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VOLUME III

DATA REQUIREMENT MA-02
FINAL REPORT

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PROGRAM ACQUISITION PLANNING

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

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Lockheed Propulsion Company
Vice President, Technical and Marketing

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ABSTRACT

Plans for conducting Phase C/D for a Solid Rocket Motor Booster Vehicle are presented. The LPC methods for conducting this program with details of scheduling, testing, and program management and control are included. LPC can meet the requirements of the Space Shuttle Program to deliver a minimum cost/maximum reliability booster vehicle.

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FOREWORD

This document is Volume III, Program Acquisition Planning, of Lockheed Propulsion Company's Final Report in response to the requirements of National Aeronautics and Space Administration's Contract NAS 8-28429, Study of Solid Rocket Motors for a Space Shuttle Booster.

The Final Report is organized as follows:

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

This volume includes the information of Data Requirement by MA-02, Item 16.3C. For clarity in reporting, the detailed program cost information is presented in Volume II, Book 3.

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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

		Motor Description		Test Data	
No.	Date	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~~ 2303.9	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 AND SUMMARY

In accordance with contractual requirements, this volume presents the Lockheed Propulsion Company (LPC) Program Acquisition Plan for Phases C and D of the Large Solid Rocket Space Shuttle Booster Program. The discussion is organized according to the format presented in NASA publication NHB 7121.2, "Phased Project Planning Guidelines" (August 1968). The objective of this volume is to plan the Phase C (Design) and D (Development/Operations) efforts that will allow refinement of the design, development, and production programs, the launch operations, and the vehicle support requirements for space shuttle vehicles propelled by solid rocket motors. To undertake this effort, selected activities (systems/subsystems) are identified for continued project engineering development; activities are supplemented with a preliminary plan to effect their singular or collective implementation in a final vehicle system.

1.1 PROGRAM SCOPE

The purpose of this acquisition plan is to present LPC's approach for continued program development and to emphasize qualitatively and quantitatively those study areas that will either pace or evolve as sequential program decision points. As a consequence of these plans, adequate basis for program management decisions will be afforded. Thus, while risk and uncertainty are recognized, the intent of this plan is to increase the probability of achieving system performance within funding and schedule constraints. The overriding goal of this plan is the eventual system/subsystem implementation, with confidence, through understanding of program, phase, and task objectives and requirements.

This volume is composed of sections that address the system relationship of phased plans: Phase C plan for system/subsystem design studies and Phase D plans for system development/operation. The latter area is primarily concerned with system manufacturing plans. The prepared phase plans do not include advanced mission studies or supporting research and technology plans. It is realized that concurrent efforts in these areas will benefit the on-going program; this is especially true in the latter (SRT) area. Discussion of the SRT topic is covered elsewhere (Volume I, Book 2) of this report.

Structuring of individual phase project schedules is shown in Section 5. For summary purposes, an integrated Phase C, D, and SRT program schedule is presented in Figure 1-1. Herein, a visual appreciation of the interrelated phase efforts with sequenced SRT study programs is afforded.

1.2 PROGRAM DIRECTION AND CONTROL

Lockheed Propulsion Company has established its design, development, and production plans, described in subsequent sections of this volume, on the basis of delivering, for the Space Shuttle Launch Program, a minimum cost/ maximum reliability, solid rocket motor booster assembly. As discussed throughout this final report, LPC has designed an SRM using conservative safety factors and proven state-of-the-art materials. Component manufacturing methods, SRM processing procedures, test procedures and methods, and management controls have been tested and proven on other solid rocket motor systems.

As prime contractor for the booster vehicle system, LPC has established a Phase C and D program as shown in Figure 1-2. Phase C, Design, and D, Development, will be conducted at LPC's Redlands and Potrero facilities in Southern California.

During Phase D, Operations/Production, the most cost-effective plan for delivery of SRMs will be implemented. This plan will include consideration of launch site location and traffic (ETR versus WTR), available capacities of industry and supplier locations, and resultant transportation/logistic costs. It is planned to expand LPC facilities to accommodate delivery of a substantial portion of SRMs, but this decision will be affected by cost and launch site/traffic considerations. The total production requirements will be satisfied by the most economical mix of LPC and industry facilities. All components will be considered for dual procurement, ensuring redundant capabilities in event of labor problems or some catastrophe (flood, fire) at any supplier's plant. Additionally, the consideration of redundant sources ensures tight cost competition to maximize the application of contract funds.

This approach to the satisfaction of production quantity deliveries results in a low-risk, low-cost program and eliminates the high facility costs associated with a single SRM contractor approach.

In Figure 1-2 are shown some of the major tasks LPC will conduct as the booster vehicle prime contractor. All tasks shown on the left will be conducted at Redlands/Potrero, while those on the right are assigned to LPC personnel at Kennedy Space Center (KSC). Under direction from NASA, liaison will be maintained with the space shuttle integration contractor at KSC. The Phase C design effort (see Section 2) will be conducted to create a firm SRM booster design and to prepare plans for Phase D. LPC will conduct

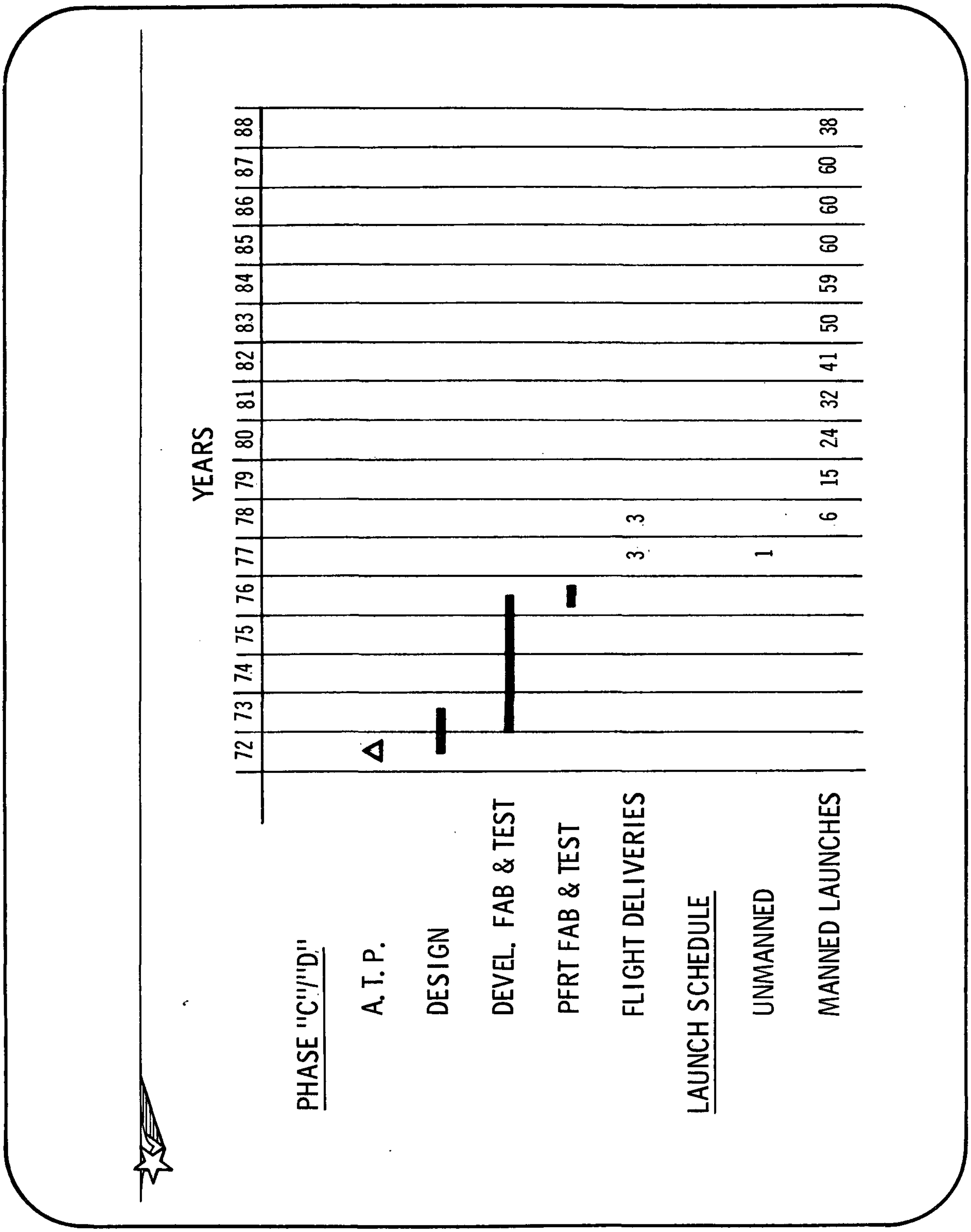


Figure 1-1 Program Schedule Showing Integration of Phases C and D and SRT Program

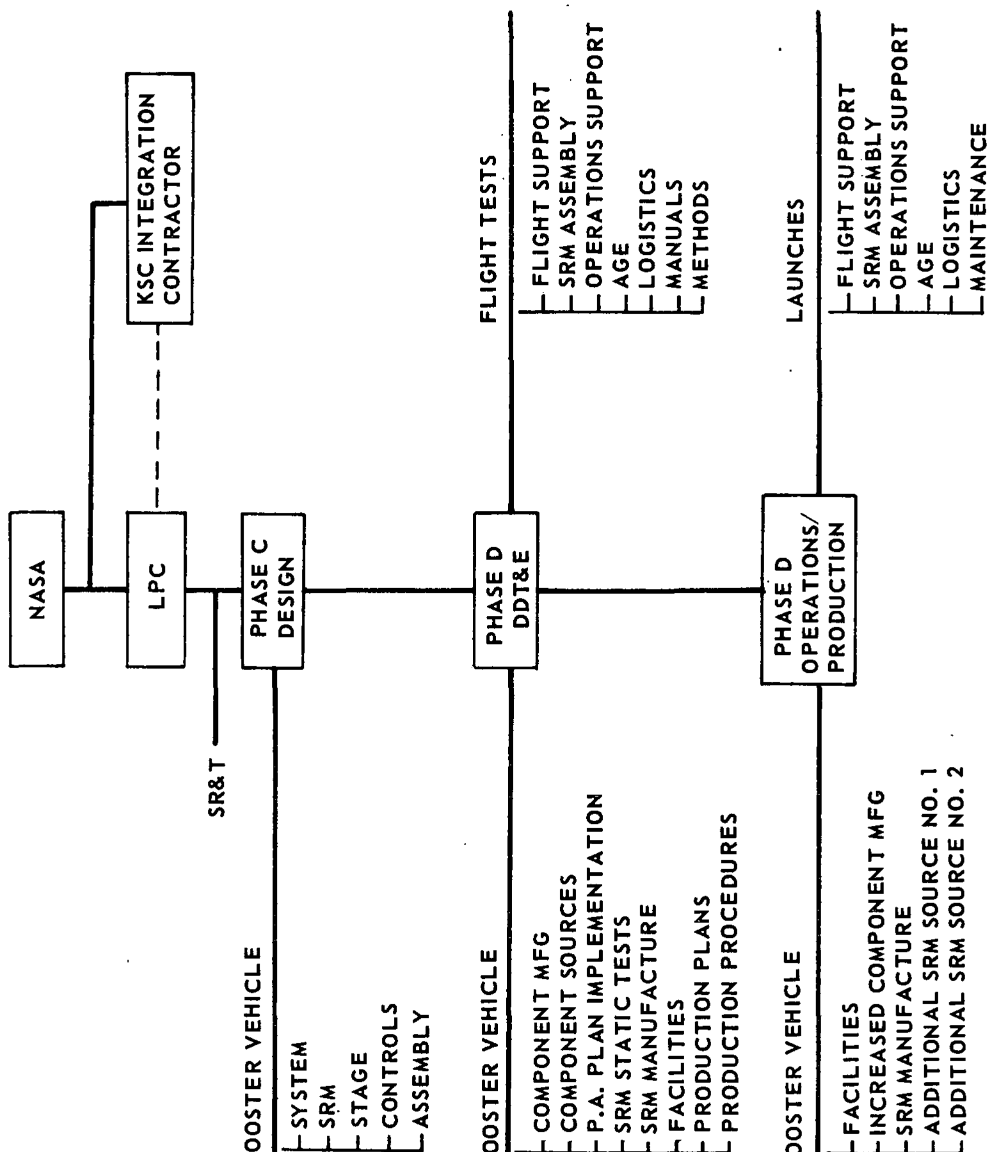


Figure 1-2 Major Task Summary

Phase D to ensure efficient and reliable transition from DDT&E to production. During the DDT&E subphase, LPC will conduct the tasks related to developing and providing a reliable booster vehicle meeting the space shuttle program requirements. In the production subphase, LPC will (1) broaden the base of material and component manufacturing sources and (2) expand its Potrero SRM manufacturing capability. LPC will also be responsible for the procurement of SRMs from two other existing industry sources to maintain the required launch rate. Static tests of SRMs produced by these added sources will be conducted to ensure that they have met the quality and performance requirements established by LPC.

Section 2

SRM PHASE C

The following sections describe the Booster Vehicle Phase C Design Program. The general objective of this Phase C Plan is to develop engineering detail for the several selected areas of study to permit generation of: (1) specific designs and specifications; (2) manufacturing and testing methods; (3) plans for long lead-time hardware components and materials: (4) practical system/subsystem fabrication schedules; (5) refined management operational methods that maximize cost-effectiveness and minimize program time schedules; and (6) plans for implementation in Phase D.

The topical categories that will be included as a part of the Phase C effort are presented in Table 2-1.

2.1 STUDY DESCRIPTION

Efforts planned under Phase C will involve the development and design necessary to permit the transition of the Solid Rocket Motor Space Shuttle Booster Vehicle from a defined design concept to the advanced development/operation phase. Experimental and analytical investigations relative to the study areas will be performed. Acquisition of detailed scientific data and engineering designs will afford the evolution of hardware components/systems from conceptual designs to prototype units. Through this action, project designs and specifications will be established for implementation at the onset of Phase D. In addition to this documentation, the following information will be developed:

- Detailed (component-by-component, system-by-system) definition of the booster vehicle system
- Engineering analyses of the integrated systems to ensure compatibility (redundancy, when required) and establishment of interface requirements
- Preliminary engineering designs for supporting systems and identification of tooling, equipment, and facility requirements for propellant manufacturing and motor test/evaluation
- A plan for backup subsystems, presently not identified, inclusive of development effort required

Table 2-1

PHASE C DESIGN CATEGORIES

BOOSTER DEFINITION

- Systems Engineering
- SRM Booster
- Booster Vehicle

BOOSTER TRANSPORTATION CONCEPTS

- Component(s) Safety Characterization
- Packaging
- Shipping
- Storage

BOOSTER RECOVERY/REUSE

- Recovery Concept Definition
- Prototype Demonstration
- Refurbishment Definition

BOOSTER ELECTROMECHANICAL INTERFACE

- Thrust Vector Control
- Electrical Power Systems
  - Checkout
  - Control Sequencing
  - Failure Detection

ENVIRONMENTAL ASPECTS - WASTE DISPOSAL

- Raw Materials
- Propellant
- Solvents

BOOSTER-VEHICLE INTEGRATION

- Booster Staging
- Booster-Tank Integration
- Booster-Tank-Vehicle Integration
- Ground System Interface
- System Integration

THRUST VECTOR CONTROL SYSTEM

- Nozzle
- Lockseal
  - Actuator
  - Hydraulics
  - Power Source
  - Controls

THRUST TERMINATION SYSTEM

- Actuation (Explosive)
- Configuration/Design
- Propellant
- Insulation
- Ignition

INERT COMPONENTS

- Booster Motor Case
- Booster Motor Insulation
- Booster Motor Liner

BOOSTER IGNITION SYSTEM

- Configuration/Design
- Propellant and Grain Design
- Insulation
- Nozzle
- Initiator

PROPULSION

- Propellant Processing

- Program operational plans for development, manufacturing, test, management, facilities, manpower, and documentation requirements, aligned to long-term Phase C tasks and long lead-time Phase D system/work modules

- Operation plans for assembly, checkout, launch, and related services.

