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STUDY OF SOLID ROCKET MOTORS FOR A SPACE SHUTTLE BOOSTER

FINAL REPORT

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APPENDIX B
PRIME ITEM
DEVELOPMENT SPECIFICATION

United Technology Center DIVISION OF UNITED AIRCRAFT CORPORATION

UTC 4205-72-7

STUDY OF SOLID ROCKET MOTORS FOR A SPACE SHUTTLE BOOSTER

FINAL REPORT

APPENDIX B
PRIME ITEM
DEVELOPMENT SPECIFICATIONS

15 March 1972

Prepared Under
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for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GEORGE C. MARSHALL SPACE FLIGHT CENTER
MARSHALL SPACE FLIGHT CENTER, ALABAMA

by

United Technology Center

DIVISION OF UNITED AIRCRAFT CORPORATION

SUNNYVALE, CALIFORNIA

PRELIMINARY

PRIME ITEM DEVELOPMENT SPECIFICATION

ROCKET MOTOR, SPACE SHUTTLE BOOSTER, P2-156

Basic Approved by____________________
(United Technology Center)

Basic Approved by____________________

Date____________________

Date____________________

1. SCOPE. This specification establishes the performance, design, development, and test requirements for the P2-156 space shuttle booster rocket motor prime item.

2. APPLICABLE DOCUMENTS. The following documents form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification
MIL-H-6083	Hydraulic Fluid, Petroleum Base, Preservative
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles

United Technology Center

(TBS)	Forward Section, Rocket Motor
(TBS)	Mechanical Hardware Set, Rocket Motor
(TBS)	Ordnance Set, Rocket Motor
(TBS)	Segment Assembly, Rocket Motor
(TBS)	Aft Section, Rocket Motor
(TBS)	Extension, Nozzle Exit Cone
(TBS)	Nose Section, Rocket Motor
(TBS)	Aft Structure, Rocket Motor
(TBS)	Interstage Structure
(TBS)	Flight Instrumentation Set, Rocket Motor
(TBS)	Battery Set

STANDARDS

Military

MIL-STD-130	Identification Marking of US Military Property
MIL-STD-447	Definitions of Interchangeability, Substitute and Replacement Items
MIL-STD-470	Maintainability Program Requirements (form Systems and Equipment)
MIL-STD-471	Maintainability Demonstration Requirements
MIL-STD-778	Maintainability Terms and Definitions
MS33586	Metals, Definition of Dissimilar

DRAWINGS

United Technology Center

C09007	Rocket Motor Assembly - 156-L
(TBS)	Electrical System - Interconnect Diagram

OTHER PUBLICATIONS

AFM-127-100	Explosives Safety Manual
(TBS)	Range Safety Manual
(TBS)	Policies, Procedures, and Criteria
(TBS)	Facility Contract End Item and Interface Specification, Performance, Design and Interface Requirements for Space Shuttle Booster
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Parametric Interfaces (Performance, Environmental and Flight Control)
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Structural and Dynamic Loading Interfaces

(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System, Electrical Interfaces
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Testing Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Physical Interfaces (Mechanical and Structural)
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Electrical Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Envelope Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Fluid Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Installation Interfaces
(TBS)	Electromagnetic Compatibility (EMC) Control Plan
(TBS)	System Effectiveness Management Plan
(TBS) (NASA)	Space Shuttle Booster System Performance/ Design Requirements, General Specification

3. REQUIREMENTS

3.1 Performance

3.1.1 Functional Characteristics. The solid rocket motor (SRM) shall conform to the following functional characteristics from sea level to 200,000 feet (when ignited in air at altitudes up to 2500 feet) for motor mean bulk temperatures of (TBS) degrees Fahrenheit ($^{\circ}F$) to (TBS). The design temperature for all calculations and reporting shall be (TBS). Thrust vector characteristics are specified relative to the motor centerline at missile station (TBS).

3.1.1.1 Primary Performance Characteristics.

3.1.1.1.1 Propulsion System Performance Characteristics.

3.1.1.1.1.1 Ignition Transient. Ignition delay shall be TBS to TBS milliseconds for motor mean bulk temperatures of (TBS)°F to (TBS)°F inclusive. The motor chamber pressure at ignition from 50 percent to 100 percent of maximum chamber pressure shall be such that the differential chamber pressure between any two motors simultaneously ignited shall not exceed TBS percent of the maximum chamber pressure. Predicted igniter nominal performance is depicted in Figures 1 and 2.

3.1.1.1.1.2 Vacuum and Sea Level Performance. The SRM shall have a vacuum and sea level performance rating as indicated in Table I. The limits specified in Table I apply to a nominal established by the maximum number of test firings available. This actual nominal may vary from the nominal of Table I by the percentages specified in the column headed "Percent 3-sigma Variation of Nominal".

3.1.1.1.1.3 Thrust Characteristics. The SRM thrust versus time shall be as shown in Figures 3 through 10. The actual nominal established by the maximum number of test firings available shall fall within the dotted lines of Figures 3 through 10. The 3σ dispersion on the actual nominal shall be ± 95,000 pounds, except during tail-off when paragraph 3.1.1.1.1.9 shall apply. Estimated head end motor pressure is shown in Figures 11 through 14. Estimated aft end stagnation pressure is shown in Figures 14 through 18. Figure 19 shows the estimated relationship between head end pressure and aft end stagnation pressure for mean bulk temperature of 40°, 60°, 70°, and 90°F.

Table I. Shuttle Booster Performance Summary
60°F

		Nominal Rating	Percent 3-Sigma Variation of Nominal
Web Time, sec		131.1	2.16
Average Pressure, psia		728	
Average Thrust (SL), lb_f	$x10^6$	2.184	
Average Thrust (vac), lb_f	$x10^6$	2.508	
Average Specific Impulse (SL), sec		234.7	0.7
Average Specific Impulse (vac), sec		269.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	286.3	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	328.8	1.0
Propellant Consumed, lb	$x10^3$	1220	
Action Time, sec		138.6	3.11
Average Pressure, psia		704	
Average Thrust (SL), lb_f	$x10^6$	2.105	
Average Thrust (vac), lb_f	$x10^6$	2.426	
Average Specific Impulse (SL), sec		233.8	0.7
Average Specific Impulse (vac), sec		269.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	291.8	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	336.3	1.0
Propellant Consumed, lb	$x10^3$	1248	

		Nominal Rating	Percent 3-Sigma Variations of Nominal
Duration, sec		140.2	
Maximum Pressure, psi		912	
Initial Thrust (SL), lb_f	$x10^6$	2.514	6.0
Maximum Thrust (vac), lb_f	$x10^6$	2.838	
Total Impulse (vac), lb_f-sec	$x10^6$	336.9	1.0
Propellant Consumed, lb	$x10^3$	1250	

3.1.1.1.1.4 Maximum Expected Operating Chamber Pressure. The maximum expected operating chamber pressure (MEOP) shall be 1000 pounds per square inch gage (psig).

3.1.1.1.1.5 SRM Thrust Vector. Solid rocket motor thruat vector performance is defined for a motor whose nozzle centerline is coincident with the motor centerline. Alignment and movement of the thrust vector is defined in paragraph 3.1.1.1.2.

3.1.1.1.1.6 Stage Thrust Vector. Stage thrust vector performance is defined for the thrust vector sum of the individual solid rocket motors. The stage thrust vector location, alignment and movement is defined in 3.1.1.2 relative to the stage centerline and to the intersection of the stage centerline with the stage/orbiter separation plane, MS (TBS).

3.1.1.1.1.7 Nozzle Characteristics. (TBS)

3.1.1.1.1.8 Propellant. (TBS)

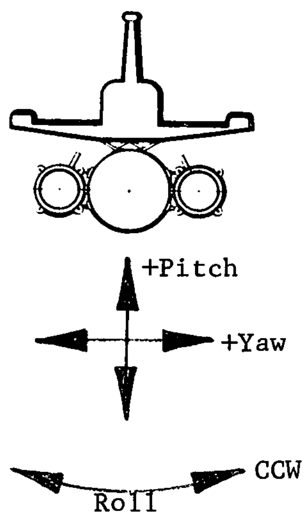
3.1.1.1.1.9 Thrust Decay. (TBS)

3.1.1.1.2 Primary Thrust Vector Control (TVC) System Performance Characteristics. The TVC system shall provide the performance indicated below during stage operation under initial pre-launch temperatures of 25°F to 100°F. The TVC system shall utilize movable nozzles on each SRM to provide omniaxial thrust vector orientation in accordance with pitch, yaw, and roll command signals from the vehicle guidance system. The TVC performance of the individual SRMs shall be as specified in the TVC Math. Model Specification (TBS).

3.1.1.1.2.1 TVC System Operation. The stage TVC system shall consist of omni-directional movable nozzles. Each SRM shall have a single movable nozzle operated by two servo-controlled hydraulic actuators located in mutually perpendicular planes. The actuators shall position the SRM nozzles in accordance with pitch, yaw, and roll commands from the vehicle guidance system. Nozzle rotation shall be limited electronically to prevent overtravel in any axis. Control axes interactions and actuator cross-coupling shall be defined and compensation provided as required to obtain vehicle response in accordance with command control moments and within the control variations defined herein.

3.1.1.1.2.2 SRM Axes Definition. Table II shows the SRM axes definition and indicates the command voltages and polarities required to provide control moments about the roll, pitch, and yaw axes.

Table II. Axes Definition and Command Voltage



Booster SRM Axes Definition Looking Forward

Command Voltage Relative to its individual corresponding return	Externally Directed Force
-10 to +10 volts on pitch command lines (three redundant pairs)	Pitch of same polarity as command
-10 to +10 volts on yaw command lines (three redundant pairs)	Yaw of same polarity as command
-10 to +10 volts on roll command lines (three redundant pairs)	Roll CW for (+) commands and CCW for (-) commands

3.1.1.1.2.3 <u>SRM Thrust Vectoring</u>. The nominal SRM pitch (yaw) thrust vector angle, as a function of command voltage and nominal motor chamber pressure, shall be as shown in Figure 20 and as described in the TVC Math. Model, for all SRM thrust vector angles between ±10 degrees.

3.1.1.1.2.4 <u>SRM Thrust Vector Moment Arm</u>. The nominal SRM pitch (yaw) thrust vector moment arm as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure 21 and as described in the TVC Math. Model, for all thrust vector moment arms within ± (TBS)inches.

3.1.1.1.2.5 TVC Hysteresis. Three-sigma deviations from nominal TVC relationships in 3.1.1.1.2.3 and 3.1.1.1.2.4, due to command voltage reversals, shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or the greater of ±(TBS)% or ± (TBS) inches, respectively, from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or ±(TBS)% or ±(TBS) inches, respectively, from web action time to action time.

3.1.1.1.2.6 TVC Variability. Three-sigma variability of the SRM thrust vector angle shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, and variability or the slope of the command voltage-to-thrust vector moment arm relationship shall not exceed the greater of ±(TBS)% or ±(TBS) inches/volt from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, and the greater of ±(TBS)% or ±(TBS) inches/volt, respectively, from web action time to action time. This variability shall include all deviations, tolerances, and cross-coupling efforts excepting variations in the nominal motor chamber pressure with SRM mean bulk temperature.

3.1.1.1.2.7 Roll Control Moments. The nominal stage roll control moment as a function of roll command voltage and nominal motor chamber pressure shall be as shown in Figure 22 and as described in the TVC Math. Model. Three-sigma variations shall not exceed the greater of ±(TBS)% or ±(TBS) inch-pounds from web action time to action time. Three-sigma deviations from the nominal command voltage-to-roll control moment relationship, due to command voltage reversal, shall not exceed ±(TBS) inch-pounds from ignition to web action time, and ±(TBS) inch-pounds from web action time to action time.

3.1.1.1.2.8 Resolution. The TVC system resolution within the range of ±10 degrees of SRM thrust vector angle shall not exceed (TBS) volts from ignition to web action time and (TBS) volts from web action time to action time.

3.1.1.1.2.9 Frequency Response. The total thrust vector control system frequency response at any ambient voltage command level in the defined nozzle axes for motor chamber pressures between (TBS) and (TBS) psia shall be as specified by the upper and lower limits of the amplitude ratio and phase lag given in Figure 23. This curve is valid as long as the maximum command voltage does not exceed TBS VDC, the velocity or rate of change of the command voltage is below the minimum slew rates specified in Figure 24 and the minimum command is greater than (TBS) VDC.

3.1.1.1.2.10 Slew Rate. The TVC system shall be capable of changing the vehicle thrust vector angle at a minimum slew rate of 5 degrees per second throughout motor operating time. This requirement shall apply for all motor and actuation system operating conditions in conjunction with external nozzle loads and environments as specified in (TBS). Slew rate is defined as the instantaneous rate of change of thrust vector angle for command changes exceeding (TBS) volts at a rate exceeding (TBS) volts per second. The minimum and maximum slew rate limits as a function of flight time shall be as shown in Figure 24. Minimum slew rate is derived assuming nominal SRM performance combined with minus 3-sigma control system performance and plus 3-sigma external nozzle loads. Maximum slew rate is derived assuming nominal SRM performance combined with plus 3-sigma control system performance and minus 3-sigma nozzle loads.

3.1.1.1.3 SRM Ignition. Each SRM of the booster stage shall provide an integral igniter motor that shall perform the function of initiating SRM ignition. Simultaneous ignition initiation of each SRM of the booster stage shall be accomplished by receipt of simultaneous command signals from the orbiter or from ground equipment to the ordnance electrical system of each SRM.

3.1.1.1.4 Staging Performance. (TBS) staging motors per SRM, (TBS) in the nose section, and (TBS) in the aft section shall supply the lateral staging impulse to each SRM to fulfill the requirements of the shuttle booster general systems specification (TBS). Staging ignition initiation shall be accomplished by the SRM ordnance electrical system upon receipt of command from the orbiter.

3.1.1.1.5 Flight Safety. To preclude or limit hazard to personnel and/or equipment, each SRM of the booster stage shall incorporate: (1) a thrust termination system with provisions for activation when commanded by the orbiter vehicle or upon detection of an inadvertent separation of an SRM from the launch vehicle, and (2) an inadvertent separation detection system (ISDS), and (3) an emergency detection system for monitoring critical booster parameters and providing signals to the orbiter crew. The design of these systems shall be in accordance with the requirements of Range Safety (TBS) Shuttle Booster General System Specification (TBS) and Component CEI Specifications.

3.1.1.1.5.1 Thrust Termination Performance. A two-port thrust termination system shall be provided on each solid rocket motor. The thrust termination system shall effectively neutralize the axial thrust of each SRM by venting the combustion chamber at the forward end of each SRM. Each solid rocket motor and its thrust termination system shall be capable of surviving the environments created by thrust termination for a period of (TBS) seconds after the initiation of thrust termination. The thrust termination performance for a single solid rocket motor is shown in Figure 25.

3.1.1.1.5.2 Emergency Detection System. The emergency detection system shall provide the following output signals to the orbiter:

(a) Fast Failure: A signal shall be present when an emergency condition exists which will result in motor failure within (TBS) seconds and an immediate abort is required;

(b) Slow Failure: A signal shall be present when an emergency condition exists which will result in motor failure after at least (TBS) seconds from initial detection;

(c) Unverfied Failure: A signal shall be present when an emergency condition is sensed by only one of a pair of redundant transducers;

(d) Emergency Detection System Self Check: A signal shall be present when all malfunction detection system self-check circuits are indicating proper operation.

