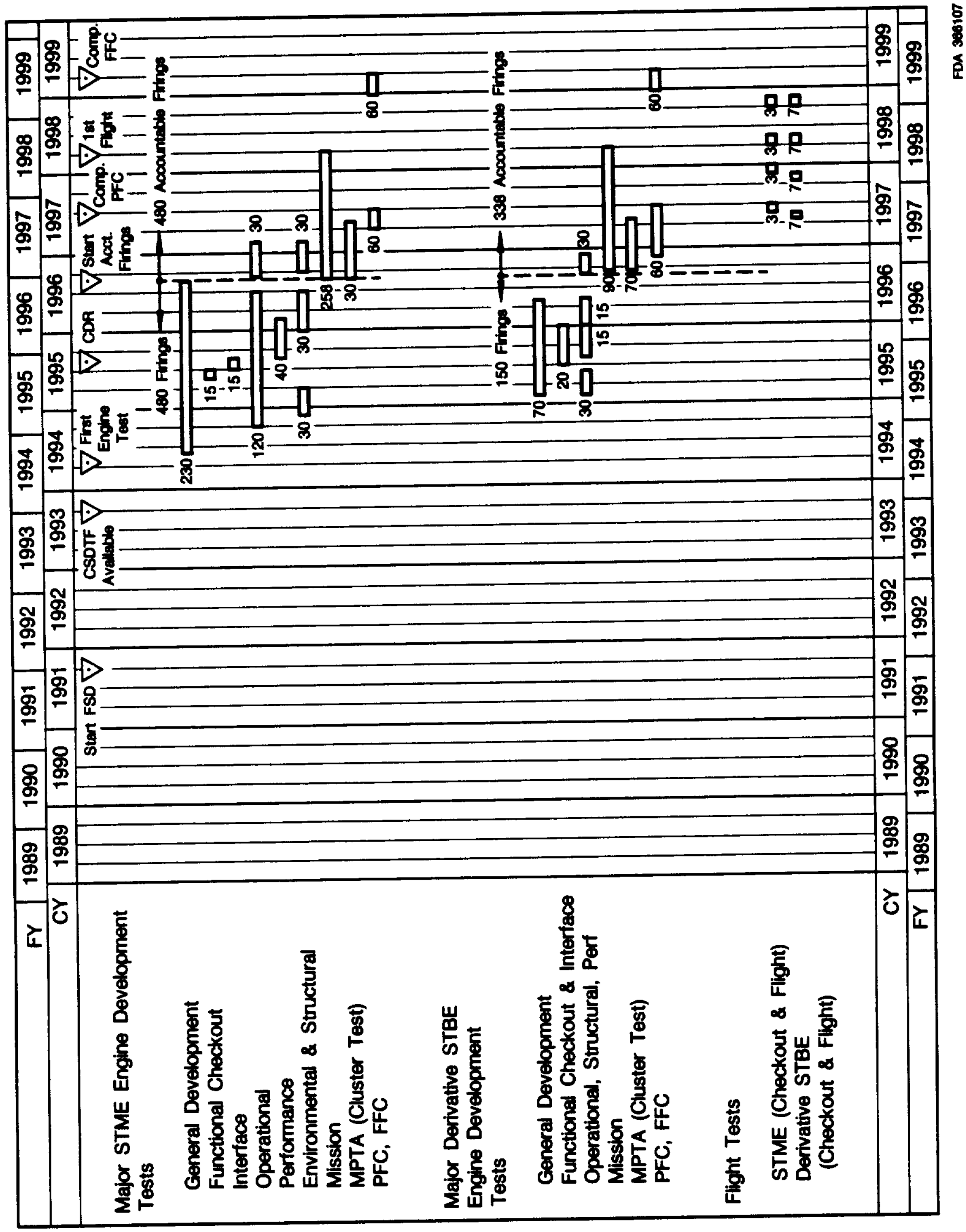

Figure 3.1.2-1. Schedule Used for the STME/STBE Development Cost Estimate (Sheet 2 of 2)

Table 3.1.2-3. *Gas Generator STME/Derivative STBE Development Tests*

Type	No. of Runs/Firings	
Rig Tests	*STME*	*Derivative STBE*
Gas Generator	150	60
Main Chamber	150	150
Fuel Pump	300 (LH_2)	120 (CH_4)
LO_2 Pump	300	120*

Engine Tests	*Total Firings*		*Accountable Firings Prior to 1st Flight*	
Test Objectives	*STME*	*Derivative STBE*	*STME*	*Derivative STBE*
Functional Checkout	15	10		
Interface	15	10		
Environmental/Structural	90	45	30	30
Operational Demonstration	150	30	30	
General Development (Pre-PFC Configuration)	230	70		
Mission Testing (PFC Configuration)	258	90	258	90
Performance Demonstration	40	15		
Preliminary Flight Certification (PFC)	60	60	60	60
MPTA	30	70	30	70
Flight Tests (With Checkout)	12	28	6	14
Final Flight Certification (FFC)	60	60		
	960	488 = 1448	414	264

* Tests Limited by Facilities (Prefer 300 Tests)

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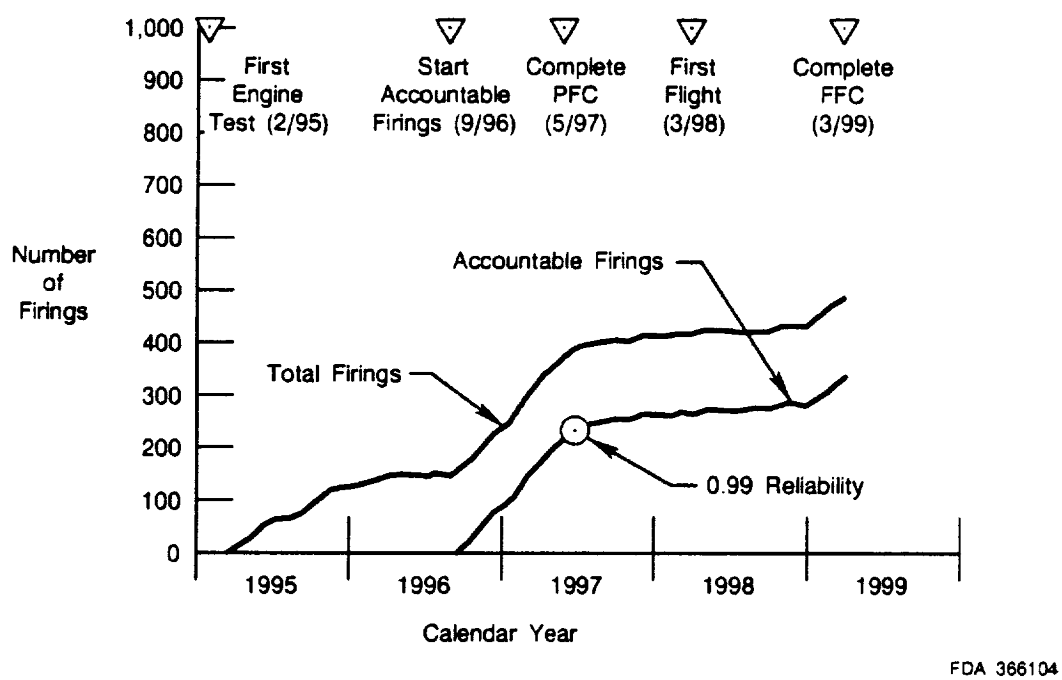

Figure 3.1.2-2. Scheduled Engine Test Firings

Table 3.1.2-4. *STME/Derivative STBE Test Facility Usage Rates Per Test Position*

	Max. Test Rate (Per Mo.)	*Avg Test Rate (Per Mo.)*			*STME Program (Reference)*
		STME	*Deriv STBE*	*Integrated*	
Component Tests					
Thrust Chamber Assy	8	7.4	7.5	7.5	5.0
Gas Generator	8	7.8	7.5	7.7	5.0
LO_2 Pump (2 Positions)	8	7.6	7.9	7.7	5.6
LH_2 Pump (2 Positions)	8	5.6	—	5.6	5.6
CH_4 Pump (1 Position)	8	—	5.4	5.6	NA
Engine Tests (8 Positions)	10	6.4	6.1	6.3	6.3
MPTA	2 Cluster Firings	1.1	1.1	1.1	1.1

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Tables 3.1.2-5 and 3.1.2-6 show a compilation of the STME and Derivative STBE development component and engine and hardware requirements. The DDT&E program costs reflect these quantities of new hardware and rebuilds.

Table 3.1.2-5. *STME/Derivative STBE Development Component Hardware Requirements*

	GG		*TCA*		*Fuel Pump*		*LO_2 Pump*	
	STME	*STBE*	*STME*	*STBE*	*STME*	*STBE*	*STME*	*STBE*
Test Positions	1	1	1	1	2	1	2	2
Test Firing Life — Rebuild	30	30	30	30	30	30	30	30
Total	60	60	60	60	60	60	60	60
Rebuild Time — Months	2	2	3	3	3	3	3	3
Dismount/Mount Time — Weeks	1	1	2	2	1	1	1	1
(With Extensive Instrumentation)	2	2	3	3	2	2	2	2
Planned Firings	150	60	150	150	300	120	300	120
Hardware Requirements								
— New Rigs	3	1	3	3	5	2	5	2
— Spare Rigs	1	1	1	1	2	1	2	1
Total	4*	2*	4	4	7*	3*	7*	3*
Rebuilds — Equivalent Total Rigs (50% New Rig Cost Each Rebuild)	2*	0*	2	2	2.5*	1.5*	2.5*	1.5*
Total Number of Equivalent Rigs	6*	2*	6	6	9.5*	4.5*	9.5*	4.5*

* GG components required for both GG and turbopump component tests.

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3.1.3 Operational Phase: Operational Production and Operations

The STME/Derivative STBE Operational Production and Operations Phase (Phase E) spans 27 years. The program requirement for production engines is based on Scenario 2 of the NASA/MSFC-supplied cost ground rules (see Table 3.1.1-1). Scenario 2 uses the STME as the core engine and the STBE derived from the STME as a booster engine.

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Table 3.1.2-6. *STME/Derivative STBE Development Engine Hardware Requirements*

	Development Engine										
	Exp. Config		*PFC Config.*		*PFC/FFC*		*MPTA*		*Flight*		
	STME	*STBE*	*STME*	*STBE*	*STME*	*STBE*	*STME*	*STBE*	*STME*	*STBE*	
Test Firing Life — Rebuild	30	30	30	30	30	30	30	30	—	—	
Total	60	60	60	60	30	30	30	30	N/A	N/A	
Rebuild Time — Months	2	2	2	3	N/A	N/A	N/A	N/A	N/A	N/A	
Dismount/Mount Time — Weeks	2	2	2	2	—	—	—	—	—	—	
(With Extensive Instrumentation)	3	3	3	3	—	—	—	—	—	—	
Planned Firings (Based on 960 STME and 488 STBE)	490	150	308	120	120	120	30	70	12	28	= 960 STME = 488 STBE
Engine Requirements											
— New Engines	10	3	3	3	4	4	3	7	6	14	
— Spare Rigs	1	1	1	1	0	0	1	2	2	5	
Total	11	4	4	4	4	4	4	9	8	19	= 31 STME = 40 STBE
Rebuilds — Equivalent Total Engines (50% New Engine Cost Each Rebuild)	8	1	1.5	3	0	0	0	0	0	0	= 9.5 STME = 4 STBE
Total Number of Equivalent Engines	19	5	5.5	7	4	4	4	9	8	19	= 40.5 STME = 44.0 STBE

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There are three cases associated with Scenario 2, nominal, maximum, and minimum. Tables 3.1.3-1 through 3.1.3-3 show the STME and Derivative STBE flight and operational production engine delivery schedules (including spares) used for the program cost estimates.

The total number of operational flights, Figure 3.1.3-1, in the nominal, maximum, and minimum cases are 300, 625 and 250, respectively, and the total number of booster and core engines delivered are 600, 1200 and 375, respectively. In addition to these operational production engines, there will be eight STME and 19 STBE refurbished flight test engines available from the development phase for use in the operational program. A two-year procurement period prior to the delivery year is used for each production engine.

In developing the manufacturing costs for the operational production engines, P&W has included and accounted for the 48 production configuration engines funded and delivered under the development program. These engines consist of the eight flight certification engines (four STME's and four STBE's), the 13 MPTA engines (four STME's and nine STBE's), and the 27 flight test engines (eight STME's and 19 STBE's). Although built in the development phase of the program, these engines are fabricated using tooling and manufacturing processes that reflect an operational production environment. The engines are considered to be part of the total quantity of production engines built and they precede the operational production engines on the cost improvement curve. The effect is to include these engines when determining the production TFU and to shift the first lot of operational production engines down the cost improvement curve below these development engines.

Table 3.1.3-1. *STME/Derivative STBE — ALS Scenario No. 2 — Nominal Case*

Fiscal Year	*Years*	*Flights*	*Quantity STBE Booster Engines**	*Quantity STME Core Engines**	*Total Engines Per Year*	*Cum. Total Engines Per Year*
1999	1	2	14	6	20	20
2000	2	4	28	12	40	60
2001	3	6	42	18	60	120
2002	4	8	56	24	80	200
2003	5	10	70	30	100	300
2004	6	12	21	9	30	330
2005	7	12	14	6	20	350
2006	8	12	14	6	20	370
2007	9	12	14	6	20	390
2008	10	12	14	6	20	410
2009	11	14	14	6	20	430
2010	12	14	14	6	20	450
2011	13	14	11	4	15	465
2012	14	14	11	4	15	480
2013	15	14	11	4	15	495
2014	16	14	11	4	15	510
2015	17	14	11	4	15	525
2016	18	14	11	4	15	540
2017	19	14	11	4	15	555
2018	20	14	11	4	15	570
2019	21	14	11	4	15	585
2020	22	14	11	4	15	600
2021	23	14	—	—	—	600
2022	24	14	—	—	—	600
2023	25	14	—	—	—	600
		300	425	175	600	600

*Based on seven reusable STBE's per booster and three reusable STME's per core stage.

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Whole spare engines are included in the total production engine quantities specified by NASA for the Scenario 2 maximum, nominal and minimum cases. Their costs are included in the recurring operational production flight hardware manufacturing costs.

Component initial spare costs are based on having a two-year supply of spare parts and components available during the period of highest mission usage. The engine spare component requirements were estimated, taking into account expected engine reliability levels and the number of reuses planned for each engine. The initial component spares are procured and delivered during the early years of engine deliveries. The assumptions used for calculating the component initial spare costs are summarized in Table 3.1.3-4.

Ground rules and assumptions used to estimate operations costs are summarized in Table 3.1.3-5. The operations ground rules are consistent with ALS planning documents and studies being conducted by the ALS vehicle contractors. The operations cost estimates in this volume reflect these assumptions.

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Table 3.1.3-2. *STME/Derivative STBE — ALS Scenario No. 2 — Maximum Case*

Fiscal Year	*Years*	*Flights*	*Quantity STBE Booster Engines**	*Quantity STME Core Engines**	*Total Engines Per Year*	*Cum. Total Engines Per Year*
1999	1	2	14	6	20	20
2000	2	4	28	12	40	60
2001	3	6	42	18	60	120
2002	4	8	56	24	80	200
2003	5	10	70	30	100	300
2004	6	14	63	27	90	390
2005	7	18	56	24	80	470
2006	8	24	49	21	70	540
2007	9	28	49	21	70	610
2008	10	30	49	21	70	680
2009	11	30	49	21	70	750
2010	12	30	45	15	60	810
2011	13	30	35	15	50	860
2012	14	32	35	15	50	910
2013	15	32	35	15	50	960
2014	16	32	35	15	50	1010
2015	17	32	28	10	38	1048
2016	18	32	28	10	38	1086
2017	19	33	28	10	38	1124
2018	20	33	28	10	38	1162
2019	21	33	28	10	38	1200
2020	22	33	—	—	—	1200
2021	23	33	—	—	—	1200
2022	24	33	—	—	—	1200
2023	25	33	—	—	—	1200
		625	850	350	1200	1200

*Based on seven reusable STBE's per booster and three reusable STME's per core stage.

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A final consideration in establishing the operational production and operations costs is the effect of cost improvement. The cost improvement slope on which P&W is basing its cost reduction as a function of production quantity due to learning, manufacturing process improvements, high volume production, etc., is a 90 percent Crawford learning curve. This slope is a conservative estimate based on cost improvements experienced during production of the F100 gas turbine engine. As shown in Figure 3.1.3-2, the F100 engine followed an 87% slope.

The cost improvement as a function of production rate, based on the lot quantity, has been estimated by P&W to be about 94.6 percent. Production TFU is baselined at a lot size of 100 units. As shown in Figure 3.1.3-3, this cost improvement effect is based on cost data for 49 different RL10 engine parts. Annual production quantities were varied from 30 to 180 units per year to generate this curve.

Pratt & Whitney is also estimating an 87 percent cost improvement curve for operations cost, based on the total number of missions flown. This operations cost improvement slope is based on maintenance cost improvements experienced for the F100 gas turbine engine. As shown in Figure 3.1.3-4, F100 maintenance costs decreased at a rate slightly steeper than an 87% slope as engine flight hours increased. These maintenance cost reductions resulted from both learning and configuration changes made to improve engine life and reliability.

Table 3.1.3-3. STME/Derivative STBE — ALS Scenario No. 2 — Minimum Case

Fiscal Year	Years	Flights	Quantity STBE Booster Engines*	Quantity STME Core Engines*	Total Engines Per Year	Cum. Total Engines Per Year
1999	1	2	14	6	20	20
2000	2	4	28	12	40	60
2001	3	6	42	18	60	120
2002	4	8	56	24	80	200
2003	5	10	70	30	100	300
2004	6	10	17	6	23	323
2005	7	10	12	4	16	339
2006	8	10	12	—	12	351
2007	9	10	12	—	12	363
2008	10	10	12	—	12	375
2009	11	10	—	—	—	375
2010	12	10	—	—	—	375
2011	13	10	—	—	—	375
2012	14	10	—	—	—	375
2013	15	10	—	—	—	375
2014	16	12	—	—	—	375
2015	17	12	—	—	—	375
2016	18	12	—	—	—	375
2017	19	12	—	—	—	375
2018	20	12	—	—	—	375
2019	21	12	—	—	—	375
2020	22	12	—	—	—	375
2021	23	12	—	—	—	375
2022	24	12	—	—	—	375
2023	25	12	—	—	—	375
		250	275	100	375	375

*Based on seven reusable STBE's per booster and three reusable STME's per core stage.

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The ALS engine cost improvement slope due to mission rate is considered to be negligible at present. Table 3.1.3-6 summarizes cost improvement factors used by P&W for these ALS engine cost estimates.

3.2 COSTING METHODOLOGY

The methodologies used to estimate costs for each of the program phases and functions, and each of the STME/Derivative STBE WBS components and subassemblies are discussed in this section. The methodologies are discussed by program phase and are based on using the ground rules and assumptions presented in Section 3.1.

3.2.1 Design and Development Phase

Detailed bottoms-up development cost estimates from the P&W 1971 SSME program, the P&W 1985 SSME Power Assembly study, and the P&W 1987 SSME Alternate Turbopump Development (ATD) program were used as a basis for the STME/Derivative STBE Design and Development Phase cost estimates. This information was supplemented in a number of areas by bottoms-up cost analyses performed specifically for the STME/Derivative STBE program. Differences in the STME/Derivative STBE size and cycle, technology level, program plans and schedule, hardware fabrication costs, and facility requirements were considered when using the cost estimates from the other programs.

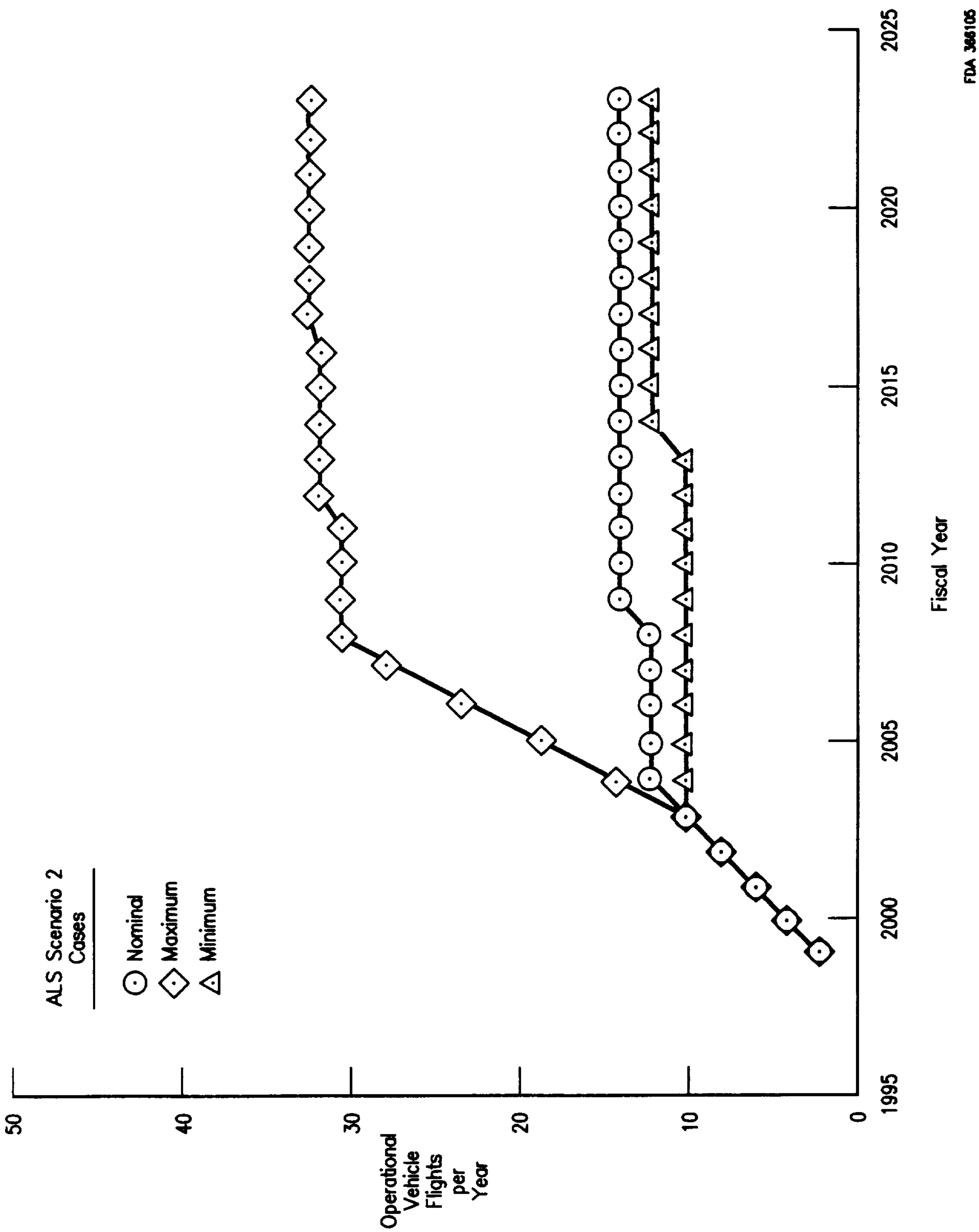

Figure 3.1.3-1. Total Number of Operational Flights Per Year

Table 3.1.3-4. ALS Scenario No. 2 Component Initial Spares

		% Component Initial Spares*				
Case	Flights/Year Max	Turbomachinery	Combustion Devices	Controls	Main Propellant Feed	Support Devices
Nominal	14	20	20	20	10	10
Maximum	33	20	20	20	10	10
Minimum	12	20	20	20	10	10

Note: • Based on seven STBE's and three STME's.
• Two-year supply of spare parts and components.
* Percent of engines flown in maximum two-year period.

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Table 3.1.3-5. Operations Cost Ground Rules

Operational Period	25 Years (FY999 through 2023)
Number Operational Flights	See Tables 3.1.3-1 through 3.1.3-3
Number of Launch Sites	1 (ESMC)
Recovery Operation	Booster Engine Recovered At Sea (Engine subject to salt spray only); Core Engine Expended Or Land Recovered.
Engine Maintenance Levels	On/Off Equipment Removal and Replace at ESMC; Depot at SSC.
Routine Engine Turnaround	At ESMC; Engine Check Run not required.
Component Repair/Refurbishment	At SSC Contractor Depot or by Supplier.
On-Pad Maintenance Procedure	Small components are LRU's; Engine removed for R&R of all other components.
Replacement Components	Calibrated during acceptance; Engine check run not required.
ESMC Labor Rate (fully burdened)	$50/man-hr
Depot Labor Rate (fully burdened)	$65/man-hr

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Initially a development program cost estimate was made for the Baseline STME in which the STME is used for both the core and booster stages. Costs for the STME/Derivative STBE program were then derived from this estimate.

The specific cost methodology used in estimating the STME/Derivative STBE development costs was as follows:

- Start with Baseline STME Design and Development cost estimate
- Determine how much could be removed from Baseline STME cost because of core only application
- The resulting costs are the DDT&E costs required to develop the STME for the core only
- Determine additional costs to develop Derivative STBE for booster application in conjunction with STME
- These additional costs are the Derivative STBE Design and Development costs
- Hardware costs were set by development hardware requirements considering cost commonality
- Test costs were set by test stand position months for each engine considering test manpower requirements.

The STME/Derivative STBE Engine Test Program is the highest cost item of the WBS functional elements. It includes both component and engine development test hardware and development test operations and support.

Engine test hardware includes the fabrication, assembly and instrumentation costs of 15 new STME and 8 new STBE development engines (including spares). Component test hardware includes the cost of 22 new core and 12 new booster engine development components (gas generator, thrust chamber assemblies, and turbopumps) (including spares). Table 3.1.2-5 in Section 3.1 shows the individual component requirements. Test hardware also includes mockups and eight new flight certification (PFC and FFC) engines (4 STME and 4 Derivative STBE). Costs for the development engines, and the development components were estimated using a development engine cost factor applied to the Theoretical First Unit cost. The cost factor, which is 1.5, is based on P&W's experience on other engine development programs and it accounts for the higher cost of building experimental hardware. The eight flight certification engines were assumed to be part of the first lot of engines on the production engine cost improvement curve. Their costs were estimated using the techniques discussed in Section 3.2.2 for operational production engines. Acceptance test costs were included for the eight certification engines.

Test operations and support, which occurs at both SSC and P&W, includes: test planning, supervision and conducting; test article installation and removal; test article instrumentation hookup and calibration; and engine mechanic, test engineer and performance engineer support. It also includes the refurbishment of development components and engines (parts and labor). The testing portion of the cost estimate is based on P&W experience on rocket and gas turbine engine development test programs. Table 3.2.1-1 shows the manpower estimates used for the engine and large component testing at SSC, and for the small component testing at P&W. Development component and engine rebuild costs were assumed to be 50 percent of the cost of a new component or engine. The development hardware is rebuilt after 30 tests and used for an additional 30 tests before being discarded. Tables 3.1.2-5 and 3.1.2-6 in Section 3.1 show the number of equivalent total components and engines used for the rebuild cost estimates.

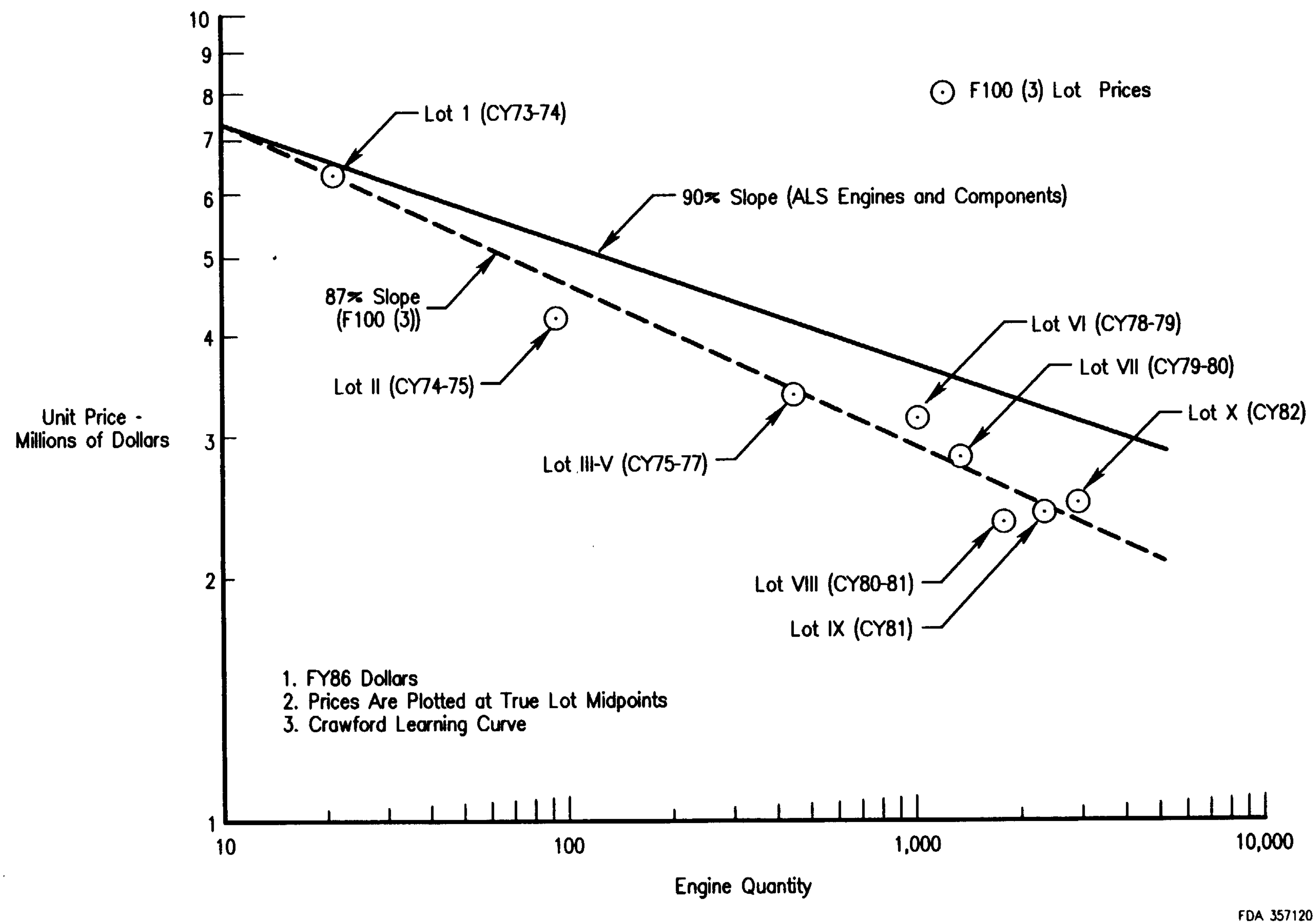

Figure 3.1.3-2. F100 Gas Turbine Engine Cost Improvement Curves

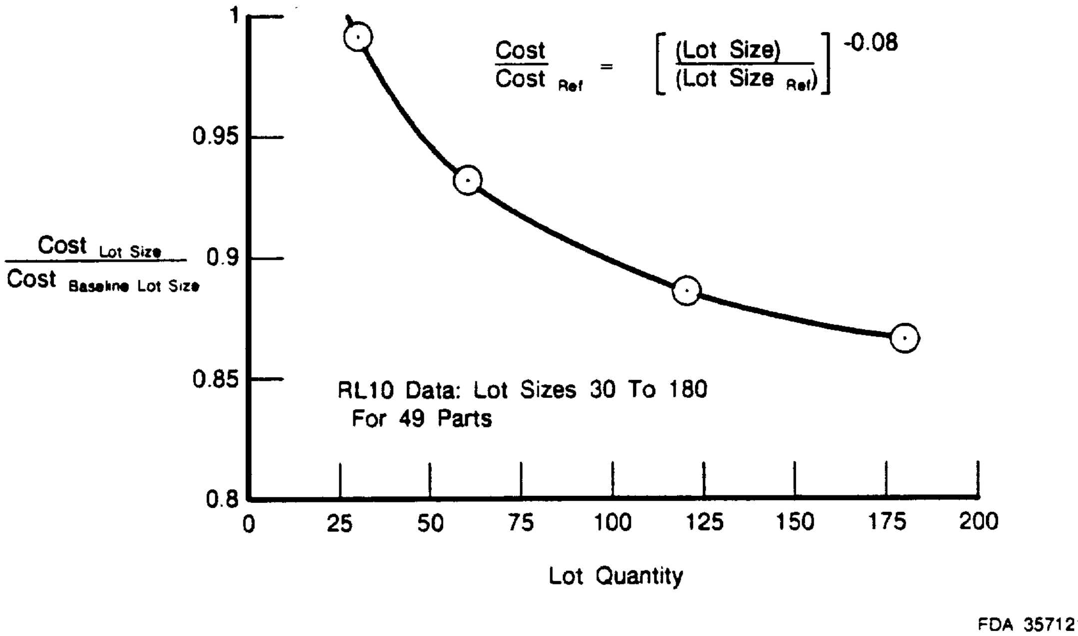

Figure 3.1.3-3. RL10 Engine Cost Improvement Curve

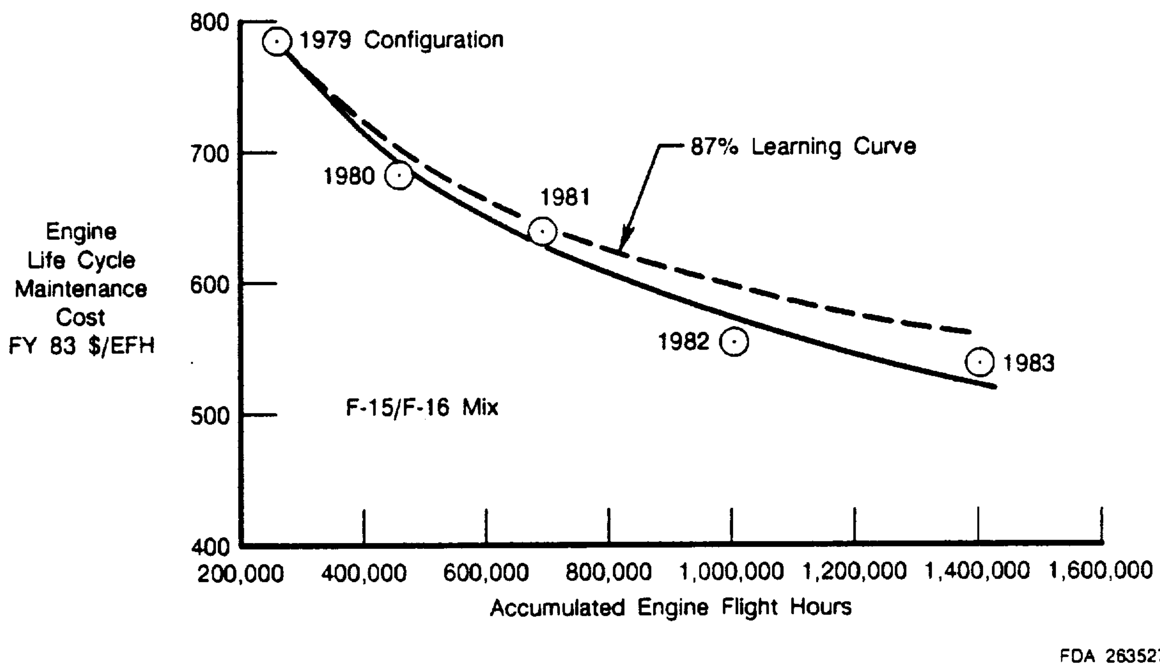

Figure 3.1.3-4. F100 Gas Turbine Engine Maintenance Cost Reduction Curves

Flight test hardware costs were estimated in a fashion similar to the costs for the eight flight certification engines. Costs for the 27 flight test engines, 19 STBE's and 8 STME's, which are also part of the first production lot, were estimated using the technique described in Section 3.2.2. Acceptance test costs were included and a factor equal to three percent of the cost of the engines was added as an allowance for spare parts and components.

Table 3.1.3-6. *P&W's Cost Improvement Considerations*

	Cost Improvement Factor — %	
	Learning	*Rate*
Production	90	94.6
Operations	87	—

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Main Propulsion Test Article (MPTA) engines, 9 STBE's and 4 STME's, are prototype production engines used in the vehicle propulsion system cluster ground test program. MPTA hardware costs were also estimated as part of the costs of the first lot of production engines. The acceptance test costs and three percent spares factor used for the flight test engines were also included in the MPTA Hardware costs.

Costs were included in the design and development phase cost estimates for the construction of facilities needed for the engine that are not part of the currently planned test facilities being provided by the Government at SSC. These facilities include a small component test facility located at P&W, an engine assembly building with equipment located at SSC and an engine launch support building with equipment located at ESMC. The cost for the small component test facility was estimated by P&W facility engineers using experience from other rocket and gas turbine engine development programs. The cost for the engine assembly facility at SSC was estimated by P&W manufacturing personnel and it includes costs for both the building and equipment. The cost estimate for the launch support building at ESMC assumes that an existing building is used but the building is modified and equipped for this purpose.

Special test equipment (STE) costs were estimated by P&W engineers considering the various engine and component test stands planned for the STME/Derivative STBE development programs and the STE needed for development component and engine buildup and assembly. Experience on other rocket and gas turbine engine programs formed the basis for these cost estimates.

Engine design and development includes all of the technical effort required to define technical requirements and establish the engine concepts and designs. It involves verifying that the engine design meets technical requirements and includes technical coordination between engineering, manufacturing and suppliers. For the STME/Derivative STBE program cost estimate this effort was estimated using experience from other P&W engine development programs including the bottoms-up cost estimates made for P&W's 1971 SSME and 1987 SSME ATD proposals.

Program management includes contract data and other management and administrative functions associated with the development program such as Program Planning and Control, Contracts Administration, Configuration Management, Procurement, etc. At P&W the costs for some of these program management functions are indirect and included in G&A and overhead. Costs for the functions that are not indirect were estimated as a percentage of the other development program costs.

Table 3.2.1-1. Gas Generator STME/Derivative STBE Test Operations and Support Assumptions — Contractor Personnel

	At Stennis Space Center						At Contractor	
	Engines		Components		Booster MPTA	Core MPTA	Small Components	
	STBE	STME	STBE	STME			STBE	STME
No. Test Stands	3	3	3	3	1	1	1	1
No. Test Positions	6	6	3 TP, 1 GG, 1 TC	4 TP, 1 GG, 1 TC	1	1	4	4
Total Stand Months	55	103	29	59	9	9	13	19
Total Test Postion Months	78	169	74	156	9	9	51	77

		Engines	Components	Booster MPTA	Core MPTA	Small Components
Technicians						
Test Operations,	#Persons/Test Position	10 (1st) 8 (2nd)	4 (1st) 3 (2nd)	-- --	-- --	2 (1st) 1 (2nd)
Data Recording & Inst.,	#Persons/Stand	-- --	-- --	-- --	-- --	4 (1st) 2 (2nd)
Engine Mechanics,	#Persons/Test Position	4 (1st) 3 (2nd)	1 (1st) 1 (2nd)	3 (1st) 2 (2nd)	2 (1st) 1 (2nd)	0.5 (1st) 0.25 (2nd)
Engineers						
Test Operations Engineers,	#Persons/Stand	2 (1st) 2 (2nd)	2 (1st) 1 (2nd)	-- --	-- --	4 (1st) 2 (2nd)
Test Engineers,	#Persons/Test Position	2 (1st) 1 (2nd)	1.5 (1st) 1 (2nd)	2 (1st) 1 (2nd)	1 (1st) 1 (2nd)	2 (1st) 1 (2nd)
Performance Engineers,	#Persons/Stand	3 (1st) 1 (2nd)	2 (1st) 1 (2nd)	1 (1st) 1 (2nd)	1 (1st) 1 (2nd)	3 (1st) 1 (2nd)
Instrumentation Engineers,	#Persons/Stand	2 (1st) 1 (2nd)	1.5 (1st) 1 (2nd)	1 (1st) 1 (2nd)	--(1st) --(2nd)	2 (1st) 1 (2nd)
Supervisors	#Persons/Stand	8 (Total)	6 (Total)	2 (Total)	1 (Total)	4 (Total)
Economics						
Technicians, Cost/Year		$ 70,000	$ 70,000	$ 70,000	$ 70,000	$ 70,000
Engineers, Cost/Year		$100,000	$100,000	$100,000	$100,000	$100,000
Supervisors, Cost/Year		$120,000	$120,000	$120,000	$120,000	$120,000

NOTE: (1) 1st = 1st Shift
(2) 2nd = 2nd Shift
(3) Personnel costs are total burdened costs

System Engineering and Integration includes such things as reliability, maintainability, safety and quality assurance, engine system analysis and integration, engine/vehicle integration, system performance, human and value engineering, logistics and training, and system cost efforts. Software engineering includes the design, development, checkout maintenance and delivery of computer software used on the engine as well as the development, implementation and maintenance of other software such as engine performance and data reduction programs used during the DDT&E program. Costs for both of these elements were estimated as a percentage of the Engine Design and Development costs.

Costs for the remaining WBS functional elements such as GSE, Tooling and Operations and Support were primarily based on the 1971 P&W SSME proposal data. Included in the GSE and tooling costs are costs for the design, development, evaluation and procurement of tooling and GSE used in the development program. Tooling costs for the prototype production engines delivered during the development program were estimated by P&W Manufacturing personnel. Operations and support costs include the costs for detailed operational planning for launch, flight, recovery and refurbishment support. Also contained are the costs of establishing an initial support capability and providing support for the two flight tests including engine refurbishment. These costs were estimated from the costs contained in the proposals and from experience on other engine programs.

3.2.2 Operations Phase: Operational Production

The Operational Production portion of the Operations Phase is broken into two types of cost elements, non-recurring operational production costs and recurring operational production costs. The following sections discuss the cost methodologies used to estimate these costs.

3.2.2.1 Non-Recurring Operational Prodűction Costs

Non-recurring Operational Production costs are composed of seven functional elements: Program Management, System Engineering and Integration (SE&I), Facilities, Ground Support Equipment, Tooling, Special Test Equipment and Initial Spares.

Initial spares is the element with the highest cost. As discussed in Section 3.1 initial spares costs are based on providing sufficient spare turbopumps, combustion devices and control components to support the two year operational period having the maximum mission rate. Using percent spare component requirements defined from expected reliability levels and the total number of engines being flown in the two-year period, the total quantity of initial spare components needed was defined. It was assumed that these spare components would be delivered as part of the early production lots along with the production engines. The quantities delivered in each lot were determined as a function of the percentage of spares needed and the number of engines being delivered in each lot. Unit costs for the spare components were assumed to be the same as the unit costs for the components in the engine lots. The methodology used to determine the engine and component unit costs for the engine lots is discussed in Section 3.2.2.2.