2.2 COST DRIVER ANALYSIS

Within the framework of the study efforts discussed above, analysis will be conducted of all materials, components, and subsystems to evaluate what design changes most affect cost. From this, the booster system will be examined to determine how the individual changes affect the system cost and performance. Table 2-2 presents three examples that are known to have cost reduction potential. The arrows indicate the expected direction of the costs of the individual side effects.

The schedule for Phase C is presented in Section 5.

Table 2-2

COST DRIVER ANALYSIS

SRM Component	Potential Cost Driver	Possible Side Effects
Motor case	↓ Alternate steels versus D6AC	↑ Heavier case/more propellant required
	↓ Reuse of cases	↓ Longer segments/lower process costs
		↑ Larger nozzle
		↑ Increased steel characterization testing
Propellant	↓ HTPB versus PBAN	↓ Improved performance/less propellant required
		↑ Increased process development
		↑ Increased characterization testing
Nozzle ablatives	↓ Less erosion-resistant materials	↓ Lower material costs
		↑ Higher safety margins/ greater thickness
		↑ Higher development costs

Section 3

SRM PHASE D

The following sections describe the effort planned to conduct the SRM Phase D effort. This includes the development and test of 25 DDT&E SRM motors and production of 440 launch vehicles. Associated AGE hardware and booster integration tasks are also included.

3.1 PROJECT ENGINEERING AND DEVELOPMENT

Lockheed Propulsion Company proposes a Booster Vehicle Program of 25 development motors and production of 440 launch vehicles, consigned as shown on Table 3-1. The objectives to be accomplished with each development SRM are discussed in detail in Section 4. The general objectives of the nonflight motors are as follows:

<u>Development Phase</u>

Development Test Motors	Verify SRM design and evaluate the operation of subsystems, such as TVC and TT
PFRT Motors	Prove the reproducibility of the developed SRM design
Inert Stages	Prove Space Shuttle/Booster interfaces, booster vehicle structural reliability, and KSC assembly and launch techniques

<u>Production Phase</u>

Facility Start-Up Test Motors	Provide for qualification of additional SRM production facilities by motor static tests

The rationale for the quantity of development test and PFRT motors is based upon LPC's expectations of the development variations to be evaluated and upon its prior large solid motor experience. It is not possible to get a true

Table 3-1

SRM BOOSTER SUMMARY BASELINE PROGRAM

SRM BOOSTER SUMMARY
BASELINE PROGRAM

	SRM'S
DEVELOPMENT - LPC POTRERO FACILITY	
DEVELOPMENT TESTS - POTRERO	5
PFRT MOTOR TESTS - POTRERO	4
TWO INERT SRM STAGES - KSC	4
ONE UNMANNED FLIGHT - KSC	2
FIRST FIVE MANNED LAUNCHES - KSC	10
TOTAL DEVELOPMENT	25
PRODUCTION	
PRODUCTION FLIGHTS (440) POTRERO OR NEW FACILITY	880
FACILITY START-UP TESTS -POTRERO	3
TOTAL PRODUCTION	883
TOTAL SRM'S	908

statistical reliability and/or confidence assessment of the SRM with any practical number of motor tests, but LPC experience has shown that unless unusual environmental conditions (such as exist for tactical weapons systems) are encountered, the quantity of motors proposed is sufficient, when proper quality control is exercised at all levels of manufacture.

The development plan is based upon the experience gained by LPC on prior programs as shown in Table 3-2.

3.2 MANUFACTURING PLAN (MATERIALS AND PROCESSES)

3.2.1 Integrated Booster Vehicle Development Flow Plan

The manner in which LPC proposes to control manufacture of the Development SRMs is shown in Figure 3-1. The major component suppliers and their relationship to the overall program are indicated. To ensure SRM producibility and reliability, LPC will provide quality control and materials process control to all significant suppliers even at the lower tiers of contract level.

3.2.2 Integrated SRM Production Flow Plan

Similar to the previous flow chart, Figure 3-2 shows the relationship of the major suppliers, LPC, and the KSC Launch Complex. LPC will be responsible for all aspects of the SRM booster components; for receipt, inspection, and storage at KSC; and for the assembly and checkout of the booster vehicle. In addition, LPC will supply engineering support at the launch complex to maintain technical cognizance of the vehicle throughout the Space Shuttle Flight Program.

The flow chart also shows how a recovery, refurbish, and reload operation would be handled and integrated into vehicle production. LPC has not detailed all of the handling assembly and integration operations at KSC, but the listing below is considered typical of functions that will be accomplished. LPC has assumed that existing equipment and buildings at KSC will be GFE.

Table 3-2

LOCKHEED PROPULSION COMPANY SRM SUMMARY

LOCKHEED PROPULSION COMPANY SRM SUMMARY

120-INCH	TEST DATE	PROPELLANT WT. (K-LB)	THRUST (M-LB)	BURN TIME (SEC)	PROPELLANT TYPE	TVC TYPE
120" ARM	5-12-62	163	0.3014	122	PBAA (543A)	SITVC (Freon / H_2O_4)
156-INCH						
L-71	5-28-64	423	0.9486	108	PBAA (543B)	JET TAB
L-72	9-30-64	626	1.101	142.8	PBAA (543D)	JET TAB
156-5	12-14-65	687	2.84	55.25	PBAN (580A)	LITVC (N_2O_4)
156-6	1-15-66	278	0.964	65	PBAN (580C)	LITVC (N_2O_4)
HGV	4-7-66	156	0.2718	121.7	PBAA (592A)	SITVC (Hot Gas)

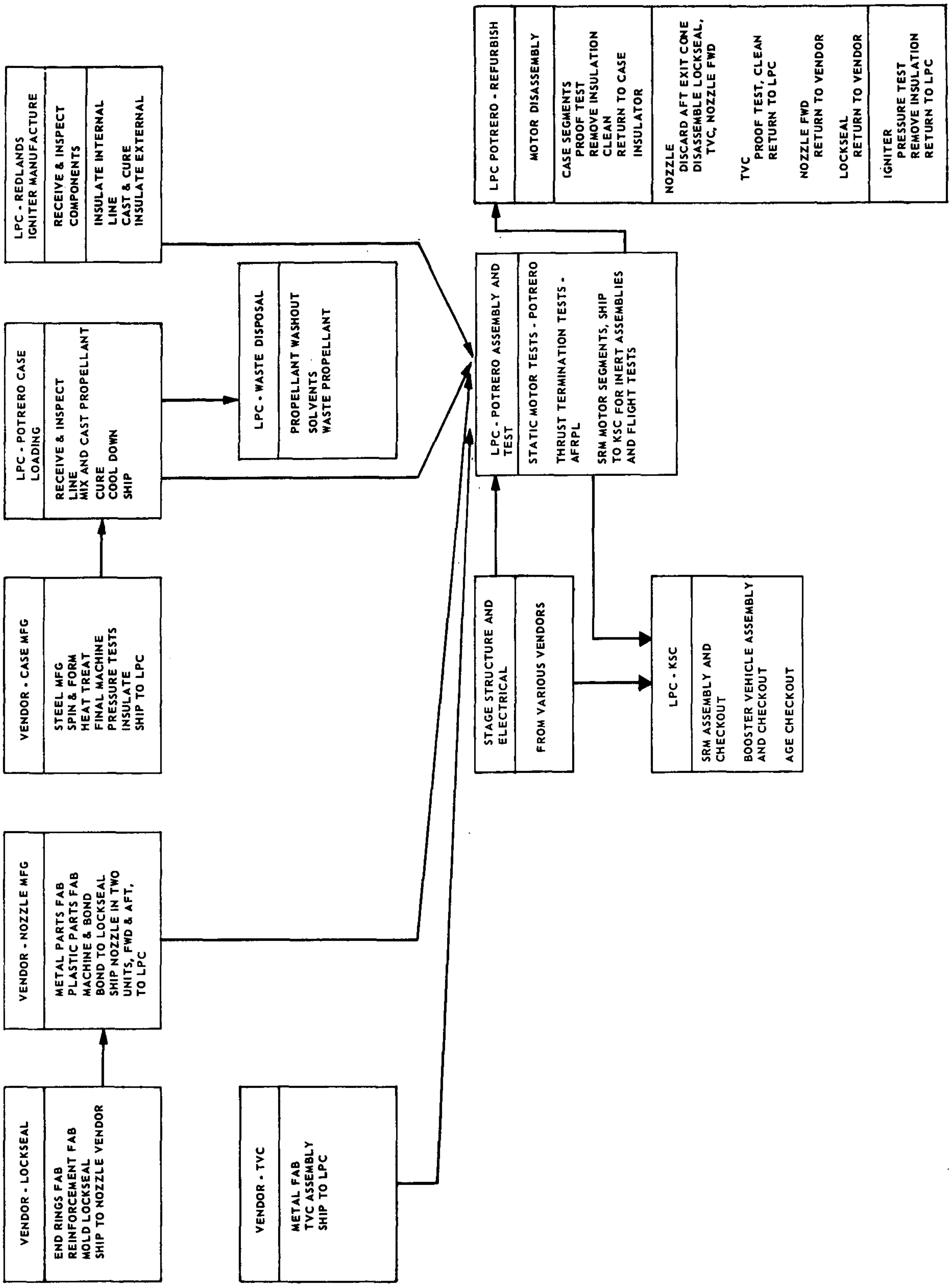


Figure 3-1 Manufacturing Plan for Development

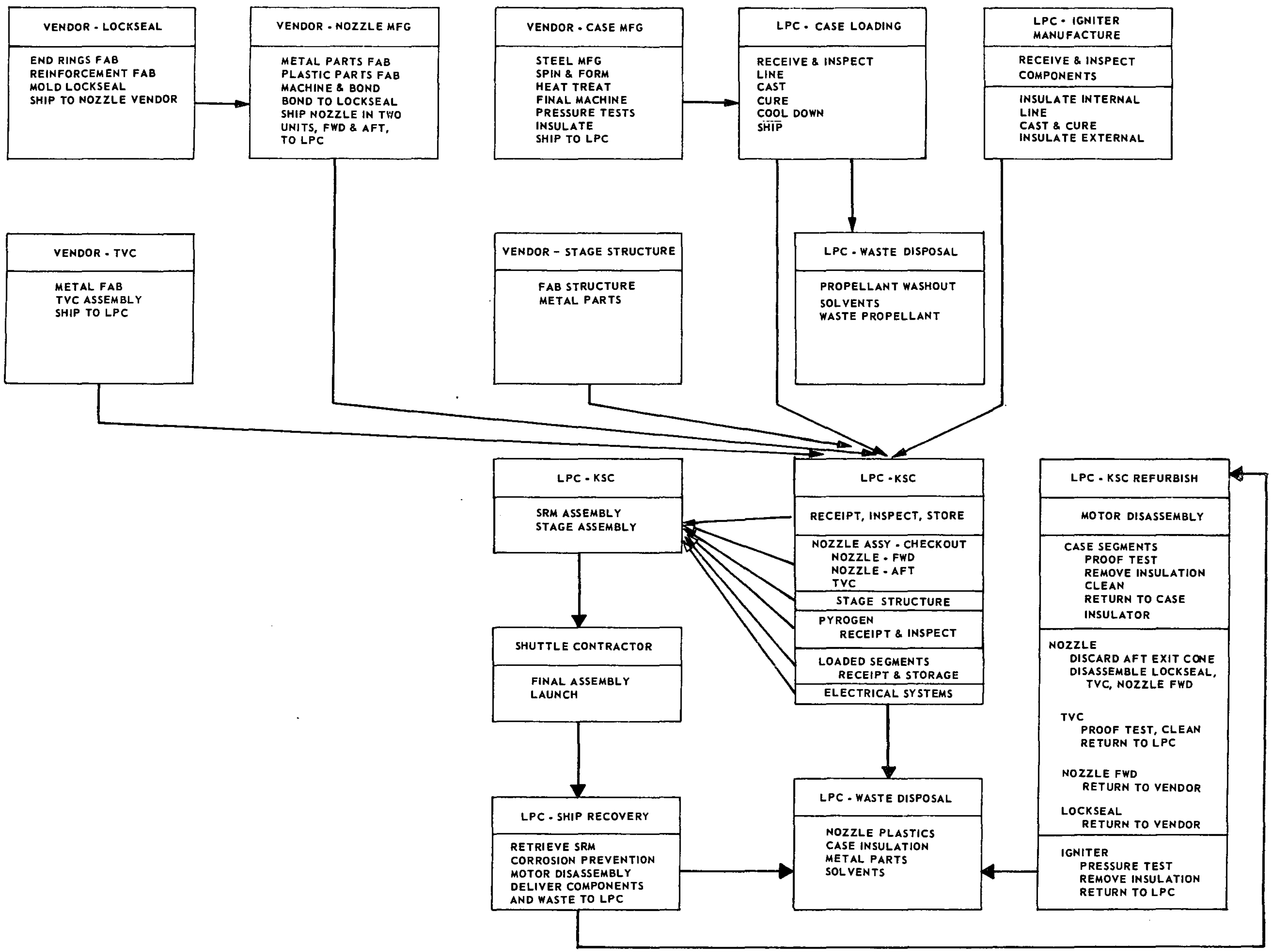


Figure 3-2 Manufacturing Plan for Production

Operation	Means
SRM segments and stage components transportation	Rail/truck
Segment initial storage/ receiving inspection	Complex 40-41 SRM Facilities or New Buildings at Complex 39
SRM environmental storage	Complex 40-41 SRS Building or New Building at Complex 39
Vehicle inert component receiving/inspection/storage and checkout	Complex 40-41 MIS Building or New Facilities at Complex 39
SRM segment/closure transfer to VAB	Clark Handler/Transporter
Vehicle assembly	On new mobile launchers (ML) in VAB
Checkout	Semi-automatic
Transfer to launch pad	Crawler/transporter transfers ML with booster/orbiter

3.2.3 Flow Diagram, 156-Inch-Diameter Motor Manufacture

Except for handling constraints related to size and weight, the processing of the 156-inch SRM is similar to that of any other solid propellant rocket motor. A flow diagram of the major SRM processing steps is shown in Figure 3-3. Continuing quality assurance inspection and testing of propellant samples are provided to ensure ballistics and structural acceptance.

3.2.4 SRM Process Schedule

SRM processing time spans for both development and production are shown in Figure 3-4. The lead time for manufacture of the required components is significant. The case delivery is considered to be the most serious constraint, requiring 15 months from supplier go-ahead to case delivery. Other items such as the nozzle, TVC, and igniter also require significant, but less, lead time. In development, the process time for LPC production of an SRM is approximately $2\frac{1}{2}$ months. This is reduced to $1\frac{1}{2}$ months in production as segments are processed in parallel rather than sequentially.

