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DATA REQUIREMENT SE-02
FINAL REPORT

CR-123616

TECHNICAL REPORT

MASS PROPERTIES REPORT

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
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ABSTRACT

This Mass Properties Report presents data for the LPC baseline 156-7 SRM (Parallel Burn) and the alternate 156-6 SRM (Series Burn). Design ground rules and assumptions applicable to generation of the mass properties data are described together with pertinent data sources.

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FOREWORD

This document is Volume IV, Mass Properties 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

Section 1

INTRODUCTION

Mass properties data are presented for LPC's baseline 7-segment, 156-inch diameter SRM (Parallel Burn) and for the alternate 6-segment, 156-inch diameter SRM (Series Burn). As described in other volumes of this report, LPC selected as its baseline, the 156-inch parallel burn SRM because it is the most cost effective approach to satisfy the NASA Phase B study requirements.

Weights for the thrust termination system, thrust vector control system, and insulation/liner system are conservative. For the latter two components, this conservatism stems from the selection of a safety factor of 2 for the TVC pressure vessel design and for insulation ablation rate and thermal protection requirements. For the thrust termination system, conservatism was inherent in the specific prediction equation used to calculate the weight of this component.

Section 2

GROUND RULES AND ASSUMPTIONS

The following ground rules and assumptions were used as data sources for mass properties of the selected baseline and alternate designs.

2.1 MOTOR CASE

A maximum expected operating pressure of 1000 psia and an ultimate safety factor of 1.40 were used.

The case material has a biaxial ultimate tensile strength of 252,000 psi, and a density of 0.283 $lb/in.^3$ Uniaxial properties are 225,000 psi minimum ultimate, and 205,000 psi minimum yield strength.

2.2 INSULATION

Insulation thickness is based on a safety factor of 2.0 on ablation rate and thermal protection thickness for a backside temperature rise of 100^0F. Material density is 0.045 $lb/in.^3$

2.3 NOZZLE

Nozzle weights are based on actual designs prepared for this study, with safety factors as specified in the NASA work statement.

The calculated weights agree closely with empirical equations generated by the Aerospace Corporation, Report TR-699 (6560)-2, as shown below:

$$\text{where nozzle weight} = 2710 \left[\frac{\left(\frac{W_p}{1000}\right)^{1.2} \epsilon^{0.7}}{P_c^{0.8}\ t_b^{0.6}} \right]^{0.916}$$

W_p = propellant weight

P_c = chamber pressure

ϵ = nozzle expansion ratio

t_b = burn time

2.4 IGNITER

Igniter weight was calculated from a design generated for this study. The igniter design was predicated on previous designs for 156-inch diameter motor tests conducted by LPC.

2.5 THRUST TERMINATION SYSTEM

A weight prediction equation was used as presented in the Aerospace Corporation Report TR-699 (6560)-2. The equation is as follows:

$$W_{tt} = \left(\frac{W_p}{P_c\ t_b}\right)^{1.45}$$

2.6 THRUST VECTOR CONTROL SYSTEM

Lockseal Element. The weight of this component was calculated by use of an LPC Lockseal Computer Program for 10^0 nozzle deflection at 15^0 per second slew rate.

Actuators. Actuator size and weights were solicited from subcontractors, based on nozzle torque requirements.

Power Supply. Tankage weights were calculated using pressure vessel design assumptions similar to those for the motor case, but utilizing a safety factor 2.0.

2.6 PROPELLANT

Propellant volumes and weights are based on detailed grain designs required to satisfy Baseline performance requirements. Propellant density was calculated at 0.0646 $lb/in.^3$ by an LPC thermochemical computer program as compared with 0.0649 $lb/in.^3$ calculated for the parent LPC-580A formulation. This latter value was verified by quality control analysis of numerous batches of LPC-580A propellant actually cast into 156-inch LPC motors.

Section 3

MASS PROPERTIES DATA

A summary of the mass properties data is presented in Table 3-1.

Table 3-1

MASS PROPERTIES SUMMARY
156-7 PARALLEL-BURN BASELINE AND 156-6 SERIES-BURN ALTERNATE

Propulsion	Weights (lb) Parallel	Series
1. Motor case		
Forward Segment	7,436	7,436
Center Segments (total)	80,500	69,000
Aft Segment	7,437	7,437
Total	95,373	83,873
2. Insulation and Liner		
Forward Segment	1,986	2,045
Center Segments (total)	7,350	6,600
Aft Segment	4,635	4,735
Total	13,971	13,380
3. Nozzle		
Total	17,004	15,734
4. Igniter		
Inert	600	600
Propellant	400	400
Total	1,000	1,000
5. Thrust Termination (abort)		
Total	7,915	5,263
6. Thrust Vector Control System		
Lockseal	8,500	8,500
Actuators	1,060	1,060
Power Supply	8,940	8,940
Total	18,500	18,500
Total Inert	153,763	137,750
7. Propellant		
Forward Segment	70,000	73,000
Center Segments (circular port) (total)	985,800	857,500
Center Segment (star port)	135,000	134,590
Aft Segment	40,230	40,230
Total	1,231,030	1,105,320
Total Motor	1,384,793	1,243,070
Motor Mass Ratio	0.889	0.889
INTERSTAGE		
Pyrotechnic	106	34
Electrical	390	1,120
Structure	63,164	98,846
Nose Cones	1,340	---
Total	65,000	100,000
Booster Liftoff Weight	2,834,586	3,829,210
Stage Mass Fraction	0.868	0.866