Ground Support Equipment (GSE) is made up of both common and peculiar GSE. Costs were estimated for sets of both types of GSE based on GSE requirements from other engine programs. The amount of GSE required and its delivery schedule were estimated from the number of flights per year and the flight buildup rates taking into account the quantity of GSE available from the development flight tests.

A large amount of production tooling, used to produce the certification, main propulsion test article and flight test engines, will be available from the development program. Costs for additional tooling needed to achieve maximum engine delivery rates were considered to be a non-recurring operational production cost. These tooling costs were estimated from the initial production tooling requirements estimated by Manufacturing personnel for use in the development program. Maximum engine production rates and delivery schedules were used to determine the additional tooling requirements and schedule.

Increased Program Management and SE&I startup efforts needed at the beginning of operational production were considered to be non-recurring cost elements. Total requirements for these two functions were determined for the early operational years using experience from other programs. Levels of effort expected to be available for these two functions from the recurring operational production and operations cost elements were then determined. The difference between the total effort required and the manpower available from the recurring cost elements defined the non-recurring operational production requirements and costs.

All production facilities and special test equipment needed in the operations phase are expected to be available from the development program. Therefore, no non-recurring operational production costs were included for these items.

3.2.2.2 *Recurring Operational Production Costs*

Recurring Operational Production costs are composed of five functional elements: Program Management, System Engineering and Integration, Flight Hardware Manufacturing, Tooling Maintenance and Facilities Maintenance.

Flight Hardware Manufacturing, which has most of the cost, includes the cost of manufacturing the production engines used in the operational flights, and the cost of performing acceptance tests on the flight engine hardware.

Unit manufacturing costs were estimated for the STME and Derivative STBE by the P&W Manufacturing Product Cost Estimating Group. The cost estimates are based on bottoms-up estimates from design layout drawings using actual costs of similar manufacturing processes for gas turbine and RL10 engine hardware, with consideration for cost reduction features and new high volume manufacturing techniques. Where available and appropriate supplier quotes were used. The bottoms-up estimates were made using a standard cost method referenced to the manufacturing cost of the 250th unit produced at rate of 88 engines/year. Appropriate variances and markups were applied to the standard manufacturing costs to obtain a total unit cost (without fee).

The cost estimating procedure used for the STME/Derivative STBE is the same procedure used by P&W for gas turbine engines. Manufacturing processes required for each major part and/or subassembly within a component were identified. A determination was then made as to whether the part would be manufactured in-house, obtained from a supplier or fabricated using a combination of the two. Using a P&W manufacturing data base, standard labor, raw material and/or purchase part costs were established for each part by making a similarity analysis with current parts and using fabrication cost information contained in the data base. Typical variances were applied for each process to adjust the standard labor hours to actual hours. Different overhead markups were added depending on whether the costs were for labor, material or a purchased part. All markups (except for fee) required to get the engine costs to a selling price were included. The various cost elements considered in the manufacturing cost analysis for material (raw material and purchase parts) and factory labor are shown in Tables 3.2.2-1 and 3.2.2-2 respectively.

Table 3.2.2-1. *STME/Derivative STBE Production Material Cost Elements*

- Direct Material and Purchase Part Elements
  - Purchase Order Value
- Plus Material Overhead
  - Source Selection
  - Bid Evaluation
  - Supplier Performance Tracking
  - Offsite Inspections
  - Supplier Rework
  - Supplier Scrap
  - Alternate Sourcing
  - Expediting
  - Purchasing Management
  - Fringe Benefits to Indirect Personnel
  - Inventory Costs
- Plus General and Administrative Elements
  - Specific Administration at Manufacturing
  - Cost of Money
  - Warranty
  - Information Systems
  - Administrative Expenses

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Table 3.2.2-2. *STME/Derivative STBE Production Labor Cost Elements*

- Direct Labor Elements
  - Labor Standard
  - Set-Up
  - Performance Relative to Standard
  - Inspection
  - Rework
  - Fringe Benefits
- Plus Factory Overhead Elements
  - Utilities
  - Maintenance
  - Factory Management
  - Mfg. Engineering
  - Plant Engineering
  - Industrial Engineering
  - Capital Depreciation
  - Recurring Tooling
  - Fringe Benefits for Indirect Personnel
- Plus General and Administrative Elements
  - Specific Administration at Manufacturing
  - Cost of Money
  - Warranty
  - Information Systems
  - Administrative Expenses

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Detailed costing of the STME/Derivative STBE components required definition of the physical characteristics (dimensions, number of stages, flowrates, etc.) of each component. Both design drawings and engine cycle sheets were used to define these characteristics.

After costs were estimated for each of the major parts or engine assemblies, they were summed to obtain component and total engine unit costs. Costs were added for assembly and test. A fixed cost of $400K per engine was used as an engine acceptance test cost. The effects of changing production quantity from the referenced 250th unit were then factored into the analysis using a 90 percent cost improvement curve. No cost improvement was assumed for the acceptance test cost. The effects of changing lot quantity (or annual production rate) from the referenced 88 units/year were included using a 94.6 percent cost improvement curve. Section 3.1 discusses the source of these cost improvement slopes.

As presented in Tables 3.1.3-1 through 3.1.3-3 of Section 3.1.3, P&W defined operational production engine delivery schedules for each ALS Scenario 2 case, i.e., nominal, maximum and minimum. Included as part of the total number of production engines produced, but not included in the operational production schedules, are 16 STME's and 32 STBE's delivered during the development program. As shown in Figure 3.2.2-1 these engines are considered to be the first production lot, with the first operational production engine starting down the cost improvement curve below these engines. Cumulative average engine unit costs were calculated for each annual operational production lot using the 90% cost improvement slope. These cumulative average lot costs were further modified to reflect the number of engines in each lot using the lot size (or production rate) cost improvement slope.

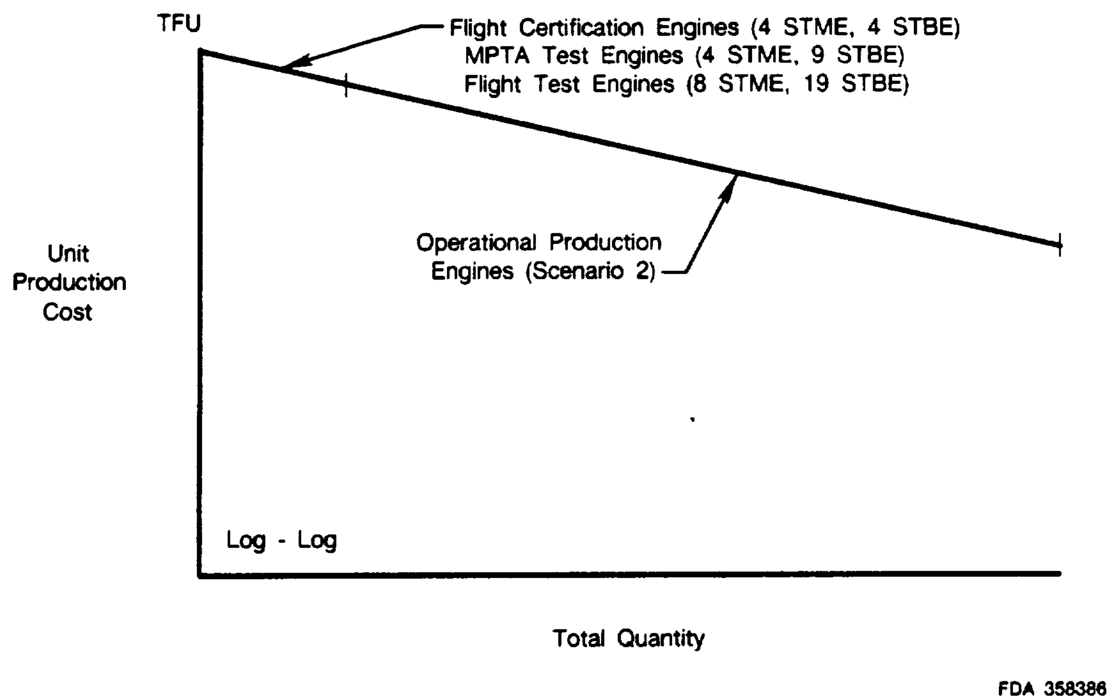

Figure 3.2.2-1. Development Engines Considered In Costing Operational Production Engines

Other Recurring Operational Production cost functions include: Program Management, System Engineering and Integration, Tooling Maintenance and Facilities Maintenance. Tooling Maintenance and Facilities Maintenance are included in the manufacturing overhead and they could not be priced separately. Also, some of the recurring program management functions are included in overhead and they could not be costed separately. The remaining Program Management functions and the SE&I costs are direct charges and their costs were estimated as a percentage of Flight Hardware costs using typical factors derived from other production engine programs.

3.2.3 Operations Phase: Operations

Operations Costs for the STME/Derivative STBE are comprised of five primary functional elements: Program Management, System Engineering and Integration (SE&I), Facilities Maintenance, Operations and Support and Training. Operations and Support (O&S), which contains most of the costs, is further broken down into five functional elements: Launch O&S, Flight O&S, Recovery O&S, Refurbishment O&S and Spares Replenishment.

The Operations cost elements generally fall into two categories. Program Management, SE&I and Flight O&S, which contain most of the management and engineering functions, have minimum fixed levels of effort required to maintain a viable staff to support the program. These elements are affected to some degree by the mission rate but not as significantly as the other cost elements. Costs for Launch O&S, Recovery O&S, Refurbishment O&S, Spares Replenishment and Training are driven directly by the number of engines and missions flown and their costs are based on costs per mission estimates.

The approach that was used for the STME/Derivative STBE operations cost estimates was to define costs at a mature point in the Operations Phase. The 100th mission was selected as this reference point. A cost improvement slope of 87 percent was then passed through this point to generate the total operations cost estimates. The cost improvement slope is a function of the cumulative number of missions flown. The source of this cost improvement slope is discussed in Section 3.1.

Program management includes those costs associated with contract management (scheduling and budgeting), configuration control, data management, etc. SE&I includes technical support for the operational engines including safety, reliability, maintainability and quality assurance. The Program Management and SE&I costs were estimated by first defining a minimum level of effort required each year to provide this support. Additional efforts that would be required for these functions as the flight rate increased were then defined and the two added to obtain total annual costs for these elements. The Program Management and SE&I estimates were based on previous experience from other programs such as the RL10 with consideration for current ALS ground rules and scenarios.

Flight O&S includes all of the engineering and technical effort required to support the flight program. It includes data analysis and anomaly resolution for the flights. The flight O&S costs were estimated by determining the minimum cost per year required to maintain a staff of engineers and technical personnel to support the flight program. A small variable cost which changes with the number of flights per year was added to this fixed cost. The total cost is the Flight O&S cost per year for the STME/Derivative STBE program. As with Program Management and SE&I these cost estimates were based on previous experience.

Launch O&S costs include all the logistic costs associated with supporting engines at the launch site that are ready for flight, as well as the costs required to perform prelaunch tasks on installed engines prior to the vehicle being flown. These costs are primarily driven by the number of engines launched. Costs for this element were calculated using an estimated unit cost of $5,000/engine/mission. This unit cost was determined from an analysis of the tasks that would be required for this function.

Recovery O&S costs are based on an ocean recovery of the vehicle propulsion module with the engines being exposed to a salt air environment only. The engines are not immersed in the salt water. Costs are included for engine personnel onboard the ship to wash and inspect the engines on the propulsion module while the ship is returning to the launch site. Costs were not included for retrieving the propulsion module and operating the ship as these functions were assumed to be included under vehicle costs. The costs for this element were determined by making an analysis of the material and labor required to perform this function for each mission. A cost estimate of $4,300 per engine per mission was used for the program cost estimates.

Refurbishment O&S costs include all the labor and consumable materials required to return an engine to a reliable operating capability after a flight. It contains all of the turnaround tasks required to ready an engine for the next flight and includes all scheduled and unscheduled maintenance that may be required on an engine. Routine scheduled refurbishment of the engines and modules will be conducted at ESMC, while refurbishment requiring component teardown will be conducted at SSC. Refurbishment costs were determined on an average cost per engine per mission basis. Routine turnaround costs were estimated from an analysis of labor and material requirements for each turnaround. Estimated failure rates and repair/refurbishment labor requirements were used to define the average unscheduled maintenance costs per mission. Average refurbishment costs of $61,000 per engine per mission were estimated for the STME and $69,000 per engine per mission were estimated for the Derivative STBE. The STBE has a slightly higher cost because of additional refurbishment tasks required due to coking of the methane fuel.

Replenishment Spares includes the cost of replacement engine parts used to repair and refurbish the operational STME/Derivative STBE. Replenishment spares costs were determined using estimated component failure rates to define the frequency of unscheduled maintenance and an analysis of the potential failure modes to define the cost of parts being replaced. The average cost for replenishment spares was estimated to be approximately $25,000 per engine per mission.

Training includes the cost of performing on-going training for engine personnel supporting the operational flight program. The training costs, which are small, were estimated form experience on previous programs.

Facilities used to support the operational flight program are all located at Government sites such as SSC and ESMC. It was assumed that Facility Maintenance would be provided by the Government, no costs were included in this Operations Cost Estimate for this functional element.

3.2.4 Product Improvement and Support Program

Cost estimates for the STME/Derivative STBE Product Improvement and Support Program are based on gas turbine engine experience. Historically, gas turbine component improvement program costs have amounted to approximately 80 percent of engine development costs. The percentage was lowered to 50 percent for the STME/Derivative STBE program since time-phasing for the production engine deliveries is front loaded and the delivery period significantly shorter than that of a typical gas turbine engine. Product improvement and support programs are most cost effective when engine improvements developed in such a program can be incorporated in the yet-to-be delivered production engines.

3.3 WORK BREAKDOWN STRUCTURE DESCRIPTION

The work breakdown structure (WBS) used for the STME/Derivative STBE program cost estimate is consistent with the format used for the ALS Vehicle Studies, ALS Cost Reporting Document Number ALS-SD-R-CRD-v 1.00, 4 March 1988, as well as with the WBS provided by NASA for the Phase A Extension study program cost estimates. Table 3.3-1 shows how the main engines (STME/Derivative STBE) fit into the overall launch vehicle system WBS. The engines are a fifth level WBS element in the launch vehicle segment under the vehicle stage.

Table 3.3-1. *Launch Vehicle System WBS*

WBS No.	*Space System Work Breakdown Structure Elements*
1.0	Advanced Launch System
1.1	System — Integration, Assembly and Test
1.2	Launch Vehicle System
1.2.1	Launch Vehicle System — Integration, Assembly and Test
1.2.N	Vehicle Stage (N=2 Booster, N=3 Core)
1.2.N.7	Liquid Fuel System
1.2.N.7.2	Main Engines
1.2.N.7.2-1	Main Engines — Design and Development
1.2.N.7.2-2	Main Engines — Non-Recurring Operational Production
1.2.N.7.2-3	Main Engines — Recurring Operational Production
1.2.N.7.2-4	Main Engines — Operations
1.2.N.7.2-X	Main Engines — Product Improvement and Support Program

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Figures 3.3-1 and 3.3-2 show the WBS structures used for the STME/Derivative STBE Design and Development Phase and Operations Phase, respectively. The Operations Phase encompasses Non-recurring and Recurring Operational Production and Operations. The STME/Derivative STBE WBS is a matrix of cost elements with the STME/Derivative STBE hardware costs broken into system hardware and integration, assembly and test. Each engine subsystem is a fourth level WBS cost element within the main engine WBS structure. Each engine subsystem level is further broken to a fifth engine component level. Costs are provided in the STME/Derivative STBE cost estimates document for each program phase and its appropriate functional elements. Most functional elements are reported at an integrated system level while the hardware functional elements (see Figures 3.3-1 and 3.3-2) are reported at an engine subsystem and/or an engine component level.

As discussed in Section 3.2.4 it is anticipated that there will be a Product Improvement and Support Program (PISP) for the STME/Derivative STBE. The WBS provided by NASA for the Phase A extension study program does not have provisions in its functions for a PISP effort. In this cost estimates document, the STME/Derivative STBE PISP costs have been included as a separate item (1.2.N.7.2-X) after the Operations phase costs. Since the PISP effort is shown in the WBS matrix as a separate line item, its costs may be removed easily from the program cost estimates if it is desired not to include them.

3.4 WORK BREAKDOWN STRUCTURE DICTIONARY

Definitions used for the STME/Derivative STBE Program Work Breakdown Structure cost elements are included in this section. Sections 3.4.1 through 3.4.4 define the types of costs included in each phase of the STME/Derivative STBE program and its respective functional elements (-1 Design and Development, -2 Non-Recurring Operational Production, -3 Recurring Operational Production, and -4 Operations). Section 3.4.5 defines the subsystems and components included in each engine hardware WBS element while Section 3.4.6 describes the Product Improvement and Support Program.

	WBS No. 1.2.N.7.2-	Prog Mgmt		SE & I		Engr'g D&D	Engine Test					Flight Test Hardware		MPTA Test Hardware		Facilities			Software Engineering	GSE		Tooling	STE	Operations & Support			
		Contract Data	Other	SRM & QA	Other		Engine Test Hardware	Engine Test Operations & Support	Component Test Hardware	Component Test Operations & Support	Propellants	Mfg.	Acceptance	Mfg.	Acceptance	Production	Launch	Test		Common	Peculiar			Launch Operations Support	Flight Operations Support	Recovery Operations Support	Refurbishment Operations Support
Integrated System	1.13	O	O	O	O	O	O	O	O	O		O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
System Hardware	1.13.1																										
Turbomachinery	1.13.1.1								O	O		O		O													
LPOTP	1.13.1.1.1											O		O													
LPFTP	1.13.1.1.2											O		O													
HPOTP	1.13.1.1.3											O		O													
HPFTP	1.13.1.1.4											O		O													
Combustion Devices	1.13.1.2								O	O		O		O													
Main Injector	1.13.1.2.1											O		O													
Thrust Chamber	1.13.1.2.2											O		O													
Nozzle	1.13.1.2.3											O		O													
Nozzle Skirt	1.13.1.2.4											O		O													
Gas Generator	1.13.1.2.5											O		O													
Igniters	1.13.1.2.6											O		O													
Controls	1.13.1.3								O	O		O		O													
Controllers/Monitors	1.13.1.3.1											O		O													
Software	1.13.1.3.2											O		O					O								
Sensors	1.13.1.3.3											O		O													
Valves	1.13.1.3.4											O		O													
Actuators	1.13.1.3.5											O		O													
Interconnects	1.13.1.3.6											O		O													
Propellant Feed	1.13.1.4											O		O													
Cold Ducts	1.13.1.4.1											O		O													
Hot Ducts	1.13.1.4.2											O		O													
Miscellaneous	1.13.1.4.3											O		O													
Support Devices	1.13.1.5											O		O													
Gimbal System	1.13.1.5.1											O		O													
Tank Repress. Sys	1.13.1.5.2											O		O													
Power Tapoff	1.13.1.5.3											O		O													
Start System	1.13.1.5.4											O		O													
POGO System	1.13.1.5.5											O		O													
Integ., Assy & Test	1.13.2											O		O					O								

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Figure 3.3-1. STME/Derivative STBE Work Breakdown Structure Design and Development Phase

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		WBS No. 1.2.N.7.2-2											WBS No. 1.2.N.7.2-3							WBS No. 1.2.N.7.2-4										
		Non-Recurring Operational Production											Recurring Oper. Prod.							Operations										
		Prog Mgmt	SE & I		Facilities			GSE		Tooling	STE	Initial Spares	Program Mgmt	SE & I		Flt Hdw Manuf		Tooling Maint	Facilities Maint	Program Mgmt	SE & I		Facilities Maint		Operations & Support					Training
	WBS No. 1.2.N.7.2-		SRM & QA	Other	Production	Launch	Test	Common	Peculiar					SRM & QA	Other	Mfg.	Acceptance				SRM & QA	Other	Launch	Test	Launch Ops.	Flight Ops.	Spares Rep.	Recovery Ops.	Refurb Ops.	
Integrated System	13	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O
System Hardware	13.1				O	O	O																							
Turbomachinery	13.1.1											O				O														
LPOTP	13.1.1.1															O														
LPFTP	13.1.1.2															O														
HPOTP	13.1.1.3															O														
HPFTP	13.1.1.4															O														
Combustion Devices	13.1.2											O				O														
Main Injector	13.1.2.1															O														
Thrust Chamber	13.1.2.2															O														
Nozzle	13.1.2.3															O														
Nozzle Skirt	13.1.2.4															O														
Gas Generator	13.1.2.5															O														
Igniters	13.1.2.6															O														
Controls	13.1.3											O				O														
Controllers/Monitors	13.1.3.1															O														
Software	13.1.3.2															O														
Sensors	13.1.3.3															O														
Valves	13.1.3.4															O														
Actuators	13.1.3.5															O														
Interconnects	13.1.3.6															O														
Main Propellant Feed	13.1.4											O				O														
Cold Ducts	13.1.4.1															O														
Hot Ducts	13.1.4.2															O														
Miscellaneous	13.1.4.3															O														
Support Devices	13.1.5											O				O														
Gimbal System	13.1.5.1															O														
Tank Repress. Sys	13.1.5.2															O														
Power Tapoff	13.1.5.3															O														
Start System	13.1.5.4															O														
POGO System	13.1.5.5															O														
Integ., Assy & Test	13.2															O														

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Figure 3.3-2. STME/Derivative STBE Work Breakdown Structure Operations Phase

3.4.1 Design and Development Phase

The terms and definitions for each STME/Derivative STBE functional cost element in the Design and Development Phase are shown below.

WBS No. 1.2.N.7.2-

1. DESIGN AND DEVELOPMENT

Design and development includes all effort necessary to convert requirements into designs and processes that are fully verified for operational use to the prescribed performance standards.

1.1 PROGRAM MANAGEMENT (PM)

Program Management includes management of every aspect of the design and development phase in the STME/Derivative STBE program. PM must assure that all requirements of a NASA contract are met within cost and schedule goals and constraints. PM is responsible for configuration control, data management, scheduling, budgeting and other functions necessary during the design and development phase of the program.

1.1.1 CONTRACT DATA

The contract data portion of Program Management includes all data items, deliverables and reports as specified in the contract for the design and development phase.

1.1.2 OTHER PROGRAM MANAGEMENT

This element includes all PM tasks not included in contract data management. Other tasks assigned to Program Management include updating the WBS schedules and budgets of the different departments and disciplines (e.g., SE&I, Launch Ops, etc.) In addition, PM will be responsible for subcontract management, procurement, and configuration management during the design and development phase of the program.

1.2 SYSTEM ENGINEERING AND INTEGRATION (SE&I)

System engineering is the management of technical efforts to develop an integrated system. Primarily it deals with defining a configuration that meets operational goals or objectives in a cost effective manner. Not included in SE&I are engineering efforts associated with designing and producing the engine or its support equipment. Integration requires that the engine and its components properly interface with adjoining or functionally interdependent systems or components. This element includes safety, reliability, maintainability, quality assurance and other elements.

WBS No. 1.2.N.7.2-

1.2.1 SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE (SRM&QA)

Safety requires that hazards in the project be identified, examined and altered to an acceptable risk level. Alterations to and variances from safety procedures must be documented by those responsible for safety. Reliability is the degree of certainty that the engine will function according to the desired performance specifications for the required period of time or number of firings. This assumes all logistics, support and maintenance requirements are met. Maintainability is the ability of a design to retain or be refurbished to certain characteristics, performance requirements, and reliability by following prescribed procedures. Quality Assurance is the effort or task of determining by destructive or non-destructive means whether an engine (or its components) meets the prescribed standards or requirements in materials, performance, fabrication or serviceability.

1.2.2 OTHER SE&I

This element includes other SE&I costs not included in SRM&QA. Other tasks assigned to SE&I include support of the design process with system requirements, performance/effectiveness specifications and interface control documentation during the design and development phase.

1.3 ENGINEERING DESIGN AND DEVELOPMENT

This element includes the engineering effort necessary to define technical requirements, propulsion concepts and designs; and to verify ability of the design to meet technical requirements.

1.4 ENGINE TEST PROGRAM

The engine test program includes requirements planning, test hardware production, test operations, results evaluation, test documentation and support activities and materials.

1.4.1 TEST ENGINES

Test engines are those engines produced for the purpose of validating design concepts and performance characteristics through single engine testing.

1.4.2 ENGINE DEVELOPMENT TEST OPERATIONS AND SUPPORT

Test operations and support includes replenishment of spares and expendables, refurbishment of hardware, and conducting tests and other support activities necessary to perform the single engine testing function. Test support services related to facilities are Government Furnished Equipment (GFE).

WBS No. 1.2.N.7.2-

1.4.3 COMPONENT TEST HARDWARE

This element includes engine components produced for the purpose of validating design concepts and performance characteristics through major component testing.

1.4.4 COMPONENT DEVELOPMENT TEST OPERATIONS AND SUPPORT

Component development test operations includes component testing, replenishment of spares, refurbishment of hardware, operation and maintenance of test facilities and other supporting activities necessary for the major component testing function.

1.4.5 PROPELLANTS

Propellants includes all effort to make projections of propellant utilization and to handle propellants, oxidizers and other chemicals required to complete the development program. Propellants will be government furnished.

1.5 FLIGHT TEST ENGINES

These are engines and spares required to support the development flight test program.

1.5.1 MANUFACTURING

Manufacturing includes the fabrication, assembly and integration of the flight test hardware.

1.5.2 ACCEPTANCE TEST

Acceptance test includes the efforts and materials necessary to perform acceptance tests on the flight test engine hardware. It includes test preparation, test conduct, data reduction, reporting, and refurbishment.

1.6 MAIN PROPULSION TEST ARTICLE HARDWARE (MPTA)

MPTA hardware are those engines and spares required to support MPTA testing.

1.6.1 MANUFACTURING

Manufacturing includes the fabrication, assembly and integraton of the engines for main propulsion test articles.

1.6.2 ACCEPTANCE TEST

Acceptance test includes the effort and materials necessary to perform acceptance tests on main propulsion test article engines. It includes test preparation, test conduct, data reduction, reporting, and refurbishment.

WBS No. 1.2.N.7.2-

1.7 FACILITIES

Facilities include new or modified buildings and other facilities needed to facilitate the space transportation engines mission. This includes all efforts necessary for design and construction of test, manufacturing and launch facilities.

1.7.1 PRODUCTION FACILITIES

Production Facilities include the design and construction of buildings and other facilities necessary to produce the STME/Derivative STBE development and production hardware.

1.7.2 LAUNCH FACILITIES

This element includes the design and construction of all engine-related facilities necessary to support engine operations for flight. All launch facilities are GFE.

1.7.3 TEST FACILITIES

Test facilities include the design and construction of buildings and other facilities, and the planning of maintenance procedures, necessary to prove the design and reliability of the Space Transportation Engines. Engine test stands are included in this element. Major component and system test facilities are GFE.

1.8 SOFTWARE ENGINEERING

Software engineering consists of the design and development of computer instructions which control the STME/Derivative STBE through valves, actuators, and solenoids during engine operation. This element also includes other software engineering required during design and development.

1.9 GROUND SUPPORT EQUIPMENT (GSE)

This element includes design and development of common and peculiar GSE which is used to test, handle or maintain the STE during ground operations. It may include checkout equipment, mock-ups, support equipment and test equipment. Production of GSE required only for DDT&E is included. Production of GSE required for operations is included in non-recurring production.

WBS No. 1.2.N.7.2-

1.9.1 COMMON GROUND SUPPORT

Common ground support equipment is GSE that is identical to equipment used on programs other than STME/Derivative STBE Programs.

1.9.2 PECULIAR GROUND SUPPORT

Peculiar GSE is designed and developed specifically for STME/Derivative STBE use.

1.10 TOOLING

Tooling includes design and development of special machinery, jigs, fixtures, dies, molds, and the like, necessary to fabricate and assemble components and the engine. This element includes all production tooling acquired under the development program even if not used until operational production. Other tooling required to produce operational engines is included under non-recurring production.

1.11 SPECIAL TEST EQUIPMENT

Special test equipment consists of the design and development of electronic, hydraulic, mechanical, optical and other types of testing devices that are used in checkout of the STME/Derivative STBE.

1.12 OPERATIONS AND SUPPORT

Operations and Support includes the design and development of detail planning for maintenance, mission control, spares and logistics procedures and equipment necessary for the STME/Derivative STBE flight operations. Also included is the planning for refurbishment of reusable hardware, storage at launch site, facilities and training of the trainers.

1.12.1 LAUNCH OPERATIONS SUPPORT

The tasks and logistics necessary to control, maintain and support the engine during and in preparation of launch are included in launch operations support. This process is planned, designed and tested during the design and development phase. It may include storage, trouble-shooting, spares replenishment and ground support at the launch site.

1.12.2 FLIGHT OPERATIONS SUPPORT

Flight operations support includes tasks and logistics necessary to control, maintain and support the engine during flight. This task is planned and designed during the design and development phase. Flight operations begins at initial engine power-up during pre-start for flights. It ends at return to the earth's surface.

WBS No. 1.2.N.7.2-

1.12.3 RECOVERY OPERATIONS SUPPORT

This element includes the design and planning of tasks and logistics necessary to recover the engines after flight, including transportation to the refurbishment facility.

1.12.4 REFURBISHMENT OPERATIONS SUPPORT

This element includes the design and development of tasks and logistics necessary to return the engine to reliable operating capability. Refurbishment operations begin at the end of recovery operations and end at the beginning of launch operations.

3.4.2 Operations Phase: Non-Recurring Operational Production

The terms and definitions for each STME/Derivative STBE functional cost element in the Operations Phase: Non-Recurring Operational Production are shown below.

WBS No. 1.2.N.7.2-

2. NON-RECURRING OPERATIONAL PRODUCTION

This category includes the production of initial tooling, GSE and special test equipment used to arrive at full rate manufacturing and operational capability. Also included is the initial equipment acquisition for launch operations, maintenance, and mission control.

2.1 PROGRAM MANAGEMENT (PM)

Program Management includes management of every aspect of non-recurring production in the STME/Derivative STBE program. PM must assure that all requirements of a NASA contract are met within cost and schedule goals and constraints. PM is also responsible for configuration control, data management, scheduling, budgeting and other functions necessary to accomplish the non-recurring production.

2.2 SYSTEM ENGINEERING AND INTEGRATION (SE&I)

System engineering is the management of technical efforts to develop an integrated system. Primarily it deals with defining a configuration that meets operational goals or objectives in a cost effective manner. Not included in SE&I are engineering efforts associated with designing and producing each individual operational production element. Integration requires that the non-recurring operational production equipment properly interface with adjoining or functionally interdependent systems or components. This element includes safety, reliability, maintainability, quality assurance and other elements for the non-recurring production.

WBS No. 1.2.N.7.2-

2.2.1 SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

Safety requires that hazards in the project be identified, examined and altered to an acceptable risk level. Alterations to and variances from safety procedures must be documented by those responsible for safety. Reliability is the degree of certainty that the non-recurring operational production equipment will function within the desired performance specifications for a period of time or number of firings. This assumes all logistics, support and maintenance requirements are met. Maintainability is the ability of a design to retain or be refurbished to certain characteristics, performance requirements, and reliability by following prescribed procedures. Quality Assurance is the effort or task of determining by destructive or non-destructive means whether the non-recurring operational production equipment meets the prescribed standards or requirements in materials, performance, fabrication or serviceability.

2.2.2 OTHER SE&I

Other tasks assigned to SE&I include support of the production process with system requirements, performance/effectiveness specifications and interface control documentation related to the non-recurring production elements. Change tracking and control are included.

2.7 FACILITIES

This element includes the acquisition of facility related support equipment needed to provide full rate production and operation of STME/Derivative STBEs. This equipment is planned and designed during the design and development phase.

2.7.1 PRODUCTION FACILITIES

Production facilities includes the acquisition of facility related support equipment necessary to provide full rate production.

2.7.2 LAUNCH FACILITIES

Launch facilities include the procurement of launch and mission control facility equipment needed to support full rate flight operations. This equipment is considered to be a part of the facility and does not include engine GSE and special test equipment. All launch facilities are GFE.

2.7.3 TEST FACILITIES

Test facilities include the acquisition of facility related support equipment necessary to provide full rate production and operations of engines. Excluded are engine test instruments and equipment which are included under GSE or special test equipment. Major component and system test facilities are GFE.

WBS No. 1.2.N.7.2-

2.9 GROUND SUPPORT EQUIPMENT

This element includes the production/acquisition of common and peculiar GSE which is used to test, handle or maintain the STME/Derivative STBE until launch. It may include checkout equipment, mock-ups, support equipment and test equipment.

2.9.1 COMMON GSE

Common ground support equipment is GSE that is identical to equipment used on programs other than the STME/Derivative STBE.

2.9.2 PECULIAR GSE

Peculiar GSE is similar to common GSE except that the hardware is designed specifically for the space transportation engine use only.

2.10 TOOLING

Tooling includes the production of machinery, jigs, fixtures, dies, molds, and the like, necessary to fabricate and assemble the engine components.

2.11 SPECIAL TEST EQUIPMENT

Special test equipment consists of the production of electronic, hydraulic, mechanical, optical or other type of testing device that is used specifically for the STME/Derivative STBE. Excluded is the special test equipment which was required only for DDT&E.

2.12.5 INITIAL SPARES

Initial spares include production of extra units of assembly, part or support equipment that are held in reserve for the beginning of the operations phase.

3.4.3 Operations Phase: Recurring Operational Production

The terms and definitions for each STME/Derivative STBE functional cost element in the Operations Phase: Recurring Operational Production are shown below.

WBS No. 1.2.N.7.2-

3. RECURRING OPERATIONAL PRODUCTION

This category includes the fabrication, assembly and test of STE flight engines.

WBS No. 1.2.N.7.2-

3.1 PROGRAM MANAGEMENT (PM)

Program Management includes management of every aspect of recurring production in the STME/Derivative STBE program. PM must assure that all requirements of a contract are met within cost and schedule goals and constraints. PM is also responsible for configuration control, data management, scheduling, budgeting and other functions related to the production phase of the program.

3.2 SYSTEM ENGINEERING AND INTEGRATION (SE&I)

System engineering is the management of technical efforts to develop an integrated system. Primarily it deals with defining a configuration that meets operational goals or objectives in a cost effective manner. This element includes safety, reliability, maintainability, quality assurance and other elements.

3.2.1 SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

Safety requires that hazards in the project be identified, examined and altered to an acceptable risk level. Alterations to and variances from safety procedures must be documented by those responsible for safety. Reliability is the degree of certainty that the engine will function within the desired performance specifications for a period of time or number of firings. This assumes all logistics, support and maintenance requirements are met. Maintainability is the ability of a design to retain or be refurbished to certain characteristics, performance requirements, and reliability by following prescribed procedures. Quality Assurance is the effort or task of determining by destructive or non-destructive means whether the recurring operational production meets the prescribed standards or requirements in materials, performance, fabrication or serviceability.

3.2.2 OTHER SE&I

Other tasks assigned to SE&I include support of the production process with system requirements, performance/effectiveness specifications and interface control documentation related to the production.

3.5 FLIGHT HARDWARE MANUFACTURING

This element includes the recurring production of engines used in the operational flights following final acceptance of design.

3.5.1 MANUFACTURING

Manufacturing includes the fabrication, assembly and integration of the flight hardware.

WBS No. 1.2.N.7.2-

3.5.2 ACCEPTANCE

Acceptance includes the effort and materials necessary to perform acceptance tests on the flight engine hardware. It also includes test preparation, test conduct, data reduction, reporting, and refurbishment.

3.7.1 FACILITIES MAINTENANCE

Facilities maintenance will include the repair and upkeep of all production buildings and equipment. Excluded is the maintenance of production tooling (see 3.10).

3.10 TOOLING MAINTENANCE

Tooling maintenance will include the inspection, test, calibration, repair or replacement of production and support tooling for the engine production. Tooling for recurring production will be 'hard' or final design tooling.

3.4.4 Operations Phase: Operations

The terms and definitions for each STME/Derivative STBE functional cost element in the Operations Phase: Operations are shown below.

WBS No. 1.2.N.7.2-

4. OPERATIONS

This category includes the maintenance, mission control, spares and logistics necessary for the engine to meet required launch schedules. Also included is refurbishment of resuable hardware, storage at launch site, spares replenishment, facilities and software maintenance and training.

4.1 PROGRAM MANAGEMENT (PM)

Program Management includes management of every aspect of operations in the STME/Derivative STBE program. PM must assure that all requirements of a contract are met within cost and schedule goals and constraints. PM is also responsible for configuration control, data management, scheduling, budgeting and other functions necessary during the operational phase of the program.

WBS No. 1.2.N.7.2-

4.2 SYSTEM ENGINEERING AND INTEGRATION (SE&I)

System engineering is the management of technical efforts to develop an integrated system. Primarily it deals with defining a configuration that meets operational goals or objectives in a cost effective manner. Not included in SE&I are the engineering efforts associated with designing and producing the operational equipment. Integration requires that the operational equipment properly interface with adjoining or functionally interdependent systems or components. This element includes safety, reliability, maintainability, quality assurance and other elements.

4.2.1 SAFETY, RELIABILITY, MAINTAINABILITY AND QUALITY ASSURANCE

Safety for operations requires that hazards in the project be identified, examined and altered to an acceptable risk level. Alterations to and variances from safety procedures must be documented by those responsible for safety. Reliability is the degree of certainty that the operational equipment will function within the desired performance specifications for a period of time or number of uses. This assumes all logistics, support and maintenance requirements are met. Maintainability is the ability of a design to retain or be refurbished to certain characteristics, performance requirements, and reliability by following prescribed procedures. Quality Assurance is the effort or task of determining by destructive or non-destructive means whether operational production meets the prescribed standards or requirements in materials, performance, fabrication or serviceability.

4.2.2 OTHER SE&I

Other tasks assigned to SE&I include support of the operational tasks with product improvements, performance/effectiveness improvements and redefinition of specifications as needed during the life of the STME/Derivative STBE.

4.7 FACILITIES MAINTENANCE

This element includes operations and maintenance of buildings and equipment needed to facilitate the STME/Derivative STBE mission of inserting the spacecraft into orbit. This will include buildings for storing ground support equipment and peculiar support equipment. These buildings and equipment are maintained and repaired during the operational phase of the STME/Derivative STBE.

4.7.2 LAUNCH FACILITIES

Launch facilities include the operation and maintenance of buildings and support equipment needed to support launch operations. This element does not include GSE. All launch facilities operations and maintenance are GFE.

WBS No. 1.2.N.7.2-

4.7.3 TEST FACILITIES MAINTENANCE AND PROCEDURES

Test facilities include the maintenance of buildings, maintenance and replacement of test equipment and maintenance of procedures necessary for engine operations. Engine test instruments and test stands are included. Major component and system test facilities operations and maintenance are GFE.

4.12 OPERATIONS AND SUPPORT

This element includes the launch operations, mission control, spares and logistics necessary for the STME/Derivative STBE to meet required launch schedules. Also included is refurbishment of reusable hardware, storage at launch site and software maintenance.

4.12.1 LAUNCH OPERATIONS AND SUPPORT

Included in this element are the tasks and logistics necessary to control, transport and support the STME/Derivative STBE from the production stage (or storage) until launch of the spacecraft. Diagnostic software used after flights are also included. Launch operations stop at launch.

4.12.2 FLIGHT OPERATIONS AND SUPPORT

Included in this element are the tasks and logistics necessary to control, track and monitor the STME/Derivative STBE during flight. Also included is post-flight data analysis. Flight operations begin with launch and continue through flight data assessment and recovery.

4.12.3 RECOVERY OPERATIONS AND SUPPORT

Included in this element are the tasks and logistics necessary to recover the engines after return to earth. The recovery effort ends when the engines have been delivered to the refurbishment facility.

4.12.4 REFURBISHMENT OPERATIONS AND SUPPORT

This element includes the tasks and logistics necessary to return the engine to reliable operating capability after flight. This effort may include scheduled or unscheduled maintenance to the reusable flight hardware.

4.12.5 SPARES REPLENISHMENT

All effort and materials required to produce and keep inventory of spare parts or components for unscheduled repair purposes during the operational phase are included. Spares replenishment does not include initial spares produced before the STME/Derivative STBE is operational.

WBS No. 1.2.N.7.2-

4.14 TRAINING

Training includes all instructional effort, services, simulators, and manuals to provide personnel with the knowledge and skills necessary to operate and support the STME/Derivative STBE. Only ongoing training is involved in the operations phase. Initial training (training the trainers) takes place in the design and development period.

3.4.5 Engine Cost Elements

The definitions used for the STME/Derivative STBE WBS hardware cost elements are presented below. Included in the definitions are the subsystems and components included in each engine cost element. The numbers shown for the subsystem elements are at the fourth WBS level, while the component elements are at the fifth WBS level.

The System Hardware element breakout is applicable for both the Design and Development Phase and the Operations Phase.

The terms and definitions for each STME/Derivative STBE subsystem and component cost element are shown below.

WBS No. 1.2.N.7.2-

13. INTEGRATED SYSTEM

This element includes all engine components and integration effort required to develop/produce an engine system. It also includes checkout required prior to flight readiness.

13.1 SYSTEM HARDWARE

This element includes all components manufactured to build the STME/Derivative STBE. Included are the turbomachinery, combustion devices, controls, propellant feed and support devices subsystems.

13.1.1 TURBOMACHINERY

This element includes the turbomachinery components. Included in the turbomachinery are the Low Pressure Oxidizer Turbopump, High Pressure Oxidizer Turbopump, Low Pressure Fuel Turbopump, and the High Pressure Fuel Turbopump. This element does not include inlet and discharge ducts.

13.1.1.1 LOW PRESSURE OXIDIZER TURBOPUMP (LPOTP) (Not applicable for current STME/Derivative STBE Designs)

This element includes the Low Pressure Oxidizer Turbopump. Included is a turbine driven pump which provides the HPOTP with higher net positive suction pressure (NPSP).

WBS No. 1.2.N.7.2-

13.1.1.2 LOW PRESSURE FUEL TURBOPUMP (LPFTP) (Not applicable for current STME/Derivative STBE Designs)

This element includes the Low Pressure Fuel Turbopump. Included is a turbine driven pump which provides the HPFTP with higher NPSP.