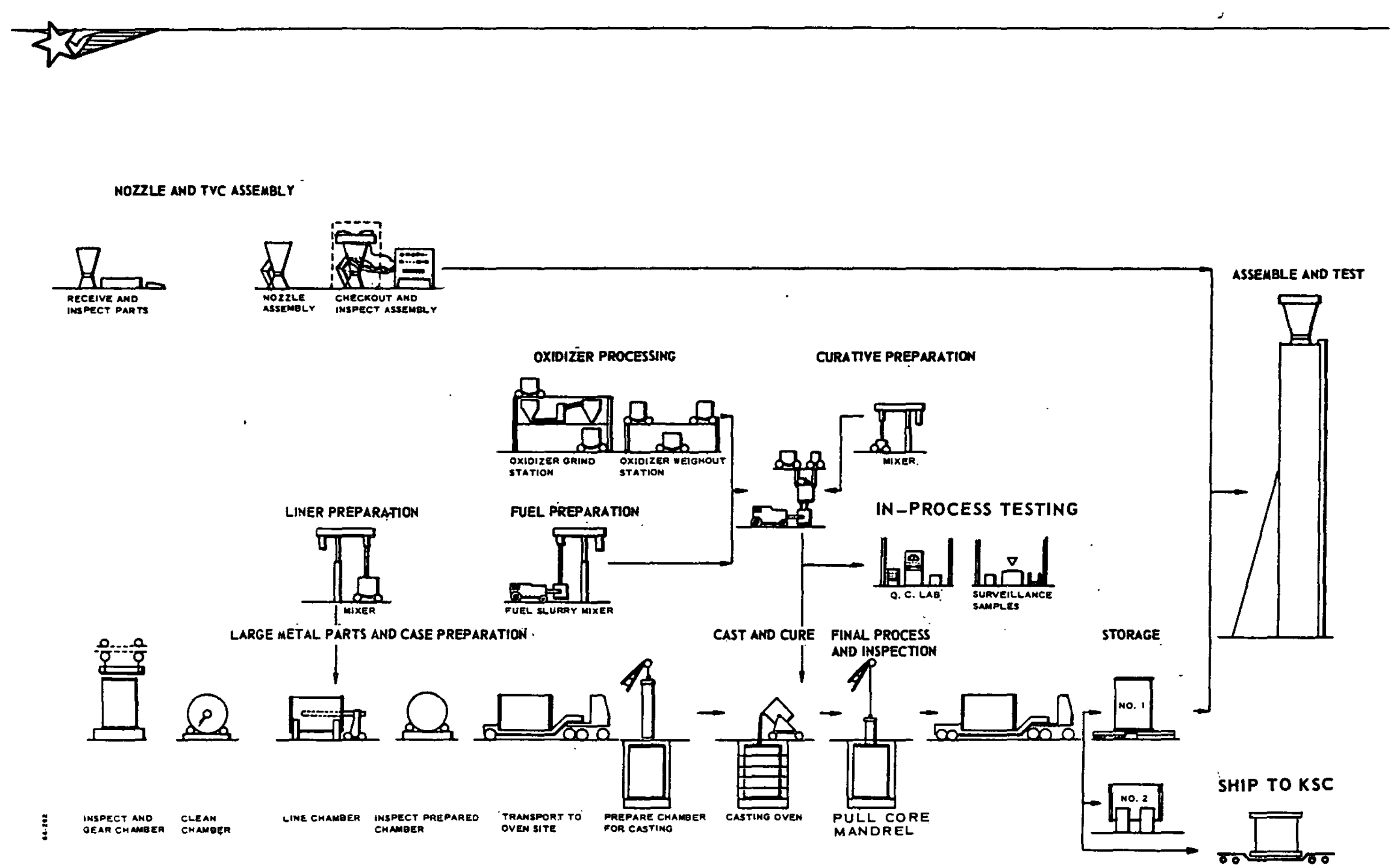


Figure 3-3 Flow Diagram, 156-Inch-Diameter Motor Manufacture

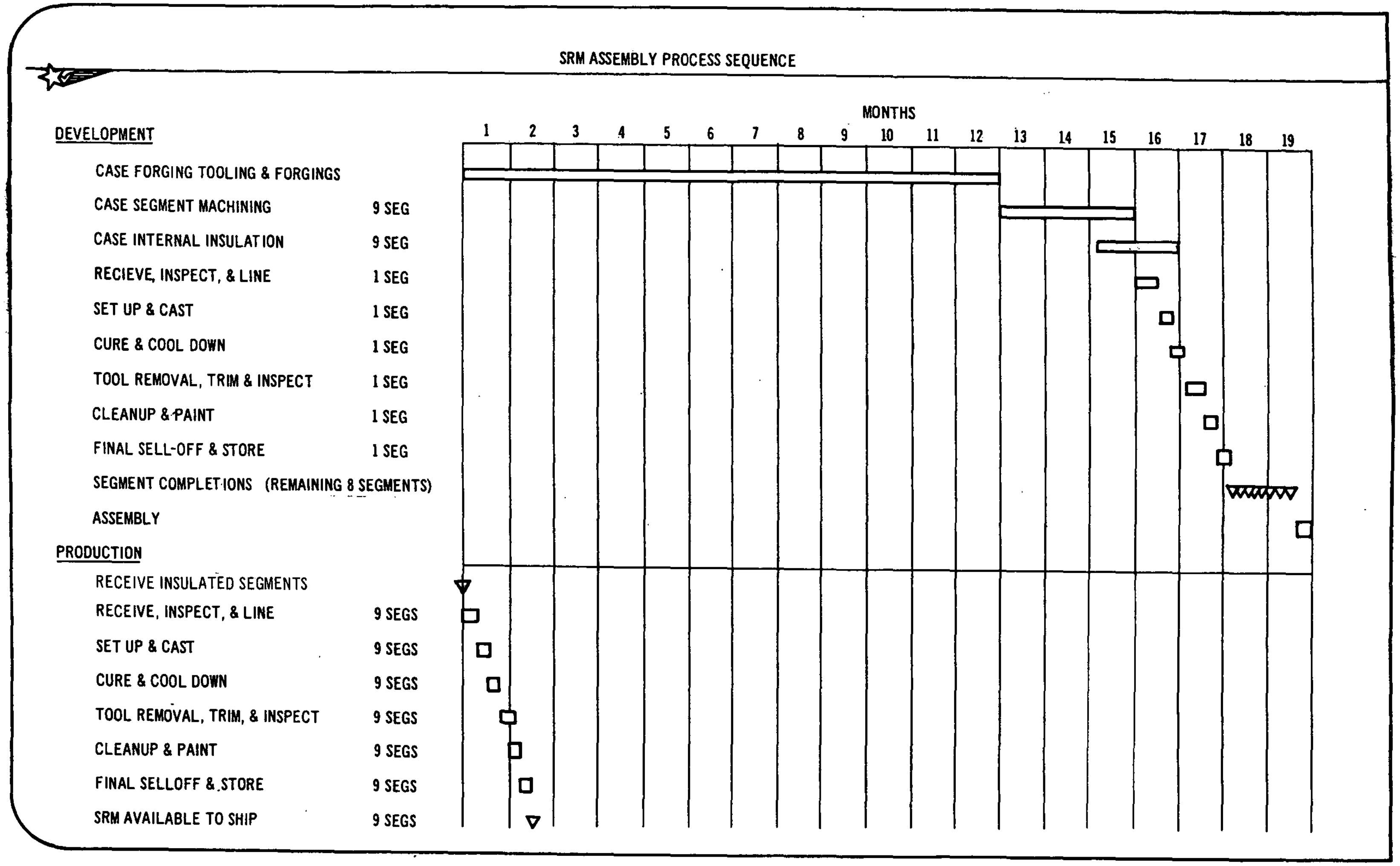


Figure 3-4 Typical SRM Process Schedule

3.2.5 SRM Propellant Flow Sheet

The PBAN propellant proposed for the Space Shuttle SRMs is very similar to the LPC-580A formulation previously used by LPC in its large motor development programs. The basic similicity of LPC-580A propellant is indicated by the flow diagram of Figure 3-5. Procedures are already available to describe the raw materials handling and weighout, fuel slurry preparation, and the final propellant mixing and casting, and need only minor updating for use on this program.

3.2.6 Component Fabrication

SRM case material and fabrication. The case material and manufacturing methods selected for the baseline SRM approach have been proven in other rocket motor programs. Table 3-3 lists the selected baseline features together with the rationale for this selection. The probable vendors for each of the manufacturing steps are listed below:

Steel Mill (Republic Steel)	Fabricate 36,000-lb billets of D6AC steel
Forge Vendor (Ladish, Cudahy Wise)	Forge billets by ring-rolling. Form cylinder segments by roll-forming the ring-rolled forging. Form end closures by swaging ring-rolled forgings. Rough machine.
Heat Treat Vendor (J. W. Rex, Phil., Penn.)	Quench and temper all components
Final Machining (Rohr, Chula Vista, Ca.)	Machine all joints.
Hydrotest (Rohr)	1 cycle to 1150 psi for each component
Mag Particle Inspection (Rohr)	Entire component

SRM internal insulation. The materials and processes selected for internal insulation (Table 3-4) of the SRM are state-of-the-art, and have been used for numerous production solid propellant rocket motors. The filled-NBR stocks are available from several industry sources and no development effort is required. Primers and adhesives to give reliable bonds to propellants and SRM inert components are similarly available. Methods of

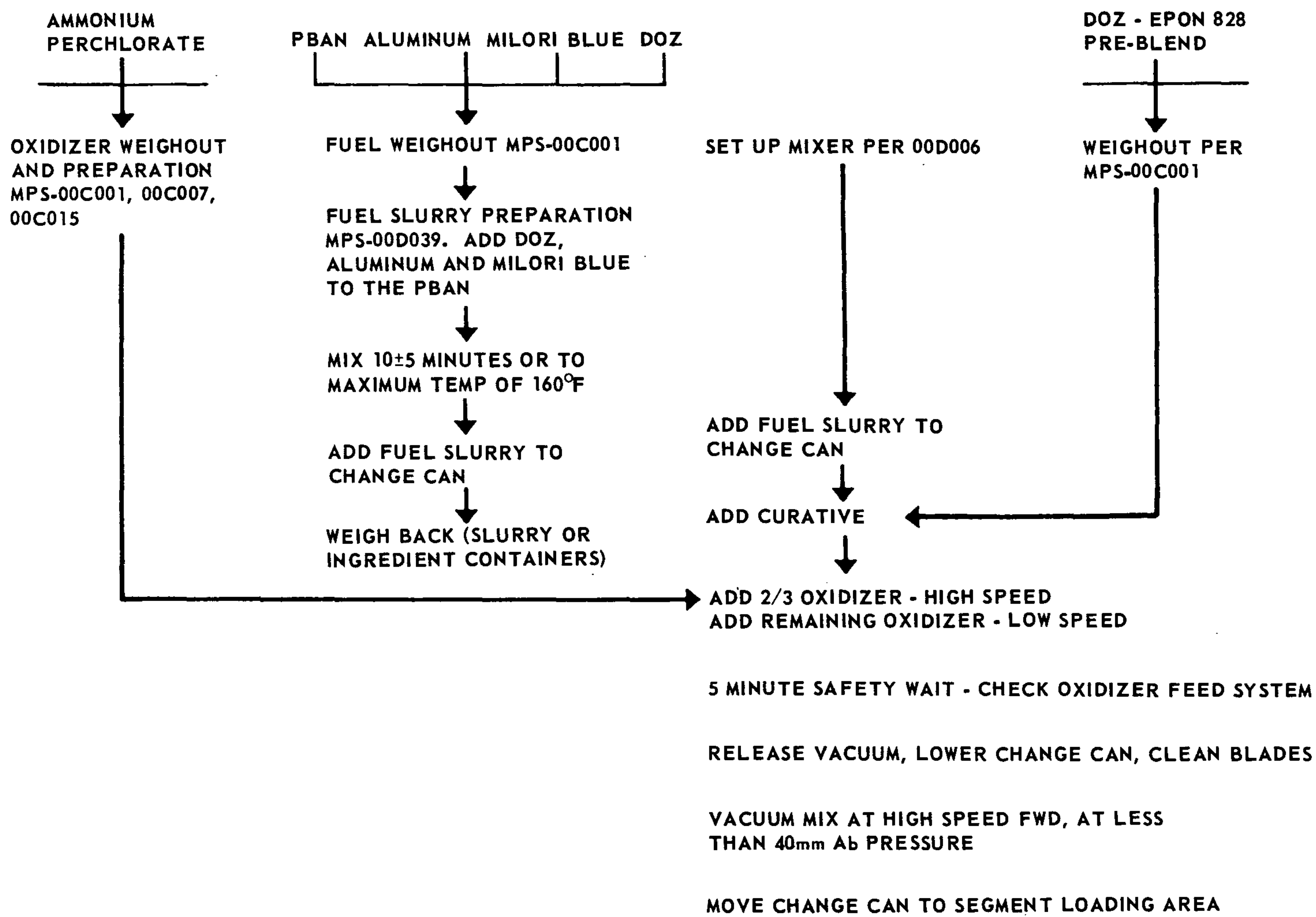


Figure 3-5 SRM Propellant LPC-580A Process Flow Chart

Table 3-3

SRM CASE MATERIAL AND FABRICATION

SRM CASE MATERIAL AND FABRICATION

FEATURE	SELECTION	RATIONALE
CASE MATERIAL	D6AC STEEL	EXPERIENCE
FABRICATION METHOD	160-INCH SEGMENTS - RING ROLL, ROLL FORM, HEAT TREAT CLOSURES - RING ROLL, SWAGE, HEAT TREAT	RELIABILITY WITH NO WELDS. EXPERIENCE, FIRM COSTS
JOINT DESIGN	CLEVIS TYPE WITH TAPERED PINS BOLTED ON SKIRTS	STIFFNESS AND REUSABILITY
WALL THICKNESS	0.46-INCH NOMINAL FOR 1000 PSI MEOP	EXPERIENCE 1.4 SAFETY FACTOR 13% BIAXIAL GAIN 225 KSI F_{TU} MINIMUM
CORROSION PREVENTIVE	PAINT PLUS SEALANT SYSTEM	EXPERIENCE

Table 3-4

SRM INTERNAL INSULATION, MATERIALS AND PROCESS

SRM INTERNAL INSULATION, MATERIALS AND PROCESS

MATERIALS-PROCESS

- SILICA-FILLED NBR/ASBESTOS-FILLED NBR
- CALENDERED SHEET STOCK
- AUTOCLAVE CURE IN PLACE

PRODUCTION EXPERIENCE

- PROVEN COMPATIBLE WITH PBAN PROPELLANT
- PROVEN PERFORMANCE IN PRIOR SRM FEASIBILITY DEMONSTRATIONS
  - LPC 156-INCH SRM'S
  - 260-INCH SRM
- PROVEN RELIABILITY IN PRODUCTION SRM PROGRAMS
  - MINUTEMAN
  - TITAN III-D
  - POLARIS/POSEIDON

manufacture for previous large solid motor programs included both pre-molding of insulation with secondary bonding in place, and layup and cure directly in the case. LPC has chosen the latter method for the baseline SRM because of its simplicity and reliability (no secondary bond joints).

SRM nozzle materials and processes. The nozzle for the SRM is perhaps its most complex component, having structural, thermal, and ablative requirements. The proposed materials and the subcomponent manufacturing methods (Table 3-5) have all been used in previous SRMs. The ablative plastics selected are all known to give reliable performance at reasonable cost. The ablative/thermal nozzle components are basically tape-wrapped parts that are hydroclave-cured at 1000 psi, except for the exit cone, which can be cured in an autoclave at 300 psi. Process improvements that were considered for future cost reduction include molding instead of tape-wrapping, autoclave instead of hydroclave cure, and use of shrink tape with oven cure instead of an autoclave or hydroclave cure. Another cost reduction consideration is the use of lower-cost ablatives that have undergone development evaluation but have yet to be used on a production SRM.

SRM igniter materials and processes. The SRM pyrogen igniter as shown in Figure 3-6 is in itself another solid rocket motor. Therefore, the same materials and processes used for the 156-inch-diameter SRM were selected for the igniter. A dual initiation system incorporating exploding bridgewire initiators was selected because of its proven reliability, performance, and safety.

3.3 GENERAL TESTING

3.3.1 SRM Motor Tests Development

The full-scale SRM static tests for the development phase listed in Table 3-6 will be conducted at the LPC Potrero Proving Ground (PPG), except those tests that include active thrust termination or simulated abort operation. These may be performed at the Air Force Rocket Propulsion Laboratory facilities at Edwards Air Force Base, California, since the possible ejection of debris during thrust termination makes this test location desirable.

In addition to the motor static tests, two inert booster assemblies will be supplied for launch vehicle assembly (and structural) tests at KSC.

