LPC DOCUMENT NO. 629-6
VOLUME II, BOOK 3

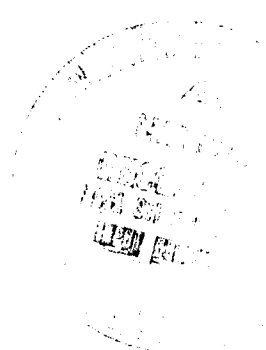
DATA REQUIREMENT MA-02
FINAL REPORT
CR-123617
TECHNICAL REPORT

COST ESTIMATING DATA

STUDY OF SOLID ROCKET MOTORS FOR A SPACE SHUTTLE BOOSTER

CONTRACT NO. NAS8-28429
JANUARY 13, 1972 TO MARCH 15, 1972

MARCH 15, 1972



PREPARED FOR
THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA 35812

LOCKHEED PROPULSION COMPANY
P.O.BOX 111 REDLANDS, CALIFORNIA 92373

Data Requirement MA-02

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January 13, 1972 to March 15, 1972

A. H. Von Der Esch
Lockheed Propulsion Company
Vice President, Technical and Marketing

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ABSTRACT

Lockheed Propulsion Company has selected the 156-inch-diameter parallel-burn Solid Rocket Motor (SRM) as the most cost-effective system that has been demonstrated. This selection is based on the use of proven materials, minimum development costs, easily transportable size, and credible engineering designs that are presently available. The criteria used above fulfill the objectives as stated in the NASA Study Contract.

The basic study approach was to concentrate the costing aspects on the baseline motor, and to draw from the baseline sufficient data to cost the alternate motor approaches.

LOCKHEED PROPULSION COMPANY
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FOREWORD

This document is Book 3, Cost Estimating Data of Volume II Technical Report. It is a part of Lockheed Propulsion Company's final report for the Study of Solid Rocket Motors for a Space Shuttle Booster. The final report consists of the following documents:

Volume I	Executive Summary
Volume II	Technical Report
Book 1	Analysis and Design
Book 2	Supporting Research and Technology
Book 3	Cost Estimating Data
Volume III	Program Acquisition Planning
Volume IV	Mass Properties Report

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SUMMARY

Lockheed Propulsion Company's objective from the outset of the Space Shuttle Program has been to provide complete and conservative design and cost parameters for an expendable Solid Rocket Motor (SRM) Booster Vehicle for the Space Shuttle Program. With this approach, LPC has attempted to identify the maximum technical and cost risks that could be encountered by NASA in employing a solid rocket motor as the Space Shuttle Booster Vehicle. Therefore, LPC believes that the baseline vehicle costs presented in this report are distinctly conservative and will be reduced upon further definition and detailed estimating. Two items, which LPC has not included and which will affect a fixed-payload program cost, are escalation and profit, both of which were directed in the Study Contract to be deleted from consideration.

As directed by NASA, LPC also attempted to determine "hard" versus "soft" costs, and an upper band was established above the baseline for a "worst condition." As a result of Lockheed's solid rocket motor experience, the propulsion system costs are "hard" and, therefore, an upper limit of 2 percent on the SRM cost has been defined. LPC believes that the Stage costs are "soft" and a 30-percent upper limit on the Stage cost was established. With the SRM and Stage combined, a total of 10-percent upward variation has been identified in the Booster Vehicle (WBS 3.3) Program costs. A lower range has also been established, which identifies potential reductions for thrust vector control, thrust termination, and recovery.

The Booster Vehicle selected as the baseline configuration is a parallel-burn (two-motor) 156-inch-diameter SRM vehicle sized for the large (65,000-pound) Orbiter payload. The baseline program assumed for study purposes includes a 5-year (1973 - 1978) development/qualification program, a 13-year (1976 - 1988) production program, and an 11-year (1978 - 1988), 440 vehicle launch program.

The development program includes 25 SRMs; 5 development motor tests, 4 PFRT motor tests, 2 inert booster vehicles (2 SRMs per vehicle) and 6 launches (1 unmanned and 5 manned flights with 2 SRMs per vehicle). All 25 motors in the development program will be fabricated in LPC's existing, large-motor Potrero manufacturing facility. The development program schedule was established at 5 years to minimize annual funding and could be shortened by as much as 1 year without impacting the launch schedule.

The production program of 440 launches includes manufacture of 883 SRMs (880 for launches and 3 for production facility start-up demonstration) and 440 sets of Stage hardware. Due to the nature of the solid rocket motor, quality is ensured by the facility process controls in manufacturing. Thus a three-motor test program is planned to demonstrate that the production facilities will reproducibly deliver the SRMs qualified during development. As directed in the Study Contract, all launches were considered to be from Kennedy Space Center (KSC).

Lockheed Propulsion Company, as prime contractor for the Booster Vehicle, would utilize all of the industry production capability before additional facility expansion. LPC would subcontract to at least two other SRM manufacturers for a portion of the production motors. Additionally, all components would be considered for dual procurement to ensure a redundant capability for Booster Vehicle delivery. This LPC plan provides Booster Vehicle procurement at a very low risk to NASA in the event of a labor, facility, or material problem at any time during the program. This approach also results in a relatively low facility expansion cost ($25.7 million) for the production program and avoids the building of a brand new facility, which would cost approximately $70 million.

The three production facility start-up demonstration tests are considered adequate by LPC to qualify the three production facilities (LPC and two others) for the baseline costing effort. It was considered that NASA might desire additional testing to qualify the new subcontractors ("second sources") and, therefore, nine motor tests were included in establishing the upper limit 2-percent variation in SRM costing. However, LPC recommends only three tests and has used this in the baseline costing.

Previously, it has been stated that the baseline design is conservative. As evidence of this, all metal structures have a minimum safety factor of 1.4. This has naturally imposed an additional cost on materials, but LPC believes that this should be maintained, thus guaranteeing the high reliability required for a man-rated system. As a bonus feature, analysis indicates that the motor chamber with this safety factor (wall thickness 0.460 inch) will withstand water impact loads at 100 feet per second and at entrance angles up to 45 degrees. Although recovery/reuse is not considered in the baseline costing, Lockheed's SRM design should therefore not require additional strengthening (higher material costs) should recovery/reuse prove cost-effective for the Booster Vehicle.

As further evidence of a conservative design, the safety factor for all ablative insulation materials was established at 2.0. Once again, it is felt that this should be maintained for man-rated reliability. In the areas of thrust termination (TT) and thrust vector control (TVC), no firm requirement was established by either the Phase B contractors or by the customer. LPC assumed that the Booster Vehicle would require both TT and TVC, plus a strenuous TVC duty cycle, which sized the system conservatively.

The baseline costs are backed by firm vendor quotes on procured components and conservative labor estimates. Lockheed's labor estimates were prepared from a task definition or "ground-up" standpoint, based on previous LPC large-motor experience, other LPC rocket motor programs, and also on related industry experience on solid propellant rocket motors. Nine full-scale, 156-inch-diameter demonstration motors have been test-fired to date, five by Lockheed Propulsion Company. These tests are summarized in the following table.

SUMMARY OF 156-INCH LARGE SOLID ROCKET MOTOR TESTS

No.	Date	Motor Description		Test Data	
		Designation	Fabrication	Maximum Thrust (lb)	Average Thrust (lb)
1.	1964 May	156-3	LPC	0.95M	0.88M
2.	Sep	156-4	LPC	1.09M	1.00M
3.	1965 Feb	156-2C-1	TCC	3.25M	2.97M
4.	Dec	156-1	TCC	1.47M	1.29M
5.	Dec	156-5	LPC	3.11M	2.84M
6.	1966 Jan	156-6	LPC	1.03M	0.94M
7.	Apr	L-73	LPC	0.66M	0.60M
8.	May	156-7	TCC	0.39M	0.32M
9.	May	156-9	TCC	0.98M	0.88M

All of these motors, with thrust levels up to three million pounds, performed within 2 percent of their calculated parameters, and only one incident (involving the loss of an exit cone in a moveable nozzle test by another contractor) was experienced. This is a significant feat in that each of the nine motors was a "one-of-a-kind" configuration and involved reuse of LPC-designed case hardware as many as four times. Lockheed is proud of this 100-percent successful completion of its five 156-inch motor tests, which were accomplished under-budget on firm fixed price contracts (see USAF Testimonials in Appendix A of the Cost Book).

As previously stated, the experience gained in these programs was applied by all LPC branches in estimating the labor for the Booster Vehicle. In the area of motor processing, the hands-on-hardware "first-unit" labor hours for the baseline were estimated, and then a 90-percent labor improvement or learning curve was applied. Comparison with both LPC experience and other SRM industry experience indicates that this is conservative; in the majority of previous programs, improvement curves in the middle to low eighties have been experienced. For example, on the basis of two large weapon systems, Minuteman and Poseidon, an improvement curve in the 80- to 85-percent range should be achievable in the Booster Vehicle. For this additional reason, LPC, employing a 90-percent curve, has estimated the baseline configuration production costs in a conservative manner.

As another consideration in development of the costs, LPC began this study on 13 January 1972 assuming that the Booster System (WBS 3.0) was to be costed. On 2 February, LPC was notified that the SRM contractors were to price at the Booster Vehicle level (WBS 3.3). While this was intended by NASA to alleviate the SRM contractors' efforts in the short study time available, it did turn out to add another variable, which is reflected as additional conservatism in the LPC costs. Included in LPC's costs are some items that could be interpreted as belonging under Booster Management (WBS 3.1), System Engineering (WBS 3.2), or Booster System Support (WBS 3.5), which may not be included in the cost estimates of the other study contractors.

The Booster Vehicle program costs (WBS 3.3) presented by LPC on 14 and 23 February 1972 were based on the previously defined configuration and costing assumptions. The LPC baseline Booster Vehicle cost estimate presented on these dates is summarized below.

	SRM	Stage	Total Booster Vehicle
Development	$ 141.6M	$ 48.2M	$ 189.8M
Production	2,545.7M	929.0M	3,474.7M
	$2,687.3M	$977.2M	$3,664.5M
Total Program Cost/Launch	$ 6.0M	$ 2.2M	$ 8.2M
Recurring Cost/Launch	$ 5.8M	$ 2.0M	$ 7.8M

The total program cost per launch is developed by dividing the total program cost (3,664.5 million) by the total number of manned launches (445). Although cost per launch does not normally include amortization of DDT&E or non-recurring production items, LPC chose to attempt to display the total program liability that NASA could encounter in employing a solid rocket motor Booster Vehicle. The standard way of displaying cost per launch is by using the recurring unit cost, which, for LPC's baseline, is $7.8M. Once again, these program costs were developed early in the Study Program with the objective of identifying the maximum technical and cost risk that could be encountered by NASA.

On 12 February, after the cut-off date for the 14 and 23 February presentations, Lockheed began a second iteration of the program baseline configuration and cost. Labor and material were analyzed in more depth, more definition was prepared to separate recurring from nonrecurring costs, and the Operations portions of the SRM and Stage were separated into more identifiable activities. This resulted in a redistribution of the baseline costs as shown in the following two tables:

	SRM	Stage	Operations	Total
Development	$ 131.0M	$ 31.0M	$ 27.8M	$ 189.8M
Production	~~2,434.9M~~ 2,303.5M	626.5M	544.3M	3,474.7M
	$2,434.9M	$657.5M	$572.1M	$3,664.5M

Note that in both tables the previously shown total program costs have remained unchanged but are redistributed by LPC for better understanding.

	Total Costs	Recurring Cost/Launch	Total Cost/Launch
Recurring SRM production	$2,242.8M	$5.1M	$5.1M
Recurring Stage production	626.5M	1.4M	1.4M
Recurring operations	544.3M	1.2M	1.2M
Nonrecurring production	61.1M	0	0.1M
Development	189.8M	0	0.4M
Total	$3,664.5M	$7.7M[a]	$8.2M

The next step in the second iteration of the baseline configuration and cost was to review areas where cost might be overly conservative and could thus be reduced. Since the hardware is a major portion of the SRM cost, additional definition and breakdown of vendor component and material costs were requested from the subcontract suppliers. In vehicle configuration, better design definition was developed and rebids were prepared in some areas. As an example, in January, prior to completion of the TVC system sizing, quotes had to be obtained on the actuator. LPC requested bids on the actuator used on the S1-C Vehicle, knowing that it would be more than adequate for the job. The actuator requirement was found to be far less and was rebid at a significantly lower cost. Safety factors of all hardware were maintained and the material costs still reflect safety factors of 1.4 on structures and 2.0 on ablative insulations.

The motor processing tasks and the improvement/learning curve were reviewed in considerable depth. A steeper curve (86 percent) was selected as realistic but still sufficiently conservative in comparison to other major solid rocket motor programs and LPC's 156-inch motor experience. Assembly and support labor were also analyzed and some areas of redundancy between WBS paragraphs were identified and deleted. The analysis of labor and material on the SRM has resulted in a lower unit cost position for the SRM baseline. These analyses have been time-consuming and, although some areas of the Stage attachment hardware and Operations have been reviewed and reduced, additional effort is being expended by Lockheed toward further definition, analysis, and reduction.

To support a final report date of 15 March, a cut-off was made on 8 March in the second costing iteration. The reduced program costs are shown in the following table as "Baseline, Revision 1" and are compared by item to the original baseline costs shown previously.

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[a] As a minor note, the redistribution identified additional nonrecurring production costs, resulting in a lower recurring cost per launch.

	Baseline Cost	Reduction	Baseline Revision 1
Recurring SRM Production	$2,242.8M	$266.8M	$1,976.0M
Recurring Stage Production	626.5M	155.7M	470.8M
Recurring Operations	544.3M	98.0M	446.3M
Nonrecurring Production	61.1M	0	61.1M
Development	189.8M	3.7M	186.1M
	$3,664.5M	$524.2M	$3,140.3M
Total Cost/Launch	$ 8.2M	$ 1.1M	$ 7.1M
Recurring Cost/Launch	$ 7.7M	$ 1.1M	$ 6.6M

Each of the reductions shown in this table is discussed in the Addendum to the cost book of the final report. The cost per launch, both recurring and total, has been reduced by over a million dollars. Further analysis will yield even more reductions in the areas of Stage and Operations. It is believed by Lockheed that the SRM, however, will not yield further major reductions without a change in either performance or hardware safety factors, which is not recommended by LPC.

Therefore, the Baseline Revision 1 costs ($3,140.3B) are submitted as Lockheed's formal position on the SRM Booster Vehicle (WBS 3.3).

The conclusions of the LPC study are:

(1) The LPC 156-inch-diameter baseline design meets all the technical requirements for the Booster Vehicle.

(2) The baseline design appears to have the structural capability to withstand recovery-load impacts should recovery/reuse prove cost-effective for the Booster Vehicle.

(3) The SRM Booster Vehicle, because of its demonstrated technology, can be developed to meet all NASA schedule requirements.

(4) The Baseline Revision 1 costs are realistic and achievable and are subject to further reduction.

(5) The cost for development ($186.1M) of an expendable SRM Booster Vehicle are less than 4.0 percent of the total Space Shuttle Development budget ($5.5B).

(6) The Baseline Revision 1 SRM Booster Vehicle cost per launch (recurring $6.6M, total $7.1M) is less expensive than that of a liquid booster.

In summary, Lockheed believes that an SRM propulsion system can perform the mission, can be easily developed in the time available, and will prove to be a cost-effective booster vehicle for the Space Shuttle Program.

Section 1

INTRODUCTION

This document is Volume II, Book 3; Cost Estimating Data, of the Lockheed Propulsion Company's (LPC) final report for the Study of Solid Rocket Motors for a Space Shuttle Booster. The study was conducted for the National Aeronautics and Space Administration (NASA) under contract number NAS 8-28429. The report is submitted in response to Data Requirement MA-02.

1.1 BASELINE COSTS

Lockheed Propulsion Company has established the baseline cost estimating data included herein, based on the following data requirements:

- SRM Program Cost Estimates have been prepared and reported in the Table 1 format for the Baseline Vehicle, and the Baseline Vehicle - Revision 1.
- SRM Program Time-Phased Funding requirements, based on Item 1 above, have been prepared and reported in the Table 2 format.
- SRM Program Parameteric Cost Estimating Relationships (CERs) have been prepared and reported in the Table 3 format as requested in Exhibit A, Scope of Work.

Lockheed Propulsion Company, utilizing further groundrules as established by Exhibit A, Scope of Work, has prepared the most realistic cost estimate possible within the time constraints. Actual costs of previous 156-inch SRM development programs have been utilized to the fullest extent and are prominently displayed to add credibility to the estimates contained herein.

More detailed groundrules were established later in the study period for costing the three major sections of the Table 1 formats. These costs are divided into three major categories as follows:

- DDT&E will consist of all costs incurred for the design, fabrication, ground test, and flight test of Orbiters 1 and 2, and Boosters 1 and 2. DDT&E will include the total cost of the dynamic test and the vertical flight designated as test or development flight. These costs include all tooling, and the STE, ground support equipment, spares,

and other efforts required leading up to, and supporting, the test flight. DDT&E also will include the cost of the first five manned orbital flights, including support for receiving assembly and checkout, spares, operations support, etc.

- Production is defined as the costs associated with producing additional flight motors and modification and/or updating of the flight test hardware required for operation through acceptance of the hardware by the Government, including all costs associated with (1) fabrication, (2) ground test and factory checkout of flight hardware, (3) initial operational spares required for malfunctioning, and (4) maintenance of tooling and special test equipment.

- Operations is defined as the cost associated with the following activities:

  Flight support is defined as (1) replacement spares to support operational airborne hardware, (2) sustaining engineering to support the production of spares and hardware modification, and (3) maintenance of GSE and spares for GSE.

  Launch Operations includes the costs for receiving the flight hardware, assembly of the vehicle, checkout, prelaunch test and checkout, servicing, launching, and refurbishing of the launch site facilities.

  Mission Operations includes the cost of supporting mission control, mission planning, flight crew training, and simulation aids required for crew training (excluding the cost of those identified elsewhere).

- Costs are stated in 1970 dollars with no LPC fee to be included, however, vendor costs include fee.

- Transportation will be included, as appropriate, in DDT&E and Production.

- Facilities will be included, as appropriate, in DDT&E and Production for both LPC and LPC's vendors depending on the launch site and rate.

- Booster Recovery Program will be costed separately.

Lockheed's baseline costs include only those program events and activities deemed essential to meet the final report objectives as stipulated in Contract NAS 8-28429. To this end LPC has added for clarification a Work Breakdown Structure (WBS) dictionary to provide the reader with a definition of the content of each WBS block. This placement of costs becomes increasingly important because of the magnitude of the total Shuttle Program.

Due to time limitations imposed for gathering information for presentation in the February NASA/MSFC and NASA/Headquarters meetings, it was not always possible to gain sufficient insight to the level desired for the final report.

Further detailed cost analysis work has been conducted at LPC in the interim period, and it is therefore possible to identify reductions that are within the "cost bands" as displayed at the briefings referenced above. The "cost band" charts are displayed in Appendix A, Miscellaneous Backup Data, and in the Executive Summary (Volume I).

1.2 ADDENDUM 1 - (BASELINE - REVISION 1)

In the latter part of the study, it became apparent that the baseline cost could be reduced and still be within the original cost bands as presented in the February 14th and 23rd presentations. Lockheed Propulsion Company accomplished this and the lower baseline costs are reflected as Baseline - Revision 1.

Because time was not available to change all the WBS forms, LPC elected in this report to show both the original baseline and Baseline -Revision 1 report. It must be clearly understood that Baseline - Revision 1 represents the best cost estimate, and LPC's cost position. The SRM is considered "hard" whereas the stage and operations cost could be reduced further.

1.3 CONCLUSION

In conclusion, it is contended that Lockheed's costs, summarized in the chart below, and based on years of 156-inch experience, are realistic figures and cover all NASA study objectives.

Total Booster Vehicle Program Costs

Baseline Cost - Revision 1

(Cost in Millions)

	Baseline Cost	Reductions	Revision 1 Baseline Costs
Recurring SRM Production	$2,242.8	$266.8	$1,976.0
Recurring Stage Production	626.5	155.7	470.8
Recurring Operations	544.3	98.0	446.3
Nonrecurring Production	61.1		61.1
DDT&E	189.8	3.8	186.1
Total	$3,664.5	$524.2	$3,140.3
Total Cost/Launch	$8.2		$7.1
Recurring Cost/Launch	$7.7		$6.6

Lockheed Propulsion Company has completed the study of the Solid Rocket Motor (SRM) as boosters for the Space Shuttle. The study results show that the 156-inch SRMs can accomplish the intended purpose of the booster at a significantly lower cost than that estimated for liquid propellant engines. The Baseline - Revision 1 presented above is LPC's best estimate and firm cost position.

The costs shown in this report reflect the results of the use of existing large solid motor technology. The costs further reflect the industry experience obtained in the successful firings of nine 156-inch motors and numerous 120-inch motors. The credibility of the use of 156-inch motors is the record of complete success for these units in testing at performance levels equivalent to the requirements of the Shuttle Booster. Lockheed Propulsion Company has built and successfully tested, within budget, more than half of the 156-inch motors produced by the solid rocket industry. This is the basis of credibility for this estimate.

Section 2

COST SUMMARY

(Cost in Millions)

BOOSTER VEHICLE - 156-7 PARALLEL

OPTION I - BASIC WITH THRUST TERM AND TVC

	SRM (WBS 3.3.2)	STAGE (WBS 3.3.1/.3/.5/.6/.7)	TOTAL (WBS 3.3)
TOTAL PROGRAM			
Total DDT&E	$ 141.608	$ 48.198	$ 189.806
Total Production	2,545.691	929.019	3,474.710
Total Program	$2,687.299	$977.217	$3,664.516
TOTAL RECURRING			
Total Production	$2,545.691	$929.019	$3,474.710
Less: Facilities (WBS 3.3.2.4)	25.700	-	25.700
Total Recurring	$2,519.991	$929.019	$3,449.010

2.1.2 Option II - Basic (W/O Thrust Termination and TVC)

(Cost in Millions)

BOOSTER VEHICLE - 156-7 PARALLEL

OPTION II - BASIC (W/ O THRUST TERM AND TVC)

	SRM (WBS 3.3.2)	STAGE (WBS 3.3.1/.3/.5/.6/.7)	TOTAL (WBS 3.3)
TOTAL PROGRAM			
Total DDT&E	$ 127.356	$ 44.111	$ 171.467
Total Production	2,214.060	859.443	3,073.483
Total Program	$2,341.396	$903.554	$3,244.950
TOTAL RECURRING			
Total Production	$2,214.040	$859.443	$3,073.483
Less: Facilities (WBS 3.3.2.4)	25.700	-	25.700
Total Recurring	$2,188.340	$859.443	$3,047.783

(Cost in Millions)

BOOSTER VEHICLE - 156-7 PARALLEL

OPTION III - BASIC WITH TVC

	SRM (WBS 3.3.2)	STAGE (WBS 3.3.1/.3/.5/.6/.7)	TOTAL (WBS 3.3)
TOTAL PROGRAM			
Total DDT&E	$ 139.504	$ 47.340	$ 186.844
Total Production	2,503.895	912.782	3,416.677
Total Program Cost	$2,643.399	$960.122	$3,603.521
TOTAL RECURRING			
Total Production	$2,503.895	$912.782	$3,416.677
Less: Facilities (WBS 3.3.2.4)	25.700	-	25.700
Total Recurring	$2,478.195	$912.782	$3,390.977

2.1.4 Option IV - Basic with Thrust Termination

(Cost in Millions)

BOOSTER VEHICLE 156-7 PARALLEL

OPTION IV - BASIC WITH THRUST TERMINATION

	SRM (WBS 3.3.2)	STAGE (WBS 3.3.1/.3/.5/.6/.7)	TOTAL (WBS 3.3)
TOTAL PROGRAM			
Total DDT&E	$ 129.460	$ 44.969	$ 174.429
Total Production	2,255.837	875.679	3,131.516
Total Program	$2,385.297	$920.648	$3,305.945
TOTAL RECURRING			
Total Production	$2,255.837	$875.679	$3,131.516
Less: Facilities (WBS 3.3.2.4)	25.700	-	25.700
Total Recurring	$2,230.137	$875.679	$3,105.816

2.2 156-6 SERIES - BASIC WITH THRUST TERMINATION AND TVC

(Cost in Millions)

BOOSTER VEHICLE - 156-6 SERIES

BASIC WITH THRUST TERM AND TVC

	SRM (WBS 3.3.2)	STAGE (WBS 3.3.1/.3/.5/.6/.7)	TOTAL (WBS 3.3)
TOTAL PROGRAM			
Total DDT&E	$ 163.834	$ 58.097	$ 221.931
Total Production	3,394.253	1,114.824	4,509.077
Total Program	$3,558.087	$1,172.921	$4,731.008
TOTAL RECURRING			
Total Production	$3,394.253	$1,114.824	$4,509.077
Less: Facilities (WBS 3.3.2.4)	32.400	-	32.400
Total Recurring	$3,361.853	$1,114.824	$4,476.677

Section 3

WORK BREAKDOWN STRUCTURE (WBS)

The Work Breakdown Structure (WBS) as presented in the NASA Work Statement has been used throughout the Study Program. Lockheed Propulsion Company has expanded this Work Breakdown Structure for clarity and to provide credible, identifiable costs for each level of the Work Breakdown Structure.

3.1 DESCRIPTION OF CONTENT

Task descriptions, as well as the costs, are segregated into two categories: (1) Design, Development, Test and Evaluation (DDT&E), and (2) Production. Each WBS description is cross-references to the WBS by WBS numbers, and are applicable to all LPC Program Options.

3.1.1 WBS Dictionary, DDT&E

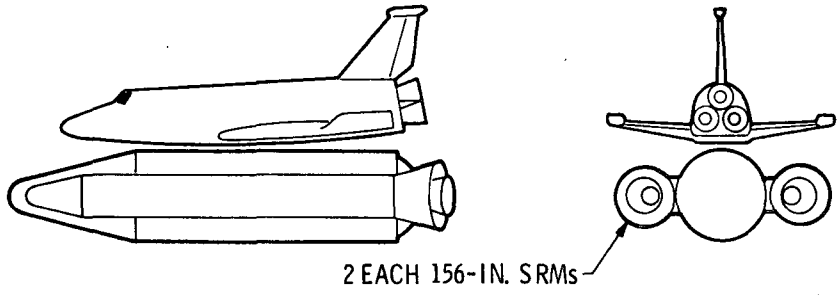
WBS NO. 3.3 BOOSTER VEHICLE

Contained herein is the total cost required to develop a Solid Rocket Motor booster assembly presented in Figure 3-1, that meets the requirements of the Space Shuttle. Included are all costs for booster system development, one unmanned KSC launch, five manned launches, and related launch support.

Facilities for the development program and tooling for the development and production program are included in this total development cost. These costs are detailed in appropriate subtasks.

All tasks considered are within the safety and performance requirements for a man-rated system.

Figure 3-1 156-INCH VEHICLE BASELINE
PARALLEL BURN

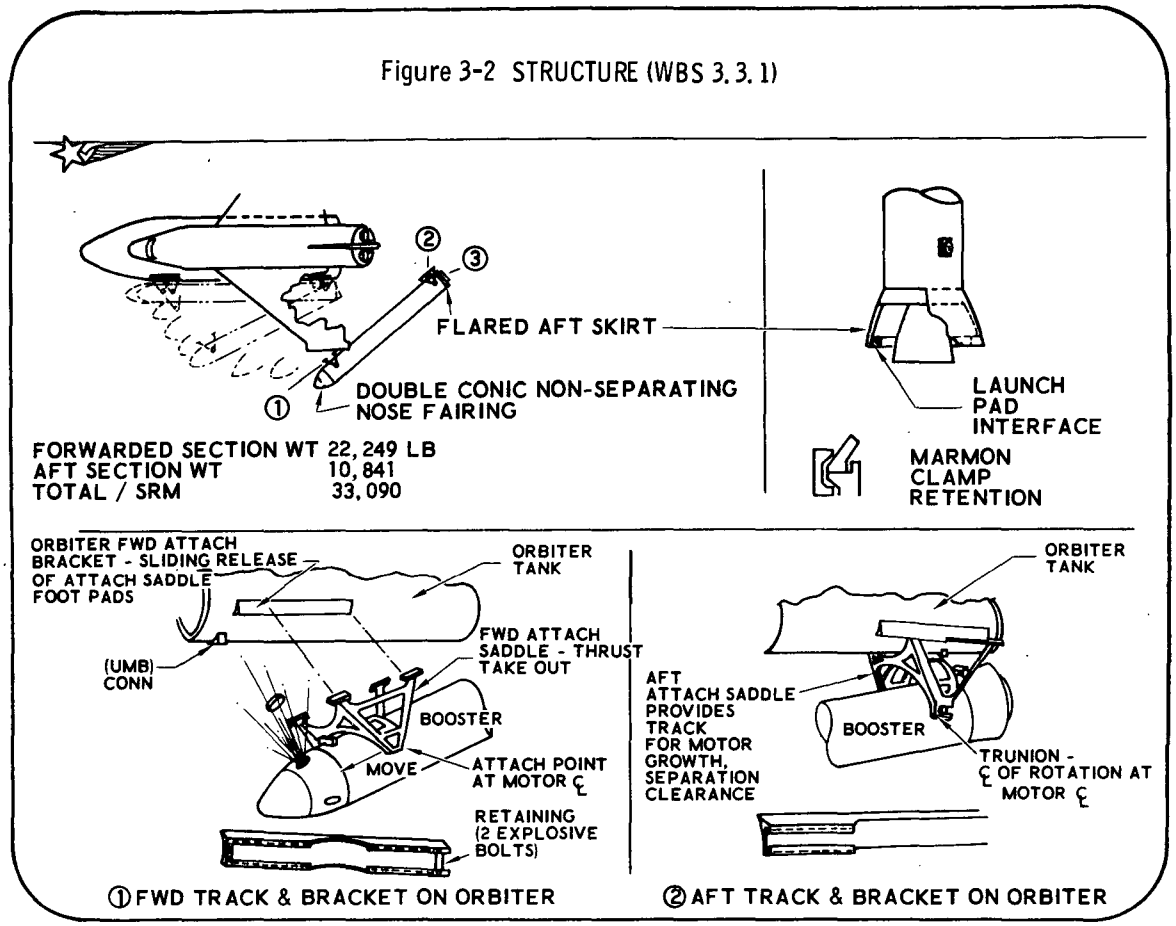


WEIGHTS LB x 10^{-6}	
ORBITER LIFT-OFF WEIGHT	1.800
BOOSTER LIFT-OFF WEIGHT	2.835
GROSS LIFT-OFF WEIGHT	4.635

WBS NO. 3.3.1 STRUCTURE

This task includes the design and development of the mechanical components necessary to attach the SRMs to the launch vehicle, and methods of SRM separation after burnout as summarized in Figure 3-2. No costs are directly chargeable to this task level, but rather to the applicable subtasks.

Figure 3-2 STRUCTURE (WBS 3.3.1)



WBS NO. 3.3.1.1 ATTACHMENTS

Assigned to this task are all labor and materials for the design, development, and manufacture of structural components required to mate the SRMs to the orbiter vehicle tank. Engineering effort will include assessment of the reaction loads into the tank during flight, hardware design, component manufacture, structural tests, material and manufacturing specification preparation, and delivery of sufficient units to support two ground test vehicle assemblies and six flight launches.

Components on the HO tank, which remain with the tank after separation, are not included.

WBS NO. 3.3.1.2 CLUSTERING AND INTERSTAGE

No effort is required under this task for the parallel configuration.

WBS NO. 3.3.1.3 FAIRINGS

This category includes all labor and materials associated with development of the forward and aft fairings on the SRMs. The forward fairing will be conical, tapering from the SRM case diameter to a rounded point at the forward end. It shall be designed to house the stage separation mechanism (and possibly recovery equipment) within a clean aerodynamic configuration. The mechanism internal to the forward fairing will not be costed in this task.

The aft fairing shall be designed to support the launch vehicle while on the pad, and to protect the nozzle from aerodynamic flight loads created by the airstream.

Costs shall include engineering design, component manufacture, and verification for two inert booster assemblies and six flight launches.

WBS NO. 3.3.1.4 AERODYNAMIC SURFACES

No effort is required under this task for the parallel burn configuration.