13.1.1.3 HIGH PRESSURE OXIDIZER TURBOPUMP (HPOTP)

This element includes the High Pressure Oxidizer Turbopump. Included is a turbine driven pump to pump LO_2 which is provided by the LPOTP. This pump provides oxygen to the heat exchanger, gas generator injector and the thrust chamber injector. The turbine is powered by hot gas supplied by the HPFTP turbine discharge flow.

13.1.1.4 HIGH PRESSURE FUEL TURBOPUMP (HPFTP)

This element includes the High Pressure Fuel Turbopump. Included is a turbine driven pump supplied with liquid fuel from the LPFTP. The turbine is powered by hot gases from the gas generator. Hot gases are discharged into the HPOTP turbine inlet duct.

13.1.2 COMBUSTION DEVICES

This element includes the combustion device components. Included are the main injector, thrust chamber, nozzle, skirt, gas generator and igniters.

13.1.2.1 MAIN INJECTOR

This element includes the main injector. Included is the main injector, which efficiently mixes and uniformly distributes propellants to the main combustion chamber.

13.1.2.2 THRUST CHAMBER

This element includes the thrust chamber. Included is the main combustion chamber (thrust chamber) where the propellant gases are burned, and the nozzle convergent/divergent section.

13.1.2.3 NOZZLE

This element includes the nozzle extension assembly. The nozzle assembly will contain the mounting hardware for the nozzle.

13.1.2.4 NOZZLE SKIRT (Core engine only)

This element includes the nozzle skirt. The nozzle skirt allows continued expansion of the combustion gases from the main combustion chamber and provides a higher specific impulse.

13.1.2.5 GAS GENERATOR

This element includes the gas generator. A gas generator is supplied with fuel and oxidizer from the propellant feed system. The gas generator combustion gases power the turbopumps.

WBS No. 1.2.N.7.2-

13.1.2.6 IGNITER

This element includes all igniters in the gas generator and main combustion chamber. Igniters ignite the propellants to begin the combustion process. The igniters include spark plugs or spark exciter electronics, injectors and combustion chambers.

13.1.3 CONTROLS

This element includes the engine controls. Included in controls are the controllers/monitors, software, sensors, valves, actuators, and interconnects.

13.1.3.1 CONTROLLER/MONITORS

This element includes the controller/monitors. The controller is an electronic/optical package that controls the engine performance and output by interacting with sensors, valves, actuators and igniters.

13.1.3.2 SOFTWARE

This element includes the programming of the software designed by software engineering. The software is in an on-line real time operational mode. It provides the instructions to control the engine through the valves, actuators, and solenoids. Commands from the vehicle are processed and executed. Performance and conditions of the engine are monitored through the software.

13.1.3.3 SENSORS

This element includes all engine sensors. Sensors monitor or detect the condition of certain parts of the engine and transmit the data to the controller/monitor that can process the data.

13.1.3.4 VALVES

This element includes the valves. Valves control the flow and pressure of propellants in the engine. Included are the main fuel valve, main oxidizer valve, gas generator valves, purge valves, check valves and the like.

13.1.3.5 ACTUATORS

This element includes the actuators. Actuators are mechanical devices that engage or disengage other devices such as valves. This element does not include thrust vector control actuators.

13.1.3.6 INTERCONNECTS

This element includes the interconnects which consist of the control interconnects, wire/cables, hydraulic lines, electrical lines, pneumatic lines, and the like.

WBS No. 1.2.N.7.2-

13.1.4 PROPELLANT FEED

This element includes the propellant feed system components. Included are the ducts, manifolds and other miscellaneous components.

13.1.4.1 COLD DUCTS

This element includes all the cold duct components. Ducts are rigid/flexible lines that transport fuel, pressurants or other material throughout the engine for operation.

13.1.4.2 HOT DUCTS

Included in this element are the hot ducts. Hot ducts transport fuel gases (usually hot) within the engine.

13.1.4.3 MISCELLANEOUS PROPELLANT FEED

This element includes other parts of the propellant feed subsystem besides ducts and manifolds. These parts contribute to getting propellant to the proper place in the correct location and in the correct proportion.

13.1.5 SUPPORT DEVICES

This element includes all vehicle support devices on the engine. Included are components such as gimbal assembly, tank repressurization, power tapoff, start system and POGO system.

13.1.5.1 GIMBAL

Included in this element is the gimbal block assembly and gimbal actuator attachment struts. Excluded is the gimbal actuator which is included in the launch vehicle. The gimbal assembly serves two basic functions. The first is transmitting thrust loads to the vehicle and secondly it is responsible for allowing thrust vector control.

13.1.5.2 TANK REPRESSURIZATION

This elements includes all parts of the tank repressurization system. The tank repressurization system consists of the hardware necessary to provide heated and pressurized fuel and LO_2 to the vehicle. Elements include lines, heat exchangers, valves, orifices, and the like.

13.1.5.3 POWER TAPOFF (Not applicable for current STME/Derivative STBE Designs)

This element includes the power tapoff system. The power tapoff system includes the generator and other hardware necessary to convert the mechanical power of turbines into electrical power for the vehicle. The power tapoff pad on the turbopump may be the only equipment provided by the engine.

WBS No. 1.2.N.7.2-

13.1.5.4 START SYSTEM

This element includes the start system. The start system consists of the feed hardware that provides gas to the high pressure turbines for start assist.

13.1.5.5 POGO FLIGHT SYSTEM

This element includes the POGO suppressor and associated hardware. The POGO suppressor is a capacitance in the LO_2 flow circuit and prevents low frequency oscillations from affecting the HPOTP.

13.2 INTEGRATION, ASSEMBLY AND TEST

This element includes the effort and materials necessary to properly attach and install the STME/Derivative STBE components to provide a complete engine assembly. In addition, the engine capability must be proven with specified test procedures.

3.4.6 Product Improvement and Support Program (PISP)

This effort covers the costs associated with a continuing engineering and testing effort during the operations phase directed toward improving STME/Derivative STBE safety, reliability, maintainability, durability, supportability, operability and cost reduction. PISP is applicable to the total engine system; engine performance is not changed.

SECTION 4.0
SUMMARY COST PRESENTATIONS

4.1 TOTAL COST ESTIMATE

Total costs estimated for the gas generator STME/Derivative STBE program over its 32-year life cycle period are summarized in Table 4.1-1. All engine-related design and development, operational production, operations and product improvement and support program cost elements have been included in the program cost estimates. The cost estimates are based on ALS Scenario 2 designated by NASA for the methane booster. Scenario 2 consists of a hydrogen/oxygen core stage powered by three reusable STME's and a methane/oxygen booster stage powered by seven reusable Derivative STBE's. Nominal, maximum and minimum flight schedules, and production engine quantities were evaluated for this scenario. Table 4.1-2 summarizes the number of missions and quantities of engines assumed for each of the three flight schedule cases.

Table 4.1-1. *STME/Derivative STBE Program Cost Summary*

	Scenario 2 Mission Schedule		
	Nominal	*Maximum*	*Minimum*
Design and Development	$1841.1 M	$1841.1 M	$1841.1 M
Non-Recurring Operational Production	366.4	694.9	352.2
Core Engines	120.0	232.8	112.9
Booster Engines	246.4	462.1	239.3
Recurring Operational Production	3226.3	5728.7	2054.5
Core Engines	1064.1	1890.0	621.7
Booster Engines	2162.2	3838.7	1432.8
Operations	479.5	739.2	437.0
Core Engines	140.1	214.9	128.0
Booster Engines	339.4	524.3	309.0
Product Improvement and Support Program	739.1	739.1	739.1
Total Program Cost	$6652.4 M	$9743.0 M	$5423.9 M

Note: All costs in millions of constant FY87 dollars.

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Table 4.1-2. *STME/Derivative STBE Scenario 2 Operations Assumptions*

	Scenario 2					
	Core Stage			*Booster Stage*		
	Nominal	*Maximum*	*Minimum*	*Nominal*	*Maximum*	*Minimum*
Total Number of Missions	300	625	250	300	625	250
Maximum Number of Missions/Year	14	33	12	14	33	12
Total Number of Operational Production Engines	175	350	100	425	850	275
Maximum Number of Production Engines/Year	30	30	30	70	70	70
Average Number of Reuses/Engine	5	5	7	5	5	6
Operational Production Period, Yrs	24	23	9	24	23	12

Note: Scenarios 1 and 3 address STME and are included in FR-19830-2.

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The cost estimates are in constant FY87 dollars and they include engine contractor costs only. They do not include profit and/or management reserve. Costs for propellants and Government-provided test facilities have not been included.

The nominal STME/Derivative STBE flight case which consists of 300 missions over a 25 year operational period results in a total program cost of approximately $6.7 billion. The highest cost STME/Derivative STBE case (maximum flight schedule with 625 missions) has a total program cost of approximately $9.7 billion. The lowest cost case (minimum flight schedule with 250 missions) results in a total program cost of approximately $5.4 billion.

Tables 4.1-3 through 4.1-5 summarize total program costs by functional element for the Design and Development, Operational Production and Operations portions of the STME/Derivative STBE program, respectively. The Design and Development Cost Summary, Table 4.1-3, provides cost visibility for the individual STME and STBE portions of the combined STME/Derivative STBE development program. Tables 4.1-4 and 4.1-5 provide cost visibility for each flight schedule case for the operational portions of the program.

Table 4.1-3. *STME/Derivative STBE Program — Design and Development Program Cost Summary*

	STME Portion	*STBE Portion*	*Total*
Program Management	$66M	$13M	$79M
System Engineering and Integration	42	24	66
Engine Design and Development	171	63	234
Engine Test			
Test Hardware	352	184	536
Test Operations and Support	254	110	364
Flight Test Hardware	73	147	220
MPTA Test Hardware	37	70	107
Facilities			
Production	8	0	8
Launch	4	0	4
Test	22	2	24
Software Engineering	12	3	15
GSE	19	9	28
Tooling	68	10	78
Special Test Equipment (STE)	25	5	30
Operations and Support	30	18	48
Total DDT&E Program Cost	$1,183M	$658M	$1,841M

Note: All costs in millions of FY87 dollars.

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Figure 4.1-1 shows the percentage of the total program costs that each portion of the program phase contributes. Pie charts are presented for the nominal, maximum and minimum Scenario 2 cases.

The Operational Production portion of the Operations Phase is the largest cost contributor in all cases. The Operations portion of the Operations Phase contributes about the same cost as the Product Improvement and Support Program in the maximum case and it is the smallest cost contributor in the nominal and minimum cases. The primary reason that Operational Production cost is the largest cost contributor is because of the expendability of the engines. As shown in Table 4.1-2 the engines are only used an average of 5-7 times before being expended, resulting in a large quantity of engines being required. The size of the Operational Production contribution increases from the minimum to the maximum case because of the increase in the number of flights and quantity of engines required. Figure 4.1-2 compares the number of operational vehicle flights per year for the three cases.

Table 4.1-4. *STME/Derivative STBE Program Operational Production Cost Summary*

	Scenario 2		
	Nominal	*Maximum*	*Minimum*
Non-Recurring Operational Production			
Program Management	$ 3.7	$ 3.7	$ 3.7
System Engineering and Integration	16.1	16.1	16.1
Facilities	0	0	0
Ground Support Equipment	33.0	77.0	33.0
Tooling	48.0	48.0	48.0
Special Test Equipment	0	0	0
Initial Spares	265.7	550.4	251.5
Total Non-Recurring Production Cost	$366.5	$695.2	$352.3
Recurring Operational Production			
Program Management	$ 13.9*	24.7*	8.9*
System Engineering and Integration	111.3	197.5	70.8
Flight Hardware Manufacturing	3,101.1	5,506.8	1,974.8
Tooling Maintenance	0 *	0 *	0 *
Facilities Maintenance	0 *	0 *	0 *
Total Recurring Production Cost	$3,226.3	$5,729.0	$2,054.5
Total Operational Production Cost	$3,592.8	$6,424.2	$2,406.8

* Some recurring program management functions and tooling maintenance and facilities maintenance included in flight hardware manufacturing markups.
Note: All costs in millions of FY87 dollars.

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Table 4.1-5. *STME/Derivative STBE Program Operations Cost Summary*

	Scenario 2		
	Nominal	*Maximum*	*Minimum*
Program Management	$ 26.5	$ 28.6	$ 26.3
System Engineering and Integration	103.7	112.4	103.1
Facilities Maintenance	0	0	0
Operations and Support			
Launch Operations	15.0	27.0	12.9
Flight Operations	43.2	46.9	43.0
Spares Replenishment	76.9	138.5	66.4
Recovery Operations	12.9	23.2	11.1
Refurbishment Operations	195.3	351.9	168.8
Training	6.0	10.8	5.2
Total Operations Cost	$479.5	$739.3	$436.8

Note: All costs in millions of FY87 dollars.

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Figure 4.1-3 shows the total annual funding requirements for each year for each case (nominal, maximum and minimum) of the STME/Derivative STBE program. For each case there are two times that peak costs occur with the annual costs eventually tapering off. The first peak occurs during Design and Development in 1995. It is caused by costs for the MPTA and the flight test hardware increasing at the same time that costs for the engine development program are at a high level. The second peak occurs during the years 2001 and 2002 and it is caused by the rapid increase in Operational Production costs as the engine production rate builds up during the first five years of the operational flight program. Operations costs, in each case, set the end years of the ALS funding requirements.

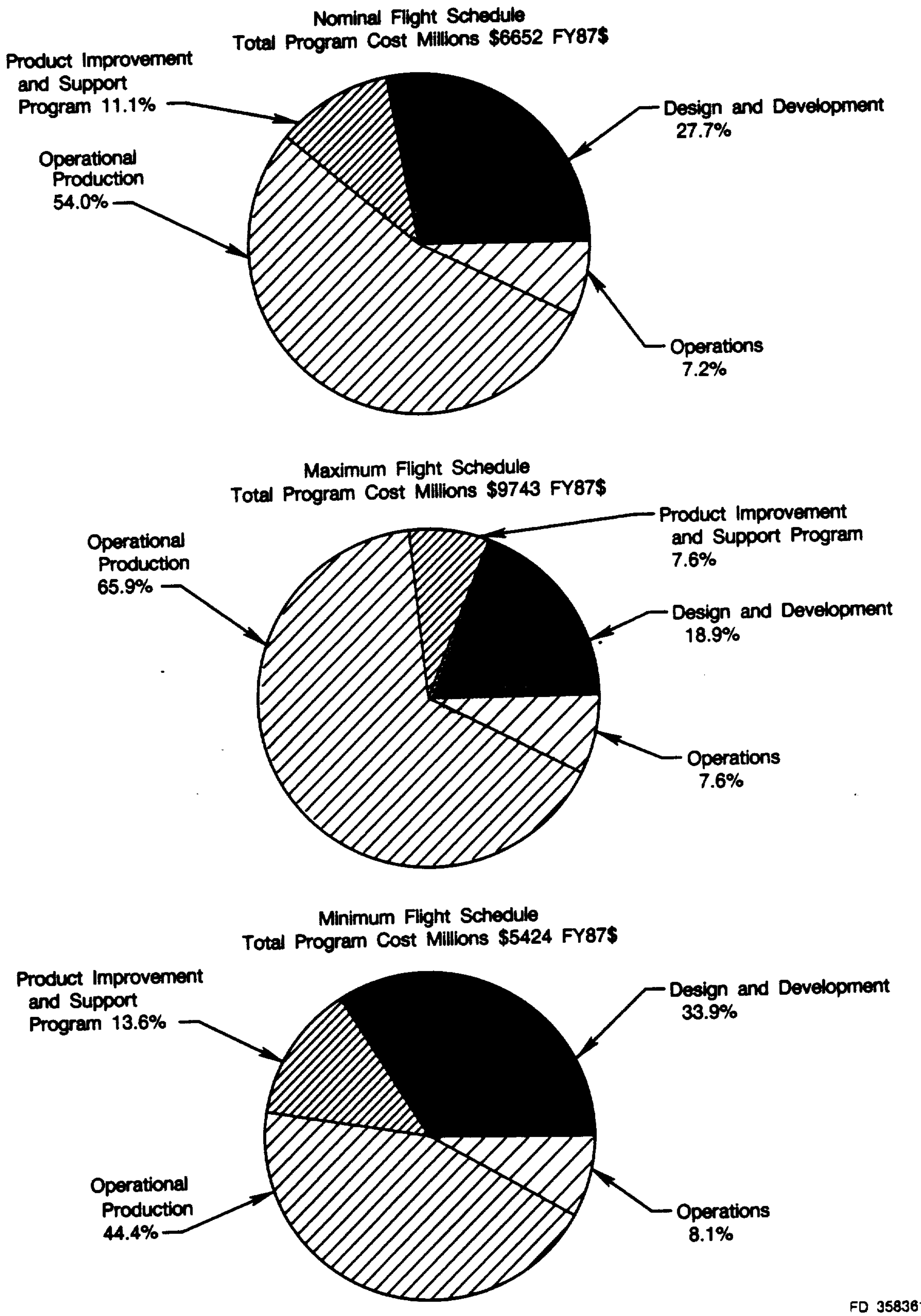

Figure 4.1-1. Contribution of Each Phase to STME/Derivative STBE (Scenario 2) Total Program Cost

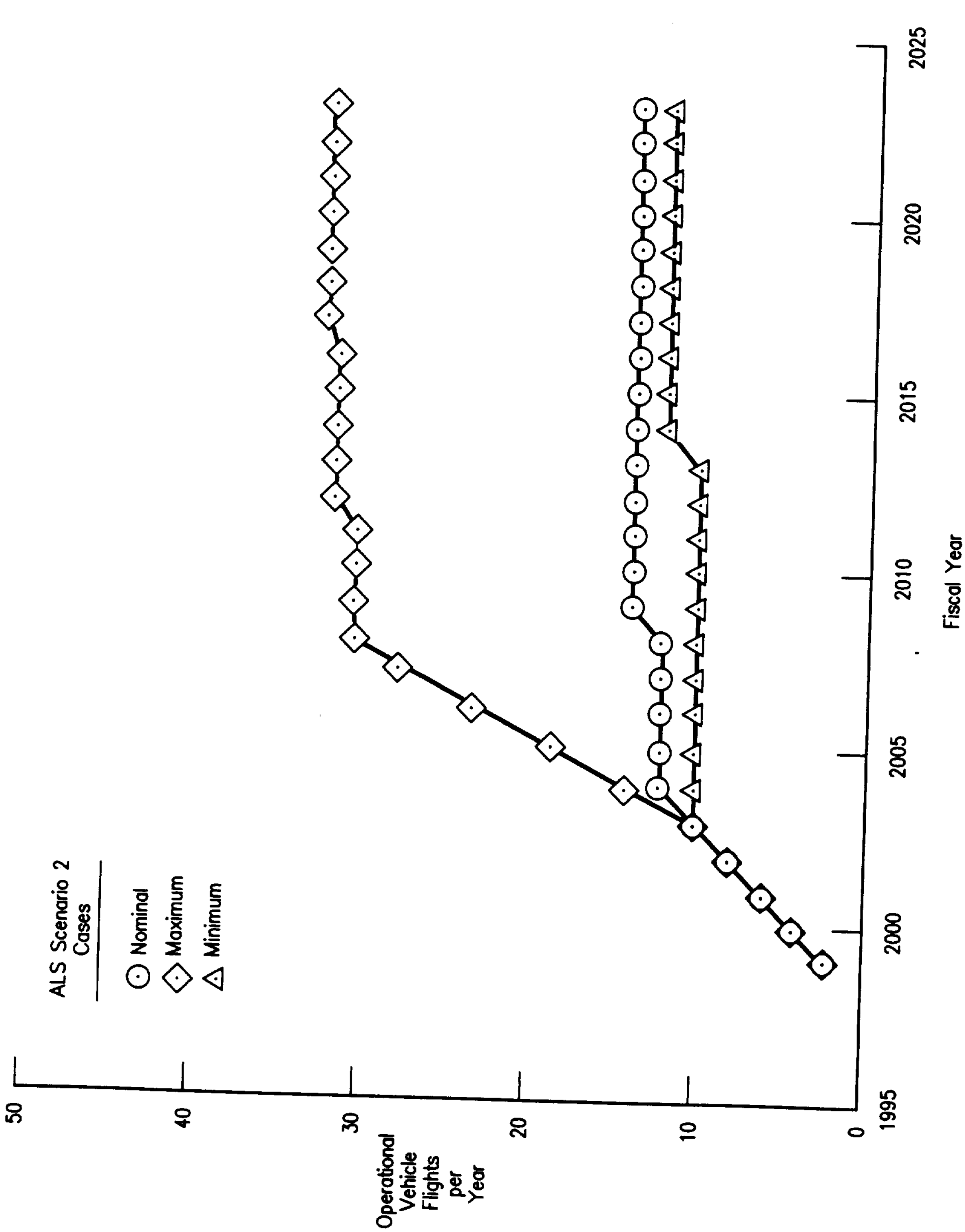

Figure 4.1-2. STME/Derivative STBE (Scenario 2) Mission Flight Rates

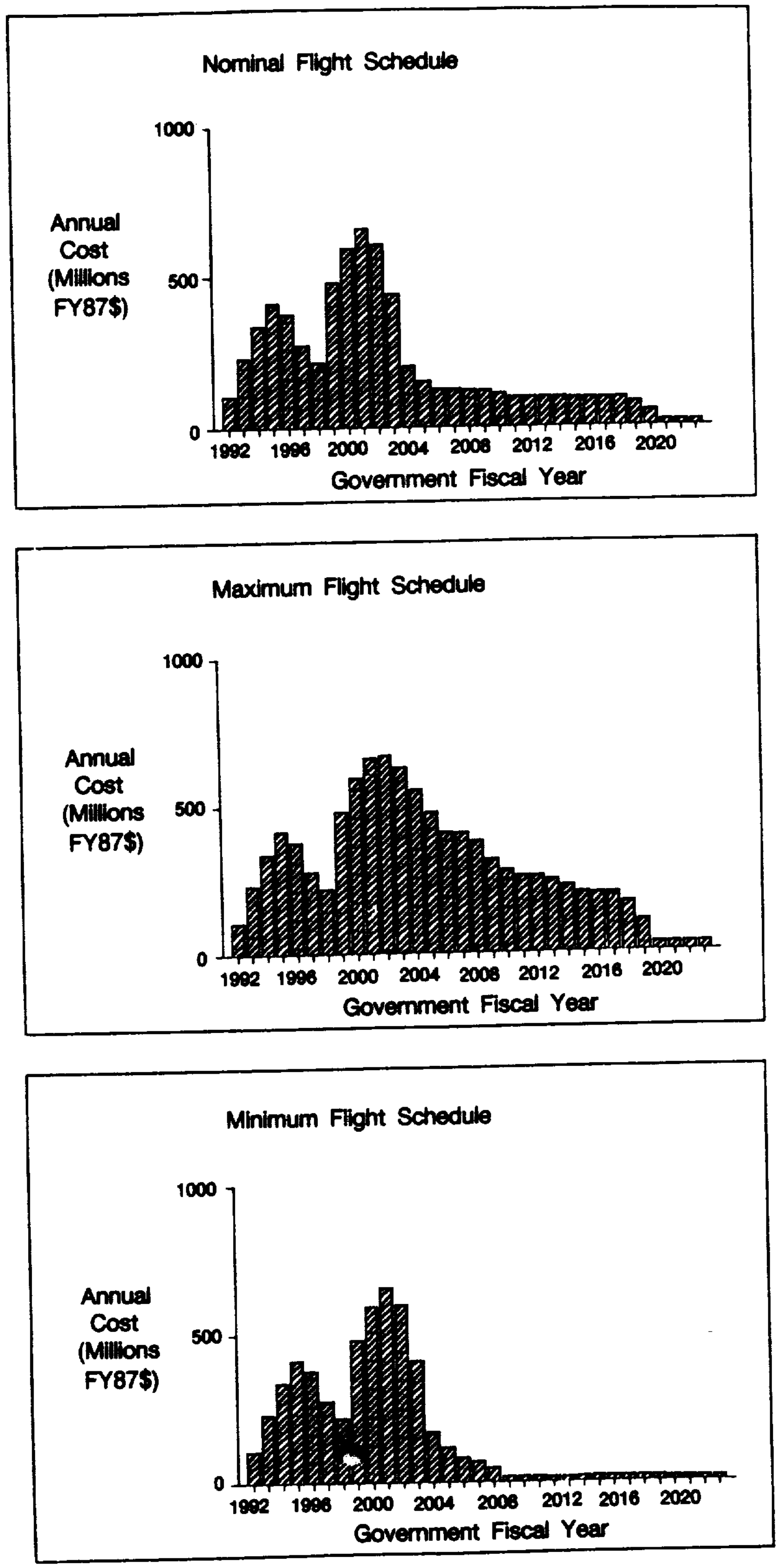

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Figure 4.1-3. STME/Derivative STBE (Scenario 2) Total Program Cost by Year

Figures 4.1-4 through 4.1-7 show annual funding requirements for each individual portion of the STME/Derivative STBE program. For the Design and Development phase (Figure 4.1-4) the highest annual cost ($413M) occurs in 1995. That is the fourth year of the development program when development program hardware and test costs are both near peak levels.

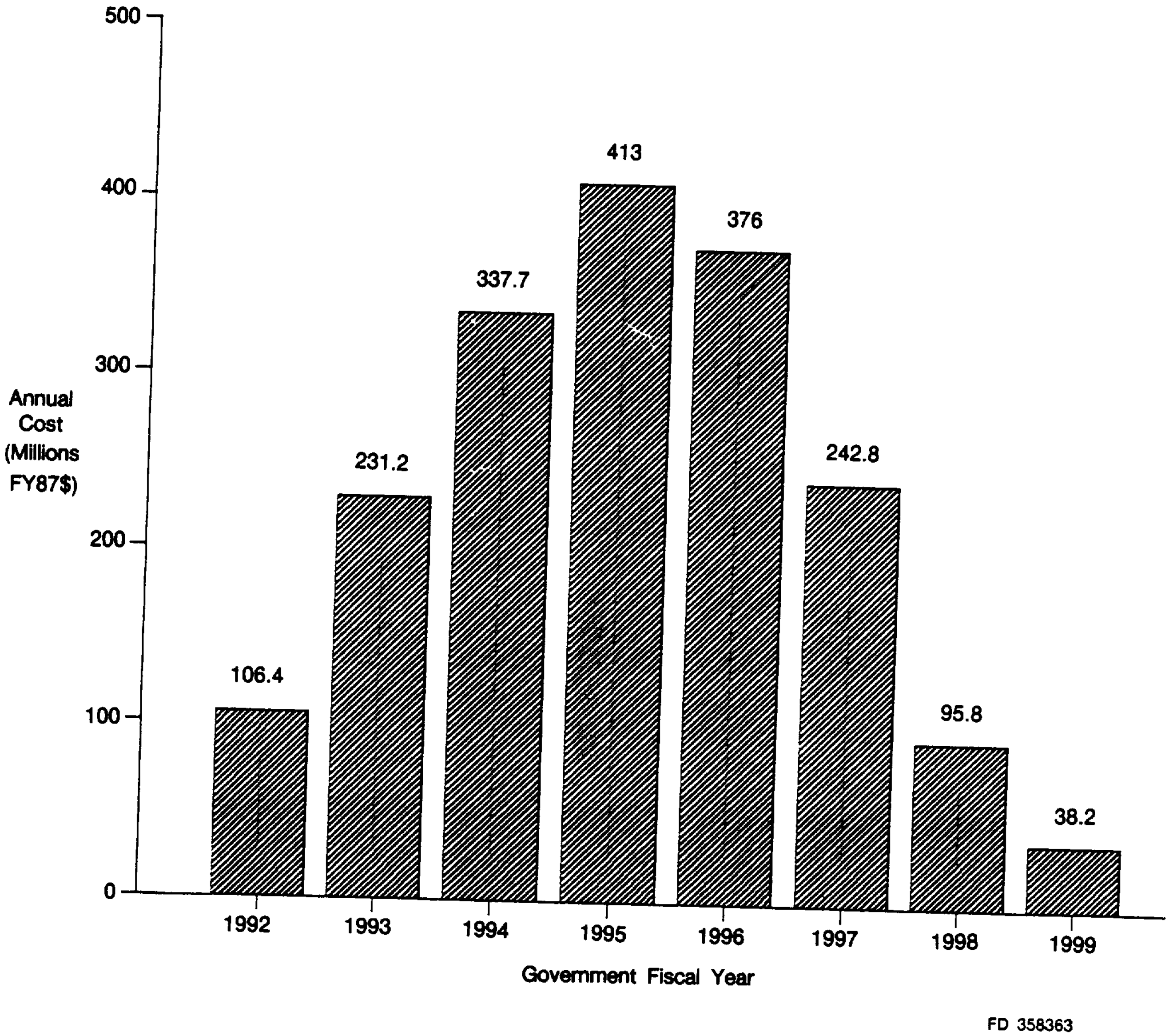

Figure 4.1-4. STME/Derivative STBE (Scenario 2) Design and Development Phase Costs by Year

The highest annual cost in the Operational Production portion of the program (Figure 4.1-5) occurs in year 2001 for the nominal ($491M) and minimum ($491M) cases and in year 2002 for the maximum case ($535M). The high cost drivers for each case are primarily the production engine hardware, initial spares and tooling. For all of the cases the overlap between the annual lots of engines being procured and delivered causes the maximum engine hardware cost to occur during the years 2001 to 2002, which is several years before the peak engine delivery occurs. Peak cost requirements for the nominal and minimum cases are identical because during the first five year of operational production the flight schedules and engine quantities are identical for those cases.

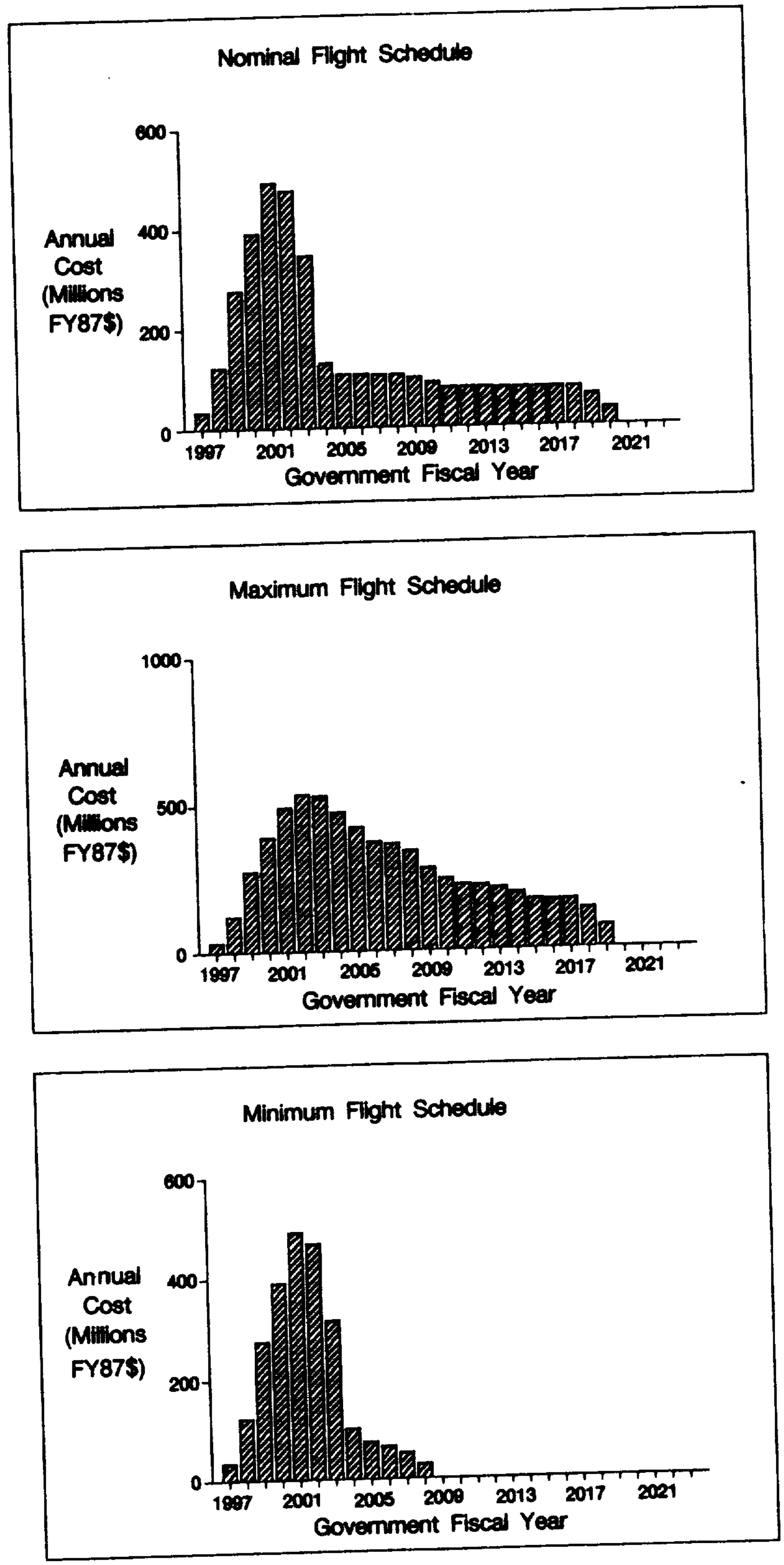

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Figure 4.1-5. STME/Derivative STBE (Scenario 2) Operational Production Costs by Year

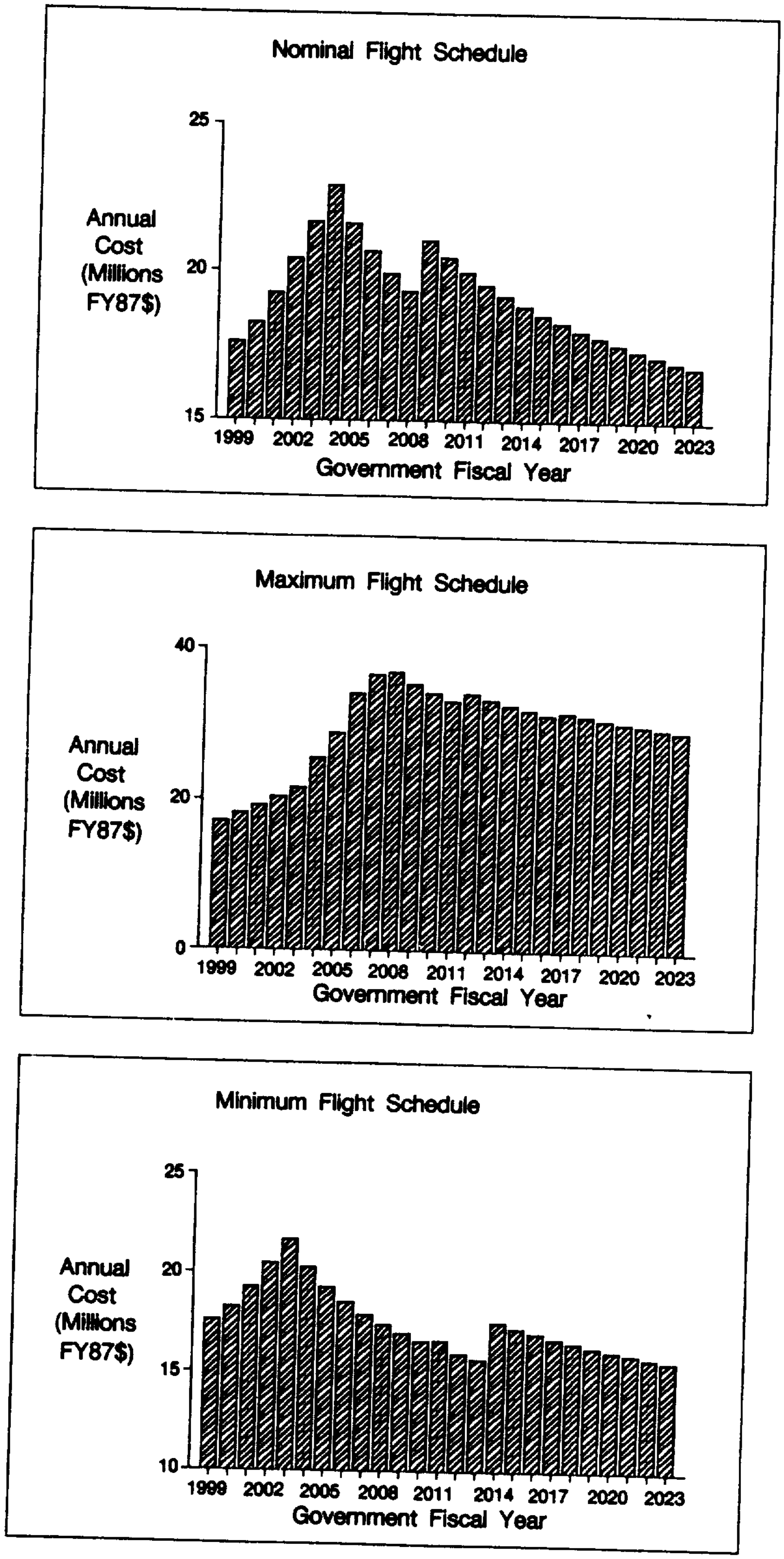

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Figure 4.1-6. STME/Derivative STBE (Scenario 2) Operations Costs by Year

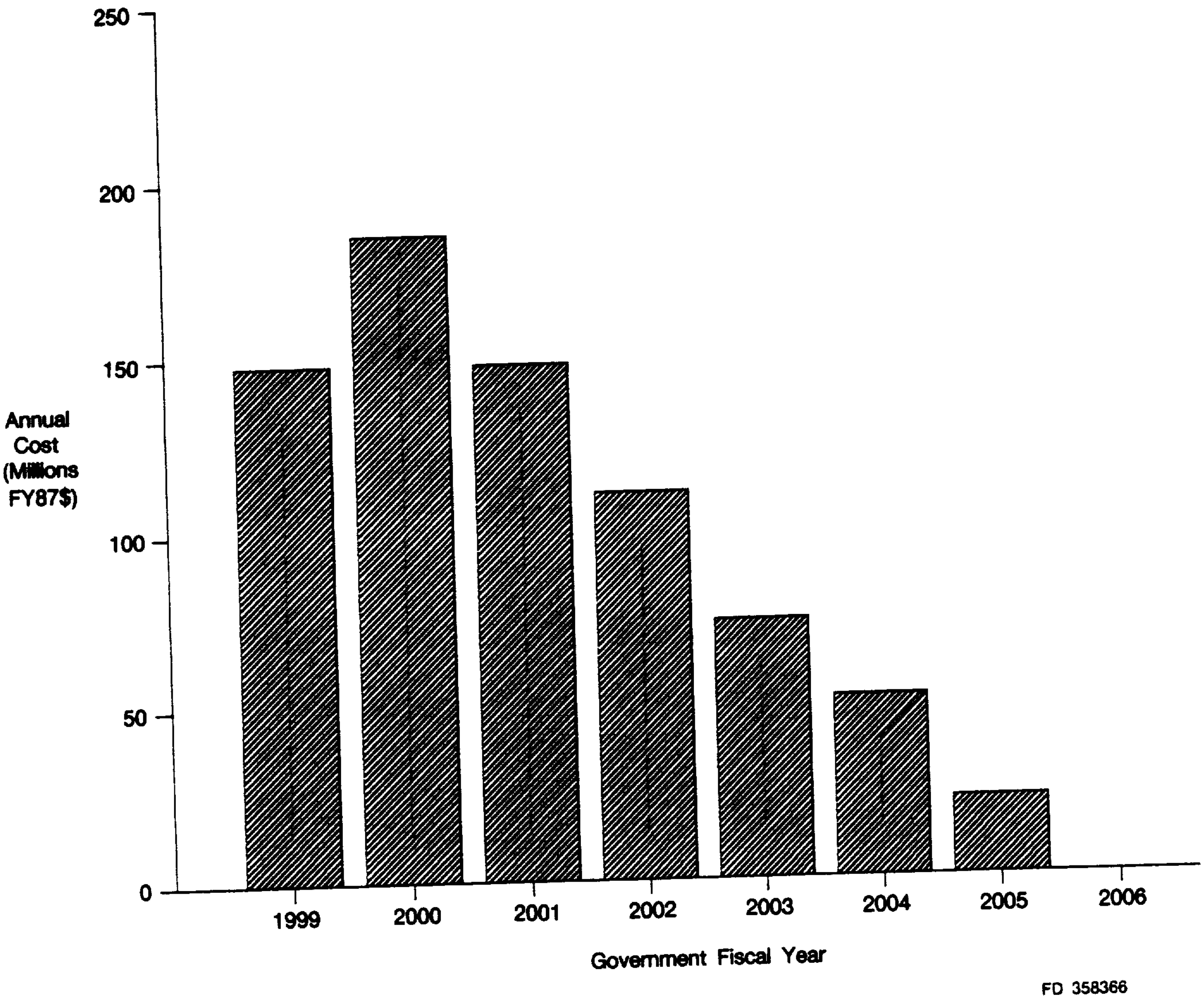

Figure 4.1-7. STME/Derivative STBE (Scenario 2) Product Improvement and Support Program Costs by Year

The year in which the highest Operations cost occurs (Figure 4.1-6) varies depending on the case (nominal, maximum or minimum). The nominal case reaches its highest cost ($23M) in year 2004, while the maximum ($37M) and minimum ($22M) cases reach their highest cost in the years 2008 and 2003 respectively. The primary contributor to Operations cost for each case is Refurbishment Operations and Support. Its annual costs are strongly driven by the number of flights in a given year, since the flight rate sets the number of engines requiring refurbishment.

Figure 4.1-7 shows the annual cost-requirements for the Product Improvement and Support Program (PISP). The highest cost ($185M) occurs in the year 2000 which is the second year of the program. To obtain maximum benefits from a product improvement effort the program must be front loaded so that the improvements developed can be included in a large quantity of the production engines delivered.

4.2 ENGINE COST ESTIMATES

STME and Derivative STBE Recurring Production unit costs and Operations unit costs are summarized in Table 4.2-1 and 4.2-2, respectively.