Table 3-5

SRM NOZZLE MATERIALS AND PROCESS

SRM NOZZLE MATERIALS AND PROCESS

WHAT

- D6AC STEEL STRUCTURAL METAL PARTS
- ABLATIVE PLASTIC THROAT
- THROAT DIAMETER 52.3 INCHES
- EXPANSION RATIO 8.3

WHY

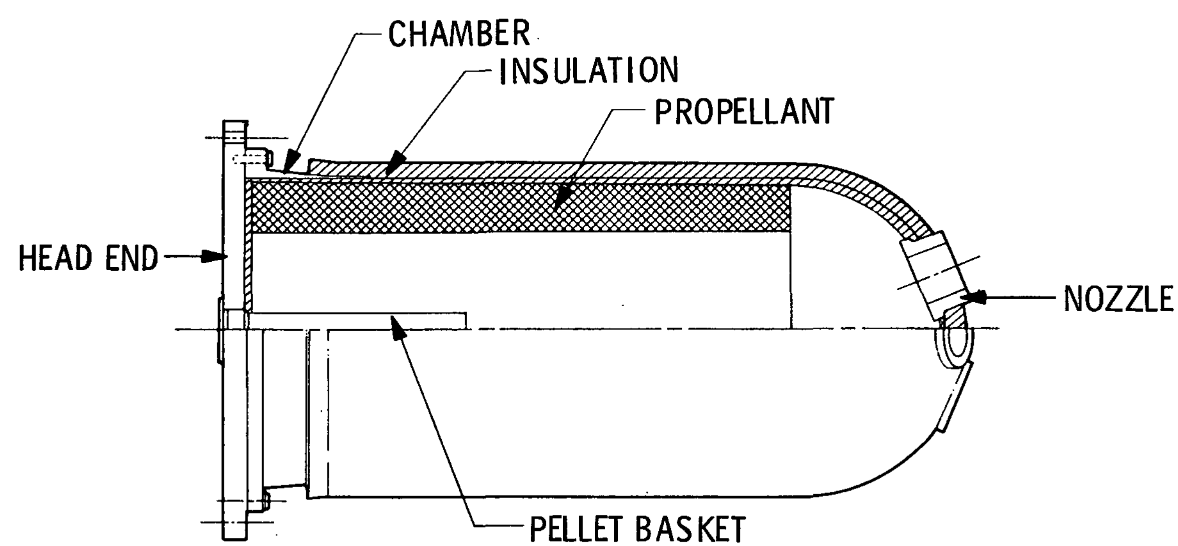
LOW RISK, PROVEN MATERIALS

- 156 AND 260-INCH SRM, TITAN IIID
  - CARBON PHENOLIC
  - SILICA PHENOLIC
  - GLASS PHENOLIC

LOW COST MATERIALS

- DEVELOPMENT TESTS ONLY
  - CANVAS PHENOLIC
  - LOW PURITY CARBON
  - ADDITIONAL DEVELOPMENT SRM's REQUIRED

156-7 IGNITER DESIGN



FEATURE	SELECTION RATIONALE
HEAD END PYROGEN	TITAN III, 156-IN. SRM
D6AC CASE	TITAN III, MINUTEMEN, SRM
NBR INSULATION	TITAN III, 156-IN. SRM
PBAN PROPELLANT	TITAN III, 156-IN. SRM
DUAL EBW INITIATORS	POLARIS, POSEIDON, SPRINT REDUNDANCY, SAFETY

Figure 3-6 SRM Igniter Materials and Process

Table 3-6

SRM STATIC MOTOR DEVELOPMENT TESTS

SRM STATIC MOTOR TESTS, DEVELOPMENT

TYPE TEST (12)	PRIMARY OBJECTIVES	SECONDARY OBJECTIVES
DEV	IGNITION/BALLISTICS/MOTOR INTEGRITY	TEST EQUIPMENT PERFORMANCE/TVC ON GROUND POWER
DEV	TVC (FLIGHT POWER)/BALLISTICS/STRUCTURAL LOADS	IGNITION/ TEST EQUIPMENT/ABORT SENSOR/ POST FIRE T.T. PORT ACTUATION
DEV	ABORT/THRUST TERMINATION (NOTE 3)	STRUCTURAL/THERMAL LOADS
DEV	BALLISTIC REFINEMENTS/MOTOR INTEGRITY	TVC/IGNITION
DEV	FINAL PLANNED COMPONENT CONFIGURATION TESTS PRE-PFRT	EVALUATE (POST TEST BASIS) RECYCLE CAPABILITY OF HARDWARE
PFRT	TVC/BALLISTICS/SUBSYSTEM PERFORMANCE	
PFRT	ABORT/THRUST TERMINATION (NOTE 3)	
PFRT	TVC/BALLISTICS/SUBSYSTEMS	
PFRT	TVC/BALLISTICS/SUBSYSTEMS	

NOTES: 1. MOTOR TEMPS 60 - 80°F RANGE
2. ALL TESTS CONDUCTED AT PPG, EXCEPT AS OTHERWISE NOTED
3. EAFB-RPL 120 IN. FACILITY MAX BE UTILIZED FOR THRUST TERMINATION FIRINGS

The five development motor tests and four PFRT tests are considered adequate to verify the SRM design. Coupled with a conservative design approach and the use of proven materials and processes, they will provide a sufficiently high reliability confidence level to proceed with the launch program at KSC for both unmanned and manned orbital flights.

3.3.2 SRM Component Development Tests

All of the SRM booster materials and components will be thoroughly proven before incorporation into the motor assembly. Tables 3-7 through 3-11 outline the type of effort proposed for each component. Raw materials for all items will be thoroughly tested and specifications will be prepared to ensure quality and reproducibility of performance. Similarly, specifications will be developed for the manufacture and acceptance testing of the finished components.

Initial development testing of electrical systems will be performed with breadboard models. Final testing will consist of system checkout on full-scale motor static tests.

Structural members of the booster stage will be proof-loaded after fabrication. Adequacy of design and manufacture will be verified on the inert Ground Test Assemblies.

3.4 PRODUCTION

3.4.1 Facilities

Lockheed Propulsion Company examined several options (Table 3-12) to determine the optimum overall plant facility concept for SRM production. The lowest total facility funding, least expenditure per year during the production startup, and overall flexibility of production and launch site needs result from the expansion of the existing solid propellant industry as presented in subsection 1.2. Selection of the optimum approach is dependent not only on facility costs, but also on production costs, other space and defense requirements, and transportation costs. Later sections discuss some of these tradeoffs.

Tables 3-13 through 3-16 are summaries of the SRM contractor and vendor facilities required to meet the baseline production requirements. The vendor facility needs and associated costs are presented for reference, although these costs are amortized in the cost of the specific raw material or component. The SRM facilities are considered typical of those required. The secondary sources selected will affect the actual items listed but the costs are representative.

Table 3-7

DEVELOPMENT TESTS, MOTOR CASES

DEVELOPMENT TESTS, CASES

TEST ASSEMBLY -

- CENTER SEGMENT PLUS END DOMES

HYDROBURST

- LOAD TO FAILURE FOR DESIGN VERIFICATION
- LOAD TO FAILURE AFTER WATER IMMERSION

CYCLIC EFFECT

- CYCLE LOAD TO 1.2 TIMES MEOP THROUGH 6 CYCLES
- LOAD TO FAILURE

Table 3-8

DEVELOPMENT PROGRAM PLAN, NOZZLE

DEVELOPMENT PROGRAM PLAN, NOZZLE

MATERIALS AND PROCESS OPTIMIZATION

- MATERIALS TESTS
- BONDING TESTS

STRUCTURAL TESTS OF COMPONENTS

Table 3-9

DEVELOPMENT PROGRAM PLAN, LOCKSEAL/TVC

DEVELOPMENT PROGRAM PLAN, LOCKSEAL / TVC

	NO. OF TESTS
FLEXIBLE SEAL - LOCKSEAL	
ELASTOMER SELECTION AND CHARACTERIZATION	
SUBSCALE SEALS: PROCESS OPTIMIZATION	6
STRUCTURAL TESTS	4
FULL SCALE SEALS: PROCESS OPTIMIZATION	3
STRUCTURAL TESTS	2
SERVO ACTUATOR SYSTEM	
SERVO VALVES: BURST TEST	1
PERFORMANCE EVALUATION	3
ACTUATOR BODIES: BURST TEST	1
PERFORMANCE EVALUATION	1
SERVO ACTUATOR: PERFORMANCE/ENVIRONMENT EVALUATION	1
HYDRAULIC POWER SUPPLY	
POWER SUPPLY ASSY: PERFORMANCE AND BURST	1
TVC SYSTEMS INTEGRATION	
FULL NOZZLE/TVC SYSTEM: BENCH TESTS SIMULATING FLIGHT LOADS	

Table 3-10

DEVELOPMENT PROGRAM PLAN, IGNITION SYSTEM

DEVELOPMENT PROGRAM PLAN, IGNITION SYSTEM

IGNITER CASE	
BURST TESTS (NEW AND REFURBISHED)	3
INITIATOR	30
FIRING TESTS	
ARM/DISARM (A/D)	
FIRING TESTS WITH INITIATORS	6
PELLET BASKET TESTS	
WITH A/D AND INITIATORS	6
IGNITER TESTS	
OPEN AIR BALLISTICS TESTS	6

Table 3-11

DEVELOPMENT PROGRAM PLAN, THRUST TERMINATION

DEVELOPMENT PROGRAM PLAN, THRUST TERMINATION

COMPONENT TESTS	
PYROTECHNIC CUTTING CAPABILITY	5
DIAPHRAGM RELEASE TESTS, COLD GAS	3
SYSTEM TESTS	
COMPONENTS WITH STACKS AND INSULATION	2

Table 3-12

PRODUCTION FACILITY OPTIONS

PRODUCTION FACILITY OPTIONS

	OPTIONS	
	EXPAND LPC AND EXISTING INDUSTRY CAPACITY	NEW FLORIDA PLANT NEAR KSC
FACILITIES COST*	$26 MILLION	$68 MILLION
FUNDING 1973 - 1980*	$3.3 MILLION/YEAR	$8.5 MILLION/YEAR
LAUNCH FLEXIBILITY	ADJUSTABLE TO LAUNCH RATE AND SITE NEEDS	EFFICIENT FOR ETR AND HIGH RATE ONLY
PRODUCTION RELIABILITY	SEPARATE PLANTS IN EVENT OF LABOR OR NATURAL INCIDENT	COMPLETE PLANT MAY BE SHUT DOWN

* 445 LAUNCHES

Table 3-13

SRM FACILITIES - LPC DEVELOPMENT
(Baseline 156-Inch Parallel Burn)

SRM FACILITIES - LPC DEVELOPMENT (BASELINE - 156-INCH PARALLEL)

FACILITY DESCRIPTION	REMARKS	AMOUNT
VISUAL INSPECTION, CLEAN, WEIGH, LINE (2) COATS AND CURE. PREP SEG. FOR CASTING	ONE (1) BUILDING	$ 181,500
S/U TO CAST, CAST, CURE, COOL, TOOL REMOVE, TRIM FLASH	ONE (1) CAST HOUSE, FIVE (5) PITS	1,070,000
FINAL PROCESS, NDT, PAINT, INSPECT	ONE (1) PAINT BOOTH, TWO (2) OVENS, STORAGE. ONE (1) BUILDING	257,000
TOOL CLEAN, ASSEMBLY TOOLS AND STORE	40' X 100' SPRAY BOOTH. ONE (1) BLDG.	198,000
LINER PREP & FUEL SLURRY	SAME AS PRODUCTION. TWO (2) BLDG.	307,500
AP GRINDING	TWO (2) 35-IN. RAYMOND MILLS	609,977
MIX STATION	425 GALLON VERTICAL MIXER	800,000
PROPELLANT LAB	EQUIPPED AND SPRINKLERED. ONE (1) 40' X 80' BLDG.	214,400
P. A. CHEM LAB - RECEIVING INSPECTION	ONE (1) 20' X 40' BLDG. WITH CHEMICAL LAB EQUIPPED	101,200
ROADS, POWER, WATER, ETC.	LAND IMPROVEMENT	380,000
ADMINISTRATIVE, MAINTENANCE, AND SECURITY	TRAILER COMPLEX AND COMMUNICATION BLDG.	62,800
NOZZLE AND TVC ASSEMBLY TEST AND CHECKOUT	ONE (1) BUILDING	64,000
TEST STANDS	TWO (2) TEST STANDS, ONE (1) DATA ACQUISITION BUILDING	1,366,500
MAJOR FIRE PROTECTION		56,000
	TOTAL	$5,668,877

Table 3-14

EXPANSION OF EXISTING SRM FACILITIES FOR PRODUCTION
(Baseline 156-Inch Parallel Burn)

EXPANSION OF EXISTING SRM FACILITIES - PRODUCTION
(BASELINE - 156-INCH PARALLEL)

FACILITY DESCRIPTION	REMARKS	AMOUNT
RECEIVING INSPECTION - SEGMENTS	THIRTEEN (13) POSITIONS	$ 267,500
CASE PREP-CLEAN, WEIGHT LINE, CURE, INSPECT	FORTY (40) POSITIONS, TWELVE (12) OVENS	1,894,600
CAST, CURE, TOOL REMOVE AND TRIM	ONE (1) TRAVEL CAST HOUSE PER LINE. THREE (3) LINES / SIXTEEN (16) PITS.	9,599,250
FINAL ASSEMBLY	FOUR (4) BUILDINGS / PORTABLE PRINT BOOTH AND DRYER	2,614,880
MIX STATION	TWO (2) LINES, THREE (3) MIXERS PER LINE	4,416,000
ADMINISTRATIVE BUILDINGS	ADMINISTRATION, ENGINEERING, OPERATIONS - THREE (3) BUILDINGS	1,121,700
LAND IMPROVEMENT	POWER, ROADS, FENCING, HEATING, PLANTS, NITROGEN SYSTEM, FIRE	3,335,520
STORAGE	HARDTOP, FENCED AND LIGHTED. FOUR (4) ACRES UPGRADING	48,000
CAST TOOL CLEANING	CLEAN WET AND CURED PROPELLANT	163,600
PROPELLANT LABORATORY	ONE (1) LAB TO SUPPORT EACH MIX LINE	264,000
MAJOR FIRE PROTECTION	WATER STORAGE AND DISTRIBUTION, HYDRANT SUPPRESSION SYSTEM, ALARMS, FIRE PUMPS AND MOBILE EQUIPMENT	2,000,000
TOTAL FACILITY COST		$25,725,050

Table 3-15

RAW MATERIALS AND COMPONENT FACILITIES
(Baseline 156-Inch Parallel Burn)

RAW MATERIAL AND COMPONENT FACILITIES, 156 INCH BASELINE, SRM

ITEM	SUPPLIER (a)	REQUIREMENT	CAPACITY	- FACILITIES - DEVELOPMENT	PRODUCTION
CASE	ROHR CORPORATION	120/YR.	4/YR.	887,500	15,551,500
FORGING MATERIAL (D6AC)	LADISH COMPANY	10,022 (b)	AVAILABLE	NONE	NONE
ROLL FORMING	LADISH COMPANY	120/YR.	0	1,000,000	7,800,000
HEAT TREATING	ROHR CORPORATION/ CAL DORAN	120/YR.	0	180,000	750,000
FINAL MACHINE/INSULATION	ROHR CORPORATION	120/YR.	4/YR.	19,000	6,068,800
INSULATION MATERIAL	ROHR CORPORATION	1,550 (b)	AVAILABLE	NONE	NONE
NOZZLE (c)	KAISER AEROSPACE	120/YR.	0	NONE	NONE
FORGING MATERIAL (D6AC)	LADISH COMPANY	1,835 (b)	AVAILABLE	NONE	NONE
FORMING	LADISH COMPANY	120/YR.	0	NONE	NONE
HEAT TREATING/ROUGH MACHINE	KAISER AEROSPACE/CAL DORAN	120/YR.	104/YR.	NONE	NONE
FINAL MACHINE	KAISER AEROSPACE	120/YR.	0	NONE	NONE
INSULATION	KAISER AEROSPACE	1,600 (b)	AVAILABLE	NONE	NONE
LOCKSEAL	OIL STATES	120/YR.	0	300,000	1,000,000
PROPELLANT	LOCKHEED PROPULSION CO.	103,493 (b)	50,000 (b)	NONE	26,200,000
A. P. (AMMONIUM PERCHLORATE)	KERR McGEE/PACIFIC ENG.	12,538 (b)	18,000 (b)	NONE	NONE
PBAN (POLYBUTADIENE-ACRYLONITRILE-ACRYLIC ACID TERPOLYMER)	AMERICAN SYNTHETIC				
ALUMINUM (c)	REYNOLDS/ALCOA	27,192 (b)	2,500 (b)	NONE	NONE
TOTAL				2,386,500	57,370,300

(a) SUBJECT TO NEGOTIATION
(b) ADD 000, QTY's IN POUNDS
(C) FACILITIES NOT OTHERWISE COSTED WILL BE PROVIDED BY SUPPLIER

Table 3-16

TOTAL FACILITIES FOR 156-INCH BASELINE

TOTAL FACILITIES 156-INCH BASELINE SRM

($ IN MILLIONS)

	DEVELOPMENT	PRODUCTION	TOTAL
LPC AND INDUSTRY	$5.7	$25.7	$31.4
VENDORS*	2.4*	57.4*	59.8*
TOTAL	$8.1	$83.1	$91.2

* AMORTIZED IN TOTAL MATERIAL COST

3.4.2 Booster Stage Facilities Assembly and Launch

A detailed analysis of the SRM booster assembly and launch facilities must be made in conjunction with those for the orbiter and its fuel tank. From a knowledge of current operations at KSC, it appears that, with modifications and approval to use, existing facilities will be adequate for handling SRM assembly. LPC has identified the need for these facilities, and in preparing its Cost Data, Volume II, has assumed these will be supplied as GFE or are included in WBS 3.4. Table 3-17 summarizes some of the major KSC facility items.