WBS NO. 3.3.1.5 SEPARATION

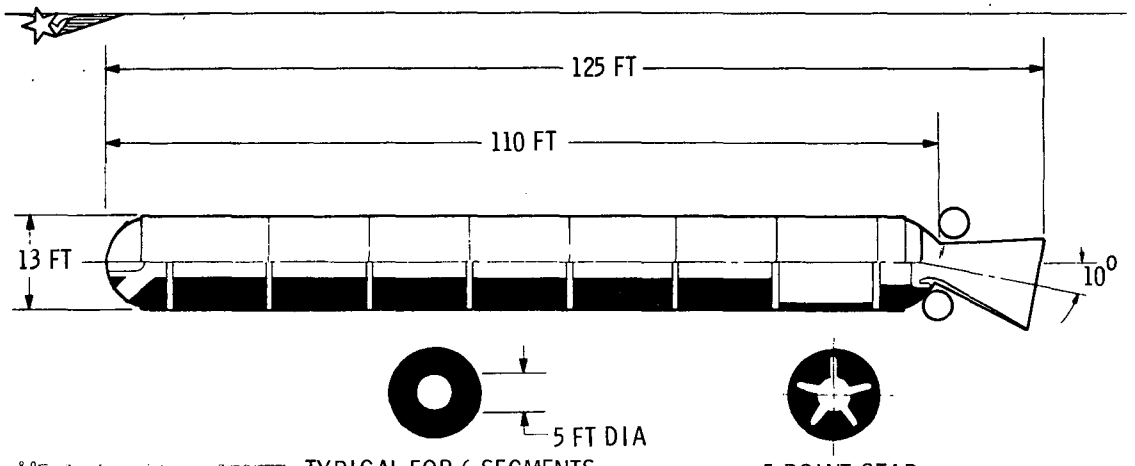
This task includes all labor and materials related to the separation of the SRM from the orbiter vehicle. Separation shall be by initiation of explosive bolts to release the SRMs from the HO tank, and the activation of separation rockets to direct the SRM away from the orbiter. Instrumentation, sensors, and electrical circuits and controls required for separation are included in WBS tasks 3.3.3 and 3.3.2.3.3.

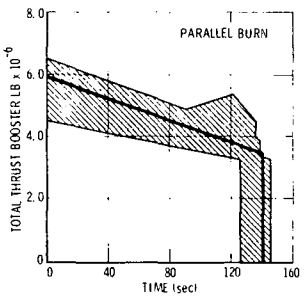
Technical effort shall consist of the separation system design, component evaluation, separation rocket development and test, and manufacture of sufficient components for two inert assemblies and six flight launches. Bench testing of all explosive and propulsive units will be conducted to ensure compliance to all system safety and reliability requirements.

WBS NO. 3.3.2 SOLID ROCKET MOTOR

This task contains the accumulation of the costs required to develop the Solid Rocket Motor portion of the Booster Vehicle as shown in Figure 3-3. Included are all efforts related to SRM design, manufacturing, material and component procurement, production and development tooling, development facilities, and flight support.

Figure 3-3 SOLID ROCKET MOTOR (WBS 3.3.2)





PERFORMANCE SUMMARY

INITIAL THRUST -	2.94×10^6 LB
BURN TIME -	138 SEC
MEOP -	1000 PSI

WEIGHT SUMMARY

GROSS WEIGHT -	1.38×10^6 LB
PROPELLANT -	1.23×10^6 LB
TOTAL INERTS -	0.15×10^6 LB
MASS RATIO -	0.89

WBS NO. 3.3.2.1 PROGRAM MANAGEMENT

This WBS number is to accumulate task assignments for all personnel directly responsible for program control. Costs will be collected under the appropriate subtasks.

WBS NO. 3.3.2.1.1 PROGRAM DIRECTION

This task will include labor related to Program Management planning and control. The Program Office shall perform tasks related to overall program direction, i. e. , ensuring schedule commitments are met, compliance with contract financial and technical requirements, and advance planning. Program direction shall be by issuance of a program plan to define the contractual scope of work, and the continued program control of the manufacturing, engineering and product assurance technical effort. The Program Office will provide the necessary contract controls to evaluate performance of program tasks against the established goals.

WBS NO. 3.3.2.1.2 DATA

The labor assigned to this task shall be that required for Administrative Services and Computer Operation personnel to prepare and maintain data records of all SRM booster designs, design changes, production performance, and customer reports. This task also includes the labor required to prepare tooling reports, safety reports, manpower utilization reports, etc.

WBS NO. 3.3.2.2 SYSTEMS ENGINEERING

This task is for the accumulation of costs associated with development effort of the SRM system, including system definition and interfaces, ground support equipment, and reliability. Costs will be assigned to the applicable subtask.

WBS NO. 3.3.2.2.1 SYSTEM DEFINITION AND INTERFACE

This task includes the effort to study the effect of the SRM operation on the Space Shuttle. Technical studies shall include such items as methods of abort control, thrust termination effects on orbiter flight and safety, requirements for destruct systems, and methods and requirements for tailoring and adjusting the SRM thrust and impulse. It also includes all aerodynamic and flight trajectory analysis.

Hardware development or testing are not included within this task.

WBS NO. 3.3.2.2.2 GROUND SUPPORT EQUIPMENT DEFINITION

Assigned to this task are the efforts associated with interfacing the engineering design to the ground support equipment. Included are studies of weight, c. g. s, safety, environmental constraints, and methods of handling. Direct effort related to equipment design and fabrication are contained in WBS No. 3.3.2.5.1.

Particular emphasis will be applied to the requirements of the booster system at KSC.

WBS NO. 3.3.2.2.3 RELIABILITY, PRODUCIBILITY, MAINTAINABILITY

This task includes the technical effort related to the study of SRM components, materials, and manufacture to assess the reliability, producibility, and maintainability of the SRM. Evaluation of methods for measuring and assuring SRM quality and the transfer of these data to meaningful control procedures will be required.

Reliability Engineering will develop and conduct a program of reliability and statistical analysis directed toward the assessment of design and verification of manufacturing processes. Tasks will include evaluation of designs, review of failure modes and effects, and corresponding numerical assessments of reliability. This task is accomplished through evolution of control criteria and statistical assessment of critical attributes or processes. Typical of these would be propellant burn rate and physical properties for which control limits are established and trends are tracked and reported to the affected organization and management. This effort directly supports preparation of periodic reporting of Quality Trends as directed by the Quality Program requirements.

WBS NO. 3.3.2.3 SOLID ROCKET MOTORS

Accumulated within this task are all aspects of design, manufacture, and materials associated with the SRM. Costs are not associated with this task as it is an accumulation of subtasks 3.3.2.3.1 thru 3.3.2.3.6.

This task encompasses 25 SRMs for use as follows:

Development	5
PFRT	4
Inert	4
Flight	12

Effort is required for technical support for all subtasks. Some of this effort is described in this category, but costs will be allocated proportionally to the applicable subtasks. Typical of this is the SRM manufacturing operations planning and control, including preparation of manufacturing schedules, process control plans, tooling schedules, and process equipment schedules.

WBS NO. 3.3.2.3.1 STRUCTURES

This task includes all effort associated with the engineering requirements for development of the SRM materials and components. The costs associated with this task are cumulative from the following major component subtasks:

3.3.2.3.1.1 SRM Motor Case

3.3.2.3.1.2 Nozzle

3.3.2.3.1.3 Igniter Assembly

3.3.2.3.1.4 Thrust Termination

3.3.2.3.1.5 Propellant

The technical development required for the SRM will be based on previous LPC and industry large motor technology, and the engineering effort required to transfer this knowledge to a man-rated, reliable space shuttle booster.

Where level-of-effort for planning and control is required, it may be described in the category, but costs will be apportioned to the applicable subtasks.

For each subtask, the costs shall include, but not be limited to, the following:

- All procurement costs
- Component inspection
- Product assurance reporting
- Process procedure preparation
- Process improvement evaluation
- Drawing and specification preparation and issuance
- Document control
- Component traceability

WBS NO. 3.3.2.3.1.1 SRM MOTOR CASE

The SRM motor case consists of seven identical center segments and two hemispherical end domes. Under this task, the engineering effort includes the structural design of the case, material selection studies, fabrication methods, and selection and verification of inspection and acceptance techniques. Also included in this task are design and proof testing of the segment joining method, stress analysis for launch and flight environments, and an evaluation of methods for corrosion prevention. Engineering technical support will be supplied to the various lower-level subcontractors to establish controls and specifications on materials and procedures. A minimum of two hydroburst tests will be conducted for case design verification.

Case insulation design and manufacture is included in this task. It shall consist of material thermal analysis, erosion analysis, and performance predictions of the static test motors. Engineering support shall be given to the insulation material supplier and case insulation vendor to develop material and process documentation for quality control purposes.

To assess the practicality of reuse/refurbishment, the cases from four static test-fired motors will be reprocessed into cases for the inert booster assemblies.

WBS NO. 3.3.2.3.1.2 NOZZLE

This task includes all engineering effort associated with design, manufacture, and verification of the nozzle and Lockseal for the SRM. Included are such basic tasks as structural attachment to the case, ablative performance predictions, and thermal stress analysis of the plastic components. Associated development effort will include materials selection and testing, manufacturing methods selection and verification, vendor manufacturing verification, and specification documentation.

No assignable nozzle component tests will be conducted, but thorough analysis of performance will be conducted on nozzles fired on the static test motors.

Lockseal testing shall, at a minimum, consist of the following:

- Subscale material and process studies
- Subscale bench tests
- Fullscale bench tests

Throughout the Development effort, particular emphasis will be placed on standardizing material and process parameters so that the Production nozzles will be of uniform quality.

Process methods will be developed to remove and replace the plastic portion of fired nozzles. A minimum of four nozzles will be so processed.

WBS NO. 3.3.2.3.1.3 IGNITER

This task includes all effort associated with design, testing, and manufacture of the igniter assembly. Design effort will include items such as case structural capability, internal and external insulation thermal protection, propellant grain design, and ignition electrical requirements. Vendor support is required for all the igniter subcomponents such as the case, insulation, and closures. A test program will be conducted to prove ignition reliability and igniter performance reproducibility.

A minimum of six open-air igniter firings will be conducted.

Effort associated with the electrical and control requirements external to the igniter are to be accumulated in WBS 3.3.3 and 3.3.5.

WBS NO. 3.3.2.3.1.4 THRUST TERMINATION

Collected within this task are the efforts required to design, manufacture, and verify the SRM thrust termination (T/T) system. The T/T system will employ shaped charges that will cut openings in the SRM forward dome. Engineering effort will include shaped charge design, exhaust stack and insulation design, and ballistics analysis. A series of tests will be conducted to sequentially verify the system as shown below:

- Charge cutting ability on flat plate
- T/T action on pressurized forward domes
- T/T performance on SRMs

The T/T system will be tested at AFRPL for evaluation. One SRM will have the T/T activated during motor tailoff with a reduced chamber pressure, and one SRM will have the T/T activated while under full pressure. These motor tests are costed in WBS No. 3.3.2.3.5.

WBS NO. 3.3.2.3.1.5 PROPELLANT

This task includes all effort related to the manufacture, testing, processing and loading of the propellant into the SRM segments. Propellant development is not required, but adjustments to the proposed LPC-580A propellant formulation may be necessary to optimize burn rate and liner bond conditions. Engineering support will be required to update and/or prepare material and process specifications, establish acceptance limits, and verify inspection methods.

Included in this category are the efforts associated with raw material lot acceptance, propellant mixing, motor line and cast operations, and surface inhibiting.

Procedures, sampling plans, inspection plans, and process control plans will be developed and updated as required.

WBS NO. 3.3.2.3.2 TVC

This task includes all effort associated with the design, development, and qualification of the SRM TVC system. It includes all effort not assignable to the fixed nozzle design such as the Lockseal actuators, plumbing, and associated hardware. Wherever possible, off-the-shelf components will be

used. The technical effort will comprise all required component designs, integration design with the case and nozzle, and system verification. In addition to full system testing on the SRM static test motors, component tests will, at a minimum, include the following:

Servo Actuator: System performance

Servo Valves: One burst test

Actuator Bodies: One burst test

Hydraulic Power Supply: One burst test

TVC System: Pressurized bench-tests to cycle life failure and/or pressure failure

Companion support will be required at the component vendors to develop adequate process and material specifications for production quality.

This category also includes a portion of the costs developed under WBS No. 3.3.3.1. Such costs are developed as a system cost, and apportioned to this category as being more applicable to the SRM than to the stage costs.

WBS NO. 3.3.2.3.3 SRM POWER AND ELECTRICAL

This category includes all labor and materials associated with the development of the SRM electrical components and consists of instrumentation including motor performance sensors and signal conditioners. Tests will be conducted to assure component reliability and safety. Mockup manufacturing testing will be conducted prior to inclusion in the SRMs.

The power system for SRM and stage operation are costed in WBS No. 3.3.5.

WBS NO. 3.3.2.3.4 SRM INSTALLATION AND ASSEMBLY

This category includes all costs associated with assembly and component installation of the SRM. It includes the development of all procedures, preparation of instruction manuals, and definition of tooling and handling requirements.

For the Development program it includes the assembly of all motors for Ground Test (WBS No. 3.3.2.3.6) and the inert and live motors at KSC. Costs associated with stage assembly and stage equipment (avionics, power, etc) are costed in WBS No. 3.3.6 and 3.3.7.

Specifically included are those items developed and manufactured in WBS No. 3.3.2.3.1. It also includes the miscellaneous assembly materials such as O-rings, adhesives and lubricants required in the SRM assembly.

WBS NO. 3.3.2.3.5 GROUND TEST

This task includes all full-scale SRM test activity except that assembly activity defined under WBS No. 3.3.2.3.4. The basic task includes coordination of test equipment procurement and installation, preparation of test procedures and authorizing documentation, conduct of specialized computer programming peculiar to the test firing operations, and similar preparations for conducting test operations. Test firing operations include filling of hydraulic and gas pressure tanks, application of instrumentation, hookup and check of control, firing and data, conduct of prefire briefings and visitor control, photography of firing activities and acquisition of firing data. Post-fire activities include reduction of data, photography and processing of still and motion picture film, removal and disposition of the expended test article and refurbishment of test and data acquisition equipment and related electronics and wiring. Post-test activity does not include any refurbishment (e. g. , hydrotest, etc) of the expended test articles.

Reporting activity includes preparation of data for engineering assessment, provision of detail test operational records and provision of still and motion picture photography.

This task is limited to five development and four PFRT static motor firings, however, procedures and manuals for KSC flight test data acquisition will be prepared.

WBS NO. 3.3.2.3.6 TOOLING

This category includes all labor and material costs to design, fabricate, inspect and verify tooling required for manufacture and assembly of the SRM, excluding AGE assembly requirements (WBS No. 3.3.2.5.1). Requirements for development and production are included but costed separately. All tool designs shall be documented and schedules and records of maintenance, repairs, and rework shall be maintained. Tool definition shall include all items required for SRM manufacture, shipping containers (reusable or expendable) required for component protection, assembly handling devices, inspection jigs and in-process protective devices. Tooling used for manufacture of a component at a vendor's facility also are included.

WBS NO. 3.3.2.4 FACILITIES

This task includes all costs associated with the purchase of land and equipment and the design, construction, and expansion of facilities required for the manufacture and assembly of the SRMs during the Development program. Effort shall include the following:

- Equipment selection and procurement
- Site selection and land improvement

- Facility and building layout concept including flow analysis and equipment integration
- Facility layout and approval
- Building design
- Construction of buildings and modification of existing buildings
- Equipment installation and checkout
- Maintenance of buildings, grounds and equipment

Facility checkout (such as mixer trials) shall be collected in WBS No. 3.3.2.3.

WBS NO. 3.3.2.5 SUPPORT EQUIPMENT AND SPARES

This category is for cost accumulation only and no costs are directly assignable. It includes costs collected under WBS No. 3.3.2.5.1 and 3.3.2.5.2.

WBS NO. 3.3.2.5.1 AGE DESIGN AND FABRICATION

This category includes all labor and materials required to design, fabricate and acceptance-test the equipment required to handle and assemble the SRM and its components. It includes that equipment for use at the factory and for the inert and live SRM boosters at KSC. Allowances shall be made for design updating, modifications, and maintenance throughout development. Manuals on design, maintenance and refurbishment shall be prepared. Considered here are the requirements for the DDT&E effort only.

WBS NO. 3.3.2.5.2 SPARES

This task includes all material and labor to procure and produce spares for the Development program. Included shall be allowances for expected repair and rework of those major items that are discrepant but not rejectable.

Although the need for spares is unanticipated, one set shall be planned to support the development ground test and launch program.

Design, quality, and data requirements for spares will be identical to the basic program requirements.

WBS NO. 3.3.2.6 FLIGHT-TEST SUPPORT

This task includes all labor associated with the flight-test performance of the SRMs. It includes the development of procedures to be used in predicting and evaluating the SRM flight performance, preparation of preflight motor assessments, analysis of flight data, updating of performance requirements and liaison with the customer and other contractors relating to SRM requirements and performance. This task covers only the first six launches at KSC.

WBS NO. 3.3.2.7 OPERATIONS SUPPORT

This task is an accumulation of costs associated with the transportation of the SRMs to KSC and the coordination of SRM operations at KSC.

WBS NO. 3.3.2.7.1 OPERATIONS SUPPORT

This category in cludes the labor of technical personnel to establish and develop a plan for control of the SRM booster logistics, maintenance, and processing at KSC in direct support of the first six launches. It will include the effort for technical personnel to handle design changes, assembly procedure reviews, receiving inspection, and storage conditions, and to maintain logistics records. This task includes effort on all components developed and delivered under WBS No. 3.3.2 and SRM Assembly WBS No. 3.3.2.3.4. It does not include support of vehicle assembly, WBS No. 3.3.6.

WBS NO. 3.3.2.7.2 TRANSPORTATION

This task is for assignment of cost directly related to the transportation of SRM segments and associated components to KSC for two inert assemblies and six live launches. Labor costs are not assignable to this WBS, but rather to the specific subtask under WBS No. 3.3.2.3.

WBS NO. 3.3.3 AVIONICS

This task includes the electronics and data collection associated with the flight control and flight performance of the SRM booster. No costs are assignable directly to this task number.

WBS NO. 3.3.3.1 FLIGHT CONTROL ELECTRONICS

All labor and material for design, development, test, and manufacture of the flight control electronics shall be charged to this task. Included are the command and control systems for the TVC. All components will be breadboard checked out and then tested for safety and reliability in the final configuration. Manufacture and performance specifications will be prepared

for all components and the total system. Sufficient assemblies shall be supplied for two inert assemblies and six flight launches.

WBS NO. 3.3.3.2 GUIDANCE AND NAVIGATION

This task is not applicable to a parallel launch configuration.

WBS NO. 3.3.3.3 DATA MANAGEMENT

The costs for this task include the labor and materials for the stage systems instrumentation/diagnostics and stage electronic logic and sequencing functions and circuit electrical initiation command systems. Technical effort is required to design, procure, and checkout the individual components (subsystem) and the total system with the electronics listed under WBS No. 3.3.3.1. Sufficient systems will be prepared to support two inert booster assemblies and six flight launches.

WBS NO. 3.3.4 CONTROL SYSTEMS

No costs are associated with this task for parallel configuration.

WBS NO. 3.3.5 POWER

This is a summation task and no charges are to be assigned directly. Because subtask 3.3.5.2 is not applicable, it is the same as 3.3.5.1 in content and costs.

WBS NO. 3.3.5.1 ELECTRICAL

This task includes all labor and materials required to develop the electrical power system for the SRM. Redundant power supplies will be used: forward end high voltage power for initiation, thrust termination, and separation; aft end low voltage power for thrust vector control actuation. This task includes all batteries, power distribution boxes and cabling, high voltage firing units and output cables and inverters, required performance characteristics, capability to meet logistic and flight environments, EMI and RF hazards, etc. Sufficient parts shall be manufactured for two inert assemblies and six launch flights. The system shall also be tested on four static test motors.

WBS NO. 3.3.5.2 HYDRAULICS

No input is required for the parallel configuration.

WBS NO. 3.3.6 INSTALLATION, ASSEMBLY, AND CHECKOUT

This category of cost includes the labor required for the development of equipment/systems/procedures for the following:

- Acceptance testing of stage packages
- Assembly and checkout of all stage systems
- Assembly and checkout associated with mating stage systems to built-up SRM
- Assembly and checkout associated with mating full SRM stage to the orbiter
- Launch support of total vehicle for the SRM stage system

It also includes the operation costs to implement the above requirements and procedures for two inert and six live assemblies.

It does not include assembly and checkout of the SRMs which are collected in WBS No. 3.3.2.3.4.

WBS NO. 3.3.7 MAJOR GROUND TESTS

This category emcompasses two major tasks; first, the effort required to support the booster/stage systems checkout and operation in the SRM ground tests (WBS No. 3.3.2.3.5), and second, launch support at KSC for all DDT&E inert structural vehicle tests and flight tests.

In the first task, although only single SRMs will be ground-tested, portions of the structures, such as fairings and separation (WBS No. 3.3.1), the TVC controls (WBS No. 3.3.3.1) and the power system (WBS No. 3.3.5) will be evaluated and performance will be measured.

For lack of a more suitable WBS assignment, all KSC launch support is to be included. This includes logistics control, component troubleshooting, documentation of components, engineering design documentation coordination, and general sustaining technical launch support personnel. On the DDT&E program, technical support will be required throughout all phases of testing and evaluating the two inert assemblies and the associated AGE.

3.1.2 WBS Dictionary, Production

WBS NO. 3.3 BOOSTER VEHICLE

All costs required to manufacture, deliver, assemble, and launch 440 Solid Rocket Motor Booster assemblies (880 SRMs) are totaled within this task.

Tooling for these SRMs was included in the Development Program.

Continuing technical support is planned during the Production program, but no major technical changes are planned.

WBS NO. 3.3.1 STRUCTURE

This category includes all costs related to the fabrication of the mechanical attachments of the SRMs to the orbiter vehicle. Costs are not assignable to the WBS number, but rather to the applicable subtasks.

WBS NO. 3.3.1.1 ATTACHMENTS

This task includes all material and labor costs to support the required launches. Included are all structural components of the attachment structure except those parts remaining with the HO tank after separation. Technical support is required to maintain design configuration and provide production engineering and quality control at the subcontractors.

WBS NO. 3.3.1.2 CLUSTERING AND INTERSTAGE

No effort is required in this task for parallel configuration.

WBS NO. 3.3.1.3 FAIRINGS

This cost includes all labor and material associated with the SRM forward and aft fairings. It includes continuing engineering design support, specification changes, and technical and product assurance liaison with manufacturing vendors.

WBS NO. 3.3.1.4 AERODYNAMIC SURFACES

No effort is required under this WBS for the parallel burn configuration.

WBS NO. 3.3.1.5 SEPARATION

Within this category are all costs for delivery of the required mechanical, ordnance, and propulsion components required to provide separation of the SRMs after burnout from the orbiter's HO tank. Included in the WBS are the explosive bolts, release pins and separation rockets, and the required continuing engineering support.

Quality assurance acceptance tasks will be conducted to inspect, on a sampling basis, all explosive and propulsive devices.

WBS NO. 3.3.2 SOLID ROCKET MOTOR

Accumulated in this task will be all SRM costs required to support 440 launches from KSC. In addition, three Pre-Production Qualification (PPQ) motors will be manufactured and static-test-fired to provide verification of any minor design changes created during the Development program, and to verify the acceptability of the production facility. These motors will be test-fired at Potrero.

No costs will be charged directly to this number.

WBS NO. 3.3.2.1 PROGRAM MANAGEMENT

This is a cost accumulation task level for all costs required to manage and control the SRM Booster Production Program. Costs will be assigned to the applicable subtasks.

WBS NO. 3.3.2.1.1 PROGRAM MANAGEMENT

This task will include all labor required to manage the SRM booster program. Program Management shall provide continual program technical direction, financial planning, customer coordination, subcontractor control, and liaison with other Space Shuttle contractors as required.

WBS NO. 3.3.2.1.2 DATA

The labor assigned to this task shall be that required for Administrative Services and Computer Operation personnel, to prepare and maintain data records of all SRM booster designs, design changes, production performance and customer reports. This task also includes the labor required to prepare documentation such as tooling reports, safety reports, manpower utilization reports, etc.

WBS NO. 3.3.2.2 SYSTEMS ENGINEERING

This task includes all effort required to maintain the SRM Booster System definition. Costs will be assigned directly to the applicable subtask and accumulated to this number.

WBS NO. 3.3.2.2.1 SYSTEM DEFINITION AND INTERFACE

This category includes all labor associated with the continuing performance effects of the SRM Booster operation on the Space Shuttle. Included herein are such items as technical liaison (not Program Management) with the Prime Contractor or other shuttle subcontractors regarding the flight affects of the SRM Boosters.

WBS NO. 3.3.2.2.2 GROUND SUPPORT EQUIPMENT DEFINITION

This task includes all technical effort, including Prime Contractor liaison, to ensure adequate interface of the SRM requirements to the ground support equipment. It will include technical preparation of all required handling procedures and manuals.

Direct effort related to the design and fabrication of the equipment is assigned to WBS No. 3.3.2.5.1.

WBS NO. 3.3.2.2.3 RELIABILITY, PRODUCIBILITY, MAINTAINABILITY

This task is for assignment of all labor required to control the reliability of the SRM booster throughout the launch program. It will include the collection and analysis of materials and manufacturing production quality records, and the SRM flight performance data. In addition, controls and recommendations will be established and updated to ensure system reliability and performance.

The control criteria established from design limits and experience in the Development program will set the baseline for controls to be used in the Production phase. These controls, including both dimensional attributes on hardware and critical processes that affect product performance will be statistically analyzed to show any quality trends.

WBS NO. 3.3.2.3 SOLID ROCKET MOTORS

This task includes all aspects of design, manufacture and material associated with the SRM. No costs are associated with this task as it is an accumulation of WBS tasks 3.3.2.3.1 thru 3.3.2.3.6.

This task encompasses 883 SRMs for use as follows:

Flight	880
PPQ (See WBS No. 3.3.2)	3
Total	883

Requirements for spares are assigned to WBS No. 3.3.2.5.2.

Certain effort is required for technical support for all subtasks. These may be described in this category, but costs will be allocated proportionally to the applicable subtasks. Typical of this is the SRM manufacturing, operations planning and control, including preparation of manufacturing schedules, process control plans, tooling schedules, and process equipment schedules.

WBS NO. 3.3.2.3.1 STRUCTURES

This task includes all costs associated with the procurement and manufacture of the SRM. It includes the requirements for the following:

3.3.2.3.1 SRM Motor Case

3.3.2.3.2 Nozzle and Lockseal

3.3.2.3.3 Igniter Assembly

3.3.2.3.4 Thrust Termination

3.3.2.3.5 Propellant and Motor Loading

The requirements for each of these were described separately in subsection 3.1.1 for the DDT&E plan under the WBS numbers indicated. For the production plan, the requirements are similar and are not separately described, however the costs will be assignable to the specific subtasks. Specific effort to be costed include the following:

- Vendor production costs including facilities
- Engineering design update and drawing maintenance
- Specification maintenance
- SRM segment production
- Product assurance testing of component acceptability
- Product assurance process inspection

- Engineering vendor control
- MRB system implementation
- Component rework
- Establishment of dual sources of critical items
- Checkout of production facilities

WBS NO. 3.3.2.3.3 TVC

This task includes all labor and materials related to delivery of TVC systems sufficient to support the production program. This includes continuing technical design support, manufacturing control, and quality assurance bench-testing. It also includes a portion of TVC control costs described in the DDT&E plan.

WBS NO. 3.3.2.3.3 SRM POWER AND ELECTRICAL

This category includes all costs for procurement and product assurance acceptance and testing of the SRM instrumentation/diagnostics including motor performance sensors and signal conditioners.

WBS NO. 3.3.2.3.4 SRM INSTALLATION AND ASSEMBLY

This category includes all costs associated with assembly and component installation of the SRMs. Specifically included are those items developed and manufactured in WBS Nos. 3.3.2.3.1, .2, and .3. It also includes the miscellaneous assembly materials such as O-rings, adhesives and lubricants required in the SRM assembly.

Costs associated with stage assembly are under WBS No. 3.3.6.

Also to be included are the costs of assembly of three PPQ motors for test at LPC.

WBS NO. 3.3.2.3.5 GROUND TEST

This task includes the costs associated with the static-test-firing of three PPQ SRMs. No stage tests are required.

WBS NO. 3.3.2.3.6 TOOLING

All tooling costs for production were included in DDT&E. This task, therefore, includes only those costs required for sustaining tool inspection, maintenance and rework.

WBS NO. 3.3.2.4 FACILITIES

This task includes all costs required to buy land and equipment and to design, construct and expand buildings for the manufacture and assembly of SRMs.

Effort shall include the following:

- Equipment selection and procurement
- Site selection and land improvement
- Facility and building layout concept including flow analysis and equipment integration
- Facility layout and approval
- Building design
- Construction of new buildings and modification of existing buildings
- Equipment installation and checkout
- Maintenance of buildings, grounds and equipment

Facility checkout (such as mixer trials) shall be costed against WBS No. 3.3.2.3.

WBS NO. 3.3.2.5 SUPPORT EQUIPMENT AND SPARES

This category is for cost accumulation of WBS tasks 3.3.2.5.1 and 3.3.2.5.2.

WBS NO. 3.3.2.5.1 AGE DESIGN AND FABRICATION

This category includes all costs associated with the design, procurement, and maintenance of AGE to handle the SRMs. This is for requirements over and above that required for DDT&E.

WBS NO. 3.3.2.5.2 SPARES FABRICATION

This task includes all labor and materials directly assignable to the production of SRM and GSE spares to support the launch program. Storage at KSC of SRM components will provide several months inventory of parts.

WBS NO. 3.3.2.6 FLIGHT TEST SUPPORT

This task includes all labor associated with the flight-test performance of the SRMs, including preflight motor assessment, analysis of SRM flight data, updating of performance requirements and liaison with the customer and other contractors relating to SRM requirements and performance.

WBS NO. 3.3.2.7 OPERATIONS SUPPORT

This task is a summation of the subtasks associated with the SRM logistics at KSC.

WBS NO. 3.3.2.7.1 OPERATIONS SUPPORT

This task includes the labor for logistics control of the SRMs and associated hardware. Sustaining engineering and manufacturing personnel will be responsible for SRM storage, assembly, and maintenance. They will also maintain SRM and component documentation records, coordinate required design, process, and procedure changes, and control liaison between LPC and the customer in any SRM problem area.

WBS NO. 3.3.2.7.2 TRANSPORTATION

This task is for assignment of cost directly related to the transportation of SRM segments to KSC. Labor costs are not assignable to this, but rather to the specific subtask under WBS No. 3.3.2.3.

WBS NO. 3.3.3 AVIONICS

This task includes the electronics and data collection associated with the flight control and flight performance of the SRM booster. No costs are assignable directly to this task number.

WBS NO. 3.3.3.1 FLIGHT CONTROL ELECTRONICS

All labor and material for sustaining design and manufacture of the flight control electronics shall be charged to this task. Included are the command and control systems for the TVC.. Manufacture and performance specifications and vendor control will be maintained for all components and the total system. Sufficient assemblies shall be supplied for the 440 launches. Quality control plan implementation will be required.

WBS NO. 3.3.3.2 GUIDANCE AND NAVIGATION

This task is not applicable to a parallel launch configuration.

WBS NO. 3.3.3.3 DATA MANAGEMENT

This task includes all the materials and labor for the stage system instrumentation/diagnostics and stage electronic logic. It also includes sequencing functions and event electrical initiation command systems for 440 launches.

WBS NO. 3.3.4 CONTROL SYSTEMS

No costs are associated with this task for parallel configuration.

WBS NO. 3.3.5 POWER

This task includes the electrical and hydraulic power systems for the booster. Because WBS No. 3.3.5.2, Hydraulic Power, is not applicable to this design, the only cost is for electrical power, WBS No. 3.3.5.1.

WBS NO. 3.3.5.1 ELECTRICAL

This task includes all material and labor costs for delivery of the booster electrical power system. Sustaining technical effort is required for design control, vendor control, and product assurance acceptance and tests.

WBS NO. 3.3.5.2 HYDRAULICS

No input is required for the parallel configuration.

WBS NO. 3.3.6 INSTALLATION, ASSEMBLY, AND CHECKOUT

This category of cost includes all effort related to the assembly of the 440 launch vehicles. It includes such tasks as stage system checkout, SRM/stage assembly, and SRM booster/vehicle assembly.

WBS NO. 3.3.7 MAJOR GROUND TESTS

Because of the lack of a defined WBS, this task includes all effort associated with support of the launch operation not assignable to another specific WBS. Included are such tasks as stage logistics, engineering design documentation maintenance, and SRM/Orbiter flight assessment and data review.

3.2 156-7 SRM, PARALLEL CONFIGURATION

In accordance with the Statement of Work, and subsequent direction received from NASA, DDT&E and Production for the Parallel configuration has been costed in the four Options listed below. A WBS chart is included for each option for DDT&E and Production. Motor quantities are listed on each WBS chart.