Table 4.2-1. *STME and Derivative STBE Recurring Production Theoretical First Unit Costs*

System	*STME TFU (FY87$)*	*Derivative STBE TFU (FY87$)*	*Derivative STBE Cost Commonality % STME TFU*
STBE Hardware	11349K	10305K	72%*
Turbomachinery	2867	3045	58
HPOTP	1379	1445	35
HPFTP	1488	1600	80
Combustion Devices	4046	2595	77*
Main Injector	330	330	100
Thrust Chamber	585	655	0
Nozzle	961	961	100
Nozzle Skirt	1521	—	—
Gas Generator	357	357	100
Igniters	292	292	100
Controls	1544	1644	68
Controllers/Monitors/Software	506	506	95
Sensors	285	285	100
Valves/Actuators	670	770	30
Interconnects	83	83	100
Propellant Feed	1686	1780	84
Ducts	939	1033	80
Miscellaneous (System Hardware)	747	747	90
Support Devices	663	698	65
Gimbal	235	270	0
Tank Repressurization	261	261	100
Start System	17	17	100
POGO Flight System	150	150	100
Integration, Assembly & Test	143	143	100
Acceptance Test	400	400	100

* Reflects % of applicable STME hardware costs.
Notes: 1. All costs in thousands of FY87 dollars.
2. Lot size = 100.

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Table 4.2-1 presents individual engine Theoretical First Unit (TFU) production costs at an assembly and sub-assembly level. It also shows the amount of cost commonality between the STME and STBE. Table 4.2-2 shows Theoretical First Unit Operations costs as well as mature operations unit costs broken down by WBS functional elements for both the STME and Derivative STBE.

The STME production costs are primarily driven by the combustion devices which are responsible for approximately 36 percent of the engine unit cost. The film cooled Columbian sheet metal nozzle skirt is the largest contributor. The turbo machinery is the second highest cost driver for the STME design, contributing approximately 25 percent to the engine unit cost.

Table 4.2-2. STME and Derivative STBE Recurring Operations Unit Cost

	Theoretical First Unit		100th Mission, 10 Missions/yr	
	STME	Derivative STBE	STME	Derivative STBE
Program Management	104.7	104.7	7.2	7.2
System Engineering and Integration	401.1	401.1	25.3	25.3
Facilities Maintenance	0	0	0	0
Operations and Support				
Launch Operations	12.6	12.6	5.0	5.0
Flight Operations	170.3	170.3	11.7	11.7
Spares Replenishment	59.8	65.8	23.7	26.1
Recovery Operations	10.8	10.8	4.3	4.3
Refurbishment Operations	153.9	153.9	61.0	61.0
Training	5.0	5.0	2.0	2.0
Total Operations Cost, $/Engine/Mission	918.3	924.3	140.2	142.6

Note: All costs are in thousands of FY87 dollars.

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Since it does not have the nozzle skirt, production cost for the Derivative STBE is primarily driven by the turbomachinery. The Derivative STBE oxidizer turbopump has a higher cost than the STME oxidizer turbopump and it only shares a 35 percent cost commonality with the STME. The Derivative STBE methane turbopump has a higher cost than the STME hydrogen turbopump but it does have a cost commonality of approximately 80 percent.

As shown in Table 4.2-2 the Derivative STBE has slightly higher operations costs than the STME. This is because of the higher cost of turbomachinery and control system replenishment parts for the Derivative STBE. These parts are expected to be replaced most often during unscheduled engine refurbishments. Coking due to the use of methane rather than hydrogen fuel also contributes to the higher STBE operations costs.

4.3 PROGRAM COST COMPARISONS

Table 4.3-1 compares program costs for the STME/Derivative STBE nominal case with program costs for the Baseline STME (Scenario 1) nominal case. In the Baseline STME scenario, the hydrogen/oxygen STME (without the nozzle skirt) is used as the booster engine in place of the Derivative STBE. The Baseline STME program costs were generated under the Space Transportation Main Engine Configuration Study and they are reported in FR-19830-2.

Total program costs for the STME/Derivative STBE are $6.65 billion compared with $5.73 billion for the Baseline STME. The STME/Derivative STBE program is $919 billion or 16% more than the Baseline STME. Higher STME/Derivative STBE design and development costs account for $443M of the difference. Other contributions are Operational Production, which costs $246M more and the Product Improvement and Support Program, which costs $211M more. The lower Production costs for the Baseline STME program are due to the booster STME having 100% commonality with the core STME as well as slightly lower TFU costs.

Table 4.3-1. *Comparison of STME/Derivative STBE and Baseline STME Program Costs*

	STME/Derivative STBE Scenario 2 Nominal Case	*Baseline STME Scenario 1 Nominal Case*
Design and Development	$1841.1M	$1398.8M
Non-Recurring Operational Production	366.4	340.5
Core Engines	120.0	113.8
Booster Engines	246.4	226.7
Recurring Operational Production	3.226.3	3006.3
Core Engines	1064.1	992.5
Booster Engines	2162.2	2013.8
Operations	479.5	459.7
Core Engines	140.1	140.1
Booster Engines	339.4	319.6
Product Improvement and Support Program	739.1	528.0
Total Program Cost	$6652.4M	$5733.3M

Note: All costs in millions of constant FY87 dollars.

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Table 4.3-2 compares costs for the STME portion of the STME/Derivative STBE Design and Development program with similar costs for the Baseline STME program. The STME costs in the derivative program are $215M less than the Design and Development costs for the Baseline STME. This lower STME development cost results because the STME in the Derivative STBE program is developed only for the core stage. However, as shown in Table 4.1-3 development of the Derivative STBE for the booster stage adds an additional $658M making the total STME/Derivative STBE development program cost $1841M, which is $443M more than the $1398M cost of developing the Baseline STME.

Table 4.3-2. *STME/Derivative STBE Program — STME Design and Development Cost Comparison*

	*Baseline STME Core and Booster**	*STME Core Only*	*STME Cost Difference*
Program Management	$70M	$66M	$4M
System Engineering and Integration	60	42	18
Engine Design and Development	180	171	9
Engine Test			
Test Hardware	329	352	-23
Test Operations and Support	246	254	-8
Flight Test Hardware	208	73	135
MPTA Test Hardware	100	37	63
Facilities			
Production	8	8	0
Launch	4	4	0
Test	22	22	0
Software Engineering	13	12	1
GSE	26	19	7
Tooling	68	68	0
Special Test Equipment (STE)	25	25	0
Operations and Support	39	30	9
Total DDT&E Program Cost	$1,398M	$1,183M	$215M

* Baseline Gas Generator STME DDT&E program costs for Scenario 1 reported in FR-19830-2.

Note: All costs in millions of FY87 dollars.

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SECTION 5.0
COST ESTIMATES BY WBS ELEMENTS

This section of the STME/Derivative STBE Program Cost Estimates Document presents cost estimates for the STME/Derivative STBE program broken down into WBS elements. Costs are included for the STME on the core stage, the STBE on the booster stage and the combined STME/Derivative STBE. Costs are included for the whole engine at the integrated system level and, where appropriate, down to the STME/Derivative STBE component level (WBS fifth level). Costs are also presented for each phase of the program and each functional element within each phase. The WBS format described in Sections 3.3 and 3.4 was used for the cost breakdowns. Functional elements not applicable to the STME/Derivative STBE and its subassemblies are indicated on the individual cost tables. Only costs incurred directly for the engine by the engine contractor have been included in the cost estimates.

5.1 DESIGN AND DEVELOPMENT PHASE

Cost estimates for each functional element in the Design and Development phase are presented in Tables 5.1-1 through 5.1-3. Table 5.1-1 shows development costs for the STME on the core stage, while Table 5.1-2 shows development costs for the Derivative STBE on the booster stage. Table 5.1-3 combines the costs for the individual STME and Derivative STBE development programs into a total STME/Derivative STBE development cost. Costs for each functional element are shown at the appropriate WBS sub-level 2, 4 and/or 5, integrated system, engine subsystem and/or engine component respectively. The categories broken down to the engine component or subsystem level include: Engine Test (Engine Test Hardware, Component Test Hardware, and Component Test O&S), Flight Test Hardware-Manufacturing and MPTA Test Hardware-Manufacturing.

The highest cost functional element for both engines is Engine Test which has test hardware costs of $352M for the STME and $184M for the Derivative STBE. Included in this functional element are the costs for development components and engines, mockups and eight new (4 STME and 4 Derivative STBE) flight certification (PFC and FFC) engines. Engine Test also includes engine and component test operations and support which has costs of $254M for the STME and $110M for the Derivative STBE.

The Engine Test functional element represents 51 percent of the STME's total Design and Development Cost and 45 percent of the Derivative STBE's total Design and Development Cost.

The Engine Design and Development functional element is the next highest cost element. It is $234M for the total combined STME/Derivative STBE program. Engine Design and Development includes most of the engineering effort needed to design and develop the STME/Derivative STBE and to verify the ability of the design to meet technical requirements.

Flight Test hardware and MPTA Test hardware are two other high cost functions, $220M and $107M, respectively. The Flight Test hardware includes 19 STBE's and 8 STME's for the two flight test vehicles plus spare components. The MPTA hardware includes 9 STBE's and 4 STME's plus spares for the vehicle propulsion system cluster ground test program.

Table 5.1-1. *Total Design and Development Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Core STME Portion
ALS Scenario 2 (Millions of FY87$)

ENGINE COMPONENT	PROGRAM MGMT		SE & I		ENGR'G D&D	ENGINE TEST					FLIGHT TEST HARDWARE		NPTA TEST HARDWARE		FACILITIES			SOFTWARE ENGR'G	GSE		TOOLING	STE	OPERATIONS & SUPPORT				TOTAL
	CONTRACT DATA	OTHER	SRM & QA	OTHER		ENGINE TEST HOWE	ENGINE TEST O&S	COMP TEST HOWE	COMP TEST O&S	PROPEL-LANTS	MFG	ACCEPT	MFG	ACCEPT	PRODUC-TION	LAUNCH	TEST		COMMON	PECUL.			LAUNCH O&S	FLIGHT O&S	RECOV. O&S	REFURB. O&S	
INTEGRATED SYSTEM	20	46	27	15	171	280	283	72	51	0	70	3	35	2	0	4	22	12	2	17	60	25	15	4	3	0	1183
SYSTEM HARDWARE						0		0			0		0														
TURBOMACHINERY						73		30	11		18		9														
LPOTP						0		0	0		0		0														
LPFTP						0		0	0		0		0														
HPOTP						34		14	5		9		5														
HPFTP						38		16	6		9		5														
COMBUSTION DEVICES						104		30	14		27		13														
MAIN INJECTOR						8		2	1		2		1														
MAIN COMB. CHAMBER						15		4	2		4		2														
NOZZLE						24		6	3		5		3														
NOZZLE SKIRT						40		9	5		11		6														
GAS GENERATOR						9		10	4		2		1														
IGNITORS						7		0	0		2		1														
CONTROLS						39		12	0		10		5														
CONTROLLERS/MONITORS						13		4	0		3		1														
SOFTWARE						0		0	0		0		0														
SENSORS						7		2	0		2		1														
VALVES						17		5	0		5		2														
ACTUATORS						0		0	0		0		0														
INTERCONNECTS						2		1	0		0		0														
PROPELLANT FEED						43		0	0		10		5														
COLD DUCTS						24		0	0		6		3														
HOT DUCTS						0		0	0		0		0														
MISCELLANEOUS						19		0	0		4		2														
SUPPORT DEVICES						17		0	0		4		2														
GIMBAL SYSTEM						6		0	0		2		0.9														
TANK REPRESS. SYS						7		0	0		1		0.7														
POWER TAPOFF						0		0	0		0		0.0														
START SYSTEM						0		0	0		0		0.0														
POGO SYSTEM						4		0	0		1		0.4														
INTEG., TEST & ASSY						4		0	0		1		0														

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS.

Table 5.1-2. *Total Design and Development Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Booster Derivative STME Portion
ALS Scenario 2, (Millions of FY87$)

ENGINE COMPONENT	PROGRAM MGMT		SE & I		ENGR'G D&D	ENGINE TEST					FLIGHT TEST HARDWARE		MPTA TEST HARDWARE		FACILITIES			SOFTWARE ENGR'G	GSE		TOOLING	STE	OPERATIONS & SUPPORT				TOTAL
	CONTRACT DATA	OTHER	SRM & QA	OTHER		ENGINE TEST MDWE	ENGINE TEST O&S	COMP TEST MDWE	COMP TEST O&S	TEST PROPEL-LANTS	MFG	ACCEPT	MFG	ACCEPT	PRODUC-TION	LAUNCH	TEST		COMMON	PECUL.			LAUNCH O&S	FLIGHT O&S	RECOV. O&S	REFURB. O&S	
INTEGRATED SYSTEM	5	0	7	17	63	147	83	37	27	0	139	0	66	4	0	0	2	0	2	7	10	5	9	2	0	4	638
SYSTEM HARDWARE						0		0			0		0														
TURBOMACHINERY						45		14	7		43		20														
LPOTP						0		0	0		0		0														
LPFTP						0		0	0		0		0														
HPOTP						22		7	3		21		10														
HPFTP						24		7	4		22		11														
COMBUSTION DEVICES						39		16	7		36		17														
MAIN INJECTOR						5		2	1		4		2														
MAIN COMB. CHAMBER						10		4	2		10		5														
NOZZLE						14		6	3		13		6														
NOZZLE SKIRT						0		0	0		0		0														
GAS GENERATOR						5		4	2		5		2														
IGNITORS						4		0	0		4		2														
CONTROLS						24		7	0		23		11														
CONTROLLERS/MONITORS						7		2	0		7		3														
SOFTWARE						0		0	0		0		0														
SENSORS						4		1	0		4		2														
VALVES						12		3	0		11		5														
ACTUATORS						0		0	0		0		0														
INTERCONNECTS						1		0	0		1		1														
PROPELLANT FEED						26		0	0		25		12														
COLD DUCTS						15		0	0		14		7														
HOT DUCTS						0		0	0		0		0														
MISCELLANEOUS						11		0	0		10		5														
SUPPORT DEVICES						10		0	0		10		5														
GIMBAL SYSTEM						4		0	0		4		1.9														
TANK REPRESS SYS						4		0	0		4		1.7														
POWER TAPOFF						0		0	0		0		0.0														
START SYSTEM						0		0	0		0		0.1														
POGO SYSTEM						2		0	0		2		1.0														
INTEG , TEST & ASSY						2		0	0		2		1														

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS.
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS.

Table 5.1-3. STME/Derivative STBE Program — Design and Development Program Cost Summary

	STME Portion	STBE Portion	Total
Program Management	$66M	$13M	$79M
System Engineering and Integration	42	24	66
Engine Design and Development	171	63	234
Engine Test			
Test Hardware	352	184	536
Test Operations and Support	254	110	364
Flight Test Hardware	73	147	220
MPTA Test Hardware	37	70	107
Facilities			
Production	8	0	8
Launch	4	0	4
Test	22	2	24
Software Engineering	12	3	15
GSE	19	9	28
Tooling	68	10	78
Special Test Equipment (STE)	25	5	30
Operations and Support	30	18	48
Total DDT&E Program Cost	$1,183M	$658M	$1,841M

Note: All costs in millions of FY87 dollars.

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5.2 OPERATIONS PHASE: OPERATIONAL PRODUCTION

The Operational Production portion of the Operations Phase is broken into two types of costs, Non-recurring Operational Production and Recurring Operational Production. Tables 5.2-1 through 5.2-9 present both types of costs for the STME in the core, the Derivative STBE in the booster and the combined STME/Derivative STBE. Cost estimates are included for the nominal, maximum and minimum flight schedule cases. Costs for initial spares under Non-recurring Operational Production are reported at a subsystem or fourth WBS engine level, while costs for flight hardware-manufacturing, under Recurring Operational Production, are reported at a component or fifth WBS engine level. All other costs are reported at a second WBS engine level.

As discussed in Section 3.2.2 engine Operational Production hardware costs were estimated through a detailed analysis of engine component costs. Other Operational Production cost elements were estimated from historical data for gas turbine and rocket engines.

Initial Spares is the largest cost driver for Non-recurring Operational Production. The spare units, which are initial spare components and modules provided for the operational flight program, are produced and delivered along with the early lots of production engines. Other cost contributors to Non-recurring Production are Program Management SE&I, Ground Support Equipment (GSE) and Tooling. The GSE costs are driven by the operational flight schedule with sufficient GSE being procured during Operational Production to support the maximum flight rates in the various mission scenarios. Tooling costs represent the cost of additional production tooling beyond that available from the Development Program required to support high production rates. The amount of additional tooling is a function of the maximum annual production rate. For the three STME/Derivative STBE cases the maximum production rates are the same (30/year for STME and 70/year for STBE) making the tooling costs the same.

Table 5.2-1. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	INITIAL SPARES	RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	0.68	1.71	1.71	0.00	0.00	0.00	4.50	6.00	13.00	0.00	92.41	4.59	18.34	18.34	955.44	67.28	0.00	0.00	1184.02
SYSTEM HARDWARE																			
TURBOMACHINERY											27.44								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															120.34				
HPFTP															129.85				
COMBUSTION DEVICES											39.85								
MAIN INJECTOR															28.80				
THRUST CHAMBER															51.05				
NOZZLE															83.86				
NOZZLE SKIRT															132.73				
GAS GENERATOR															31.15				
IGNITORS															25.48				
CONTROLS											14.41								
CONTROLLERS/MONITORS															44.15				
SOFTWARE															0.00				
SENSORS															24.87				
VALVES															58.47				
ACTUATORS															0.00				
INTERCONNECTS															7.24				
PROPELLANT FEED											7.55								
COLD DUCTS															81.94				
HOT DUCTS															0.00				
MISCELLANEOUS															65.19				
SUPPORT DEVICES											3.16								
GIMBAL SYSTEM															20.51				
TANK REPRESS SYS															22.78				
POWER TAPOFF															0.00				
START SYSTEM															1.48				
POGO SYSTEM															13.09				
INTEG., TEST & ASSY											0.00				12.48				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Table 5.2-2. Total Operational Production Cost by WBS Element Gas Generator STME/Derivative STBE Program Booster Derivative STBE Scenario 2, Nominal Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I		FACILITIES			GSE		TOOLING	STE	INITIAL SPARES	RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I		FLIGHT HDW MANUFACT		TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
		SRM & QA	OTHER	PRODUCTION	LAUNCH	TEST	COMMON	PECUL					SRM & QA	OTHER	MFG	ACCEPT			
INTEGRATED SYSTEM	3.05	6.32	6.32	0.00	0.00	0.00	9.00	13.50	35.00	0.00	173.30	9.32	37.28	37.28	1915.01	163.41	0.00	0.00	2408.77
SYSTEM HARDWARE																			
TURBOMACHINERY											62.37								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															279.37				
HPFTP															309.34				
COMBUSTION DEVICES											52.23								
MAIN INJECTOR															63.80				
THRUST CHAMBER															126.64				
NOZZLE															185.80				
NOZZLE SKIRT															0.00				
GAS GENERATOR															69.02				
IGNITORS															56.45				
CONTROLS											33.72								
CONTROLLERS/MONITORS															97.83				
SOFTWARE															0.00				
SENSORS															55.10				
VALVES															148.87				
ACTUATORS															0.00				
INTERCONNECTS															16.05				
PROPELLANT FEED											17.96								
COLD DUCTS															199.72				
HOT DUCTS															0.00				
MISCELLANEOUS															144.42				
SUPPORT DEVICES											7.02								
GIMBAL SYSTEM															52.20				
TANK REPRESS SYS															50.46				
POWER TAPOFF															0.00				
START SYSTEM															3.29				
POGO SYSTEM															29.00				
INTEG., TEST & ASSY											0.00				27.65				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Table 5.2-3. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	INITIAL SPARES	RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	3.73	8.03	8.03	0.00	0.00	0.00	13.50	19.50	48.00	0.00	265.71	13.91	55.63	55.63	2870.44	230.69	0.00	0.00	3592.78
SYSTEM HARDWARE																			
TURBOMACHINERY											89.81								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															399.71				
HPFTP															439.19				
COMBUSTION DEVICES											92.09								
MAIN INJECTOR															92.60				
THRUST CHAMBER															177.68				
NOZZLE															269.66				
NOZZLE SKIRT															132.73				
GAS GENERATOR															100.17				
IGNITORS															81.94				
CONTROLS											48.12								
CONTROLLERS/MONITORS															141.98				
SOFTWARE															0.00				
SENSORS															79.97				
VALVES															207.34				
ACTUATORS															0.00				
INTERCONNECTS															23.29				
PROPELLANT FEED											25.51								
COLD DUCTS															281.66				
HOT DUCTS															0.00				
MISCELLANEOUS															209.61				
SUPPORT DEVICES											10.18								
GIMBAL SYSTEM															72.71				
TANK REPRESS SYS															73.24				
POWER TAPOFF															0.00				
START SYSTEM															4.77				
POGO SYSTEM															42.09				
INTEG., TEST & ASSY											0.00				40.13				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Table 5.2-4. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	RECURRING OPERATIONAL PRODUCTION: INITIAL SPARES	PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	0.68	1.71	1.71	0.00	0.00	0.00	10.50	14.00	13.00	0.00	191.29	8.15	32.59	32.59	1682.30	134.57	0.00	0.00	2123.09
SYSTEM HARDWARE																			
TURBOMACHINERY											56.79								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															211.88				
HPFTP															228.63				
COMBUSTION DEVICES											82.51								
MAIN INJECTOR															50.70				
THRUST CHAMBER															89.88				
NOZZLE															147.66				
NOZZLE SKIRT															233.70				
GAS GENERATOR															54.85				
IGNITORS															44.87				
CONTROLS											29.81								
CONTROLLERS/MONITORS															77.75				
SOFTWARE															0.00				
SENSORS															43.79				
VALVES															102.94				
ACTUATORS															0.00				
INTERCONNECTS															12.75				
PROPELLANT FEED											15.63								
COLD DUCTS															144.28				
HOT DUCTS															0.00				
MISCELLANEOUS															114.78				
SUPPORT DEVICES											6.55								
GIMBAL SYSTEM															36.11				
TANK REPRESS SYS															40.10				
POWER TAPOFF															0.00				
START SYSTEM															2.61				
POGO SYSTEM															23.05				
INTEG. TEST & ASSY											0.00				21.97				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

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Table 5.2-5. Total Operational Production Cost by WBS Element Gas Generator STME/Derivative STBE Program Booster Derivative STBE Scenario 2, Maximum Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	RECURRING OPERATIONAL PRODUCTION: INITIAL SPARES	PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	3.05	6.32	6.32	0.00	0.00	0.00	21.00	31.50	35.00	0.00	359.10	16.55	66.19	66.19	3363.08	326.81	0.00	0.00	4301.10
SYSTEM HARDWARE																			
TURBOMACHINERY											129.23								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															490.63				
HPFTP															543.25				
COMBUSTION DEVICES											108.25								
MAIN INJECTOR															112.05				
THRUST CHAMBER															222.39				
NOZZLE															326.29				
NOZZLE SKIRT															0.00				
GAS GENERATOR															121.21				
IGNITORS															99.14				
CONTROLS											69.87								
CONTROLLERS/MONITORS															171.80				
SOFTWARE															0.00				
SENSORS															96.77				
VALVES															261.44				
ACTUATORS															0.00				
INTERCONNECTS															28.18				
PROPELLANT FEED											37.21								
COLD DUCTS															350.74				
HOT DUCTS															0.00				
MISCELLANEOUS															253.63				
SUPPORT DEVICES											14.55								
GIMBAL SYSTEM															91.67				
TANK REPRESS SYS															88.62				
POWER TAPOFF															0.00				
START SYSTEM															5.77				
POGO SYSTEM															50.93				
INTEG., TEST & ASSY											0.00				48.55				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Table 5.2-6. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	RECURRING OPERATIONAL PRODUCTION: INITIAL SPARES	PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	3.73	8.03	8.03	0.00	0.00	0.00	31.50	45.50	48.00	0.00	550.39	24.78	98.78	98.78	5045.39	461.38	0.00	0.00	6424.19
SYSTEM HARDWARE																			
TURBOMACHINERY											186.02								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															782.51				
HPFTP															771.88				
COMBUSTION DEVICES											190.76								
MAIN INJECTOR															162.75				
THRUST CHAMBER															312.28				
NOZZLE															473.95				
NOZZLE SKIRT															233.70				
GAS GENERATOR															176.07				
IGNITORS															144.01				
CONTROLS											99.68								
CONTROLLERS/MONITORS															249.55				
SOFTWARE															0.00				
SENSORS															140.56				
VALVES															364.39				
ACTUATORS															0.00				
INTERCONNECTS															40.93				
PROPELLANT FEED											52.84								
COLD DUCTS															495.01				
HOT DUCTS															0.00				
MISCELLANEOUS															368.41				
SUPPORT DEVICES											21.09								
GIMBAL SYSTEM															127.78				
TANK REPRESS SYS															128.72				
POWER TAPOFF															0.00				
START SYSTEM															8.38				
POGO SYSTEM															73.98				
INTEG., TEST & ASSY											0.00				70.53				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

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Table 5.2-7. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	INITIAL SPARES	RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	0.68	1.71	1.71	0.00	0.00	0.00	4.50	6.00	13.00	0.00	85.25	2.68	10.72	10.72	559.03	38.45	0.00	0.00	734.45
SYSTEM HARDWARE																			
TURBOMACHINERY											25.31								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															70.41				
HPFTP															75.97				
COMBUSTION DEVICES											36.76								
MAIN INJECTOR															16.85				
THRUST CHAMBER															29.87				
NOZZLE															49.07				
NOZZLE SKIRT															77.66				
GAS GENERATOR															18.23				
IGNITORS															14.91				
CONTROLS											13.29								
CONTROLLERS/MONITORS *															25.84				
SOFTWARE															0.00				
SENSORS															14.55				
VALVES															34.21				
ACTUATORS															0.00				
INTERCONNECTS															4.24				
PROPELLANT FEED											6.97								
COLD DUCTS															47.94				
HOT DUCTS															0.00				
MISCELLANEOUS															38.14				
SUPPORT DEVICES											2.92								
GIMBAL SYSTEM															12.00				
TANK REPRESS SYS															13.33				
POWER TAPOFF															0.00				
START SYSTEM															0.87				
POGO SYSTEM															7.66				
INTEG., TEST & ASSY											0.00				7.30				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Table 5.2-8. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Booster Derivative STBE
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

	NON-RECURRING OPERATIONAL PRODUCTION											RECURRING OPERATIONAL PRODUCTION							
ENGINE COMPONENT	PROGRAM MGMT	SE & I		FACILITIES			GSE		TOOLING	STE	INITIAL SPARES	PROGRAM MGMT	SE & I		FLIGHT HDW MANUFACT		TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
		SRM & QA	OTHER	PRODUCTION	LAUNCH	TEST	COMMON	PECUL					SRM & QA	OTHER	MFG	ACCEPT			
INTEGRATED SYSTEM	3.05	6.32	6.32	0.00	0.00	0.00	9.00	13.50	35.00	0.00	166.25	6.18	24.71	24.71	1271.57	105.73	0.00	0.00	1672.34
SYSTEM HARDWARE																			
TURBOMACHINERY											59.83								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															185.50				
HPFTP															205.40				
COMBUSTION DEVICES											50.11								
MAIN INJECTOR															42.36				
THRUST CHAMBER															84.09				
NOZZLE															123.37				
NOZZLE SKIRT															0.00				
GAS GENERATOR															45.83				
IGNITORS															37.49				
CONTROLS											32.35								
CONTROLLERS/MONITORS															64.96				
SOFTWARE															0.00				
SENSORS															36.59				
VALVES															98.85				
ACTUATORS															0.00				
INTERCONNECTS															10.66				
PROPELLANT FEED											17.23								
COLD DUCTS															132.61				
HOT DUCTS															0.00				
MISCELLANEOUS															95.90				
SUPPORT DEVICES											6.73								
GIMBAL SYSTEM															34.66				
TANK REPRESS SYS															33.51				
POWER TAPOFF															0.00				
START SYSTEM															2.18				
POGO SYSTEM															19.26				
											0.00								
INTEG., TEST & ASSY															18.36				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

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Table 5.2-9. *Total Operational Production Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

ENGINE COMPONENT	NON-RECURRING OPERATIONAL PRODUCTION: PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FACILITIES: PRODUCTION	FACILITIES: LAUNCH	FACILITIES: TEST	GSE: COMMON	GSE: PECUL	TOOLING	STE	RECURRING OPERATIONAL PRODUCTION: INITIAL SPARES	PROGRAM MGMT	SE & I: SRM & QA	SE & I: OTHER	FLIGHT HDW MANUFACT: MFG	FLIGHT HDW MANUFACT: ACCEPT	TOOLING MAINT	FACIL MAINT	TOTAL PRODUCT COST
INTEGRATED SYSTEM	3.73	8.03	8.03	0.00	0.00	0.00	13.50	19.50	48.00	0.00	251.51	8.86	35.42	35.42	1830.60	144.18	0.00	0.00	2406.78
SYSTEM HARDWARE																			
TURBOMACHINERY											85.15								
LPOTP															0.00				
LPFTP															0.00				
HPOTP															255.91				
HPFTP															281.38				
COMBUSTION DEVICES											86.88								
MAIN INJECTOR															59.21				
THRUST CHAMBER															113.96				
NOZZLE															172.44				
NOZZLE SKIRT															77.66				
GAS GENERATOR															64.06				
IGNITORS															52.39				
CONTROLS											45.64								
CONTROLLERS/MONITORS															90.79				
SOFTWARE															0.00				
SENSORS															51.14				
VALVES															133.06				
ACTUATORS															0.00				
INTERCONNECTS															14.87				
PROPELLANT FEED											24.20								
COLD DUCTS															180.56				
HOT DUCTS															0.00				
MISCELLANEOUS															134.04				
SUPPORT DEVICES											9.65								
GIMBAL SYSTEM															46.66				
TANK REPRESS SYS															46.83				
POWER TAPOFF															0.00				
START SYSTEM															3.05				
POGO SYSTEM															26.92				
INTEG., TEST & ASSY											0.00				25.66				

SOFTWARE COSTS INCLUDED WITH CONTROLLERS/MONITORS COSTS
HOT DUCT COSTS INCLUDED WITH COLD DUCT COSTS

Production Facility costs are zero since the only new production facilities required by P&W (assembly buildings at SSC) will be funded and used initially under the Development Program. All other facilities needed for engine production are available at P&W.

Flight Hardware is a very large contributor to Recurring Operational Production costs. Other items which contribute a small amount to Recurring Production are Program Management and SE&I. Tooling Maintenance and Facility Maintenance are zero because these costs are included in overhead and are not priced separately. A portion of the Program Management functions are also included in overhead.

Approximately 81-86% of the total Operational Production costs, depending on the flight schedule case, are flight hardware costs. These costs include both manufacturing and acceptance testing costs. Initial spares are the next largest contributor accounting for 7-10% of the total Operational Production costs.

5.3 OPERATIONS PHASE: OPERATIONS

Operations Costs include costs for the following WBS elements: Program Management, System Engineering and Integration, Facilities, Launch Operations, Flight Operations, Replenishment Spares, Recovery Operations, Refurbishment Operations, and Training. Cost estimates for the STME/Derivative STBE program for each of these functions are presented in Table 5.3-1. This table displays the estimated costs for each of these WBS elements for all three flight schedule cases — Nominal, Maximum, and Minimum. The core and booster engine costs are displayed separately and then totaled for each WBS element.

Refurbishment Operations has the highest cost of the Operations WBS elements. Its cost is estimated to be $195M for the nominal flight schedule case, $352M for the maximum case, and $169M for the minimum case. These costs include all of the labor costs associated with engine refurbishment, including scheduled and unscheduled maintenance. The methodologies for estimating Refurbishment costs and the other operations costs are discussed in Section 3.2.3.

Replenishment Spares is the next highest cost WBS element. This cost includes the component parts and materials needed for the Refurbishment Operations. The Replenishment Spares cost for the nominal flight schedule case is estimated to be $77M, and $138M and $66M for the maximum and minimum cases respectively.

Systems Engineering and Integration (SE&I) is broken into two components. Safety, Reliability, Maintainability, and Quality Assurance engineering activities are included in one component and support activities such as Logistics Support and Product Support are included in the other component.

The estimated costs for SE&I for the nominal case are $104M. Costs for the maximum and minimum cases are estimated to be $112M and $103M, respectively. As can be seen from the cost differences the SE&I cost element consists mostly of a fixed cost per year. Only a small portion of the SE&I costs are flight schedule dependent.

Flight Operations is estimated to cost $43M for the nominal case. This cost is also mostly a fixed cost per year and it varies only between $47M and $43M for the maximum and minimum cases. This activity includes the engineering staff that supports the flight operations and its size does not change appreciably as the number of flights change.

Table 5.3-1. *Total Operations Cost by WBS Element*
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
ALS Scenario 2, (Millions of FY87$)

ENGINE COMPONENT	OPERATIONS: PROGRAM MGMT	SE&I		FACILITIES		OPERATIONS & SUPPORT						TOTAL
		SRM QA	OTHER	LAUNCH	TEST	LAUNCH OPS	FLIGHT OPS	REPLEN SPARES	RECOV OPS	REFUR OPS	TRAIN-ING	
INTEGRATED SYSTEM												
Nominal Case												
CORE	7.94	15.56	15.56	0.00	0.00	4.49	12.96	23.05	3.87	54.83	1.80	140.06
BOOSTER	18.53	36.30	36.30	0.00	0.00	10.49	30.25	53.82	9.02	140.52	4.19	339.41
TOTAL	26.48	51.85	51.85	0.00	0.00	14.98	43.21	76.87	12.88	195.35	5.99	479.47
Maximum Case												
CORE	8.59	16.86	16.86	0.00	0.00	8.10	14.05	41.53	6.96	98.77	3.24	214.97
BOOSTER	20.03	39.35	39.35	0.00	0.00	18.89	32.79	96.94	16.25	253.13	7.56	524.29
TOTAL	28.62	56.22	56.22	0.00	0.00	26.99	46.85	138.47	23.21	351.90	10.79	739.26
Minimum Case												
CORE	7.90	15.46	15.46	0.00	0.00	3.88	12.89	19.91	3.34	47.36	1.55	127.76
BOOSTER	18.43	36.08	36.08	0.00	0.00	9.06	30.07	46.49	7.79	121.38	3.62	309.00
TOTAL	26.33	51.54	51.54	0.00	0.00	12.94	42.95	66.40	11.13	168.75	5.18	436.77

Program Management is the lowest cost element among the elements containing fixed costs. It is estimated to be $26M for the nominal case, $29M for the maximum case, and $26M for the minimum case.

Launch Operations, Recovery Operations, and Training are relatively low cost items being estimated at $15M, $13M, and $6M respectively for the nominal case. Since these cost elements are largely flight schedule dependent, the costs run from $27M, $23M, and $11M for the maximum case to $13M, $11M, and $5M for the minimum case.

Although Facilities Maintenance costs are included as a WBS element under Operations no costs are displayed for this element in Table 5.3-1. Most of the facilities use during operations are government provided and their maintenance will be a government expense not included in these cost estimates. Maintenance of P&W facilities is included in overhead and these costs can not be broken out separately.

5.4 PRODUCT IMPROVEMENT AND SUPPORT PROGRAM

Product Improvement and Support Program (PISP) costs are $739M for the nominal, maximum and minimum flight schedule cases. The PISP costs have not been broken down into lower level WBS elements. The total PISP costs are displayed in Table 5.5-1.

PISP does not fit under any of the functional elements in the standard WBS. Its costs have been included in this cost estimate as a separate line item to preserve the WBS structure set forth by NASA. PISP costs were estimated using historical data from Component Improvement Programs on gas turbine engines. As discussed in Section 3.2.4, the STME/Derivative STBE PISP costs were reduced relative to the gas turbine experience because of the short time period over which most of STME and Derivative STBE are produced. PISP efforts are most cost effective when the engine improvements can be incorporated in a large quantity of new production engines.

5.5 TOTAL STME/DERIVATIVE STBE PROGRAM

Cost for each Phase of the STME/Derivative STBE program, for the nominal, maximum and minimum cases are presented in Table 5.5-1. These costs are only broken down to the first level WBS categories. More detailed breakdowns can be obtained from the tables in the previous sections.

Table 5.5-1. *Total Program Costs by Work Breakdown Structure Total STME/Derivative STBE Program (Millions of FY87$)*

	1.2.3.7.2.1 and 1.2.2.7.2.1 - DESIGN & DEVELOPMENT	1.2.3.7.2.2 and 1.2.2.7.2.2 - NON-RECURRING PRODUCTION	1.2.3.7.2.3 and 1.2.2.7.2.3 - RECURRING PRODUCTION	1.2.3.7.2.4 and 1.2.2.7.2.4 - OPERATIONS	1.2.2.7.2.x and 1.2.3.7.2.x - PRODUCT IMPROVEMENT AND SUPPORT PROGRAM	1.2.2.7.2 and 1.2.3.7.2 TOTAL PROGRAM
STME/DERIVATIVE STBE PROGRAM						
SCENARIO 2---FLIGHT SCHEDULE						
Nominal	1,841.1	366.4	3,226.3	479.5	739.1	6,652.4
Maximum	1,841.1	694.9	5,728.7	737.2	739.1	9,741.0
Minimum	1,841.1	352.2	2,054.5	437.0	739.1	5,423.9

SECTION 6.0
TOTAL PROGRAM FUNDING SCHEDULE

This section of the STME/Derivative STBE Program Cost Estimates Document presents time-phase cost estimates for the STME/Derivative STBE program for each major Work Breakdown Structure element. Time-phased costs are included for the STME on the core, the Derivative STBE on the booster, and the combined STME/Derivative STBE for the nominal, maximum and minimum flight schedule.

6.1 DESIGN AND DEVELOPMENT PHASE

Costs for each functional element of the core STME and the booster Derivative STBE Design and Development programs were time-phased to provide funding schedules for this portion of the STME/Derivative STBE program. These costs are presented in Tables 6.1-1 and 6.1-2.

The Design and Development program schedules presented in Figure 3.1.2-1, Section 3.1 were used as a guide for the time-phasing. Milestone dates shown on this schedule plus estimated task completion times were used to determine the timing for the various functions. General functional elements like Program Management and System Engineering and Integration (SE&I) were allocated on a level of effort basis over much of the Design and Development program phase.

The highest annual cost for the STME development program occurs in 1995 and is approximately $254M. For the Derivative STBE development program it occurs in 1996 and is approximately $177M. These peak funding levels occur at this time because development hardware and testing costs are high while the Engineering Design and Development costs are also still at a relatively, high level.

6.2 OPERATIONS PHASE: OPERATIONAL PRODUCTION

Costs for the Operational Production portion of the Operations Phase were bookkept into two types of cost categories, Non-recurring Operational Production Costs and Recurring Operational Production Costs. Tables 6.2-1 through 6.2-9 present the time-phased Non-recurring Operational Production and Recurring Operational Production funding schedules broken down into their respective WBS functional elements.

In the Non-recurring Operational Production cost estimates Program Management and SE&I are funded only for the first four years of Operational Production. Non-recurring costs are included for these items to cover the transition from development to high rate production. Tooling and GSE start in the third and fifth years of Operational Production, respectively. They reflect the cost of additional equipment needed to support the increased rate of hardware production and the increased flight rate. The cost for Initial Spares increases from the first year of production, generally following the cost build-up of production hardware. The funding schedule for initial spares is driven by the production delivery schedule, with all the spares required acquired early in the production portion of the Operations Phase.