An emergency detection system input shall be provided such that the system can be disabled on command from the orbiter.

3.1.1.1.5.3 Inadvertent Separation Detection System (ISDS). Each SRM of the booster stage shall provide an ISDS that shall detect the inadvertent loss of electrical cabling between the orbiter/launch vehicle and automatically initiate thrust termination prior to receipt of a disable command from the orbiter. The ISDS shall be an integral part of the SRM ordnance electrical system.

3.1.1.1.6 Electrical Power, Control, and Distribution. Each SRM of the booster stage shall provide the airborne power, switching capability from ground power to airborne power, and the distribution of all airborne power to the TVC system, ordnance system, emergency detection system, and flight instrumentation system. Each SRM of the booster stage shall receive and distribute ground power for SRM systems ground operation and checkout. All systems shall operate from 28 VDC (nominal) power sources.

3.1.1.2 Secondary Performance Characteristics.

3.1.1.2.1 Instrumentation System Performance Characteristics. The booster stage instrumentation system shall provide signal outputs to the orbiter for the purpose of verification and evaluation of booster stage status and performance prior to and during flight. The functional status of specified redundancy features included in the other booster stage systems shall be indicated by discrete output signals to the orbiter.

3.1.1.2.2 Checkout Provisions. Provisions shall be made to allow the following booster stage verification tests to be performed on an assembled launch vehicle via the airborne and ground electrical interfaces.

(a) Detailed functional tests, as specified in (TBS), of all electrical and mechanical subsystems, including operational status of redundant features.

(b) System operability (quick-look) tests, as specified in (TBS) of the flight critical active systems, providing go/no go signals, including checks of redundant features.

(c) Integrated-system test, as specified in (TBS), performed as a simulated countdown and flight with the complete launch system.

(d) Booster stage component malfunction isolation and component checkout tests as specified in (TBS).

During these tests, airborne items which are not operated due to safety, one-operation capability, reduced hold capability, or physical difficulty will be checked in a non-operating mode to verify operable status and proper installation. No nonflight hardware will be connected to the stage for these tests except the normal ground umbilical cable.

3.1.1.2.3 Mass Property Requirements. Nominal values of mass, center of gravity (cg) location, and moments of inertia shall be determined as a function of flight characteristics. Three sigma tolerances on the prelaunch values shall be as follows:

	Individual SRMs	Stage
cg location - longitudinal	±7.7 inches	±
pitch plane	±1.6 inches	±
yaw plane	±1.7 inches	±
Mass	±3,600 pounds	±
Moments of inertia	±10 percent	±

TBS

The mass fraction of the motor shall be TBS minimum using the "inert" motor definition in Section 6.

3.1.1.2.4 Hold and Reaction Time Requirements. The booster stage shall be capable of maintaining a launch hold at T-(TBS) minutes for 30 days without environmental protection (shall allow electrical maintenance of batteries via the ground umbilical cable during the hold). The booster stage shall be capable of a launch reaction time of (TBS) hours after integrated system test and a system abort recycle time for causes external to the vehicle of TBS hours. The booster stage shall be capable of proceeding to T-(TBS) seconds returning to T-(TBS) minutes and holding for 30 days.

3.1.2 Operability. The SRM shall conform to the following operability requirements.

3.1.2.1 Reliability. The reliability of the SRM booster stage shall be as specified in the shuttle booster general systems specification (TBS).

3.1.2.2 Maintainability. The SRM booster stage shall meet the maintainability requirements of MIL-STD-470. Quantitative requirements shall be established for the contributions to system downtime considering the AGE, facilities, and airborne portions of the vehicle system. The maintainability apportionment shall be consistent with the probability of launch-on-time requirements. Downtime shall be interpreted as active downtime defined in MIL-STD-778 and shall not be greater than (TBS) hours mean active time to restore. Mean maintenance-downtime (M) is described for corrective-maintenance functions as:

$$\bar{M}_{ct} = \frac{\sum_{1}^{N_c} M_{ct}}{N_c} = \bar{M} \text{ hours}$$

Where:

$\bar{M}_{ct}$ = mean maintenance correction-time for sub-system (arithmetic mean)

N_c = number of corrective maintenance-functions for modular remove/replace maintenance concept

M_{ct} = active maintenance correction-time per corrective maintenance task

The quantitative $\bar{M}$ allocations shall be as follows:

(TBS)

The M allocations do not apply on a lower level of assembly because maintenance or test results pertinent to a requirement for maintenance only occurs at the fully assembled level. The above subsystems are defined in the UTC System Effectiveness Plan, (TBS).

3.1.2.2.1 Maintenance and Repair Cycles. Maintainability analyses shall establish time goals for the completion of maintenance activities and the associated design and procedural approaches. This data will be incorporated into equipment specifications and, thus, constitute objectives to be accomplished during the design process. Maintenance functions for support of the SRM are corrective-maintenance functions. Preventive maintenance is not considered in the maintenance concept.

3.1.2.2.2 Service and Access. Access shall be provided so all interface connections and maintenance operations can be performed. The ordnance and TVC subsystems shall be capable of checkout and servicing while installed in the SRM. Access requirements shall be evaluated to ascertain performance of corrective-maintenance tasks upon which active maintenance downtime is based, and which are organizational level remove/replace maintenance functions.

3.1.2.3 Useful Life. The SRM booster stage shall comply with shuttle booster general system specifications (TBS). The SRM booster stage shall meet the requirements of this specification after exposure to the environment specified in paragraph 3.1.2.4 for a period of one year. Cyclic life limitations shall be as defined in the component CEI specifications (see paragraph 3.3.1.3)

3.1.2.4 Environmental.

3.1.2.4.1 Prelaunch. The SRM booster stage shall perform as specified herein after exposure to the following environments:

(a) Temperature - Surrounding air temperatures between 25° and 100°F with mean bulk propellant temperatures of 40° to 90°F for periods up to 60 days

(b) Humidity - Relative humidities of up to 100 percent including condensation in the form of water or frost for periods up to 60 days.

(c) Fungus - Exposure to fungi equivalent to 28 days of exposure to selected fungi as described in Specification MIL-E-5272. As a design goal, materials which are fungus nutrient shall not be used.

(d) Sand and dust - Exposure to windblown graded sand and dust equivalent to exposure for 6 hours in a sand-and-dust chamber as described in Specification MIL-E-5272

(e) Sunshine - Normally exposed, nonmetallic materials shall withstand the deteriorating effects of direct sunlight for periods up to 60 days.

(f) Salt fog - Exposure to salt fog equivalent to exposure to a 20-percent salt spray for:

(i) 10 hours for internally-mounted equipment

(ii) 50 hours for externally-mounted equipment

(g) Rain - Exposure to rain equivalent to 4 inches per hour for 2 hours

(h) Wind and gusts - Exposure to the wind and gusts prevalent at the launch base as defined in (TBS)

(i) Propellant compatibility - (TBS)

(j) Loads - Exposure to loads induced by the winds and gusts specified in (h) above

(k) Overpressure - Exposure to overpressures induced by an incident on an adjacent launch pad as defined in (TBS)

3.1.2.4.2 Launch and Flight. The SRM booster stage shall perform as specified herein during and after exposure to the environments specified in the shuttle booster general system specification (TBS)

3.1.2.4.3 Storage. The SRM shall perform as specified herein when its components CEI's are stored at mean bulk temperatures between $40^{o}F$ and $90^{o}F$ with propellant surfaces protected from humidity in excess of 50 percent RH.

3.1.2.5 Transportability. The assembled SRM will not be transported. Transportation environments will be within the limits specified in paragraph 3.1.2.4. The forward section, segments, and aft section shall be transportable in the clevis-down or horizontal position without degradation of the propellant or bonding to the extent that would preclude the SRM from performing as specified herein. Component CEI's shall be designed so that only passive means of environmental protection are required during transportation.

3.1.2.6 Human Performance. The SRM booster stage and associated ground equipment shall meet the human-performance requirements of (TBS).

3.1.2.7 Safety.

3.1.2.7.1 Flight Safety - Design of airborne systems shall meet the requirements of applicable range safety specifications (TBS).

3.1.2.7.2 Ground Safety. The SRM shall be compatible with the shuttle booster general specification (TBS).

3.1.2.7.3 Nuclear Safety. Not applicable.

3.1.2.7.4 Personnel Safety. Provisions for personnel safety shall be in accordance with the shuttle booster general specification (TBS).

3.1.2.7.5 Explosive and/or Ordnance Safety. The system shall comply with the requirements of paragraph 3.1.2.7.4 of this CEI Specification and the shuttle booster general specification (TBS) to the extent specified in the component CEI Specifications. The explosive classification of each assembled SRM shall be Class 2 in accordance with AFM-127-100.

3.2 Configuration Item Definition.

3.2.1 Interface Requirements.

3.2.1.1 Schematic Arrangement. Each SRM shall conform to the dimensions shown in UTC Drawing C09007. The schematic arrangement of the overall system and each electrical system shall be as shown in Figures 26 through 30 and UTC Drawing (TBS).

3.2.1.2 Detailed Interface Definition.

3.2.1.2.1 System Interfaces. All interfaces between the SRM booster stage, the orbiter vehicle, and the facility will be defined and controlled by the following interface documents:

(TBS)

3.2.1.2.2 AGE Interfaces. Necessary interfaces for the SRM booster stage launch pad testing shall be provided for mating with the following equipment:

(TBS)

3.2.2 Component Definition.

3.2.2.1 Customer-Furnished Property List. The following items, which are to be furnished by the customer, are required for flight CEI operation:

(a) Component CEI's (see paragraph 3.3.1.3)

3.2.2.2 Engineering-Critical-Components List. Engineering critical components are listed in the component CEI specifications.

3.2.2.3 Logistics Critical Components List. Logistics critical components are listed in the component CEI specifications.

3.3 Design and Construction.

3.3.1 General Design Features.

3.3.1.1 General Design and Construction Requirements. The SRM design shall comply with the shuttle booster general system specification (TBS).

3.3.1.2 Description.

3.3.1.2.1 Solid Rocket Booster Stage. The solid rocket booster stage shall consist of two solid rocket motors, their attach structure, and the various systems required by this specification. Each motor shall be a three-segment 156-inch diameter motor with spherical end closures at each end. The segments and closures are joined with a pressure sealing clevis joint. An aerodynamic nose fairing attaches to the forward end and houses portions of the electrical system and the forward staging rocket motors.

3.3.1.2.2 Segments and Closures. Each segment is insulated with rubber and cast with composite, aluminized propellant in the form of a hollow cylinder. One end of the grain is restricted from burning by a rubber restrictor and a tapering of the central perforation provides the required tailoff thrust characteristics. The forward closure is insulated with rubber and propellant is cast in the form of an eight-point star with ports provided to allow for thrust termination. The aft closure is rubber insulated and has a circular port grain configuration.

3.3.1.2.3 Nozzle and Exit Cone. To the aft closure is attached a 52-inch diameter ablative throat and a 20° conical ablative exit cone with an expansion ratio of 10·6:1.

3.3.1.2.4 Thrust Vector Control System. Thrust vector control is provided by movable nozzles on each SRM. Each nozzle is supported by a constant volume fluid filled bearing which transmits the nozzle blowoff loads and thrust vectoring loads to the SRM by means of two annular rolling convolutes. Movement of the nozzle, within the limits of the fluid bearing, is produced by actuators placed in mutually perpendicular planes. Hydraulic power for the actuators is provided by a regulated pressure supply system using a solid propellant gas generation as the energy source. Actuator position control is accomplished by an electronic control unit which resolves and conditions vehicle guidance system steering commands into the appropriate control responses.

3.3.1.2.5 Attach Structure. The two solid rocket motors are attached to the orbiter tank by a thrust transmission structure near the forward end of each SRM which transmits SRM thrust to the orbiter, and by an aft structure which reacts the transverse and radial loads. The aft structure also provides ground support for a single SRM during buildup and ground support for the assembled vehicle. Provisions for mounting staging motors are provided at the fore and aft ends of each SRM.

3.3.1.2.6 Emergency Detection System. Detection of impending solid rocket motor failures necessitating a mission abort is provided by this system. The output of various pairs of redundant transducers are compared to predetermined criteria to determine presence of an impending failure situation. Parallel redundancy is utilized in this system to reduce the possibility of an inadvertent mission abort.

3.3.1.2.7 Instrumentation System. The instrumentation system shall monitor pertinent booster stage parameters and supply conditioned signals to the orbiter telemetry system to verify and evaluate booster stage status and performance prior to and during flight. The system also provides signal inputs and outputs via the ground umbilical cable required to accomplish verification tests on the booster stage. The design of the instrumentation system shall be such that no single instrumentation system component failure will result in performance degradation of any other booster stage system such that the limits of this specification are exceeded.

3.3.1.2.8 Ordnance System. The ordnance systems for the SRM booster stage provides the capability of performing the functions of booster ignition, staging, thrust termination, and inadvertent separation detection by initiation of ordnance devices. The ordnance electrical system provides the power and control of the firing units to initiate the devices. Firing unit charging is accomplished upon command from the orbiter vehicle or ground station.

3.3.1.2.9 Redundancy. Redundancy shall be utilized, to the maximum extent practicable, in all systems to exclude the possibility of a single non-structural failure causing out-of-specification performance.

3.3.1.2.10 Weights. The predicted component weights are given in Table III.

Table III. Component Weights

Component	Weight
Attach structure	(20,450)
Forward	7,850
Aft	12,600
Separation system	1,238
Solid motor (empty)	(135,857)
Case	(99,799)
Forward Closure	18,518
Segments (Total)	73,137
Aft Closure	7,744
Assembly Hardware	400
Insulation	(15,963)
Forward Closure	3,364
Segments (Total)	9,246
Aft Closure	3,353
Ignitor	378
Thrust Termination	2,043
Nozzle	(17,674)
Movable	13,631
Fixed	4,043
Actuation System	1,080
Electrical and Instrumentation	1,403
Weight Empty	160,028
Solid Propellant	1,250,000
Single Loaded Motor — Total	1,410,028
STAGE TOTAL	2,820,556

3.3.1.3 Component Configuration Items. The following subparagraphs identify the component configuration items which form each SRM of the booster stage.

3.3.1.3.1 Forward Section, Rocket Motor. Each rocket motor forward section shall be in accordance with UTC Specification (TBS).

3.3.1.3.2 Aft Section, Rocket Motor. The rocket motor aft section shall be in accordance with UTC Specification (TBS).

3.3.1.3.3 Segment Assembly, Rocket Motor. The rocket motor segment assembly shall be in accordance with UTC Specification (TBS).

3.3.1.3.4 Nose Section, Rocket Motor. The rocket motor nose section shall be in accordance with UTC Specification (TBS).

3.3.1.3.5 Extension, Nozzle Exit Cone. The nozzle exit cone extension shall be in accordance with UTC Specification (TBS).

3.3.1.3.6 Battery Set. All flight batteries shall be in accordance with UTC Specification (TBS).

3.3.1.3.7 Ordnance Set, Rocket Motor. The rocket motor ordnance set shall be in accordance with UTC Specification (TBS).

3.3.1.3.8 Mechanical Hardware Set, Rocket Motor. The rocket motor mechanical hardware set shall be in accordance with UTC Specification (TBS).

3.3.1.3.9 Aft Structure, Rocket Motor. The rocket motor aft structure shall be in accordance with UTC Specification (TBS).

3.3.1.3.10 Flight Instrumentation Set, Rocket Motor. The rocket motor flight instrumentation set shall be in accordance with UTC Specification (TBS).