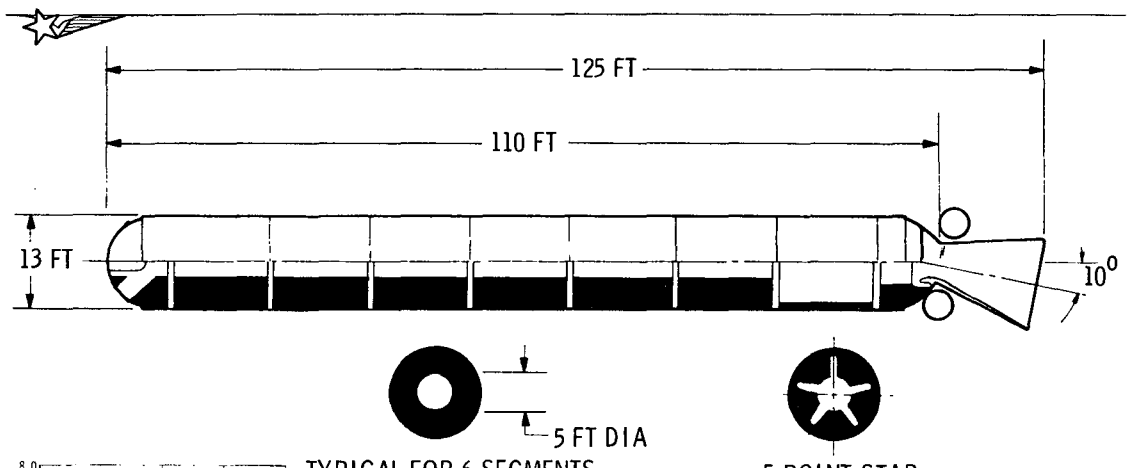
Option I (subsection 3.2.1) Basic motor with Thrust Vector Control (TVC) and Thrust Termination (TT)

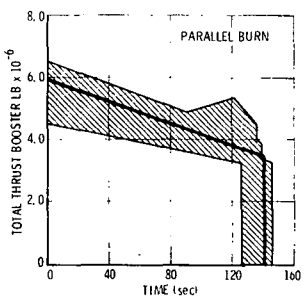
Option II (subsection 3.2.2) Basic motor without TVC and TT

Option III (subsection 3.2.3) Basic motor with TVC only

Option IV (subsection 3.2.4) Basic motor with TT only

Figure 3-4 OPTION I
SRM PARALLEL BASELINE





PERFORMANCE SUMMARY

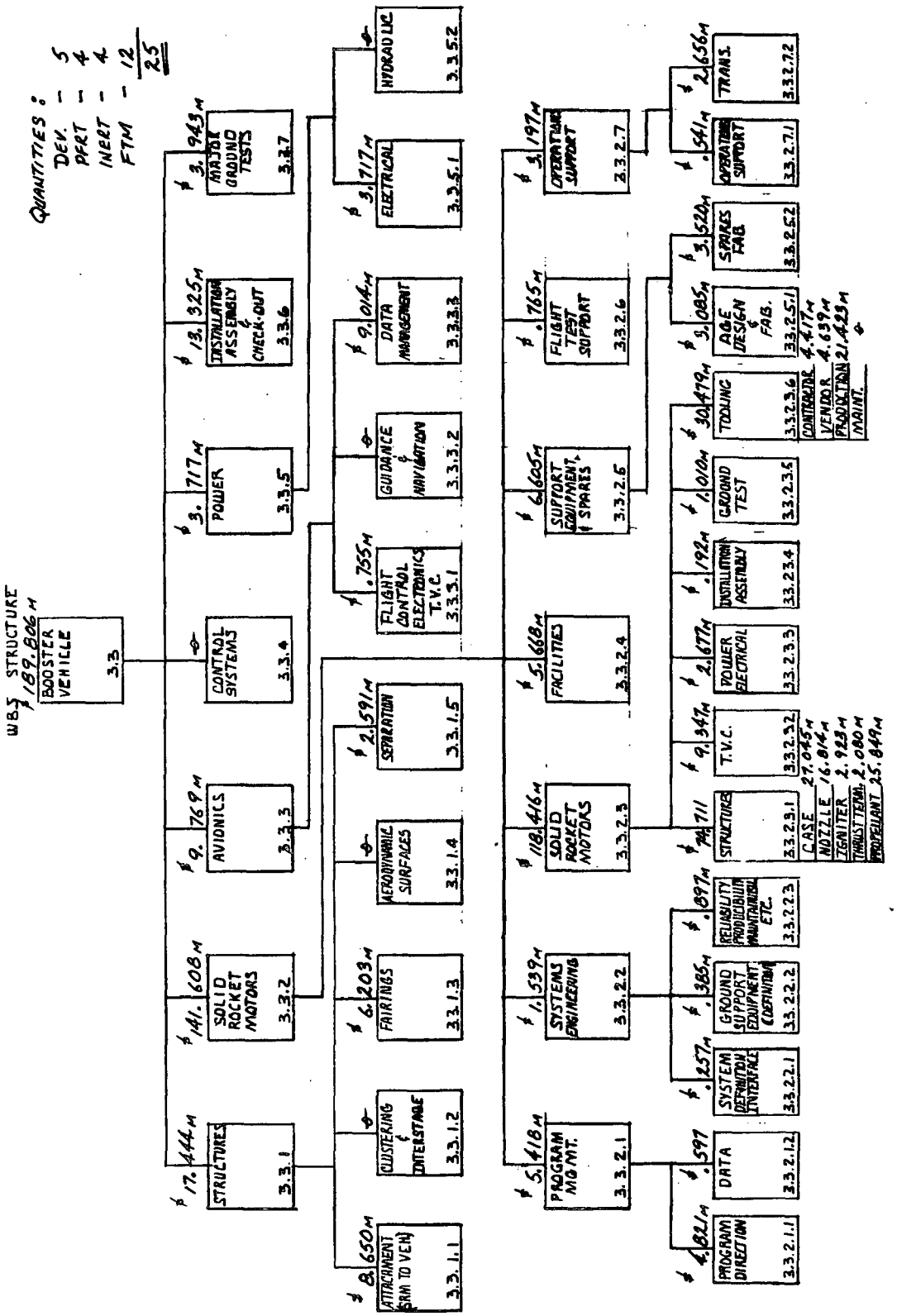
INITIAL THRUST -	2.94×10^6 LB
BURN TIME -	138 SEC
MEOP -	1000 PSI

WEIGHT SUMMARY

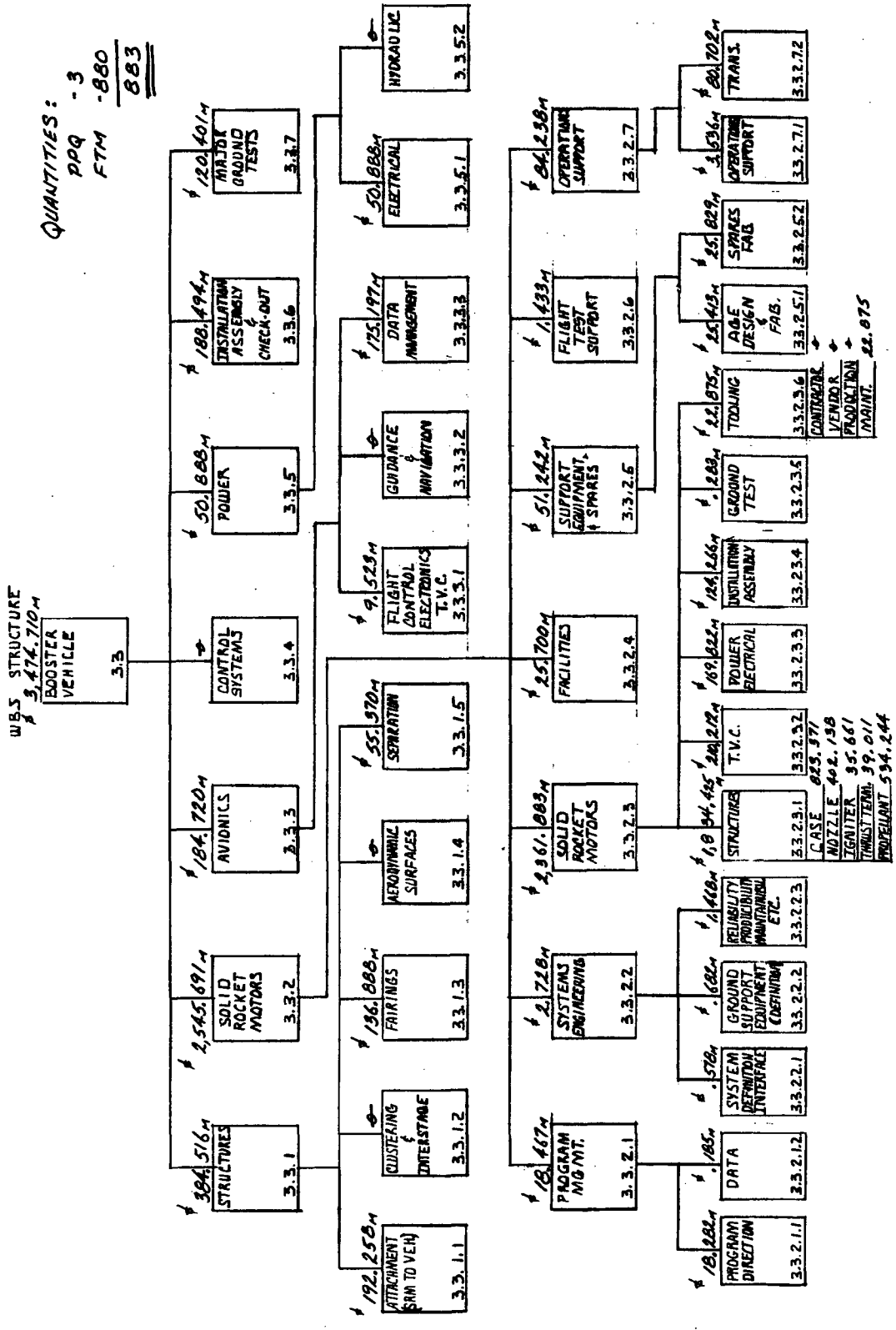
GROSS WEIGHT -	1.38×10^6 LB
PROPELLANT -	1.23×10^6 LB
TOTAL INERTS -	0.15×10^6 LB
MASS RATIO -	0.89

3.2.1 Option I - Basic Motor with TVC and TT

3.2.1.1 DDT&E

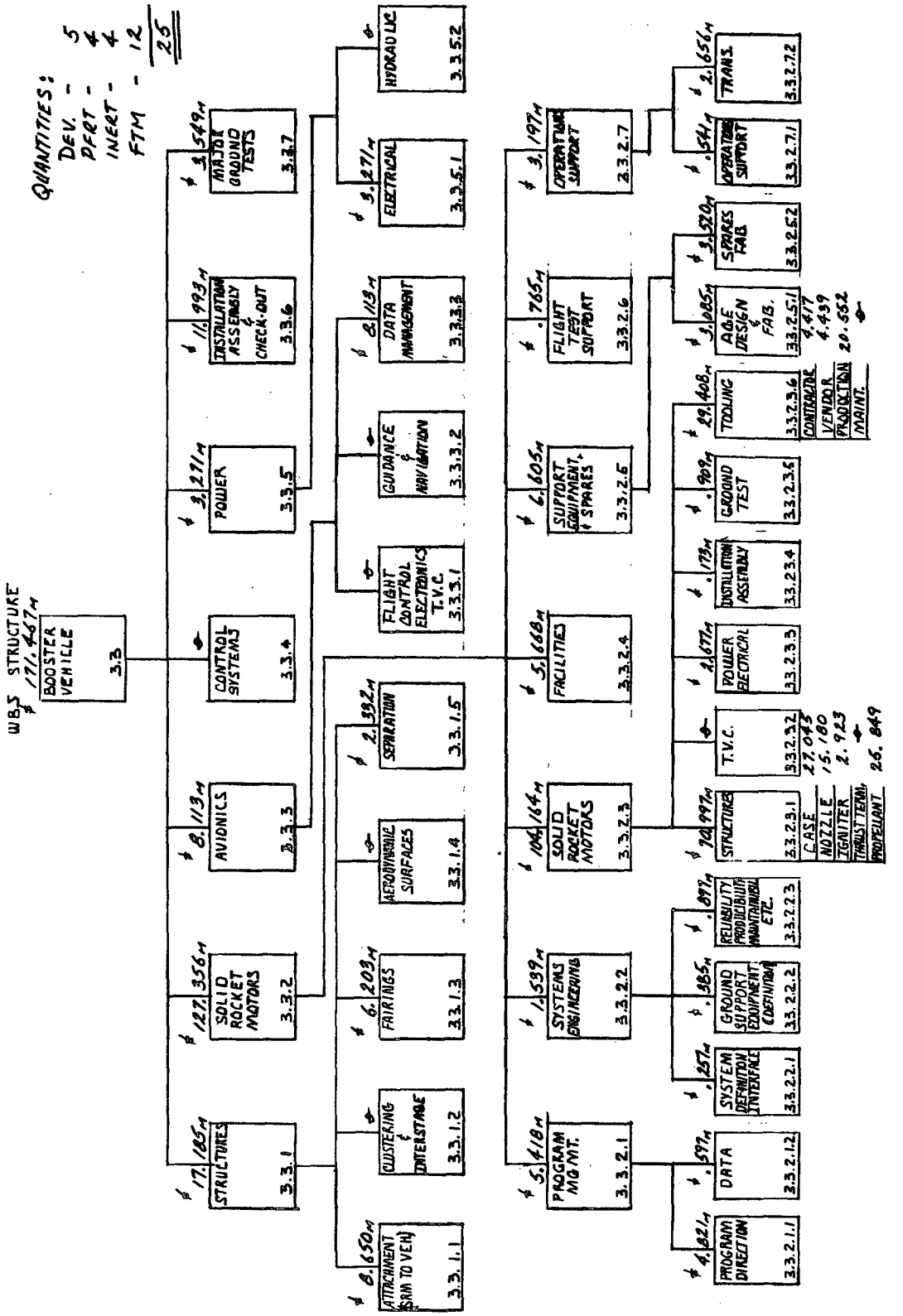


3.2.1.2 Production

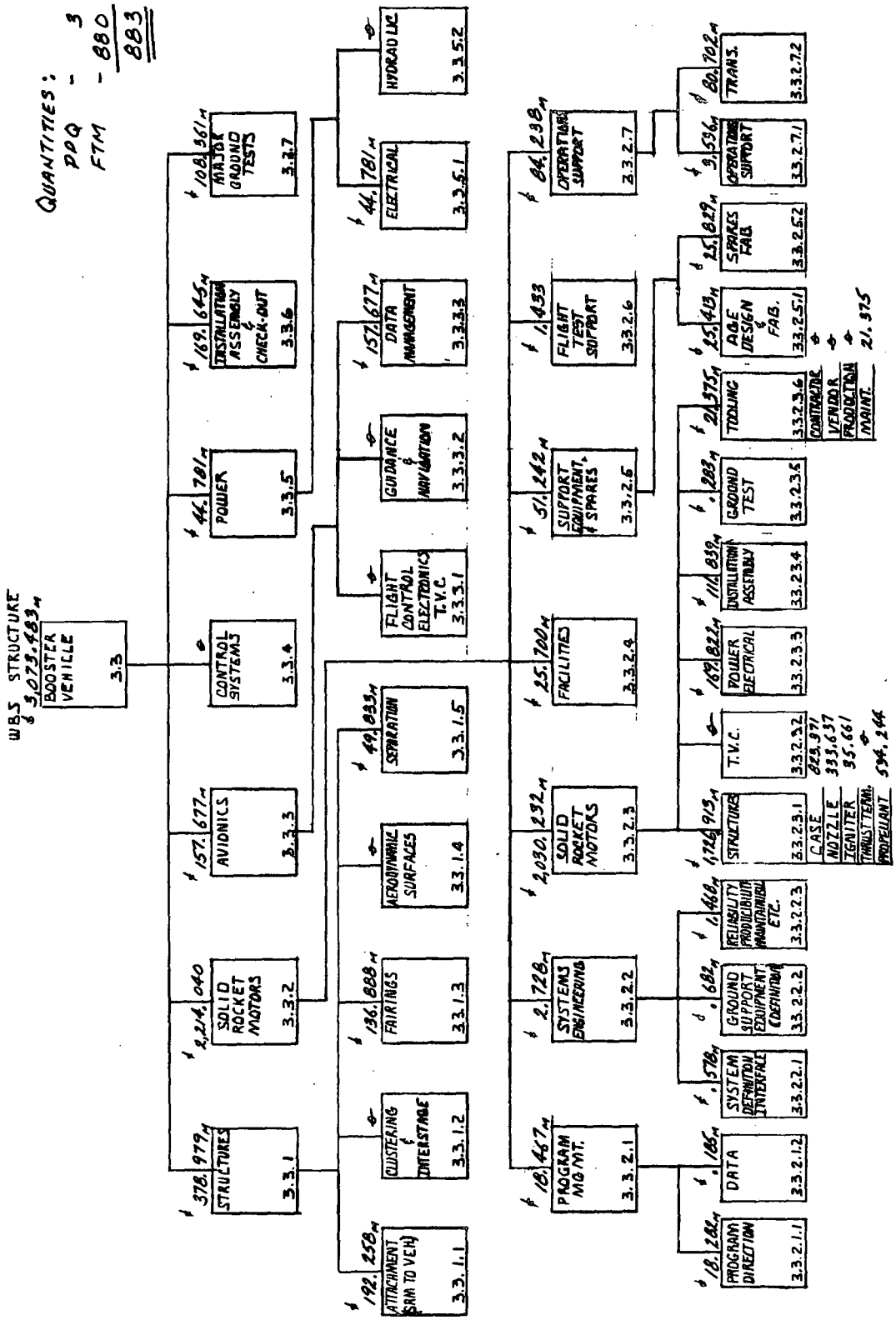


3.2.2 Option II - Basic Motor without TVC and TT

3.2.2.1 DDT&E

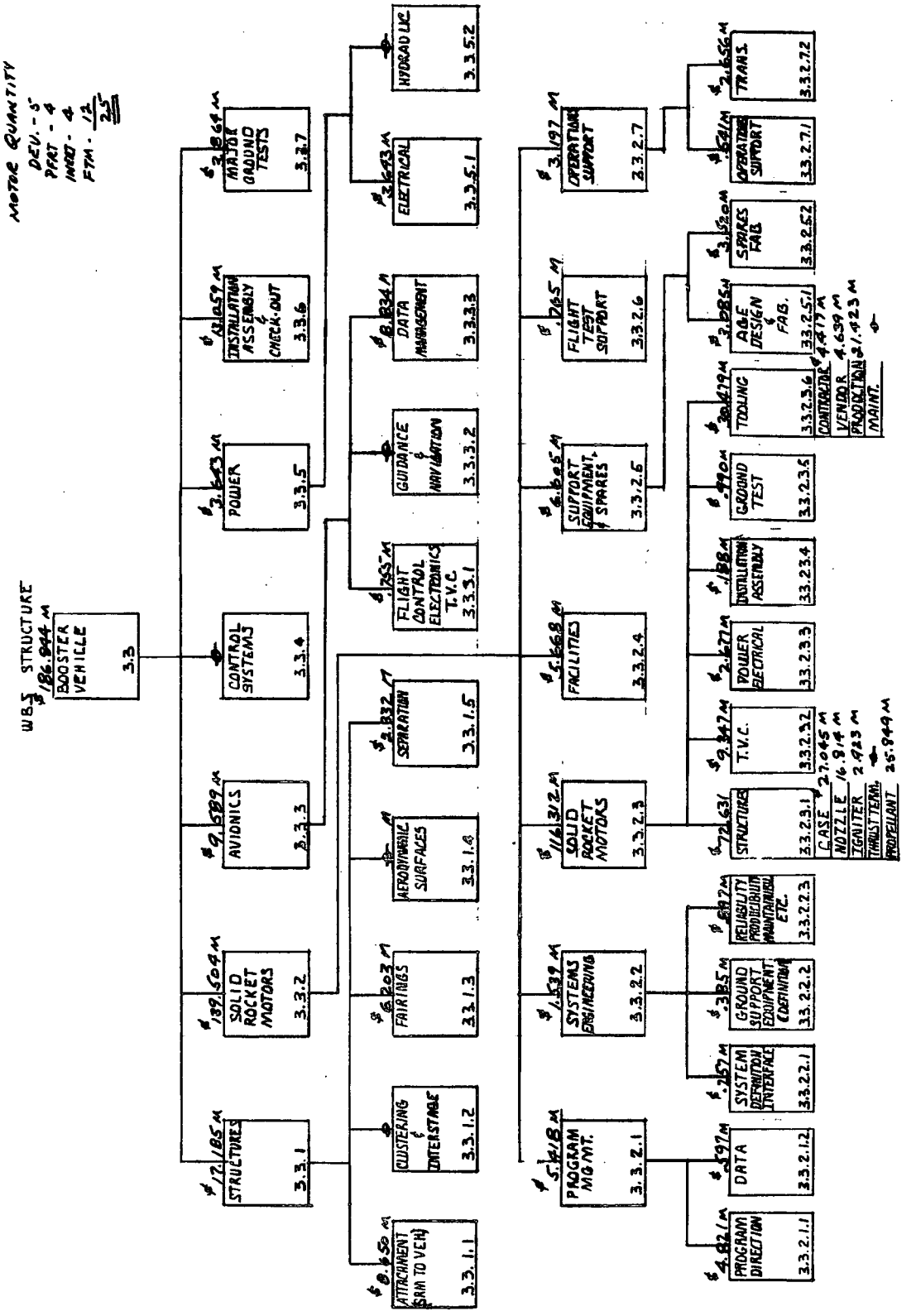


3.2.2.2 Production

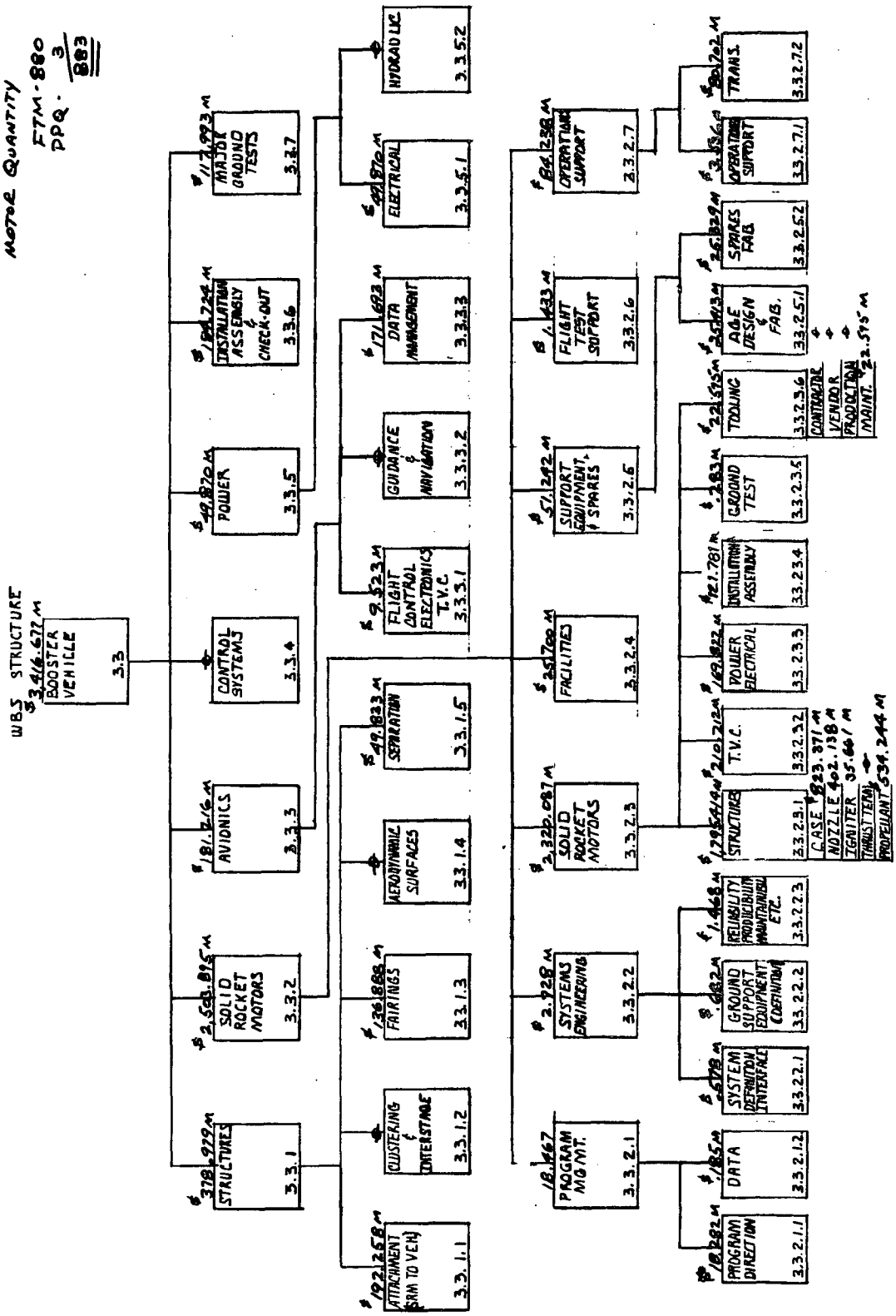


3.2.3 Option III - Basic Motor with TVC Only

3.2.3.1 DDT&E

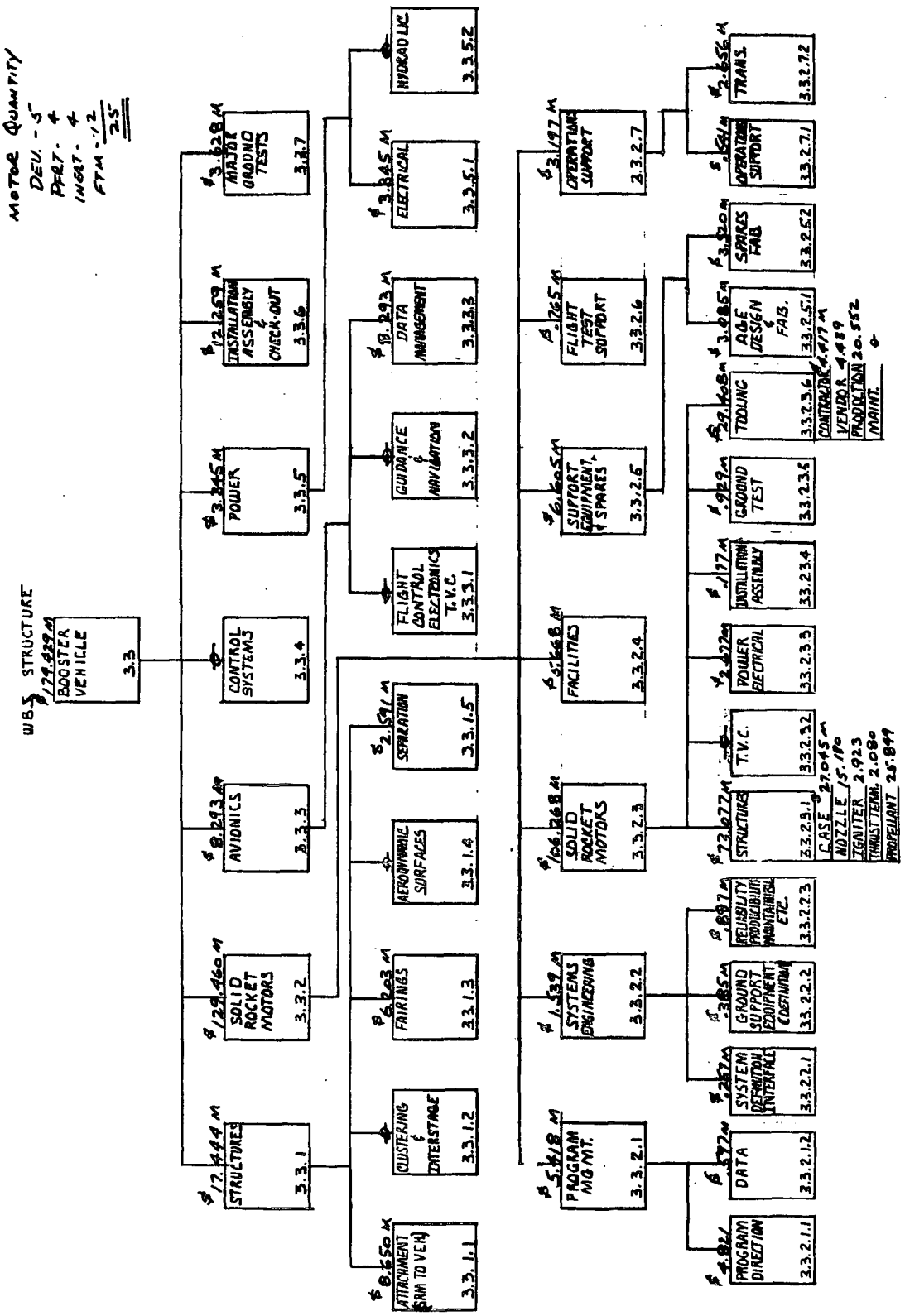


3.2.3.2 Production

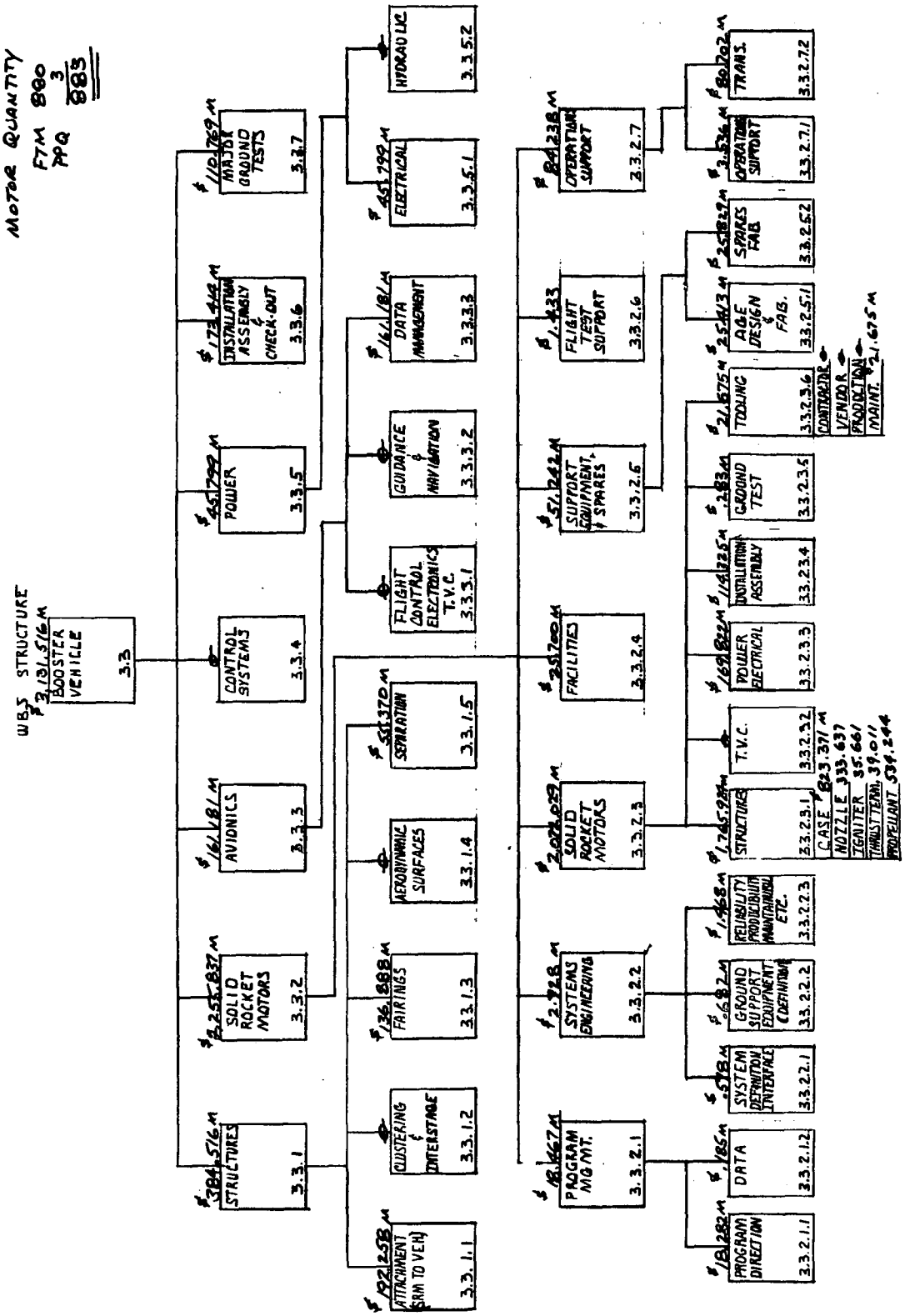


3.2.4 Option IV - Basic Motor with TT Only

3.2.4.1 DDT&E



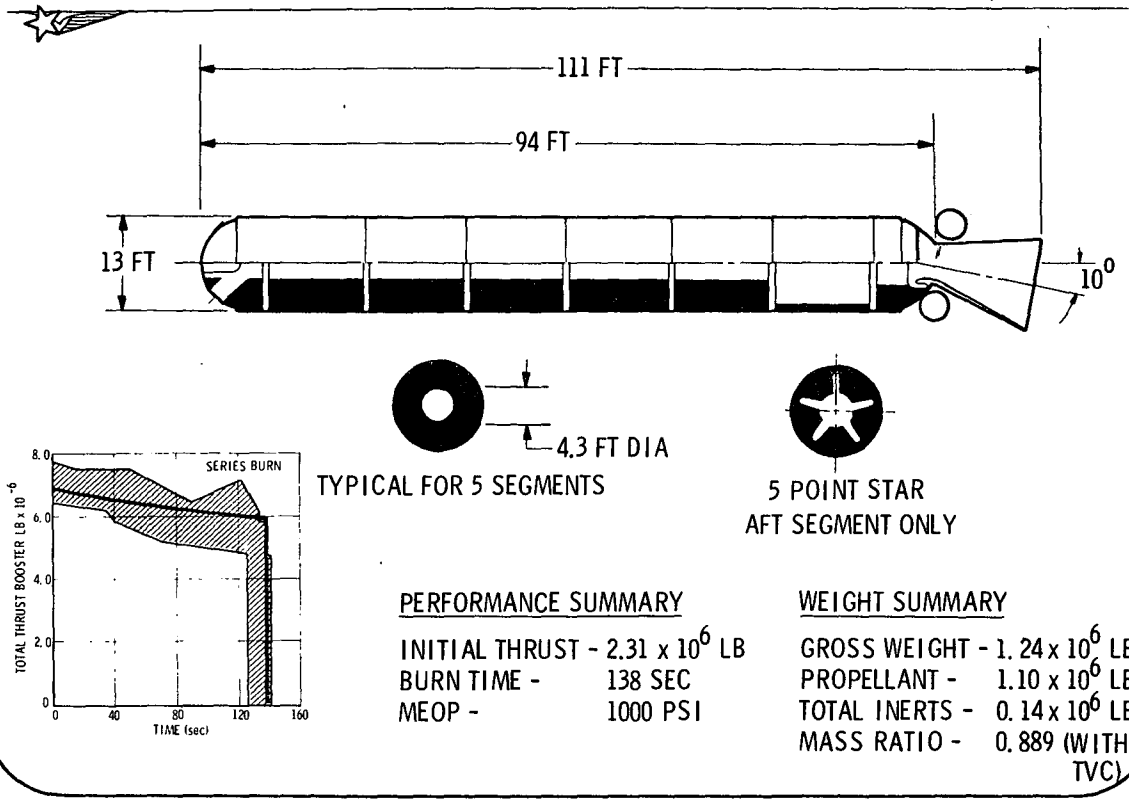
3.2.4.2 Production



3.3 156-6 SRM, SERIES CONFIGURATION

The 156-6 SRM is costed in one configuration only. The basic motor costed includes TVC and TT. Motor quantities are listed on each WBS chart.