3.4.3 Facility and Transportation Alternatives

Figure 3-7 shows a typical example of how the facilities and transportation costs (as a total) are affected by facility location, launch quantity, and launch site.

The bases for this chart are:

(1) Facility costs for a new Florida plant (68M) versus facility costs for arbitrary production of 50 percent at existing East Coast plants and 50 percent at existing West Coast plants (26M).

(2) Reduction in total launch requirements from 445 to 220 after the facility funds have been expended (1980).

(3) Change from 100-percent launch at KSC to a split between KSC and VAFB.

Based on total cost of facilities and transportation, it is apparent that the new-plant concept is least expensive for the maximum launch requirements if all vehicles are launched at KSC. However, as the requirements vary from this point in terms of reduced total quantity or the shifting of some launches to the West Coast, the new plant concept becomes less attractive.

Figures 3-8 and 3-9 show how varying the aforementioned parameters affect the annual funding requirements. The selected approach requires less annual and total funding until well into the mid 1980s. Other variations can be prepared with the same general results. These results confirm the presented LPC position that a multiple SRM production source is most desirable and efficient.

Table 3-17

FACILITIES FOR ASSEMBLY AND LAUNCH OF
156-INCH SRM AND BOOSTER STAGE

FACILITIES FOR ASSEMBLY AND LAUNCH OF 156 INCH SRM AND BOOSTER STAGE

OPERATION	BASELINE	ALTERNATIVE
TRANSPORT OF SRM SEGMENTS, NOZZLES AND STAGE COMPONENTS	RAIL/TRUCK	BARGE SRM SEGMENTS AND CLOSURES
SEGMENT STORAGE AT KSC	COMPLEX 40-41 SAS BLDG.	
SEGMENT RECEIVING INSPECTION	COMPLEX 40-41 RIS BLDG.	NEW FACILITIES AT LAUNCH COMPLEX (LC) 39
SEGMENT ENVIRONMENTAL STORAGE	COMPLEX 40-41 SRS BLDG.	
SEGMENT TRANSFER TO VAB (OR SMAB)	TRUCK TRANSPORTER	RAIL
BOOSTER STAGE STRUCTURAL/INERT COMPONENTS TRANSPORT	RAIL/TRUCK	--
MOTOR INERT COMPONENT ASSEMBLY STORAGE (MIS) BLDG.	COMPLEX 40-41 MIS BLDG.	NEW BLDG E AT LC 39
SRM BOOSTER ASSEMBLY	ON NEW MOBILE LAUNCHER (ML) IN VAB	ON ML IN NEW SMAB AT LC 39
SRM BOOSTER/ORBITER MATE	VAB HIGH BAYS	ON ML IN NEW SMAB AT LC 39
VEHICLE LAUNCH	LAUNCH COMPLEX 39	ON ML IN NEW SMAB AT LC 39

NOTE: BASELINE FACILITIES ARE ASSUMED TO BE GFE

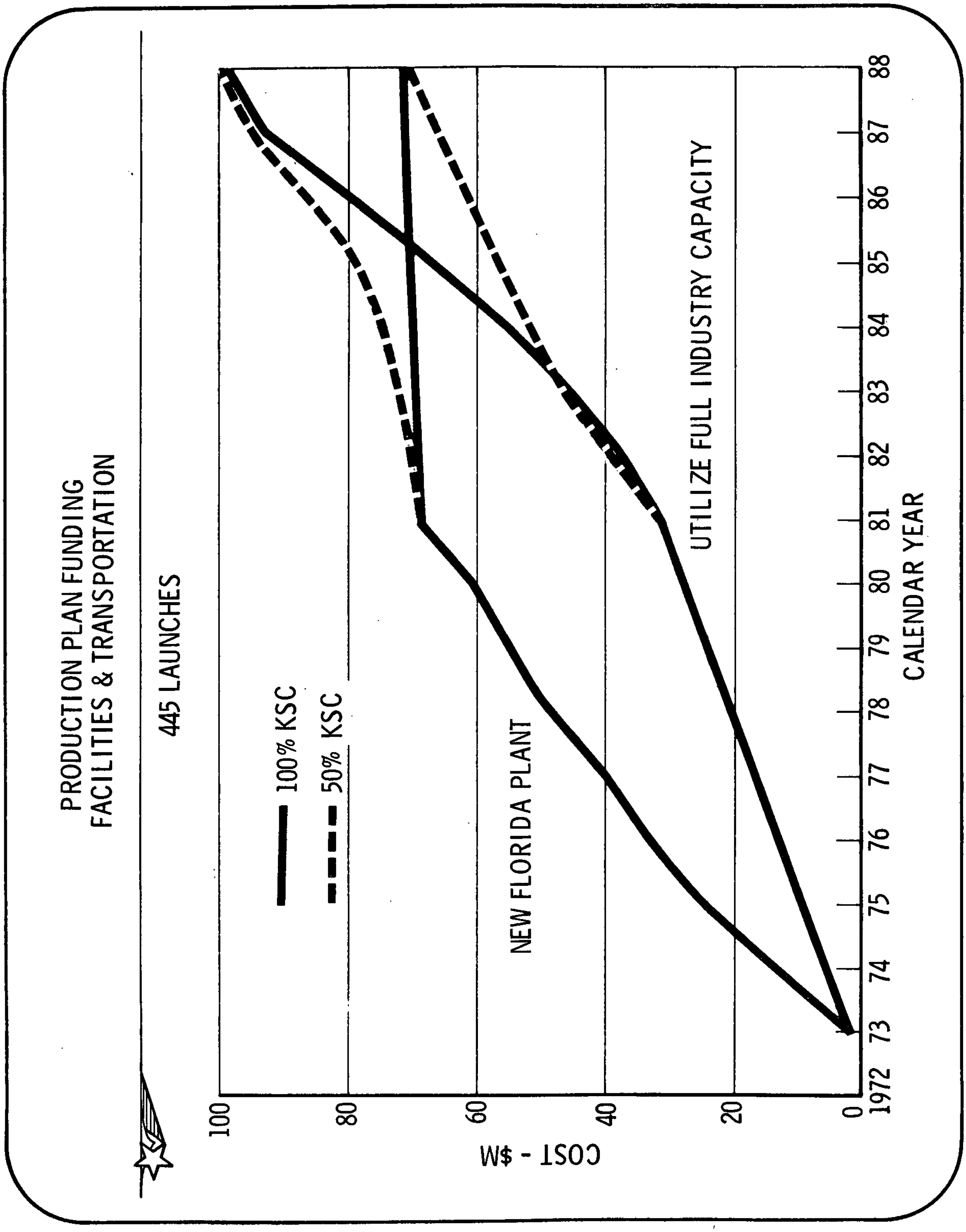


Figure 3-9 SRM Facility and Transportation Alternatives

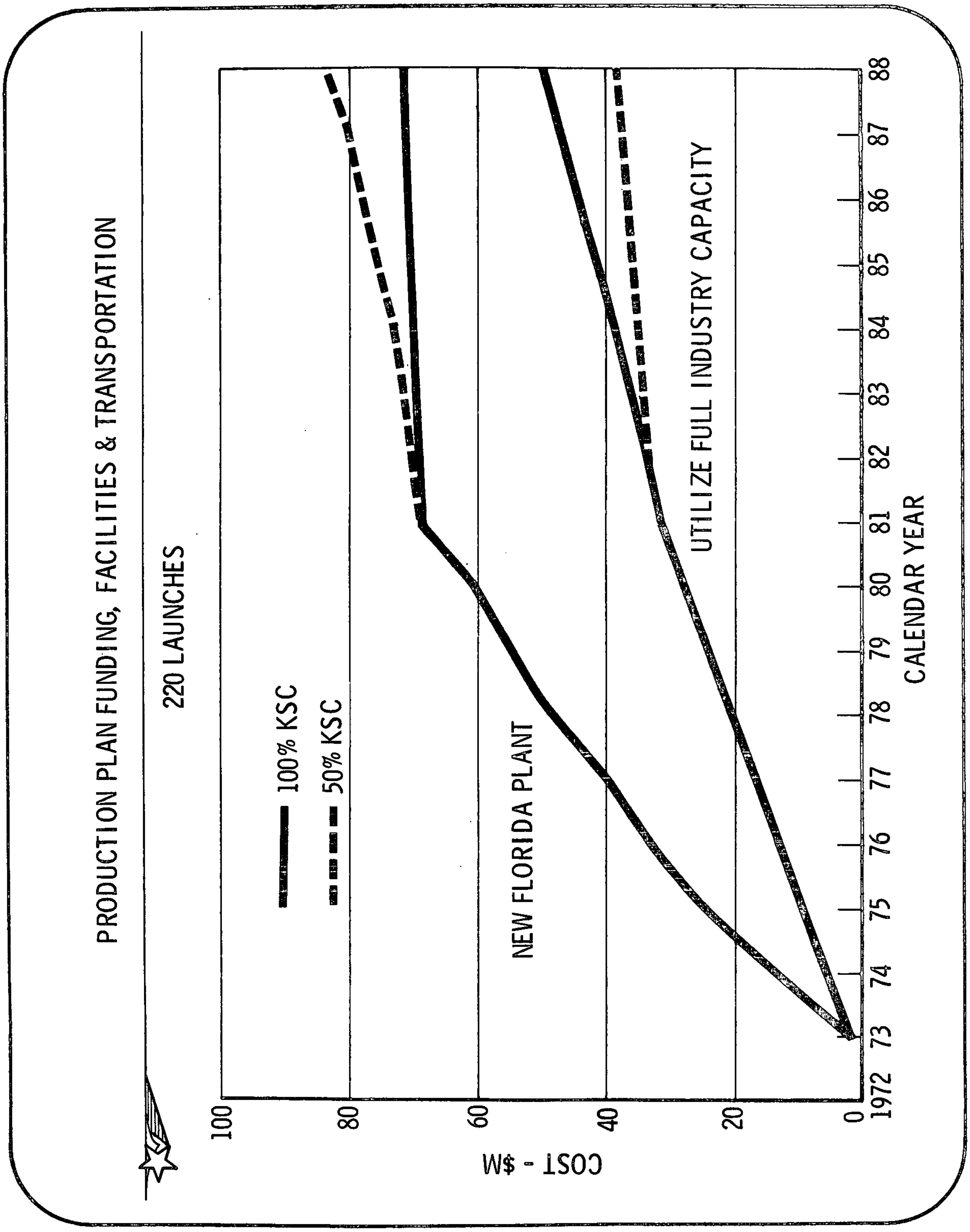


Figure 3-7 Production Plan Funding for Facilities and Transportation (220 Launches)

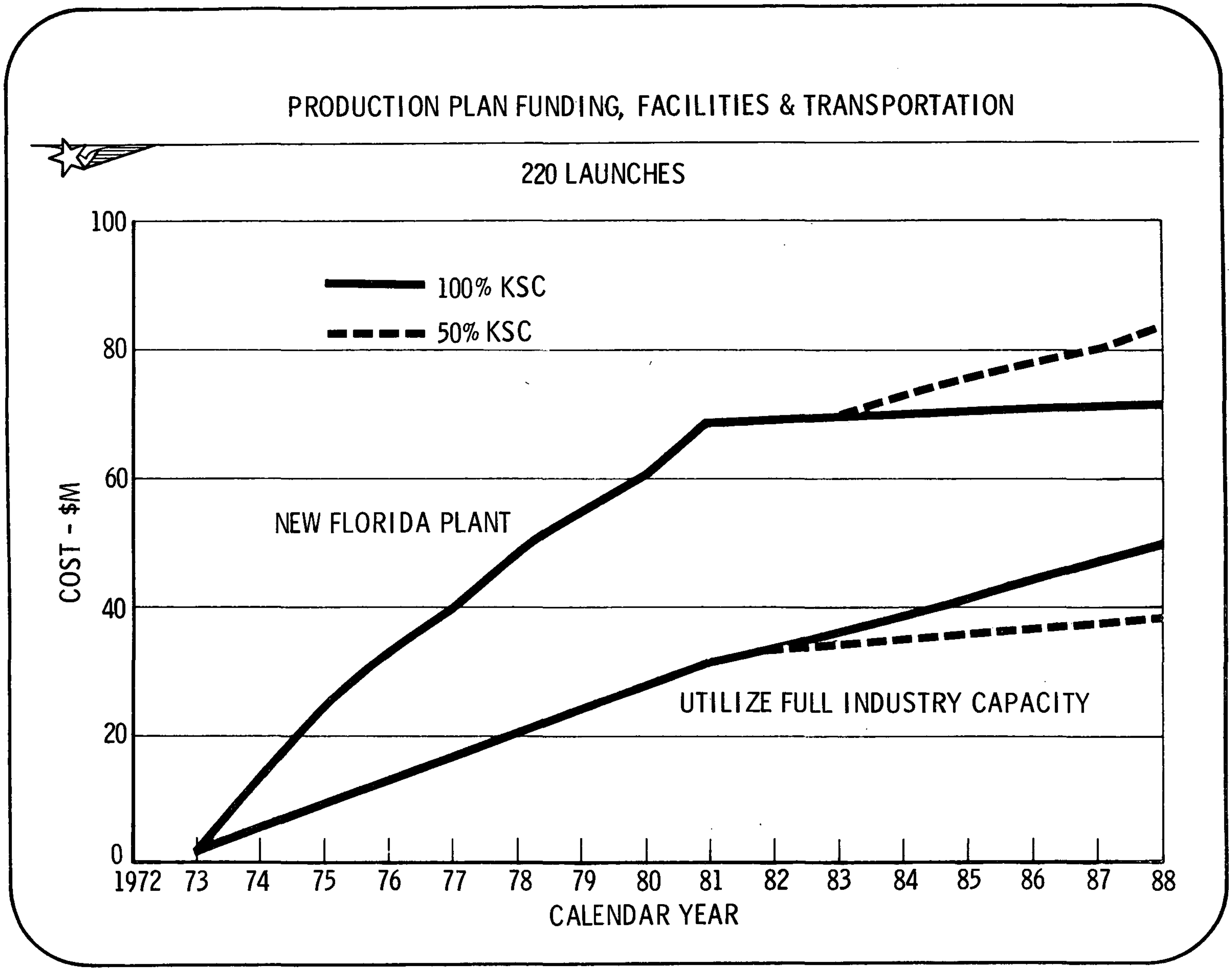


Figure 3-8 Production Plan Funding for Facilities and Transportation (445 Launches)

3.5 PRODUCT ASSURANCE

3.5.1 Product Assurance and Reliability

The approach that LPC has taken to ensure that the booster vehicle conforms to a "man-rated" level of performance is to design for high reliability using high safety factors and to conduct sufficient testing at subcomponent and full-scale levels to demonstrate that the design goals are met.