3.3.2 Selection of Specifications and Standards. The selection of specifications and standards shall be in accordance with shuttle booster general specification (TBS).

3.3.3 Materials, Parts, and Processes. Materials, parts and processes used in each SRM shall conform to the applicable requirement as specified in shuttle booster general specification (TBS) as further defined by component CEI Specifications referenced in paragraph 3.3.1.

3.3.4 Standard and Commercial Parts. Standard and commercial parts shall be in accordance with shuttle booster general system specification (TBS).

3.3.5 Moisture and Fungus Resistance. Materials used in this CEI shall comply with the requirements of shuttle booster general system specification (TBS) as specified in the component CEI Specifications.

3.3.6 Corrosion of Metal Parts. All metal parts used in fabrication of the SRM shall be corrosion resistant or suitably treated to resist corrosion when exposed to the environmental conditions specified in paragraph 3.1.2.4. Wherever practical, the use of dissimilar metals, as defined in Standard MS33586, in contact with each other shall be avoided.

3.3.7 Interchangeability and Replaceability. The interchangeability and replaceability, as specified in MIL-STD-447, of the SRM components shall be in accordance with MIL-I-8500.

3.3.8 Workmanship. Each SRM shall be fabricated and finished in such a manner that criteria of appearance, fit, and adherence to specified tolerances shall be observed. Particular attention shall be given to the neatness and thoroughness of soldering, wiring, marking of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.9 Electromagnetic Interference. Each SRM shall meet the electromagnetic interference requirements of Electromagnetic Compatibility Control Plan (TBS).

3.3.10 Identification and Marking. Each SRM shall be identified and marked in accordance with MIL-STD-130 and (TBS).

3.3.11 Storage. Each assembled SRM and its components shall conform to the storage requirements of paragraphs 3.1.2.3 and 3.1.2.4, as applicable.

3.3.12 Cleanliness. Each SRM and its components shall meet the cleanliness requirements of (TBS).

4. QUALITY ASSURANCE PROVISIONS.

4.1 Category I Test. Category I tests as used herein shall be defined as contractor-performed component, subsystem and full-scale static sea level tests. Records and documentation of results of all Category I testing shall be maintained in comprehensive, legible format.

4.1.1 Engineering Test and Evaluation. Engineering tests and evaluations shall be conducted to provide maximum assurance of successful completion of the qualification and category II system tests specified below.

4.1.1.1 Development Testing. (TBS) motor firing tests shall be conducted at a UTC test facility during the development phase, (TBS) vertical at UTC and (TBS) horizontal thrust termination test. Motors shall be instrumented during these firings to evaluate the internal ballistic performance, TVC performance, and electrical system performance. Test configuration shall be as specified in (TBS).

4.1.2 Preliminary Qualification Tests. (TBS) rocket motors identical in configuration to the final flight configuration will be fired in a preliminary flight rating test (PFRT) program to be conducted at a UTC test facility. The differences in configuration will be limited to those required for the inverted-from-flight attitude firings and are defined in (TBS). Successful completion of these firings will constitute the preliminary qualification test program.

4.1.3 Formal Qualification Tests. The following subparagraphs specify the requirements for, and methods of, formally verifying that each requirement in Section 3 has been satisfied.

4.1.3.1 Inspection. The following requirements of Section 3 shall be verified by an inspection at a time and place to be determined mutually by the customer and UTC: (TBS)

4.1.3.2 Analysis. Conformance to the following requirements shall be verified by comparative analysis of engineering documentation developed under previous programs and during the testing of 4.1.1.1 and 4.1.2. No further testing will be conducted to verify conformance to these requirements. (TBS)

4.1.3.3 Demonstrations. Not applicable.

4.1.3.4 Tests. The following requirements in Section 3 shall be verified during the preliminary qualification tests of 4.1.2: (TBS)

4.1.4 Reliability Tests and Analysis. At the start of the acquisition phase a reliability mathematical model shall be presented to justify reliability failure allocations for the various CEI components. The results of tests, failure reports, and conclusions as to system reliability shall be presented to the customer throughout the acquisition program. No special testing shall be specifically conducted to satisfy the provisions of 3.1.2.1.

4.1.5 Engineering Critical Component Qualification. Not applicable.

4.1.6. Interface Testing.

4.1.6.1 System Interfaces. Conformance to the requirement of paragraph 3.2.1.2.1 "System Interface" shall be verified by comparative analysis of engineering documentation developed under previous programs and during selected testing according to 4.1.1.1 and 4.1.2 as follows:

4.1.6.1.1 Parametric Interfaces. SRM seal-level ballistic and TVC performance as specified in (TBS) shall be verified to the extent analyzed by 4.1.3.2 and 4.1.3.4.

4.1.6.1.2 Structural and Dynamic Load Interfaces. These interfaces as specified in (TBS), shall be verified only to the extent that mass property requirements shall be verified as appropriate according to 4.1.3.2.

4.1.6.1.3 Electrical Interfaces. These interfaces as specified in (TBS) shall be tested as defined by (TBS). (ref: 4.1.6.1.4)

4.1.6.1.4 Testing Interfaces. These interfaces, as specified in (TBS) shall be verified to the extent where UTC electrical test requirements are applicable to the testing of 4.1.1.1 and 4.1.2. (reference 4.1.6.1.8 for fluid systems verifications.)

4.1.6.1.5 Physical Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.6 Electrical Interfaces. These interfaces, as specified in (TBS), shall be verified by testing as defined by (TBS). (ref.: 4.1.6.1.4)

4.1.6.1.7 Envelope Interface. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.8 Fluid Interfaces. To the extent that the fluid interfaces are required for the testing of 4.1.1.1 and 4.1.2, the interfaces (mechanical, fluid quantity and fluid quality) used for static test will be consistent with the requirements of (TBS) and thereby verify adequacy of requirements.

4.1.6.1.9 Installation Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.2 Category II Test Program. The requirements of 3.3.9 shall be verified by tests to be performed after the SRM stage has been integrated into an assembled launch vehicle. The solid rocket motors shall demonstrate the following minimum vehicle centerline vacuum web action time total impulse when assembled and launched as a Stage of the space shuttle launch vehicle in accordance with MIL-STD-471: (TBS)

5. PREPARATION FOR DELIVERY. (TBS)

6. NOTES.

6.1 Supplemental Information. Maximum use shall be made of components qualified under other programs.

6.1.1 Definitions. For purposes of this specification the following definitions shall apply:

6.1.1.1 Web Action Time. Web action time shall be defined as follows: The start of web action time shall be that point in the pressure/time trace at which the head end pressure has reached 75 percent of maximum. The end of web action time shall be defined by the following geometric construction. Extend the general shape of the pressure time curve prior to and immediately after the beginning of tail-off. Then bisect the angle formed by this extension. Extend this bisector to intersect the pressure/time trace. The time that corresponds to this intersection point is the end of web action time.

6.1.1.2 Action Time. Action time is defined as beginning when the pressure has risen to 75 percent of the maximum chamber pressure and ending when the head end pressure has fallen to 10 percent of the maximum chamber pressure.

6.1.1.3 Delivered Specific Impulse. The delivered specific impulse shall be defined as the total impulse along the nozzle centerline delivered during web action time divided by the weight of propellant expended during web action time. Delivered specific impulse at plant site shall be extrapolated to specific impulse at vacuum conditions. The methods used to determine the weight of expended propellant and to extrapolate the data shall be presented subject to customer approval.

6.1.1.4 Regressivity. Regressivity is defined as the maximum vacuum thrust minus the vacuum thrust at end of web action time divided by the maximum vacuum thrust. All thrusts are taken along the nozzle centerline.

6.1.1.5 Action Time Total Impulse. Action time total impulse is defined as the integrated thrust along the nozzle centerline over the action time.

6.1.1.6 Initial Vacuum Thrust. Initial vacuum thrust is defined as that vacuum thrust along with the nozzle centerline at the completion of ignition. Initial vacuum thrust may be calculated from sea level data by adding 183,603 lb_f to the measured sea level nozzle centerline thrust.

6.1.1.7 Web Action Time Total Impulse. Web action time total impulse is defined as the integrated thrust along the nozzle centerline over the web action time.

6.1.1.8 Ignition Delay. Ignition delay is defined as the time interval between fire signal and when the motor chamber pressure reaches 75 percent of the initial peak pressure.

6.1.1.9 Tailoff. Tailoff is defined as the time interval between web action time and action time.

6.1.1.10 Total Prelaunch Weight (Nominal). Total prelaunch weight is defined as the sum of all motor weights which includes propellants and inerts.

6.1.1.11 Expendable Weight. Expendable weight is defined as the weight of those items that are expended from the motor which include propellant, insulation and liner, nozzle, igniter charge, and weather seal.

6.1.1.12 Weight Empty. Weight empty is defined as the total of inert motor component weights excluding R&D instrumentation.

6.1.1.13 Burnout Motor Weight. Total prelaunch weight minus expendables is burnout condition. A definition of burnout weight is prelaunch weight minus inert expendable weight excluding expended propellant and igniter charge weight.

6.1.1.14 Loaded Propellant Weight. Loaded propellant weight is defined as all solid propellant weight in the rocket motor.

6.1.1.15 Nominal Inert Motor Weight. Nominal inert motor weight includes the following: The motor case with nozzle, thrust termination port covers and stacks, skirts, igniter, and internal insulation. It does not include the TVC system and its attachments, instrumentation, ordnance system, power supplies, other electrical systems, external insulation, all vehicle attachment and aerodynamic fairings.

6.1.1.16 Mass Fraction. The nominal propellant mass fraction ($\lambda \rho$) is determined by the following method:

$$\lambda \rho = W_p / (W_p + W_i)$$

Where: W_p = Loaded Propellant Weight

W_i = Nominal Inert Motor Weight

6.1.1.17 Resolution. Resolution is defined as the minimum change in input voltage necessary to produce a change in generated side force, in the same direction as the previous change.

6.1.1.18 Hysteresis. Hysteresis is defined as the difference in input voltage required to produce a change in generated thrust vector moment arm (TVMA) when the direction of the TVMA is changed due to command voltage reversals.

6.1.1.19 Deflection Angle. Deflection angle is defined as the arctan of the side thrust measured perpendicular to the nozzle centerline divided by the axial thrust measured along the nozzle centerline.

6.1.1.20 Launch Reaction Time. Launch reaction time is defined as the time required to prepare to launch a vehicle following the completion of prelaunch checkout.

6.1.1.21 Abort Recycle Time. Abort recycle time is defined as the time required to launch a vehicle following an abortive launch attempt.

6.1.1.22 The SRM Pitch (Yaw) Thrust Vector Angle. The angle between the SRM motor centerline and the projection of the SRM thrust vector into the SRM pitch (yaw) plane.

6.1.1.23 <u>SRM Pitch (Yaw) Plane</u>. The plane defined by the SRM motor centerline and a line which is normal to the SRM centerline and parallel to the vehicle pitch (yaw) plane.

6.1.1.24 <u>The SRM Pitch (Yaw) Thrust Vector Moment Arm</u>. The length of the perpendicular line from the SRM motor centerline at missle station (TBS) to the SRM projection of the thrust vector into the pitch (yaw) plane.

6.1.1.25 <u>Solid Rocket Motor Centerline</u>. The line joining the center of the aft closure-to-nozzle throat bolt circle to the center of the forward closure in the plane of the forward attach structure.

6.1.1.26 <u>Nozzle Centerline</u>. The line joining the center of the nozzle throat to the center of the nozzle exit.

6.1.1.27 <u>Stage Centerline</u>. The line joining the center of the stage/orbiter assembly joint bolt circle and the center of the aft structure support structure.

6.1.1.28 <u>SRM Thrust Vector</u>. The force vector whose magnitude and variability is defined by paragraph 3.1.1.1.1, and whose direction and variability is defined by paragraph 3.1.1.1.2.

6.1.1.29 <u>Stage Roll Plane</u>. A plane perpendicular to the stage centerline which intersects the stage centerline at missile station (TBS).

6.1.1.30 <u>Stage Roll Control Moment</u>. The resultant moment about the stage centerline of the sum of the SRM thrust vectors projected into the stage roll plane.

10. APPENDIX

10.1 Test Configuration. The static test configuration of the SRM shall conform to UTC drawing (TBS). This drawing shows several obvious differences from the flight configuration. These differences shall not affect performance but are related to ordance, structural, and instrumentation measurements which pertain directly to the static test program.

Specific differences shall include the following areas: (TBS)

The following figures are to be supplied:

Figure 23. Frequency Response

Figure 24. Slew Rates

Figure 25. Net Thrust Versus Time from Thrust Termination Actuation

Figures 26 through 30. Schematic Arrangements of SRM Electrical Systems

(PRELIMINARY)

PRIME ITEM DEVELOPMENT SPECIFICATION

SOLID ROCKET MOTOR, SPACE SHUTTLE BOOSTER, S3-156

Basic Approved by____________________
(United Technology Center)

Date________________________________

Basic Approved by_________________________

Date______________________________________

1. SCOPE. This specification establishes the performance, design, development, and test requirements for the S3-156 space shuttle booster stage prime item.

2. APPLICABLE DOCUMENTS. The following documents form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for
MIL-H-6083	Hydraulic Fluid, Petroleum Base, Preservative
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles

United Technology Center

(TBS)	Forward Section, Rocket Motor
(TBS)	Mechanical Hardware Set, Rocket Motor
(TBS)	Ordnance Set, Rocket Motor
(TBS)	Segment Assembly, Rocket Motor
(TBS)	Aft Section, Rocket Motor
(TBS)	Extension, Nozzle Exit Cone
(TBS)	Nose Section, Rocket Motor
(TBS)	Aft Structure, Rocket Motor
(TBS)	Interstage Structure
(TBS)	Flight Instrumentation Set, Rocket Motor
(TBS)	Battery Set (31 July 1964)

STANDARDS

Military

MIL-STD-130	Identification Marking of US Military Property
MIL-STD-447	Definitions of Interchangeability, Substitute and Replacement Items
MIL-STD-470	Maintainability Program Requirements (for Systems and Equipment)
MIL-STD-471	Maintainability Demonstration Requirements
MIL-STD-778	Maintainability Terms and Definitions
MS33586	Metals, Definition of Dissimilar

DRAWINGS

United Technology Center

(TBS)	Rocket Motor Configuration
(TBS)	Electrical System - Interconnect Diagram

OTHER PUBLICATIONS

AFM 127-100	Explosives Safety Manual
(TBS)	Range Safety Manual
(TBS)	Policies, Procedures, and Criteria
(TBS)	Facility Contract End Item and Interface Specification, Performance, Design and Interface Requirements for Space Shuttle Booster
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Parametric Interfaces (Performance, Environmental and Flight Control)
(TBS)	Interface Specification, Solid Rocket Booster Stage Orbiter Vehicle System - Structural and Dynamic Loading Interfaces
(TBS)	Interface Specification, Solid Rocket Booster Stage to Orbiter Vehicle System - Electrical Interfaces

(TBS)	Interface Specification, Solid Rocket Booster Stage to Orbiter Vehicle System - Testing Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Physical Interfaces (Mechanical & Structural)
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiert Vehicle System - Electrical Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Envelope Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Fluid Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Launch Orbiter Vehicle System
(TBS)	Electromagnetic Compatibility (EMC) Control Plan
(TBS)	System Effectiveness Management Plan
(TBS-NASA)	Space Shuttle Booster System Performance/ Design Requirements, General Specification

3. REQUIREMENTS

3.1 Performance.

3.1.1 Functional Characteristics. The solid Rocket Motor (SRM) booster stage shall conform to thefollowing functional characteristics from sea level to 200,000 feet (when ignited in air at altitudes up to 2500 feet) for motor mean bulk temperatures of (TBS) degrees Fahrenheit (°F) to (TBS). The design temperature for all calculations and reporting shall be (TBS). Thrust vector characteristics are specified relative to the motor centerline at missile station (TBS).