Figure 3-5 SRM SERIES CONFIGURATION (156-6)



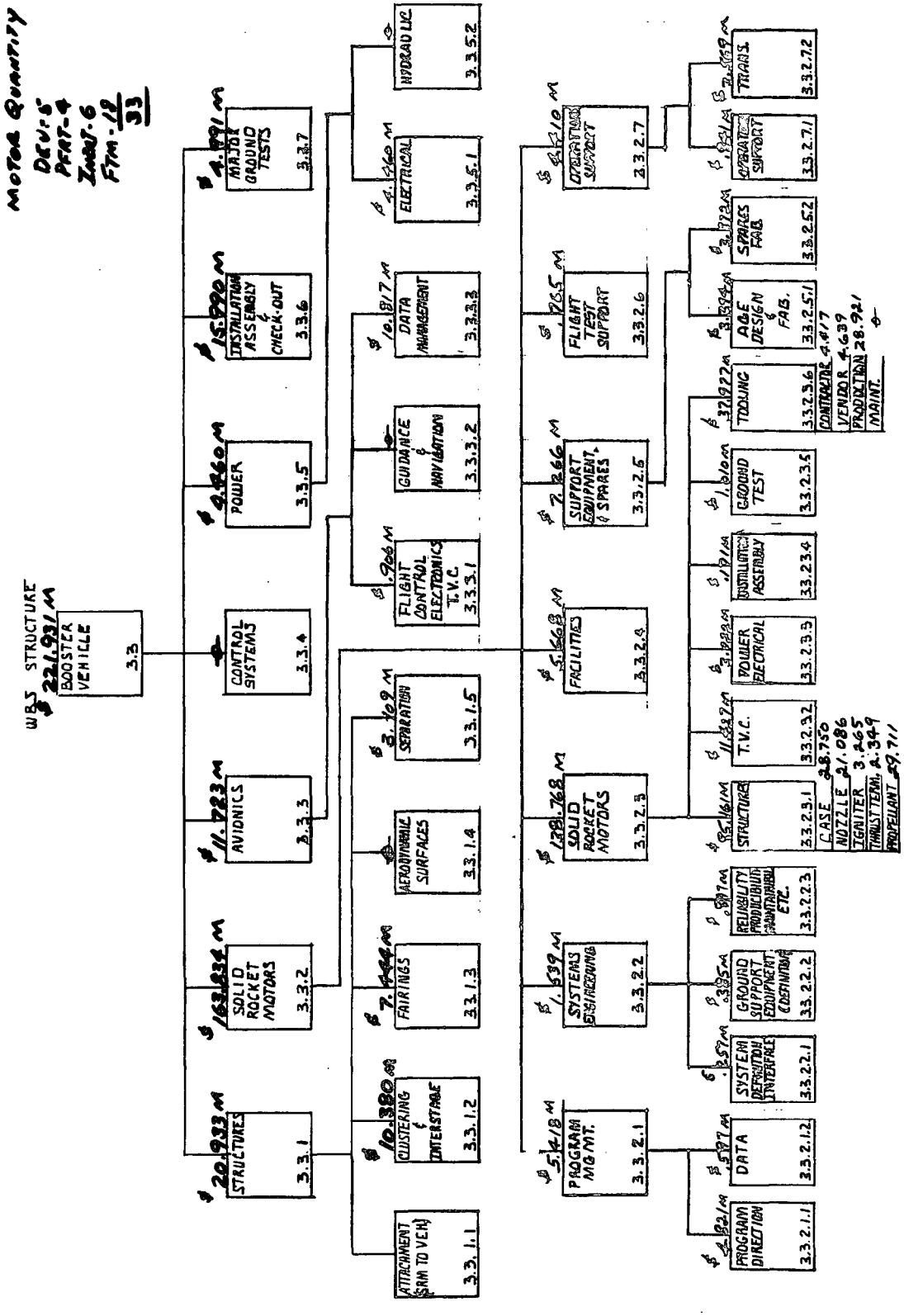
PERFORMANCE SUMMARY

INITIAL THRUST -	2.31×10^6 LB
BURN TIME -	138 SEC
MEOP -	1000 PSI

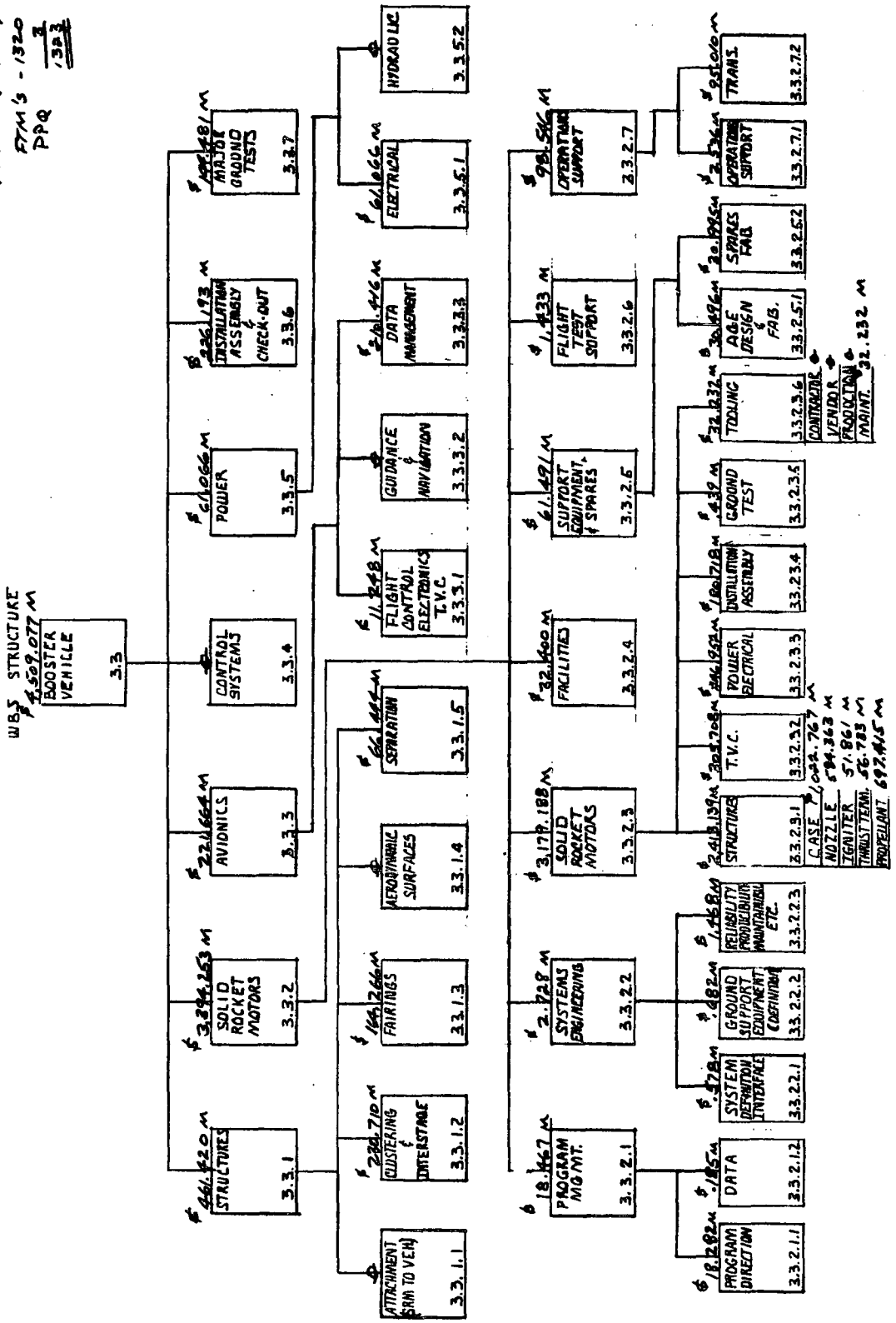
WEIGHT SUMMARY

GROSS WEIGHT -	1.24×10^6 LB
PROPELLANT -	1.10×10^6 LB
TOTAL INERTS -	0.14×10^6 LB
MASS RATIO -	0.889 (WITH TVC)

3.3.1 DDT&E - Basic with TVC and TT



3.3.2 Production - Basic with TVC and TT



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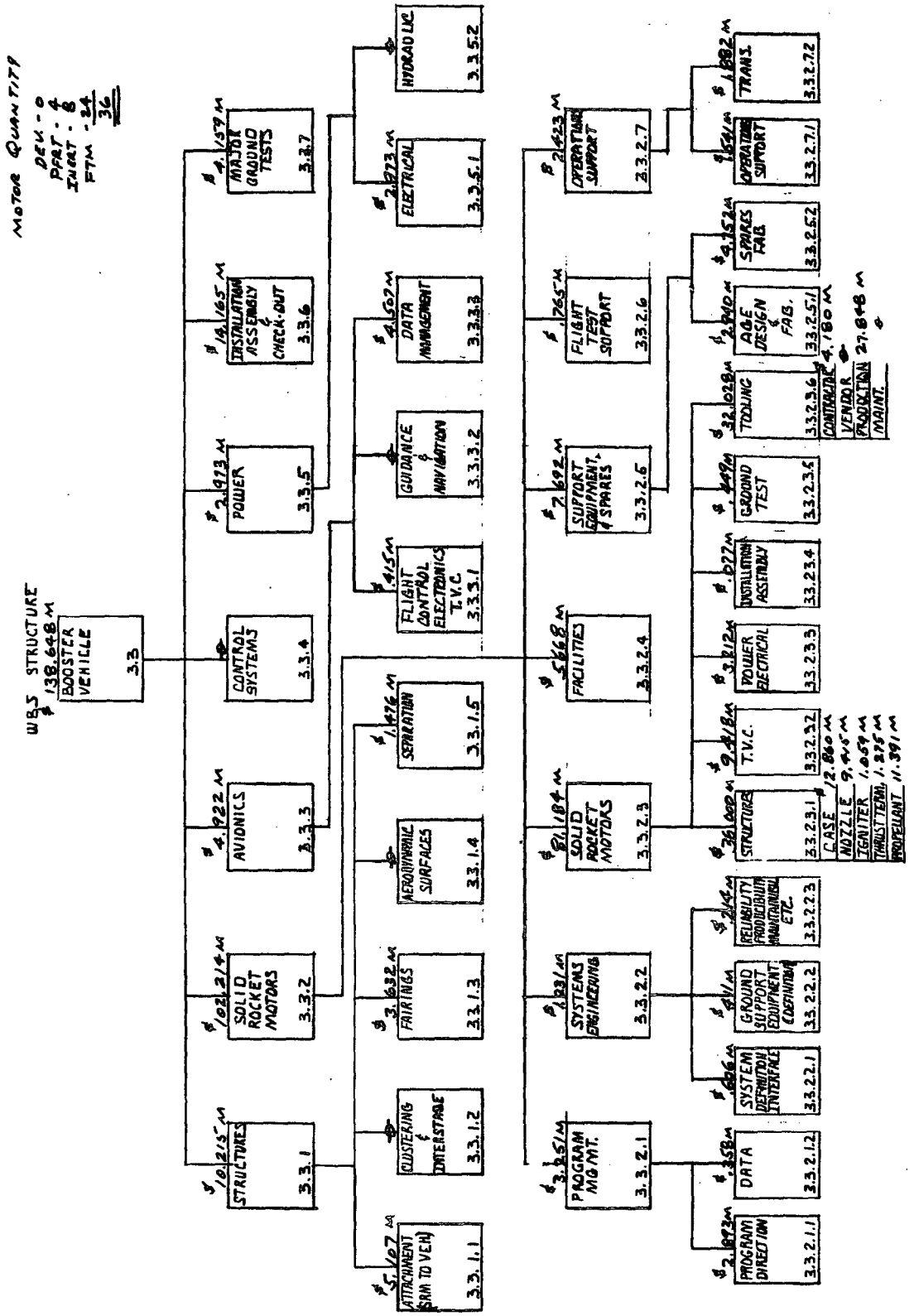
3.4 120-7 SRM, PARALLEL CONFIGURATION

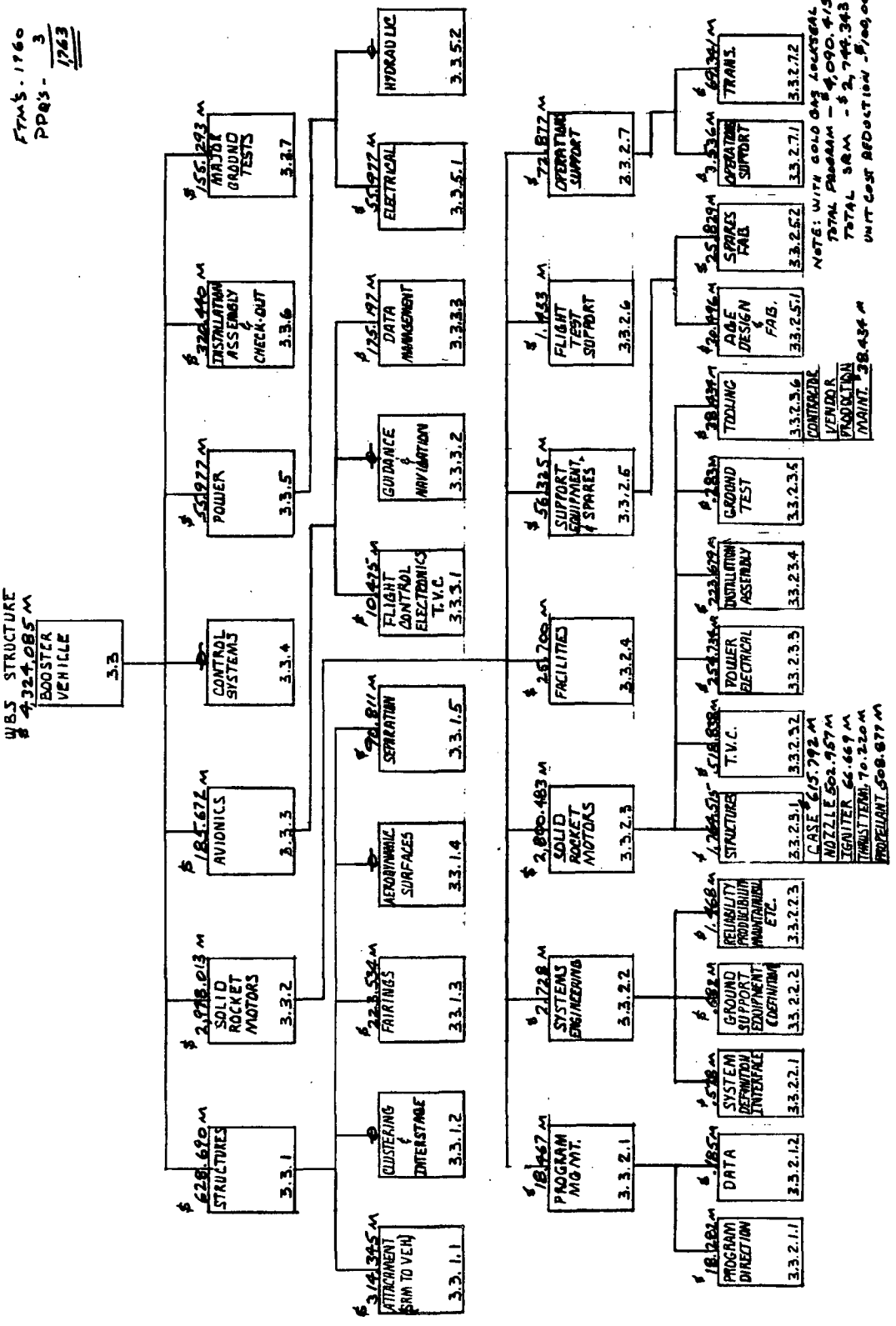
The 120-7 SRM consists of the basic motor and includes Liquid Injection, TVC, and Thrust Termination. Motor quantities are listed on each WBS chart.

It should be noted that if the 120-7 SRM used a Cold Gas Lockseal TVC system, the Production unit cost would be reduced by approximately $100,000 each.

3.4.1 DDT&E - 120-7 Parallel Configuration with LI-TVC and TT



3.4.2 Production - 120-7 Parallel Configuration with LI-TVC and TT



Section 4

PROGRAM COST ESTIMATES, TABLE 1

Cost estimates for the 156-7 SRM (Parallel Configuration), Options I, II, III, and IV, and the 156-6 SRM (Series Configuration) are presented in Table 1 format. Table 1(a) (WBS 3.3.2) is for the SRM only, and Table 1(b) (WBS 3.3) is for the total Booster Vehicle. The costs listed in each category are taken from the appropriate WBS block(s) and spread into the various categories. The following description of task content is provided to assist the reader in understanding the cost content of each category.

4.1 DESCRIPTION OF TASK CONTENT - TABLE 1

4.1.1 Table 1(a), SRM Only (WBS 3.3.2)

Design, Development, Test and Evaluation (DDT&E). DDT&E consists of all costs incurred for the design, fabrication, ground test, and flight tests. DDT&E also includes the cost of two dynamic tests and the vertical-flight, designated as test or development flight. These costs include all tooling/ STE required for DDT&E and Production. DDT&E also includes the cost of the first five manned orbital flights.

Engineering Design and Development (EDD). EDD includes Engineering design and development, component testing, subscale testing, and inert motors.

Structures (WBS 3.3.2.3.1)

Case:	Includes design and development, component testing, subscale testing, and refurbishment of four cases for inert motors and inspection
Nozzle:	Includes design and development, component testing, subscale testing, and inspection. Options I and III include a Lockseal nozzle, Options II and IV include a fixed nozzle
Igniter:	Includes design and development, component testing, subscale testing, and inspection

Thrust Termination: Includes design and development, component testing, subscale testing, and inspection. Options II and III exclude Thrust Termination

Propellant: Includes process development, subscale mixing and casting for live and inert propellant, and inspection.

TVC (WBS 3.3.2.3.2)

Includes design and development, component testing, bench tests, and full-scale testing. This category is for the actuation system only. Options II and IV exclude Thrust Vector Control.

Power, Electrical (WBS 3.3.2.3.3)

Includes design and development and component testing. Includes power and electrical system for TVC, TT, and Initiators.

Installation, Assembly and Checkout (WBS 3.3.2.3.4)

No effort in EDD. Applies to full-scale motors in Ground Test Hardware (GTH) and Flight Test Hardware (FTH).

Ground Test (WBS 3.3.2.3.5)

Includes batch-check motor firings, subscale firings, and full-scale igniter firings.

Tooling (WBS 3.3.2.3.6). Includes all tooling and test equipment required for the DDT&E and Production Program.

Ground Test Hardware (GTH). Includes the costs for procurement, fabrication, and static test firing of five development and four PFRT full-scale motors. These costs are contained in the following WBS blocks:

(1) Structures, WBS 3.3.2.3.1

(2) TVC, WBS 3.3.2.3.2, Options I and III

(3) Power, Electrical, WBS 3.3.2.3.3

(4) Installation, Assembly and Checkout, WBS 3.3.2.3.4

(5) Ground Test, WBS 3.3.2.3.5

Flight Test Hardware (FTH). Includes the costs of procurement and fabrication of Flight Test Motors (FTMs). This includes one unmanned launch and five manned launches. Transportation and launch support are included in the Operations category. The WBS blocks for GTH also include costs for FTHs.

Other. Includes the cost of all Program Management (WBS 3.3.2.1), Systems Engineering (WBS 3.3.2.2), and Facilities (WBS 3.3.2.4) for the DDT&E program.

Production. Includes all costs for procurement, fabrication, facilities, and tooling maintenance for the Production Program.

Program Management (WBS 3.3.2.1). Includes cost for program direction, coordination, and data requirements for the Production Program.

Systems Engineering (WBS 3.3.2.2). Includes cost for Systems Engineering and Quality Engineering for the Production Program.

SRM (WBS 3.3.2.3). Includes costs for procurement, fabrication, tooling maintenance, and assembly of the FTM segments at the launch site. These costs are contained in the following WBS blocks:

(1) Structures, WBS 3.3.2.3.1

(2) TVC, WBS 3.3.2.3.2, Options I and III

(3) Power, Electrical, WBS 3.3.2.3.3

(4) Installation, Assembly and Checkout, WBS 3.3.2.3.4

(5) Ground Test, WBS 3.3.2.3.5

(6) Tooling Maintenance, WBS 3.3.2.3.6

Facilities (WBS 3.3.2.4). Includes the cost for Production facilities.

Operations. Includes all transportation, Operations Support, Spares, and AGE for the DDT&E and Production Programs. These costs are contained in the following WBS blocks:

(1) Support Equipment and Spares, WBS 3.3.2.5

(2) Flight Test Support, WBS 3.3.2.6

(3) Operations Support, WBS 3.3.2.7

4.1.2 Table 1(b), Booster Vehicle (WBS 3.3)

Design, Development, Test and Evaluation (DDT&E). Table 1(b), as presented herein, contains the costs for the SRM (WBS 3.3.2) and the Booster Vehicle (WBS 3.3). The tasks associated with each category are the same as described in Table 1(a).

Production. The costs for Production include the SRM and stage. The content of each category is the same as presented in Table 1(a).

Operations. The costs for Operations are for the SRM and stage. The content of each category is the same as presented in Table 1(a).

4.2 156-7 PARALLEL CONFIGURATION

The costs for this section are presented in format 1(a) and 1(b) for the following options:

4.2.1 Option I (with TVC and Thrust Termination)

4.2.2 Option II (without TVC and Thrust Termination)

4.2.3 Option III (with TVC)

4.2.4 Option IV (with Thrust Termination)

4.2.1 Option I - Basic with Thrust Termination and TVC

4.2.1.1 Solid Rocket Motor (WBS 3.3.2)

(Dollars in Millions)

SRM	DDT&E: Engineering Design Development (EDD)	DDT&E: Tooling (TOOL)	DDT&E: Ground Test Hardware (GTH)	DDT&E: Flight Test Hardware (FTH)	DDT&E: Other (OTH)	DDT&E: Total (TOT)	Production	Operations	Total Program
Program Management					$ 5.418	$ 5.418	$ 18.467		$ 23.885
System Engineering					1.539	1.539	2.728		4.267
SRMs									
Structures									
Case	$ 1.490	$ 7.296	$10.963	$14.592		34.341	827.647		861.988
Nozzle	3.655	2.526	5.645	7.514		19.340	403.887		423.227
Igniter	1.477	1.403	.620	.826		4.326	36.633		40.959
Thrust Termination	.984	-	.470	.626		2.080	39.788		41.868
Propellant	2.445	16.839	10.040	13.364		42.688	545.905		588.593
TVC	1.591	1.071	3.327	4.429		10.418	212.644		223.062
Power, Electrical, Avionics	1.110	.927	.672	.895		3.604	170.517		174.121
Installation, Assembly and C/O		.067	.081	.111		.259	124.316		124.575
Ground Test	.353	.350	.657			1.360	.546		1.906
Facilities					5.668	5.668	25.700		31.368
Support Equipment and Spares								$ 57.847	57.847
Flight Test Support								2.198	2.198
Operations Support								87.435	87.435
Total Program	$13.105	$30.479	$32.475	$42.357	$12.625	$131.041	$2,408.778	$147.480	$2,687.299

(Dollars in Millions)

Booster Vehicle	DDT&E						Production	Operations	Total Program
	Engineering Design Development (EDD)	Tooling (TOOL)	Ground Test Hardware (GTH)	Flight Test Hardware (FTH)	Other (OTH)	Total (TOT)			
Structures									
Attach (SRM to Vehicle)	$ 2.477	$ 2.174		$ 3.999		$ 8.650	$ 192.258		$ 200.908
Clustering and Interstage									
Fairings	1.778	1.554		2.871		6.203	136.888		143.091
Aerodynamic Surfaces									
Separation	.738	.659		1.194		2.591	55.370		57.961
Solid Rocket Motors	13.105	30.479	$32.475	42.357	$12.625	131.041	2,408.778	$147.480	2,687.299
Avionics									
Flight Control Electronics	.399			.356		.755	9.523		10.278
Guidance and Navigation									
Data Management	4.762			4.252		9.014	175.197		184.211
Control Systems	-0-			-0-		-0-	-0-		-0-
Power									
Electrical	1.989			1.728		3.717	50.888		54.605
Hydraulic									
Installation, Assembly and C/O								201.819	201.819
Major Ground Tests								124.344	124.344
Total Program	$25.248	$34.866	$32.475	$56.757	$12.625	$161.971	$3,028.902	$473.643	$3,664.516

4.2.2 Option II - Basic (w/o Thrust Termination and TVC

4.2.2.1 Solid Rocket Motor (WBS 3.3.2)

(Dollars in Millions)

SRM	DDT&E Engineering Design Development (EDD)	DDT&E Tooling (TOOL)	DDT&E Ground Test Hardware (GTH)	DDT&E Flight Test Hardware (FTH)	DDT&E Other (OTH)	DDT&E Total (TOT)	Production	Operations	Total Program
Program Management					$ 5.418	$ 5.418	$ 18.467		$ 23.885
System Engineering					1.539	1.539	2.728		4.267
SRMs									
Structures									
Case	$ 1.490	$ 7.296	$10.963	$14.592		34.341	828.758		863.099
Nozzle	3.655	2.526	4.944	6.581		17.706	335.502		353.208
Igniter	1.477	1.403	.620	.826		4.326	36.697		41.023
Thrust Termination	-	-	-	-		-	-		-
Propellant	2.445	16.839	10.040	13.364		42.688	546.825		589.513
TVC	-	-	-	-		-	-		-
Power, Electrical, Avionics	1.110	.927	.672	.895		3.604	170.481		174.085
Installation, Assembly and C/O		.067	.074	.099		.240	111.437		111.677
Ground Test	.353	.350	.556			1.259	.532		1.791
Facilities					5.668	5.668	25.700		31.368
Support Equipment and Spares								$ 57.847	57.847
Flight Test Support								2.198	2.198
Operations Support								87.435	87.435
Total Program	$10.530	$29.408	$27.869	$36.357	$12.625	$116.789	$2,077.127	$147.480	$2,341.396

4.2.2.2 Booster Vehicle (WBS 3.3)

(Dollars in Millions)

Booster Vehicle	DDT&E: Engineering Design Development (EDD)	DDT&E: Tooling (TOOL)	DDT&E: Ground Test Hardware (GTH)	DDT&E: Flight Test Hardware (FTH)	DDT&E: Other (OTH)	DDT&E: Total (TOT)	Production	Operations	Total Program
Structures									
Attach (SRM to Vehicle)	$ 2.477	$ 2.174		$ 3.999		$ 8.650	$ 192.258		$ 200.908
Clustering and Interstage									
Fairings	1.778	1.554		2.871		6.203	136.888		143.091
Aerodynamic Surfaces									
Separation	.738	.437		1.157		2.332	49.833		52.165
Solid Rocket Motors	10.530	29.408	$27.869	36.357	$12.625	116.789	2,077.127	$147.480	2,341.396
Avionics									
Flight Control Electronics									
Guidance and Navigation									
Data Management	4.041			4.072		8.113	157.677		165.790
Control Systems									
Power									
Electrical	1.617			1.654		3.271	44.781		48.052
Hydraulic									
Installation, Assembly and C/O								181.638	181.638
Major Ground Tests								111.910	111.910
Total Program	$21.181	$33.573	$27.869	$50.110	$12.625	$145.358	$2,658.564	$441.028	$3,244.950

4.2.3 Option III - Basic with TVC

4.2.3.1 Solid Rocket Motor (WBS 3.3.2)

(Dollars in Millions)

SRM	DDT&E Engineering Design Development (EDD)	DDT&E Tooling (TOOL)	DDT&E Ground Test Hardware (GTH)	DDT&E Flight Test Hardware (FTH)	DDT&E Other (OTH)	DDT&E Total (TOT)	Production	Operations	Total Program
Program Management					$ 5.418	$ 5.418	$ 18.467		$ 23.885
System Engineering					1.539	1.539	2.728		4.267
SRMs									
Structures									
Case	$ 1.490	$ 7.296	$10.963	$14.592		34.341	827.647		861.988
Nozzle	3.655	2.526	5.645	7.514		19.340	403.887		423.227
Igniter	1.477	1.403	.620	.826		4.326	36.633		40.959
Thrust Termination	-	-	-	-		-	-		-
Propellant	2.445	16.839	10.040	13.364		42.688	545.905		588.593
TVC	1.591	1.071	3.327	4.429		10.418	212.644		223.062
Power, Electrical, Avionics	1.110	.927	.672	.895		3.604	170.517		174.121
Installation, Assembly and C/O		.067	.081	.107		.255	122.308		122.563
Ground Test	.353	.350	.637			1.340	.546		1.886
Facilities					5.668	5.668	25.700		31.368
Support Equipment and Spares								$ 57.847	57.847
Flight Test Support								2.198	2.198
Operations Support								87.435	87.435
Total Program	$12.121	$30.479	$31.985	$41.727	$12.625	$128.937	$2,366.982	$147.480	$2,643.399

(Dollars in Millions)

Booster Vehicle	DDT&E						Production	Operations	Total Program
	Engineering Design Development (EDD)	Tooling (TOOL)	Ground Test Hardware (GTH)	Flight Test Hardware (FTH)	Other (OTH)	Total (TOT)			
Structures									
Attach (SRM to Vehicle)	$ 2.477	$ 2.174		$ 3.999		$ 8.650	$ 192.258		$ 200.908
Clustering and Interstage									
Fairings	1.778	1.554		2.871		6.203	136.888		143.091
Aerodynamic Surfaces									
Separation	.738	.437		1.157		2.332	49.833		52.165
Solid Rocket Motors	12.121	30.479	31.985	41.727	$12.625	128.937	2,366.982	$147.480	2,643.399
Avionics									
Flight Control Electronics	.399			.356		.755	9.523		10.278
Guidance and Navigation									
Data Management	4.041			4.793		8.834	171.693		180.527
Control Systems									
Power									
Electrical	1.989			1.654		3.643	49.870		53.513
Hydraulic									
Installation, Assembly and C/O								197.783	197.783
Major Ground Tests								121.857	121.857
Total Program	$23.543	$34.644	$31.985	$56.557	$12.625	$159.354	$2,977.047	$467.120	$3,603.521

4.2.4 Option IV - Basic with Thrust Termination

4.2.4.1 Solid Rocket Motor (WBS 3.3.2)

(Dollars in Millions)