Throughout the manufacture of the vehicle, various inspection techniques will be used to ensure performance reliability. Dimensional inspection and in-process inspection in terms of process times, temperature, and other environmental conditions will be planned into the manufacturing instruction system. In-process testing of material properties, such as propellant viscosity, will be conducted in accordance with material specification requirements. Vendor-supplied components will be subjected to the same degree of quality assurance control as exercised on in-house manufacture by LPC. Some of the specific test methods are shown in Table 3-18.

Design practices that contribute to the development of a man-rated vehicle are shown in Table 3-19. Reliability apportionment for the baseline 156-inch SRM is shown in Table 3-20, and for this parallel-burn booster stage in Figure 3-10.

Reliability and Safety Engineering are both concerned with the determination of failure probabilities. The principal difference between the two disciplines is the emphasis placed upon the consequence of failure. Reliability Engineering concerns itself chiefly with the effect of failure on mission accomplishment, and Safety Engineering concerns itself primarily with the effect of failure on the safety of personnel and equipment. Because of this similarity between disciplines, safety analyses will be performed with the same techniques used in relaibility analyses. During the program, vehicle system components will be evaluated by safety engineers and reliability engineers to determine failure modes and probability of occurrence. Close integration of Reliability and Safety will be ensured by the organizational structure and also by the similarities in goals, procedures, and techniques of the two disciplines.

The malfunction modes possible for the SRM have been examined and the method of ensuring reliability and possible detection techniques have been considered. The results of this study are shown in Table 3-21.

3.5.2 Safety

This subsection presents an approach to the System Safety Plan that LPC will prepare for the booster system. The approach is submitted in response

Table 3-18

QUALITY ASSURANCE TEST METHODS

QUALITY ASSURANCE TEST METHODS

SRM PROPELLANT GRAIN	FM MICROWAVE*
SRM INSULATION	FM MICROWAVE* ULTRASONICS
SRM NOZZLE PLASTICS	FM MICROWAVE* ULTRASONICS
SRM IGNITER PROPELLANT	X-RADIOGRAPHY
VEHICLE STRUCTURAL WELDS	X-RADIOGRAPHY LIQUID PENETRANT MAGNETIC PARTICLE
VEHICLE PRESSURE VESSELS	HYDROSTATIC PRESSURIZATION
SRM ASSEMBLY	LOW PRESSURE LEAK

* NASA-DEVELOPED TECHNIQUE

Table 3-19

SRM MAN-RATING DESIGN PRACTICES

SRM MANRATING - DESIGN PRACTICES

SYSTEM ORIENTED SRM DESIGN FEATURES

- THRUST TERMINATION FOR ABORT
- PERFORMANCE ANOMALY SENSORS ON SRM
- SRM "INSTANT TURN-ON" HOLDS LAUNCH COMMIT TO T-1 SEC
- SRM CASE PROVIDES BASIC BOOSTER STRUCTURE

SRM BASE-LINE DESIGN FEATURES

- PROVEN CASE DESIGN/MATERIALS/ FABRICATION METHOD
- PROVEN PROPELLANT AND INSULATION
- PROVEN NOZZLE DESIGN/MATERIALS
- PROVEN TVC SYSTEM APPROACH
- PROVEN IGNITION SYSTEM
- AVIONICS AND DATA COMPLEXITIES ON ORBITER

SRM SAFETY FACTORS

- 1.4 MEOP ULT ON CASE
- 1.15 MEOP PROOF TEST ON CASE
- 2.0 ON NOZZLE ABLATIVES
- 2.0 ON CASE INSULATION
- 2.0 ON TVC PRESSURE TANKS, VALVES
- 2.5 ON TVC PLUMBING

REDUNDANT SUBSYSTEMS

- IGNITION CONTROL AND COMMAND
- THRUST TERMINATION CONTROL AND COMMAND
- TVC ACTUATION/VALVING
- ELECTRICAL CONTROL/DATA SENSING

DEVELOPMENT/QUALIFICATION PROGRAM

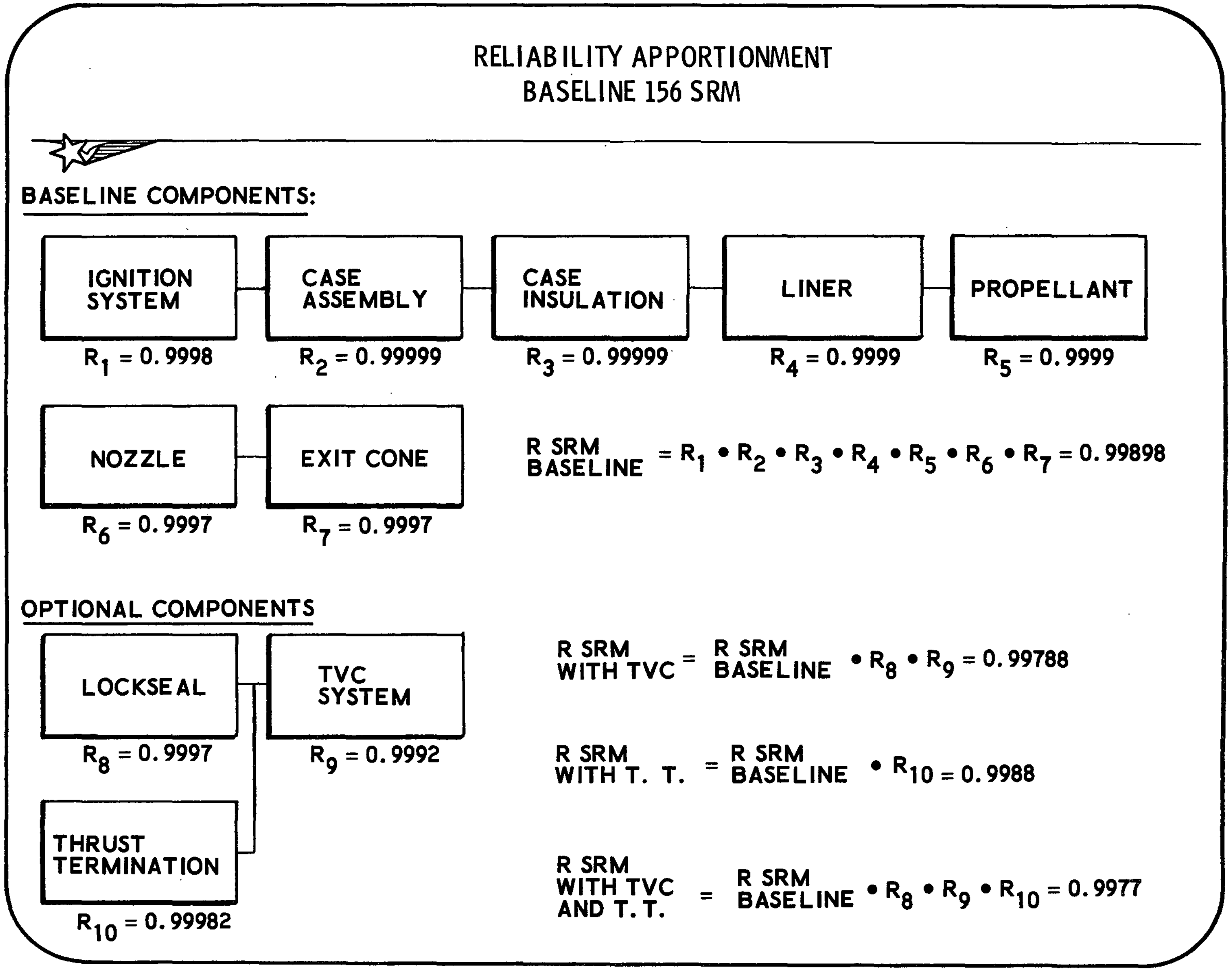
- MAJOR COMPONENTS DEVELOPED/QUALIFIED SEPARATELY PRIOR TO FULLSCALE PROGRAM
- PROGRAM OF 5 DEVELOPMENT AND 4 PFRT MOTORS
- PROGRAM OF 3 FACILITY QUALIFICATION MOTORS

SRM RELIABILITY FACTORS

- LARGE SIZE "SMOOTHS" VARIABILITY OF PROCESS
- SEGMENTING ALLOWS REJECTING AT MINIMUM COST IMPACT
- SRM SIMPLIFIES HUMAN ELEMENT IN BOOSTER ASSEMBLY
- USE OF PREVIOUSLY QUALIFIED COMPONENTS
- USE OF PROVEN, TESTED METHODS FOR NON-QUALIFIED COMPONENTS OR SUBSYSTEMS

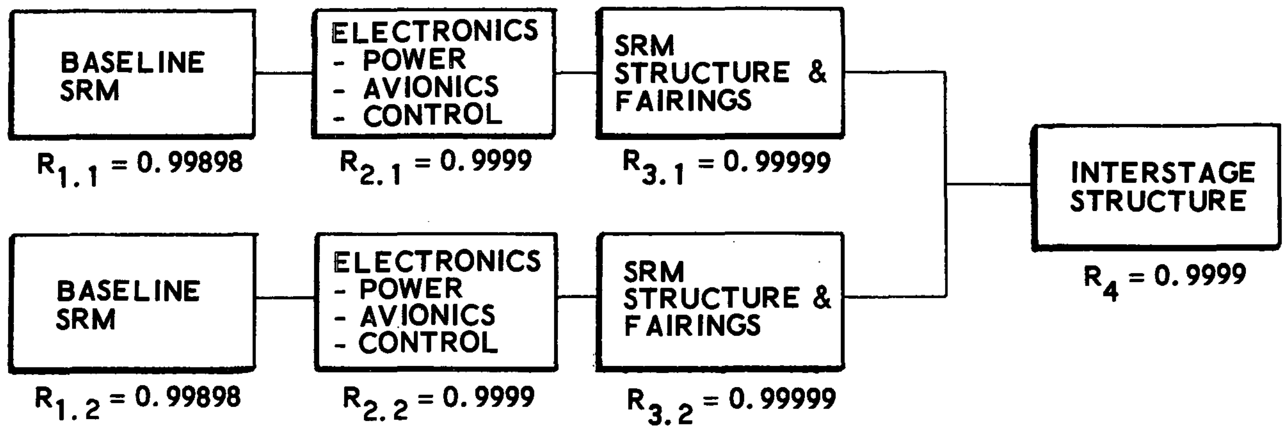
Table 3-20

RELIABILITY APPORTIONMENT FOR BASELINE 156-INCH SRM



2 ④

RELIABILITY APPORTIONMENT
SRM PARALLEL BURN BOOSTER



$$R_{\substack{\text{STAGE}\\\text{BASELINE}}} = \left[R_{1.1} \bullet R_{2.1} \bullet R_{3.1}\right]\left[R_{1.2} \bullet R_{2.2} \bullet R_{3.2}\right] R_4 = 0.99764$$

WHEN $R_{1.1,\ 1.2} = 0.9977$, (ie with TVC & T.T.) $R_{STAGE} = 0.9950$

NOTE: SRMS ARE PARALLEL BUT NOT REDUNDANT, THEREFORE PROBABILITY MUST BE CALCULATED AS A SERIES EVENT

Figure 3-10 Reliability Apportionment for SRM Parallel-Burn Booster

Table 3-21

SRM MALFUNCTION MODES AND DETECTION METHODS

Malfunction	Analysis of Mode	Reliability Assurance	Possible Detection Methods
1. Failure of motor to ignite	Solid propellant will ignite readily when subjected to a combination of heat and pressure for a reasonably short time	1. Dual electrical circuits 2. Dual initiators 3. Sustained impulse to the motor igniter 4. Sustain burning of the igniter charge 5. Conservative design	1. Breakwire across nozzle closure 2. Preset pressure switch to register acceptable ignition pressure limit
2. Propellant grain crack	A propellant grain crack exposes added surface area for burning and premature exposure of the chamber wall	1. Internal port is highest stress in the grain and therefore easily inspected 2. Motor is designed for very low grain stress	Pressure sensor to detect large motor overpressure
3. Motor case overpressure	Additional burning surface causes high operating pressure	1. Safety factor allows for very large increase in surface area without failure 2. Surface area increase necessary to overpressure the chamber is easily detected before firing. 3. Grain stresses are reduced when motor chamber pressurizes and grain burns	Pressure sensor to detect large motor overpressure
4. Joint leakage	Chamber joint leaks during firing because of seal failure	1. Basic joint integrity will be proven during hydrotest of segment 2. Low-pressure leak check will be performed to ensure seal integrity before launch 3. Joint insulation will be designed for 100% safety margin and demonstrated during DDT&E 4. Proven design practice will be applied to joint design	Hot gas leak through O-ring seal can be detected by placing breakwire in groove of case joint immediately adjacent (outside) of O-ring groove
5. Inadvertent ignition	Motor ignites because of stray electrical signal or thermal input	1. High-energy initiation system avoids stray energy problem 2. Motor is sealed with a thermally insulating closure in the nozzle 3. Case thickness and liner insulates grain against accidental heat input to motor case	Thrust neutralization could be immediately established by countdown preset
6. Failure of thrust vector control system	Thrust vector control system failure causes unwanted vector or inoperable system	1. Redundant actuation systems are specified 2. System failure will cause nozzle to return to null 3. Conservative cold-gas design is used	Sensor on cold-gas pressure system and feedback position sensor on nozzle could identify TVC failure. Backup pressure system then returns nozzle to null position
7. Nozzle throat structural failure	Nozzle throat is ejected, leading to low motor pressure, offset thrust vector, and nozzle structural failure	1. Conservative design is specified 2. Proven processes and material are used 3. Very large changes in throat are required to affect motor pressure 4. NDT inspection of the nozzle will be performed	Thermocouple monitoring of the nozzle exterior at selected areas could identify gross loss of throat/exit cone components or Lockseal malfunctioning
8. Unbond of insulation or grain	Unbond provides a path for gases, which leads to unplanned heating of the chamber	1. Grain bond strength is very high relative to stresses through use of proven materials and processes 2. NDT inspection of all insulation bonds will be performed 3. Visual inspection of grain bonds will be performed	Thermocouple monitoring of selected areas of motor exterior could identify unacceptable internal insulation functioning
9. Unbond of Lockseal	Lockseal elements unbond from reinforcements, causing leakage or failure of the seal	1. Lockseal element is in compression during firing 2. Lockseal will be subjected to bench test before installation on nozzle to ensure integrity of bonds 3. Lockseal element will be pressure-tested before installation on motor 4. Unbond of Lockseal will not cause failure	See Item 8 above
10. Inadvertent or nonfunction of thrust neutralization ports	Lack of proper function will cause compromise of abort system or premature thrust neutralization	1. Redundant electrical circuitry 2. High-energy initiation system 3. Redundant initiators 4. Conservative design practice	Breakwire system on interior or exterior of each TT port

to paragraph 4.1.1 "System Safety Analysis", of the NASA Study Work Statement. The System Safety Program Plan will:

- Present the system safety criteria, complete with definitions, hazard categories, and a discussion of system safety procedure
- Define and summarize the system safety tasks, i. e. , Hazard Analysis reports, corrective action reports, reviews and audits, and safety surveillance
- Define and explain system safety organization, authority, responsibilities, and implementation required to complete the system safety tasks

The basic objective of this plan is to establish a sound approach to SRM System Safety. The system safety objectives are to insure that:

- Safety consistent with mission requirements is designed into the system.
- Hazards associated with each system, subsystem, and equipment are identified and evaluated, and eliminated or controlled to an acceptable level.
- Minimum risk is involved in the acceptance and use of new materials and new production and testing techniques.
- The historical safety data generated on similar system programs will be considered and used where appropriate.

The following document will be used as a guide in preparation of this plan:

OMSF SAFETY PROGRAM DIRECTIVE NO. 1A "System Safety Requirements for Manned Space Flight", dated December 1969.

To maximize the inherent safety of the SRM, the items listed below will be accomplished during the design phase:

- Design for minimum hazard.
- Use redundant subsystems for ignition control and command, thrust termination control and command, TVC actuation/valving, and electrical control data sensing.
- Ensure careful selection of propellant system and pyrotechnic materials for SRM and igniter assembly.