3.1.1.1 Primary Performance Characteristics.

3.1.1.1.1 Propulsion System Performance Characteristics.

3.1.1.1.1.1 Ignition Transient. Ignition delay shall be (TBS) to (TBS) milliseconds for motor mean bulk temperatures of (TBS) to (TBS) inclusive. The motor chamber pressure at ignition from 50 percent to 100 percent of maximum chamber pressure shall be such that the differential chamber pressure between any two motors simultaneously ignited shall not exceed (TBS) percent of the maximum chamber pressure. Predicted igniter nominal performance is depicted in Figures 1 and 2.

3.1.1.1.1.2 Vacuum and Sea Level Performance. Each SRM shall have a vacuum (vac) and sea level (SL) performance rating as specified in Table I. The limits specified in Table I apply to a nominal established by the maximum number of test firings available. This actual nominal may vary from the nominal of Table I by the percentages specified in the column headed "Percent 3-Sigma Variation of Nominal".

3.1.1.1.1.3 Thrust Characteristics. Each SRM thrust versus time shall be as shown in Figures 3 through 10. The actual nominal established by the maximum number of test firings available shall fall within the dotted lines of Figures 3 through 10. The 3 σ dispersion on the actual nominal shall be ±95,000 pounds, except during tail-off when paragraph 3.1.1.1.9 shall apply. Estimated head end motor pressure is shown in Figures 11 through 14. Estimated aft end stagnation pressure is shown in Figures 14 through 18. Figure 19 shows the estimated relationship between head end pressure and aft end stagnation pressure for mean bulk temperature of 40°, 60°, 70°, and 90°F.

TABLE I. SHUTTLE BOOSTER PERFORMANCE SUMMARY 60°F

		Nominal Rating	Percent 3-Sigma Variation of Nominal
Web Time, sec		131.3	2.16
Average Pressure, psia		731	
Average Thrust (SL), lb_f	$x10^6$	1.872	
Average Thrust (vac), lb_f	$x10^6$	2.196	
Average Specific Impulse (SL), sec		232.1	0.7
Average Specific Impulse (vac), sec		272.3	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	245.8	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	288.4	1.0
Propellant Consumed, lb	$x10^3$	1059	
Action Time, sec		138.5	3.11
Average Pressure, psia		705	
Average Thrust (SL), lb_f	$x10^6$	1.801	
Average Thrust (vac), lb_f	$x10^6$	2.121	
Average Specific Impulse (SL), sec		231.2	0.7
Average Specific Impulse (vac), sec		272.3	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	249.5	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	293.8	1.0
Propellant Consumed, lb	$x10^3$	1079	
Duration, sec		140.7	
Maximum Pressure, psi		914	
Initial Thrust (SL), lb_f	$x10^6$	2.215	6.0
Maximum Thrust (vac), lb_f	$x10^6$	2.539	
Total Impulse (vac), lb_f-sec	$x10^6$	294.1	1.0
Propellant Consumed, lb	$x10^3$	1080	

3.1.1.1.1.4 Maximum Expected Operating Chamber Pressure. The maximum expected operating chamber pressure (MEOP) shall be 1,000 pounds per square inch gage (psig).

3.1.1.1.1.5 SRM Thrust Vector. Solid rocket motor thrust performance is defined for a motor whose nozzle centerline is coincident with the motor centerline. Alignment and movement of the thrust vector is defined in 3.1.1.1.2.

3.1.1.1.1.6 Stage Thrust Vector. Stage thrust vector performance is defined for the thrust vector sum of the individual solid rocket motors. The stage thrust vector location, alignment and movement is defined in 3.1.1.1.2 relative to the stage centerline and to the intersection of the stage centerline with the stage/orbiter separation plane, MS (TBS).

3.1.1.1.1.7 Nozzle Characteristics. (TBS)

3.1.1.1.1.8 Propellant. (TBS)

3.1.1.1.1.9 Thrust Decay (TBS)

3.1.1.1.2 Primary Thrust Vector Control (TVC) System Performance Characteristics. The TVC system shall provide the performance indicated below during stage operation under initial prelaunch temperature of 25°F to 100°F. The TVC system shall utilize moveable nozzles on each SRM to provide omni-axial thrust vector orientation in accordance with pitch, yaw, and roll command signals from the vehicle guidance system. The TVC performance of the individual SRMs and combined stage shall be as specified in the TVC Math Model, specification (TBS).

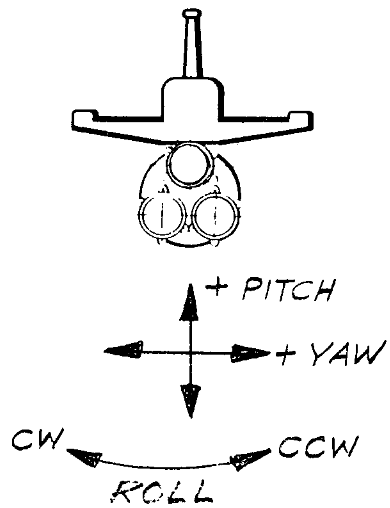
3.1.1.1.2.1 TVC System Operation. The stage TVC system shall consist of omni-directional moveable nozzles. Each SRM shall have a single moveable nozzle operated by two servo-controlled hydraulic actuators located in mutually perpendicular planes. The actuators shall position the SRM nozzles in accordance with pitch, yaw, and roll commands from the vehicle guidance system. Nozzle rotation shall be limited electronically to prevent overtravel in any axis. Control axes interactions and actuator cross coupling shall be defined and compensation provided as required to obtain vehicle response in accordance with command control moments within the control variation defined herein.

3.1.1.1.2.2 Booster Stage Axes Definition. Table II shows the stage axes definition and indicates the command voltages and polarities required to provide control moments about the roll, pitch, and yaw axes.

3.1.1.1.2.3 Stage Thrust Vectoring. The nominal stage pitch (yaw) thrust vector angle as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure and described in the TVC Math Model, for all stage thrust vector angles between ±10 degrees.

3.1.1.1.2.4 Stage Thrust Vector Moment Arm. The nominal stage pitch (yaw) thrust vector moment arm as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure and as described in the TVC Math Model, for all thrust vector moment arms within ± (TBS) meters.

Table II. Axes Definition and Command Voltage.



Booster SRM Axes Definition Looking Forward

Command voltage relative to its individual corresponding return	Externally directed force
-10 to + 10 volts on pitch command lines (three redundant pairs)	Pitch of same polarity as command
-10 to + 10 volts on yaw command lines (three redundant pairs)	Yaw of same polarity as command
-10 to + 10 volts on roll command lines (three redundant pairs)	Roll, cw for + commands and ccw for - commands

3.1.1.1.2.5 <u>TVC Hysteresis</u>. Three-sigma deviations from nominal TVC relationships in 3.1.1.1.2.3 and 3.1.1.1.2.4 due to command voltage reversals shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or the greater of ±(TBS)% or ±(TBS) inches, respectively, from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or ±(TBS)% or ±(TBS) inches, respectively, from web action time to action time.

3.1.1.1.2.6 <u>TVC Variability</u>. Three-sigma variability of the stage thrust vector angle shall not exceed the greater of ±(TBS)% or ±(TBS) degree, and variability of the slope of the command voltage to thrust vector moment arm relationship shall not exceed the greater of ±(TBS)% or ±(TBS) inches/volt from ignition to web action times; and shall not exceed ±(TBS) degrees, and the greater of ±(TBS)% or ±(TBS) inches/volt, respectively, from web action time to action time. This variability shall include all deviations, tolerances, and cross-coupling effects excepting variations in the nominal motor chamber pressure with stage mean bulk temperature.

3.1.1.1.2.7 <u>Roll Control Moments</u>. The nominal stage roll control moment as a function of roll command voltage and nominal motor chamber pressure shall be as shown in Figure 22 and as described in the TVC Math Model. Three-sigma variations shall not exceed the greater of ±(TBS)% or ±(TBS) Newton meters from ignition to web action time; or the greater of ±(TBS)% or ±(TBS) inch-pounds from web action time to action time. Three-sigma deviations from the nominal command voltage-to-roll control moment relationship due to command voltage reversal shall not exceed ±(TBS) inch-pounds from ignition to web action time; and ±(TBS) inch-pounds from web action time to action time.

3.1.1.1.2.8 <u>Resolution</u>. The TVC system resolution within the range of ±10 degrees of SRM thrust vector angle shall not exceed (TBS) volts from ignition to web action time and (TBS) volts from web action time to action time.

3.1.1.1.2.9 <u>Frequency Response</u>. The total thrust vector control system frequency response at any ambient voltage command level in the defined nozzle axes for motor chamber pressures between (TBS) and (TBS) psia shall be as specified by the upper and lower limits of the amplitude ratio and phase lag given in Figure 23. This curve is valid as long as the maximum command voltage does not exceed 10 VDC, the velocity or rate of change of the command voltage is below the minimum slew rates specified in Figure 24, and the minimum command is greater than (TBS) VDC.

3.1.1.1.2.10 <u>Slew Rate</u>. The TVC system shall be capable of changing the vehicle thrust vector angle at a minimum slew rate of 5 degrees per second throughout motor operating time. This requirement shall apply for all motor and actuation system operating conditions in conjunction with external nozzle loads and environments as specified in (TBS). Slew rate is defined as the instantaneous rate of change of thrust vector angle for command changes exceeding (TBS) volts at a rate exceeding (TBS) volts per second. The minimum and maximum slew rate limits as a function of flight time shall be as shown in Figure 24. Minimum slew rate is derived assuming nominal SRM performance combined with minus 3-sigma control system performance and plus 3-sigma external nozzle loads. Maximum slew rates is derived assuming nominal SRM performance combined with plus 3-sigma control system performance and minus 3-sigma external nozzle loads.

3.1.1.1.3 <u>SRM Ignition</u>. Each SRM of the booster stage shall provide an integral igniter motor that shall perform the function of initiating SRM ignition. Simultaneous ignition of each SRM of the booster stage shall be accomplished by receipt of simultaneous command signals, from the orbiter or from ground equipment, to the ordnance electrical system of the SRM stage.

3.1.1.1.4 <u>Staging Performance</u>. The SRM booster stage shall provide staging ordnance in the form of linear shaped charges shall, upon command from the orbiter vehicle, sever the booster stage from the launch vehicle at the booster/orbiter interstage interface. Initiation of staging ignition shall be accomplished by the SRM booster stage ordnance electrical system, upon command signal from the orbiter.

3.1.1.1.5 <u>Flight Safety</u>. To preclude or limit hazard to personnel and/or equipment, each SRM of the booster stage shall incorporate: 1) a thrust termination system with provisions for activation when commanded by the orbiter vehicle or upon detection of an inadvertent separation of an SRM from the launch vehicle, and, 2) an inadvertent separation detection system (ISDS), and 3) an emergency detection system for monitoring critical booster parameters and providing signals to the orbiter crew. The design of these systems shall be in accordance with the requirements of Range Safety Manual (TBS), Shuttle Booster General System Specification (TBS) and Component CEI Specifications.

3.1.1.1.5.1 <u>Thrust Termination Performance</u>. A two-port thrust termination system shall be provided on each solid rocket motor. The thrust termination system shall effectively neutralize the axial thrust of each SRM by venting the combustion chamber at the forward end of each SRM. Each solid rocket motor and its thrust termination system shall be capable of surviving the environments created by thrust termination for a period of (TBS) seconds after the initiation of thrust termination. The thrust termination performance for a single solid rocket motor is shown in Figure 25.

3.1.1.1.5.2 <u>Emergency Detection System</u>. The emergency detection system shall provide the following output signals to the orbiter.

(a) Fast Failure: A signal shall be present when an emergency condition exists which will result in motor failure with (TBD) seconds and an immediate abort is required.

(b) Slow Failure: A signal shall be present when an emergency condition exists which will result in motor failure after at least (TBD) seconds from initial detection.

(c) Unverified Failure: A signal shall be present when an emergency condition is sensed by only one of a pair of redundant transducers.

(d) Emergency Detection System Self Check: a signal shall be present when all Malfunction Detection System self check circuits are indicating proper operation.

An emergency detection system input shall be provided such that the system can be disabled on command from the orbiter.

3.1.1.1.5.3 Inadvertent Separation Detection System (ISDS). Each SRM of the booster stage shall provide an ISDS that shall detect the inadvertent loss of electrical cabling between the orbiter/launch vehicle and automatically initiate thrust termination prior to receipt of a disable command from the orbiter. The ISDS shall be an integral part of the booster ordnance electrical system.

3.1.1.1.6 Electrical Power, Control, and Distribution. Each SRM of the booster stage shall provide the airborne power, switching capability from ground power to airborne power, and the distribution of all airborne power to the TVC system, ordnance system, emergency detection system, and flight instrumentation system. The electrical systems of the booster stage shall receive and distribute ground power for SRM systems ground operation and checkout. All systems shall operate from 28 VDC (nominal) power sources.

3.1.1.2 Secondary Performance Characteristics.

3.1.1.2.1 Instrumentation System Performance Characteristics. The booster stage instrumentation system shall provide signal outputs to the orbiter for the purpose of verification and evaluation of booster stage status and performance prior to and during flight. The functional status of specified redundancy features included in the other booster stage systems shall be indicated by discrete output signals to the orbiter.

3.1.1.2.2 Checkout Provisions. Provisions shall be made to allow the following booster stage verification tests to be performed on an assembled launch vehicle via the airborne and ground electrical interfaces.

(a) Detailed functional tests, as specified in (TBS), of all electrical and mechanical subsystems including operational status of redundant features.

(b) System operability (quick look) tests, as specified in (TBS) of the flight critical active systems, providing go/no go signals, including checks of redundant features.

(c) Integrated-system test, as specified in (TBS), performed as a simulated countdown and flight with the complete launch system.

(d) Booster stage component malfunction isolation and component checkout tests as specified in (TBS).

During these tests, airborne items which are not operated due to safety, one operation capability, reduced hold capability, or physical difficulty will be checked in a non-operating mode to verify operable status and proper installation. No non-flight hardware will be connected to the stage for these tests except the normal ground umbilical cable.

3.1.1.2.3 Mass Property Requirements. Nominal values of mass, center of gravity (cg) location, and momemnts of inertia shall be determined as a function of flight characteristics. Three-sigma tolerances on the prelaunch values shall be as follows:

		Individual SRMs	Stage
cg location -	longitudinal	±7.7 inches	±
	pitch plane	±1.6 inches	±
	yaw plane	±1.7 inches	±
Mass		±3,600 pounds	±

Moments of inertia - ±10 percent

The mass fraction of the stage shall be (TBS) minimum using the inch motor definition in Section 6.

3.1.1.2.4 Hold and Reaction Time Requirements. The booster stage shall be capable of maintaining a launch hold at T-(TBS) minutes for 30 days without environmental protection (shall allow electrical maintenance of batteries via the ground umbilical cable during the hold). The booster stage shall be capable of a launch reaction time of TBS hours after integrated system test and a system abort recycle time for causes external to the vehicle of TBS hours. The booster stage shall be capable of proceeding to T-(TBS) seconds returning to T-(TBS) minutes and holding for 30 days.