SRM	DDT&E						Production	Operations	Total Program
	Engineering Design Development (EDD)	Tooling (TOOL)	Ground Test Hardware (GTH)	Flight Test Hardware (FTH)	Other (OTH)	Total (TOT)			
Program Management					$ 5.418	$ 5.418	$ 18.467		$ 23.885
System Engineering					1.539	1.539	2.728		4.267
SRMs									
Structures									
Case	$ 1.490	$ 7.296	$10.963	$14.592		34.341	828.758		863.099
Nozzle	3.655	2.526	4.944	6.581		17.706	335.502		353.208
Igniter	1.477	1.403	.620	.826		4.326	36.697		41.023
Thrust Termination	.984	-	.470	.626		2.080	39.011		41.091
Propellant	2.445	16.839	10.040	13.364		42.688	546.675		589.363
TVC	-	-	-	-		-	-		-
Power, Electrical, Avionics	1.110	.927	.672	.895		3.604	170.481		174.085
Installation, Assembly and C/O		.067	.076	.101		.244	144.373		114.617
Ground Test	.353	.350	.576			1.279	.532		1.811
Facilities					5.668	5.668	25.700		31.368
Support Equipment and Spares								$ 57.847	57.847
Flight Test Support								2.198	2.198
Operations Support								87.435	87.435
Total Program	$11.514	$29.408	$28.361	$36.985	$12.625	$118.893	$2,118.924	$147.480	$2,385.297

(Dollars in Millions)

Booster Vehicle	DDT&E						Production	Operations	Total Program
	Engineering Design Development (EDD)	Tooling (TOOL)	Ground Test Hardware (GTH)	Flight Test Hardware (FTH)	Other (OTH)	Total (TOT)			
Structures									
Attach (SRM to Vehicle)	$ 2.477	$ 2.174		$ 3.999		$ 8.650	$ 192.258		$ 200.908
Clustering and Interstage									
Fairings	1.778	1.554		2.871		6.203	136.888		143.091
Aerodynamic Surfaces									
Separation	.738	.659		1.194		2.591	55.370		57.961
Solid Rocket Motors	11.514	29.408	$28.361	36.985	$12.625	118.893	2,118.924	$147.480	2,385.297
Avionics									
Flight Control Electronics									
Guidance and Navigation									
Data Management	4.041			4.252		8.293	161.181		169.474
Control Systems									
Power									
Electrical	1.617			1.728		3.345	45.799		49.144
Hydraulic									
Installation, Assembly and C/O								185.673	185.673
Major Ground Tests								114.397	114.397
Total Program	$22.165	$33.795	$28.361	$51.029	$12.625	$147.975	$2,710.420	$447.550	$3,305.945

4.3 156-6 SERIES BASIC WITH THRUST TERMINATION AND TVC

4.3.1 Solid Rocket Motor (WBS 3.3.2)

(Dollars in Millions)

SRM	DDT&E Engineering Design Development (EDD)	DDT&E Tooling (TOOL)	DDT&E Ground Test Hardware (GTH)	DDT&E Flight Test Hardware (FTH)	DDT&E Other (OTH)	DDT&E Total (TOT)	Production	Operations	Total Program
Program Management					$ 5.418	$ 5.418	$ 18.467		$ 23.885
System Engineering					1.539	1.539	2.728		4.267
SRMs									
Structures									
Case	$ 1.490	$ 9.092	$11.695	$15.565		37.842	1,030.484		1,068.326
Nozzle	3.655	3.147	7.478	9.953		24.233	587.034		611.267
Igniter	1.477	1.748	.767	1.021		5.013	53.345		58.358
Thrust Termination	.984	-	.586	.779		2.349	56.733		59.082
Propellant	2.445	20.982	11.697	15.569		50.693	715.222		765.915
TVC	1.591	1.333	4.220	5.616		12.760	306.839		319.599
Power, Electrical, Avionics	1.110	1.155	.820	1.092		4.177	247.932		252.109
Installation, Assembly and C/O		.084	.073	.098		.255	180.789		181.044
Ground Test	.353	.436	.657			1.446	.810		2.256
Facilities					5.668	5.668	32.400		38.068
Support Equipment and Spares								$ 68.757	68.757
Flight Test Support								2.198	2.198
Operations Support								102.956	102.956
Total Program	$13.105	$37.977	$37.993	$49.693	$12.625	$151.393	$3,232.783	$173.911	$3,558.087

(Dollars in Millions)

Booster Vehicle	DDT&E Engineering Design Development (EDD)	DDT&E Tooling (TOOL)	DDT&E Ground Test Hardware (GTH)	DDT&E Flight Test Hardware (FTH)	DDT&E Other (OTH)	DDT&E Total (TOT)	Production	Operations	Total Program
Structures									
Attach (SRM to Vehicle)									
Clustering and Interstage	$ 2.477	$ 2.609		$ 5.294		$ 10.380	$ 230.710		$ 241.090
Fairings	1.778	1.865		3.801		7.444	164.266		171.710
Aerodynamic Surfaces									
Separation	.738	.790		1.581		3.109	66.444		69.553
Solid Rocket Motors	13.105	37.977	$37.993	49.693	$12.625	151.393	3,232.783	$173.911	3,558.087
Avionics									
Flight Control Electronics	.399			.507		.906	11.248		12.154
Guidance and Navigation									
Data Management	4.762			6.055		10.817	210.416		221.233
Control Systems									
Power									
Electrical	1.989			2.471		4.460	61.066		65.526
Hydraulic									
Installation, Assembly and C/O								242.183	242.183
Major Ground Tests								149.472	149.472
Total Program	$25.248	$43.241	$37.993	$69.402	$12.625	$188.509	$3,976.933	$565.566	$4,731.008

Section 5

PROGRAM TIME-PHASED FUNDING REQUIREMENTS, TABLE 2

Funding requirements for the 156-7 SRM (Parallel) and 156-6 SRM (Series) are presented in Table 2 format for the SRM (Table 2(a), WBS 3.3.2), and the total Booster Vehicle (Table 2(b), WBS 3.3). The costs for the various elements are taken from the appropriate WBS blocks on Table 1, and are spread consistent with the directions contained in NASA letter PM-EP-MGR, dated 31 January 1972.

5.1 DESCRIPTION OF CONTENT

Table 2(a), SRM Only (WBS 3.3.2)

Design, Development, and Test (DDT&E). DDT&E consists of all costs incurred for the design, fabrication, ground test, and flight tests. DDT&E includes the total cost of the two dynamic test vehicles and the vertical flight designated as test or development flight. These costs include all tooling, and the STE, ground support equipment, spares and other efforts required, leading up to and supporting the test flight. DDT&E also includes the cost of the first five manned orbital flights, including support for receiving, assembly and checkout, spares, operations support, etc.

Cost Elements - Nonrecurring

Development	Includes EDD (less inert motors), GTH, and Other (less Facilities) from Table 1
STE/ST	Includes Tooling from Table 1
Dummy Engines	Includes the inert motors from Table 1, EDD
Flight Engines	Includes FTH and part of Program Management from Table 1
OS FS & Spares	Includes the following WBS blocks from DDT&E: Support Equipment and Spares, WBS 3.3.2.5 Flight Test Support, WBS 3.3.2.6 Operations Support, WBS 3.3.2.7

Recurring (Production). Production is defined as the costs associated with producing additional flight engines and modification and/or updating of the flight test hardware required for operation through acceptance of the

hardware by the Government, including all costs associated with: (1) fabrication, modification, updating, assembly and checkout of flight hardware, (2) ground test and factory checkout of flight hardware, (3) initial operational spares required for manufacturing, and (4) maintenance of tooling and special test equipment.

Cost Elements - Investment

Deliver New Engines	Includes total Production (less Facilities) from Table 1
Ground Support Equipment	Includes WBS block for Ground Support Equipment, 3.3.2.5.1

Operations. Operations is defined as the cost associated with the following activities:

a. Flight support is defined as (1) replacement spares to support operational airborne hardware, (2) sustaining engineering to support the production of spares and hardware modifications, and (3) maintenance of GSE and spares for GSE.

b. Launch Operations: The costs for receiving the flight hardware, assembly of the vehicle, checkout, prelaunch test and checkout, servicing, launching, and refurbishing of the launch site facilities.

Flight Support	Includes cost from WBS block 3.3.2.6, Flight Test Support
Operations	Includes cost from WBS block 3.3.2.7, Operations Support
Parts	Includes cost from WBS block 3.3.2.5.2, Spares

Facilities. Includes cost from WBS block 3.3.2.4, Facilities.

Table 2(b), SRM and Stage (WBS 3.3)

Table 2(b) costs were derived by using the same rationale as described above, however costs are for the total program.

5.2 156-7 SRM, PARALLEL CONFIGURATION (Reference Subsection 3.2)

This subsection contains Table 2s for the following configurations:

5.2.1 Option I (with TVC and Thrust Termination)

5.2.2 Option II (without TVC and Thrust Termination)

5.2.3 Option III (with TVC)

5.2.4 Option IV (with Thrust Termination)

5.2.1 Option I - Basic with Thrust Termination and TVC

5.2.1.1 Solid Rocket Motor (WBS 3.3.2)

Cost Element	Fiscal Year (Dollars in Millions)																Total
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
Non-Recurring Total	3.8	17.7	19.7	14.9	28.5	49.9	1.5											$ 134.940
DDT&E																		
Development																		
Development	3.8	8.6	16.2	9.5	5.2	4.3												47.587
STE/ST		9.1			7.1	14.3												30.479
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				1.4	13.7	29.0												44.107
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total				0.4	11.1	32.9	125.7	168.8	203.7	259.6	301.5	330.9	329.6	322.4	293.0	133.0	7.3	$2,519.991
Investment																		
Deliver New Engines					10.3	23.5	113.4	154.0	192.9	248.5	288.5	316.2	314.0	309.1	280.0	125.7	7.0	2,383.078
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations						0.4	2.7	4.6	5.9	7.6	9.2	10.9	11.8	11.8	11.8	7.2	0.3	84.238
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	9.5	17.7	27.7	33.0	39.6	82.8	127.2	168.8	203.7	259.6	301.5	330.9	329.6	322.4	293.0	133.0	7.3	$2,687.299

5.2.1.2 WBS 3.3

Cost Element	Fiscal Year (Dollars in Millions)																	Total
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
Non-Recurring Total	4.8	20.7	23.8	18.7	35.8	61.6	1.5											$ 166.870
DDT&E																		
Development																		
Development	4.8	10.8	20.3	11.9	6.5	5.4												59.730
STE/ST		9.9			8.6	16.4												34.866
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				2.8	18.2	37.5												58.507
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total			3.0	5.8	14.8	54.5	179.3	235.1	283.1	351.3	404.9	445.4	441.8	432.1	396.7	201.2	17.3	$3,466.278
Investment																		
Deliver New Engines					12.0	25.8	144.1	195.4	245.3	311.0	360.5	397.1	393.0	385.6	350.5	171.9	11.0	3,003.202
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations			3.0	5.4	2.0	19.6	25.6	29.5	32.9	36.8	40.6	44.5	45.0	45.0	45.0	29.2	6.3	410.401
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	10.5	20.7	34.8	42.2	50.6	116.1	180.8	235.1	283.1	351.3	404.9	445.4	441.8	432.1	396.7	201.2	17.3	$3,664.516

5.2.2 Option II - Basic without Thrust Termination and TVC

5.2.2.1 Solid Rocket Motor (WBS 3.3.2)

Cost Element	Fiscal Year (Dollars in Millions)																Total
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
Non-Recurring Total	3.2	16.1	17.2	13.3	25.7	44.7	1.5											$ 121.688
DDT&E																		
Development																		
Development	3.2	7.3	13.7	8.1	4.4	3.7												40.406
STE/ST		8.8			6.9	13.7												29.408
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				1.2	11.9	25.0												38.107
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total				0.4	9.0	28.0	110.8	148.1	177.0	224.4	261.2	287.5	286.4	280.0	253.0	116.0	6.5	$2,188.340
Investment																		
Deliver New Engines					8.2	18.5	98.5	133.3	166.2	213.3	248.2	272.8	270.8	266.7	240.0	108.7	6.2	2,051.427
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations						0.4	2.7	4.6	5.9	7.6	9.2	10.9	11.8	11.8	11.8	7.2	0.3	84.238
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	8.9	16.1	25.2	31.4	34.7	72.7	112.3	148.1	177.0	224.4	261.2	287.5	286.4	280.0	253.0	116.0	6.5	$2,341.396

5.2.2.2 Booster Vehicle (WBS 3.3)

Cost Element	Fiscal Year (Dollars in Millions)																	
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	4.1	18.7	20.9	16.7	32.6	55.8	1.5											$ 150.257
DDT&E																		
Development																		
Development	4.1	9.2	17.4	10.2	5.6	4.5												51.057
STE/ST		9.5			8.3	15.8												33.573
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				2.5	16.2	33.2												51.860
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total			2.6	5.3	13.2	50.9	159.4	208.4	251.0	311.3	357.1	392.1	390.3	380.1	350.8	177.0	13.8	$3,063.325
Investment																		
Deliver New Engines					10.5	23.7	126.4	171.1	215.9	273.8	315.9	347.5	344.9	337.0	308.0	150.1	8.1	2,632.864
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations			2.6	4.9	1.9	18.1	23.4	27.2	30.2	34.0	37.4	40.8	41.6	41.6	41.6	26.8	5.7	377.786
Parts				0.4	0.8	1.3	1.8	2.2	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	9.8	18.7	31.5	39.7	45.8	106.7	160.9	208.4	251.0	311.3	357.1	392.1	390.3	380.1	350.8	177.0	13.8	$3,244.950

5.2.3 Option III - Basic with TVC

5.2.3.1 Solid Rocket Motor (WBS 3.3.2)

Cost Element	Fiscal Year (Dollars in Millions)																	
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	3.7	17.4	19.2	14.6	28.1	49.3	1.5											$ 133.836
DDT&E																		
Development																		
Development	3.7	8.3	15.7	9.2	5.0	4.2												46.113
STE/ST		9.1			7.1	14.3												30.479
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				1.4	13.5	28.5												43.477
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total				0.4	10.2	30.6	124.7	167.0	200.4	254.6	296.3	326.1	324.6	317.7	286.9	131.4	7.3	$2,478.195
Investment																		
Deliver New Engines					9.4	21.1	112.4	152.2	189.6	243.5	283.3	311.4	309.0	304.4	273.9	124.1	7.0	2,341.282
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations						0.4	2.7	4.6	5.9	7.6	9.2	10.9	11.8	11.8	11.8	7.2	0.3	84.238
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	9.4	17.4	27.2	32.7	38.3	79.9	126.2	167.0	200.4	254.6	296.3	326.1	324.6	317.7	286.9	131.4	7.3	$2,643.399

5.2.3.2 Booster Vehicle (WBS 3.3)

Cost Element	Fiscal Year (Dollars in Millions) 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	4.6	20.2	23.1	18.2	35.4	61.2	1.5											$ 164.253
DDT&E																		
Development																		
Development	4.6	10.4	19.6	11.4	6.3	5.2												57.535
STE/ST		9.8			8.5	16.3												34.644
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				2.8	18.1	37.4												58.307
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total			2.8	5.7	14.6	55.1	176.3	231.1	279.2	346.7	398.0	437.0	434.8	423.7	390.9	197.0	15.0	$3,407.900
Investment																		
Deliver New Engines					11.8	26.6	141.7	191.8	242.0	306.9	354.2	389.6	386.6	377.8	345.3	168.2	8.8	2,951.347
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations			2.8	5.3	2.0	19.4	25.0	29.1	32.3	36.3	40.0	43.6	44.4	44.4	44.4	28.7	6.2	403.878
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	10.3	20.2	33.9	41.6	50.0	116.3	177.8	231.1	279.2	346.7	398.0	437.0	434.8	423.7	390.9	197.0	15.0	$3,603.521

5.2.4 Option IV - Basic with Thrust Termination

5.2.4.1 Solid Rocket Motor (WBS 3.3.2)

Cost Element	Fiscal Year (Dollars in Millions) 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	3.4	16.4	17.7	13.5	26.1	45.2	1.5											$ 123.792
DDT&E																		
Development																		
Development	3.4	7.6	14.2	8.3	4.6	3.8												41.882
STE/ST		8.8			6.9	13.7												29.408
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				1.2	12.1	25.4												38.735
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total				0.4	9.2	28.3	112.8	150.9	180.4	228.8	266.3	293.1	291.9	285.4	257.9	118.2	6.5	$2,230.137
Investment																		
Deliver New Engines					8.4	18.8	100.5	136.1	169.6	217.7	253.3	278.4	276.3	272.1	244.9	110.9	6.2	2,093.224
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations						0.4	2.7	4.6	5.9	7.6	9.2	10.9	11.8	11.8	11.8	7.2	0.3	84.238
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	9.1	16.4	25.7	31.6	35.3	73.5	114.3	150.9	180.4	228.8	266.3	293.1	291.9	285.4	257.9	118.2	6.5	$2,385.297

5.2.4.2 Booster Vehicle (WBS 3.3)

Cost Element	Fiscal Year (Dollars in Millions) 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	4.2	19.1	21.4	17.0	33.0	56.7	1.5											$ 152.874
DDT&E																		
Development																		
Development	4.2	9.5	17.9	10.5	5.7	4.7												52.533
STE/ST		9.6			8.3	15.9												33.795
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				2.5	16.5	33.8												52.779
OS FS & Spares			2.5	1.8	2.5	2.3	1.5											10.567
Recurring Total			2.7	5.4	13.4	51.7	162.3	212.4	255.7	317.3	364.0	399.7	397.8	387.4	357.6	180.4	13.9	$3,121.763
Investment																		
Deliver New Engines					10.7	24.2	128.9	174.5	220.1	279.2	322.2	354.4	351.7	343.6	314.1	153.0	8.1	2,684.720
Ground Support Equip						7.8	7.8	7.8	2.0									25.413
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations			2.7	5.0	1.9	18.4	23.8	27.7	30.7	34.6	38.0	41.5	42.3	42.3	42.3	27.3	5.8	384.308
Parts				0.4	0.8	1.3	1.8	2.3	2.8	3.4	3.6	3.6	3.6	1.3	1.0			25.829
Facilities	5.7		8.0	17.7														31.368
Total Program	9.9	19.1	32.1	40.1	46.4	108.4	163.8	212.4	255.7	317.3	364.0	399.7	397.8	387.4	357.6	180.4	13.9	$3,305.945

5.3 156-6 SRM SERIES (Basic with Thrust Termination and TVC)

5.3.1 Solid Rocket Motor (WBS 3.3.2)

Cost Element	Fiscal Year (Dollars in Millions) 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	4.2	20.9	22.0	16.5	33.5	59.2	1.8											$ 158.166
DDT&E																		
Development																		
Development	4.2	9.6	18.1	10.6	5.8	4.8												53.105
STE/ST		11.3			8.8	17.9												37.977
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				1.6	16.0	33.8												51.443
OS FS & Spares			2.9	2.1	2.9	2.7	1.8											12.441
Recurring Total				0.4	13.8	39.9	168.1	225.5	272.5	345.9	402.4	442.9	440.9	431.6	389.7	178.1	10.2	$3,361.853
Investment																		
Deliver New Engines					12.8	28.8	153.6	208.0	259.2	332.8	387.2	425.7	422.5	416.0	374.4	169.6	9.8	3,200.383
Ground Support Equip						9.2	9.2	9.2	2.9									30.496
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations						0.4	3.1	5.4	6.9	8.9	10.7	12.7	13.9	13.9	13.9	8.4	0.4	98.546
Parts				0.4	1.0	1.5	2.2	2.8	3.4	4.1	4.3	4.3	4.3	1.5	1.2			30.995
Facilities	6.9		9.7	21.5														38.068
Total Program	11.1	20.9	31.7	38.4	47.3	99.1	169.9	225.5	272.5	345.9	402.4	442.9	440.9	431.6	389.7	178.1	10.2	$3,558.087

5.3.2 Booster Vehicle (WBS 3.3)

Cost Element	Fiscal Year (Dollars in Millions) 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total
Non-Recurring Total	5.2	24.1	26.1	20.7	42.8	74.6	1.8											$ 195.282
DDT&E																		
Development																		
Development	5.2	11.8	22.2	13.0	7.1	6.0												65.248
STE/ST		12.3			10.6	20.3												43.241
Deliverable Hardware																		
Dummy Engines			1.0	2.2														3.200
Flight Engines				3.4	22.2	45.6												71.152
OS FS & Spares			2.9	2.1	2.9	2.7	1.8											12.441
Recurring Total			3.4	6.8	19.3	69.7	231.1	303.8	369.1	458.5	526.3	578.1	575.1	560.5	516.8	259.7	19.4	$4,497.658
Investment																		
Deliver New Engines					15.8	35.5	189.3	256.4	323.5	410.2	473.3	520.7	516.7	504.9	461.5	224.8	11.9	3,944.533
Ground Support Equip						9.2	9.2	9.2	2.9									30.496
Parts																		
Operations																		
Flight Support								0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.1		1.433
Operations			3.4	6.4	2.5	23.5	30.4	35.3	39.2	44.1	48.5	52.9	53.9	53.9	53.9	34.8	7.5	490.201
Parts				0.4	1.0	1.5	2.2	2.8	3.4	4.1	4.3	4.3	4.3	1.5	1.2			30.995
Facilities	6.9		9.7	21.5														38.068
Total Program	12.1	24.1	39.2	49.0	62.1	144.3	232.9	303.8	369.1	458.5	526.3	578.1	575.1	560.5	516.8	259.7	19.4	$4,731.008

Section 6

RECURRING COST PER ALTERNATE LAUNCH RATE

6.1 DESCRIPTION OF COSTING APPROACH

The recurring cost-per-launch is presented for each launch rate, including the basic mission model of 60. Data tables have been prepared for each of the alternate booster vehicles (options) of the baseline 156-7 parallel configuration. A summary of the calculation method follows:

SRM/Stage. The recurring cost presented in this subsection encompasses 880 Production SRMs to support 440 manned launches. Cost also includes three nonrecurring SRMs for production facility start-up test.

The 880 production SRMs were preceded by 12 SRMs used for the unmanned booster and the first five manned launches, which are part of the design, development, test and evaluation (DDT&E) phase of the program. Because these units are the same configuration as those in the production phase, they will be manufactured on the same configuration of tools and will be part of the basic production run. They are included in the base for T_1 and the production learning application.

The first flight SRM in the production phase is thus identified as T_{16} summarized as follows:

	SRM	
	Quantity	Cumulative Quantity
Unmanned Booster (1)	2	1 and 2
Manned Booster (5)	10	3 through 12
Production Facilities Start-up Motors	3	13 through 15
Production Motors	880	16 through 895

The unit and attendant costs were laid on a 95-percent cost curve. This percentage is deemed appropriate for a solid rocket program that encompasses a variety of hardware, systems engineering, program management, etc.

The production run quantity for stage is the same as the SRM in that the flight units in DDT&E are identified as the first 6 production units. Therefore, the first production phase unit is T_7 on a 90-percent production progress cost curve, for a total of 440 sets to T_{446}.

Operation/Transportation. Unlike factory costs, which is learning oriented, operations effort is primarily a function of launch rate and the operations costs are applied in the tables by the launches. The transportation cost takes into effect shipping motors and hardware to KSC from factories located both in the vicinity of KSC and the West coast. The cost is spread on an average basis.

Detailed calculations displaying the method and rationale used in deriving the cost data on the tables is included in this section following the tables for each optional configuration. As the details show, the recurring costs used are the production amounts exclusive of the facilities and three production facilities start-up motors.

6.2 156-7 PARALLEL CONFIGURATION

6.2.1 Option I - Basic with Thrust Termination and TVC

6.2.1.1 Launch Rate Cost Summaries (Rates of 60, 40, 20 and 10)

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION I - BASIC WITH THRUST TERMINATION AND TVC
LAUNCH RATE OF 60

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	16	24	32	41	50	59	60	60	60	38	440
SRM per Year	32	48	64	82	100	118	120	120	120	76	880
COST											
SRM	$103.4	$145.6	$185.9	$230.3	$273.1	$314.7	$313.9	$309.1	$305.2	$191.6	$2,372.8
Stage	32.9	43.1	52.4	62.5	72.0	80.9	79.0	76.5	74.5	46.3	620.1
Operation	19.8	27.0	34.2	36.0	43.2	43.9	43.9	43.9	43.9	29.3	365.1
Shipping	2.9	4.4	5.9	7.5	9.2	10.8	11.0	11.0	11.0	6.9	80.6
Total	$159.0	$220.1	$278.4	$336.3	$397.5	$450.3	$447.8	$440.5	$434.6	$274.1	$3,438.6
Booster Vehicle Cost per Launch	$ 9.9	$ 9.2	$ 8.7	$ 8.2	$ 8.0	$ 7.6	$ 7.5	$ 7.3	$ 7.2	$ 7.2	$ 7.8

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION I - BASIC WITH THRUST TERMINATION AND TVC

LAUNCH RATE OF 40

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	24	32	40	40	40	40	40	40	40	351
SRM per Year	30	48	64	80	80	80	80	80	80	80	702
COST											
SRM	$ 97.1	$145.9	$186.1	$224.9	$219.3	$215.2	$212.0	$209.3	$207.1	$205.2	$1,922.1
Stage	31.0	43.3	52.5	61.1	58.0	55.8	54.1	52.7	51.5	50.6	510.6
Operation	18.6	27.0	34.2	35.1	35.1	35.1	35.1	35.1	35.1	32.1	322.5
Shipping	2.7	4.4	5.9	7.4	7.3	7.3	7.3	7.3	7.3	7.3	64.2
Total	$149.4	$220.6	$278.7	$328.5	$319.7	$313.4	$308.5	$304.4	$301.0	$295.2	$2,819.4
Booster Vehicle Cost per Launch	$ 10.0	$ 9.2	$ 8.7	$ 8.2	$ 8.0	$ 7.8	$ 7.7	$ 7.6	$ 7.5	$ 7.4	$ 8.0

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

(Cost in Millions)

OPTION I - BASIC WITH THRUST TERMINATION AND TVC

LAUNCH RATE OF 20

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	20	20	20	20	20	20	20	20	20	195
SRM per Year	30	40	40	40	40	40	40	40	40	40	390
COST											
SRM	$ 97.1	$122.1	$117.8	$115.0	$112.9	$111.3	$110.0	$108.8	$107.8	$107.0	$1,109.8
Stage	31.0	36.4	33.7	32.0	30.8	29.9	29.2	28.6	28.0	27.6	307.2
Operation	18.6	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	22.5	221.1
Shipping	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	36.0
Total	$149.4	$184.7	$177.7	$173.2	$169.9	$167.4	$165.4	$163.6	$162.0	$160.8	$1,674.1
Booster Vehicle Cost per Launch	$ 10.0	$ 9.2	$ 8.9	$ 8.7	$ 8.5	$ 8.4	$ 8.3	$ 8.2	$ 8.1	$ 8.0	$ 8.6

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

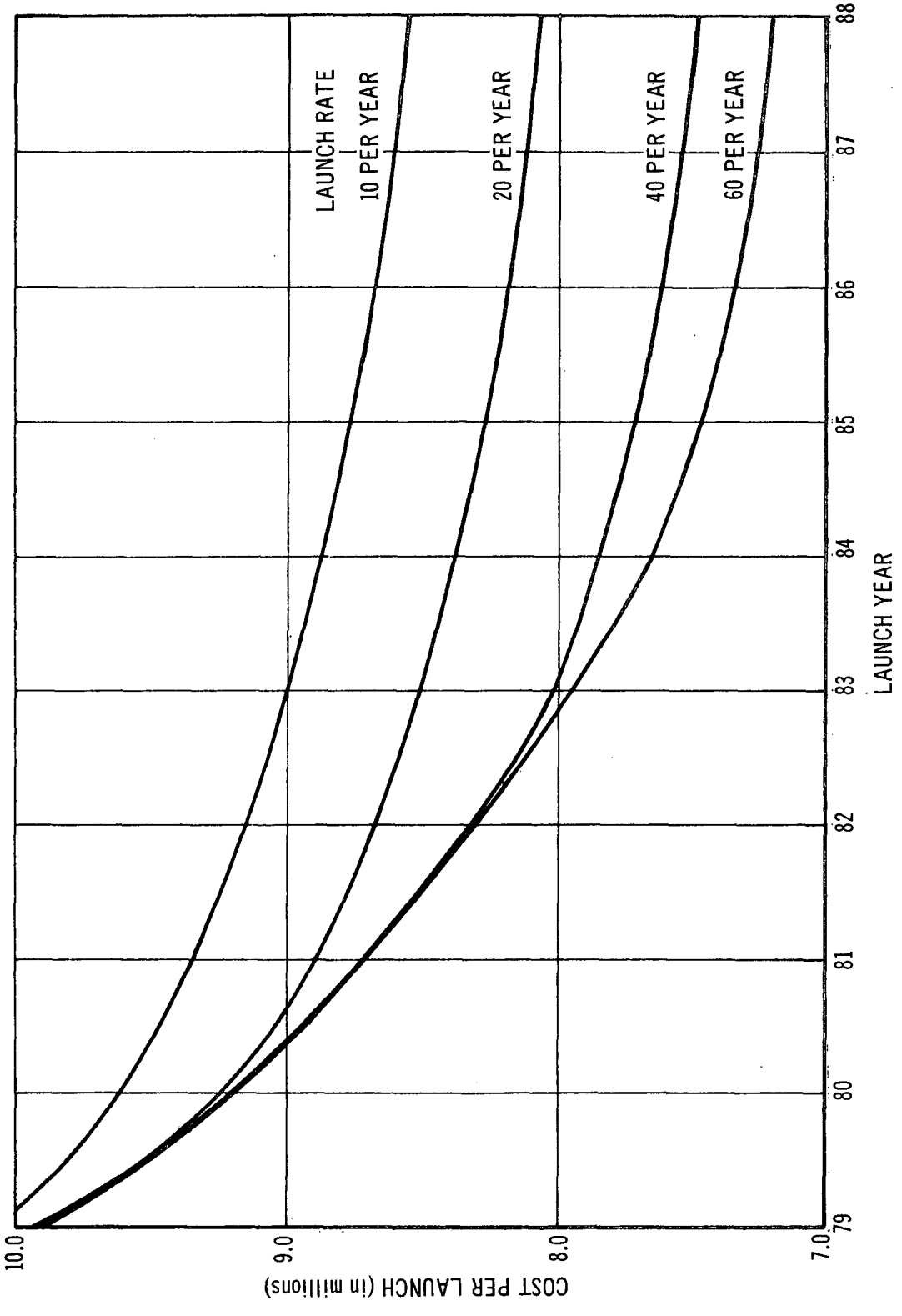
(Cost in Millions)

OPTION I - BASIC WITH THRUST TERMINATION AND TVC

LAUNCH RATE OF 10

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	10	10	10	10	10	10	10	10	10	10	100
SRM per Year	20	20	20	20	20	20	20	20	20	20	200
COST											
SRM	$ 65.5	$62.7	$61.0	$59.8	$58.9	$58.1	$57.5	$56.9	$56.5	$56.0	$592.9
Stage	21.3	19.2	18.1	17.4	16.8	16.4	16.0	15.7	15.4	15.2	171.5
Operation	12.4	12.4	12.4	12.4	12.4	12.3	12.3	12.3	12.3	12.3	123.5
Shipping	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	18.0
Total	$101.0	$96.1	$93.3	$91.4	$89.9	$88.6	$87.6	$86.7	$86.0	$85.3	$905.9
Booster Vehicle Cost per Launch	$ 10.1	$ 9.6	$ 9.3	$ 9.1	$ 9.0	$ 8.9	$ 8.8	$ 8.7	$ 8.6	$ 8.5	$ 9.1

6.2.1.2 Comparison Curves



Option I - Basic with Thrust Termination and TVC

6.2.1.3 Costing Rationale/Detail

OPTION I - BASIC w/TT & TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	32	CTF_{47}	37.9745	-	CTF_{15}	13.0921	=	24.8824	$ 103.378
1980	48	CTF_{95}	73.0250	-	CTF_{47}	37.9745	=	35.0505	145.623
1981	64	CTF_{159}	117.7696	-	CTF_{95}	73.0250	=	44.7446	185.898
1982	82	CTF_{241}	173.1938	-	CTF_{159}	117.7696	=	55.4242	230.268
1983	100	CTF_{341}	238.9272	-	CTF_{241}	173.1938	=	65.7334	273.099
1984	118	CTF_{459}	314.6826	-	CTF_{341}	238.9272	=	75.7554	314.737
1985	120	CTF_{579}	390.2446	-	CTF_{459}	314.6826	=	75.5620	313.934
1986	120	CTF_{699}	464.6489	-	CTF_{579}	390.2446	=	74.4043	309.124
1987	120	CTF_{819}	538.1099	-	CTF_{699}	464.6489	=	73.4610	305.204
1988	76	CTF_{895}	584.2166	-	CTF_{819}	538.1099	=	46.1067	191.557
Total	880							571.1245	$2,372,822