- Select adequate safety factors, such as:

  1.4 MEOP ultimate case strength

  1.1 MEOP proof test on case

  2.0 on nozzle ablatives

  2.0 on case insulation

  2.0 on TVC pressure tanks, valves

  2.5 on TVC plumbing

The basic System Safety tasks that will be addressed are defined in the following paragraphs.

Gross Hazard Analysis. The Gross Hazard Analysis is a comprehensive, qualitative, nonmathematical assessment of the safety features of the subsystem. Hazardous areas to be considered may include, but not be limited to, the following:

- Isolation of energy sources
- Propellants: characteristics; hazard levels; handling, storage, and transportation safety features
- System environmental constraints
- Explosive devices and their hazard classification
- Compatibility of materials
- Human factors
- Effect of transient current and radio-frequency energy
- Personnel training pertaining to safe operation and maintenance of the system

The Gross Hazard Analysis will precede and serve as a basis for the Hazard Analysis.

Hazard Analysis. The Hazard Analysis will determine, from a safety standpoint, the functional relationships of components and equipments comprising each subsystem. The analysis will identify all components and equipment in which performance degradation or functional failure could result in hazardous conditions. The analysis will include a determination of the modes of failure and the effects on safety when failures occur in subsystem components.

3.6 LOGISTICS

3.6.1 Booster Vehicle Logistics

Lockheed Propulsion Company has examined the logistics of the SRM booster at KSC, and has determined that all operations can be handled with safety and within the turnaround launch schedule desired. After receiving inspection, inert and live components will be stored separately in appropriate areas. Assembly and checkout of major subsystems (such as TVC and electrical controls) will be conducted off-line to reduce assembly time. Figure 3-11 shows the SRM Booster Vehicle flow plan at KSC.

On the basis that the Space Shuttle Vehicle will be assembled off-site and transported to the launch pad on a GFE mobile launcher, a launch-to-launch time span of 12 days is proposed for the booster phase of the launch operation. This schedule, Figure 3-12, is consistent with the following constraints:

(1) Booster buildup based on three 6- to 8-hour shifts per day, 7 days per week

(2) Three new GFE mobile launchers (ML); to replace existing LUTS

(3) SRM buildup on ML in VAB high bays

(4) The VAB high bays utilized for SRM booster/orbiter assembly

(5) Two launch pads

(6) Parallel-burn type Shuttle Assembly

Numerous logistics and handling conditions existing for each option (Table 3-22) are possible. Study will be required (in coordination with all systems contractors) to evaluate the approaches and to determine the optimum solution.

3.6.2 SRM Booster Logistics Spares

The spares listed in Table 3-23 are the quantities required at the launch site for replacement of damaged items and to facilitate their immediate availability for launch assembly. No spares are included for the development program because needed extra parts can be obtained by refurbishment of fired components. In addition to these spares, LPC has included a certain quantity of spares for in-process replacements.

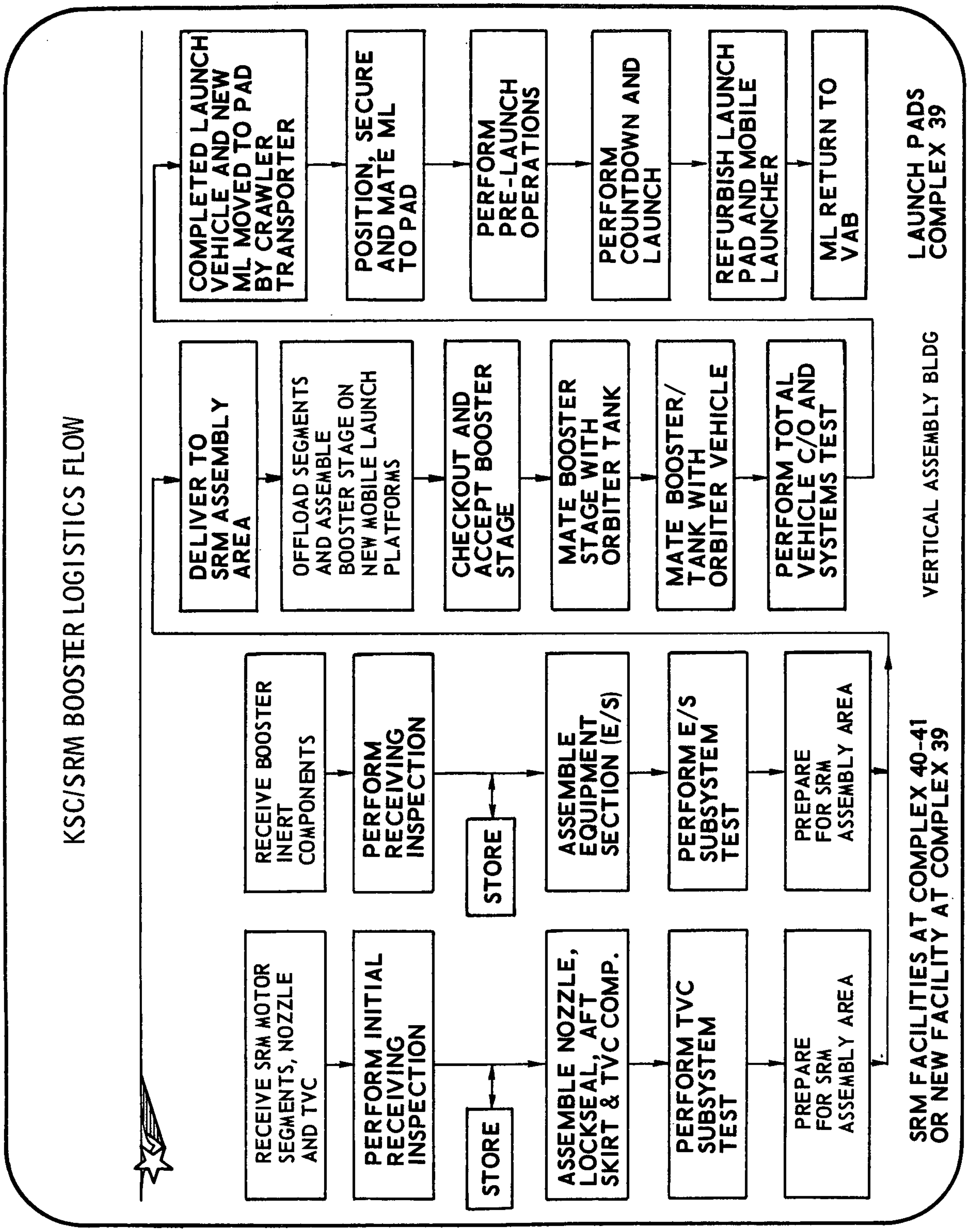


Figure 3-11 KSC SRM Booster Logistics Flow

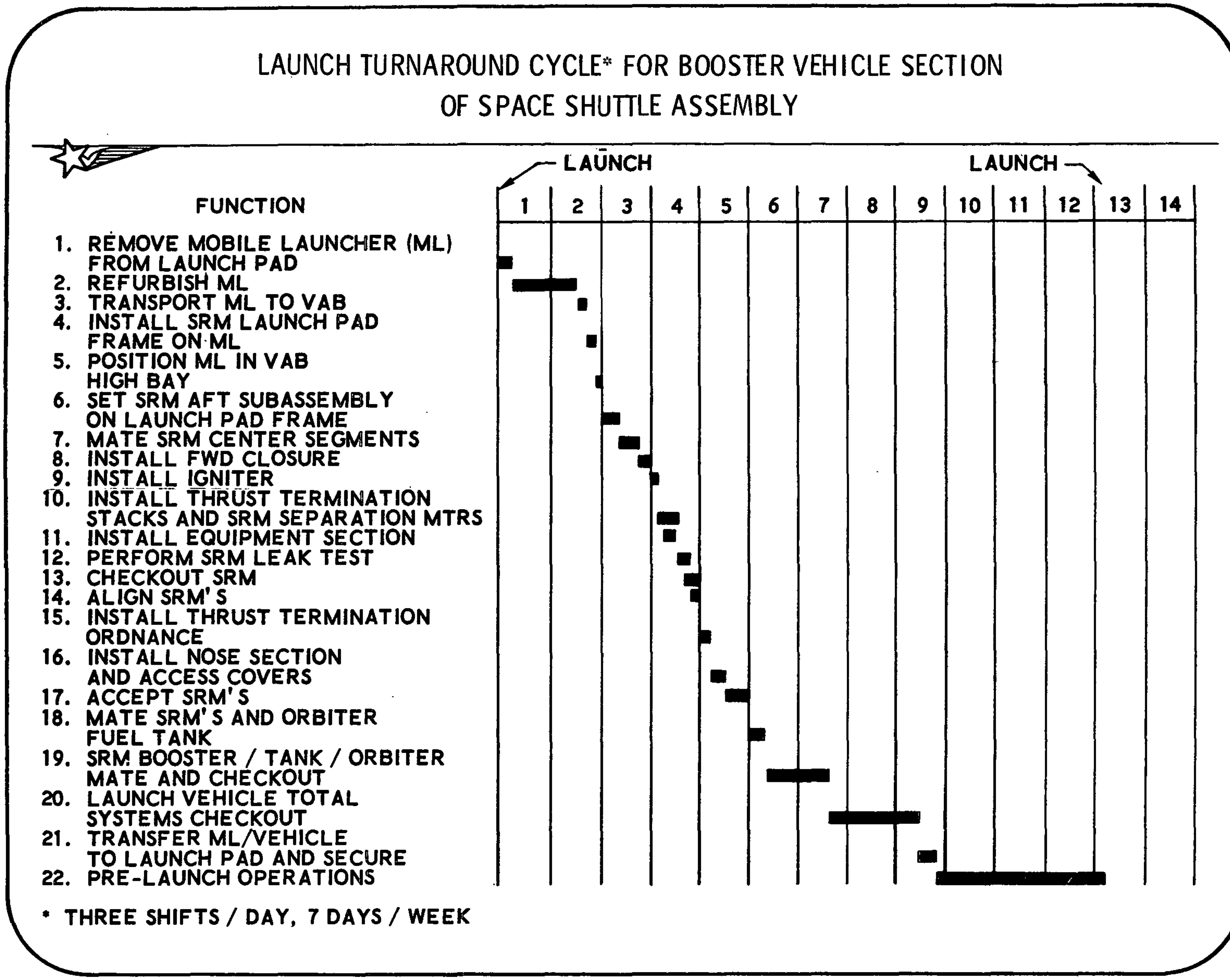


Figure 3-12 Launch Turnaround Cycle for Booster Vehicle Section of Space Shuttle Assembly

Table 3-22

LOGISTICS OPTIONS

LOGISTICS OPTIONS

CHECKOUT - MAXIMUM LAUNCH RATE, MANUAL VS AUTOMATIC AT FACTORY AND KSC

SRM SEGMENT/CLOSURE TRANSPORTATION TO KSC - RAIL VERSUS BARGE

KSC SRM FACILITIES - USE COMPLEX 40-41 SRM BUILDINGS VS NEW BUILDINGS AT COMPLEX 39

KSC SRM SEGMENT TEMPERATURE CONDITIONING - DETERMINE IF REQUIRED

KSC INTRA-PLANT SRM SEGMENT TRANSPORT - RAILROAD CARS VS TRUCK TRANSPORTER/HANDLER

SRM STAGE ASSEMBLY - MODIFIED LUT's OR NEW MOBILE LAUNCHER ON MOBILE LAUNCHER IN VAB OR EXISTING/NEW SMAB

Table 3-23

SRM BOOSTER LOGISTICS SPARES

Item No.	Description	Quantity
1	Case	
	Center segments (center-perforated grains)	4
	Aft end	1
	Forward end	1
	Aft segment (star grain)	2
2	Nozzle	
	Exit cone	2
	Throat segment with Lockseal	2
3	Igniter	
	Initiators	3
	Subigniters (Pyrogen)	3
	Case/grain subassembly	3
4	Thrust Termination	
	Linear shaped charge	2
	Detonator	2
5	TVC	
	Actuators	2
	Power supply	2
6	Miscellaneous	
	(Extra storage containers, seals, repair glue, electrical connectors, pins, wire, paint, etc)	

3.6.3 Logistics Support Maintenance

Logistics Support Maintenance is a composite of the elements necessary to ensure the effective and economical support of the SRM booster at all levels of maintenance. These include such activities as Maintenance Planning, Support and Test Equipment, Transportation and Handling, and Technical Data.

Maintenance planning will establish concepts and requirements for each level of equipment maintenance to be performed. It will define the actions to maintain the designed system and equipment in its prescribed state of operations, including checkout, servicing, status monitoring, inspection, fault isolation, replacement, modification, and overhaul. The degree to which these various functions are to be performed by organizational, intermediate, or launch-site-level maintenance will be specified.

Maintenance engineering analysis documentation will provide:

- Identification and description of tools, test equipment, facilities, personnel, spares, repair parts, and technical data
- Quantification of most maintenance support needs by time and place
- Personnel requirements analysis by skill, type and number
- Facilities loading to establish adequacy and utilization

The support and test equipment program will ensure that the required support and test equipment is available to the operating personnel, and supporting maintenance will be supported by equipment identified or developed concurrently with the prime system and equipment. Support and test equipment will consist of tools, metrology and calibration equipment, monitoring and checkout equipment, maintenance stands and handling devices, which are categorized into special (peculiar to the system under development) and common (commercially available or currently available at the launch assembly/site).

A technical data program will be established to provide for the timely development and distribution of technical data necessary to conduct operations, training, maintenance, supply, modification, repair, and overhaul of the systems and equipment to provide the link between personnel and equipment. It includes drawings; operating, maintenance, and modification instructions; provisioning and facilities information; specifications; inspection, test, and calibration procedures; instruction cards and equipment placards; special purpose computer programs; and other forms of audio/visual presentation required to guide people performing operations and support tasks.

Section 4

PROGRAM MANAGEMENT

A strong central program organization has been structured to manage the Space Shuttle SRM Booster Vehicle efforts at LPC. Figure 4-1 shows the relationship of the Program Office to the functional branches of the company.

To provide the desired degree of control, a dual approach to the organization is utilized, structured vertically according to function and horizontally by product line. This approach provides a direct, clear-cut line of authority from the president of the company to the Booster Program Manager and makes available to the program office the resources of the entire functional organization. Each functional branch contributes to the program tasks, with the Program Manager providing direction and control. This approach results in efficient use of manpower, improved performance, and lower costs by providing flexibility in the allocation of company resources. It is being used on all current LPC programs.

The proposed Booster Program organization is based on a minimum of program office personnel, with maximum use being made of the functional organizations to perform tasks as a part of the team. A small staff function will perform tasks associated with overall direction of the program, including technical, manufacturing, cost controls, schedule requirements, contract compliance, quality assurance, and advance planning. Specific tasks are described in the following subsections.

Program plan. The Program Office will prepare and maintain a program plan. This document will describe the required contractual scope of work and define the implementation responsibilities of all LPC organizations. A program master schedule will be prepared and maintained as part of the program plan.

Additional program directives will be prepared and released to supplement or revise the program plan as necessary. The plan will be updated periodically to incorporate these releases.

Manufacturing operations. Program Management will provide direction to the manufacturing organization and will monitor the processing of all propulsion subsystems, associated components, and related tooling and facilities. This activity will include a liaison function with major component suppliers to ensure compliance with program requirements and to implement timely corrective action in the event of any indicated deviation.

The Program Office will direct preparation of master schedules and monitor the functional branch organizations in developing detail schedules and programming commitments.