3.1.2 Operability. The SRM booster stage conform to the following operability requirements.

3.1.2.1 Reliability. The reliability of the SRM booster stage shall be as specified in the shuttle booster general system specification (TBS).

3.1.2.2 Maintainability. The SRM booster stage shall meet the maintainability requirements of MIL-STD-470. Quantitative requirements shall be established for the contributions to system downtime considering the AGE, facilities, and airborne portions of the vehicle system. The maintainability apportionment shall be consistent with the probability of launch-on-time requirements. Downtime shall be interpreted as active downtime defined in MIL-STD-778 and shall not be greater than (TBS) hours mean active time to restore. Mean maintenance-downtime (M) is described for corrective-maintenance functions as:

$$\bar{M}_{ct} = \frac{\sum_{1}^{N_c} M_{ct}}{N_c} = \bar{M} \text{ hours}$$

Where:

$\bar{M}_{ct}$ = mean maintenance correction-time for sub-system (arithmetic mean)

N_c = number of corrective maintenance-functions for modular remove/replace maintenance concept

M_{ct} = active maintenance correction-time per corrective maintenance task

The quantitative $\bar{M}$ allocations shall be as follows:

(TBS)

The M allocations do not apply on a lower level of assembly because maintenance or test results pertinent to a requirement for maintenance only occurs at the fully assembled level. The above subsystems are defined in the UTC System Effectiveness Plan, (TBS).

3.1.2.2.1 Maintenance and Repair Cycles. Maintainability analyses shall establish time goals for the completion of maintenance activities and the associated design and procedural approaches. This data will be incorporated into equipment specifications and, thus, constitute objectives to be accomplished during the design process. Maintenance functions for support of the SRM are corrective-maintenance functions. Preventive maintenance is not considered in the maintenance concept.

3.1.2.2.2 Service and Access. Access shall be provided so all interface connections and maintenance operations can be performed. The ordnance and TVC subsystems shall be capable of checkout and servicing while installed in the booster stage SRM. Access requirements shall be evaluated to ascertain performance of corrective-maintenance tasks upon which active maintenance downtime is based, and which are organizational level remove/replace maintanance functions.

3.1.2.3 Useful Life. The SRM booster stage shall comply with shuttle booster general system specification (TBS). The SRM booster stage shall meet the requirements of this specification after exposure to the environment specified in 3.1.2.4 for a period of one year. Cyclic life limitations shall be as defined in the component CEI specifications (see 3.3.1.3).

3.1.2.4 Environmental.

3.1.2.4.1 Prelaunch. The SRM booster stage shall perform as specified herein after exposure to the following environments.

(a) Temperature - Surrounding air temperatures between 25° and 100°F with mean bulk propellant temperatures of 40° to 90°F for periods up to 60 days.

(b) Humidity - Relative humidities of up to 100 percent including condensation in the form of water or frost for periods up to 60 days.

(c) Fungus - Exposure to fungi equivalent to 28 days of exposure to selected fungi as described in Specification MIL-E-5272. As a design goal materials which are fungus nutrients shall not be used.

(d) Sand and dust - Exposure to windblown graded sand and dust equivalent to exposure for 6 hours in a sand-and-dust chamber as described in Specification MIL-E-5272.

(e) Sunshine - Normally exposed, non-metallic materials shall withstand the deteriorating effects of direct sunlight for periods up to 60 days.

(f) Salt fog - Exposure to salt fog equivalent to exposure to a 20-percent salt spray for:

(i) 10 hours for internally-mounted equipment

(ii) 50 hours for externally-mounted equipment

(g) Rain - Exposure to rain equivalent to 4 inches per hour for 2 hours.

(h) Wind and gusts - Exposure to the wind and gusts prevalent at the launch base as defined in (TBS).

(i) Propellant compatibility - (TBS)

(j) Loads - Exposure to loads induced by the winds and gusts specified in (h) above.

(k) Overpressure - Exposure to overpressures induced by an incident on an adjacent launch pad as defined in (TBS).

3.1.2.4.2 Launch and Flight. The SRM booster stage shall perform as specified herein during and after exposure to the environment specified in the shuttle booster general system specification (TBS).

3.1.2.4.3 Storage. The SRM booster stage shall perform as specified herein when its components CEIs are stored at mean bulk temperatures between 40°F and 90°F with propellant surfaces protected from humidity in excess of 50 percent RH.

3.1.2.5 Transportability. The assembled SRM booster stage will not be transported. Transportation environments will be within the limits specified in 3.1.2.4. The forward section, segments, and aft section shall be transportable in the clevis-down or horizontal position without degradation of the propellant or bonding to the extent that would preclude the booster stage from performing as specified herein. Component CEIs shall be designed so that only passive means of environmental protection are required during transportation.

3.1.2.6 Human Performance. The SRM booster stage and associated ground equipment shall meet the human-performance requirements of (TBS).

3.1.2.7 Safety.

3.1.2.7.1 Flight Safety. Design of airborne systems shall meet the requirements of applicable Range Safety Specification (TBS).

3.1.2.7.2 Ground Safety. The SRM shall be compatible with the shuttle booster general specification (TBS).

3.1.2.7.3 Nuclear Safety. Not applicable.

3.1.2.7.4 Personnel Safety. Provisions for personnel safety shall be in accordance with the shuttle booster general specification (TBS).

3.1.2.7.5 Explosive and/or Ordnance Safety. The system shall comply with the requirements of paragraph 3.1.2.7.4 of this CEI Specification and the shuttle booster general specification (TBS) to the extent specified in the component CEI Specifications. The explosive classification of each assembled SRM of the booster stage shall be Class 2 in accordance with AFM-127-100.

3.2 CEI Definition.

3.2.1 Interface Requirements.

3.2.1.1 Schematic Arrangement. The SRM booster stage shall conform to the dimensions shown in UTC Drawing (TBS). The schematic arrangement of the overall system and each electrical system shall be as shown in Figures 26 through 30 and UTC Drawing (TBS).

3.2.1.2 Detailed Interface Definition.

3.2.1.2.1 System Interfaces. All interfaces between the SRM booster stage and the orbiter vehicle and facility will be defined and controlled by the following interface documents:

(TBS)

3.2.1.2.2 AGE Interfaces. Necessary interfaces for the SRM booster stage launch pad testing shall be provided for mating with the following equipment:

(TBS)

3.2.2 Component Definition.

3.2.2.1 Customer-Furnished-Property List. The following items, which are to be furnished by the customer, are required for flight CEI operation:

(a) Component CEIs (see 3.3.1.3) of each SRM

3.2.2.2 Engineering-Critical-Components List. Engineering critical components are listed in the component CEI specifications.

3.2.2.3 Logistics Critical Components List. Logistics critical components are listed in the component CEI specifications.

3.3 Design and Construction.

3.3.1 General Design Features.

3.3.1.1 General Design and Construction Requirements. The SRM design shall comply with the shuttle booster general system specification (TBS).

3.3.1.2 Description.

3.3.1.2.1 Solid Rocket Booster Stage. The SRM booster stage shall consist of three solid rocket motors attached together by their attach structure, interstage structure, and the various systems required by this specification. Each motor shall be a 3-segment 156-inch diameter motor with spherical end closure at each end. The segments and closures are joined with a pressure sealing clevis joint. The attach structure also serves to collect the thrust and steering loads from each of the solid rocket motors and applies them to the orbiter at the interstage structure.

3.3.1.2.2 Segments and Closures. Each segment is insulated with rubber and cast with composite, aluminized propellant in the form of a hollow cylinder. One end of the grain is restricted from burning by a rubber restrictor and a tapering of the central perforation provides the required tailoff thrust characteristics. The forward closure is insulated with rubber and propellant is cast in the form of an eight-point star with ports provided to allow for thrust termination. The aft closure is rubber insulated and has a circular port grain configuration.

3.3.1.2.3 Nozzle and Exit Cone. To the aft closure is attached a 50-inch diameter ablative throat and a 20°-conical ablative exit cone with an expansion ratio of 12.7:1.

3.3.1.2.4 Thrust Vector Control System. Thrust vector control is provided by moveable nozzles on each SRM. Each nozzle is supported by a constant-volume-fluid-filled bearing which transmits the nozzle blowoff loads and thrust vectoring loads to the SRM by means of two annular rolling convolutes. Movement of the nozzle, within the limits of the fluid bearing, is provided by actuators placed in mutually perpendicular planes. Hydraulic power for the actuators is provided by a regulated pressure supply system using a solid propellant gas generator as the energy source. Actuator position control is accomplished by an electronic control unit, which resolves and conditions vehicle guidance system steering commands into the appropriate control responses.

3.3.1.2.5 Attach and Interstage Structures. The Attach Structure consists of a thrust transmission structure and an aft skirt for each SRM. The aft skirt provides ground support during buildup of a single SRM and ground support for the assembled launch vehicle. The thrust transmission structure transmits the SRM thrust to the interstage structure described in UTC Specification (TBS). Provisions for mounting staging motors are provided in the thrust transmission structure and in the aft skirts. The interstage structure interfaces with the orbiter stage and includes the system required to separate the booster stage after SRM burnout.

3.3.1.2.6 Emergency Detection System. Detection of impending SRM booster failures necessitating a mission abort is provided by this system. The output of various pairs of redundant transducers are compared to predetermined criteria to determine presence of an impending failure situation. Parallel redundancy is utilized in this system to reduce the possibility of occurrence of an inadvertent mission abort.

3.2.1.2.7 Instrumentation System. The instrumentation system shall monitor pertinent booster stage parameters and supply conditioned signals to the orbiter telemetry system to verify and evaluate booster stage status and performance prior to and during flight. The system also provides signal input and output via the ground umbilical cable, required to accomplish verification tests on the booster stage. The design of the instrumentation system component failure will result in performance degradation of any other booster stage system such that the limits of this specification are exceeded.

3.3.1.2.8 <u>Ordnance System</u>. The ordnance systems for the SRM booster stage provided the capability of performing the functions of booster ignition, staging, thrust termination, and inadvertent separation detection by initiation of ordnance devices. The ordnance electrical system provides the power and control of the firing units. Firing unit charging and triggering is accomplished upon command from the orbiter vehicle or ground station.

3.3.1.2.9 <u>Interstage Structure</u>. The interstage structure shall transmit and distribute axial force, shear, and bending movement between the individual SRMs of the booster stage to the hydrogen-oxygen tank and shall provide sufficient separation between the SRM stage and the orbiter vehicle to allow SRM thrust termination port covers to clear the orbiter if the thrust termination system is activated. The interstage structure shall provide an equipment bay for housing some electrical components of the TVC, ordnance, emergency detection and flight instrumentation systems. Provisions for compartment environmental control shall be made as necessary.

3.3.1.2.10 <u>Redundancy</u>. Redundancy shall be utilized, to the maximum extent practicable, in all systems to exclude the possibility of a single non-structural failure causing out-of-specification performance.

3.3.1.2.11 <u>Weight</u>. The predicted component weights are given in table III.

3.3.1.3 <u>Component CEIs</u>. The following sub-paragraphs identify the component CEIs which form each SRM of the booster stage.

3.3.1.3.1 <u>Forward Section, Rocket Motor</u>. Each booster forward section shall be in accordance with UTC Specification (TBS).

3.3.1.3.2 <u>Aft Section, Rocket Motor</u>. The booster aft section shall be in accordance with UTC Specification (TBS).

3.3.1.3.3 <u>Segment Assembly, Rocket Motor</u>. The booster segment assembly shall be in accordance with UTC Specification (TBS).

3.3.1.3.4 <u>Nose Section, Rocket Motor</u>. The booster nose section shall be in accordance with UTC Specification (TBS).

3.3.1.3.5 <u>Extension, Nozzle Exit Cone</u>. The nozzle exit cone extension shall be in accordance with UTC Specification (TBS).

3.3.1.3.6 <u>Battery Set</u>. All flight batteries shall be in accordance with UTC Specification (TBS).

3.3.1.3.7 <u>Ordnance Set, Rocket Motor</u>. The booster ordnance set shall be in accordance with UTC Specification (TBS).

3.3.1.3.8 <u>Mechanical Hardware Set, Rocket Motor</u>. The booster mechanical hardware set shall be in accordance with UTC Specification (TBS).

3.3.1.3.9 <u>Aft Structure, Rocket Motor</u>. The booster aft section shall be in accordance with UTC Specification (TBS).

TABLE III. COMPONENT WEIGHTS

Component	
Attach Structure	(15,850)
Forward	3,250
Aft	12,600
Separation System	---
Solid Motor (Empty)	(120,710)
Case	(85,358)
Forward Closure	18,378
Segments (Total)	58,836
Aft Closure	7,744
Assembly Hardware	400
Insulation	(15,257)
Forward Closure	3,342
Segments (Total)	8,562
Aft Closure	3,353
Igniter	378
Thrust Termination	2,043
Nozzle	(17,674)
Moveable	13,631
Fixed	4,043
Actuation System	1,080
Electrical & Instrumentation	634
Weight Empty	138,274
Solid Propellant	1,080,000
Single Loaded Motor - Total	1,218,274
Interstage Structure	25,500
Stage Elect. & Inst.	905
STAGE TOTAL	3,681,227

3.3.1.3.10 Flight Instrumentation Set, Rocket Motor. The rocket motor flight instrumentation set shall be in accordance with UTC Specification (TBS).

3.3.1.3.11 Interstage Structure. The rocket motor booster interstage structure shall be in accordance with UTC Specification (TBS).

3.3.2 Selection of Specifications and Standards. The selection of specifications and standards shall be in accordance with shuttle booster general system specification (TBS).

3.3.3 Materials, Parts, and Processes. Materials, parts and processes used in each SRM shall conform to the applicable requirements as specified in shuttle booster general system specification (TBS) as further defined by component CEI Specifications referenced in paragraph 3.3.1.

3.3.4 Standard and Commercial Parts. Standard and commercial parts shall be in accordance with shuttle booster general system specification (TBS).

3.3.5 Moisture and Fungus Resistance. Materials used in this CEI shall comply with the requirements of the shuttle booster general specification (TBS).

3.3.6 Corrosion of Metal Parts. All metal parts used in fabrication of the SRM shall be corrosion resistant or suitably treated to resist corrosion when exposed to the environmental conditions specified in 3.1.2.4. Wherever practical, the use of dissimilar metals, as defined in Standard MS33586, in contact with each other shall be avoided.

3.3.7 Interchangeability and Replaceability. The interchangeability and replaceability, as specified in MIL-STD-447, of the SRM components shall be in accordance with MIL-I-8500.

3.3.8 Workmanship. The SRM shall be fabricated and finished in such a manner that criteria of appearnce, fit, and adherence to specified tolerances shall be observed. Particular attention shall be given to the neatness and thoroughness of soldering, wiring, marking of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.9 Electromagnetic Interference. The SRM shall meet the electromagnetic interference requirements of Electromagnetic Compatibility Control Plan (TBS).

3.3.10 Identification and Marking. The SRM shall be identified and marked in accordance with MIL-STD-130 and (TBS).

3.3.11 Storage. The assembled SRM booster stage and its components shall conform to the storage requirements of 3.1.2.3 and 3.1.2.4, as applicable.