T_1 = $4,154,650

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	16	CTF_{22}	15.8624	-	CTF_{6}	5.1008	=	10.7616	$ 32.954
1980	24	CTF_{46}	29.9246	-	CTF_{22}	15.8624	=	14.0622	43.061
1981	32	CTF_{78}	47.0255	-	CTF_{46}	29.9246	=	17.1009	52.366
1982	41	CTF_{119}	67.4425	-	CTF_{78}	47.0255	=	20.4170	62.520
1983	50	CTF_{169}	90.9413	-	CTF_{119}	67.4425	=	23.4988	71.957
1984	59	CTF_{228}	117.3471	-	CTF_{169}	90.9413	=	26.4058	80.859
1985	60	CTF_{288}	143.1472	-	CTF_{228}	117.3471	=	25.8001	79.004
1986	60	CTF_{348}	168.1382	-	CTF_{288}	143.1472	=	24.9910	76.527
1987	60	CTF_{408}	192.4802	-	CTF_{348}	168.1382	=	24.3420	74.539
1988	38	CTF_{446}	207.6123	-	CTF_{408}	192.4802	=	15.1321	46.337
Total	440							202.5115	$620.124

T_1 = $3,062,166

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 97.124
1980	48	CTF_{93}	71.5966	-	CTF_{45}	36.4692	=	35.1274	145.942
1981	64	CTF_{157}	116.3948	-	CTF_{93}	71.5966	=	44.7982	186.121
1982	80	CTF_{237}	170.5270	-	CTF_{157}	116.3948	=	54.1322	224.900
1983	80	CTF_{317}	223.2995	-	CTF_{237}	170.5270	=	52.7725	219.251
1984	80	CTF_{397}	275.0862	-	CTF_{317}	223.2995	=	51.7867	215.156
1985	80	CTF_{477}	326.1019	-	CTF_{397}	275.0862	=	51.0157	211.952
1986	80	CTF_{557}	376.4860	-	CTF_{477}	326.1019	=	50.3841	209.328
1987	80	CTF_{637}	426.3360	-	CTF_{557}	376.4860	=	49.8500	207.109
1988	80	CTF_{717}	475.7240	-	CTF_{637}	426.3360	=	49.3880	205.190
Total	702							462.6319	$1,922.073

$T_1 = \$4,154,650$

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 31.040
1980	24	CTF_{45}	29.3658	-	CTF_{21}	15.2373	=	14.1285	43.264
1981	32	CTF_{77}	46.5098	-	CTF_{45}	29.3658	=	17.1440	52.498
1982	40	CTF_{117}	66.4746	-	CTF_{77}	46.5098	=	19.9648	61.136
1983	40	CTF_{157}	85.4111	-	CTF_{117}	66.4746	=	18.9365	57.987
1984	40	CTF_{197}	103.6223	-	CTF_{157}	85.4111	=	18.2112	55.766
1985	40	CTF_{237}	121.2772	-	CTF_{197}	103.6223	=	17.6549	54.062
1986	40	CTF_{277}	138.4836	-	CTF_{237}	121.2772	=	17.2064	52.689
1987	40	CTF_{317}	155.3158	-	CTF_{277}	138.4836	=	16.8322	51.543
1988	40	CTF_{357}	171.8278	-	CTF_{317}	155.3158	=	16.5120	50.562
Total	351							166.7270	$510.547

T_1 = $3,062,166

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 97.124
1980	40	CTF_{85}	65.8598	-	CTF_{45}	36.4692	=	29.3906	122.108
1981	40	CTF_{125}	94.2095	-	CTF_{85}	65.8598	=	28.3497	117.783
1982	40	CTF_{165}	121.8863	-	CTF_{125}	94.2095	=	27.6768	114.987
1983	40	CTF_{205}	149.0674	-	CTF_{165}	121.8863	=	27.1811	112.928
1984	40	CTF_{245}	175.8574	-	CTF_{205}	149.0674	=	26.7900	111.303
1985	40	CTF_{285}	202.3247	-	CTF_{245}	175.8574	=	26.4673	109.962
1986	40	CTF_{325}	228.5181	-	CTF_{285}	202.3247	=	26.1934	108.824
1987	40	CTF_{365}	254.4738	-	CTF_{325}	228.5181	=	25.9557	107.837
1988	40	CTF_{405}	280.2197	-	CTF_{365}	254.4738	=	25.7459	106.965
Total	390							267.1276	$1,109.821

T_1 = $4,154,650

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 31.040
1980	20	CTF_{41}	27.1114	-	CTF_{21}	15.2373	=	11.8741	36.360
1981	20	CTF_{61}	38.1093	-	CTF_{41}	27.1114	=	10.9979	33.677
1982	20	CTF_{81}	48.5666	-	CTF_{61}	38.1093	=	10.4573	32.022
1983	20	CTF_{101}	58.6369	-	CTF_{81}	48.5666	=	10.0703	30.837
1984	20	CTF_{121}	68.4079	-	CTF_{101}	58.6369	=	9.7710	29.920
1985	20	CTF_{141}	77.9363	-	CTF_{121}	68.4079	=	9.5284	29.178
1986	20	CTF_{161}	87.2614	-	CTF_{141}	77.9363	=	9.3251	28.555
1987	20	CTF_{181}	96.4122	-	CTF_{161}	87.2614	=	9.1508	28.021
1988	20	CTF_{201}	105.4107	-	CTF_{181}	96.4122	=	8.9985	27.555
Total	195							100.3099	$307.165

T_1 = $3,062,166

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	20	CTF_{35}	28.8636	-	CTF_{15}	13.0921	=	15.7715	$ 65.525
1980	20	CTF_{55}	43.9511	-	CTF_{35}	28.8636	=	15.0875	62.683
1981	20	CTF_{75}	58.6323	-	CTF_{55}	43.9511	=	14.6812	60.995
1982	20	CTF_{95}	73.0250	-	CTF_{75}	58.6323	=	14.3927	59.797
1983	20	CTF_{115}	87.1947	-	CTF_{95}	73.0250	=	14.1697	58.870
1984	20	CTF_{135}	101.1830	-	CTF_{115}	87.1947	=	13.9883	58.116
1985	20	CTF_{155}	115.0190	-	CTF_{135}	101.1830	=	13.8360	57.484
1986	20	CTF_{175}	128.7231	-	CTF_{155}	115.0190	=	13.7041	56.936
1987	20	CTF_{195}	142.3121	-	CTF_{175}	128.7231	=	13.5890	56.458
1988	20	CTF_{215}	155.7985	-	CTF_{195}	142.3121	=	13.4864	56.031
Total	200							142.7064	$592.895

T_1 = $4,154,650

6.2.1.3 (Continued)

OPTION I - BASIC w/TT & TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	10	CTF_{16}	12.0398	-	CTF_{6}	5.1008	=	6.9390	$ 21.248
1980	10	CTF_{26}	18.3227	-	CTF_{16}	12.0398	=	6.2829	19.239
1981	10	CTF_{36}	24.2461	-	CTF_{26}	18.3227	=	5.9234	18.138
1982	10	CTF_{46}	29.9246	-	CTF_{36}	24.2461	=	5.6785	17.389
1983	10	CTF_{56}	35.4189	-	CTF_{46}	29.9246	=	5.4943	16.824
1984	10	CTF_{66}	40.7667	-	CTF_{56}	35.4189	=	5.3478	16.376
1985	10	CTF_{76}	45.9930	-	CRF_{66}	40.7667	=	5.2263	16.004
1986	10	CTF_{86}	51.1163	-	CTF_{76}	45.9930	=	5.1233	15.688
1987	10	CTF_{96}	56.1501	-	CTF_{86}	51.1163	=	5.0338	15.414
1988	10	CTF_{106}	61.1051	-	CTF_{96}	56.1501	=	4.9550	15.173
Total	100							56.0043	$171.493

T_1 = $3,062,166

6.2.1.3 (Continued)

OPTION I - BASIC WITH T. T. AND TVC

RECURRING AND FIRST UNIT COST

		WBS	COST
SRM (WBS 3.3.2) - Incl 3 PPQ's			
Total SRM		3.3.2	$2,545.691M
Less:	Facitilies	3.3.2.4	(25.700M)
	Transportation	3.3.2.7.2	(80.702M)
	Support Equipment Spares	3.3.2.5	(51.242M)
	Flight Test Support	3.3.2.6	(1.433M)
	Operations Support	3.3.2.7.1	(3.536M)
	Recurring SRM Incl 3 PPQ's		$2,383.078M
STAGE			
	Structures	3.3.1	$ 384.516M
	Avionics	3.3.3	184.720M
	Power	3.3.5	50.888M
	Recurring Stage		$ 620.124M
OPERATION			
	Support Equipment Spares	3.3.2.5	$ 51.242M
	Flight Test Support	3.3.2.6	1.433M
	Operations Support	3.3.2.7.1	3.536M
	Installation Assembly and Checkout	3.3.6	188.494M
	Major Ground Test	3.3.7	120.401M
	Recurring Operations		$ 365.106M
TRANSPORTATION		3.3.2.7.2	$ 80.702M
	Total Recurring Cost - Incl 3 PPQ's		$3,449.010M
	Reconcil. w/WBS - Facilities		25.700M
	TOTAL PRODUCTION		$3,474.710M

6.2.1.3 (Continued)

OPTION I - BASIC WITH TT & TVC

T_1 SRM

CTF_{895}, @ 95%	584.2166
CTF_{12}, @ 95%	(10.6239)
CTF_{883}, $T_{13} \rightarrow 895$	573.5927

T_1 = \$2.383.078M ÷ 573.5927 = \$4.15465M

3 PPQ's	CTF_{15}, @ 95%	13.0921		
	CTF_{12}, @ 95%	(10.6239)		
	CTF_3, $T_{13} \rightarrow 15$	2.4682	x \$4.15465M =	\$ 10.255M
880 Prod.	CTF_{895}, @ 95%	584.2166		
	CTF_{15}, @ 95%	(13.0921)		
	CTF_{880}, $T_{16} \rightarrow 895$	571.1245	x \$4.15465M =	\$2,372.823M
	TOTAL PRODUCTION INCL PPQ			\$2,383.078M

T_1 STAGE

CTF_{446}, @ 90%	207.6123
CTF_6, @ 90%	(5.1008)
CTF_{440}, $T_7 \rightarrow 446$	202.5115

T_1 = \$620.124M ÷ 202.5115 = \$3,062.166M

6.2.2 Option II - Basic (without Thrust Termination and TVC)

6.2.2.1 Launch Rate Cost Summaries (Rates of 60, 40, 20, and 10)

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

6.2.2 OPTION II - BASIC (W/O THRUST TERM AND TVC)

6.2.2.1 LAUNCH RATE OF 60

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	16	24	32	41	50	59	60	60	60	38	440
SRM per Year	32	48	64	82	100	118	120	120	120	76	880
COST											
SRM	$ 89.0	$125.4	$160.0	$198.2	$235.1	$270.9	$270.3	$266.1	$262.7	$164.9	$2,042.6
Stage	30.9	40.4	49.1	58.6	67.5	75.8	74.1	71.7	69.9	43.4	581.4
Operation	18.1	24.7	31.3	33.0	39.5	40.2	40.2	40.2	40.2	26.8	334.2
Shipping	2.9	4.4	5.9	7.5	9.2	10.8	11.0	11.0	11.0	6.9	80.6
Total	$140.9	$194.9	$246.3	$297.3	$351.3	$397.7	$395.6	$389.0	$383.8	$242.0	$3,038.8
Booster Vehicle Cost per Launch	$ 8.8	$ 8.1	$ 7.7	$ 7.3	$ 7.0	$ 6.7	$ 6.6	$ 6.5	$ 6.4	$ 6.4	$ 6.9

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

(Cost in Millions)

OPTION II - BASIC (W/O THRUST TERM AND TVC)

6.2.2.1 LAUNCH RATE OF 40

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	24	32	40	40	40	40	40	40	40	351
SRM per Year	30	48	64	80	80	80	80	80	80	80	702
COST											
SRM	$ 83.6	$125.6	$160.2	$193.6	$188.8	$185.2	$182.5	$180.2	$178.3	$176.6	$1,654.6
Stage	29.1	40.6	49.2	57.3	54.4	52.3	50.7	49.4	48.3	47.4	478.7
Operation	17.0	24.7	31.3	32.2	32.2	32.2	32.1	32.1	32.1	29.3	295.2
Shipping	2.7	4.4	5.9	7.4	7.3	7.3	7.3	7.3	7.3	7.3	64.2
Total	$132.4	$195.3	$246.6	$290.5	$282.7	$277.0	$272.6	$269.0	$266.0	$260.6	$2,492.7
Booster Vehicle Cost per Launch	$ 8.8	$ 8.1	$ 7.7	$ 7.3	$ 7.1	$ 6.9	$ 6.8	$ 6.7	$ 6.6	$ 6.5	$ 7.1

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION II - BASIC (W/O THRUST TERM AND TVC)

LAUNCH RATE OF 20

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	20	20	20	20	20	20	20	20	20	195
SRM per Year	30	40	40	40	40	40	40	40	40	40	390
COST											
SRM	$ 83.6	$105.1	$101.4	$ 99.0	$ 97.2	$ 95.8	$ 94.7	$ 93.7	$ 92.8	$ 92.1	$ 955.4
Stage	29.1	34.1	31.6	30.0	28.9	28.0	27.4	26.8	26.3	25.8	288.0
Operation	17.0	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	20.6	202.4
Shipping	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	36.0
Total	$132.4	$163.5	$157.3	$153.3	$150.4	$148.1	$146.4	$144.8	$143.4	$142.2	$1,481.8
Booster Vehicle Cost per Launch	$ 8.8	$ 8.2	$ 7.9	$ 7.7	$ 7.5	$ 7.4	$ 7.3	$ 7.2	$ 7.2	$ 7.1	$ 7.6

LOCKHEED PROPULSION COMPANY

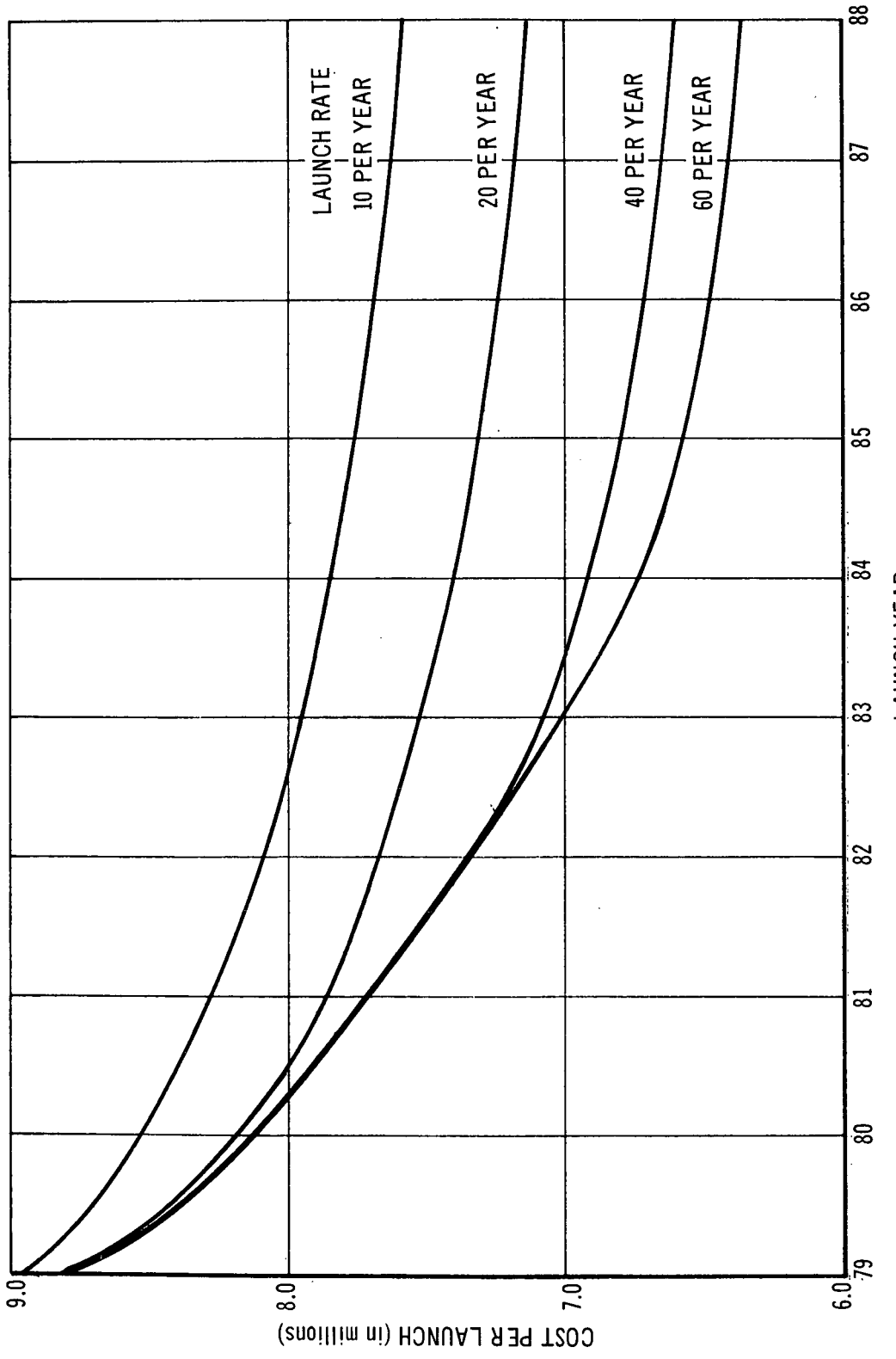
BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION II - BASIC (W/O THRUST TERM AND TVC)

LAUNCH RATE OF 10

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	10	10	10	10	10	10	10	10	10	10	100
SRM per Year	20	20	20	20	20	20	20	20	20	20	200
COST											
SRM	$56.4	$54.0	$52.5	$51.5	$50.7	$50.0	$49.5	$49.0	$48.6	$48.2	$510.4
Stage	19.9	18.0	17.0	16.3	15.8	15.4	15.0	14.7	14.5	14.2	160.8
Operation	11.4	11.4	11.3	11.3	11.3	11.3	11.3	11.3	11.3	11.3	113.2
Shipping	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	18.0
Total	$89.5	$85.2	$82.6	$80.9	$79.6	$78.5	$77.6	$76.8	$76.2	$75.5	$802.4
Booster Vehicle Cost per Launch	$ 9.0	$ 8.5	$ 8.3	$ 8.1	$ 8.0	$ 7.9	$ 7.8	$ 7.7	$ 7.6	$ 7.5	$ 8.0

6.2.2.2 Comparison Curves



Option II - Basic w/o Thrust Termination and TVC

6.2.2.3 Costing Rationale/Detail

OPTION II -- BASIC (W/O TT & TVC)

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}$
1979	32	CTF_{47}	37.9745	-	CTF_{15}	13.0921	=	24.8824	$ 88.991
1980	48	CTF_{95}	73.0250	-	CTF_{47}	37.9745	=	35.0505	125.356
1981	64	CTF_{159}	117.7696	-	CTF_{95}	73.0250	=	44.7446	160.027
1982	82	CTF_{241}	173.1938	-	CTF_{159}	117.7696	=	55.4242	198.222
1983	100	CTF_{341}	238.9272	-	CTF_{241}	173.1938	=	65.7334	235.092
1984	118	CTF_{459}	314.6826	-	CTF_{341}	238.9272	=	75.7554	270.936
1985	120	CTF_{579}	390.2446	-	CTF_{459}	314.6826	=	75.5620	270.244
1986	120	CTF_{699}	464.6489	-	CTF_{579}	390.2446	=	74.4043	266.103
1987	120	CTF_{819}	538.1099	-	CTF_{699}	464.6489	=	73.4610	262.730
1988	76	CTF_{895}	584.2166	-	CTF_{819}	538.1099	=	46.1067	164.899
Total	880							571.1245	$2,042.600

T_1 = $3,576,452

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	16	CTF_{22}	15.8624	-	CTF_{6}	5.1008	=	10.7616	$ 30.898
1980	24	CTF_{46}	29.9246	-	CTF_{22}	15.8624	=	14.0622	40.374
1981	32	CTF_{78}	47.0255	-	CTF_{46}	29.9246	=	17.1009	49.099
1982	41	CTF_{119}	67.4425	-	CTF_{78}	47.0255	=	20.4170	58.620
1983	50	CTF_{169}	90.9413	-	CTF_{119}	67.4425	=	23.4988	67.468
1984	59	CTF_{228}	117.3471	-	CTF_{169}	90.9413	=	26.4058	75.814
1985	60	CTF_{288}	143.1472	-	CTF_{228}	117.3471	=	25.8001	74.076
1986	60	CTF_{348}	168.1382	-	CTF_{288}	143.1472	=	24.9910	71.753
1987	60	CTF_{408}	192.4802	-	CTF_{348}	168.1382	=	24.3420	69.889
1988	38	CTF_{446}	207.6123	-	CTF_{408}	192.4802	=	15.1321	43.446
Total	440							202.5115	$581.431

T_1 = 2,871,130

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 83.607
1980	48	CTF_{93}	71.5966	-	CTF_{45}	36.4692	=	35.1274	125.631
1981	64	CTF_{157}	116.3948	-	CTF_{93}	71.5966	=	44.7982	160.219
1982	80	CTF_{237}	170.5270	-	CTF_{157}	116.3948	=	54.1322	193.601
1983	80	CTF_{317}	223.2995	-	CTF_{237}	170.5270	=	52.7725	188.738
1984	80	CTF_{397}	275.0862	-	CTF_{317}	223.2995	=	51.7867	185.213
1985	80	CTF_{477}	326.1019	-	CTF_{397}	275.0862	=	51.0157	182.455
1986	80	CTF_{557}	376.4860	-	CTF_{477}	326.1019	=	50.3841	180.196
1987	80	CTF_{637}	426.3360	-	CTF_{557}	376.4860	=	49.8500	178.286
1988	80	CTF_{717}	475.7240	-	CTF_{637}	426.3360	=	49.3880	176.634
Total	702							462.6319	$1,654.580

T_1 = $3,576,452

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 29.103
1980	24	CTF_{45}	29.3658	-	CTF_{21}	15.2373	=	14.1285	40.565
1981	32	CTF_{77}	46.5098	-	CTF_{45}	29.3658	=	17.1440	49.223
1982	40	CTF_{117}	66.4746	-	CTF_{77}	46.5098	=	19.9648	57.322
1983	40	CTF_{157}	85.4111	-	CTF_{117}	66.4746	=	18.9365	54.369
1984	40	CTF_{197}	103.6223	-	CTF_{157}	85.4111	=	18.2112	52.287
1985	40	CTF_{237}	121.2772	-	CTF_{197}	103.6223	=	17.6549	50.690
1986	40	CTF_{277}	138.4836	-	CTF_{237}	121.2772	=	17.2064	49.402
1987	40	CTF_{317}	155.3158	-	CTF_{277}	138.4836	=	16.8322	48.327
1988	40	CTF_{357}	171.8278	-	CTF_{317}	155.3158	=	16.5120	47.408
Total	351							166.7270	$478.676

T_1 = $2,871,130

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 83.607
1980	40	CTF_{85}	65.8598	-	CTF_{45}	36.4692	=	29.3906	105.114
1981	40	CTF_{125}	94.2095	-	CTF_{85}	65.8598	=	28.3497	101.391
1982	40	CTF_{165}	121.8863	-	CTF_{125}	94.2095	=	27.6768	98.985
1983	40	CTF_{205}	149.0674	-	CTF_{165}	121.8863	=	27.1811	97.212
1984	40	CTF_{245}	175.8574	-	CTF_{205}	149.0674	=	26.7900	95.813
1985	40	CTF_{285}	202.3247	-	CTF_{245}	175.8574	=	26.4673	94.659
1986	40	CTF_{325}	228.5181	-	CTF_{285}	202.3247	=	26.1934	93.679
1987	40	CTF_{365}	254.4738	-	CTF_{325}	228.5181	=	25.9557	92.829
1988	40	CTF_{405}	280.2197	-	CTF_{365}	254.4738	=	25.7459	92.079
Total	390							267.1276	$955.368

T_1 = $3,576,452

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 29.103
1980	20	CTF_{41}	27.1114	-	CTF_{21}	15.2373	=	11.8741	34.092
1981	20	CTF_{61}	38.1093	-	CTF_{41}	27.1114	=	10.9979	31.576
1982	20	CTF_{81}	48.5666	-	CTF_{61}	38.1093	=	10.4573	30.024
1983	20	CTF_{101}	58.6369	-	CTF_{81}	48.5666	=	10.0703	28.913
1984	20	CTF_{121}	68.4079	-	CTF_{101}	58.6369	=	9.7710	28.054
1985	20	CTF_{141}	77.9363	-	CTF_{121}	68.4079	=	9.5284	27.357
1986	20	CTF_{161}	87.2614	-	CTF_{141}	77.9363	=	9.3251	26.774
1987	20	CTF_{181}	96.4122	-	CTF_{161}	87.2614	=	9.1508	26.273
1988	20	CTF_{201}	105.4107	-	CTF_{181}	96.4122	=	8.9985	25.836
Total	195							100.3099	$288.002

T_1 = $2,871,130

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

SRM PRODUCTION RECURRING
CUM TOTAL FACTORS
(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}$
1979	20	CTF_{35}	28.8636	-	CTF_{15}	13.0921	=	15.7715	$ 56.406
1980	20	CTF_{55}	43.9511	-	CTF_{35}	28.8636	=	15.0875	53.960
1981	20	CTF_{75}	58.6323	-	CTF_{55}	43.9511	=	14.6812	52.507
1982	20	CTF_{95}	73.0250	-	CTF_{75}	58.6323	=	14.3927	51.475
1983	20	CTF_{115}	87.1947	-	CTF_{95}	73.0250	=	14.1697	50.677
1984	20	CTF_{135}	101.1830	-	CTF_{115}	87.1947	=	13.9883	50.028
1985	20	CTF_{155}	115.0190	-	CTF_{135}	101.1830	=	13.8360	49.484
1986	20	CTF_{175}	128.7231	-	CTF_{155}	115.0190	=	13.7041	49.012
1987	20	CTF_{195}	142.3121	-	CTF_{175}	128.7231	=	13.5890	48.600
1988	20	CTF_{215}	155.7985	-	CTF_{195}	142.3121	=	13.4864	48.233
Total	200							142.7064	$510.382

$T_1 = 3,576,452$

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT & TVC)

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	10	CTF_{16}	12.0398	-	CTF_{6}	5.1008	=	6.9390	$ 19.923
1980	10	CTF_{26}	18.3227	-	CTF_{16}	12.0398	=	6.2829	18.039
1981	10	CTF_{36}	24.2461	-	CTF_{26}	18.3227	=	5.9234	17.007
1982	10	CTF_{46}	29.9246	-	CTF_{36}	24.2461	=	5.6785	16.304
1983	10	CTF_{56}	35.4189	-	CTF_{46}	29.9246	=	5.4943	15.775
1984	10	CTF_{66}	40.7667	-	CTF_{56}	35.4189	=	5.3478	15.354
1985	10	CTF_{76}	45.9930	-	CRF_{66}	40.7667	=	5.2263	15.005
1986	10	CTF_{86}	51.1163	-	CTF_{76}	45.9930	=	5.1233	14.710
1987	10	CTF_{96}	56.1501	-	CTF_{86}	51.1163	=	5.0338	14.453
1988	10	CTF_{106}	61.1051		CTF_{96}	56.1501	=	4.9550	14.226
Total	100							56.0043	$160.796

T_1 = $2,871,130

6.2.2.3 (Continued)

OPTION II - BASIC (W/O TT AND TVC)

RECURRING AND FIRST UNIT COST

		WBS	COST
SRM (WBS 3.3.2) Incl 3 PPQ's			
Total SRM		3.3.2	$2,214.040M
Less:	Facilities	3.3.2.4	(25.700M)
	Operations Support	3.3.2.7	(84.238M)
	Support Equipment Spares	3.3.2.5	(51.242M)
	Flight Test Support	3.3.2.6	(1.433M)
	Recurring Incl 3 PPQ's		$2,051.427M
STAGE			
	Structures	3.3.1	$ 378.979M
	Avionics	3.3.3	157.677M
	Power	3.3.5	44.781M
	Recurring State		$ 581.437M
OPERATION			
	Support Equipment Spares	3.3.2.5	$ 51.242M
	Flight Test Support	3.3.2.6	1.433M
	Operations Support	3.3.2.7.1	3.536M
	Installation Assembly and Checkout	3.3.6	169.645M
	Major Ground Test	3.3.7	108.361M
	Recurring Operations		$ 334.217M
TRANSPORTATION		3.3.2.7.2	$ 80.702M
Total Recurring Cost - Incl 3 PPQ's			$3,047.783M
FACILITIES			25.700M
	TOTAL PRODUCTION		$3,073.483M

6.2.2.3 (Continued)

OPTION II - BASIC (w/o TT & TVC)

T_1 - SRM

I.	CTF_{895}, @ 95%	584.2166		
	CTF_{12}, @ 95%	(10.6239)		
	CTF_{883}, $T_{13} \rightarrow 895$	573.5927		
	T_1 = \$2,051.427M ÷ 573.5927 =			\$3,576,452
II.	3 PPQ's			
	CTF_{15}, @ 95%	13.0921		
	CTF_{12}, @ 95%	(10.6239)		
	CTF_3, $T_{13} \longrightarrow 15$	2.4682	x \$3,576,452 =	\$ 8.827M
III.	880 Production			
	CTF_{895}, @ 95%	584.2166		
	CTF_{15}, @ 95%	(13.0921		
	CTF_{880}, $T_{16} \longrightarrow 895$	571.1245	x \$3,576,452 =	\$2,042.600M
	TOTAL SRM RECURRING INCL 3 PPQ's (PRODUCTION)			\$2,051,427M

T_1 STAGE

CTF_{446}, @ 90%	207.6123	
CTF_6, @ 90%	(5.1008)	
CTF_{440}, $T_7 \longrightarrow 446$	202.5115	
T_1 = \$581.437M ÷ 202.5115 =		\$2,871,130

6.2.3 Option III - Basic with TVC

6.2.3.1 Launch Rate Cost Summaries (Rates of 60, 40, 20 and 10)

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION III - BASIC WITH TVC

LAUNCH RATE OF 60

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	16	24	32	41	50	59	60	60	60	38	440
SRM per Year	32	48	64	82	100	118	120	120	120	76	880
COST											
SRM	$101.6	$143.1	$182.6	$226.2	$268.3	$309.2	$308.4	$303.7	$299.9	$188.2	$2,331.2
Stage	32.4	42.4	51.5	61.5	70.8	79.6	77.7	75.3	73.3	45.6	610.1
Operation	17.4	26.5	33.6	35.4	42.5	43.2	43.2	43.2	43.2	28.7	358.9
Shipping	2.9	4.4	5.9	7.5	9.2	10.8	11.0	11.0	11.0	6.9	80.6
Total	$156.3	$216.4	$273.6	$330.6	$390.8	$442.8	$440.3	$433.2	$427.4	$269.4	$3,380.8
Booster Vehicle Cost per Launch	$ 9.8	$ 9.0	$ 8.6	$ 8.1	$ 7.8	$ 7.5	$ 7.3	$ 7.2	$ 7.1	$ 7.1	$ 7.7

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION III - BASIC WITH TVC
LAUNCH RATE OF 40

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	24	32	40	40	40	40	40	40	40	351
SRM per Year	30	48	64	80	80	80	80	80	80	80	702
COST											
SRM	$ 95.4	$143.4	$182.9	$221.0	$215.4	$211.4	$208.2	$205.6	$203.5	$201.6	$1,888.4
Stage	30.5	42.6	51.6	60.1	57.1	54.9	53.2	51.8	50.7	49.8	502.3
Operation	18.3	26.6	33.6	34.5	34.5	34.5	34.5	34.5	34.5	31.5	317.0
Shipping	2.7	4.4	5.9	7.4	7.3	7.3	7.3	7.3	7.3	7.3	64.2
Total	$146.9	$217.0	$274.0	$323.0	$314.3	$308.1	$303.2	$299.2	$296.0	$290.2	$2,771.9
Booster Vehicle Cost per Launch	$ 9.8	$ 9.0	$ 8.6	$ 8.1	$ 7.9	$ 7.7	$ 7.6	$ 7.5	$ 7.4	$ 7.3	$ 7.9

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL
RECURRING PRODUCTION COST PER LAUNCH
(Cost in Millions)

OPTION III - BASIC WITH TVC

LAUNCH RATE OF 20

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	20	20	20	20	20	20	20	20	20	195
SRM per Year	30	40	40	40	40	40	40	40	40	40	390
COST											
SRM	$ 95.4	$120.0	$115.7	$113.0	$110.9	$109.4	$108.0	$106.9	$105.9	$105.1	$1,090.3
Stage	30.5	35.8	33.1	31.5	30.4	29.4	28.7	28.1	27.6	27.1	302.2
Operation	18.3	22.2	22.1	22.1	22.1	22.1	22.1	22.1	22.1	22.1	217.3
Shipping	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	36.0
Total	$146.9	$181.7	$174.6	$170.3	$167.1	$164.6	$162.5	$160.8	$159.3	$158.0	$1,645.8
Booster Vehicle Cost per Launch	$ 9.8	$ 9.1	$ 8.7	$ 8.5	$ 8.4	$ 8.3	$ 8.2	$ 8.1	$ 8.0	$ 7.9	$ 8.4