Table 6.1-1. *Annual Design and Development Cost*
Gas Generator STME/Derivative STBE Program
Core STME Portion
ALS Scenario 2 (Millions of FY87$)

DDT&E SPREAD BY GFY	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
PROGRAM MANAGEMENT	0.0	7.1	8.4	8.8	8.8	8.8	8.8	8.8	6.5	66.0
CONTRACT DATA	0.0	2.0	2.2	2.6	2.6	2.6	2.6	2.6	2.8	20.0
OTHER	0.0	5.1	6.2	6.2	6.2	6.2	6.2	6.2	3.7	46.0
SE & I	0.0	3.7	5.8	5.8	5.8	5.8	5.8	5.8	3.5	42.0
SRM & QA	0.0	2.2	3.8	3.8	3.8	3.8	3.8	3.8	2.2	27.0
OTHER	0.0	1.5	2.0	2.0	2.0	2.0	2.0	2.0	1.3	15.0
ENGINEERING D&D	0.0	39.3	20.5	25.7	25.7	25.7	17.1	12.0	5.1	171.0
ENGINE TEST	0.0	16.8	93.6	161.5	155.1	96.7	66.2	13.6	2.7	606.4
ENGINE TEST HDWE	0.0	11.2	56.0	70.1	64.5	39.2	28.0	11.2	0.0	280.2
ENGINE TEST O&S	0.0	0.0	7.8	49.5	59.1	43.0	38.2	2.4	2.7	202.8
COMPONENT TEST HDWE	0.0	5.6	26.1	25.0	13.4	2.0	0.0	0.0	0.0	72.1
COMPONENT TEST O&S	0.0	0.0	3.7	16.9	18.1	12.5	0.0	0.0	0.0	51.2
PROPELLANTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT TEST HARDWARE	0.0	0.0	0.0	2.1	16.0	27.9	25.3	1.6	0.0	73.0
MFG	0.0	0.0	0.0	2.1	16.0	27.9	23.7	0.0	0.0	69.8
ACCEPTANCE	0.0	0.0	0.0	0.0	0.0	0.0	1.6	1.6	0.0	3.2
MPTA TEST HARDWARE	0.0	0.0	0.0	7.0	14.0	15.6	0.0	0.0	0.0	36.5
MFG.	0.0	0.0	0.0	7.0	14.0	14.0	0.0	0.0	0.0	34.9
ACCEPTANCE	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0	0.0	1.6
FACILITIES	0.0	4.1	22.5	3.4	0.4	3.0	0.6	0.0	0.0	34.0
PRODUCTION	0.0	0.8	6.0	1.2	0.0	0.0	0.0	0.0	0.0	8.0
LAUNCH	0.0	0.0	0.0	0.0	0.4	3.0	0.6	0.0	0.0	4.0
TEST	0.0	3.3	16.5	2.2	0.0	0.0	0.0	0.0	0.0	22.0
SOFTWARE ENGINEERING	0.0	1.2	2.4	3.0	2.4	1.2	1.2	0.4	0.2	12.0
GSE	0.0	0.0	0.7	3.4	6.1	5.1	2.5	0.9	0.3	19.0
COMMON	0.0	0.0	0.0	0.0	0.2	0.8	0.8	0.2	0.0	2.0
PECULIAR	0.0	0.0	0.7	3.4	5.9	4.3	1.7	0.7	0.3	17.0
TOOLING	0.0	8.8	17.0	18.4	12.9	4.1	2.7	2.0	2.0	68.0
STE	0.0	2.5	7.5	6.3	5.0	2.5	1.3	0.0	0.0	25.0
OPERATIONS & SUPPORT	0.0	0.3	0.3	0.8	1.7	3.1	7.4	11.6	4.8	30.0
LAUNCH O&S	0.0	0.3	0.3	0.8	1.5	2.4	3.5	4.5	1.8	15.0
FLIGHT O&S	0.0	0.0	0.0	0.0	0.0	0.0	0.8	2.4	0.8	4.0
RECOVERY O&S	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.5	0.6	3.0
REFURBISHMENT O&S	0.0	0.0	0.0	0.1	0.2	0.6	2.4	3.2	1.6	8.0
TOTAL	0.0	83.8	178.7	246.1	253.9	199.4	138.9	56.7	25.3	1182.8

Table 6.1-2. *Annual Design and Development Cost*
Gas Generator STME/Derivative STBE Program
Booster Derivative STBE Portion
ALS Scenario 2 (Millions of FY87$)

DDT&E SPREAD BY GFY	1991	1992	1993	1994	1995	1996	1997	1998	1999	TOTAL
PROGRAM MANAGEMENT	0.0	1.4	1.6	1.7	1.7	1.7	1.7	1.7	1.3	13.0
CONTRACT DATA	0.0	0.5	0.6	0.7	0.7	0.7	0.7	0.7	0.7	5.0
OTHER	0.0	0.9	1.1	1.1	1.1	1.1	1.1	1.1	0.6	8.0
SE & I	0.0	2.3	3.3	3.3	3.3	3.3	3.3	3.3	2.1	24.0
SRM & QA	0.0	0.6	1.0	1.0	1.0	1.0	1.0	1.0	0.6	7.0
OTHER	0.0	1.7	2.3	2.3	2.3	2.3	2.3	2.3	1.5	17.0
ENGINEERING D&D	0.0	14.5	7.6	9.5	9.5	9.5	6.3	4.4	1.9	63.0
ENGINE TEST	0.0	1.9	33.5	57.2	76.4	70.9	40.2	11.1	4.2	295.3
ENGINE TEST HDWE	0.0	0.0	19.1	32.4	30.9	33.9	20.6	8.8	1.5	147.3
ENGINE TEST O&S	0.0	0.0	0.0	5.9	26.3	27.3	18.6	2.2	2.7	83.2
COMPONENT TEST HDWE	0.0	1.9	12.4	12.4	9.4	1.5	0.0	0.0	0.0	37.5
COMPONENT TEST O&S	0.0	0.0	2.0	6.5	9.9	8.1	1.0	0.0	0.0	27.4
PROPELLANTS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FLIGHT TEST HARDWARE	0.0	0.0	0.0	0.0	34.7	55.6	45.5	10.7	0.0	146.5
MFG	0.0	0.0	0.0	0.0	34.7	55.6	41.7	6.9	0.0	138.9
ACCEPTANCE	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.8	0.0	7.6
MPTA TEST HARDWARE	0.0	0.0	0.0	13.2	26.3	29.9	0.0	0.0	0.0	69.4
MFG.	0.0	0.0	0.0	13.2	26.3	26.3	0.0	0.0	0.0	65.8
ACCEPTANCE	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0	0.0	3.6
FACILITIES	0.0	0.3	1.5	0.2	0.0	0.0	0.0	0.0	0.0	2.0
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TEST	0.0	0.3	1.5	0.2	0.0	0.0	0.0	0.0	0.0	2.0
SOFTWARE ENGINEERING	0.0	0.3	0.6	0.8	0.6	0.3	0.3	0.1	0.1	3.0
GSE	0.0	0.0	0.3	1.4	2.7	2.6	1.5	0.5	0.1	9.0
COMMON	0.0	0.0	0.0	0.0	0.2	0.8	0.8	0.2	0.0	2.0
PECULIAR	0.0	0.0	0.3	1.4	2.4	1.8	0.7	0.3	0.1	7.0
TOOLING	0.0	1.3	2.5	2.7	1.9	0.6	0.4	0.3	0.3	10.0
STE	0.0	0.5	1.5	1.3	1.0	0.5	0.3	0.0	0.0	5.0
OPERATIONS & SUPPORT	0.0	0.2	0.2	0.5	1.0	1.9	4.4	7.0	2.9	18.0
LAUNCH O&S	0.0	0.2	0.2	0.5	0.9	1.4	2.1	2.7	1.1	9.0
FLIGHT O&S	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.2	0.4	2.0
RECOVERY O&S	0.0	0.0	0.0	0.0	0.0	0.2	0.8	1.5	0.6	3.0
REFURBISHMENT O&S	0.0	0.0	0.0	0.0	0.1	0.3	1.2	1.6	0.8	4.0
TOTAL	0.0	22.6	52.5	91.6	159.1	176.6	103.9	39.1	12.9	658.3

Table 6.2-1. *Annual Operational Production Cost*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING																												
OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.68
SE & I	0.5	0.8	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.42
SRM & QA	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
OTHER	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	3.5	3.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.50
COMMON	0.0	0.0	0.0	0.0	1.5	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.50
PECULIAR	0.0	0.0	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.00
TOOLING	0.0	0.0	3.0	4.5	4.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	1.5	5.8	12.3	17.5	21.0	21.4	12.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.41
TOTAL NON-RECURRING	2.1	6.7	16.9	23.0	29.0	25.9	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	120.01
RECURRING																												
OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.2	0.3	0.5	0.6	0.6	0.4	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	4.39
SE & I	0.4	1.3	2.7	3.9	4.8	4.5	3.2	1.5	1.2	1.2	1.2	1.2	1.1	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.6	0.3	0.0	0.0	0.0	36.69
SRM & QA	0.2	0.7	1.4	1.9	2.4	2.2	1.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.1	0.0	0.0	0.0	18.34
OTHER	0.2	0.7	1.4	1.9	2.4	2.2	1.6	0.7	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.1	0.0	0.0	0.0	18.34
FLIGHT HDWE MANUF	8.7	32.8	71.6	103.2	130.2	130.0	97.0	42.2	34.8	34.5	34.3	34.1	31.9	27.8	23.0	22.9	22.8	22.7	22.6	22.6	22.5	22.4	18.2	9.8	0.0	0.0	0.0	1022.72
MFG	8.7	32.8	69.3	98.6	123.3	120.8	85.5	38.7	32.5	32.2	32.0	31.8	29.6	25.5	21.4	21.3	21.3	21.2	21.1	21.0	20.9	20.9	16.7	8.3	0.0	0.0	0.0	955.44
ACCEPTANCE	0.0	0.0	2.3	4.6	6.9	9.2	11.5	3.5	2.3	2.3	2.3	2.3	2.3	2.3	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	0.0	0.0	0.0	67.28
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	9.1	34.3	74.7	107.6	135.7	135.1	100.6	43.8	36.2	35.9	35.7	35.5	33.2	28.9	23.9	23.8	23.7	23.6	23.5	23.5	23.4	23.3	18.9	10.2	0.0	0.0	0.0	1064.00
GRAND TOTAL	11.2	41.0	91.5	130.6	165.5	161.0	116.2	43.8	36.2	35.9	35.7	35.5	33.2	28.9	23.9	23.8	23.7	23.6	23.5	23.5	23.4	23.3	18.9	10.2	0.0	0.0	0.0	1184.02

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Table 6.2-2. *Annual Operational Production Cost Gas Generator STME/Derivative STBE Program Booster Derivative Scenario 2, Nominal Flight Schedule (Millions of FY87$)*

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NON-RECURRING														
OPERATIONAL PRODUCTION														
PROGRAM MANAGEMENT	0.4	0.5	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SE & I	1.6	2.7	5.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SRM & QA	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
OTHER	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GSE	0.0	0.0	0.0	0.0	7.5	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMMON	0.0	0.0	0.0	0.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PECULIAR	0.0	0.0	0.0	0.0	4.5	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOOLING	0.0	0.0	9.0	12.0	12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
INITIAL SPARES	2.9	10.9	23.1	32.8	40.9	40.1	22.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL NON-RECURRING	4.8	14.1	38.1	49.2	60.4	49.6	30.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
RECURRING														
OPERATIONAL PRODUCTION														
PROGRAM MANAGEMENT	0.1	0.3	0.7	1.0	1.2	1.1	0.8	0.4	0.3	0.3	0.3	0.3	0.3	0.3
SE & I	0.8	2.7	5.4	7.6	9.5	8.7	6.1	2.9	2.4	2.4	2.4	2.4	2.3	2.1
SRM & QA	0.4	1.3	2.7	3.8	4.8	4.3	3.1	1.4	1.2	1.2	1.2	1.2	1.1	1.0
OTHER	0.4	1.3	2.7	3.8	4.8	4.3	3.1	1.4	1.2	1.2	1.2	1.2	1.1	1.0
FLIGHT HDWE MANUF	16.9	63.7	139.6	201.6	254.4	254.8	192.0	82.8	68.0	67.6	67.1	66.7	63.9	58.8
MFG	16.9	63.7	134.3	190.8	238.3	233.3	165.0	74.7	62.6	62.2	61.7	61.3	58.6	53.5
ACCEPTANCE	0.0	0.0	5.4	10.8	16.1	21.5	26.9	8.1	5.4	5.4	5.4	5.4	5.4	5.4
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTAL RECURRING	17.8	66.7	145.7	210.1	265.1	264.6	198.8	86.0	70.8	70.3	69.8	69.4	66.5	61.2
GRAND TOTAL	22.6	80.8	183.9	259.4	325.6	314.1	229.0	86.0	70.8	70.3	69.8	69.4	66.5	61.2

SPREAD BY GFY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING														
OPERATIONAL PRODUCTION														
PROGRAM MANAGEMENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.05
SE & I	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.63
SRM & QA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
OTHER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.50
COMMON	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.00
PECULIAR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.50
TOOLING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	173.30
TOTAL NON-RECURRING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246.48
RECURRING														
OPERATIONAL PRODUCTION														
PROGRAM MANAGEMENT	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	9.32
SE & I	1.9	1.9	1.9	1.9	1.9	1.9	1.8	1.8	1.3	0.7	0.0	0.0	0.0	74.56
SRM & QA	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.3	0.0	0.0	0.0	37.28
OTHER	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.7	0.3	0.0	0.0	0.0	37.28
FLIGHT HDWE MANUF	52.7	52.4	52.2	52.0	51.8	51.7	51.5	51.3	41.8	23.0	0.0	0.0	0.0	2078.41
MFG	48.4	48.2	48.0	47.8	47.6	47.4	47.2	47.1	37.6	18.7	0.0	0.0	0.0	1915.01
ACCEPTANCE	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	0.0	0.0	0.0	163.41
TOOLING MAINTENANCE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	54.8	54.6	54.3	54.1	53.9	53.7	53.6	53.4	43.3	23.7	0.0	0.0	0.0	2162.29
GRAND TOTAL	54.8	54.6	54.3	54.1	53.9	53.7	53.6	53.4	43.3	23.7	0.0	0.0	0.0	2408.77

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Table 6.2-3. *Annual Operational Production Cost*
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.4	0.6	1.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.78
SE & I	2.1	3.5	6.3	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.05
SRM & QA	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
OTHER	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	11.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.00
COMMON	0.0	0.0	0.0	0.0	4.5	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.50
PECULIAR	0.0	0.0	0.0	0.0	6.5	6.5	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.50
TOOLING	0.0	0.0	12.0	16.5	16.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	4.43	16.75	35.32	50.22	62.75	61.45	34.78	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	265.71
TOTAL NON-RECURRING	6.9	20.8	55.0	72.2	90.3	73.5	45.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	344.49
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.2	0.5	1.0	1.4	1.8	1.6	1.2	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	13.91
SE & I	1.2	4.0	8.1	11.5	14.4	13.1	9.3	4.3	3.7	3.7	3.6	3.6	3.4	3.0	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.6	1.9	1.0	0.0	0.0	0.0	111.25
SRM & QA	0.6	2.0	4.1	5.7	7.2	6.6	4.6	2.2	1.8	1.8	1.8	1.8	1.7	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.0	0.5	0.0	0.0	0.0	55.63
OTHER	0.6	2.0	4.1	5.7	7.2	6.6	4.6	2.2	1.8	1.8	1.8	1.8	1.7	1.5	1.4	1.4	1.3	1.3	1.3	1.3	1.3	1.3	1.0	0.5	0.0	0.0	0.0	55.63
FLIGHT HDWE MANUF	25.6	96.5	211.2	304.8	384.7	384.9	289.0	124.9	102.8	102.1	101.4	100.8	95.9	86.7	75.6	75.3	75.0	74.8	74.5	74.2	74.0	73.7	60.0	32.8	0.0	0.0	0.0	3101.13
MFG	25.6	96.5	203.5	289.4	361.6	354.1	250.5	113.4	95.1	94.4	93.7	93.1	88.2	79.0	69.9	69.6	69.3	69.0	68.7	68.4	68.2	67.9	54.2	27.1	0.0	0.0	0.0	2870.44
ACCEPTANCE	0.0	0.0	7.7	15.4	23.1	30.8	38.4	11.5	7.7	7.7	7.7	7.7	7.7	7.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	0.0	0.0	0.0	230.69
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	26.9	101.0	220.4	317.7	400.8	399.6	299.4	129.8	106.9	106.2	105.5	104.9	99.7	90.1	78.7	78.4	78.1	77.8	77.5	77.2	76.9	76.7	62.2	33.9	0.0	0.0	0.0	3226.30
GRAND TOTAL	33.8	121.9	275.4	389.9	491.1	475.1	345.2	129.8	106.9	106.2	105.5	104.9	99.7	90.1	78.7	78.4	78.1	77.8	77.5	77.2	76.9	76.7	62.2	33.9	0.0	0.0	0.0	3592.78

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Table 6.2-4. *Annual Operational Production Cost*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.68
SE & I	0.5	0.8	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.42
SRM & QA	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
OTHER	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	3.5	3.5	3.5	7.0	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.50
COMMON	0.0	0.0	0.0	0.0	1.5	1.5	1.5	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.50
PECULIAR	0.0	0.0	0.0	0.0	2.0	2.0	2.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.00
TOOLING	0.0	0.0	3.0	4.5	4.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	1.5	5.8	12.3	17.5	21.8	24.3	23.8	20.7	18.4	17.1	16.8	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	191.29
TOTAL NON-RECURRING	2.1	6.7	16.9	23.0	29.8	28.8	27.3	27.7	25.4	17.1	16.8	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	232.89
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.2	0.3	0.5	0.6	0.7	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.0	0.0	0.0	0.0	8.15
SE & I	0.4	1.3	2.7	3.9	4.8	5.3	5.2	4.5	4.0	3.8	3.7	3.4	3.0	2.6	2.6	2.6	2.3	2.0	1.7	1.7	1.7	1.3	0.6	0.0	0.0	0.0	0.0	65.18
SRM & QA	0.2	0.7	1.4	1.9	2.4	2.6	2.6	2.2	2.0	1.9	1.9	1.7	1.5	1.3	1.3	1.3	1.2	1.0	0.9	0.9	0.9	0.6	0.3	0.0	0.0	0.0	0.0	32.59
OTHER	0.2	0.7	1.4	1.9	2.4	2.6	2.6	2.2	2.0	1.9	1.9	1.7	1.5	1.3	1.3	1.3	1.2	1.0	0.9	0.9	0.9	0.6	0.3	0.0	0.0	0.0	0.0	32.59
FLIGHT HDWE MANUF	0.7	32.8	71.6	103.2	130.2	146.5	146.0	127.4	113.0	104.7	103.1	96.7	85.7	72.7	72.4	71.8	67.3	58.6	48.2	48.0	47.8	38.9	21.3	0.0	0.0	0.0	0.0	1816.87
MFG	0.7	32.8	69.3	98.6	123.3	137.3	134.5	117.0	103.8	96.7	95.1	88.7	77.6	67.0	66.6	66.1	61.5	52.9	44.4	44.2	44.0	35.0	17.5	0.0	0.0	0.0	0.0	1682.30
ACCEPTANCE	0.0	0.0	2.3	4.6	6.9	9.2	11.5	10.4	9.2	8.1	8.1	8.1	8.1	5.8	5.8	5.8	5.8	5.8	3.8	3.8	3.8	3.8	3.8	0.0	0.0	0.0	0.0	134.57
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	9.1	34.3	74.7	107.6	135.7	152.4	151.8	132.4	117.5	109.0	107.3	100.5	89.1	75.7	75.3	74.7	69.9	60.9	50.2	49.9	49.7	40.3	22.0	0.0	0.0	0.0	0.0	1890.20
GRAND TOTAL	11.2	41.0	91.5	130.6	165.5	181.2	179.2	160.1	142.9	126.1	124.1	111.8	89.1	75.7	75.3	74.7	69.9	60.9	50.2	49.9	49.7	40.3	22.0	0.0	0.0	0.0	0.0	2123.09

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Table 6.2-5. *Annual Operational Production Cost Gas Generator STME/Derivative STBE Program Booster Derivative STBE Scenario 2, Maximum Flight Schedule (Millions of FY87$)*

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON RECURRING																												
OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.4	0.5	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.05
SE & I	1.6	2.7	5.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.63
SRM & QA	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
OTHER	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
FACILITIES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	7.5	7.5	7.5	15.0	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	52.50
COMMON	0.0	0.0	0.0	0.0	3.0	3.0	3.0	6.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.00
PECULIAR	0.0	0.0	0.0	0.0	4.5	4.5	4.5	9.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.50
TOOLING	0.0	0.0	9.0	12.0	12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	2.9	10.9	23.1	32.8	40.9	45.5	44.6	38.7	34.4	32.0	31.5	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	359.10
TOTAL NON-RECURRING	4.8	14.1	38.1	49.2	60.4	55.0	52.1	53.7	49.4	32.0	31.5	21.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	462.20
RECURRING																												
OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.3	0.7	1.0	1.2	1.3	1.3	1.1	1.0	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.6	0.5	0.5	0.5	0.5	0.4	0.2	0.0	0.0	0.0	0.0	16.55
SE & I	0.8	2.7	5.4	7.6	9.5	10.4	10.1	8.8	7.9	7.4	7.3	7.0	6.4	5.6	5.1	5.0	4.8	4.4	4.0	4.0	4.0	2.9	1.4	0.0	0.0	0.0	0.0	132.37
SRM & QA	0.4	1.3	2.7	3.8	4.8	5.2	5.0	4.4	3.9	3.7	3.6	3.5	3.2	2.8	2.5	2.5	2.4	2.2	2.0	2.0	2.0	1.4	0.7	0.0	0.0	0.0	0.0	66.19
OTHER	0.4	1.3	2.7	3.8	4.8	5.2	5.0	4.4	3.9	3.7	3.6	3.5	3.2	2.8	2.5	2.5	2.4	2.2	2.0	2.0	2.0	1.4	0.7	0.0	0.0	0.0	0.0	66.19
FLIGHT HDWE MANUF	16.9	63.7	139.6	201.6	254.4	286.5	286.5	249.9	221.7	205.3	202.2	196.9	182.7	160.6	141.8	140.7	135.2	125.2	112.7	112.1	111.6	91.2	50.9	0.0	0.0	0.0	0.0	3689.89
MFG	16.9	63.7	134.3	190.8	238.3	265.0	259.6	225.7	200.2	186.4	183.3	178.1	163.8	143.3	128.3	127.3	121.7	111.7	101.9	101.4	100.9	80.4	40.1	0.0	0.0	0.0	0.0	3363.08
ACCEPTANCE	0.0	0.0	5.4	10.8	16.1	21.5	26.9	24.2	21.5	18.8	18.8	18.8	18.8	17.3	13.5	13.5	13.5	13.5	10.8	10.8	10.8	10.8	10.8	0.0	0.0	0.0	0.0	326.81
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	17.8	66.7	145.7	210.1	265.1	298.2	297.9	259.8	230.6	213.6	210.3	204.8	189.8	166.9	147.5	146.4	140.5	130.1	117.2	116.7	116.1	94.4	52.5	0.0	0.0	0.0	0.0	3838.81
GRAND TOTAL	22.6	80.8	183.9	259.4	325.6	353.2	349.9	313.5	280.0	245.6	241.8	226.6	189.8	166.9	147.5	146.4	140.5	130.1	117.2	116.7	116.1	94.4	52.5	0.0	0.0	0.0	0.0	4301.09

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Table 6.2-6. *Annual Operational Production Cost
Gas Generator STME/Derivative STBE Program
Combined Core and Booster Engines
Scenario 2, Maximum Flight Schedule (Millions of FY87$)*

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.4	0.6	1.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.73
SE & I	2.1	3.5	6.3	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.05
SRM & QA	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
OTHER	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	11.0	11.0	11.0	22.0	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	77.00
COMMON	0.0	0.0	0.0	0.0	4.5	4.5	4.5	9.0	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.50
PECULIAR	0.0	0.0	0.0	0.0	6.5	6.5	6.5	13.0	13.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	45.50
TOOLING	0.0	0.0	12.0	16.5	16.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	4.43	16.75	35.32	50.22	62.75	69.81	68.39	59.46	52.75	49.13	48.32	33.05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	550.39
TOTAL NON-RECURRING	6.9	20.8	55.0	72.2	90.3	83.8	79.4	81.5	74.8	49.1	48.3	33.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	695.17
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.2	0.5	1.0	1.4	1.8	2.0	1.9	1.7	1.5	1.4	1.4	1.3	1.2	1.0	1.0	1.0	0.9	0.8	0.7	0.7	0.7	0.5	0.3	0.0	0.0	0.0	0.0	24.70
SE & I	1.2	4.0	8.1	11.5	14.4	15.7	15.2	13.3	11.9	11.1	11.0	10.4	9.4	8.2	7.7	7.6	7.1	6.4	5.8	5.7	5.7	4.1	2.1	0.0	0.0	0.0	0.0	197.55
SRM & QA	0.6	2.0	4.1	5.7	7.2	7.8	7.6	6.6	5.9	5.6	5.5	5.2	4.7	4.1	3.8	3.8	3.5	3.2	2.9	2.9	2.9	2.1	1.0	0.0	0.0	0.0	0.0	98.78
OTHER	0.6	2.0	4.1	5.7	7.2	7.8	7.6	6.6	5.9	5.6	5.5	5.2	4.7	4.1	3.8	3.8	3.5	3.2	2.9	2.9	2.9	2.1	1.0	0.0	0.0	0.0	0.0	98.78
FLIGHT HDWE MANUF	25.6	96.5	211.2	304.8	384.7	433.0	432.6	377.3	334.8	310.0	305.3	293.7	268.4	233.3	214.1	212.6	202.4	183.8	160.9	160.1	159.4	130.1	72.2	0.0	0.0	0.0	0.0	5506.77
MFG	25.6	96.5	203.5	289.4	361.6	402.3	394.1	342.6	304.0	283.1	278.4	266.7	241.4	210.2	194.9	193.4	183.2	164.6	146.3	145.5	144.8	115.5	57.6	0.0	0.0	0.0	0.0	5045.39
ACCEPTANCE	0.0	0.0	7.7	15.4	23.1	30.8	38.4	34.6	30.8	26.9	26.9	26.9	26.9	23.1	19.2	19.2	19.2	19.2	14.6	14.6	14.6	14.6	14.6	0.0	0.0	0.0	0.0	461.38
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	26.9	101.0	220.4	317.7	400.8	450.7	449.7	392.2	348.1	322.5	317.7	305.4	278.9	242.6	222.8	221.2	210.4	191.1	167.4	166.6	165.9	134.7	74.5	0.0	0.0	0.0	0.0	5729.02
GRAND TOTAL	33.8	121.9	275.4	389.9	491.1	534.5	529.1	473.6	422.9	371.7	366.0	338.4	278.9	242.6	222.8	221.2	210.4	191.1	167.4	166.6	165.9	134.7	74.5	0.0	0.0	0.0	0.0	6424.18

Table 6.2-7. *Annual Operational Production Cost*
Gas Generator STME/Derivative STBE Program
Core STME
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.1	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.68
SE & I	0.5	0.8	1.3	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.42
SRM & QA	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
OTHER	0.3	0.4	0.7	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.71
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	3.5	3.5	3.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.50
COMMON	0.0	0.0	0.0	0.0	1.5	1.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.50
PECULIAR	0.0	0.0	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.00
TOOLING	0.0	0.0	3.0	4.5	4.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	1.5	5.8	12.3	17.5	21.8	20.9	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	85.25
TOTAL NON-RECURRING	2.1	6.7	16.9	23.0	29.2	25.4	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.85
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.2	0.3	0.5	0.6	0.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.68
SE & I	0.4	1.3	2.7	3.9	4.8	4.3	2.8	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.43
SRM & QA	0.2	0.7	1.4	1.9	2.4	2.2	1.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.72
OTHER	0.2	0.7	1.4	1.9	2.4	2.2	1.4	0.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.72
FLIGHT HDWE MANUF	8.7	32.8	71.6	103.2	130.2	127.0	89.0	24.4	10.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	597.48
MFG	8.7	32.8	69.3	98.6	123.3	117.8	77.4	22.1	9.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	559.03
ACCEPTANCE	0.0	0.0	2.3	4.6	6.9	9.2	11.5	2.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.45
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	9.1	34.3	74.7	107.6	135.7	131.9	92.2	25.3	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	621.59
GRAND TOTAL	11.2	41.0	91.5	130.6	165.5	157.2	101.1	25.3	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	734.45

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Table 6.2-8. *Annual Operational Production Cost*
Gas Generator STME/Derivative STBE Program
Booster Derivative STBE
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.4	0.5	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.05
SE & I	1.6	2.7	5.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.63
SRM & QA	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
OTHER	0.8	1.4	2.5	1.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.32
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	7.5	7.5	7.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	22.50
COMMON	0.0	0.0	0.0	0.0	3.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.00
PECULIAR	0.0	0.0	0.0	0.0	4.5	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.50
TOOLING	0.0	0.0	9.0	12.0	12.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	2.9	10.9	23.1	32.8	40.9	39.5	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	166.25
TOTAL NON-RECURRING	4.8	14.1	38.1	49.2	60.4	49.0	23.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239.43
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.1	0.3	0.7	1.0	1.2	1.1	0.7	0.3	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.18
SE & I	0.8	2.7	5.4	7.6	9.5	8.5	5.8	2.5	2.1	2.2	1.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.41
SRM & QA	0.4	1.3	2.7	3.8	4.8	4.2	2.9	1.2	1.1	1.1	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.71
OTHER	0.4	1.3	2.7	3.8	4.8	4.2	2.9	1.2	1.1	1.1	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.71
FLIGHT HDWE MANUF	16.9	63.7	139.6	201.6	254.4	251.6	184.0	70.3	59.9	60.0	48.7	26.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1377.31
MFG	16.9	63.7	134.3	190.8	238.3	230.1	157.0	63.7	55.3	55.3	44.1	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1271.57
ACCEPTANCE	0.0	0.0	5.4	10.8	16.1	21.5	26.9	6.5	4.6	4.6	4.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	105.73
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	17.8	66.7	145.7	210.1	265.1	261.2	190.5	73.0	62.3	62.4	50.5	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1432.89
GRAND TOTAL	22.6	80.8	183.9	259.4	325.6	310.2	214.2	73.0	62.3	62.4	50.5	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1672.33

Table 6.2-9. *Annual Operational Production Cost Gas Generator STME/Derivative STBE Program Combined Core and Booster Engines Scenario 2, Minimum Flight Schedule (Millions of FY87$)*

SPREAD BY GFY	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	TOTAL
NON-RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.4	0.6	1.4	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.73
SE & I	2.1	3.5	6.3	4.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.05
SRM & QA	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
OTHER	1.1	1.8	3.1	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.03
FACILITES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
PRODUCTION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
LAUNCH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TEST	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
GSE	0.0	0.0	0.0	0.0	11.0	11.0	11.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.00
COMMON	0.0	0.0	0.0	0.0	4.5	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.50
PECULIAR	0.0	0.0	0.0	0.0	6.5	6.5	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.50
TOOLING	0.0	0.0	12.0	16.5	16.5	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.00
STE	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
INITIAL SPARES	4.4	16.7	35.3	50.2	62.8	60.4	21.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	251.51
TOTAL NON-RECURRING	6.9	20.8	55.0	72.2	90.3	74.4	32.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	352.29
RECURRING OPERATIONAL PRODUCTION																												
PROGRAM MANAGEMENT	0.2	0.5	1.0	1.4	1.0	1.6	1.1	0.4	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.84
SE & I	1.2	4.0	8.1	11.5	14.4	12.8	8.6	3.2	2.5	2.2	1.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70.84
SRM & QA	0.6	2.0	4.1	5.7	7.2	6.4	4.3	1.6	1.2	1.1	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.42
OTHER	0.6	2.0	4.1	5.7	7.2	6.4	4.3	1.6	1.2	1.1	0.8	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	35.42
FLIGHT HDWE MANUF	25.6	96.5	211.2	304.8	384.7	378.7	272.9	94.7	70.4	60.0	48.7	26.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1974.78
MFG	25.6	96.5	203.5	289.4	361.6	347.9	234.5	85.8	64.3	55.3	44.1	22.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1830.60
ACCEPTANCE	0.0	0.0	7.7	15.4	23.1	30.8	38.4	8.8	6.2	4.6	4.6	4.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	144.18
TOOLING MAINTENANCE	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
FACILITIES MAINT	0.00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00
TOTAL RECURRING	26.9	101.0	220.4	317.7	400.8	393.1	282.6	98.3	73.2	62.4	50.5	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2054.49
GRAND TOTAL	33.8	121.9	275.4	389.9	491.1	467.4	315.3	98.3	73.2	62.4	50.5	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2406.77

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Time-phasing of the individual Recurring Operational Production Cost elements is dictated by the production engine delivery schedule. Comparing costs for the nominal, maximum and minimum cases, readily shows the greater funding requirements with the higher hardware acquisition levels. Hardware acquisition cost begins in the year of lot procurement and it ends in the year of lot delivery. This procurement to delivery period spans approximately three years, with 60% of the procurement costs being incurred in the first two years and 40% in the delivery year. Costs for Project Management and SE&I are based on a percentage of production engine hardware costs, with the higher annual costs coinciding with the period of higher production engine deliveries.

6.3 OPERATIONS PHASE: OPERATIONS

Costs for each WBS element in Operations were time-phased over a 25 year operational period beginning in 1999, the year of the first operational flight. Tables 6.3-1 through 6.3-9 present the time-phased cost estimates for the STME/Derivative STBE program. Funding profiles for each WBS functional element are presented in the tables.

Table 6.3-1. *Annual Operations Cost*
Gas Generator STME/Derivative STBE Program Core STME
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

Spread by GFY	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Flights	2	4	6	8	10	12	12	12	12	12	14	14
	Cum	2	6	12	20	30	42	54	66	78	90	104	118
OPERATIONS COST													
Program Management		0.59	0.48	0.43	0.40	0.38	0.36	0.34	0.33	0.31	0.30	0.30	0.30
System Eng. & Int		2.29	1.89	1.68	1.55	1.47	1.41	1.33	1.27	1.23	1.19	1.19	1.16
SRM & QA		1.15	0.95	0.84	0.78	0.74	0.71	0.67	0.64	0.61	0.60	0.60	0.58
Other		1.15	0.95	0.84	0.78	0.74	0.71	0.67	0.64	0.61	0.60	0.60	0.58
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		2.31	2.96	3.48	3.96	4.41	4.82	4.56	4.35	4.20	4.07	4.55	4.43
Launch Operations & Support		0.07	0.11	0.15	0.17	0.20	0.22	0.21	0.20	0.19	0.19	0.21	0.21
Flight Operations & Support		0.96	0.79	0.70	0.65	0.61	0.59	0.56	0.53	0.51	0.50	0.50	0.48
Recovery Operations & Support		0.06	0.10	0.12	0.15	0.17	0.19	0.18	0.17	0.17	0.16	0.18	0.18
Refurbishment Operation & Support		0.86	1.38	1.77	2.11	2.41	2.69	2.54	2.43	2.34	2.27	2.58	2.51
Spares Replenishment		0.36	0.58	0.74	0.89	1.01	1.13	1.07	1.02	0.99	0.96	1.08	1.05
Training		0.03	0.05	0.06	0.07	0.08	0.09	0.08	0.08	0.08	0.07	0.08	0.08
TOTAL OPERATIONS COST		5.22	5.38	5.65	5.98	6.33	6.68	6.31	6.03	5.82	5.64	6.13	5.97

Spread by GFY	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
	Flights	14	14	14	14	14	14	14	14	14	14	14	14	14	
	Cum	132	146	160	174	188	202	216	230	244	258	272	286	300	
OPERATIONS COST															
Program Management		0.29	0.28	0.28	0.27	0.27	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.24	7.94
System Eng. & Int		1.14	1.11	1.09	1.07	1.05	1.04	1.02	1.01	1.00	0.99	0.98	0.97	0.96	31.11
SRM & QA		0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50	0.49	0.49	0.48	0.48	15.56
Other		0.57	0.56	0.55	0.54	0.53	0.52	0.51	0.51	0.50	0.49	0.49	0.48	0.48	15.56
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		4.32	4.23	4.15	4.08	4.01	3.95	3.90	3.85	3.80	3.76	3.72	3.68	3.64	99.21
Launch Operations & Support		0.20	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.17	0.17	0.17	0.17	4.49
Flight Operations & Support		0.47	0.46	0.45	0.45	0.44	0.43	0.43	0.42	0.42	0.41	0.41	0.40	0.40	12.96
Recovery Operations & Support		0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15	3.87
Refurbishment Operation & Support		2.45	2.40	2.35	2.31	2.27	2.24	2.21	2.18	2.15	2.13	2.11	2.08	2.06	54.83
Spares Replenishment		1.03	1.01	0.99	0.97	0.96	0.94	0.93	0.92	0.91	0.90	0.89	0.88	0.87	23.05
Training		0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	1.80
TOTAL OPERATIONS COST		5.83	5.71	5.60	5.50	5.41	5.33	5.26	5.19	5.13	5.07	5.01	4.96	4.91	140.06

Table 6.3-2. *Annual Operations Cost*
Gas Generator STME/Derivative STBE Program Booster Derivative STBE
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

Spread by GFY	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Flights	2	4	6	8	10	12	12	12	12	12	14	14	14
	Cum	2	6	12	20	30	42	54	66	78	90	104	118	132
OPERATIONS COST														
Program Management		1.37	1.13	1.00	0.93	0.88	0.84	0.79	0.76	0.73	0.71	0.71	0.69	0.68
System Eng. & Int		5.35	4.42	3.92	3.63	3.43	3.29	3.11	2.97	2.87	2.78	2.79	2.71	2.65
SRM & QA		2.67	2.21	1.96	1.81	1.72	1.65	1.56	1.49	1.43	1.39	1.39	1.36	1.32
Other		2.67	2.21	1.96	1.81	1.72	1.65	1.56	1.49	1.43	1.39	1.39	1.36	1.32
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		5.60	7.21	8.53	9.73	10.84	11.87	11.21	10.72	10.33	10.02	11.21	10.91	10.65
Launch Operations & Support		0.17	0.26	0.34	0.40	0.46	0.51	0.49	0.46	0.45	0.43	0.49	0.48	0.47
Flight Operations & Support		2.23	1.84	1.64	1.51	1.43	1.37	1.30	1.24	1.20	1.16	1.16	1.13	1.10
Recovery Operations & Support		0.14	0.23	0.29	0.35	0.40	0.44	0.42	0.40	0.39	0.37	0.42	0.41	0.40
Refurbishment Operation & Support		2.21	3.53	4.53	5.40	6.18	6.90	6.51	6.23	6.01	5.82	6.60	6.42	6.27
Spares Replenishment		0.85	1.35	1.74	2.07	2.37	2.64	2.49	2.39	2.30	2.23	2.53	2.46	2.40
Training		0.07	0.11	0.14	0.16	0.18	0.21	0.19	0.19	0.18	0.17	0.20	0.19	0.19
TOTAL OPERATIONS COST		12.38	12.84	13.60	14.45	15.33	16.21	15.31	14.64	14.11	13.68	14.90	14.58	14.16

Spread by GFY	Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
	Flights	14	14	14	14	14	14	14	14	14	14	14	14	
	Cum	146	160	174	188	202	216	230	244	258	272	286	300	
OPERATIONS COST														
Program Management		0.66	0.65	0.64	0.63	0.62	0.61	0.60	0.59	0.59	0.58	0.58	0.57	18.53
System Eng. & Int		2.59	2.54	2.50	2.46	2.42	2.39	2.36	2.33	2.30	2.28	2.25	2.23	72.60
SRM & QA		1.30	1.27	1.25	1.23	1.21	1.19	1.18	1.16	1.15	1.14	1.13	1.12	36.30
Other		1.30	1.27	1.25	1.23	1.21	1.19	1.18	1.16	1.15	1.14	1.13	1.12	36.30
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		10.43	10.23	10.05	9.89	9.74	9.61	9.48	9.37	9.26	9.16	9.07	8.98	244.09
Launch Operations & Support		0.46	0.45	0.44	0.43	0.43	0.42	0.42	0.41	0.41	0.40	0.40	0.39	10.49
Flight Operations & Support		1.08	1.06	1.04	1.02	1.01	1.00	0.98	0.97	0.96	0.95	0.94	0.93	30.25
Recovery Operations & Support		0.39	0.39	0.38	0.37	0.37	0.36	0.36	0.35	0.35	0.35	0.34	0.34	9.02
Refurbishment Operation & Support		6.14	6.02	5.92	5.83	5.74	5.66	5.59	5.52	5.46	5.40	5.34	5.29	140.52
Spares Replenishment		2.35	2.31	2.27	2.23	2.20	2.17	2.14	2.11	2.09	2.07	2.05	2.03	53.82
Training		0.18	0.18	0.18	0.17	0.17	0.17	0.17	0.16	0.16	0.16	0.16	0.16	4.19
TOTAL OPERATIONS COST		13.86	13.60	13.34	13.15	12.95	12.78	12.61	12.44	12.32	12.18	12.06	11.94	339.41

Table 6.3-3. *Annual Operations Cost*
Gas Generator STME/Derivative STBE Program Combined Core and Booster Engines
Scenario 2, Nominal Flight Schedule (Millions of FY87$)

Spread by GFY	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
	Flights	2	4	6	8	10	12	12	12	12	12	14	14
	Cum	2	6	12	20	30	42	54	66	78	90	104	118
OPERATIONS COST													
Program Management		1.96	1.62	1.43	1.32	1.25	1.20	1.13	1.08	1.05	1.01	1.02	0.99
System Eng. & Int		7.64	6.31	5.61	5.18	4.90	4.71	4.44	4.25	4.10	3.97	3.98	3.87
SRM & QA		3.82	3.16	2.80	2.59	2.45	2.35	2.22	2.12	2.05	1.99	1.99	1.94
Other		3.82	3.16	2.80	2.59	2.45	2.35	2.22	2.12	2.05	1.99	1.99	1.94
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		7.91	10.16	12.02	13.69	15.24	16.69	15.76	15.07	14.53	14.09	15.76	15.34
Launch Operations & Support		0.24	0.38	0.48	0.58	0.66	0.74	0.69	0.66	0.64	0.62	0.70	0.68
Flight Operations & Support		3.18	2.63	2.34	2.16	2.04	1.96	1.85	1.77	1.71	1.66	1.66	1.61
Recovery Operations & Support		0.20	0.32	0.42	0.50	0.57	0.63	0.60	0.57	0.55	0.53	0.61	0.59
Refurbishment Operation & Support		3.08	4.90	6.30	7.51	8.59	9.59	9.05	8.66	8.35	8.09	9.18	8.93
Spares Replenishment		1.21	1.93	2.48	2.95	3.38	3.77	3.56	3.41	3.29	3.19	3.61	3.51
Training		0.09	0.15	0.19	0.23	0.26	0.29	0.28	0.27	0.26	0.25	0.28	0.27
TOTAL OPERATIONS COST		17.60	18.24	19.25	20.43	21.66	22.90	21.61	20.67	19.93	19.33	21.03	20.47

Spread by GFY	Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
	Flights	14	14	14	14	14	14	14	14	14	14	14	14	14	
	Cum	132	146	160	174	188	202	216	230	244	258	272	286	300	
OPERATIONS COST															
Program Management		0.97	0.94	0.93	0.91	0.90	0.88	0.87	0.86	0.85	0.84	0.83	0.82	0.81	26.48
System Eng. & Int		3.78	3.70	3.63	3.57	3.51	3.46	3.41	3.37	3.33	3.29	3.25	3.22	3.19	103.71
SRM & QA		1.89	1.85	1.82	1.79	1.76	1.73	1.71	1.68	1.66	1.65	1.63	1.61	1.59	51.85
Other		1.89	1.85	1.82	1.79	1.76	1.73	1.71	1.68	1.66	1.65	1.63	1.61	1.59	51.85
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		14.97	14.66	14.38	14.13	13.90	13.70	13.51	13.33	13.17	13.02	12.88	12.75	12.62	343.30
Launch Operations & Support		0.67	0.65	0.64	0.63	0.62	0.61	0.60	0.60	0.59	0.58	0.58	0.57	0.56	14.98
Flight Operations & Support		1.58	1.54	1.51	1.49	1.46	1.44	1.42	1.40	1.39	1.37	1.36	1.34	1.33	43.21
Recovery Operations & Support		0.58	0.56	0.55	0.54	0.53	0.53	0.52	0.51	0.51	0.50	0.49	0.49	0.48	12.88
Refurbishment Operation & Support		8.72	8.54	8.38	8.23	8.10	7.98	7.87	7.77	7.67	7.58	7.50	7.43	7.35	195.35
Spares Replenishment		3.43	3.36	3.30	3.24	3.19	3.14	3.10	3.06	3.02	2.98	2.95	2.92	2.89	76.87
Training		0.27	0.26	0.26	0.25	0.25	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23	5.99
TOTAL OPERATIONS COST		19.99	19.67	19.20	18.86	18.56	18.29	18.03	17.80	17.58	17.38	17.20	17.02	16.85	479.47

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Table 6.3-4. Annual Operations Cost
Gas Generator STME/Derivative STBE Program Core STME
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