3.3.12 Cleanliness. The SRM booster stage and its components shall meet the cleanliness requirements (TBS).

4. QUALITY ASSURANCE PROVISIONS.

4.1 Category I Test. Category I tests as used herein shall be defined as contractor performed component, subsystem and full scale static level tests. Records and documentation of results of all Category I testing shall be maintained in comprehensive, legible format.

4.1.1 Engineering Test and Evaluation. Engineering tests and evaluations shall be conducted to provide maximum assurance of successful completion of the qualification and category II system tests specified below.

4.1.1.1 <u>Development Testing</u>. (TBS) motor firing tests shall be conducted at a UTC test facility during the development phase, (TBS) vertical at UTC and (TBS) horizontal thrust termination test. Motors shall be instrumented during these firings to evaluate the internal ballistic performance, TVC performance, and electrical system performance. Test configuration shall be as specified in (TBS).

4.1.2 <u>Preliminary Qualification Tests</u>. (TBS) rocket motors identical in configuration to the final flight configuration will be fired in a preliminary flight rating test (PFRT) program to be conducted at a UTC test facility. The differences in configuration will be limited to those required for the inverted-from-flight attitude firings and are defined in (TBS). Successful completion of these firings will constitute the preliminary qualification test program.

4.1.3 <u>Formal Qualification Tests</u>. The following subparagraphs specify the requirements for, and methods of, formally verifying that each requirement in Section 3 has been satisfied.

4.1.3.1 <u>Inspection</u>. The following requirements of Section 3 shall be verified by an inspection at a time and place to be determined mutually by the customer and UTC: (TBS)

4.1.3.2 <u>Analysis</u>. Conformance to the following requirements shall be verified by comparative analysis of engineering documentation developed under previous programs and during the testing of 4.1.1.1 and 4.1.2. No further testing will be conducted to verify conformance to these requirements. (TBS)

4.1.3.3 <u>Demonstrations</u>. Not applicable.

4.1.3.4 <u>Tests</u>. The following requirements in Section 3 shall be verified during the preliminary qualification tests of 4.1.2: (TBS)

4.1.4 <u>Reliability Tests and Analysis</u>. At the start of the acquisition phase a reliability mathematical model shall be presented to justify reliability failure allocations for the various CEI components. The results of tests, failure reports, and conclusions as to system reliability shall be presented to the customer throughout the acquisition program. No special testing shall be specifically conducted to satisfy the provisions of 3.1.2.1.

4.1.5 <u>Engineering Critical Component Qualification</u>. Not applicable.

4.1.6. <u>Interface Testing</u>.

4.1.6.1 <u>System Interfaces</u>. Conformance to the requirement of paragraph 3.2.1.2.1 "System Interface" shall be verified by comparative analysis of engineering documentation developed under previous programs and during selected testing according to 4.1.1.1 and 4.1.2 as follows:

4.1.6.1.1 Parametric Interfaces. SRM seal-level ballistic and TVC performance as specified in (TBS) shall be verified to the extent analyzed by 4.1.3.2 and 4.1.3.4.

4.1.6.1.2 Structural and Dynamic Load Interfaces. These interfaces as specified in (TBS), shall be verified only to the extent that mass property requirements shall be verified as appropriate according to 4.1.3.2.

4.1.6.1.3 Electrical Interfaces. These interfaces as specified in (TBS) shall be tested as defined by (TBS). (ref: 4.1.6.1.4)

4.1.6.1.4 Testing Interfaces. These interfaces, as specified in (TBS) shall be verified to the extent where UTC electrical test requirements are applicable to the testing of 4.1.1.1 and 4.1.2. (reference 4.1.6.1.8 for fluid systems verifications.)

4.1.6.1.5 Physical Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.6 Electrical Interfaces. These interfaces, as specified in (TBS), shall be verified by testing as defined by (TBS). (ref.: 4.1.6.1.4)

4.1.6.1.7 Envelope Interface. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.8 Fluid Interfaces. To the extent that the fluid interfaces are required for the testing of 4.1.1.1 and 4.1.2, the interfaces (mechanical, fluid quantity and fluid quality) used for static test will be consistent with the requirements of (TBS) and thereby verify adequacy of requirements.

4.1.6.1.9 Installation Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.2 Category II Test Program. The requirements of 3.3.9 shall be verified by tests to be performed after the SRM stage has been integrated into an assembled launch vehicle. The solid rocket motors shall demonstrate the following minimum vehicle centerline vacuum web action time total impulse when assembled and launched as a Stage of the space shuttle launch vehicle in accordance with MIL-STD-471: (TBS)

5. PREPARATION FOR DELIVERY. (TBS)

6. NOTES.

6.1 Supplemental Information. Maximum use shall be made of components qualified under other programs.

6.1.1 Definitions. For purposes of this specification the following definitions shall apply:

6.1.1.1 Web Action Time. Web action time shall be defined as follows: The start of web action time shall be that point in the pressure/time trace at which the head end pressure has reached 75 percent of maximum. The end of web action time shall be defined by the following geometric construction. Extend the general shape of the pressure time curve prior to and immediately after the beginning of tail-off. Then bisect the angle formed by this extension. Extend this bisector to intersect the pressure/time trace. The time that corresponds to this intersection point is the end of web action time.

6.1.1.2 Action Time. Action time is defined as beginning when the pressure has risen to 75 percent of the maximum chamber pressure and ending when the head end pressure has fallen to 10 percent of the maximum chamber pressure.

6.1.1.3 Delivered Specific Impulse. The delivered specific impulse shall be defined as the total impulse along the nozzle centerline delivered during web action time divided by the weight of propellant expended during web action time. Delivered specific impulse at plant site shall be extrapolated to specific impulse at vacuum conditions. The methods used to determine the weight of expended propellant and to extrapolate the data shall be presented subject to customer approval.

6.1.1.4 Regressivity. Regressivity is defined as the maximum vacuum thrust minus the vacuum thrust at end of web action time divided by the maximum vacuum thrust. All thrusts are taken along the nozzle centerline.

6.1.1.5 Action Time Total Impulse. Action time total impulse is defined as the integrated thrust along the nozzle centerline over the action time.

6.1.1.6 Initial Vacuum Thrust. Initial vacuum thrust is defined as that vacuum thrust along with the nozzle centerline at the completion of ignition. Initial vacuum thrust may be calculated from sea level data by adding 183,603 lb_f to the measured sea level nozzle centerline thrust.

6.1.1.7 Web Action Time Total Impulse. Web action time total impulse is defined as the integrated thrust along the nozzle centerline over the web action time.

6.1.1.8 Ignition Delay. Ignition delay is defined as the time interval between fire signal and when the motor chamber pressure reaches 75 percent of the initial peak pressure.

6.1.1.9 Tailoff. Tailoff is defined as the time interval between web action time and action time.

6.1.1.10 Total Prelaunch Weight (Nominal). Total prelaunch weight is defined as the sum of all motor weights which includes propellants and inerts.

6.1.1.11 Expendable Weight. Expendable weight is defined as the weight of those items that are expended from the motor which include propellant, insulation and liner, nozzle, igniter charge, and weather seal.

6.1.1.12 Weight Empty. Weight empty is defined as the total of inert motor component weights excluding R&D instrumentation.

6.1.1.13 Burnout Motor Weight. Total prelaunch weight minus expendables is burnout condition. A definition of burnout weight is prelaunch weight minus inert expendable weight excluding expended propellant and igniter charge weight.

6.1.1.14 Loaded Propellant Weight. Loaded propellant weight is defined as all solid propellant weight in the rocket motor.

6.1.1.15 Nominal Inert Motor Weight. Nominal inert motor weight includes the following: The motor case with nozzle, thrust termination port covers and stacks, skirts, igniter, and internal insulation. It does not include the TVC system and its attachments, instrumentation, ordnance system, power supplies, other electrical systems, external insulation, all vehicle attachment and aerodynamic fairings.

6.1.1.16 Mass Fraction. The nominal propellant mass fraction ($\lambda \rho$) is determined by the following method:

$$\lambda \rho = W_p / (W_p + W_i)$$

Where: W_p = Loaded Propellant Weight

W_i = Nominal Inert Motor Weight

6.1.1.17 Resolution. Resolution is defined as the minimum change in input voltage necessary to produce a change in generated side force, in the same direction as the previous change.

6.1.1.18 Hysteresis. Hysteresis is defined as the difference in input voltage required to produce a change in generated thrust vector moment arm (TVMA) when the direction of the TVMA is changed due to command voltage reversals.

6.1.1.19 Deflection Angle. Deflection angle is defined as the arctan of the side thrust measured perpendicular to the nozzle centerline divided by the axial thrust measured along the nozzle centerline.

6.1.1.20 Launch Reaction Time. Launch reaction time is defined as the time required to prepare to launch a vehicle following the completion of prelaunch checkout.

6.1.1.21 Abort Recycle Time. Abort recycle time is defined as the time required to launch a vehicle following an abortive launch attempt.

6.1.1.22 The SRM Pitch (Yaw) Thrust Vector Angle. The angle between the SRM motor centerline and the projection of the SRM thrust vector into the SRM pitch (yaw) plane.

6.1.1.23 <u>SRM Pitch (Yaw) Plane</u>. The plane defined by the SRM motor centerline and a line which is normal to the SRM centerline and parallel to the vehicle pitch (yaw) plane.

6.1.1.24 <u>The SRM Pitch (Yaw) Thrust Vector Moment Arm</u>. The length of the perpendicular line from the SRM motor centerline at missle station (TBS) to the SRM projection of the thrust vector into the pitch (yaw) plane.

6.1.1.25 <u>Solid Rocket Motor Centerline</u>. The line joining the center of the aft closure-to-nozzle throat bolt circle to the center of the forward closure in the plane of the forward attach structure.

6.1.1.26 <u>Nozzle Centerline</u>. The line joining the center of the nozzle throat to the center of the nozzle exit.

6.1.1.27 <u>Stage Centerline</u>. The line joining the center of the stage/orbiter assembly joint bolt circle and the center of the aft structure support structure.

6.1.1.28 <u>SRM Thrust Vector</u>. The force vector whose magnitude and variability is defined by paragraph 3.1.1.1.1, and whose direction and variability is defined by paragraph 3.1.1.1.2.

6.1.1.29 <u>Stage Roll Plane</u>. A plane perpendicular to the stage centerline which intersects the stage centerline at missile station (TBS).

6.1.1.30 <u>Stage Roll Control Moment</u>. The resultant moment about the stage centerline of the sum of the SRM thrust vectors projected into the stage roll plane.

10. APPENDIX

10.1 Test Configuration. The static test configuration of the SRM shall conform to UTC drawing (TBS). This drawing shows several obvious differences from the flight configuration. These differences shall not affect performance but are related to ordance, structural, and instrumentation measurements which pertain directly to the static test program.

Specific differences shall include the following areas: (TBS)

The following figures are to be supplied:

Figure 1. Ignition Transient 156-Inch Thrust Versus Time & Nozzle Sea Level at 60°F

Figure 2. Ignition Transient 156-Inch Pressure Versus Time at 60°F

Figure 3. Vacuum Thrust Versus Time, 40°F

Figure 4. Vacuum Thrust Versus Time, 60°F

Figure 5. Vacuum Thrust Versus Time, 70°F

Figure 6. Vacuum Thrust Versus Time, 90°F

Figure 7. Sea Level Thrust Versus Time, 40°F

Figure 8. Sea Level Thrust Versus Time, 60°F

Figure 9. Sea Level Thrust Versus Time, 70°F

Figure 10. Sea Level Thrust Versus Time, 90°F

Figure 11. Forward Head Pressure Versus Time, 40°F

Figure 12. Forward Head Pressure Versus Time, 60°F

Figure 13. Forward Head Pressure Versus Time, 70°F

Figure 14. Forward Head Pressure Versus Time, 90°F

Figure 15. Aft End Pressure Versus Time, 40°F

Figure 16. Aft End Pressure Versus Time, 60°F

Figure 17. Aft End Pressure Versus Time, 70°F

Figure 18. Aft End Pressure Versus Time, 90°F

Figure 19. Aft to Forward Head Pressure Ratio Versus Time

Figure 20. Thrust Vector Angle Versus Command Voltage and Chamber Pressure

Figure 21. Thrust Vector Moment Arm Versus Command Voltage and Nominal Chamber Pressure

Figure 22. Roll Control Moment Versus Roll Command Voltage and Nominal Chamber Pressure

Figure 23. Frequency Response

Figure 24. Slew Rates

Figure 25. Net Thrust Versus Time from Thrust Termination Actuation

Figures 26 through 30. Schematic Arrangements of SRM Electrical Systems

PRELIMINARY

PRIME ITEM DEVELOPMENT SPECIFICATION

ROCKET MOTOR, SPACE SHUTTLE BOOSTER, P4-120

Basic Approved by______________________
(United Technology Center)

Basic Approved by______________________

Date______________________

Date______________________

1. SCOPE. This specification establishes the performance, design, development, and test requirements for the P4-120 space shuttle booster rocket motor prime item.

2. APPLICABLE DOCUMENTS. The following documents form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification
MIL-H-6083	Hydraulic Fluid, Petroleum Base, Preservative
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles

United Technology Center

(TBS)	Forward Section, Rocket Motor
(TBS)	Mechanical Hardware Set, Rocket Motor
(TBS)	Ordnance Set, Rocket Motor
(TBS)	Segment Assembly, Rocket Motor
(TBS)	Aft Section, Rocket Motor
(TBS)	Extension, Nozzle Exit Cone
(TBS)	Nose Section, Rocket Motor
(TBS)	Aft Structure, Rocket Motor
(TBS)	Interstage Structure
(TBS)	Flight Instrumentation Set, Rocket Motor
(TBS)	Battery Set

STANDARDS

Military

MIL-STD-130	Identification Marking of US Military Property
MIL-STD-447	Definitions of Interchangeability, Substitute and Replacement Items
MIL-STD-470	Maintainability Program Requirements (form Systems and Equipment)
MIL-STD-471	Maintainability Demonstration Requirements
MIL-STD-778	Maintainability Terms and Definitions
MS33586	Metals, Definition of Dissimilar

DRAWINGS

United Technology Center

C09008	Rocket Motor Assembly - 120 Parallel
(TBS)	Electrical System - Interconnect Diagram

OTHER PUBLICATIONS

AFM-127-100	Explosives Safety Manual
(TBS)	Range Safety Manual
(TBS)	Policies, Procedures, and Criteria
(TBS)	Facility Contract End Item and Interface Specification, Performance, Design and Interface Requirements for Space Shuttle Booster
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Parametric Interfaces (Performance, Environmental and Flight Control)
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Structural and Dynamic Loading Interfaces

(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System, Electrical Interfaces
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Testing Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Physical Interfaces (Mechanical and Structural)
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Electrical Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Envelope Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Fluid Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Motor to Launch Vehicle System - Installation Interfaces
(TBS)	Electromagnetic Compatibility (EMC) Control Plan
(TBS)	System Effectiveness Management Plan
(TBS) (NASA)	Space Shuttle Booster System Performance/Design Requirements, General Specification

3. REQUIREMENTS

3.1 Performance

3.1.1 Functional Characteristics. The solid rocket motor (SRM) shall conform to the following functional characteristics from sea level to 200,000 feet (when ignited in air at altitudes up to 2500 feet) for motor mean bulk temperatures of (TBS) degrees Fahrenheit (°F) to (TBS). The design temperature for all calculations and reporting shall be (TBS). Thrust vector characteristics are specified relative to the motor centerline at missile station (TBS).