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

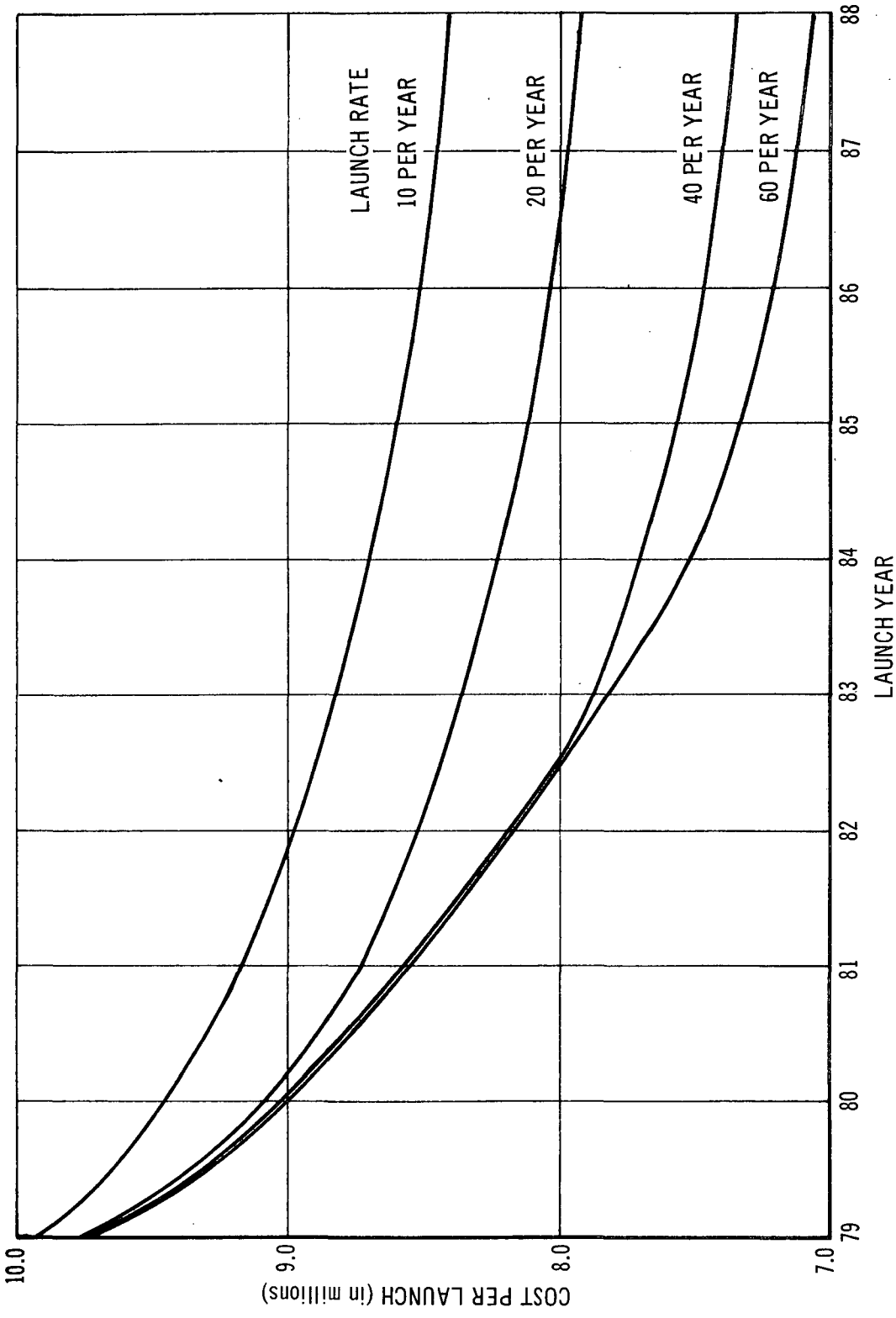
(Cost in Millions)

OPTION III - BASIC WITH TVC

LAUNCH RATE OF 10

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	10	10	10	10	10	10	10	10	10	10	100
SRM per Year	20	20	20	20	20	20	20	20	20	20	200
COST											
SRM	$64.4	$61.6	$59.9	$58.7	$57.8	$57.1	$56.5	$55.9	$55.5	$55.1	$582.5
Stage	20.9	18.9	17.8	17.1	16.6	16.1	15.8	15.4	15.2	14.9	168.7
Operation	12.2	12.2	12.2	12.2	12.2	12.2	12.1	12.1	12.1	12.1	121.6
Shipping	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	18.0
Total	$99.3	$94.5	$91.7	$89.8	$88.4	$87.2	$86.2	$85.2	$84.6	$83.9	$890.8
Booster Vehicle Cost per Launch	$ 9.9	$ 9.5	$ 9.2	$ 9.0	$ 8.8	$ 8.7	$ 8.6	$ 8.5	$ 8.5	$ 8.4	$ 8.9

6.2.3.2 Comparison Curves



Option III - Basic with TVC

6.2.3.3 Costing Rationale/Detail

OPTION III - BASIC WITH TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}$
1979	32	CTF_{47}	37.9745	-	CTF_{15}	13.0921	=	24.8824	$ 101.564
1980	48	CTF_{95}	73.0250	-	CTF_{47}	37.9745	=	35.0505	143.068
1981	64	CTF_{159}	117.7696	-	CTF_{95}	73.0250	=	44.7446	182.638
1982	82	CTF_{241}	173.1938	-	CTF_{159}	117.7696	=	55.4242	226.230
1983	100	CTF_{341}	238.9272	-	CTF_{241}	173.1938	=	65.7334	268.310
1984	118	CTF_{459}	314.6826	-	CTF_{341}	238.9272	=	75.7554	309.217
1985	120	CTF_{579}	390.2446	-	CTF_{459}	314.6826	=	75.5620	308.428
1986	120	CTF_{699}	464.6489	-	CTF_{579}	390.2446	=	74.4043	303.702
1987	120	CTF_{819}	538.1099	-	CTF_{699}	464.6489	=	73.4610	299.852
1988	76	CTF_{895}	584.2166		CTF_{819}	538.1099	=	46.1067	188.198
Total	880							571.1245	$2,331.207

T_1 = $4,081,785

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	16	CTF_{22}	15.8624	-	CTF_{6}	5.1008	=	10.7616	$ 32.419
1980	24	CTF_{46}	29.9246	-	CTF_{22}	15.8624	=	14.0622	42.363
1981	32	CTF_{78}	47.0255	-	CTF_{46}	29.9246	=	17.1009	51.517
1982	41	CTF_{119}	67.4425	-	CTF_{78}	47.0255	=	20.4170	61.506
1983	50	CTF_{169}	90.9413	-	CTF_{119}	67.4425	=	23.4988	70.790
1984	59	CTF_{228}	117.3471	-	CTF_{169}	90.9413	=	26.4058	79.547
1985	60	CTF_{288}	143.1472	-	CTF_{228}	117.3471	=	25.8001	77.723
1986	60	CTF_{348}	168.1382	-	CTF_{288}	143.1472	=	24.9910	75.285
1987	60	CTF_{408}	192.4802	-	CTF_{348}	168.1382	=	24.3420	73.330
1988	38	CTF_{446}	207.6123	-	CTF_{408}	192.4802	=	15.1321	45.585
Total	440							202.5115	$610.065

T_1 = $3,012,496

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	95%		-	95%		=	CTF	Cost $\$\overline{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 95.420
1980	48	CTF_{93}	71.5966	-	CTF_{45}	36.4692	=	35.1274	143.382
1981	64	CTF_{157}	116.3948	-	CTF_{93}	71.5966	=	44.7982	182.857
1982	80	CTF_{237}	170.5270	-	CTF_{157}	116.3948	=	54.1322	220.956
1983	80	CTF_{317}	223.2995	-	CTF_{237}	170.5270	=	52.7725	215.406
1984	80	CTF_{397}	275.0862	-	CTF_{317}	223.2995	=	51.7867	211.382
1985	80	CTF_{477}	326.1019	-	CTF_{397}	275.0862	=	51.0157	208.235
1986	80	CTF_{557}	376.4860	-	CTF_{477}	326.1019	=	50.3841	205.657
1987	80	CTF_{637}	426.3360	-	CTF_{557}	376.4860	=	49.8500	203.477
1988	80	CTF_{717}	475.7240	-	CTF_{637}	426.3360	=	49.3880	201.591
Total	702							462.6319	$1,888,363

T_1 = $4,081,785

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	90%		-	90%		=	CTF	Cost $\$\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 30.536
1980	24	CTF_{45}	29.3658	-	CTF_{21}	15.2373	=	14.1285	42.562
1981	32	CTF_{77}	46.5098	-	CTF_{45}	29.3658	=	17.1440	51.646
1982	40	CTF_{117}	66.4746	-	CTF_{77}	46.5098	=	19.9648	60.144
1983	40	CTF_{157}	85.4111	-	CTF_{117}	66.4746	=	18.9365	57.046
1984	40	CTF_{197}	103.6223	-	CTF_{157}	85.4111	=	18.2112	54.861
1985	40	CTF_{237}	121.2772	-	CTF_{197}	103.6223	=	17.6549	53.185
1986	40	CTF_{277}	138.4836	-	CTF_{237}	121.2772	=	17.2064	51.834
1987	40	CTF_{317}	155.3158	-	CTF_{277}	138.4836	=	16.8322	50.707
1988	40	CTF_{357}	171.8278	-	CTF_{317}	155.3158	=	16.5120	49.742
Total	351							166.7270	$502,263

T_1 = $3,012,496

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 95.420
1980	40	CTF_{85}	65.8598	-	CTF_{45}	36.4692	=	29.3906	119.966
1981	40	CTF_{125}	94.2095	-	CTF_{85}	65.8598	=	28.3497	115.717
1982	40	CTF_{165}	121.8863	-	CTF_{125}	94.2095	=	27.6768	112.971
1983	40	CTF_{205}	149.0674	-	CTF_{165}	121.8863	=	27.1811	110.947
1984	40	CTF_{245}	175.8574	-	CTF_{205}	149.0674	=	26.7900	109.351
1985	40	CTF_{285}	202.3247	-	CTF_{245}	175.8574	=	26.4673	108.034
1986	40	CTF_{325}	228.5181	-	CTF_{285}	202.3247	=	26.1934	106.916
1987	40	CTF_{365}	254.4738	-	CTF_{325}	228.5181	=	25.9557	105.946
1988	40	CTF_{405}	280.2197	-	CTF_{365}	254.4738	=	25.7459	105.089
Total	390							267.1276	$1,090.357

T_1 = $4,081,785

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 30.536
1980	20	CTF_{41}	27.1114	-	CTF_{21}	15.2373	=	11.8741	35.771
1981	20	CTF_{61}	38.1093	-	CTF_{41}	27.1114	=	10.9979	33.131
1982	20	CTF_{81}	48.5666	-	CTF_{61}	38.1093	=	10.4573	31.503
1983	20	CTF_{101}	58.6369	-	CTF_{81}	48.5666	=	10.0703	30.337
1984	20	CTF_{121}	68.4079	-	CTF_{101}	58.6369	=	9.7710	29.435
1985	20	CTF_{141}	77.9363	-	CTF_{121}	68.4079	=	9.5284	28.704
1986	20	CTF_{161}	87.2614	-	CTF_{141}	77.9363	=	9.3251	28.092
1987	20	CTF_{181}	96.4122	-	CTF_{161}	87.2614	=	9.1508	27.567
1988	20	CTF_{201}	105.4107	-	CTF_{181}	96.4122	=	8.9985	27.108
Total	195							100.3099	$302.184

T_1 = $3,012,496

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	95%		-	95%		=	CTF	Cost $\$\overline{M}$
1979	20	CTF_{35}	28.8636	-	CTF_{15}	13.0921	=	15.7715	$ 64.376
1980	20	CTF_{55}	43.9511	-	CTF_{35}	28.8636	=	15.0875	61.584
1981	20	CTF_{75}	58.6323	-	CTF_{55}	43.9511	=	14.6812	59.926
1982	20	CTF_{95}	73.0250	-	CTF_{75}	58.6323	=	14.3927	58.748
1983	20	CTF_{115}	87.1947	-	CTF_{95}	73.0250	=	14.1697	57.838
1984	20	CTF_{135}	101.1830	-	CTF_{115}	87.1947	=	13.9883	57.097
1985	20	CTF_{155}	115.0190	-	CTF_{135}	101.1830	=	13.8360	56.476
1986	20	CTF_{175}	128.7231	-	CTF_{155}	115.0190	=	13.7041	55.937
1987	20	CTF_{195}	142.3121	-	CTF_{175}	128.7231	=	13.5890	55.467
1988	20	CTF_{215}	155.7985	-	CTF_{195}	142.3121	=	13.4864	55.049
Total	200							142.7064	$582.498

T_1 = $4,081,785

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	90%		-	90%		=	CTF	Cost $\$\bar{M}$
1979	10	CTF_{16}	12.0398	-	CTF_{6}	5.1008	=	6.9390	$ 20.904
1980	10	CTF_{26}	18.3227	-	CTF_{16}	12.0398	=	6.2829	18.927
1981	10	CTF_{36}	24.2461	-	CTF_{26}	18.3227	=	5.9234	17.844
1982	10	CTF_{46}	29.9246	-	CTF_{36}	24.2461	=	5.6785	17.106
1983	10	CTF_{56}	35.4189	-	CTF_{46}	29.9246	=	5.4943	16.552
1984	10	CTF_{66}	40.7667	-	CTF_{56}	35.4189	=	5.3478	16.110
1985	10	CTF_{76}	45.9930	-	CRF_{66}	40.7667	=	5.2263	15.744
1986	10	CTF_{86}	51.1163	-	CTF_{76}	45.9930	=	5.1233	15.434
1987	10	CTF_{96}	56.1501	-	CTF_{86}	51.1163	=	5.0338	15.164
1988	10	CTF_{106}	61.1051	-	CTF_{96}	56.1501	=	4.9550	14.927
Total	100							56.0043	$168.712

T_1 = $3,012,496

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

RECURRING AND FIRST UNIT COST

		WBS	COST
SRM (WBS 3.3.2) Inc. 3 PPQ's			
Total SRM		3.3.2	$2,503,895M
Less:	Facilities	3.3.2.4	(25.700M)
	Operations Support	3.3.2.7	(84.238M)
	Support Equipment Spares	3.3.2.5	(51.242M)
	Flight Test Support	3.3.2.6	(1.433M)
	Recurring Incl 3 PPQ's		$2,341.282M
STAGE			
	Structures	3.3.1	$ 378.979M
	Avionics	3.3.3	181.216M
	Power	3.3.5	49.870M
	Recurring Stage		$ 610.065M
OPERATION			
	Support Equipment Spares	3.3.2.5	$ 51.242M
	Flight Test Support	3.3.2.6	1.433M
	Operations Support	3.3.2.7.1	3.536M
	Install, Assemble and Checkout	3.3.6	184.724M
	Major Ground Test	3.3.7	117.993M
	Recurring Operations		$ 358.928M
TRANSPORTATION		3.3.2.7.2	$ 80.702M
Total Recurring Incl 3 PPQ's			$3,390.977M
FACILITIES			25.700M
TOTAL PRODUCTION			$3,416.677M

6.2.3.3 (Continued)

OPTION III - BASIC WITH TVC

T_1 - SRM

I.	CTF_{895}, @ 95%	584.2166			
	CTF_{12}, @ 95%	(10.6239)			
	CTF_{883}, $T_{13} \rightarrow 895$	573.5927			
	T_1 = \$2,341.282M ÷ 573.5927 =			\$4,081,785	
II.	3 PPQ's				
	CTF_{15}, @ 95%	13.0921			
	CTF_{12}, @ 95%	(10.6239)			
	CTF_3, $T_{13} \rightarrow 15$	2.4682	x	\$4,081,785	= \$ 10.075M
III.	880 Production				
	CTF_{895}, @ 95%	584.2166			
	CTF_{15}, @ 95%	(13.0921)			
	CTF_{880}, $T_{16} \rightarrow 895$	571.1245	x	\$4,081,785	= \$2,331.207M
	TOTAL SRM PRODUCTION RECURRING INCL 3 PPQ's				\$2,341.282M

T_1 STAGE

CTF_{446}, @ 90%	207.6123			
CTF_6, @ 90%	(5.1008)			
CTF_{440}, $T_7 \rightarrow 446$	202.5115			
T_1 = \$610.065 ÷ 202.5115 =			\$3,012,496	

6.2.4 Option IV - Basic with Thrust Termination

6.2.4.1 Launch Rate Cost Summaries (Rates of 60, 40, 20 and 10)

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

(Cost in Millions)

OPTION IV - BASIC WITH THRUST TERMINATION

LAUNCH RATE OF 60

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	16	24	32	41	50	59	60	60	60	38	440
SRM per Year	32	48	64	82	100	118	120	120	120	76	880
COST											
SRM	$ 90.8	$127.9	$163.3	$202.3	$239.9	$276.4	$275.8	$271.5	$268.1	$168.2	$2,084.2
Stage	31.4	41.1	50.0	59.6	68.6	77.1	75.4	73.0	71.1	44.2	591.5
Operation	18.5	25.2	31.9	33.6	40.3	40.9	40.9	40.9	40.9	27.3	340.4
Shipping	2.9	4.4	5.9	7.5	9.2	10.8	11.0	11.0	11.0	6.9	80.6
Total	$143.6	$198.6	$251.1	$303.0	$358.0	$405.2	$403.1	$396.4	$391.1	$246.6	$3,096.7
Booster Vehicle Cost per Launch	$ 9.0	$ 8.3	$ 7.8	$ 7.4	$ 7.2	$ 6.9	$ 6.7	$ 6.6	$ 6.5	$ 6.5	$ 7.0

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

(Cost in Millions)

OPTION IV - BASIC WITH THRUST TERMINATION

LAUNCH RATE OF 40

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	24	32	40	40	40	40	40	40	40	351
SRM per Year	30	48	64	80	80	80	80	80	80	80	702
COST											
SRM	$ 85.3	$128.2	$163.5	$197.5	$192.6	$189.0	$186.2	$183.9	$181.9	$180.2	$1,688.3
Stage	29.6	41.3	50.1	58.3	55.3	53.2	51.6	50.2	49.2	48.2	487.0
Operation	17.3	25.2	31.9	32.8	32.8	32.8	32.7	32.7	32.7	29.8	300.7
Shipping	2.7	4.4	5.9	7.4	7.3	7.3	7.3	7.3	7.3	7.3	64.2
Total	$134.9	$199.1	$251.4	$296.0	$288.0	$282.3	$277.8	$274.1	$271.1	$265.5	$2,540.2
Booster Vehicle Cost per Launch	$ 9.0	$ 8.3	$ 7.9	$ 7.4	$ 7.2	$ 7.1	$ 7.0	$ 6.9	$ 6.8	$ 6.6	$ 7.2

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

(Cost in Millions)

OPTION IV - BASIC WITH THRUST TERMINATION

LAUNCH RATE OF 20

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	15	20	20	20	20	20	20	20	20	20	195
SRM per Year	30	40	40	40	40	40	40	40	40	40	390
COST											
SRM	$ 85.3	$107.3	$103.4	$101.0	$ 99.2	$ 97.8	$ 96.6	$ 95.6	$ 94.7	$ 93.9	$ 974.8
Stage	29.6	34.7	32.1	30.6	29.4	28.5	27.8	27.3	26.7	26.3	293.0
Operation	17.3	21.0	21.0	21.0	21.0	21.0	21.0	21.0	20.9	20.9	206.1
Shipping	2.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	36.0
Total	$134.9	$166.7	$160.2	$156.3	$153.3	$151.0	$149.1	$147.6	$146.0	$144.8	$1,509.9
Booster Vehicle Cost per Launch	$ 9.0	$ 8.3	$ 8.0	$ 7.8	$ 7.7	$ 7.6	$ 7.5	$ 7.4	$ 7.3	$ 7.2	$ 7.7

LOCKHEED PROPULSION COMPANY

BOOSTER VEHICLE - 156-7 PARALLEL

RECURRING PRODUCTION COST PER LAUNCH

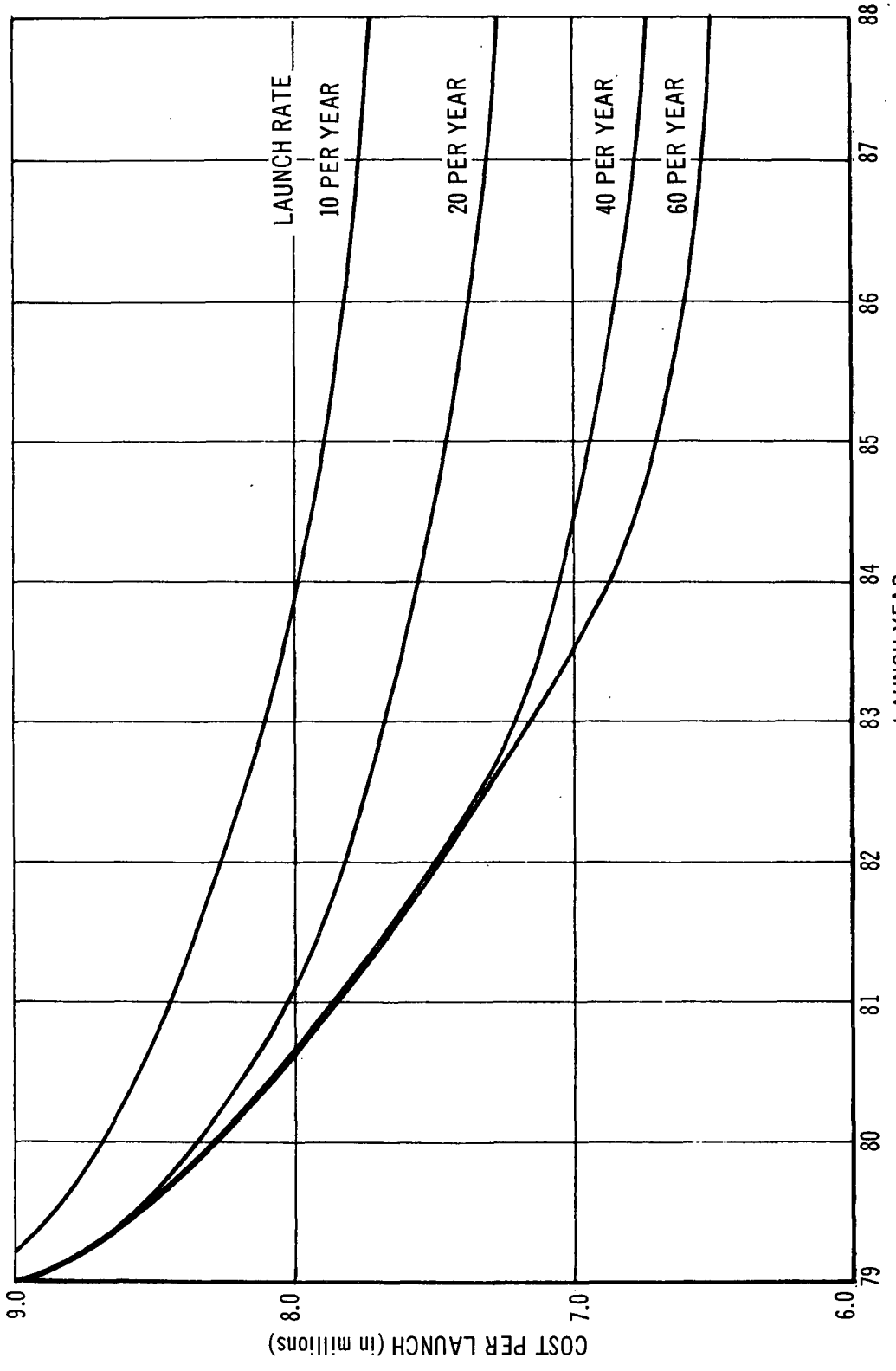
(Cost in Millions)

OPTION IV - BASIC WITH THRUST TERMINATION

LAUNCH RATE OF 10

Calendar Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Launch per Year	10	10	10	10	10	10	10	10	10	10	100
SRM per Year	20	20	20	20	20	20	20	20	20	20	200
COST											
SRM	$57.6	$55.1	$53.6	$52.5	$51.7	$51.0	$50.5	$50.0	$49.6	$49.2	$520.8
Stage	20.3	18.3	17.3	16.6	16.0	15.6	15.3	15.0	14.7	14.5	163.6
Operation	11.6	11.6	11.6	11.5	11.5	11.5	11.5	11.5	11.5	11.5	115.3
Shipping	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	18.0
Total	$91.3	$86.8	$84.3	$82.4	$81.0	$79.9	$79.1	$78.3	$77.6	$77.0	$817.7
Booster Vehicle Cost per Launch	$ 9.1	$ 8.7	$ 8.4	$ 8.2	$ 8.1	$ 8.0	$ 7.9	$ 7.8	$ 7.8	$ 7.7	$ 8.2

6.2.4.2 Comparison Curves



Option IV - Basic with Thrust Termination

6.2.4.3 Costing Rationale/Detail

OPTION IV - BASIC WITH THRUST TERM

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	95%		-	95%		=	CTF	Cost $\bar{M}$
1979	32	CTF_{47}	37.9745	-	CTF_{15}	13.0921	=	24.8824	$ 90.804
1980	48	CTF_{95}	73.0250	-	CTF_{47}	37.9745	=	35.0505	127.911
1981	64	CTF_{159}	117.7696	-	CTF_{95}	73.0250	=	44.7446	163.287
1982	82	CTF_{241}	173.1938	-	CTF_{159}	117.7696	=	55.4242	202.261
1983	100	CTF_{341}	238.9272	-	CTF_{241}	173.1938	=	65.7334	239.882
1984	118	CTF_{459}	314.6826	-	CTF_{341}	238.9272	=	75.7554	276.456
1985	120	CTF_{579}	390.2446	-	CTF_{459}	314.6826	=	75.5620	275.750
1986	120	CTF_{699}	464.6489	-	CTF_{579}	390.2446	=	74.4043	271.525
1987	120	CTF_{819}	538.1099	-	CTF_{699}	464.6489	=	73.4610	268.083
1988	76	CTF_{895}	584.2166	-	CTF_{819}	538.1099	=	46.1067	168.258
Total	880							571.1245	$2,084.217

T_1 = $3,649,321

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 60

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	16	CTF_{22}	15.8624	-	CTF_{6}	5.1008	=	10.7616	$ 31.433
1980	24	CTF_{46}	29.9246	-	CTF_{22}	15.8624	=	14.0622	41.073
1981	32	CTF_{78}	47.0255	-	CTF_{46}	29.9246	=	17.1009	49.948
1982	41	CTF_{119}	67.4425	-	CTF_{78}	47.0255	=	20.4170	59.634
1983	50	CTF_{169}	90.9413	-	CTF_{119}	67.4425	=	23.4988	68.635
1984	59	CTF_{228}	117.3471	-	CTF_{169}	90.9413	=	26.4058	77.126
1985	60	CTF_{288}	143.1472	-	CTF_{228}	117.3471	=	25.8001	75.357
1986	60	CTF_{348}	168.1382	-	CTF_{288}	143.1472	=	24.9910	72.994
1987	60	CTF_{408}	192.4802	-	CTF_{348}	168.1382	=	24.3420	71.098
1988	38	CTF_{446}	207.6123	-	CTF_{408}	192.4802	=	15.1321	44.198
Total	440							202.5115	$591.496

T_1 = $2,920,802

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23.3771	$ 85.311
1980	48	CTF_{93}	71.5966	-	CTF_{45}	36.4692	=	35.1274	128.191
1981	64	CTF_{157}	116.3948	-	CTF_{93}	71.5966	=	44.7982	163.483
1982	80	CTF_{237}	170.5270	-	CTF_{157}	116.3948	=	54.1322	197.546
1983	80	CTF_{317}	223.2995	-	CTF_{237}	170.5270	=	52.7725	192.584
1984	80	CTF_{397}	275.0862	-	CTF_{317}	223.2995	=	51.7867	188.986
1985	80	CTF_{477}	326.1019	-	CTF_{397}	275.0862	=	51.0157	186.173
1986	80	CTF_{557}	376.4860	-	CTF_{477}	326.1019	=	50.3841	183.868
1987	80	CTF_{637}	426.3360	-	CTF_{557}	376.4860	=	49.8500	181.919
1988	80	CTF_{717}	475.7240	-	CTF_{637}	426.3360	=	49.3880	180.233
Total	702							462.6319	$1,688.294

T_1 = $3,649,321

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 40

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 29.607
1980	24	CTF_{45}	29.3658	-	CTF_{21}	15.2373	=	14.1285	41.267
1981	32	CTF_{77}	46.5098	-	CTF_{45}	29.3658	=	17.1440	50.074
1982	40	CTF_{117}	66.4746	-	CTF_{77}	46.5098	=	19.9648	58.313
1983	40	CTF_{157}	85.4111	-	CTF_{117}	66.4746	=	18.9365	55.310
1984	40	CTF_{197}	103.6223	-	CTF_{157}	85.4111	=	18.2112	53.191
1985	40	CTF_{237}	121.2772	-	CTF_{197}	103.6223	=	17.6549	51.566
1986	40	CTF_{277}	138.4836	-	CTF_{237}	121.2772	=	17.2064	50.256
1987	40	CTF_{317}	155.3158	-	CTF_{277}	138.4836	=	16.8322	49.164
1988	40	CTF_{357}	171.8278	-	CTF_{317}	155.3158	=	16.5120	48.228
Total	351							166.7270	$486.976

T_1 = $2,920,802

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	30	CTF_{45}	36.4692	-	CTF_{15}	13.0921	=	23,3771	$ 85.311
1980	40	CTF_{85}	65.8598	-	CTF_{45}	36.4692	=	29.3906	107.256
1981	40	CTF_{125}	94.2095	-	CTF_{85}	65.8598	=	28.3497	103.457
1982	40	CTF_{165}	121.8863	-	CTF_{125}	94.2095	=	27.6768	101.002
1983	40	CTF_{205}	149.0674	-	CTF_{165}	121.8863	=	27.1811	99.193
1984	40	CTF_{245}	175.8574	-	CTF_{205}	149.0674	=	26.7900	97.765
1985	40	CTF_{285}	202.3247	-	CTF_{245}	175.8574	=	26.4673	96.588
1986	40	CTF_{325}	228.5181	-	CTF_{285}	202.3247	=	26.1934	95.588
1987	40	CTF_{365}	254.4738	-	CTF_{325}	228.5181	=	25.9557	94.721
1988	40	CTF_{405}	280.2197	-	CTF_{365}	254.4738	=	25.7459	93.955
Total	390							267.1276	$974.836

$T_1 = \$3,649,321$

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 20

Year	Qty	90%		-	90%		=	CTF	Cost $\bar{M}$
1979	15	CTF_{21}	15.2373	-	CTF_{6}	5.1008	=	10.1365	$ 29.607
1980	20	CTF_{41}	27.1114	-	CTF_{21}	15.2373	=	11.8741	34.682
1981	20	CTF_{61}	38.1093	-	CTF_{41}	27.1114	=	10.9979	32.123
1982	20	CTF_{81}	48.5666	-	CTF_{61}	38.1093	=	10.4573	30.544
1983	20	CTF_{101}	58.6369	-	CTF_{81}	48.5666	=	10.0703	29.413
1984	20	CTF_{121}	68.4079	-	CTF_{101}	58.6369	=	9.7710	28.539
1985	20	CTF_{141}	77.9363	-	CTF_{121}	68.4079	=	9.5284	27.831
1986	20	CTF_{161}	87.2614	-	CTF_{141}	77.9363	=	9.3251	27.237
1987	20	CTF_{181}	96.4122	-	CTF_{161}	87.2614	=	9.1508	26.728
1988	20	CTF_{201}	105.4107	-	CTF_{181}	96.4122	=	8.9985	26.283
Total	195							100.3099	$292.987

T_1 = $2,920,802

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

SRM PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	95%		-	95%		=	CTF	Cost $\$\bar{M}$
1979	20	CTF_{35}	28.8636	-	CTF_{15}	13.0921	=	15.7715	$ 57.555
1980	20	CTF_{55}	43.9511	-	CTF_{35}	28.8636	=	15.0875	55.059
1981	20	CTF_{75}	58.6323	-	CTF_{55}	43.9511	=	14.6812	53.576
1982	20	CTF_{95}	73.0250	-	CTF_{75}	58.6323	=	14.3927	52.524
1983	20	CTF_{115}	87.1947	-	CTF_{95}	73.0250	=	14.1697	51.710
1984	20	CTF_{135}	101.1830	-	CTF_{115}	87.1947	=	13.9883	51.048
1985	20	CTF_{155}	115.0190	-	CTF_{135}	101.1830	=	13.8360	50.492
1986	20	CTF_{175}	128.7231	-	CTF_{155}	115.0190	=	13.7041	50.011
1987	20	CTF_{195}	142.3121	-	CTF_{175}	128.7231	=	13.5890	49.591
1988	20	CTF_{215}	155.7985	-	CTF_{195}	142.3121	=	13.4864	49.216
Total	200							142.7064	$520.782

T_1 = $3,649,321

6.2.4.3 (Continued)

OPTION IV - BASIC WITH THRUST TERM

STAGE PRODUCTION RECURRING

CUM TOTAL FACTORS

(156-7 Para)

LAUNCH RATE OF 10

Year	Qty	90%		-	90%		=	CTF	Cost $\$\bar{M}$
1979	10	CTF_{16}	12.0398	-	CTF_{6}	5.1008	=	6.9390	$ 20.267
1980	10	CTF_{26}	18.3227	-	CTF_{16}	12.0398	=	6.2829	18.351
1981	10	CTF_{36}	24.2461	-	CTF_{26}	18.3227	=	5.9234	17.301
1982	10	CTF_{46}	29.9246	-	CTF_{36}	24.2461	=	5.6785	16.586
1983	10	CTF_{56}	35.4189	-	CTF_{46}	29.9246	=	5.4943	16.048
1984	10	CTF_{66}	40.7667	-	CTF_{56}	35.4189	=	5.3478	15.620
1985	10	CTF_{76}	45.9930	-	CRF_{66}	40.7667	=	5.2263	15.265
1986	10	CTF_{86}	51.1163	-	CTF_{76}	45.9930	=	5.1233	14.964
1987	10	CTF_{96}	56.1501	-	CTF_{86}	51.1163	=	5.0338	14.703
1988	10	CTF_{106}	61.1051	-	CTF_{96}	56.1501	=	4.9550	14.473
Total	100							56.0043	$163.578

T_1 = $2,920,802

6.2.4.3 (Continued)

OPTION IV - BASIC WITH T. T.