Spread by GFY	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Flights	2	4	6	8	10	14	18	24	28	30	30	30
Cum	2	6	12	20	30	44	62	86	114	144	174	204
OPERATIONS COST												
Program Management	0.59	0.48	0.43	0.40	0.38	0.37	0.36	0.37	0.37	0.36	0.34	0.33
System Eng. & Int	2.29	1.89	1.68	1.55	1.47	1.45	1.43	1.45	1.44	1.40	1.34	1.30
SRM & QA	1.15	0.95	0.84	0.78	0.74	0.72	0.72	0.73	0.72	0.70	0.67	0.65
Other	1.15	0.95	0.84	0.78	0.74	0.72	0.72	0.73	0.72	0.70	0.67	0.65
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	2.31	2.95	3.48	3.96	4.41	5.52	6.48	7.94	8.66	8.79	8.43	8.14
Launch Operations & Support	0.07	0.11	0.15	0.17	0.20	0.26	0.31	0.38	0.42	0.43	0.41	0.40
Flight Operations & Support	0.96	0.79	0.70	0.65	0.61	0.60	0.60	0.61	0.60	0.58	0.56	0.54
Recovery Operations & Support	0.06	0.10	0.12	0.15	0.17	0.22	0.26	0.33	0.36	0.37	0.35	0.34
Refurbishment Operation & Support	0.86	1.38	1.77	2.11	2.41	3.12	3.74	4.66	5.12	5.21	5.00	4.83
Spares Replenishment	0.36	0.58	0.74	0.89	1.01	1.31	1.57	1.96	2.15	2.19	2.10	2.03
Training	0.03	0.05	0.06	0.07	0.08	0.10	0.12	0.15	0.17	0.17	0.16	0.16
TOTAL OPERATIONS COST	5.22	5.38	5.65	5.98	6.33	7.44	8.40	9.92	10.63	10.72	10.27	9.92

Spread by GFY	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	
Flights	30	32	32	32	32	32	33	33	33	33	33	33	33	
Cum	234	266	298	330	362	394	427	460	493	526	559	592	625	
OPERATIONS COST														
Program Management	0.32	0.32	0.31	0.31	0.30	0.29	0.29	0.29	0.28	0.28	0.28	0.27	0.27	8.59
System Eng. & Int	1.26	1.26	1.23	1.20	1.18	1.16	1.15	1.13	1.12	1.10	1.09	1.08	1.06	33.73
SRM & QA	0.63	0.63	0.61	0.60	0.59	0.58	0.58	0.57	0.56	0.55	0.54	0.54	0.53	16.86
Other	0.63	0.63	0.61	0.60	0.59	0.58	0.58	0.57	0.56	0.55	0.54	0.54	0.53	16.86
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	7.90	8.18	7.99	7.82	7.67	7.53	7.63	7.51	7.41	7.31	7.22	7.13	7.05	169.41
Launch Operations & Support	0.38	0.40	0.39	0.38	0.37	0.37	0.37	0.37	0.36	0.36	0.35	0.35	0.34	8.10
Flight Operations & Support	0.53	0.52	0.51	0.50	0.49	0.48	0.48	0.47	0.47	0.46	0.45	0.45	0.44	14.05
Recovery Operations & Support	0.33	0.34	0.34	0.33	0.32	0.32	0.32	0.32	0.31	0.31	0.30	0.30	0.30	6.96
Refurbishment Operation & Support	4.69	4.87	4.75	4.65	4.56	4.48	4.55	4.48	4.41	4.35	4.30	4.25	4.20	98.77
Spares Replenishment	1.97	2.05	2.00	1.96	1.92	1.88	1.91	1.88	1.86	1.83	1.81	1.79	1.77	41.53
Training	0.15	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	0.14	3.24
TOTAL OPERATIONS COST	9.63	9.92	9.68	9.48	9.29	9.13	9.22	9.08	8.95	8.83	8.72	8.62	8.52	214.97

Table 6.3-5. *Annual Operations Cost*
Gas Generator STME/Derivative STBE Program Booster Derivative STBE
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

Spread by GFY — Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Flights	2	4	6	8	10	14	18	24	28	30	30	30
Cum	2	6	12	20	30	44	62	86	114	144	174	204
OPERATIONS COST												
Program Management	1.37	1.13	1.00	0.93	0.88	0.86	0.85	0.86	0.85	0.83	0.80	0.77
System Eng. & Int	5.35	4.42	3.92	3.63	3.43	3.38	3.34	3.39	3.36	3.27	3.14	3.03
SRM & QA	2.67	2.21	1.96	1.81	1.72	1.69	1.67	1.70	1.68	1.64	1.57	1.51
Other	2.67	2.21	1.96	1.81	1.72	1.69	1.67	1.70	1.68	1.64	1.57	1.51
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	5.60	7.21	8.53	9.73	10.84	13.59	15.97	19.60	21.38	21.70	20.81	20.10
Launch Operations & Support	0.17	0.26	0.34	0.40	0.46	0.60	0.72	0.89	0.98	1.00	0.96	0.92
Flight Operations & Support	2.23	1.84	1.64	1.51	1.43	1.41	1.39	1.41	1.40	1.36	1.31	1.26
Recovery Operations & Support	0.14	0.23	0.29	0.35	0.40	0.51	0.62	0.77	0.84	0.86	0.82	0.79
Refurbishment Operation & Support	2.21	3.53	4.53	5.40	6.18	8.01	9.58	11.95	13.13	13.37	12.81	12.38
Spares Replenishment	0.85	1.35	1.74	2.07	2.37	3.07	3.67	4.58	5.03	5.12	4.91	4.74
Training	0.07	0.11	0.14	0.16	0.18	0.24	0.29	0.36	0.39	0.40	0.38	0.37
TOTAL OPERATIONS COST	12.38	12.86	13.60	14.45	15.33	18.08	20.45	24.21	25.98	26.20	25.12	24.27

Spread by GFY — Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Flights	30	32	32	32	32	32	33	33	33	33	33	33	33	
Cum	234	266	298	330	362	394	427	460	493	526	559	592	625	
OPERATIONS COST														
Program Management	0.75	0.75	0.73	0.71	0.70	0.69	0.68	0.67	0.66	0.65	0.65	0.64	0.63	20.03
System Eng. & Int	2.94	2.93	2.86	2.80	2.75	2.70	2.69	2.65	2.61	2.57	2.54	2.51	2.48	78.70
SRM & QA	1.47	1.47	1.43	1.40	1.37	1.35	1.34	1.32	1.30	1.29	1.27	1.26	1.24	39.35
Other	1.47	1.47	1.43	1.40	1.37	1.35	1.34	1.32	1.30	1.29	1.27	1.26	1.24	39.35
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	19.81	20.22	19.73	19.31	18.94	18.61	18.86	18.56	18.30	18.05	17.82	17.61	17.42	418.00
Launch Operations & Support	0.90	0.93	0.91	0.89	0.87	0.86	0.87	0.86	0.84	0.83	0.82	0.81	0.80	18.89
Flight Operations & Support	1.23	1.22	1.19	1.17	1.15	1.13	1.12	1.10	1.09	1.07	1.06	1.05	1.03	32.79
Recovery Operations & Support	0.77	0.80	0.78	0.77	0.75	0.74	0.75	0.74	0.73	0.72	0.71	0.70	0.69	16.25
Refurbishment Operation & Support	12.02	12.48	12.18	11.92	11.69	11.49	11.65	11.47	11.31	11.16	11.02	10.89	10.77	253.13
Spares Replenishment	4.60	4.78	4.67	4.57	4.48	4.40	4.46	4.39	4.33	4.27	4.22	4.17	4.12	96.94
Training	0.36	0.37	0.36	0.36	0.35	0.34	0.35	0.34	0.34	0.33	0.33	0.32	0.32	7.56
TOTAL OPERATIONS COST	23.56	24.27	23.69	23.18	22.74	22.34	22.57	22.22	21.90	21.61	21.34	21.09	20.85	524.29

Table 6.3-6. *Annual Operations Cost*
Generator STME/Derivative STBE Program Combined Core and Booster Engines
Scenario 2, Maximum Flight Schedule (Millions of FY87$)

Spread by GFY	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Flights	2	4	6	8	10	14	18	24	28	30	30	30	30
Cum	2	6	12	20	30	44	62	86	114	144	174	204	234
OPERATIONS COST													
Program Management	1.96	1.62	1.43	1.32	1.25	1.23	1.21	1.23	1.22	1.19	1.14	1.10	1.07
System Eng. & Int	7.64	6.31	5.61	5.18	4.90	4.83	4.77	4.84	4.80	4.67	4.48	4.33	4.20
SRM & QA	3.82	3.16	2.80	2.59	2.45	2.41	2.38	2.42	2.40	2.34	2.24	2.16	2.10
Other	3.82	3.16	2.80	2.59	2.45	2.41	2.38	2.42	2.40	2.34	2.24	2.16	2.10
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	7.91	10.16	12.02	13.69	15.24	19.11	22.45	27.55	30.04	30.49	29.23	28.84	27.41
Launch Operations & Support	0.24	0.38	0.48	0.58	0.66	0.85	1.02	1.27	1.40	1.42	1.37	1.32	1.28
Flight Operations & Support	3.18	2.63	2.34	2.16	2.04	2.01	1.99	2.02	2.00	1.95	1.87	1.80	1.75
Recovery Operations & Support	0.20	0.32	0.42	0.50	0.57	0.73	0.88	1.10	1.20	1.23	1.17	1.13	1.10
Refurbishment Operation & Support	3.08	4.90	6.30	7.51	8.59	11.13	13.32	16.62	18.25	18.58	17.82	17.21	16.71
Spares Replenishment	1.21	1.93	2.48	2.95	3.38	4.38	5.24	6.54	7.18	7.31	7.01	6.77	6.57
Training	0.09	0.15	0.19	0.23	0.26	0.34	0.41	0.51	0.56	0.57	0.55	0.53	0.51
TOTAL OPERATIONS COST	17.60	18.24	19.25	20.43	21.66	25.52	28.84	34.13	36.62	36.92	35.40	34.19	33.19

Spread by GFY	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Flights	32	32	32	32	32	33	33	33	33	33	33	33	
Cum	266	298	330	362	394	427	460	493	526	559	592	625	
OPERATIONS COST													
Program Management	1.06	1.04	1.02	1.00	0.98	0.97	0.96	0.95	0.93	0.92	0.91	0.90	28.62
System Eng. & Int	4.19	4.09	4.00	3.93	3.86	3.84	3.78	3.73	3.68	3.63	3.59	3.55	112.43
SRM & QA	2.10	2.05	2.00	1.96	1.93	1.92	1.89	1.86	1.84	1.82	1.79	1.77	56.22
Other	2.10	2.05	2.00	1.96	1.93	1.92	1.89	1.86	1.84	1.82	1.79	1.77	56.22
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	28.40	27.72	27.13	26.61	26.14	26.48	26.07	25.70	25.36	25.04	24.75	24.47	587.41
Launch Operations & Support	1.33	1.30	1.27	1.25	1.22	1.24	1.22	1.21	1.19	1.17	1.16	1.15	26.99
Flight Operations & Support	1.75	1.70	1.67	1.64	1.61	1.60	1.58	1.55	1.53	1.51	1.49	1.48	46.85
Recovery Operations & Support	1.14	1.12	1.09	1.07	1.05	1.07	1.05	1.04	1.02	1.01	1.00	0.99	23.21
Refurbishment Operation & Support	17.35	16.94	16.58	16.26	15.97	16.20	15.95	15.72	15.61	15.32	15.14	14.97	351.90
Spares Replenishment	6.83	6.66	6.52	6.40	6.28	6.37	6.28	6.19	6.10	6.03	5.96	5.89	138.47
Training	0.53	0.52	0.51	0.50	0.49	0.50	0.49	0.48	0.48	0.47	0.46	0.46	10.79
TOTAL OPERATIONS COST	34.19	33.37	32.66	32.03	31.47	31.79	31.30	30.86	30.44	30.06	29.71	29.38	739.26

Table 6.3-7. Annual Operations Cost
Gas Generator STME/Derivative STBE Program Core STME
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

Spread by GFY	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Flights	2	4	6	8	10	10	10	10	10	10	10	10	10
	Cum	2	6	12	20	30	40	50	60	70	80	90	100	110
OPERATIONS COST														
Program Management		0.59	0.48	0.43	0.40	0.38	0.35	0.33	0.32	0.31	0.30	0.29	0.29	0.28
System Eng. & Int		2.29	1.89	1.68	1.55	1.47	1.38	1.31	1.26	1.22	1.18	1.15	1.13	1.10
SRM & QA		1.15	0.95	0.84	0.78	0.74	0.69	0.65	0.63	0.61	0.59	0.58	0.56	0.55
Other		1.15	0.95	0.84	0.78	0.74	0.69	0.65	0.63	0.61	0.59	0.58	0.56	0.55
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		2.31	2.95	3.48	3.96	4.41	4.12	3.92	3.76	3.64	3.54	3.45	3.37	3.31
Launch Operations & Support		0.07	0.11	0.15	0.17	0.20	0.18	0.18	0.17	0.16	0.16	0.15	0.15	0.15
Flight Operations & Support		0.96	0.79	0.70	0.65	0.61	0.57	0.54	0.52	0.51	0.49	0.48	0.47	0.46
Recovery Operations & Support		0.06	0.10	0.12	0.15	0.17	0.16	0.15	0.15	0.14	0.14	0.13	0.13	0.13
Refurbishment Operation & Support		0.84	1.38	1.77	2.11	2.41	2.26	2.14	2.06	1.99	1.94	1.89	1.85	1.81
Spares Replenishment		0.36	0.58	0.74	0.89	1.01	0.95	0.90	0.87	0.84	0.81	0.79	0.78	0.76
Training		0.03	0.05	0.06	0.07	0.08	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06
TOTAL OPERATIONS COST		5.22	5.38	5.65	5.98	6.33	5.92	5.63	5.41	5.23	5.08	4.96	4.86	4.75

Spread by GFY	Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
	Flights	10	10	12	12	12	12	12	12	12	12	12	12	
	Cum	120	130	142	154	166	178	190	202	214	226	238	250	
OPERATIONS COST														
Program Management		0.28	0.27	0.28	0.27	0.27	0.26	0.26	0.26	0.25	0.25	0.25	0.25	7.90
System Eng. & Int		1.08	1.07	1.08	1.06	1.05	1.03	1.02	1.01	0.99	0.98	0.97	0.96	30.93
SRM & QA		0.54	0.53	0.54	0.53	0.52	0.52	0.51	0.50	0.50	0.49	0.49	0.48	15.46
Other		0.54	0.53	0.54	0.53	0.52	0.52	0.51	0.50	0.50	0.49	0.49	0.48	15.46
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		3.25	3.19	3.70	3.63	3.58	3.53	3.48	3.44	3.39	3.36	3.32	3.29	87.38
Launch Operations & Support		0.15	0.14	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	3.88
Flight Operations & Support		0.45	0.44	0.45	0.44	0.44	0.43	0.42	0.42	0.41	0.41	0.41	0.40	12.89
Recovery Operations & Support		0.13	0.12	0.15	0.14	0.14	0.14	0.14	0.14	0.13	0.13	0.13	0.13	3.34
Refurbishment Operation & Support		1.78	1.75	2.06	2.03	2.00	1.97	1.94	1.92	1.89	1.87	1.85	1.83	47.36
Spares Replenishment		0.75	0.74	0.87	0.85	0.84	0.83	0.82	0.81	0.80	0.79	0.78	0.77	19.91
Training		0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	1.55
TOTAL OPERATIONS COST		4.67	4.59	5.12	5.04	4.96	4.89	4.82	4.76	4.70	4.65	4.60	4.54	127.76

Table 6.3-8. Annual Operations Cost
Gas Generator STME/Derivative STBE Program Booster Derivative STBE
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

Spread by GFY Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Flights	2	4	6	8	10	10	10	10	10	10	10	10	10
Cum	2	6	12	20	30	40	50	60	70	80	90	100	110
OPERATIONS COST													
Program Management	1.37	1.13	1.00	0.93	0.88	0.82	0.78	0.75	0.72	0.70	0.69	0.67	0.66
System Eng. & Int	5.35	4.42	3.92	3.63	3.43	3.21	3.05	2.93	2.84	2.76	2.69	2.63	2.58
SRM & QA	2.67	2.21	1.96	1.81	1.72	1.60	1.53	1.47	1.42	1.38	1.34	1.31	1.29
Other	2.67	2.21	1.96	1.81	1.72	1.60	1.53	1.47	1.42	1.38	1.34	1.31	1.29
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	5.60	7.21	8.53	9.73	10.84	10.13	9.64	9.26	8.95	8.70	8.49	8.30	8.13
Launch Operations & Support	0.17	0.26	0.34	0.40	0.44	0.43	0.41	0.39	0.38	0.37	0.36	0.35	0.35
Flight Operations & Support	2.23	1.84	1.64	1.51	1.43	1.34	1.27	1.22	1.18	1.15	1.12	1.10	1.07
Recovery Operations & Support	0.14	0.23	0.29	0.35	0.40	0.37	0.35	0.34	0.33	0.32	0.31	0.30	0.30
Refurbishment Operation & Support	2.21	3.53	4.53	5.40	6.18	5.78	5.50	5.28	5.11	4.96	4.84	4.73	4.64
Spares Replenishment	0.85	1.35	1.74	2.07	2.37	2.21	2.11	2.02	1.96	1.90	1.85	1.81	1.78
Training	0.07	0.11	0.14	0.16	0.18	0.17	0.16	0.16	0.15	0.15	0.14	0.14	0.14
TOTAL OPERATIONS COST	12.38	12.86	13.60	14.45	15.33	14.33	13.63	13.10	12.67	12.31	12.00	11.74	11.51

Spread by GFY Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
Flights	10	10	12	12	12	12	12	12	12	12	12	12	
Cum	120	130	142	154	166	178	190	202	214	226	238	250	
OPERATIONS COST													
Program Management	0.65	0.64	0.64	0.63	0.62	0.61	0.61	0.60	0.59	0.59	0.58	0.57	18.43
System Eng. & Int	2.53	2.49	2.53	2.48	2.44	2.41	2.38	2.35	2.32	2.29	2.27	2.25	72.16
SRM & QA	1.26	1.24	1.26	1.24	1.22	1.20	1.19	1.17	1.16	1.15	1.13	1.12	36.08
Other	1.26	1.24	1.26	1.24	1.22	1.20	1.19	1.17	1.16	1.15	1.13	1.12	36.08
Facilities Maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support	7.99	7.86	9.10	8.95	8.81	8.68	8.56	8.44	8.36	8.26	8.17	8.09	214.79
Launch Operations & Support	0.34	0.33	0.39	0.39	0.38	0.38	0.37	0.37	0.36	0.36	0.35	0.35	9.06
Flight Operations & Support	1.05	1.04	1.05	1.03	1.02	1.00	0.99	0.98	0.97	0.96	0.95	0.94	30.07
Recovery Operations & Support	0.29	0.29	0.34	0.33	0.33	0.32	0.32	0.32	0.31	0.31	0.30	0.30	7.79
Refurbishment Operation & Support	4.56	4.48	5.29	5.20	5.12	5.04	4.98	4.91	4.86	4.80	4.75	4.70	121.38
Spares Replenishment	1.75	1.72	2.02	1.99	1.96	1.93	1.91	1.88	1.86	1.84	1.82	1.80	46.49
Training	0.14	0.13	0.16	0.16	0.15	0.15	0.15	0.15	0.14	0.14	0.14	0.14	3.62
TOTAL OPERATIONS COST	11.30	11.11	12.43	12.22	12.03	11.85	11.70	11.55	11.41	11.28	11.16	11.05	309.00

Table 6.3-9. *Annual Operations Cost*
Gas Generator STME/Derivative STBE Program Combined Core and Booster Engines
Scenario 2, Minimum Flight Schedule (Millions of FY87$)

Spread by GFY	Year	1999	2000	2001	2002	2003	2004	2005	2006	2007
	Flights	2	4	6	8	10	10	10	10	10
	Cum	2	6	12	20	30	40	50	60	70
OPERATIONS COST										
Program Management		1.96	1.62	1.43	1.32	1.25	1.17	1.11	1.07	1.03
System Eng. & Int		7.64	6.31	5.61	5.18	4.90	4.58	4.36	4.19	4.05
SRM & QA		3.82	3.16	2.80	2.59	2.45	2.29	2.18	2.09	2.03
Other		3.82	3.16	2.80	2.59	2.45	2.29	2.18	2.09	2.03
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		7.91	10.16	12.02	13.69	15.24	14.25	13.55	13.02	12.59
Launch Operations & Support		0.24	0.38	0.48	0.58	0.66	0.62	0.59	0.56	0.54
Flight Operations & Support		3.18	2.63	2.34	2.16	2.04	1.91	1.82	1.75	1.69
Recovery Operations & Support		0.20	0.32	0.42	0.50	0.57	0.53	0.50	0.48	0.47
Refurbishment Operation & Support		3.08	4.90	6.30	7.51	8.59	8.03	7.64	7.34	7.10
Spares Replenishment		1.21	1.93	2.48	2.95	3.38	3.16	3.01	2.89	2.79
Training		0.09	0.15	0.19	0.23	0.26	0.25	0.23	0.23	0.22
TOTAL OPERATIONS COST		17.60	18.24	19.25	20.43	21.66	20.25	19.26	18.51	17.90

Spread by GFY	Year	2008	2009	2010	2011	2012	2013	2014	2015	2016
	Flights	10	10	10	10	10	10	12	12	12
	Cum	80	90	100	110	120	130	142	154	166
OPERATIONS COST										
Program Management		1.01	0.98	0.96	0.94	0.92	0.91	0.92	0.91	0.89
System Eng. & Int		3.94	3.84	3.75	3.68	3.61	3.55	3.61	3.55	3.49
SRM & QA		1.97	1.92	1.88	1.84	1.81	1.78	1.80	1.77	1.75
Other		1.97	1.92	1.88	1.84	1.81	1.78	1.80	1.77	1.75
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		12.26	11.94	11.67	11.44	11.26	11.06	12.79	12.58	12.38
Launch Operations & Support		0.53	0.52	0.50	0.49	0.49	0.48	0.56	0.55	0.55
Flight Operations & Support		1.64	1.60	1.56	1.53	1.51	1.48	1.50	1.48	1.45
Recovery Operations & Support		0.46	0.44	0.43	0.43	0.42	0.41	0.48	0.48	0.47
Refurbishment Operation & Support		6.90	6.73	6.50	6.45	6.35	6.23	7.35	7.23	7.11
Spares Replenishment		2.72	2.65	2.69	2.54	2.49	2.45	2.89	2.84	2.80
Training		0.21	0.21	0.20	0.20	0.19	0.19	0.23	0.22	0.22
TOTAL OPERATIONS COST		17.39	16.94	16.59	16.26	15.97	15.70	17.55	17.25	16.99

Spread by GFY	Year	2017	2018	2019	2020	2021	2022	2023	Total
	Flights	12	12	12	12	12	12	12	
	Cum	178	190	202	214	226	238	250	
OPERATIONS COST									
Program Management		0.88	0.87	0.86	0.85	0.84	0.83	0.82	26.33
System Eng. & Int		3.44	3.40	3.35	3.31	3.28	3.24	3.21	103.09
SRM & QA		1.72	1.70	1.68	1.66	1.64	1.62	1.60	51.54
Other		1.72	1.70	1.68	1.66	1.64	1.62	1.60	51.54
Facilities Maintenance		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Launch		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Test		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Operations & Support		12.21	12.04	11.89	11.75	11.62	11.50	11.38	302.17
Launch Operations & Support		0.54	0.53	0.52	0.52	0.51	0.51	0.50	12.94
Flight Operations & Support		1.43	1.41	1.40	1.38	1.37	1.35	1.34	42.95
Recovery Operations & Support		0.46	0.46	0.45	0.45	0.44	0.44	0.43	11.13
Refurbishment Operation & Support		7.01	6.92	6.83	6.75	6.67	6.60	6.54	168.75
Spares Replenishment		2.76	2.72	2.69	2.66	2.63	2.60	2.57	66.40
Training		0.22	0.21	0.21	0.21	0.20	0.20	0.20	5.18
TOTAL OPERATIONS COST		16.74	16.52	16.31	16.12	15.94	15.77	15.61	436.77

Some of the operations cost elements have a minimum fixed cost which is incurred each year regardless of the number of operational flights flown. Costs for these functional elements are still affected by the number of missions but the effect is not very pronounced. Other costs in operations are variable costs which are a direct function of the number of missions flown. These variable costs result in the annual operations costs increasing significantly as the flight rate increases each year.

There are three flight schedules which were evaluated for the operations cost estimates. The nominal case has 300 total flights, the maximum case has 625 total flights, and the minimum case 250 flights. Tables 6.3-1 through 6.3-3 contain cost estimates for the nominal case. Tables 6.3-4 through 6.3-6 cover the maximum case and Tables 6.3-7 through 6.3-9 cover the minimum case. In addition to the cost estimates, each table has a yearly and cumulative flight schedule at the top of the table. The STME/Derivative STBE operations cost estimates are separated into core engine costs, booster engine costs, and total costs.

The highest annual Operations Cost occurs in years 2003 to 2008 depending on the flight schedule case. The peak cost occurs at that time because of an interaction between mission build-up rate which is increasing annual costs and operating cost improvement which is decreasing annual costs.

6.4 PRODUCT IMPROVEMENT AND SUPPORT PROGRAM

Annual Product Improvement and Support Program (PISP) costs are displayed in Table 6.4-1. The total cost of the program is $739M. This cost is the same for the maximum, minimum, and nominal flight schedule cases. The PISP costs occur over the first seven years of operations with the highest costs in the first three years.

This front loading is necessary so that the PISP design improvements can be incorporated in as many new production engines as possible. The PISP costs are the same for the three flight schedule cases because for the first five years the production engine schedules are the same making the PISP schedules the same.

6.5 TOTAL STME/DERIVATIVE STBE PROGRAM

Time-phased total funding requirements for the nominal, maximum and minimum flight schedule cases of the STME/Derivative STBE program are shown in Tables 6.5-1, 6.5-2, and 6.5-3 respectively. Included are time-phased costs for the booster and core engines for each major portion of the program. The highest annual funding requirements are $658M, $666M, and $658M for the nominal, maximum and minimum cases respectively. These peak funding requirements occur in years 2001 and 2002 when Operational Production costs are near a peak and Operations and PISP costs are at relatively high levels.

Table 6.4-1. *Annual Product Improvement and Support Program Costs Gas Generator STME/Derivative STBE*

Government Fiscal Year / Program	1999	2000	2001	2002	2003	2004	2005	2006	Total
SCENARIO 2 - GG STME/DERIVATIVE STBE (Nominal, Maximum, and Minimum Cases)	147.8	184.8	147.8	110.9	73.9	51.7	22.2	0.0	739.0

Table 6.5-1. *Total Annual Program Costs*
Total STME/Derivative STBE Program
Core and Booster Engines
ALS Scenario 2, Nominal Flight Schedule
(Millions of FY87$)

Government Fiscal Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
WBS ELEMENT																
1.2.2.7.2-1 and 1.2.3.7.2-1 DESIGN & DEVELOPMENT	106.4	231.2	337.7	413.0	376.0	242.0	95.8	30.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NON-RECURRING PRODUCTION																
1.2.3.7.2-2 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	2.1	6.7	14.9	25.0	29.0	25.9	15.6	0.0	0.0	0.0	0.0
1.2.2.7.2-2 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	4.8	14.1	38.1	49.2	60.4	49.6	30.2	0.0	0.0	0.0	0.0
RECURRING PRODUCTION																
1.2.3.7.2-3 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	9.1	34.3	74.7	107.6	135.7	135.1	100.6	45.0	34.2	35.9	25.7
1.2.2.7.2-3 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	17.0	46.7	146.7	210.1	245.1	264.6	190.8	86.0	70.6	70.3	69.0
OPERATIONS																
1.2.3.7.2-4 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.4	5.7	6.0	6.3	6.7	6.3	6.0	5.8
1.2.2.7.2-4 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	12.9	13.6	14.5	15.3	16.2	15.3	14.6	16.1
1.2.2.7.2-x and 1.2.3.7.2-x PRODUCT IMPROVEMENT AND SUPPORT PROGRAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	147.8	184.0	147.0	110.9	73.9	51.7	22.2	0.0	0.0
1.2.2.7.2 and 1.2.3.7.2 TOTAL PROGRAM COST	106.4	231.2	337.7	413.0	376.0	276.6	217.6	479.0	598.9	660.1	606.5	440.8	204.4	150.0	124.9	135.4

Government Fiscal Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
WBS ELEMENT																	
1.2.2.7.2-1 and 1.2.3.7.2-1 DESIGN & DEVELOPMENT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,841.1
NON-RECURRING PRODUCTION																	
1.2.3.7.2-2 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	120.0
1.2.2.7.2-2 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	246.4
RECURRING PRODUCTION																	
1.2.3.7.2-3 CORE ENGINES	30.5	33.2	28.9	23.9	23.8	23.7	23.6	23.5	23.5	23.4	23.1	18.9	18.2	0.0	0.0	0.0	1,044.1
1.2.2.7.2-3 BOOSTER ENGINES	69.4	64.5	61.2	54.0	54.6	54.3	54.1	53.9	53.7	53.6	53.4	43.3	23.7	0.0	0.0	0.0	2,162.2
OPERATIONS																	
1.2.3.7.2-4 CORE ENGINES	5.6	6.1	6.0	5.8	5.7	5.6	5.5	5.4	5.3	5.3	5.2	5.1	5.1	5.0	5.0	4.9	140.1
1.2.2.7.2-4 BOOSTER ENGINES	13.7	14.9	14.5	14.2	13.9	13.6	13.4	13.2	13.0	12.8	12.6	12.5	12.3	12.2	12.1	11.9	339.4
1.2.2.7.2-x and 1.2.3.7.2-x PRODUCT IMPROVEMENT AND SUPPORT PROGRAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	739.1
1.2.2.7.2 and 1.2.3.7.2 TOTAL PROGRAM COST	130.2	120.7	110.6	98.7	98.0	97.2	96.6	96.0	95.5	95.0	94.5	79.0	61.3	17.2	17.0	16.9	6,652.4

Table 6.5-2. *Total Annual Program Costs*
Total STME/Derivative STBE Program
Core and Booster Engines
ALS Scenario 2, Maximum Flight Schedule
(Millions of FY87$)

Government Fiscal Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
WBS ELEMENT																																	
1.2.2.7.2-1 and 1.2.3.7.2-1 DESIGN & DEVELOPMENT	106.4	231.2	337.7	413.0	376.0	242.0	95.0	30.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,041.1
NON-RECURRING PRODUCTION																																	
1.2.3.7.2-2 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	2.1	6.7	16.9	23.0	29.0	28.0	27.3	27.7	25.4	17.1	16.0	11.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	232.0
1.2.2.7.2-2 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	4.0	14.1	30.1	49.2	60.4	56.0	52.1	65.7	49.4	32.0	31.8	21.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	462.1
RECURRING PRODUCTION																																	
1.2.3.7.2-3 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	9.1	34.5	76.7	107.6	135.7	152.4	151.0	132.4	117.5	109.0	107.3	100.5	89.1	75.7	75.3	76.7	69.9	60.9	50.2	49.9	49.7	40.3	22.0	0.0	0.0	0.0	0.0	1,890.0
1.2.2.7.2-3 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	17.8	66.7	145.7	210.1	265.1	290.2	297.9	259.0	230.6	213.6	210.3	204.0	189.0	166.9	147.5	146.4	140.5	130.1	117.2	116.7	116.1	96.4	52.5	0.0	0.0	0.0	0.0	3,838.7
OPERATIONS																																	
1.2.3.7.2-4 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.4	5.7	6.0	6.3	7.4	8.4	9.9	10.6	10.7	10.3	9.9	9.6	9.9	9.7	9.5	9.3	9.1	9.2	9.1	9.0	8.8	8.7	8.6	8.5	214.9
1.2.2.7.2-4 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	12.9	13.6	14.8	15.3	18.1	20.5	24.2	26.0	26.2	25.1	24.3	23.6	24.3	23.7	23.2	22.7	22.5	22.6	22.2	21.9	21.6	21.5	21.1	20.9	624.3
1.2.2.7.2-x and 1.2.3.7.2-x PRODUCT IMPROVEMENT AND SUPPORT PROGRAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	147.0	106.0	147.0	110.9	73.9	61.7	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	739.1
1.2.2.7.2 and 1.2.3.7.2 TOTAL PROGRAM COST	106.4	231.2	337.7	413.0	376.0	276.6	217.6	479.0	592.9	680.1	665.7	624.7	560.8	474.0	466.0	408.8	375.2	314.3	276.8	256.0	255.3	245.8	223.7	199.4	190.1	197.6	166.0	106.4	30.4	30.1	29.7	29.4	9,763.0

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Table 6.5-3. *Total Annual Program Costs*
Total STME/Derivative STBE Program
Core and Booster Engines
ALS Scenario 2, Minimum Flight Schedule
(Millions of FY87$)

Government Fiscal Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	Total
WBS ELEMENT																																	
1.2.2.7.2-1 and 1.2.3.7.2-1 DESIGN & DEVELOPMENT	106.4	231.2	337.7	413.0	376.0	242.0	95.8	38.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,841.1
NON-RECURRING PRODUCTION																																	
1.2.3.7.2-2 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	2.1	6.7	16.9	25.0	29.8	25.4	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	112.9
1.2.2.7.2-2 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	4.8	14.1	38.1	49.2	60.4	49.0	23.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	239.3
RECURRING PRODUCTION																																	
1.2.3.7.2-3 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	9.1	34.3	76.7	107.6	135.7	131.9	92.2	25.3	10.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	621.7
1.2.2.7.2-3 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	17.8	64.7	145.7	210.1	265.1	261.2	190.5	73.0	62.3	62.4	80.5	27.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1,452.8
OPERATIONS																																	
1.2.3.7.2-4 CORE ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.2	5.4	5.7	6.0	6.3	5.9	5.6	5.4	5.2	5.1	5.0	4.9	4.8	4.7	4.6	5.1	5.0	5.0	4.9	4.8	4.8	4.7	4.7	4.6	4.6	120.0
1.2.2.7.2-4 BOOSTER ENGINES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.4	12.9	13.6	14.5	15.3	14.3	13.6	13.1	12.7	12.3	12.0	11.7	11.5	11.3	11.1	12.4	12.2	12.0	11.9	11.7	11.6	11.4	11.3	11.2	11.1	309.0
1.2.2.7.2-x and 1.2.3.7.2-x PRODUCT IMPROVEMENT AND SUPPORT PROGRAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	167.8	104.8	147.8	110.9	73.9	51.7	22.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	739.1
1.2.2.7.2 and 1.2.3.7.2 TOTAL PROGRAM COST	106.4	231.2	337.7	413.0	376.0	276.6	217.6	479.0	595.0	658.1	590.9	410.9	170.2	114.6	80.9	68.4	44.9	17.0	16.6	16.3	16.0	15.7	17.5	17.2	17.0	16.8	16.5	16.4	16.1	16.0	15.8	15.7	5,423.9

SECTION 7.0
PARAMETRIC COST EQUATIONS

This section contains parametric equations which provide performance, development, production and operation costs for the STME/Derivative STBE.

Section 7.1 presents parametric performance data and performance curves covering the STME/Derivative STBE configurations. Performance data is included for the STME and the STBE derivative LO_2/CH_4 gas generator cycle adapted from the LO_2/LH_2 gas generator STME.

Section 7.2 presents parametric cost relationships covering development, production, operations and product improvement and support program costs. Included are ground rules and assumptions which form the basis for the cost estimates.

Also provided for each type of cost are parametric cost curves covering the range and characteristics of the parametric cost equations.

Table 7-1 summarizes the parameters and range of values that can be varied in the parametric equations. The equations are designed to provide performance and costs as engine design parameters are varied from a set of baseline reference characteristics. These baseline reference characteristics which are contained in the equations are shown in Table 7-2.

Table 7-3 lists and defines the acronyms used in the equations.

Table 7-1. *STME/Derivative STBE Parameter Variables*

Input Parameter	*STME*	*Applicable Range*	*Derivative STBE*
Engine Maximum, Thrust Level, lbf vacuum	400-800K		200K-1,000K
Chamber Pressure, psia	800-3,000		1,400-2,400
Nozzle Area Ratio, Overall	20-100		20-50
Throttling Capability		100-50% thrust	
Fuel Pump Minimum Inlet Pressure		20-50 psi	
LO_2 Pump Minimum Inlet Pressure		40-100 psi	
Mixture Ratio	5.0-7.0		2.3-3.7
Total Engine Quantity		100-2,000 engines	
Nominal Lot Size*		10-200 engines/year	
Number of Engines/Stage		1-5 core; 3-10 booster	
Launch Rate		10-450 engines/year	
Number of Reuses		0-25 missions/engine	

*Annual Production Rate Effect included with lot size.

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7.1 PERFORMANCE PARAMETRICS

These performance parametrics have been provided in this cost volume to supplement the cost parametrics presented in Section 7.2. This inclusion enhances the usability of the cost parametrics since some of the parameters described by the cost equations must be derived from the performance parametrics.

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Table 7-2. Baseline STME/Derivative STBE Parameter Reference Values

	STME	Derivative STBE
Thrust Level, lbf Vacuum	580K	712K
Mixture Ratio	6.0	2.7
Chamber Pressure, psia	2,250	2,250
Area Ratio: Overall	62	28
Regen Nozzle	35	—
Fuel NPSP, psi	8.5	—
Oxidizer NPSP, psi	30.8	—
Throttle Capability, (% thrust)	2-step (100 and 75%)	2-step (100 and 75%)
Number of Engines/Stage	3-Core	7-Booster
Production Lot Size	100	100
Control System	Open Loop	Open Loop

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Table 7-3. STME/Derivative STBE Performance and Cost Parametric Equation Variable and Acronym Definitions

AR	Overall Nozzle Area Ratio
AR_R	Regeneratively Cooled Nozzle Exit Area Ratio
AR_E	Nozzle Extension Exit Area Ratio
BLS	Booster Lot Size
CCAP	Corrected Cumulative Average Engine Production Cost, M$/Engine For Any Number of Engines or Lot Size
CIPC	Component Improvement Program Costs, M$
CLS	Core Lot Size
DC	Total Development Cost, M$
DPB	Total Number of Production Engines (Booster) in Development Program
DPC	Total Number of Production Engines (Core) in Development Program
DPE	Total Number of Production Engines (Booster and Core) in Development Program
ENVH	Number of engines Per Vehicle (Booster and Core)
FPY	Vehicle Flights Per Year
FVAC(Fn)	Engine Design Thrust: K lbf
GG	Gas Generator Cycle
ISP	Vacuum Specific Impulse
NB	Number of Engines Per Booster Stage
NC	Number of Engines Per Core Stage
NPSP	Net Positive Suction Pressure
OC	Engine Operations Cost, M$/Engine/Flight
OF(MR)	Engine Mixture Ratio
PC	Chamber Pressure, psia
PISP	Product Improvement and Support Program
SE	Split Expander Cycle
TFU	Theoretical First Unit Production Cost, M$/Engine, LS = 100
TLS	Total Lot Size
TNB	Total Number of Booster Engines
TNC	Total Number of Core Engines
TNE	Total Number of Production Engines (Booster and Core)
TOB	Total Number of Operational Production Booster Engines
TOC	Total Number of Operational Production Core Engines
TOE	Total Number of Operational Production Engines (Booster and Core)
TPC	Total Production Cost, M$
β	Learning Curve Slope (90% = −0.152)

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Table 7.1-1 shows the STME performance equations. Since this engine is used on the core stage, it includes the film cooled nozzle extension.

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***Table 7.1-1.** STME LO_2/H_2 Gas Generator Parametrics — STME (LO_2/H_2) Engine With Film Cooled Nozzle Extension*

Max Area Ratio	=	$1.28 + 0.0355\,(P_C) - 1.2 \times 10^{-6}\,(P_C)^2$
I_{sp}	=	$290.4 + 67.62\,(OF) - 6.20\,(OF)^2$ $-189.1\,OF/AR - 0.301\,(P_C)^{0.5}$
Nozzle Dia, in.	=	$108.0\,(F_{VAC}/580000)^{0.5} \times (AR/62.)^{0.5} \times (2250/P_C)^{0.5}$
Overall Length, in.	=	$134.7\,(2250/P_C)^{0.5} \times (F_{VAC}/580000)^{0.5}\,(OF/6.0)^{-0.228}\,(AR/62)^{0.644}$ $+ 20\,(OF/6.0)^{2.7}\,(P_C)/2250)^{-0.59}\,(F_{VAC}/580000)^{0.635}$ $+ 1.27\,(F_{VAC}/P_C)^{0.5}$
Powerhead Dia, in.	=	$0.002682\,[\,(F_{VAC})^{0.5}(P_C)^{0.472}\,]\,/\,[\,(Fuel\ NPSP)^{0.503}\,]$ $+ 0.0166\,[\,(F_{VAC})^{0.5}\,(P_C)^{0.376}\,]\,/\,[\,(LO_2\ NPSP)^{0.609}\,]$ $+ 2.61\,(F_{VAC}/P_C)^{0.5}$
Weight	=	$5491\,(F_{VAC}/580000)^{0.875}\,(OF/6.0)^{0.0127}\,(P_C/2250)^{0.0915}$ $+ A\,[3.182\,(F_{VAC}\,AR/P_C) + 2156 \times 10^{-4}\,(F_{VAC})]$ Where $A = 0.42$ When $1000 \le P_C \le 1100$ $A = 0.67$ When $1100 \le P_C \le 1800$

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Figures 7.1-1 through 7.1-3 show STME design characteristics as vacuum thrust, area ratio and chamber pressure are varied. These curves were generated from the parametric performance equations.

The Derivative STBE characteristics are dependent upon the STME engine from which it is derived. Table 7.1-2 shows the Derivative STBE performance relationships.

7.2 COST PARAMETRICS

The cost parametrics included in this section are Development Cost, Operational Production Cost, Operations Cost and Product Improvement and Support Program (PISP) costs.

The Derivative STBE has been designed to use as many of the STME components as possible. Because of this commonality, costs for the STBE configurations are driven directly by costs for the STME design.

The parametric cost equations are based on maintaining this commonality between the STME and STBE engines. The equations are set up for the user to select and input variables such as thrust, chamber pressure, area ratio, etc. for the core STME. Costs for both the STME and the booster Derivative STBE that falls out from the selected STME configuration are then provided by the equations. The equations cannot be used to obtain costs for Derivative STBE engines that do not have the same commonality as in the baseline STBE design.

Because common engine components will have larger quantities and more cost improvement benefits than uncommon components, the production cost equations separate production costs into these two categories. This permits the user to include the different quantity effects in his cost studies. Separate STME and Derivative STBE development and operations costs are generated by the equations and these costs must be combined to obtain total program costs.