3.1.1.1 Primary Performance Characteristics.

3.1.1.1.1 Propulsion System Performance Characteristics.

3.1.1.1.1.1 Ignition Transient. Ignition delay shall be TBS to TBS milliseconds for motor mean bulk temperatures of (TBS)°F to (TBS)°F inclusive. The motor chamber pressure at ignition from 50 percent to 100 percent of maximum chamber pressure shall be such that the differential chamber pressure between any two motors simultaneously ignited shall not exceed TBS percent of the maximum chamber pressure. Predicted igniter nominal performance is depicted in Figures 1 and 2.

3.1.1.1.1.2 Vacuum and Sea Level Performance. The SRM shall have a vacuum and sea level performance rating as indicated in Table I. The limits specified in Table I apply to a nominal established by the maximum number of test firings available. This actual nominal may vary from the nominal of Table I by the percentages specified in the column headed "Percent 3-sigma Variation of Nominal".

3.1.1.1.1.3 Thrust Characteristics. The SRM thrust versus time shall be as shown in Figures 3 through 10. The actual nominal established by the maximum number of test firings available shall fall within the dotted lines of Figures 3 through 10. The 3σ dispersion on the actual nominal shall be ± 95,000 pounds, except during tail-off when paragraph 3.1.1.1.1.9 shall apply. Estimated head end motor pressure is shown in Figures 11 through 14. Estimated aft end stagnation pressure is shown in Figures 14 through 18. Figure 19 shows the estimated relationship between head end pressure and aft end stagnation pressure for mean bulk temperature of 40°, 60°, 70°, and 90°F.

Table I. Shuttle Booster Performance Summary
60°F

		Nominal Rating	Percent 3-Sigma Variation of Nominal
Web Time, sec		128.3	2.16
Average Pressure, psia		514	
Average Thrust (SL), lb_f	$x10^6$	0.991	
Average Thrust (vac), lb_f	$x10^6$	1.172	
Average Specific Impulse (SL), sec		227.0	0.7
Average Specific Impulse (vac), sec		268.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	127.2	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	150.4	1.0
Propellant Consumed, lb	$x10^3$	560.2	
Action Time, sec		140.2	3.11
Average Pressure, psia		496	
Average Thrust (SL), lb_f	$x10^6$	0.952	
Average Thrust (vac), lb_f	$x10^6$	1.131	
Average Specific Impulse (SL), sec		225.8	0.7
Average Specific Impulse (vac), sec		268.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	133.5	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	158.6	1.0
Propellant Consumed, lb	$x10^3$	591.0	

		Nominal Rating	Percent 3-Sigma Variations of Nominal
Duration, sec		142.0	
Maximum Pressure, psi		837	
Initial Thrust (SL), lb_f	$x10^6$	1.431	6.0
Maximum Thrust (vac), lb_f	$x10^6$	1.615	
Total Impulse (vac), lb_f-sec	$x10^6$	158.9	1.0
Propellant Consumed, lb	$x10^3$	591.8	

3.1.1.1.1.4 Maximum Expected Operating Chamber Pressure. The maximum expected operating chamber pressure (MEOP) shall be 1000 pounds per square inch gage (psig).

3.1.1.1.1.5 SRM Thrust Vector. Solid rocket motor thruat vector performance is defined for a motor whose nozzle centerline is coincident with the motor centerline. Alignment and movement of the thrust vector is defined in paragraph 3.1.1.1.2.

3.1.1.1.1.6 Stage Thrust Vector. Stage thrust vector performance is defined for the thrust vector sum of the individual solid rocket motors. The stage thrust vector location, alignment and movement is defined in 3.1.1.2 relative to the stage centerline and to the intersection of the stage centerline with the stage/orbiter separation plane, MS (TBS).

3.1.1.1.1.7 Nozzle Characteristics. (TBS)

3.1.1.1.1.8 Propellant. (TBS)

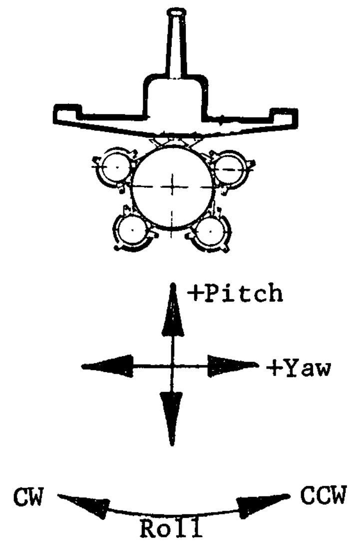
3.1.1.1.1.9 Thrust Decay. (TBS)

3.1.1.1.2 Primary Thrust Vector Control (TVC) System Performance Characteristics. The TVC system shall provide the performance indicated below during stage operation under initial pre-launch temperatures of 25°F to 100°F. The TVC system shall utilize movable nozzles on each SRM to provide omniaxial thrust vector orientation in accordance with pitch, yaw, and roll command signals from the vehicle guidance system. The TVC performance of the individual SRMs shall be as specified in the TVC Math. Model Specification (TBS).

3.1.1.1.2.1 TVC System Operation. The stage TVC system shall consist of omni-directional movable nozzles. Each SRM shall have a single movable nozzle operated by two servo-controlled hydraulic actuators located in mutually perpendicular planes. The actuators shall position the SRM nozzles in accordance with pitch, yaw, and roll commands from the vehicle guidance system. Nozzle rotation shall be limited electronically to prevent overtravel in any axis. Control axes interactions and actuator cross-coupling shall be defined and compensation provided as required to obtain vehicle response in accordance with command control moments and within the control variations defined herein.

3.1.1.1.2.2 SRM Axes Definition. Table II shows the SRM axes definition and indicates the command voltages and polarities required to provide control moments about the roll, pitch, and yaw axes.

Table II. Axes Definition and Command Voltage



Booster SRM Axes Definition Looking Forward

Command Voltage Relative to its individual corresponding return	Externally Directed Force
-10 to +10 volts on pitch command lines (three redundant pairs)	Pitch of same polarity as command
-10 to +10 volts on yaw command lines (three redundant pairs)	Yaw of same polarity as command
-10 to +10 volts on roll command lines (three redundant pairs)	Roll CW for (+) commands and CCW for (-) commands

3.1.1.1.2.3 <u>SRM Thrust Vectoring</u>. The nominal SRM pitch (yaw) thrust vector angle, as a function of command voltage and nominal motor chamber pressure, shall be as shown in Figure 20 and as described in the TVC Math. Model, for all SRM thrust vector angles between ± 10 degrees.

3.1.1.1.2.4 <u>SRM Thrust Vector Moment Arm</u>. The nominal SRM pitch (yaw) thrust vector moment arm as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure 21 and as described in the TVC Math. Model, for all thrust vector moment arms within $\pm$ (TBS)inches.

3.1.1.1.2.5 TVC Hysteresis. Three-sigma deviations from nominal TVC relationships in 3.1.1.1.2.3 and 3.1.1.1.2.4, due to command voltage reversals, shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or the greater of ±(TBS)% or ± (TBS) inches, respectively, from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or ±(TBS)% or ±(TBS) inches, respectively, from web action time to action time.

3.1.1.1.2.6 TVC Variability. Three-sigma variability of the SRM thrust vector angle shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, and variability or the slope of the command voltage-to-thrust vector moment arm relationship shall not exceed the greater of ±(TBS)% or ±(TBS) inches/volt from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, and the greater of ±(TBS)% or ±(TBS) inches/volt, respectively, from web action time to action time. This variability shall include all deviations, tolerances, and cross-coupling efforts excepting variations in the nominal motor chamber pressure with SRM mean bulk temperature.

3.1.1.1.2.7 Roll Control Moments. The nominal stage roll control moment as a function of roll command voltage and nominal motor chamber pressure shall be as shown in Figure 22 and as described in the TVC Math. Model. Three-sigma variations shall not exceed the greater of ±(TBS)% or ±(TBS) inch-pounds from web action time to action time. Three-sigma deviations from the nominal command voltage-to-roll control moment relationship, due to command voltage reversal, shall not exceed ±(TBS) inch-pounds from ignition to web action time, and ±(TBS) inch-pounds from web action time to action time.

3.1.1.1.2.8 Resolution. The TVC system resolution within the range of ±10 degrees of SRM thrust vector angle shall not exceed (TBS) volts from ignition to web action time and (TBS) volts from web action time to action time.

3.1.1.1.2.9 Frequency Response. The total thrust vector control system frequency response at any ambient voltage command level in the defined nozzle axes for motor chamber pressures between (TBS) and (TBS) psia shall be as specified by the upper and lower limits of the amplitude ratio and phase lag given in Figure 23. This curve is valid as long as the maximum command voltage does not exceed TBS VDC, the velocity or rate of change of the command voltage is below the minimum slew rates specified in Figure 24 and the minimum command is greater than (TBS) VDC.

3.1.1.1.2.10 Slew Rate. The TVC system shall be capable of changing the vehicle thrust vector angle at a minimum slew rate of 5 degrees per second throughout motor operating time. This requirement shall apply for all motor and actuation system operating conditions in conjunction with external nozzle loads and environments as specified in (TBS). Slew rate is defined as the instantaneous rate of change of thrust vector angle for command changes exceeding (TBS) volts at a rate exceeding (TBS) volts per second. The minimum and maximum slew rate limits as a function of flight time shall be as shown in Figure 24. Minimum slew rate is derived assuming nominal SRM performance combined with minus 3-sigma control system performance and plus 3-sigma external nozzle loads. Maximum slew rate is derived assuming nominal SRM performance combined with plus 3-sigma control system performance and minus 3-sigma nozzle loads.

3.1.1.1.3 <u>SRM Ignition</u>. Each SRM of the booster stage shall provide an integral igniter motor that shall perform the function of initiating SRM ignition. Simultaneous ignition initiation of each SRM of the booster stage shall be accomplished by receipt of simultaneous command signals from the orbiter or from ground equipment to the ordnance electrical system of each SRM.

3.1.1.1.4 <u>Staging Performance</u>. (TBS) staging motors per SRM, (TBS) in the nose section, and (TBS) in the aft section shall supply the lateral staging impulse to each SRM to fulfill the requirements of the shuttle booster general systems specification (TBS). Staging ignition initiation shall be accomplished by the SRM ordnance electrical system upon receipt of command from the orbiter.

3.1.1.1.5 <u>Flight Safety</u>. To preclude or limit hazard to personnel and/or equipment, each SRM of the booster stage shall incorporate: (1) a thrust termination system with provisions for activation when commanded by the orbiter vehicle or upon detection of an inadvertent separation of an SRM from the launch vehicle, and (2) an inadvertent separation detection system (ISDS), and (3) an emergency detection system for monitoring critical booster parameters and providing signals to the orbiter crew. The design of these systems shall be in accordance with the requirements of Range Safety (TBS) Shuttle Booster General System Specification (TBS) and Component CEI Specifications.

3.1.1.1.5.1 <u>Thrust Termination Performance</u>. A two-port thrust termination system shall be provided on each solid rocket motor. The thrust termination system shall effectively neutralize the axial thrust of each SRM by venting the combustion chamber at the forward end of each SRM. Each solid rocket motor and its thrust termination system shall be capable of surviving the environments created by thrust termination for a period of (TBS) seconds after the initiation of thrust termination. The thrust termination performance for a single solid rocket motor is shown in Figure 25.

3.1.1.1.5.2 <u>Emergency Detection System</u>. The emergency detection system shall provide the following output signals to the orbiter:

(a) Fast Failure: A signal shall be present when an emergency condition exists which will result in motor failure within (TBS) seconds and an immediate abort is required;

(b) Slow Failure: A signal shall be present when an emergency condition exists which will result in motor failure after at least (TBS) seconds from initial detection;

(c) Unverfied Failure: A signal shall be present when an emergency condition is sensed by only one of a pair of redundant transducers;

(d) Emergency Detection System Self Check: A signal shall be present when all malfunction detection system self-check circuits are indicating proper operation.

An emergency detection system input shall be provided such that the system can be disabled on command from the orbiter.

3.1.1.1.5.3 Inadvertent Separation Detection System (ISDS). Each SRM of the booster stage shall provide an ISDS that shall detect the inadvertent loss of electrical cabling between the orbiter/launch vehicle and automatically initiate thrust termination prior to receipt of a disable command from the orbiter. The ISDS shall be an integral part of the SRM ordnance electrical system.

3.1.1.1.6 Electrical Power, Control, and Distribution. Each SRM of the booster stage shall provide the airborne power, switching capability from ground power to airborne power, and the distribution of all airborne power to the TVC system, ordnance system, emergency detection system, and flight instrumentation system. Each SRM of the booster stage shall receive and distribute ground power for SRM systems ground operation and checkout. All systems shall operate from 28 VDC (nominal) power sources.

3.1.1.2 Secondary Performance Characteristics.

3.1.1.2.1 Instrumentation System Performance Characteristics. The booster stage instrumentation system shall provide signal outputs to the orbiter for the purpose of verification and evaluation of booster stage status and performance prior to and during flight. The functional status of specified redundancy features included in the other booster stage systems shall be indicated by discrete output signals to the orbiter.

3.1.1.2.2 Checkout Provisions. Provisions shall be made to allow the following booster stage verification tests to be performed on an assembled launch vehicle via the airborne and ground electrical interfaces.

(a) Detailed functional tests, as specified in (TBS), of all electrical and mechanical subsystems, including operational status of redundant features.

(b) System operability (quick-look) tests, as specified in (TBS) of the flight critical active systems, providing go/no go signals, including checks of redundant features.

(c) Integrated-system test, as specified in (TBS), performed as a simulated countdown and flight with the complete launch system.

(d) Booster stage component malfunction isolation and component checkout tests as specified in (TBS).

During these tests, airborne items which are not operated due to safety, one-operation capability, reduced hold capability, or physical difficulty will be checked in a non-operating mode to verify operable status and proper installation. No nonflight hardware will be connected to the stage for these tests except the normal ground umbilical cable.

3.1.1.2.3 Mass Property Requirements. Nominal values of mass, center of gravity (cg) location, and moments of inertia shall be determined as a function of flight characteristics. Three sigma tolerances on the prelaunch values shall be as follows:

	Individual SRMs	Stage
cg location - longitudinal	±7.7 inches	±
pitch plane	±1.6 inches	±
yaw plane	±1.7 inches	± (TBS)
Mass	±3,600 pounds	±
Moments of inertia	±10 percent	±

The mass fraction of the motor shall be (TBS) minimum using the "inert" motor definition in Section 6.

3.1.1.2.4 Hold and Reaction Time Requirements. The booster stage shall be capable of maintaining a launch hold at T-(TBS) minutes for 30 days without environmental protection (shall allow electrical maintenance of batteries via the ground umbilical cable during the hold). The booster stage shall be capable of a launch reaction time of (TBS) hours after integrated system test and a system abort recycle time for causes external to the vehicle of TBS hours. The booster stage shall be capable of proceeding to T-(TBS) seconds returning to T-(TBS) minutes and holding for 30 days.

3.1.2 Operability. The SRM shall conform to the following operability requirements.

3.1.2.1 Reliability. The reliability of the SRM booster stage shall be as specified in the shuttle booster general systems specification (TBS).