RECURRING AND FIRST UNIT COST

	WBS	COST
SRM (WBS 3.3.2) Incl 3 PPQ's		
Total SRM	3.3.2	$2,255.837M
Less: Facilities	3.3.2.4	(25.700M)
Support Equipment Spares	3.3.2.5	(51.242M)
Flight Test Support	3.3.2.6	(1.433M)
Operation Support	3.3.2.7	(84.238M)
Recurring Incl 3 PPQ's		$2,093.224M
STAGE		
Structures	3.3.1	$ 384.516M
Avionics	3.3.3	161.181M
Power	3.3.5	45.799M
Recurring Stage		$ 591.496M
OPERATION		
Support Equipment Spares	3.3.2.5	$ 51.242M
Flight Test Support	3.3.2.6	1.433M
Operation Support	3.3.2.7.1	3.536M
Install, Assemble and Checkout	3.3.6	173.414M
Major Ground Test	3.3.7	110.769M
Recurring Operations		$ 340.394M
TRANSPORTATION	3.3.2.7.2	$ 80.702M
Total Recurring Incl 3 PPQ's		$3,105.816M
FACILITIES	3.3.2.4	25.700M
TOTAL PRODUCTION		$3,131.516M

6.2.4.3 (Continued)

OPTION IV - BASIC WITH T. T.

T_1 - SRM

I.	CTF_{895}, @ 95%	584.2166			
	CTF_{12}, @ 95%	(10.6239)			
	CTF_{883}, $T_{13} \rightarrow 895$	573.5927			
	T_1 = \$2,093.224M ÷ 573.5927 =				\$3,649,321
II.	3 PPQ's				
	CTF_{15}, @ 95%	13.0921			
	CTF_{12}, @ 95%	(10.6239)			
	CTF_3, $T_{13} \rightarrow 15$	2.4682	x	\$3,649,321 =	\$ 9.007M
III.	880 Production				
	CTF_{895}, @ 95%	584.2166			
	CTF_{15}, @ 95%	(13.0921)			
	CTF_{880}, $T_{16} \rightarrow 895$	571.1245	x	\$3,649,321 =	\$2,084.217M
	TOTAL SRM PRODUCTION RECURRING INCL 3 PPQ's				\$2,093.224M

T_1 STAGE

	CTF_{446}, @ 90%	207.6123			
	CTF_6, @ 90%	(5.1008)			
	CTF_{440}, $T_7 \rightarrow 446$	202.5115			
	T_1 = \$591.496 ÷ 202.5115 =				\$2,920,802

Section 7

PROGRAM COST ESTIMATING RELATIONSHIPS (CERS), TABLE 3

Table 3 is presented in three subsections: 7.1 Total Program costs as a function of gross weight, 7.2 Production/Operations cost as a function of production rate, and 7.3 DDT&E costs as a function of full-scale firings (GTH) and Flight-Test Motors (FTMs).

(7.1) Total Program costs = f (Booster Vehicle gross weight)

The costs presented are the cost-per-pound of total gross weight for DDT&E, and production quantities for 10, 20, 40, and 60 launches per year. These costs are for the total Booster Vehicle (WBS 3.3).

(7.2) Production/Operations cost = f (Production Rate)

These costs represent the total Booster Vehicle (WBS 3.3) recurring costs with 3 PPQs for launch rates of 10, 20, 40, and 60 launches per year.

(7.3) DDT&E Costs = f (GTH and FTH)

These costs represent the total Booster Vehicle (WBS 3.3) less Facilities and those costs that are part of Operations (WBS 3.3.2.5, 3.3.2.6, 3.3.2.7, 3.3.6, and 3.3.7).

7.1 SRM 156-7 TOTAL PROGRAM COST = F (Booster Vehicle Gross Weight)

	Cost Per Pound					
SRMs w/Stage	9	12	203*	393*	705*	883*
Maximum Launch Rate			10/yr	20/yr	40/yr	60/yr
OPTION I (w/TVC & TT)						
DDT&E	$7.66	$3.60				
Production			$2.66	$2.55	$2.44	$2.40
Operations		1.64	.49	.46	.39	.36
OPTION II (w/o TVC & TT)						
DDT&E	7.02	3.23				
Production			2.38	2.27	2.18	2.14
Operations		1.56	.46	.44	.37	.34
OPTION III (w/TVC)						
DDT&E	7.63	3.57				
Production			2.63	2.52	2.41	2.37
Operations		1.63	.49	.46	.38	.35
OPTION IV (w/TT)						
DDT&E	7.10	3.27				
Production			2.41	2.30	2.21	2.17
Operations		1.58	.47	.44	.37	.34

* Includes 3 Production Facilities Start-up Motors

7.2 PRODUCTION/OPERATIONS COSTS = F (Production Rate)

(Cost in Millions)

SRMs w/Stage*	203	393	705	883
Maxmium Launch Rate	10/yr	20/yr	40/yr	60/yr
OPTION I (w/TVC & TT)				
Production	$3.766	$3.606	$3.451	$3.389
Operations	.697	.654	.549	.505
OPTION II (w/o TVC & TT)				
Production	3.306	3.164	3.026	2.972
Operations	.646	.607	.510	.470
OPTION III (w/TVC)				
Production	3.700	3.543	3.391	3.331
Operations	.688	.645	.541	.498
OPTION IV (w/TT)				
Production	3.371	3.226	3.086	3.030
Operations	.657	.616	.518	.477

* Includes 3 Production Facilities Start-up Motors

7.3 DDT&E COST = F (Number of GTH or Full-Scale Firings and FTH)

(Cost in Millions)

	Development			PFRT			TOTAL		
GTH	Qty	Unit Cost	Total	Qty	Unit Cost	Total	Qty	Unit Cost	Total
OPTION I (w/TVC&TT)	5	$19.611	$98.055	4	$14.562	$58.248	9	$17.367	$156.303
Option II (w/o TVC & TT)	5	17.404	87.018	4	13.168	52.672	9	15.521	139.690
OPTION III (w/TVC)	5	19.169	95.846	4	14.460	57.840	9	17.076	153.686
OPTION IV (w/TT)	5	17.782	88.911	4	13.349	53.396	9	15.812	142.307
156-6 SERIES (w/TVC & TT)	5	22.560	112.801	4	17.510	70.040	9	20.316	182.841
FTH									
OPTION I (w/TVC & TT)							12	13.025	156.303
OPTION II (w/o TVC & TT)							12	11.641	139.690
OPTION III (w/TVC)							12	12.807	153.686
OPTION IV (w/TT)							12	11.859	142.307
156-6 SERIES (w/TVC & TT)							18	10.158	182.841

Appendix A

MISCELLANEOUS COST BACK-UP DATA

A.1 INTRODUCTION

The following cost data are supplied to clarify possible questions that might arise while reading the text of this book.

Section A.2 contains contract evaluation reports in LPC's behalf regarding previous LPC 156-inch LSM contracts and testing conducted at LPC's Potrero Proving Ground, California.

Section A.3 is concerned with the information disclosed in the NASA/Headquarters briefing on 23 February 1972.

The cost bands, discussed in Section 1, Introduction, are shown on three financial charts contained in this Appendix; Cost versus Total Impulse, and the final two charts in this Appendix showing cost effect of total booster vehicle weight. Our potential reductions fall within these bands and are in line with our program projections as discussed in the 23 Feb 72 NASA/Headquarters presentation.

A.2 CONTRACT EVALUATION REPORTS

EVALUATION

Lockheed Propulsion Company's performance on Contract AF 04(695)-364 is noted below. This contract effort involved the design fabrication and test firing of two (2) segmented 156-inch diameter solid propellant rocket motors with jet tab thrust vector control. Period of performance - 1964.

Department of Defense Terminal Contractor
Performance Evaluation Report

(1) Strong Points. Corporate program management during the period of performance was good, with close working relationship between the program manager, technical director, manufacturing, and test personnel. The organization employed was very effective in keeping management on top of the technical difficulties as they were encountered. Excellent working relationship existed between the contractor, subcontractors, and the Air Force Systems Program Office. The contractor has been very prompt in submitting reports on or before due dates. The quality and content of reports have been excellent. The contractor used sound engineering approaches that resulted in cost savings to the program.

(2) Weak Points. No significant weak points were encountered during the performance of this contract.

EVALUATION

Lockheed Propulsion Company's performance on Contract AF 04(695)-772 is noted below. This contract effort involved the design, fabrication and test firing of two (2) flightweight 156-inch solid propellant rocket motors with liquid injection thrust vector control. Period of performance 1965-1966.

Department of Defense Terminal Contractor Performance Evaluation Report

(1) The results obtained by the Lockheed Propulsion Company in satisfying the technical and schedule requirements of this contract are considered excellent in all respects. Two 156-inch diameter motors of advanced configuration were designed, fabricated, and successfully tested well within the time period specified.

As a direct result of the contractor's efforts, several highly significant advancements in the large solid motor state-of-the-art were achieved. For example, large submerged nozzles were tested for the first time, thus permitting a significant reduction in overall motor length. A nozzle-mounted omniaxial thrust vector control system was developed and tested at a motor thrust level twice that of any previous system. The high burn rate propellant (0.8 in./sec) developed is a particularly significant advancement in that the increased burn rate was achieved with no degradation in performance or increase in unit cost. Significant cost reductions are possible with the mastic insulation demonstrated.

This was the first firm fixed price contract awarded under Program 623A for the demonstration test of a large solid propellant motor. Since the contract was tightly negotiated, cost performance became heavily incentivized and firm financial control was exercised by Lockheed management.

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CONTRACTOR PERFORMANCE EVALUATION REPORT	1. CONTRACTOR, NAME AND LOCATION UNCLASSIFIED LOCKHEED PROPULSION COMPANY	REPORT CONTROL SYMBOL DD-I&L(SA)[X]: 966
SUMMARY DATA	REDLANDS, CALIFORNIA	2. DATE (From - To) 1 APR '65 - 31 MAR '66

3. CONTRACTOR'S PROJECT OFFICER
FRANK V. GENETTI
LARGE SOLID MOTOR PROGRAM MANAGER

4. [X] ENGINEERING DEV. [ ] OPERATIONAL SYSTEMS DEV. [ ] OTHER

5. COMMAND, AGENCY, OFFICE AND LOCATION
AFSC-SSD-SSBS
LOS ANGELES AFS, AFUPO, LOS ANGELES, CALIF.

6. [ ] PERIODIC [X] TERMINAL

7. CONTRACT NUMBER
AF 04(695)-772

8. ORIGINAL CONTRACT DATE(S) a. AWARD	b. EFFECTIVE	9. ORIGINALLY SCHEDULED COMPLETION DATE	10. CURRENTLY SCHEDULED COMPLETION DATE	11. ACTUAL COMPLETION DATE	12. TYPE OF CONTRACT
6 JULY 1965	1 APRIL 1965	31 MARCH 1966	31 MARCH 1966	15 FEBRUARY 1966	[ ] CPFF

13. ORIGINAL CONTRACT PRICE ($ Millions)	14. CURRENT CONTRACT PRICE ($ Millions)	15. ACTUAL COST ($ Millions)	[ ] CPIF [ ] FPI [X] FP
5.500	5.510	5.510	[ ] OTHER

16. PROJECT NAME	17. RDT & E PROJECT NUMBER	18. MAJOR END ITEM
LARGE SOLID PROPELLANT MOTOR PROGRAM	623A	LARGE SOLID MOTOR DEMONSTRATION TEST

19. BRIEF DESCRIPTION (What it is, its purpose, technology involved):

a. BRIEF STATEMENT OF CHARACTERISTICS OF MAJOR END ITEM. This effort is a continuation of prior FY programs involving development and demonstration test of 156-inch diameter solid propellant rocket motors and related advanced technology. This contract required the design, fabrication, and static test firing of one (1) segmented 156-inch motor and one (1) monolithic 156-inch motor. Both motors were flight configured and incorporated a nozzle mounted liquid injection thrust vector control system, a deep submerged nozzle, high burn rate propellant, and reused case components.

b. STATE-OF-THE-ART ADVANCES REQUIRED OR NOT; COMPARATIVE DIFFICULTY; TECHNOLOGY THAT MUST BE DEVELOPED.

Advancements in the state-of-the-art were required and successfully accomplished in the following areas:

1) Large deep submerged nozzles
2) High burn rate propellant
3) Nozzle mounted liquid injection thrust vector control systems
4) Mastic insulation

This effort is judged highly difficult because the contractor had to accomplish two 156-inch motor firings requiring state-of-the-art advancements in a relatively short time under a fixed price contract.

c. DEPENDENCE UPON GOVERNMENT FURNISHED EQUIPMENT, DATA OR OTHER SUPPORT.

Availability of motor case components from earlier 156-inch motor firings permitted reuse of these items as GFP. Case components for the segmented motor were reused without modification. Components for the monolithic case required extensive modification. In addition, certain items of an industrial facilities nature were provided, the largest of which was a two-hundred (200) ton crane excess to the requirements of a related program. No funding was required for these items of a facility nature since they were GFP excess to other program requirements.

DOWNGRADED AT 3 YEAR INTERVALS.
DECLASSIFIED AFTER 12 YEARS.
DOD DIR 5200.10

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(If additional space is required, continue on reverse side.)

20. EVALUATOR NAME (Typed)	SIGNATURE	TITLE	DATE
HAROLD W. ROBBINS COLONEL, USAF	Harold W. Robbins	DIRECTOR, PROGRAM 623A	1 JULY 1966

DD FORM 1 AUG 64 1446 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. AFSC (AAFB) 1965

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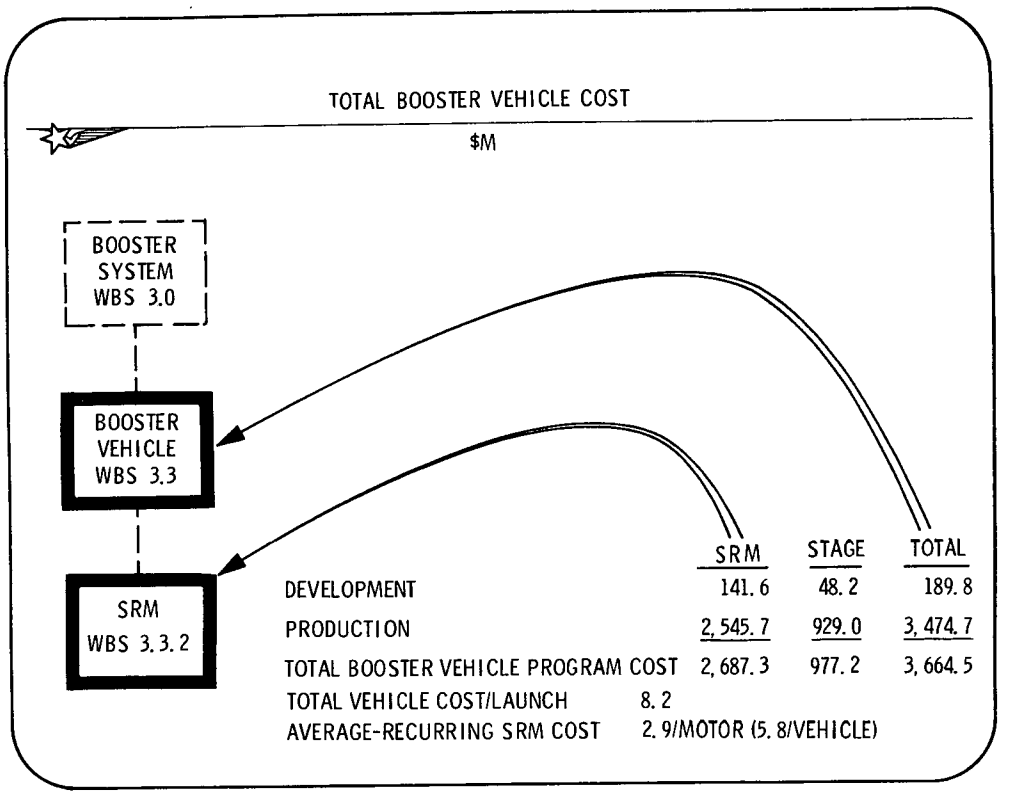
UNCLASSIFIED

A.3 NASA COST BRIEFING SUMMARY

Key Baseline costs are summarized on the chart below. The total program cost for the Booster Vehicle (Work Breakdown Structure Item 3.3) is $3.66 billion. These values result in a total program cost per launch of $8.2 million, or a recurring cost per SRM of $2.9 million.

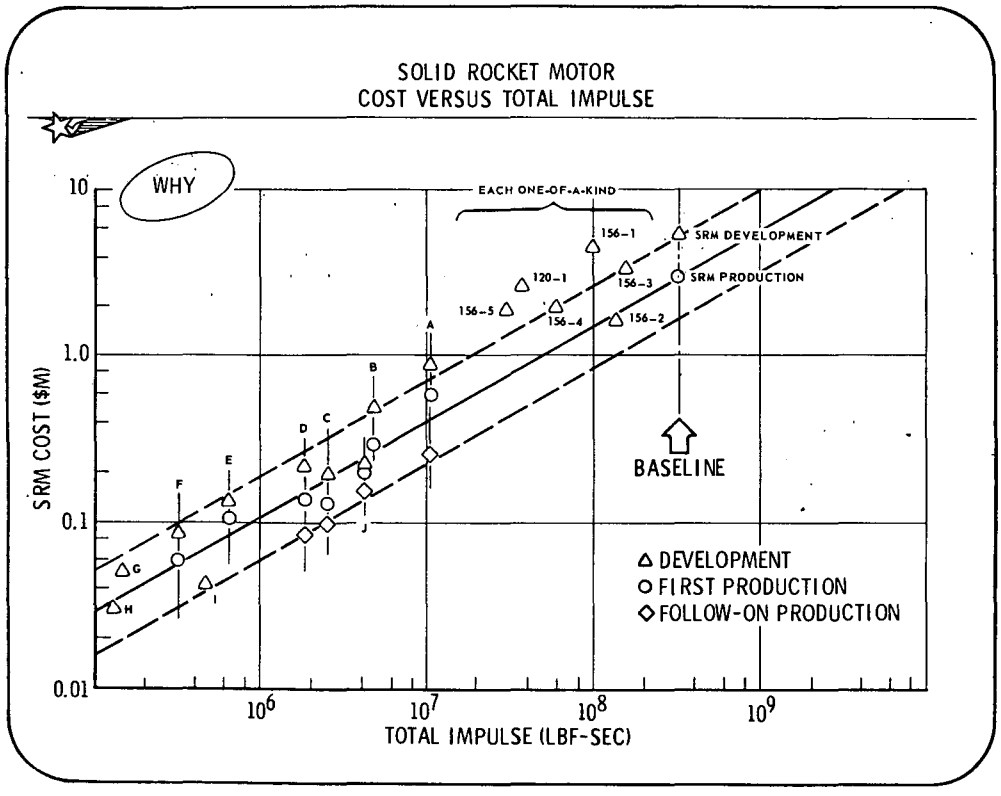


	SRM	STAGE	TOTAL
DEVELOPMENT	141.6	48.2	189.8
PRODUCTION	2,545.7	929.0	3,474.7
TOTAL BOOSTER VEHICLE PROGRAM COST	2,687.3	977.2	3,664.5
TOTAL VEHICLE COST/LAUNCH	8.2		
AVERAGE-RECURRING SRM COST	2.9/MOTOR (5.8/VEHICLE)		

A further analysis of LPC's Baseline cost is summarized in the figure below. The costs of various SRMs are plotted versus the total impulse (total energy) in the motor. The various data points on the left half of the chart represent actual cost history from major solid rocket motor development and production programs. The triangles represent the development phase, the circles reflect the first production buy, and the squares denote subsequent production buys. The development phase of each of these programs comprised more than 50 rocket motors, with further production learning indicated by the decreasing cost for each production buy.

The triangles located in the center of the chart represent the actual cost of the large solid motor programs conducted by Lockheed Propulsion Company. These programs, designated 120-1 and 156-1 through 156-5, were single-motor programs, with each motor a different configuration. The costs shown include all nonrecurring expenses such as design, tooling, and test.

The Baseline SRM development and production costs are shown at the extreme right side of the chart. The development cost appears to be reasonable, but conservative, considering that the Baseline program has 25 development motors as compared to the one-of-a-kind large solid motor development costs previously discussed. The Baseline production cost also appears to be realistic, based on experience. Experience (shown on the left half of the chart) also indicates that production motors may well fall into the lower half of the cost bands. An individual SRM cost of $1.8 million, or a recurring booster vehicle launch cost of $6 million, appears to be feasible based on experience.



LPC 156-INCH DIAMETER EXPERIENCE COMPARISON

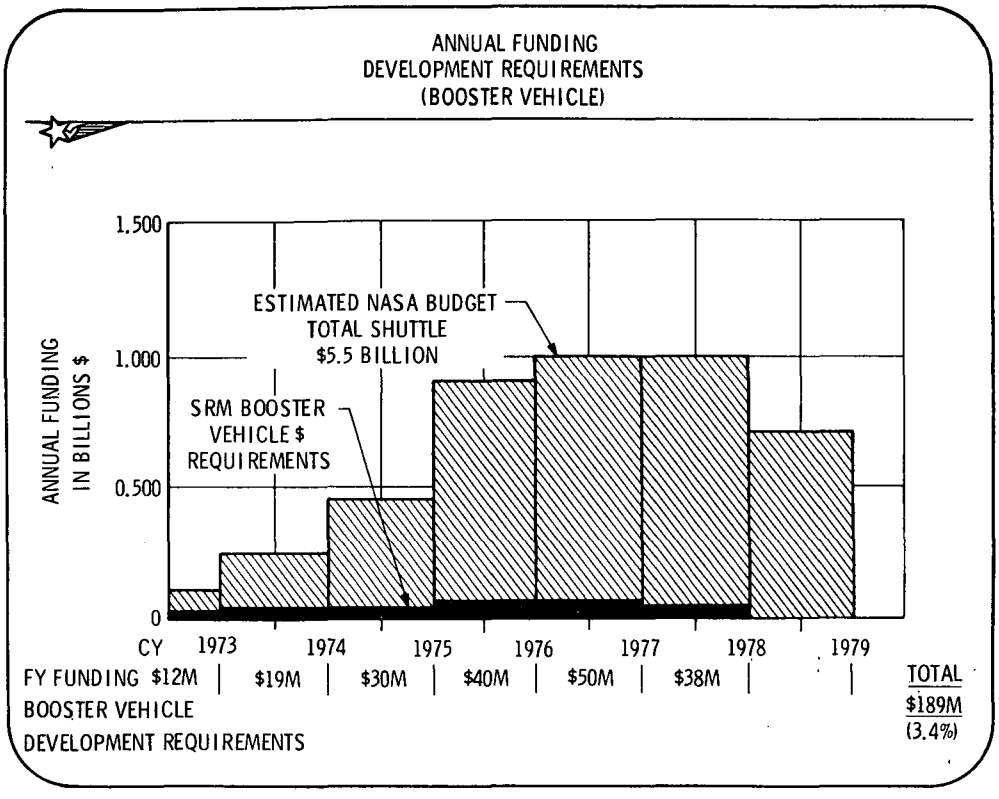
TOTAL PROGRAM COSTS

	L-71	L-72	156-5	156-6	HGV	TOTAL
DESIGN	$1.571	$0.409	$0.737	$0.333	$0.304	$ 3.354
MANUFACTURING	2.380	1.017	2.349	1.566	1.440	8.752
TEST	0.526	0.192	0.366	0.166	0.157	1.407
TOTAL	$4.477	$1.618	$3.452	$2.065	$1.901	$13.513
TOTAL IMPULSE (X 10^0)	100	140	160	60	30	490
PROPELLANT WEIGHT	0.423	0.626	0.687	0.273	0.156	2.165

SRM DEVELOPMENT COST COMPARISON

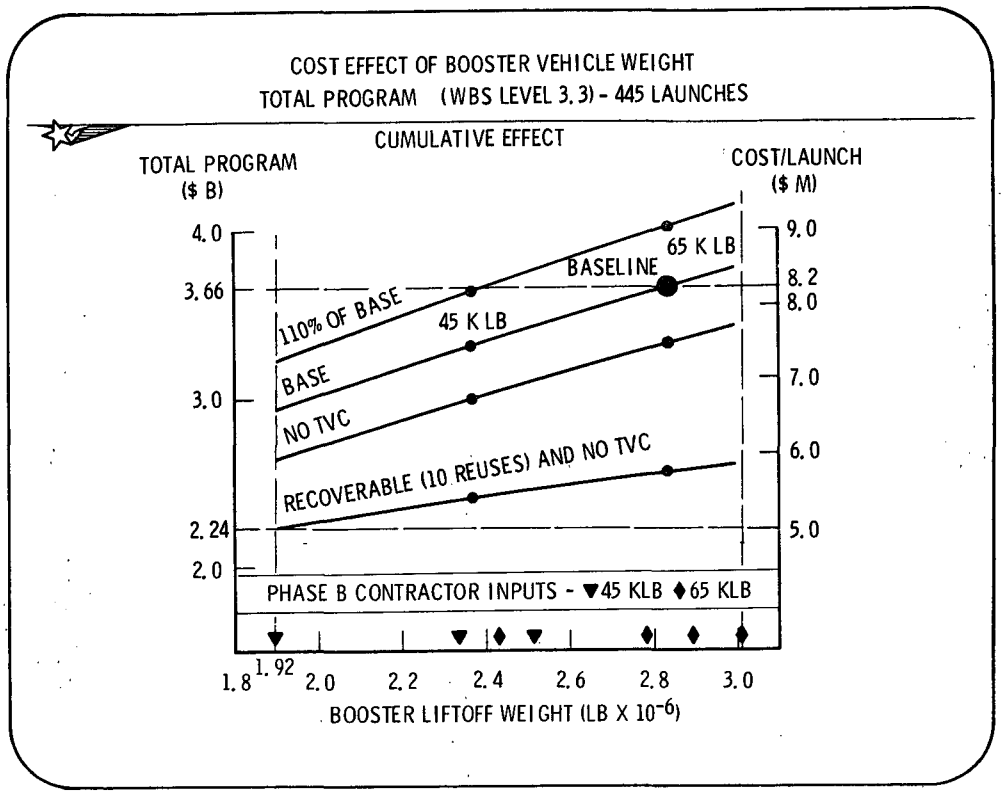
	ALL PREVIOUS 156-INCH	BASELINE SRM
TOTAL COST	$13.513M	$141.608M
SRM QUANTITIES	5	25
COST/SRM	$2.7M	$5.7M
COST/# SEC TOTAL IMPULSE	$0.03	$0.02

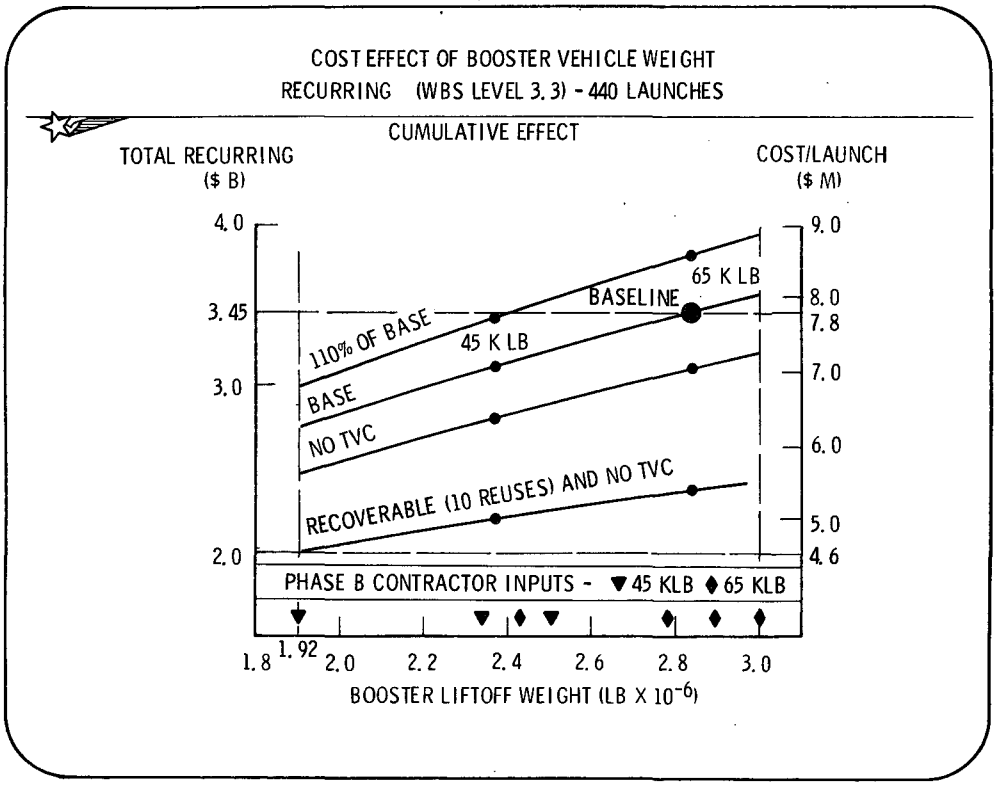
A cost analysis also was performed to determine the peak development funding requirements. Results are shown in the graph below. The estimate for total Space Shuttle funding indicates a peak level of $1 billion per year. By comparison, the peak funding requirements for the 156-inch solid rocket motor baseline program are small, reaching a maximum of $50 million per year. These costs reflect the total booster vehicle development program.



An analysis was also conducted to determine the variation of program costs as a function of booster lift-off weight. The range of lift-off weights considered reflects the variation noted in the inputs received by LPC from the individual Phase B system contractors. The first figure following shows the effect on total program costs and cost per launch. It can be noted from the graph that LPC's baseline design is at the conservative end, and that the effect of the range of contractor inputs for booster lift-off weight can affect the costs by as much as 20 percent. This amount of variation can result in bringing the total program cost down to $3.0 billion, and the total cost per launch to $6.7 million.

The second figure shows the same effect on the total recurring cost and the total recurring cost per launch. In this case, the total recurring cost, and cost per launch, can also vary as much as 20 percent, down to $2.75 billion total cost and to $6.75 million per launch.


COST EFFECT OF BOOSTER VEHICLE WEIGHT
TOTAL PROGRAM (WBS LEVEL 3.3) - 445 LAUNCHES
CUMULATIVE EFFECT
TOTAL PROGRAM ($ B)
COST/LAUNCH ($ M)
4.0
3.66
3.0
2.24
2.0
9.0
8.2
8.0
7.0
6.0
5.0
65 K LB
BASELINE
110% OF BASE
45 K LB
BASE
NO TVC
RECOVERABLE (10 REUSES) AND NO TVC
PHASE B CONTRACTOR INPUTS - ▼45 KLB ♦65 KLB
1.8
1.92
2.0
2.2
2.4
2.6
2.8
3.0
BOOSTER LIFTOFF WEIGHT (LB X 10⁻⁶)


COST EFFECT OF BOOSTER VEHICLE WEIGHT
RECURRING (WBS LEVEL 3.3) - 440 LAUNCHES
CUMULATIVE EFFECT
TOTAL RECURRING ($ B)
COST/LAUNCH ($ M)
4.0
3.45
3.0
2.0
9.0
8.0
7.8
7.0
6.0
5.0
4.6
65 K LB
BASELINE
110% OF BASE
45 K LB
BASE
NO TVC
RECOVERABLE (10 REUSES) AND NO TVC
PHASE B CONTRACTOR INPUTS - ▼45 KLB ♦65 KLB
1.8
1.92
2.0
2.2
2.4
2.6
2.8
3.0
BOOSTER LIFTOFF WEIGHT (LB X 10⁻⁶)