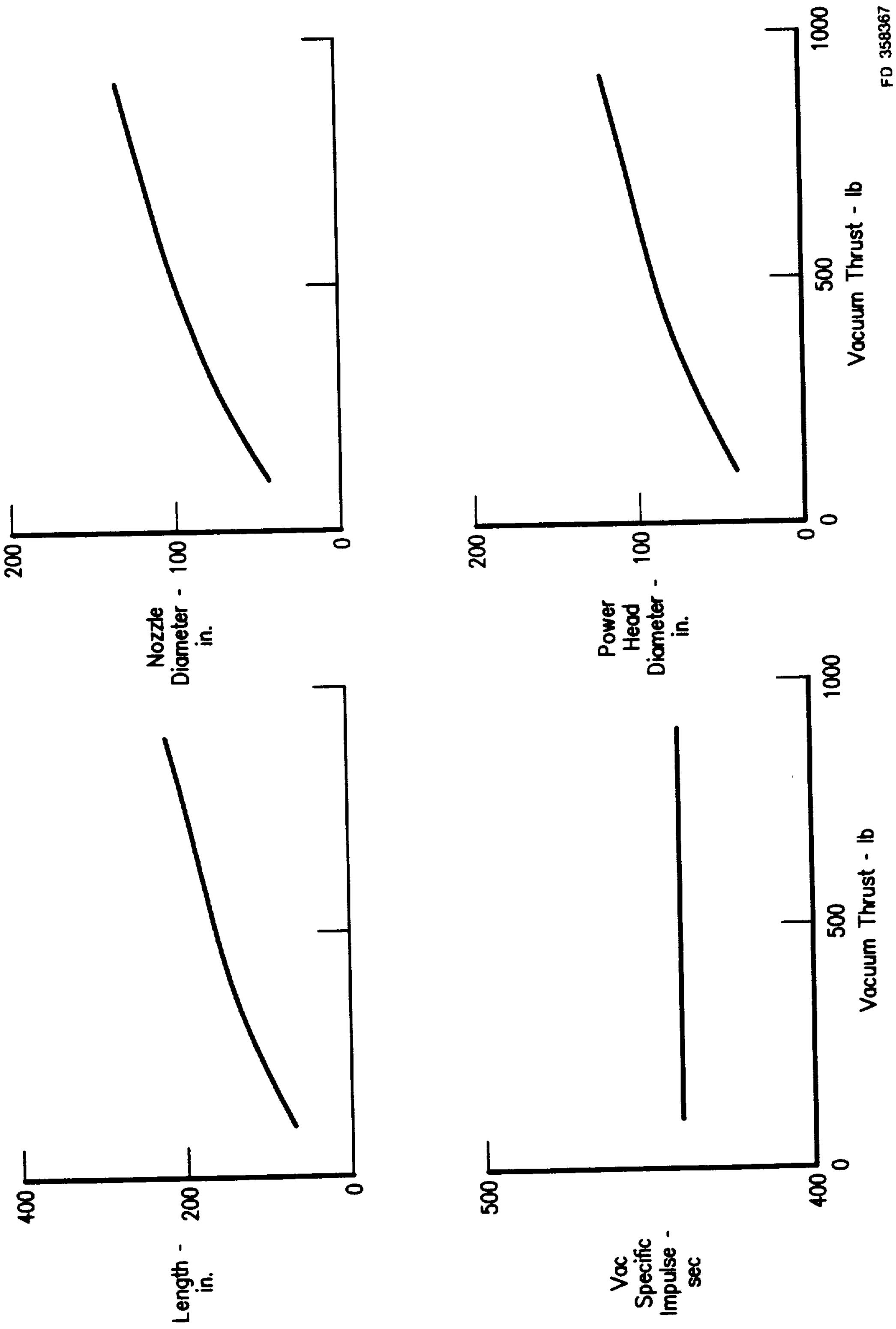

Figure 7.1-1. Vacuum Thrust Curves for STME (LO_2/H_2) Parametrics, Gas Generator Cycle, P_c = 2250 psia, AR = 62

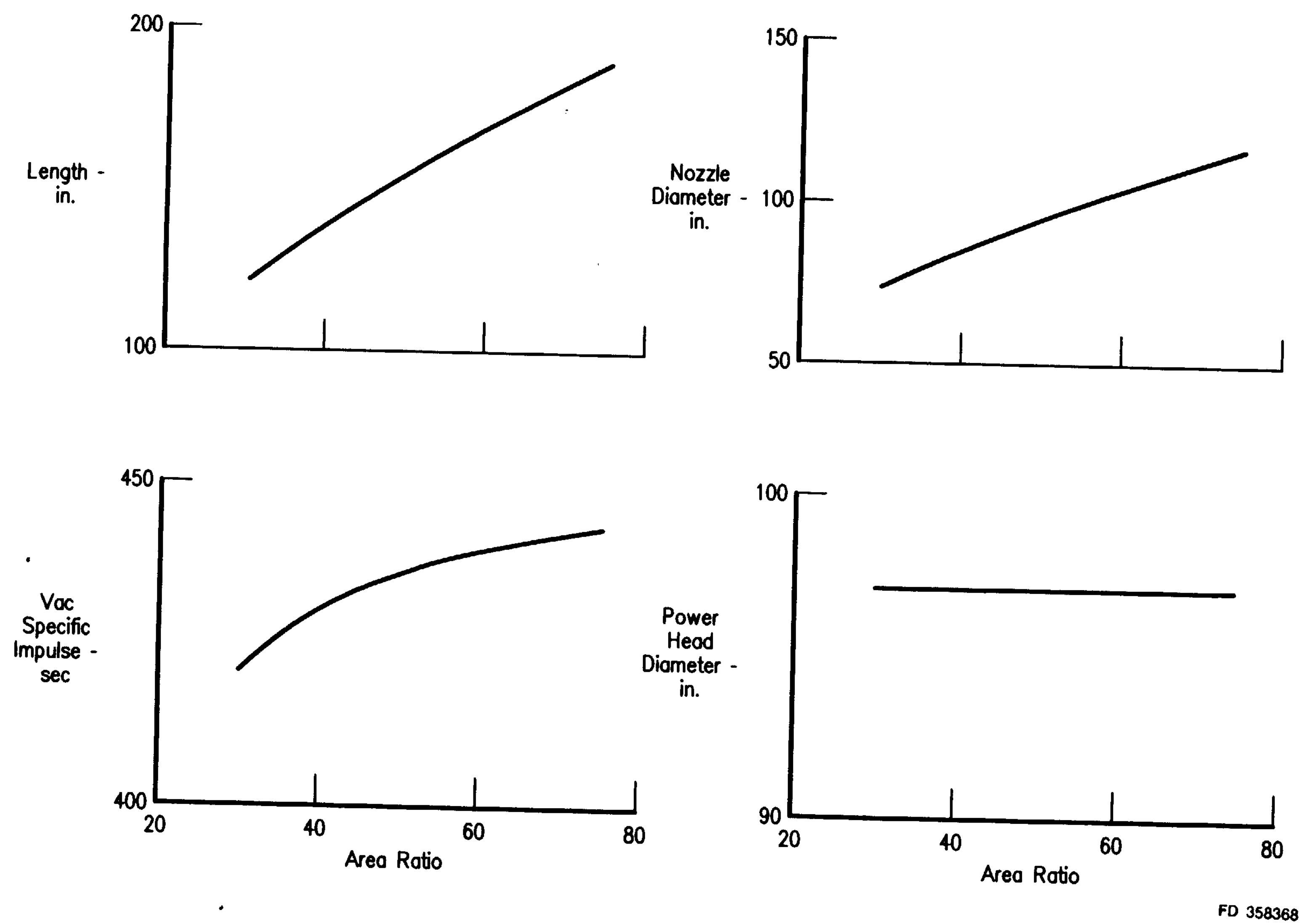

Figure 7.1-2. Area Ratio Curves for STME (LO_2/H_2) Parametrics, Gas Generator Cycle, P_c = 2250 psia, Thrust = 580K

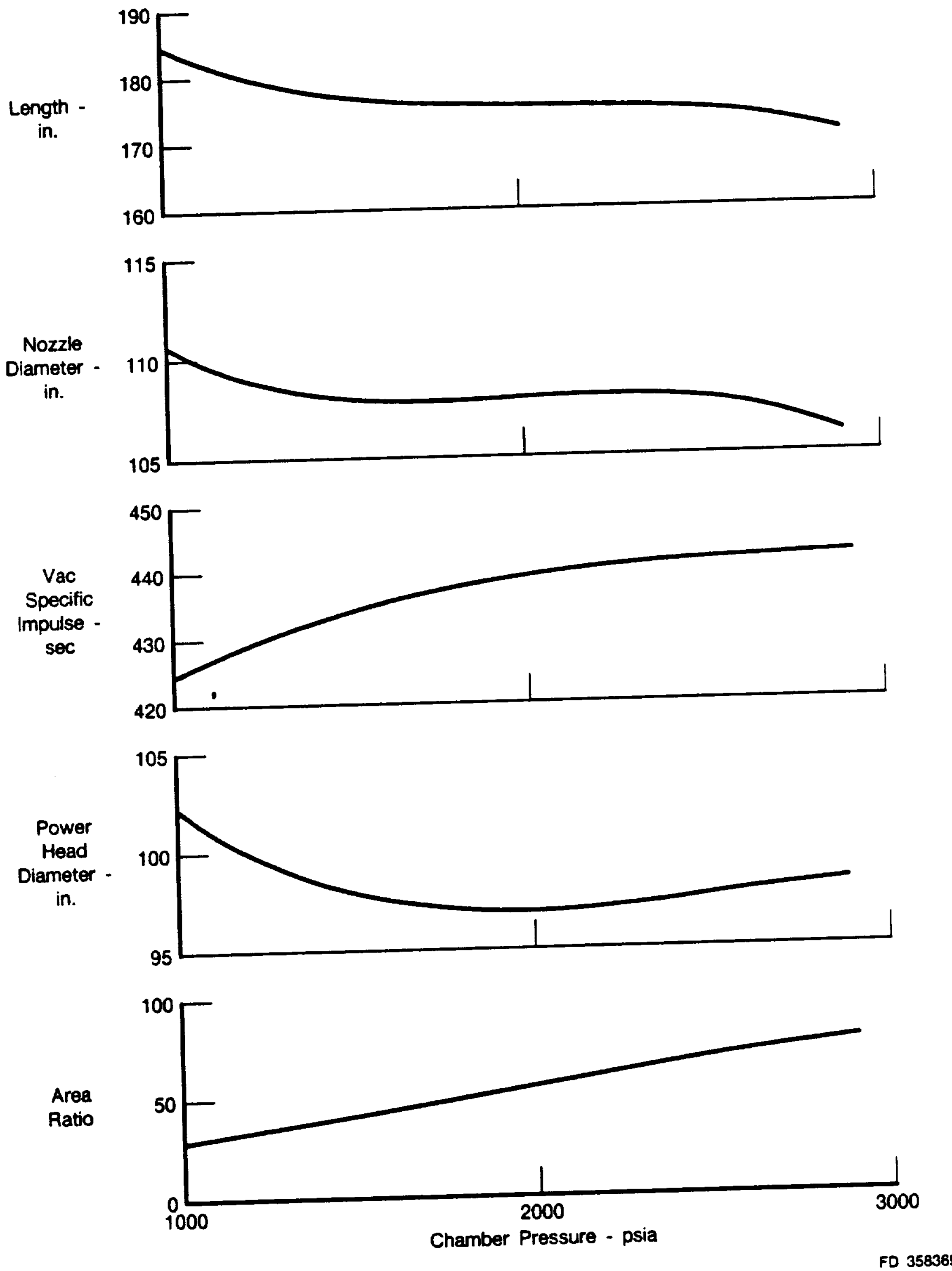

Figure 7.1-3. Chamber Pressure Curves for STME (LO_2/H_2) Parametrics, Gas Generator Cycle, Optimum AR, Thrust = 580K

Table 7.1-2. Derivative STBE Gas Generator Parametrics

Vacuum Thrust (F_{VAC})	= 1.23 × STME Vacuum Thrust
Area Ratio (AR)	= 0.80 × STME Regen Exit AR
Chamber Pressure (P_C)	= 1.00 × STME
Mixture Ratio (OF)	= 2.3 to 3.7
I_{sp}(VAC)	$= -319.7 - 182.2(OF) - 130.6\left(\frac{OF}{AR}\right) + 689.6\sqrt{OF} + 1.638\sqrt{AE} + 0.0048\,(P_C)$
Nozzle Diameter (in.)	$= 88.0\left(\frac{F_{VAC}}{711823}\right)^{0.5}\left(\frac{AR}{28}\right)^{0.5}\left(\frac{2250}{P_C}\right)^{0.6}$
Engine Length (in.)	$= 69.6\left(\frac{Dia}{88.0}\right)^{1.14}\left(\frac{711823}{F_{VAC}}\right)^{0.07}\left(\frac{AE}{28}\right)^{0.05} + 3.02 \times 10^{-5}\,(F_{VAC}) + 12.0$

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Production cost equations provide recurring engine production costs for the operational production engines. Both Theoretical First Unit and Cumulative Average Production costs can be calculated form the equations. Included in the production costs are the following cost elements:

Program Management
System Engineering and Integration
Facilities Maintenance
Tooling Maintenance
Hardware Manufacturing
Integration, Assembly and Test
Acceptance Test.

Development costs generated by the equations include contractor costs for the following functional elements:

Program Management
System Engineering and Integration
Engine Design and Development
Engine Test (including components)
Flight Test Hardware
MPTA Test Hardware
Facilities
Software Engineering
General Support Equipment
Tooling
Special Test Equipment
Operations and Support (Launch, Flight, Recovery and Refurbishment).

Operations costs provided by the equations include the following operational cost elements:

Program Management
System Engineering and Integration

Facilities Maintenance
Operations and Support
Training.

Separate equations are included in this package to estimate the costs of Product Improvement and Support programs for the engines.

Government furnished test facilities and propellants are not included in any of the costs provided by the equations.

7.2.1 Ground Rules and Assumptions

The cost estimates provided by the equations are based on the following ground rules or assumptions.

Parameter	*Ground Rules or Assumptions*
Costs	Constant FY87 Dollars
Profit or Fee	Not Included
Management Reserve	Not Included
Development Program	90 months (7½ years)
Development Engine Tests	960 Firings STME; 488 Firings STBE
Demonstrated Reliability at First Flight Test	0.99 @ 90% Confidence
Propellants	Government Furnished (Not Included)
Engine Test Facilities	Government Furnished (Not Included)
Major Component Test Facilities	Government Furnished (Not Included)
Small Component Test Facilities	Contractor Furnished
MPTA Engines	1 Set + 33% Spares
Flight Test Engines	2 Sets + 33% Spares
Core Gas Generator STME	Operated With Nozzle Skirt
Booster Gas Generator STBE	Operated With Nozzle Skirt Removed
Thrust and Mixture Ratio Setting Accuracy	±3% for Thrust at 75% and 100% Fn and ±3% for MR at 75% Fn only
Production Engine Assembly	At SSC
Engine Acceptance Test	At SSC ($400K/Engine)
Production Learning Rate	90% Crawford
Operational Engine Recovery	Water Landing (Engine Subjected to Salt Air Environment Only)
Engine Maintenance	3 Level
On Launch Pad	LRU Replacement; Prelaunch Checkout
At ESMC Engine Shop	Component Replacement; Turn-Around Refurbishment
At Contractor Depot (SSC)	Component/Engine Rebuild

7.2.2 Operational Production Costs

The production cost equations can be used to determine the Theoretical First Unit (TFU) cost and the total recurring production cost as a function of a number of design and programatic variables. These variables include thrust size, chamber pressure, overall nozzle area ratio (with two-piece nozzle), throttle range, number of booster and core engines per vehicle, total quantity of production engines, cost improvement slope and lot size (which includes production rate effects). Over the ranges considered, variables such as gas generator temperature, design mixture ratio and the number of engine reuses do not have a significant impact on engine production cost and they have not been included in the equations.

To calculate TFU's for each engine under consideration, up to five supplementary equations are presented in Table 7.2-1, each containing a constant which is a function of the chamber pressure range selected, or whether the TFU is for Common parts, Core Uncommon parts or Booster Uncommon parts. These five supplementary equations are set up for the STME configuration (PC, FVAC, AR, etc.) and they require STME input parameters. TFU differences between the STME Core engine and Derivative STBE Booster engine are taken care of in the TFU equations, also in Table 7.2-1. The production cost constants used to calculate the TFU equations are presented in Tables 7.2-2 and 7.2-3. The constant A in Table 7.2-2, is not chamber pressure sensitive, so it is used as presented for all chamber pressure ranges. The control constants in Table 7.2-3 are added to the calculated TFUs.

Table 7.2-1. *Production Cost Equations for the STME/Derivative STBE GG Engine*

Equation (1) $= A\left(\frac{F_{VAC}}{580}\right)^{0.4}\left(\frac{2250}{P_C}\right)^{0.04}$

Equation (2) $= B\left(\frac{F_{VAC}}{580}\right)^{0.4}\left(\frac{2250}{P_C}\right)^{0.12}$

Equation (3) $= C_1\,(2.1147)\left(\frac{F_{VAC}}{580}\right)\left(\frac{2250}{P_C}\right)(AR)^{1.083}\left(\frac{3.636 + 0.01407 \times P_C}{AR}\right)^{1.366}$

Equation (4) $= C_2\,(2.506)\left(\frac{F_{VAC}}{580}\right)\left(\frac{2250}{P_C}\right)(AR)^{1.083}\left[1 - 0.844\left(\frac{3.636 + 0.01407 \times P_C}{AR}\right)^{1.366}\right]$

Equation (5) = D, f (Engine Configuration and Whether Parts Are Common or Uncommon)

For Core Application:

Core Common $TFU_{M87\$}$ = Equation (1) × (0.7235) + Equation (3) + Equation (5)

Core Uncommon $TFU_{M87\$}$ = Equation (1) × (0.2765) + Equation (2) + Equation (4) + Equation (5)

TFU_{Core} = Core Common TFU + Core Uncommon TFU

For Booster Application:

Booster Common $TFU_{M87\$}$ = Equation (1) × (0.7235) + Equation (3) + Equation (5)

Booster Uncommon $TFU_{M87\$}$ = Equation (1) × (0.3264) + Equation (2) × (1.12) + Equation (5)

$TFU_{Booster}$ = Booster Common TFU + Booster Uncommon TFU

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Table 7.2-2. *Production Cost Constants for the STME/Derivative STBE GG Core and Booster Applications With Dual Run Point Control*

		800 < P_C ≤ 1100 psia			*1100 ≤ P_C < 1800 psia*			*1800 ≤ P_C ≤ 3000 psia*		
	A	*B*	*C_1*	*C_2*	*B*	*C_1*	*C_2*	*B*	*C_1*	*C_2*
Core Booster	6.121	0.136	0.00925	0.00592	0.467	0.00406	0.00592	0.585	0.00406	0.00789
Common:		D = 2.187			D = 2.280			D = 2.280		
Core Uncommon:		D = 0.542			D = 0.542			D = 0.964		
Booster Uncommon:		D = 0.594			D = 0.594			D = 0.594		

Notes:
1. When Constants Are Used as Presented, Resulting Costs Are in MFY87$
2. Costs Do Not Include Management Reserve or Profit
3. All Costs Generated by These Equations Are Engineering Estimates. These Costs Should Not Be Considered as Contractual Commitments and Should Be used for Life Cycle Cost (LCC) Evaluations and Planning Purposes Only.

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Table 7.2-3. Production Cost Control System Cost Impacts Applicable to STME/Derivative STBE Gas Generator Engines

	Fn Accuracy	*MR Accuracy*	*Control Type*	*Production TFU Cost Impact MFY87$*
Baseline (Two Run Points)	±3% (100 and 75% Fn)	±3% (75% Fn Only)	Open Loop	
Two Run Points	±3% (100 and 75% Fn)	±3% (100 and 75% Fn)	Open Loop	+0.025M
Single Run Point	±3% (100% Fn)	±3% (100% Fn)	Open Loop	Same Cost As Baseline
Continuously Variable	±3% (100 - 75% Fn)	±3% (100 - 75% Fn)	Open Loop	+0.025M
Continuously Variable	±3% (100 - 50% Fn)	±3% (100 - 50% Fn)	Open Loop	TBD
Two Run Points	±1% (100 and 75% Fn)	±1% (100 and 75% Fn)	Closed Loop	TBD
Continuously Variable	±1% (100 - 75% Fn)	±1% (100 - 75% Fn)	Closed Loop	TBD
Continuously Variable	±1% (100 - 50% Fn)	±1% (100 - 50% Fn)	Closed Loop	TBD

Note: This production TFU cost change applies to TFU values used in all cost equations.

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By solving the numbered equations and combining them as shown under the TFU equations, the Theoretical First Unit cost in millions of FY87 dollars can be determined.

The first quantity of production engines will be manufactured during the DDT&E phase with the associated costs reported under the DDT&E program costs. The TFU cost used in calculating operational production cost is defined as the first unit cost for those engines produced under the DDT&E phase. The Corrected Cumulative Average Production Costs (CCAP) for the operational production engines manufactured during the production phase are first determined individually for Common Core and Booster, Uncommon Core and Uncommon Booster components. They are then combined to give the STME Core CCAP and Derivative STBE Booster CCAP values.

The following equations show how the CCAP's are calculated.

Common (Core and Booster) Parts

$$\text{CCAP} = \frac{\left\{\left[\frac{(\text{TFU} - 0.4)(\text{TNE})^{\beta}}{\beta + 1}\right]\text{TNE} - \left[\frac{(\text{TFU} - 0.4)(\text{DPE})^{\beta}}{\beta + 1}\right]\text{DPE}\right\}\left\{\left(\frac{\text{TLS}}{100}\right)^{-0.08}\right\} + 0.4}{\text{TOE}}$$

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Where: TFU — Theoretical First Unit for Core and Booster common parts, M87$
DPE — Number of Production Engines (Core and Booster) Manufactured During DDT&E Phase
TOE — Total Number of Operational Production Engines (Core and Booster)
TNE — Total Number of Production Engines (Core and Booster)
TLS — Total Lot Size (Core and Booster)
β — Learning Curve Slope, P&W expected value is 90% = −0.152.

Uncommon Core Parts

$$CCAP = \frac{\left\{\left[\frac{(TFU)(TNC)^{\beta}}{\beta + 1}\right] TNC - \left[\frac{(TFU)(DPC)^{\beta}}{\beta + 1}\right] DPC\right\}\left\{\left(\frac{CLS}{100}\right)^{-0.08}\right\}}{TOC}$$

Where: TFU — Theoretical First Unit for Uncommon Core Parts, M87$
DPC — Number of Production Core Engines Manufactured During DDT&E Phase
TOC — Total Number of Operational Production Core Engines
TNC — Total Number of Production Core Engines
CLS — Core Lot Size
β — Learning Curve Slope, P&W expected value is 90% = −0.152.

Uncommon Booster Parts

$$CCAP = \frac{\left\{\left[\frac{(TFU)(TNB)^{\beta}}{\beta + 1}\right] TNB - \left[\frac{(TFU)(DPB)^{\beta}}{\beta + 1}\right] DPB\right\}\left\{\left(\frac{BLS}{100}\right)^{-0.08}\right\}}{TOB}$$

Where: TFU — Theoretical First Unit for Uncommon Booster Parts, M87$
DPB — Number of Production Booster Engines Manufactured During DDT&E Phase
TOB — Total Number of Operational Production Booster Engines
TNB — Total Number of Production Booster Engines
BLS — Booster Lot Size
β — Learning Curve Slope, P&W expected value is 90% = −0.152.

The following equations define the parameters used in the above CCAP equations:

DPE = DPC + DPB
DPC = 4 + 4 (NC)
DPB = 4 + 4 (NB)
TOE = TOC + TOB
TNC = DPC + TOC
TNB = DPB + TOB
TNE = DPE + TOE.

Total Corrected Cumulative Average Production Costs for the STME Core engine and Derivative STBE Booster Engines can be calculated using the following equations:

$$CCAP_{Core} = CCAP_{Common} + CCAP_{Uncommon}$$

$$CCAP_{Booster} = CCAP_{Common} + CCAP_{Uncommon}.$$

Total Production Cost can be calculated using the following equation:

$$TPC = CCAP_{Core} \times TOC + CCAP_{Booster} \times TOB.$$

Figures 7.2-1 through 7.2-3 depict the relationship between Production Cost (TFU) for both Core and Booster Space Transportation Engines and STME Pc, Overall Area Ratio, and Vacuum Thrust. The STBE is a fallout of these STME variations. For the Pc variation an Optimum Core Vehicle Area Ratio is used.

7.2.3 Design and Development Costs

The development cost equations can be used to determine total Contractor development costs as a function of a number of design variables. These variables include thrust size, chamber pressure, overall nozzle area ratio (with two-piece nozzle), throttle range, and the number of booster engines and core engines per vehicle. Gas generator temperature, design mixture ratio and the number of engine reuses, over the ranges shown, do not have a significant impact on engine development cost.

For each type of engine under consideration, four supplementary equations are provided (Table 7.2-4). Constant values for the equations are found in Tables 7.2-5 and 7.2-6 for each engine. The control cost constants in Table 7.2-6 are added to the calculated development costs. By solving the numbered equations and combining them as shown, Contractor Development Costs in millions of FY87 dollars can be determined for the STME Core and Derivative STBE Booster engines. Total Contractor Development cost can then be obtained by combining the individual STME Core and Derivative STBE Booster development costs.

Theoretical First Unit values and the total number of production engines manufactured during the DDT&E phase, should be taken from the Production Cost section.

Figures 7.2-4 through 7.2-6 depict the relationship between Development Cost for both Core and Booster Space Transportation Engines and STME Pc, Overall Area Ratio, and Vacuum Thrust. The STBE is a fallout of these STME variations. For the Pc variation an Optimum Core Vehicle Area Ratio is used.

7.2.4 Operations Costs

Operations Costs include all of the recurring operational costs associated with the Space Transportation Engines for the Advanced Launch System. The following cost elements are addressed within the parametric equations: Program Management, Systems Engineering and Integration, Facilities Maintenance, Operations and Support, and Training. Product improvement and support costs are not addressed here as they are addressed in another section. Propellants are Government furnished and no propellant costs have been included in the operations cost.

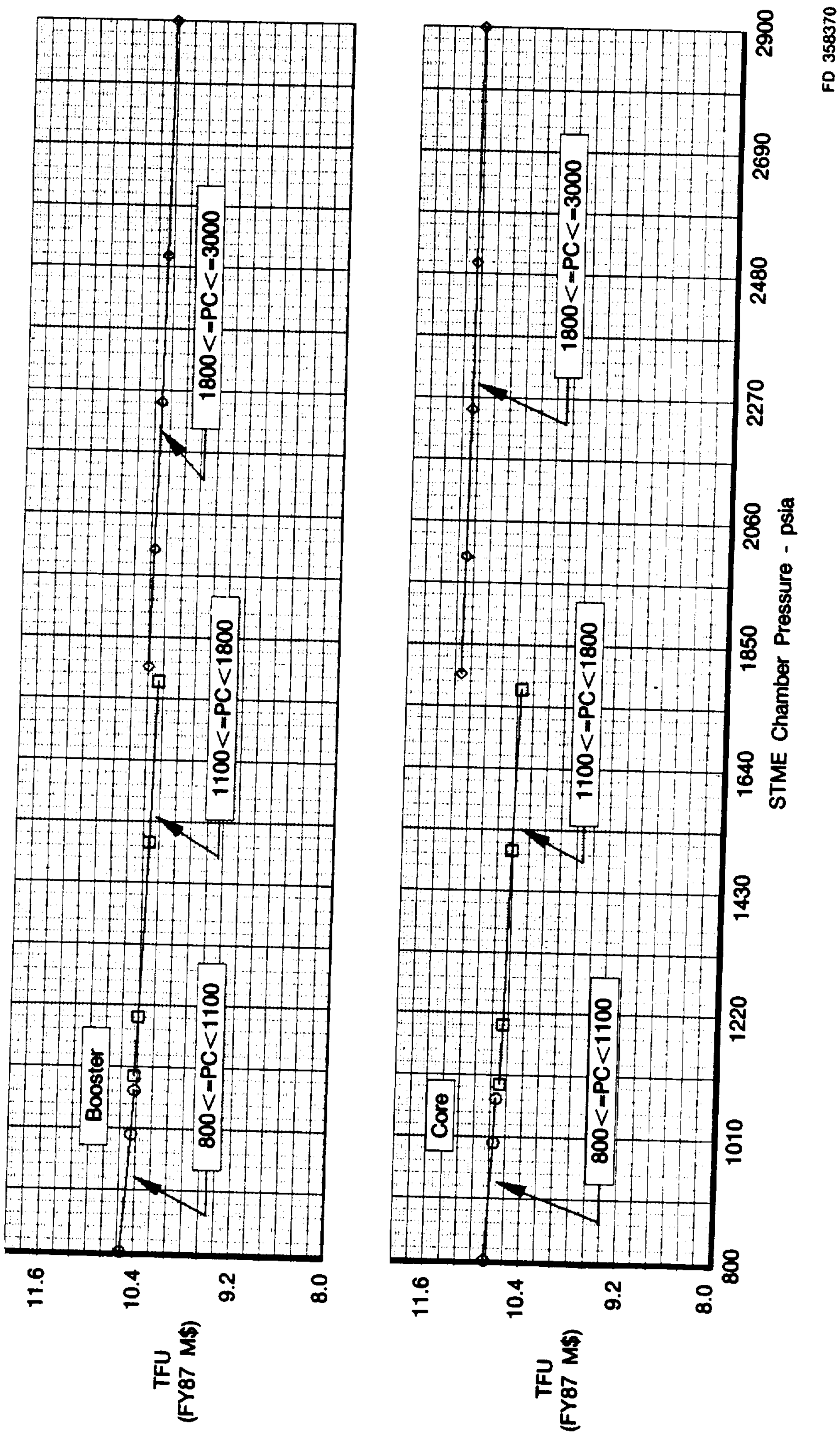

Figure 7.2-1. STME/Derivative STBE Gas Generator Theoretical First Unit Cost vs Chamber Pressure

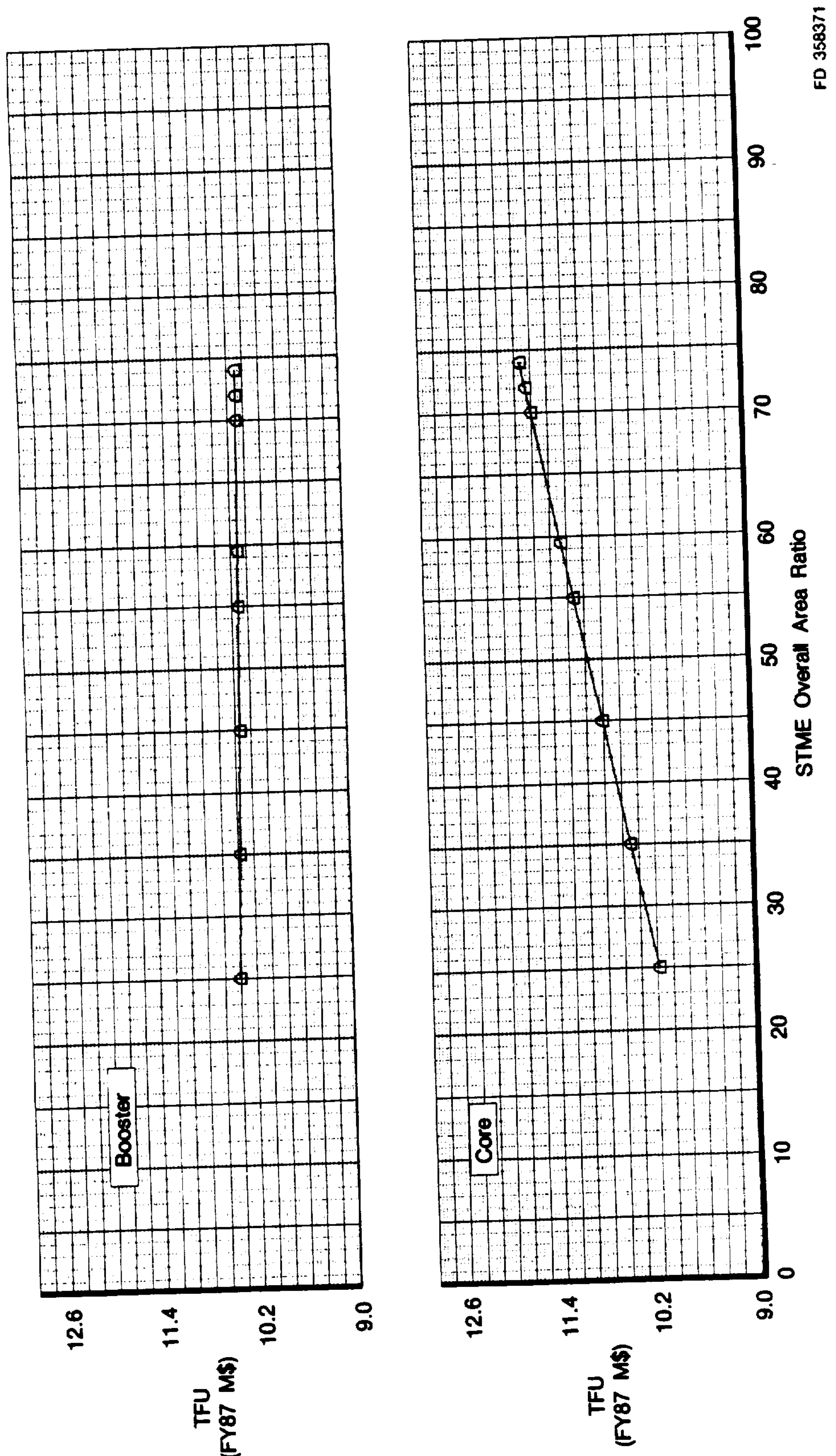

Figure 7.2-2. STME/Derivative STBE Gas Generator Theoretical First Unit Cost vs Overall Area Ratio

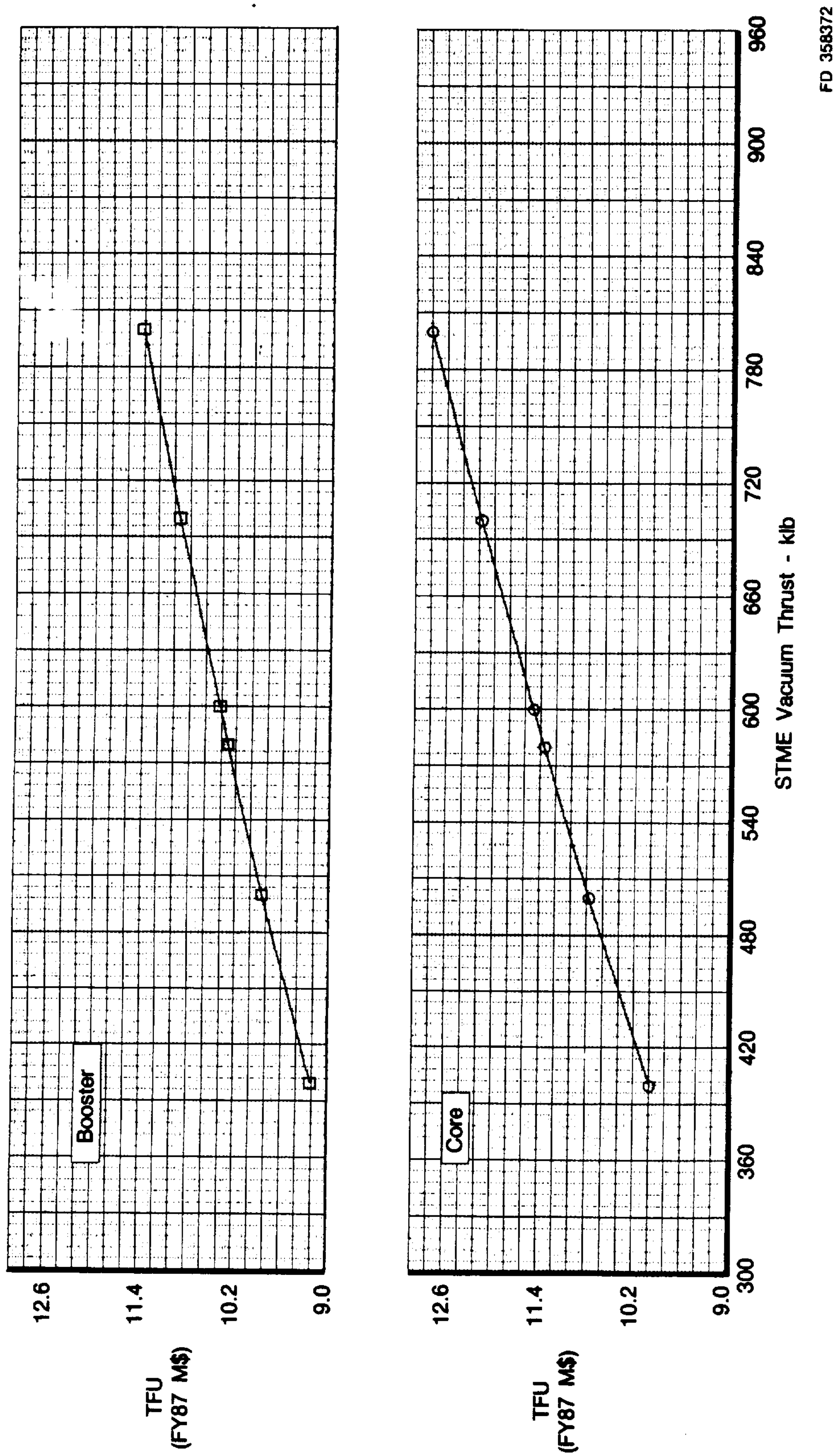

Figure 7.2-3. STME/Derivative STBE Gas Generator Theoretical First Unit Cost vs Vacuum Thrust

Table 7.2-4. *Development Cost Equations for the STME/Derivative STBE GG Development for Core and Booster Applications*

Core

Equation (1) $= F\left(\frac{F_{VAC}}{580}\right)^{0.1}\left(\frac{P_C}{2250}\right)^{0.1}$

Equation (2) $= G(TFU_{Core})$

Equation (3) $= \left\{\left[\frac{(TFU_{Core} - 0.4)(DPC)^{\beta}}{\beta+1}\right]\left[\left(\frac{CLS}{100}\right)^{-0.08}\right] + 0.4\right\} DPC$

Equation (4) $= H$

$DC_{M87\$}$ = Equation (1) + Equation (2) + Equation (3) + Equation (4)

Where: DPC - Number of Production Core Engines in Development Program (Defined Under Production Cost Equation Section)

TFU_{Core} - Theoretical First Unit Cost, M87$ (Core Common + Core Uncommon)

CLS - Lot Size for Production Core Engines in Development Program

For Development Cost Equation Only CLS = DPC

β Learning Curve Slope 90% = −0.152

Booster

Equation (1) $= F\left(\frac{F_{VAC}}{580}\right)^{0.1}\left(\frac{P_C}{2250}\right)^{0.1}$

Equation (2) $= G(TFU_{Booster})$

Equation (3) $= \left\{\left[\frac{(TFU_{Booster} - 0.4)(DPB)^{\beta}}{\beta+1}\right]\left[\left(\frac{BLS}{100}\right)^{-0.08}\right] + 0.4\right\} DPB$

Equation (4) $= H$

$DC_{M87\$}$ = Equation (1) + Equation (2) + Equation (3) + Equation (4)

Where: DPB - Number of Production Core Engines in Development Program (Defined Under Production Cost Equation Section)

$TFU_{Booster}$ - Theoretical First Unit Cost, M87$ (Core Common + Core Uncommon)

BLS - Lot Size for Production Core Engines in Development Program

For Development Cost Equation Only BLS = DPB

β Learning Curve Slope 90% = −0.152

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The operations costs are directly affected by the number of engines per vehicle, the number of flights per year, and the operational production TFU costs and the equations are function of these variables. Other variables such as thrust size, chamber pressure, area ratio, and throttle range affect operations costs only through the TFU cost used which is a function of these variables. Gas generator temperature, design mixture ratio, the number of engine reuses and the total quantity of flights do not have a significant impact on engine operational cost.

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Table 7.2-5. *Development Cost Constants*

STME/Derivative STBE GG
With Dual Run Point Control

Development STME for Core Application

F = 506	G = 42.3	H = 34

Development Derivative STBE for Booster Application

F = 182	G = 21.3	H = 2

Notes:

1. Development Costs Are Contractor Costs Only. Government Furnished Test Facilities and propellants are not included.
2. When Constants Are Used as Presented, Resulting Costs Are in MFY87$.
3. Costs Do Not Include Management Reserve or Profit.
4. All Costs Generated By These Equations Are Engineering Estimates. These Costs Should Not Be considered As Contractual Commitments and Should Be Used for Life Cycle Cost (LCC) Evaluations and Planning Purposes Only.

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Table 7.2-6. *Development Cost Control System Cost Impacts Applicable to STME/Derivative STBE Gas Generator Engines*

	Fn Accuracy	*MR Accuracy*	*Control Type*	*Development Cost Impact MFY87$**
Baseline (Two Run Points)	±3% (100 and 75% Fn)	±3% (75% Fn Only)	Open Loop	—
Two Run Points	±3% (100 and 75% Fn)	±3% (100 and 75% Fn)	Open Loop	Same Cost As Baseline
Single Run Point	±3% (100% Fn)	±3% (100% Fn)	Open Loop	Same Cost As Baseline
Continuously Variable	±3% (100 - 75% Fn)	±3% (100 - 75% Fn)	Open Loop	Same Cost As Baseline
Continuously Variable	±3% (100 - 50% Fn)	±3% (100 - 50% Fn)	Open Loop	TBD
Two Run Points	±1% (100 and 75% Fn)	±1% (100 and 75% Fn)	Closed Loop	TBD
Continuously Variable	±1% (100 - 75% Fn)	±1% (100 - 75% Fn)	Closed Loop	TBD
Continuously Variable	±1% (100 - 50% Fn)	±1% (100 - 50% Fn)	Closed Loop	TBD

*This Development Cost Impact Applies to the STME Only and It Is in Addition to the Production TFU Change Which Impacts Both STME and Derivative STBE Development Costs.