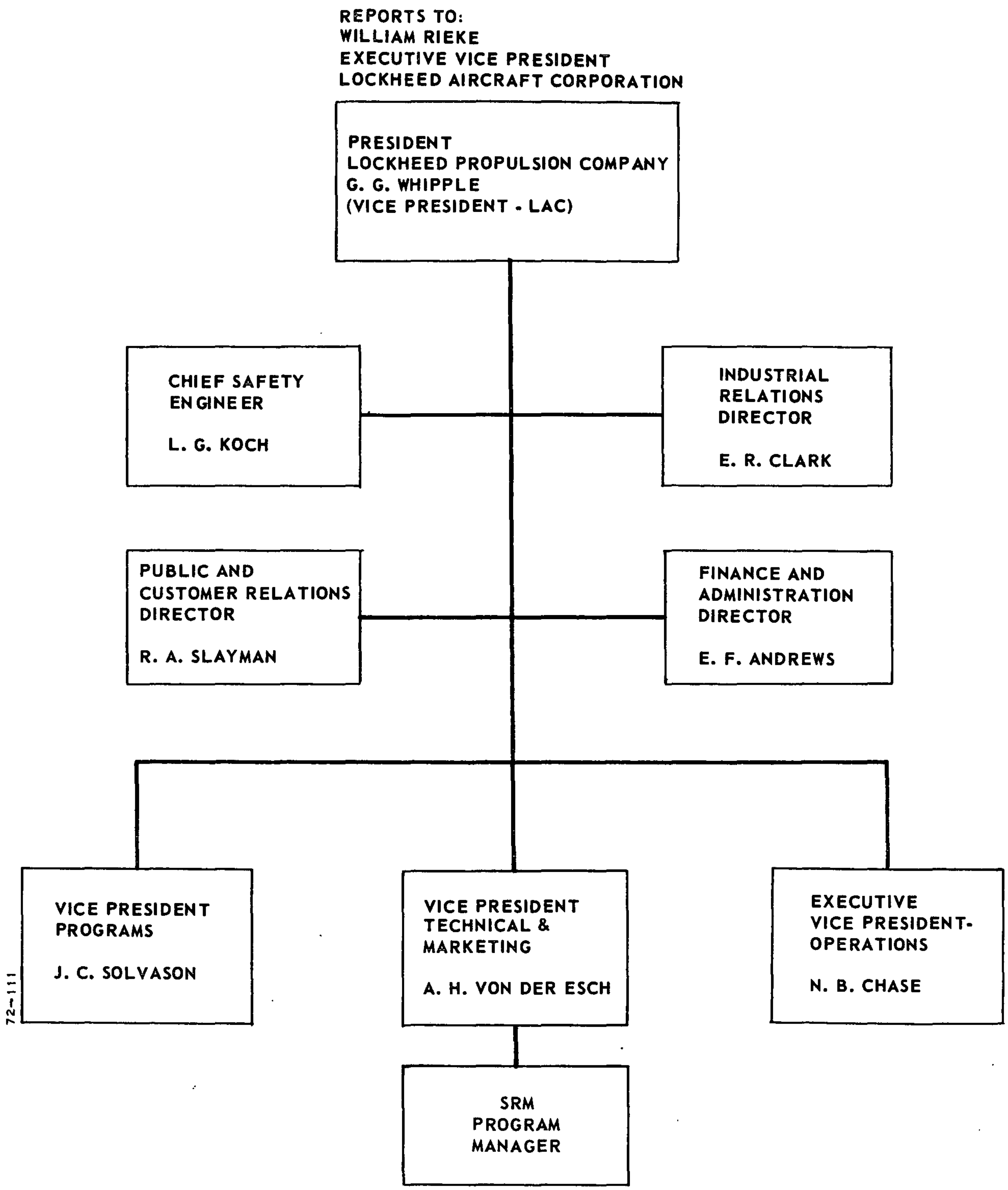


Figure 4-1 Lockheed Propulsion Company Organization

Technical compliance. The program technical organization will review drawing releases, design changes, and supplier change proposals (SCPs) to ensure that the configuration of all deliverable end items complies technically with contract requirements. Technical cognizance will also be maintained over all production facility qualification and lot acceptance testing of propulsion subsystems and related components.

Program controls. Program controls will continually measure and evaluate performance of program tasks against the established plan. The program master schedule will be closely monitored to ensure that all milestone objectives are adequately identified, programmed, and controlled. Line-of-balance reports will be maintained. Program budgets for functional organizations will be established and monitored. This activity will include approval of detail program work orders (PWOs) for specific tasks within the work scope of each organization.

Program Office personnel will prepare and maintain program management review charts to track actual performance against planned objectives.

Configuration control. The Program Office will administer a configuration control plan and will chair the Design Change Committee (DCC) in the coordination and programming of all design changes. Supplier requests for instruction (SRIs), other than those handled by the Material Review Board, will be coordinated by the DCC under this chairmanship.

Data and correspondence. The Program Office will regularly review all incoming customer correspondence and direct required response action. Outgoing correspondence and all contractual reports will be reviewed and approved to ensure the timely and cost-effective delivery of all contract data items.

Contract changes. The Program Office will review all contract change notices, direct all related implementation and cost proposal preparation efforts, and participate in contract negotiations resulting therefrom.

4.1 TECHNICAL MANAGEMENT

Responsibility for direction of all design and development operations is vested in the SRM Chief Project Engineer, who supports the SRM Program Manager. A staff of senior project engineers will report to the SRM Chief Engineer. They will direct the major individual subsystem designs and development efforts.

4.2 MANUFACTURING

The manufacturing tasks will be performed by the Operations Branch, a functional organization of the company. The SRM Manufacturing Manager assigned to the program supports the Program Manager and his staff on production matters and is responsible for all program effort performed by his functional support organizations. The Operations Branch tasks include fabrication, processing, assembly, production planning, tooling, manufacturing engineering, industrial engineering, production control, procurement, and material operations and controls.

4.3 PRODUCT ASSURANCE

The quality assurance and test operations functions will be performed by the Product Assurance Branch, a functional organization of the company. The Booster Product Assurance Manager provides support to the Program Manager and is responsible for all SRM tasks performed by his functional organization. The primary Product Assurance tasks include quality and reliability engineering, supplier product assurance, inspection and non-destructive testing, and all product test operations including component tests as well as full-scale motor tests at LPC's Potrero Proving Ground.

4.4 KSC OPERATIONS

An Operations Manager reporting to the LPC SRM Program Manager will be located at KSC to perform SRM assembly operations and support the integration of the SRM into the Space Shuttle Vehicle for launch operations. The LPC KSC Operations Manager will direct the efforts of an integrated team of engineers, technical specialists, test personnel, and manufacturing specialists in performing all SRM and booster vehicle prelaunch operations at KSC.

4.5 PROJECT REPORTING AND CONTROL

Phase C project planning includes the preparation and publication of the following documents. Included within this effort are general program, project, and motor hardware associated data packages. Initial format and content guidelines are assumed to be in conformance with NASA SP-7013, "NASA Publications Manual" (Technical Contractor Reports) and MIL-STD-100, "Engineering Drawing Practices" (Engineering Drawings). Typical reporting is as shown below:

Project Technical Reporting

- Informal letter technical status reports (monthly)
- Technical Progress Reports (quarterly)
- Technical Report (final)
- Environmental Impact Statement

Project Fiscal Reporting

- Contract Fiscal Status (monthly)

Project Management Reporting

- Executive Summary (semiannual)

Project Planning Documents

- Detailed Phase D Acquisition Plan
- System/Subsystem Project Task Plans
- Project Management Plan
- Facilities Plan
- Special Test Equipment and Tooling Plan
- Manufacturing Plan (total project plan with detailed major components/hardware plans)
- Ballistic Test Plan (integrated project plan with detailed booster auxiliary motor test plans)
- Configuration Management Plan
- Logistics Supply and Maintenance Plan
- Quality Assurance and Reliability Plan (total project summary with detailed system/subsystem and/or hardware end item plans)
- Alternate Subsystems Development Plan

In conformance with current LPC practice under Government contracts, selected reviews are planned with NASA project personnel during the course of Phases C and D. Planned reviews judged necessary to the program are noted below:

- Executive Technical Summary Review (semiannual)
- Technical Reviews (as required) on specific components/subsystems
- Technical Interchange and Program Status Reviews (monthly)
- Production Status Review (monthly)

In addition to the above NASA reports and program reviews, a Preliminary Design Review and Critical Design Review of the SRM Booster Vehicle will be held at an appropriate program date.

Lockheed Propulsion Company also has a prescribed system of in-house program and design reviews by management and technical specialists to ensure that all objectives of the program are being attained.

Section 5

SCHEDULES

Figure 5-1 depicts a preliminary planning schedule for the conduct of Phases C and D. Phase C, Design, is planned as a 9-month effort. It is assumed that a substantial Phase B, Definition, effort will precede the initiation of Phase C.

Phase D, Development/Operations (including production for 440 launches) would take approximately 15 years from initiation through the completion of deliveries and operation support for the last flight.

The schedules shown are representative of a conservative approach to the conduct of the program and could be termed middle-of-the-road. Certain schedule economies can be instituted if shortened time spans are desirable, or, conversely, a schedule stretch-out can be accommodated, both without any significant change in cost.

Key dates after authority to proceed (ATP) are noted below:

Item	Months after ATP
Complete Phase C	9
Phase D	
SRM PDR	22
SRM CDR	49
First unmanned flight	63
First manned flight	69
Fifth manned flight	77

In summary, LPC is confident the NASA schedule requirements can be met.

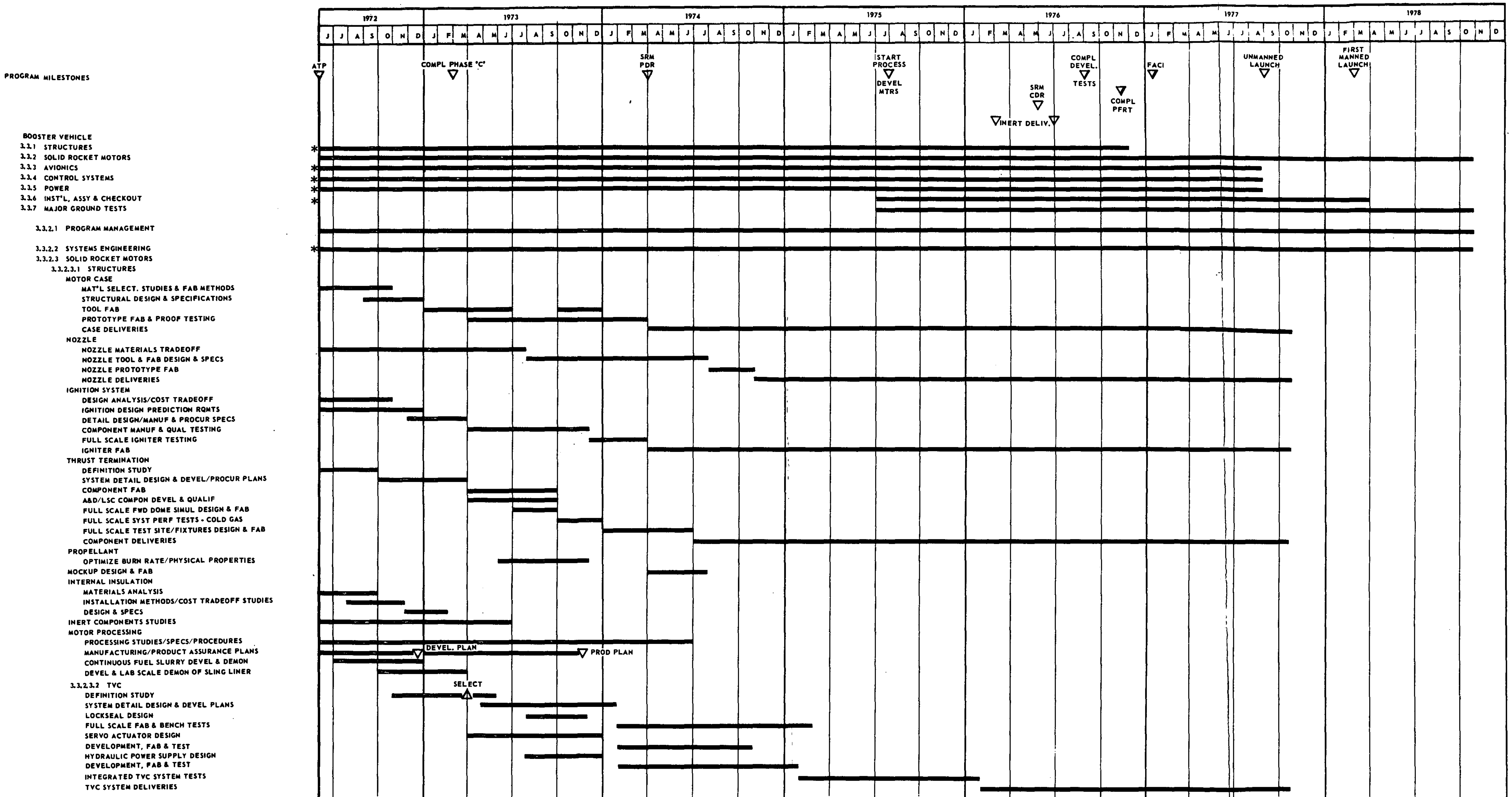


Figure 5-1 Program Schedule
(Sheet 1 of 2)

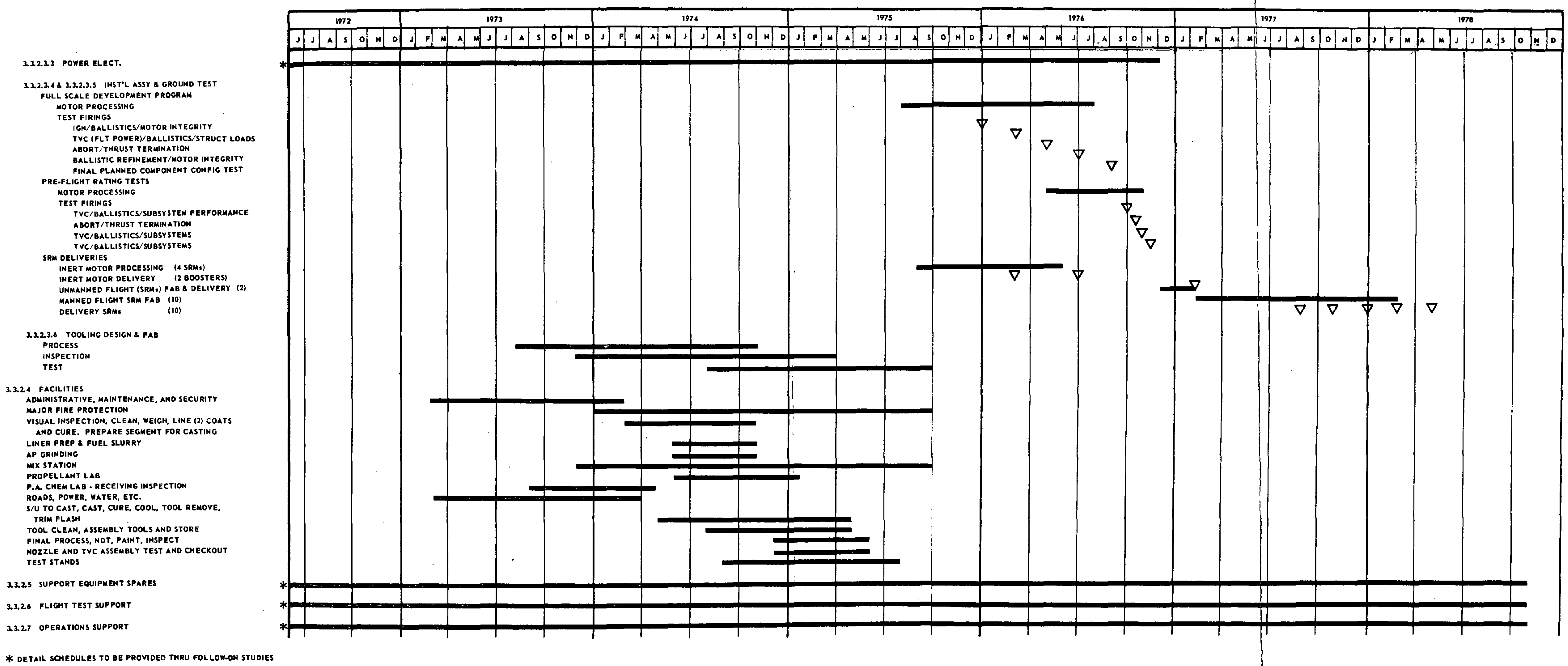


Figure 5-1 Program Schedule (Sheet 2 of 2)