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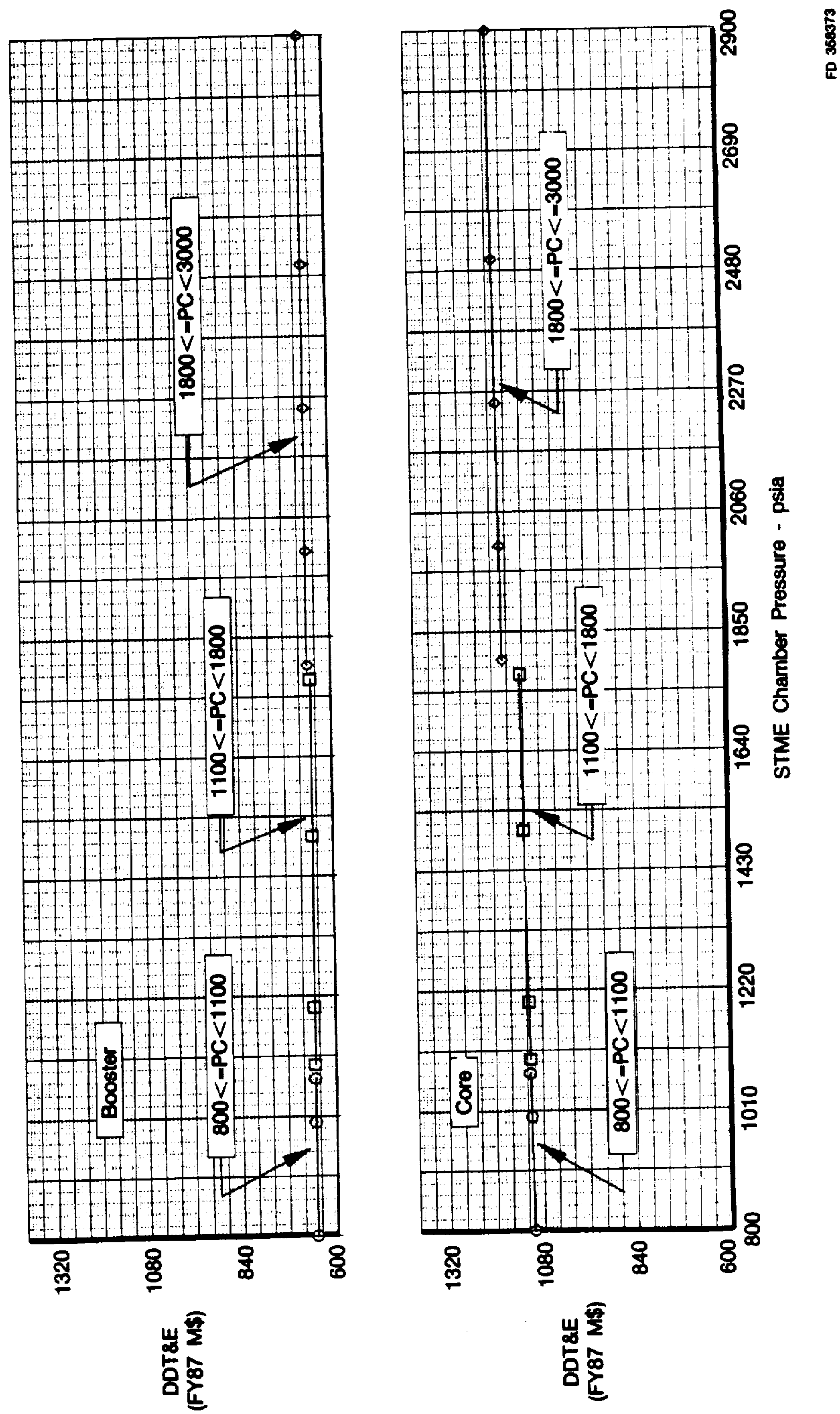

Figure 7.2-4. STME/Derivative STBE Gas Generator Development Cost vs Chamber Pressure

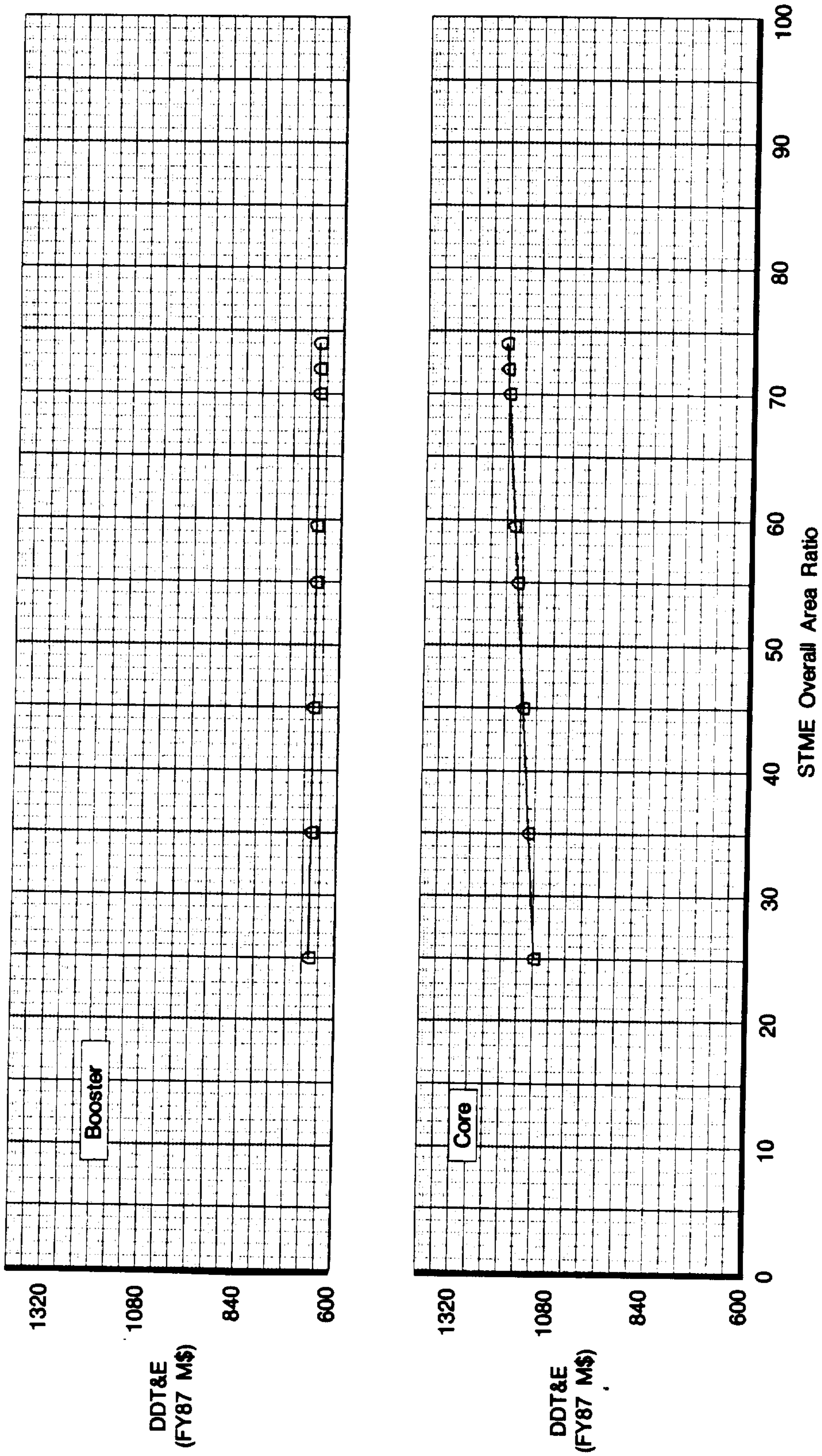

Figure 7.2-5. STME/Derivative STBE Gas Generator Development Cost vs Overall Area Ratio

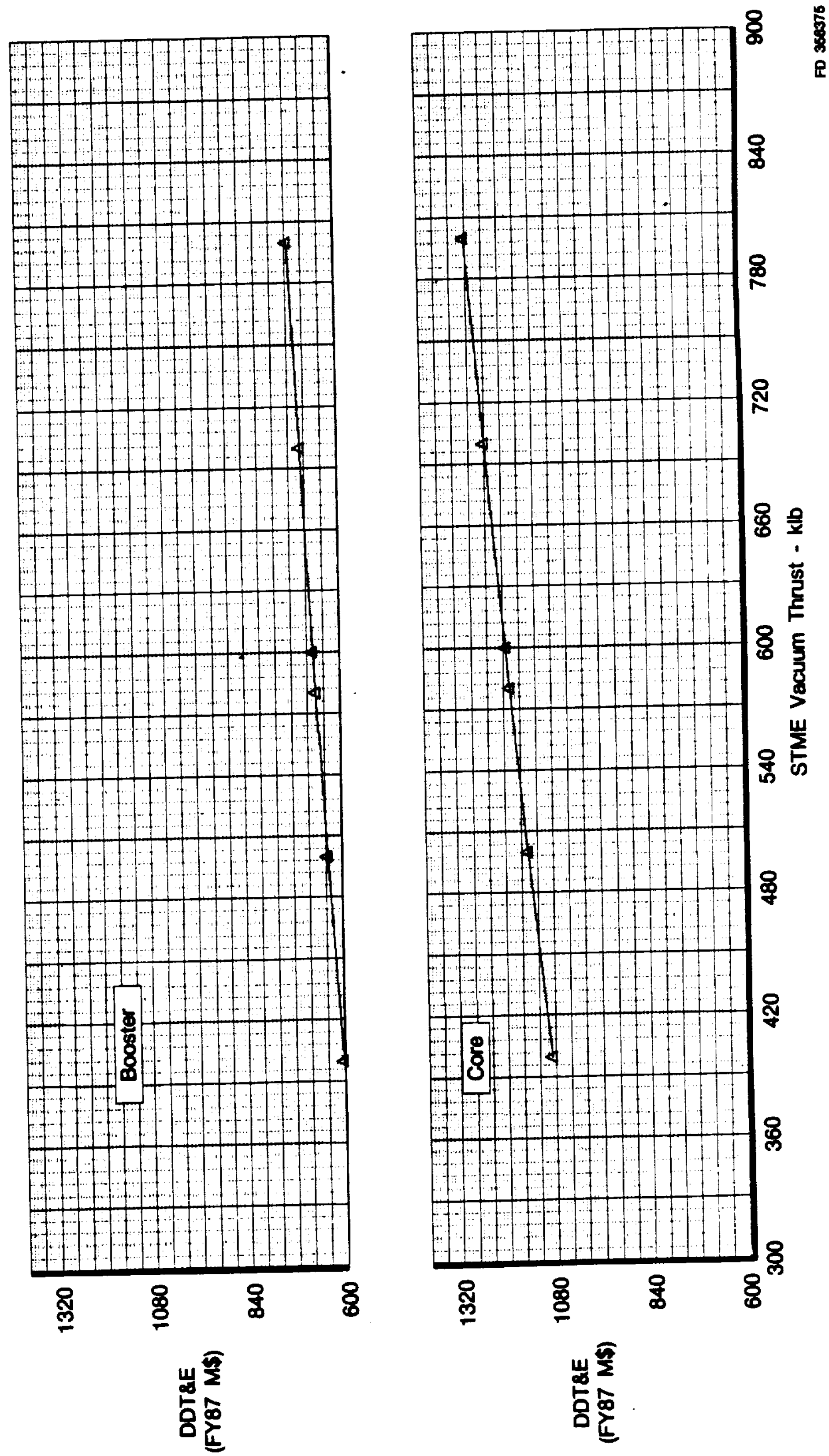

Figure 7.2-6. STME/Derivative STBE Gas Generator Development Cost vs Vacuum Thrust

General Equation

The general form of the operations cost parametric equation is as follows:

$$OC = \frac{OFC}{FPY * ENVH} + OVC$$

Where:

OC = Operations Cost per Engine, per mission, in Millions of FY87 Dollars.

OFC = Fixed operations costs per year associated with providing Program Management, Systems Engineering and Integration, Facilities Maintenance, Training, and Operations and Support.

OVC = Variable operations costs per engine per mission associated with providing Program Management, Systems Engineering and Integration, Facilities Maintenance, Training, and Operations and Support.

FPY = Number of Flights per Year

ENVH = Number of Engines per Vehicle (Booster and Core) (NB + NC)

NB = Number of Engines per Booster Stage

NC = Number of Engines per Core Stage.

Specific Engine Configuration Equations

For the reusable gas generator Hydrogen/Oxygen Space Transportation Main Engine (STME) and Methane/Oxygen Derivative Space Transportation Booster Engine (STBE) the following equations apply:

$$OC\ Core = \frac{5.5}{FPY * ENVH} + 0.0193 + RMOU + RRH(TFU\ Core)$$

$$OC\ Booster = \frac{5.5}{FPY * ENVH} + 0.0193 + RMOU + RRH(TFU\ Booster)$$

Where:

RMOU = Unscheduled Refurbishment/Maintenance Labor Constant
0.063 for gas generator STME
0.069 for Derivative STBE

RRH = Repair/Replacement Hardware Constant
0.00226 for gas generator STME
0.00249 for Derivative STBE

TFU Core = Theoretical First Unit Cost for STME
(from Production Cost Equation section)

TFU Booster = Theoretical First Unit Cost for STBE
(from Production Cost Equation section).

Figures 7.2-7 through 7.2-10 depict the relationship between Operations Costs for both the Core and Booster Space Transportation Engines and variables such as STME chamber pressure (Pc), Overall Area Ratio, and Vacuum Thrust and total Engine Flights per Year (EFPY). The STBE cost is a fallout of these STME variations. For the Pc variation an Optimum Core Vehicle Area Ratio which is a function of the Pc selected is used for the engine cost.

7.2.5 Product Improvement and Support Program Costs

The Product Improvement and Support Program (PISP) cost equations can be used to determine total product improvement costs as function of a number of design variables. These variables include thrust size, chamber pressure, overall nozzle area ratio and throttling range.

For each type of engine under consideration two supplementary equations (two for Core and two for Booster) are provided, Table 7.2-7. Constant values for the equations are found in the same table, following the equations. By solving the numbered equations and combining them as shown, Contractor PISP cost in millions of FY87 dollars can be determined for the STME Core and Derivative STBE Booster engines. Total contractor PISP cost can then be obtained by combining the individual STME Core and Derivative STBE Booster PISP costs.

Theoretical First Unit values should be taken from the Production Cost section.

Figures 7.2-11 through 7.2-13 depict the relationship between Product Improvement and Support Program (PISP) costs for both Core and Booster Space Transportation Engines and STME chamber pressure (Pc), Overall Area Ratio and Vacuum Thrust. The STBE is a fallout of these STME variations. For the Pc variation an Optimum Core Vehicle Area Ratio is used.

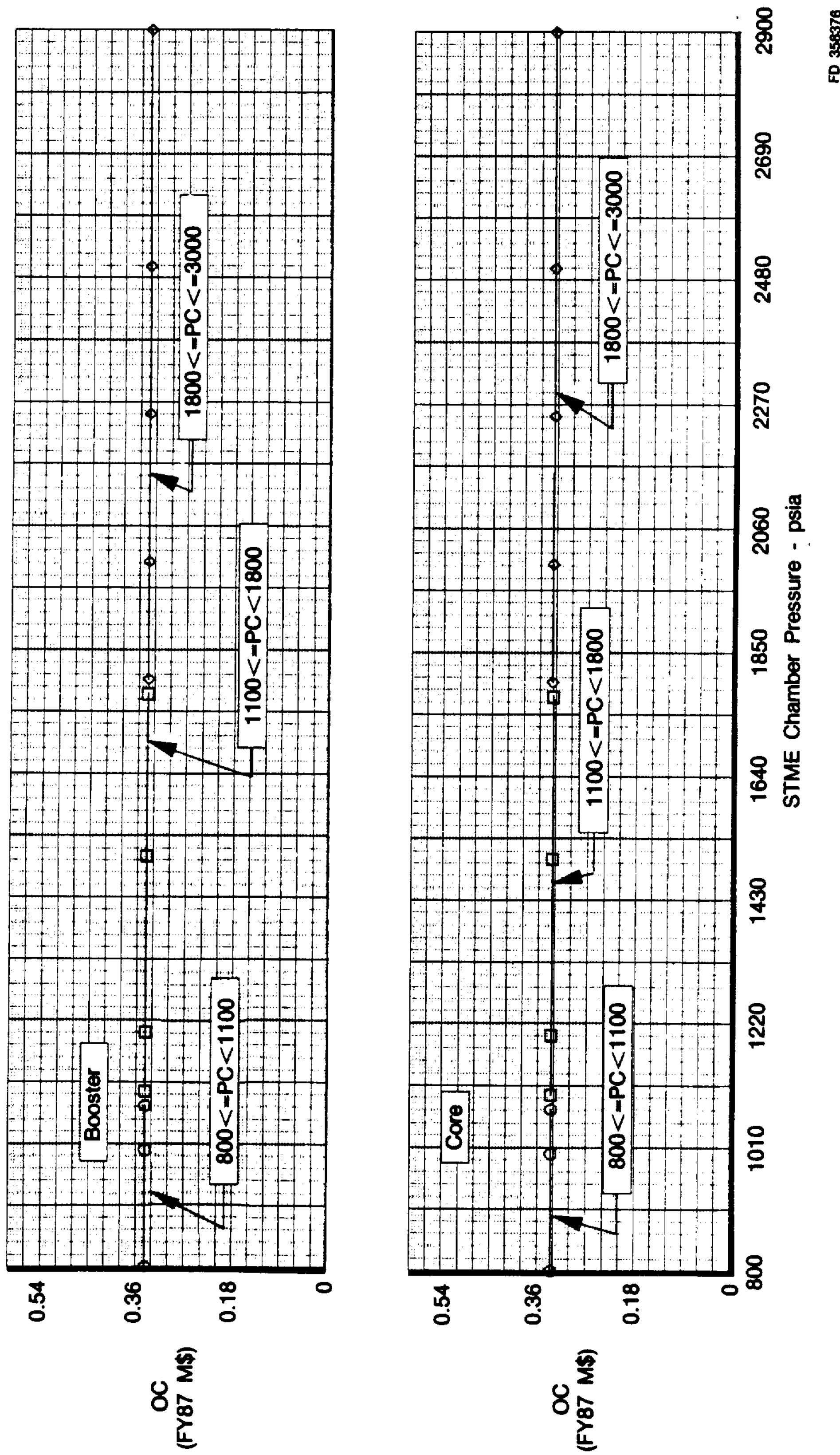

Figure 7.2-7. STME/Derivative STBE Gas Generator Operations Cost vs Chamber Pressure

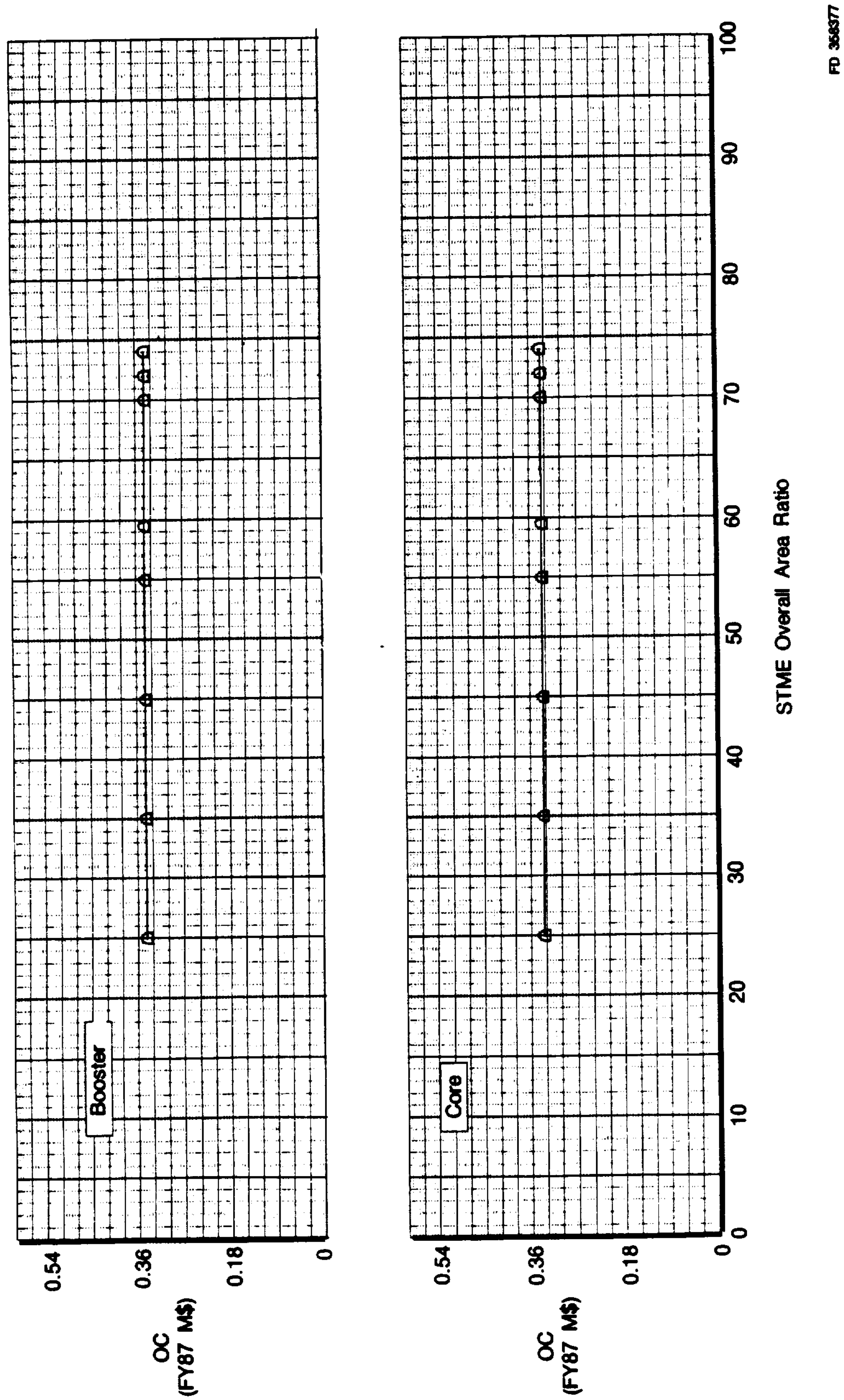

Figure 7.2-8. STME/Derivative STBE Gas Generator Operations Cost vs Overall Area Ratio

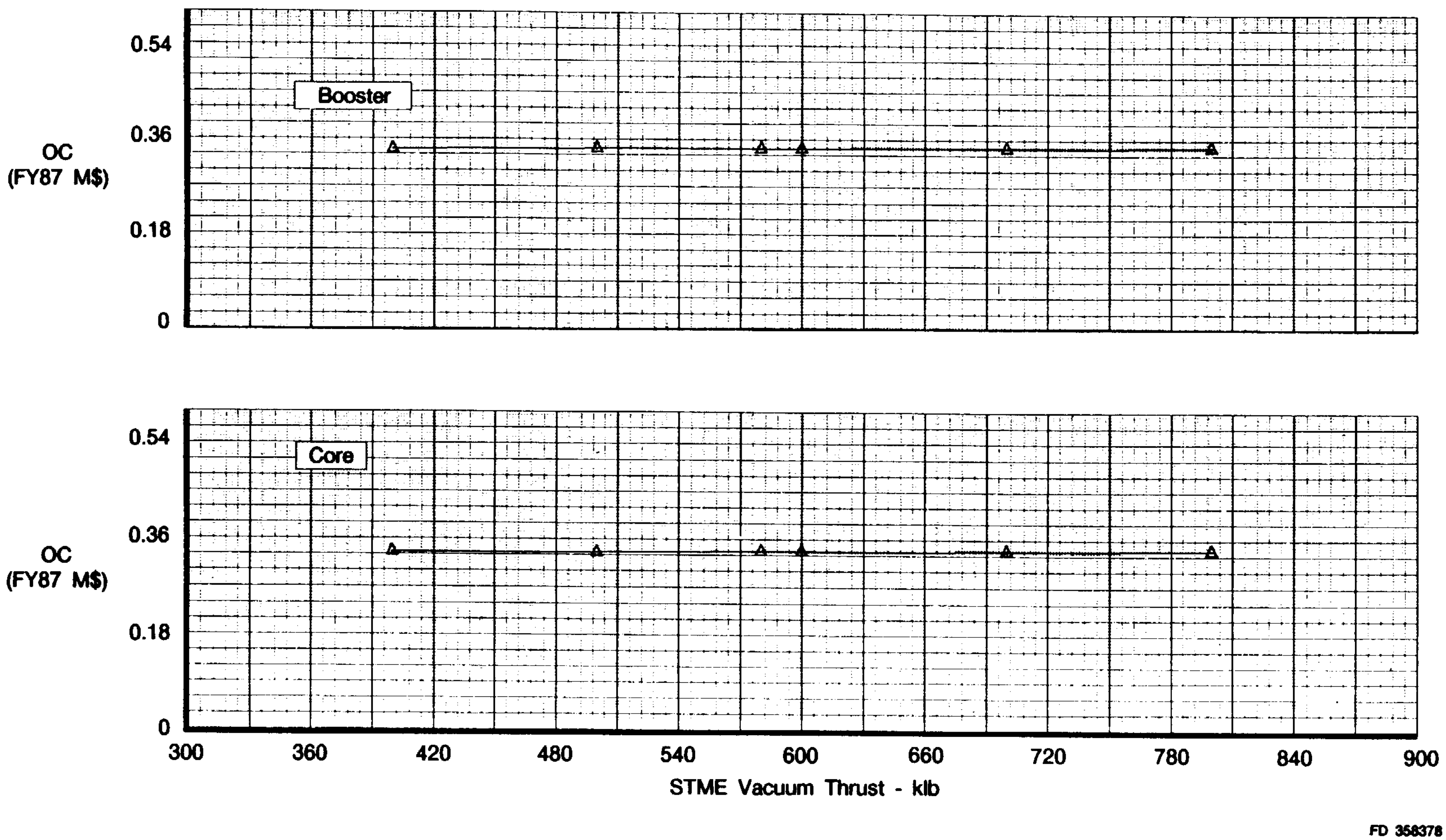

Figure 7.2-9. STME/Derivative STBE Gas Generator Operations Cost vs Vacuum Thrust

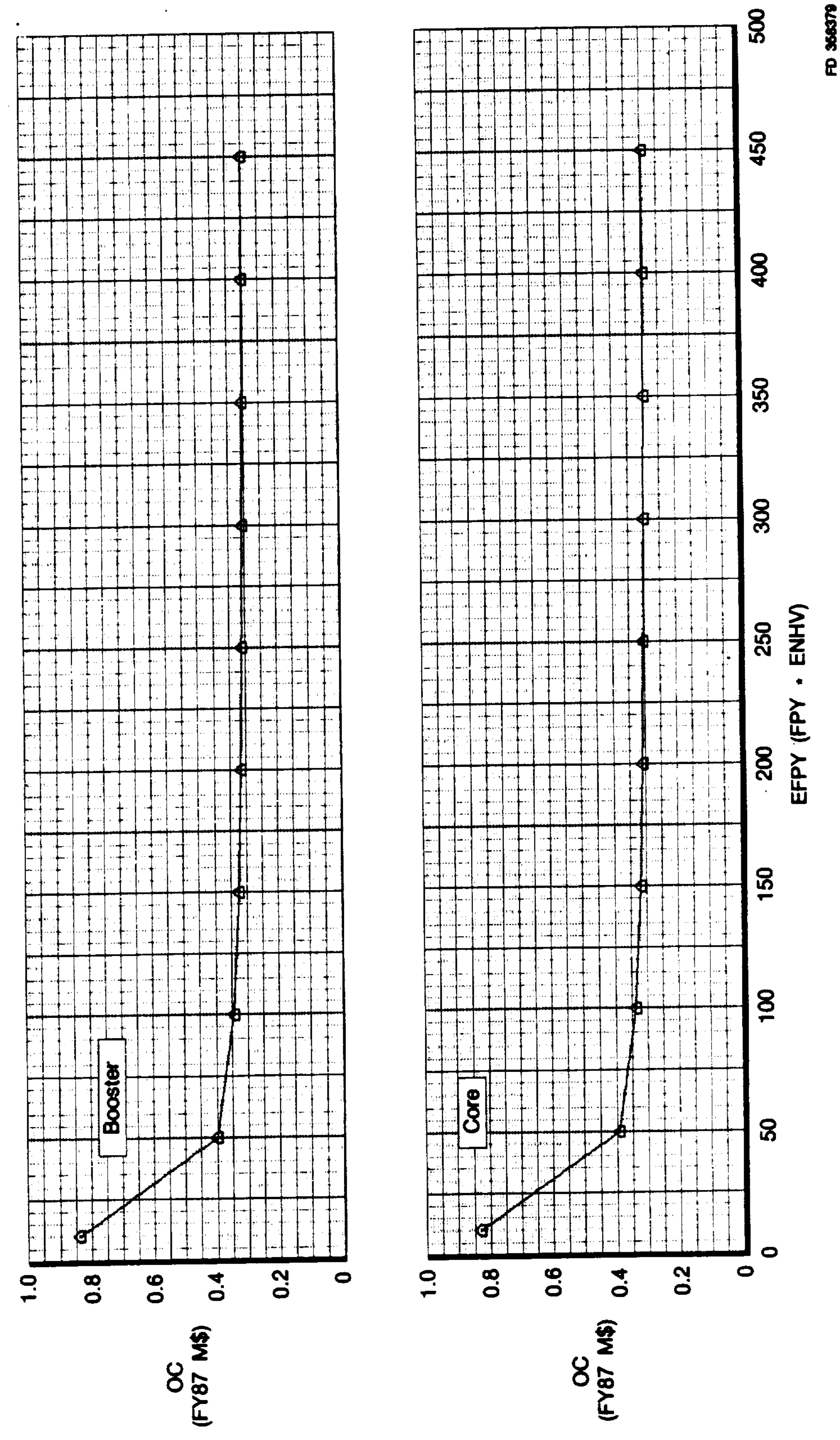

Figure 7.2-10. STME/Derivative STBE Gas Generator Operations Cost vs Engine Flights Per Year

Table 7.2-7. *Product Improvement and Support Program Cost Equations for the STME/Derivative STBE GG Product Improvement and Support Programs for Core and Booster Applications*

Core	*Booster*
Equation (1) = $F_{Core}\left(\frac{F_{VAC}}{580}\right)^{0.1}\left(\frac{P_C}{2250}\right)^{0.1}$	Equation (1) = $F_{Booster}\left(\frac{F_{VAC}}{580}\right)^{0.1}\left(\frac{P_C}{2250}\right)^{0.1}$
Equation (2) = G_{Core} (TFU_{Core})	Equation (2) = $G_{Booster}$ ($TFU_{Booster}$)
Core $PISP_{M87\$}$ = (Equation (1)+Equation (2))×0.5	Booster $PISP_{M87\$}$ = (Equation (1)+Equation (2))×0.5

Where:

TFU_{Core}	-	Theoretical First Unit Cost, M87$ (Core Common + Core Uncommon)
F_{Core}	-	506
G_{Core}	-	42.3
$TFU_{Booster}$	-	Theoretical First Unit Cost, M87$ (Booster Common + Booster Uncommon)
$F_{Booster}$	-	182
$G_{Booster}$	-	21.3

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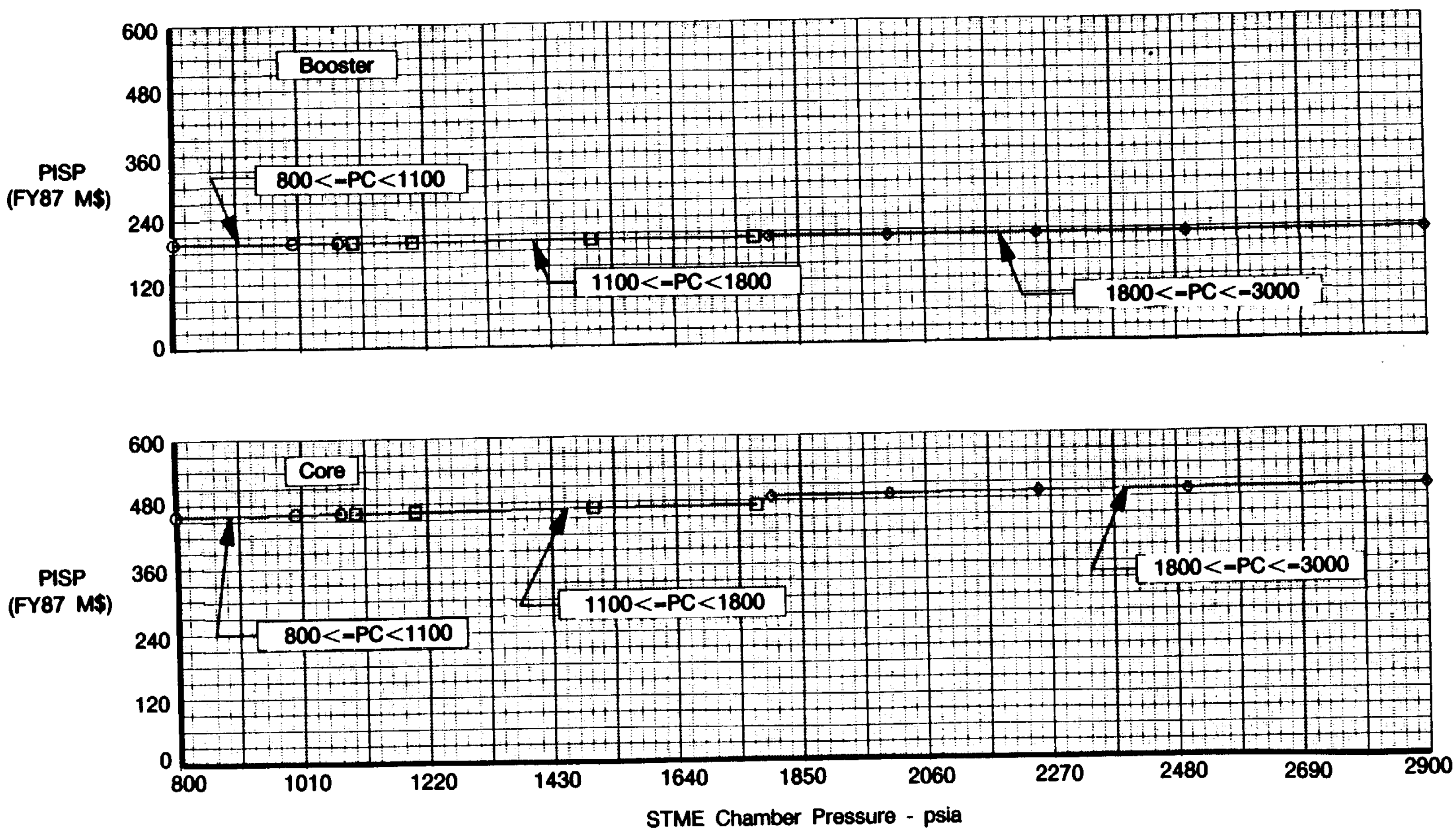

Figure 7.2-11. STME/Derivative STBE Gas Generator Product Improvement and Support Program Cost vs Chamber Pressure

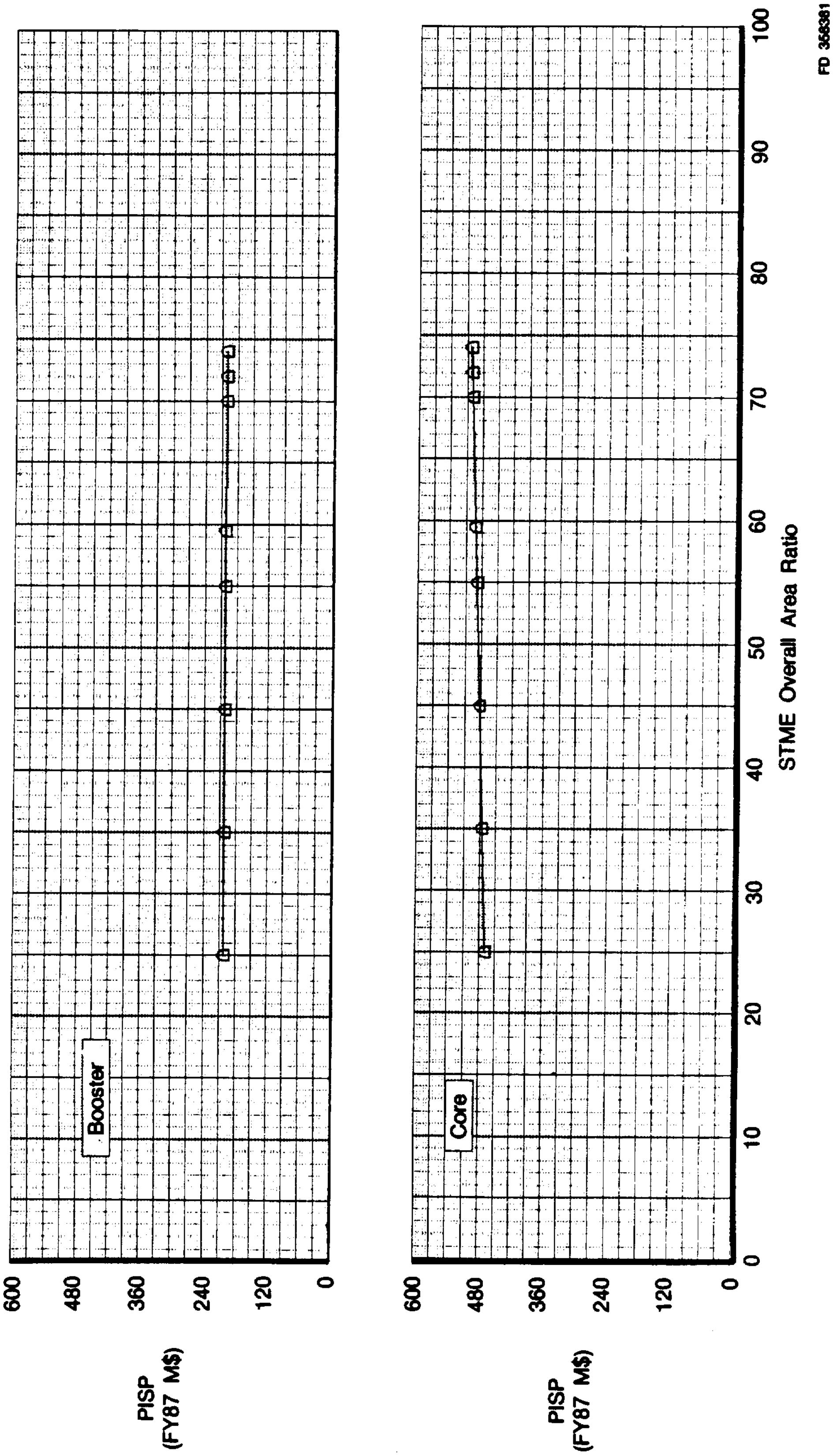

Figure 7.2-12. STME/Derivative STBE Gas Generator Product Improvement and Support Program Cost vs Overall Area Ratio

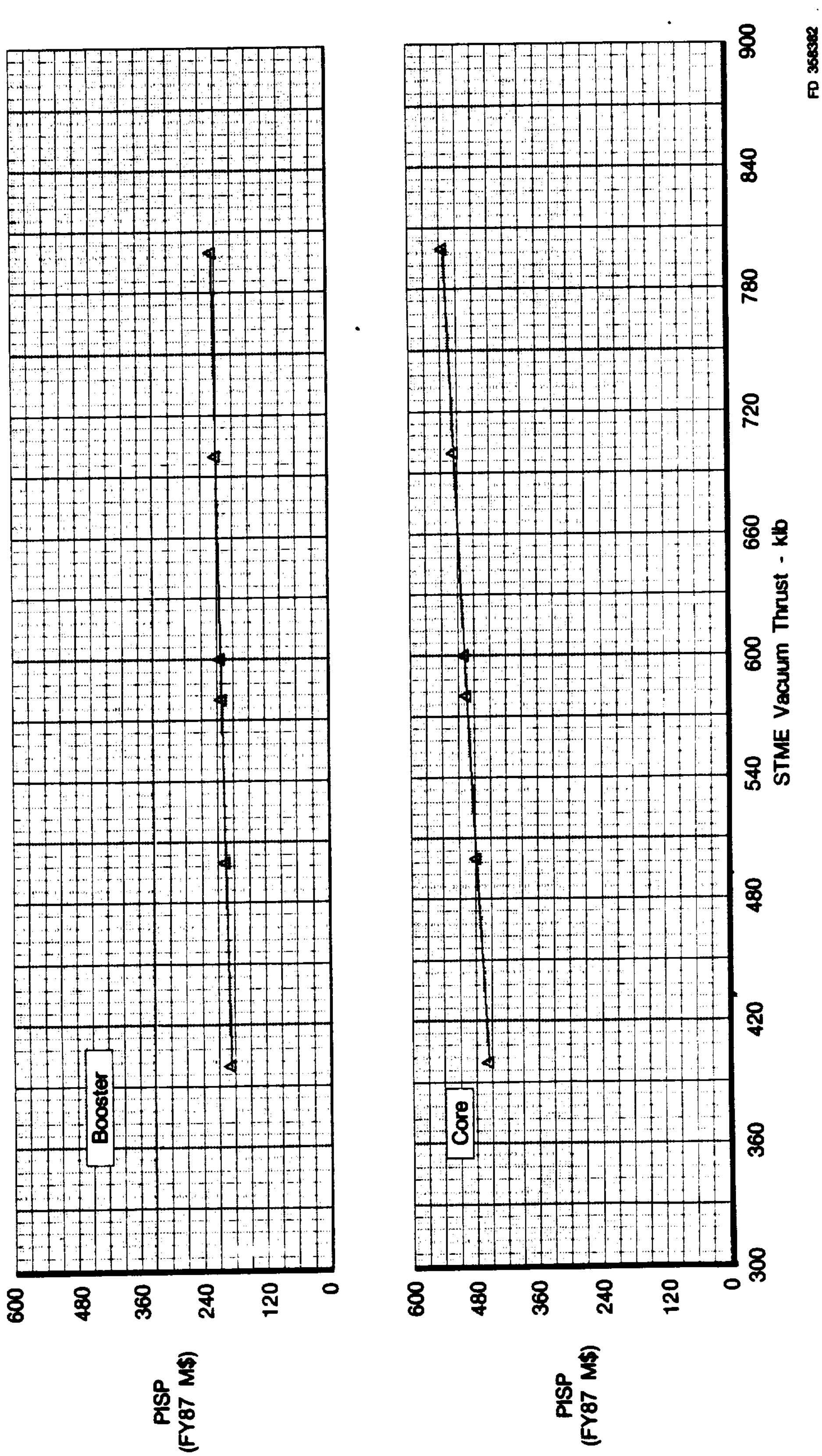

Figure 7.2-13. STME/Derivative STBE Gas Generator Product Improvement and Support Program Cost vs Vacuum Thrust