3.1.2.2 Maintainability. The SRM booster stage shall meet the maintainability requirements of MIL-STD-470. Quantitative requirements shall be established for the contributions to system downtime considering the AGE, facilities, and airborne portions of the vehicle system. The maintainability apportionment shall be consistent with the probability of launch-on-time requirements. Downtime shall be interpreted as active downtime defined in MIL-STD-778 and shall not be greater than (TBS) hours mean active time to restore. Mean maintenance-downtime (M) is described for corrective-maintenance functions as:

$$\bar{M}_{ct} = \frac{\sum_{1}^{N_c} M_{ct}}{N_c} = \bar{M} \text{ hours}$$

Where:

$\bar{M}_{ct}$ = mean maintenance correction-time for sub-system (arithmetic mean)

N_c = number of corrective maintenance-functions for modular remove/replace maintenance concept

M_{ct} = active maintenance correction-time per corrective maintenance task

The quantitative $\bar{M}$ allocations shall be as follows:

(TBS)

The M allocations do not apply on a lower level of assembly because maintenance or test results pertinent to a requirement for maintenance only occurs at the fully assembled level. The above subsystems are defined in the UTC System Effectiveness Plan, (TBS).

3.1.2.2.1 Maintenance and Repair Cycles. Maintainability analyses shall establish time goals for the completion of maintenance activities and the associated design and procedural approaches. This data will be incorporated into equipment specifications and, thus, constitute objectives to be accomplished during the design process. Maintenance functions for support of the SRM are corrective-maintenance functions. Preventive maintenance is not considered in the maintenance concept.

3.1.2.2.2 Service and Access. Access shall be provided so all interface connections and maintenance operations can be performed. The ordnance and TVC subsystems shall be capable of checkout and servicing while installed in the SRM. Access requirements shall be evaluated to ascertain performance of corrective-maintenance tasks upon which active maintenance downtime is based, and which are organizational level remove/replace maintenance functions.

3.1.2.3 Useful Life. The SRM booster stage shall comply with shuttle booster general system specifications (TBS). The SRM booster stage shall meet the requirements of this specification after exposure to the environment specified in paragraph 3.1.2.4 for a period of one year. Cyclic life limitations shall be as defined in the component CEI specifications (see paragraph 3.3.1.3)

3.1.2.4 Environmental.

3.1.2.4.1 Prelaunch. The SRM booster stage shall perform as specified herein after exposure to the following environments:

(a) Temperature - Surrounding air temperatures between 25° and $100^{\circ}F$ with mean bulk propellant temperatures of 40° to $90^{\circ}F$ for periods up to 60 days

(b) Humidity - Relative humidities of up to 100 percent including condensation in the form of water or frost for periods up to 60 days.

(c) Fungus - Exposure to fungi equivalent to 28 days of exposure to selected fungi as described in Specification MIL-E-5272. As a design goal,materials which are fungus nutrient shall not be used.

(d) Sand and dust - Exposure to windblown graded sand and dust equivalent to exposure for 6 hours in a sand-and-dust chamber as described in Specification MIL-E-5272

(e) Sunshine - Normally exposed, nonmetallic materials shall withstand the deteriorating effects of direct sunlight for periods up to 60 days.

(f) Salt fog - Exposure to salt fog equivalent to exposure to a 20-percent salt spray for:

(i) 10 hours for internally-mounted equipment

(ii) 50 hours for externally-mounted equipment

(g) Rain - Exposure to rain equivalent to 4 inches per hour for 2 hours

(h) Wind and gusts - Exposure to the wind and gusts prevalent at the launch base as defined in (TBS)

(i) Propellant compatibility - (TBS)

(j) Loads - Exposure to loads induced by the winds and gusts specified in (h) above

(k) Overpressure - Exposure to overpressures induced by an incident on an adjacent launch pad as defined in (TBS).

3.1.2.4.2 Launch and Flight. The SRM booster stage shall perform as specified herein during and after exposure to the environments specified in the shuttle booster general system specification (TBS).

3.1.2.4.3 Storage. The SRM shall perform as specified herein when its components CEI's are stored at mean bulk temperatures between $40^{\circ}F$ and $90^{\circ}F$ with propellant surfaces protected from humidity in excess of 50 percent RH.

3.1.2.5 Transportability. The assembled SRM will not be transported. Transportation environments will be within the limits specified in paragraph 3.1.2.4. The forward section, segments, and aft section shall be transportable in the clevis-down or horizontal position without degradation of the propellant or bonding to the extent that would preclude the SRM from performing as specified herein. Component CEI's shall be designed so that only passive means of environmental protection are required during transportation.

3.1.2.6 Human Performance. The SRM booster stage and associated ground equipment shall meet the human-performance requirements of (TBS).

3.1.2.7 Safety.

3.1.2.7.1 Flight Safety - Design of airborne systems shall meet the requirements of applicable range safety specifications (TBS).

3.1.2.7.2 Ground Safety. The SRM shall be compatible with the shuttle booster general specification (TBS).

3.1.2.7.3 Nuclear Safety. Not applicable.

3.1.2.7.4 Personnel Safety. Provisions for personnel safety shall be in accordance with the shuttle booster general specification (TBS).

3.1.2.7.5 Explosive and/or Ordnance Safety. The system shall comply with the requirements of paragraph 3.1.2.7.4 of this CEI Specification and the shuttle booster general specification (TBS) to the extent specified in the component CEI Specifications. The explosive classification of each assembled SRM shall be Class 2 in accordance with AFM-127-100.

3.2 Configuration Item Definition.

3.2.1 Interface Requirements.

3.2.1.1 Schematic Arrangement. Each SRM shall conform to the dimensions shown in UTC Drawing C09008. The schematic arrangement of the overall system and each electrical system shall be as shown in Figures 26 through 30 and UTC Drawing (TBS).

3.2.1.2 Detailed Interface Definition.

3.2.1.2.1 System Interfaces. All interfaces between the SRM booster stage, the orbiter vehicle, and the facility will be defined and controlled by the following interface documents:

(TBS)

3.2.1.2.2 AGE Interfaces. Necessary interfaces for the SRM booster stage launch pad testing shall be provided for mating with the following equipment:

(TBS)

3.2.2 Component Definition.

3.2.2.1 Customer-Furnished Property List. The following items, which are to be furnished by the customer, are required for flight CEI operation:

(a) Component configuration items (see 3.3.1.3)

3.2.2.2 Engineering-Critical-Components List. Engineering critical components are listed in the component configuration item specifications.

3.2.2.3 Logistics Critical Components List. Logistics critical components are listed in the component configuration item specifications.

3.3 Design and Construction.

3.3.1 General Design Features.

3.3.1.1 General Design and Construction Requirements. The SRM design shall comply with the shuttle booster general system specification (TBS).

3.3.1.2 Description.

3.3.1.2.1 Solid Rocket Booster Stage. The solid rocket booster stage shall consist of four solid rocket motors, their attach structure and the various systems required by this specification. Each motor shall be a 7 segment 120-inch diameter motor with spherical end closures at each end. The segments and closures are joined with a pressure sealing clevis joint. An aerodynamic nose fairing attaches to the forward end and houses portions of the electrical system and the forward staging rocket motors.

3.3.1.2.2 Segments and Closures. Each segment is insulated with rubber and cast with composite, aluminized propellant in the form of a hollow cylinder. One end of the grain is restricted from burning by a rubber restrictor and a tapering of the central perforation provides the required tailoff thrust characteristics. The forward closure is insulated with rubber and propellant is cast in the form of an eight-point star with ports provided to allow for thrust termination. The aft closure is rubber insulated and has a circular port grain configuration.

3.3.1.2.3 Nozzle and Exit Cone. To the aft closure is attached a 52-inch diameter ablative throat and a 20° conical ablative exit cone with an expansion ratio of 10.6:1.

3.3.1.2.4 Thrust Vector Control System. Thrust vector control is provided by movable nozzles on each SRM. Each nozzle is supported by a constant volume fluid filled bearing which transmits the nozzle blowoff loads and thrust vectoring loads to the SRM by means of two annular rolling convolutes. Movement of the nozzle, within the limits of the fluid bearing, is produced by actuators placed in mutually perpendicular planes. Hydraulic power for the actuators is provided by a regulated pressure supply system using a solid propellant gas generation as the energy source. Actuator position control is accomplished by an electronic control unit which resolves and conditions vehicle guidance system steering commands into the appropriate control responses.

3.3.1.2.5 Attach Structure. The four solid rocket motors are attached to the orbiter tank by a thrust transmission structure near the forward end of the SRM which transmits SRM thrust to the orbiter, and by an aft structure which reacts the transverse and radial loads. The aft structure also provides ground support for a single SRM during buildup and ground support for the assembled vehicle. Provisions for mounting staging motors are provided at the fore and aft ends of each SRM.

3.3.1.2.6 Emergency Detection System. Detection of impending solid rocket motor failures necessitating a mission abort is provided by this system. The output of various pairs of redundant transducers are compared to predetermined criteria to determine presence of an impending failure situation. Parallel redundancy is utilized in this system to reduce the possibility of an inadvertent mission abort.

3.3.1.2.7 Instrumentation System. The instrumentation system shall monitor pertinent booster stage parameters and supply conditioned signals to the orbiter telemetry system to verify and evaluate booster stage status and performance prior to and during flight. The system also provides signal inputs and outputs via the ground umbilical cable required to accomplish verification tests on the booster stage. The design of the instrumentation system shall be such that no single instrumentation system component failure will result in performance degradation of any other booster stage system such that the limits of this specification are exceeded.

3.3.1.2.8 Ordnance System. The ordnance systems for the SRM booster stage provides the capability of performing the functions of booster ignition, staging, thrust termination, and inadvertent separation detection by initiation of ordnance devices. The ordnance electrical system provides the power and control of the firing units to initiate the devices. Firing unit charging is accomplished upon command from the orbiter vehicle or ground station.

3.3.1.2.9 Redundancy. Redundancy shall be utilized, to the maximum extent practicable, in all systems to exclude the possibility of a single non-structural failure causing out-of-specification performance.

3.3.1.2.10 Weights. The predicted component weights are given in Table III.

Table III. Component Weights

Component	Weight
Attach structure	(12,342)
Forward	5,516
Aft	6,826
Separation system	1,238
Solid motor (empty)	(73,938)
Case	(49,252)
Forward Closure	5,928
Segments (Total)	38,780
Aft Closure	4,196
Assembly Hardware	348
Insulation	(12,230)
Forward Closure	1,710
Segments (Total)	9,345
Aft Closure	1,175
Ignitor	378
Thrust Termination	1,556
Nozzle	(10,522)
Movable	8,258
Fixed	2,264
Actuation System	930
Electrical and Instrumentation	1,123
Weight Empty	89,571
Solid Propellant	591,800
Single Loaded Motor — Total	681,371
Interstage Structure	1,000
STAGE TOTAL	2,726,484

3.3.1.3 Component Configuration Items. The following subparagraphs identify the component configuration items which form each SRM of the booster stage.

3.3.1.3.1 Forward Section, Rocket Motor. Each rocket motor forward section shall be in accordance with UTC Specification (TBS).

3.3.1.3.2 Aft Section, Rocket Motor. The rocket motor aft section shall be in accordance with UTC Specification (TBS).

3.3.1.3.3 Segment Assembly, Rocket Motor. The rocket motor segment assembly shall be in accordance with UTC Specification (TBS).

3.3.1.3.4 Nose Section, Rocket Motor. The rocket motor nose section shall be in accordance with UTC Specification (TBS).

3.3.1.3.5 Extension, Nozzle Exit Cone. The nozzle exit cone extension shall be in accordance with UTC Specification (TBS).

3.3.1.3.6 Battery Set. All flight batteries shall be in accordance with UTC Specification (TBS).

3.3.1.3.7 Ordnance Set, Rocket Motor. The rocket motor ordnance set shall be in accordance with UTC Specification (TBS).

3.3.1.3.8 Mechanical Hardware Set, Rocket Motor. The rocket motor mechanical hardware set shall be in accordance with UTC Specification (TBS).

3.3.1.3.9 Aft Structure, Rocket Motor. The rocket motor aft structure shall be in accordance with UTC Specification (TBS).

3.3.1.3.10 Flight Instrumentation Set, Rocket Motor. The rocket motor flight instrumentation set shall be in accordance with UTC Specification (TBS).

3.3.2 Selection of Specifications and Standards. The selection of specifications and standards shall be in accordance with shuttle booster general specification (TBS).

3.3.3 Materials, Parts, and Processes. Materials, parts and processes used in each SRM shall conform to the applicable requirement as specified in shuttle booster general specification (TBS) as further defined by component CEI Specifications referenced in paragraph 3.3.1.

3.3.4 Standard and Commercial Parts. Standard and commercial parts shall be in accordance with shuttle booster general system specification (TBS).

3.3.5 Moisture and Fungus Resistance. Materials used in this CEI shall comply with the requirements of shuttle booster general system specification (TBS) as specified in the component CEI Specifications.

3.3.6 Corrosion of Metal Parts. All metal parts used in fabrication of the SRM shall be corrosion resistant or suitably treated to resist corrosion when exposed to the environmental conditions specified in paragraph 3.1.2.4. Wherever practical, the use of dissimilar metals, as defined in Standard MS33586, in contact with each other shall be avoided.

3.3.7 Interchangeability and Replaceability. The interchangeability and replaceability, as specified in MIL-STD-447, of the SRM components shall be in accordance with MIL-I-8500.

3.3.8 Workmanship. Each SRM shall be fabricated and finished in such a manner that criteria of appearance, fit, and adherence to specified tolerances shall be observed. Particular attention shall be given to the neatness and thoroughness of soldering, wiring, marking of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.9 Electromagnetic Interference. Each SRM shall meet the electromagnetic interference requirements of Electromagnetic Compatibility Control Plan (TBS).

3.3.10 Identification and Marking. Each SRM shall be identified and marked in accordance with MIL-STD-130 and (TBS).

3.3.11 Storage. Each assembled SRM and its components shall conform to the storage requirements of paragraphs 3.1.2.3 and 3.1.2.4, as applicable.

3.3.12 Cleanliness. Each SRM and its components shall meet the cleanliness requirements of (TBS).

4. QUALITY ASSURANCE PROVISIONS.

4.1 Category I Test. Category I tests as used herein shall be defined as contractor-performed component, subsystem and full-scale static sea level tests. Records and documentation of results of all Category I testing shall be maintained in comprehensive, legible format.

4.1.1 Engineering Test and Evaluation. Engineering tests and evaluations shall be conducted to provide maximum assurance of successful completion of the qualification and category II system tests specified below.

4.1.1.1 Development Testing. (TBS) motor firing tests shall be conducted at a UTC test facility during the development phase, (TBS) vertical at UTC and (TBS) horizontal thrust termination test. Motors shall be instrumented during these firings to evaluate the internal ballistic performance, TVC performance, and electrical system performance. Test configuration shall be as specified in (TBS).

4.1.2 Preliminary Qualification Tests. (TBS) rocket motors identical in configuration to the final flight configuration will be fired in a preliminary flight rating test (PFRT) program to be conducted at a UTC test facility. The differences in configuration will be limited to those required for the inverted-from-flight attitude firings and are defined in (TBS). Successful completion of these firings will constitute the preliminary qualification test program.

4.1.3 Formal Qualification Tests. The following subparagraphs specify the requirements for, and methods of, formally verifying that each requirement in Section 3 has been satisfied.

4.1.3.1 Inspection. The following requirements of Section 3 shall be verified by an inspection at a time and place to be determined mutually by the customer and UTC: (TBS)

4.1.3.2 Analysis. Conformance to the following requirements shall be verified by comparative analysis of engineering documentation developed under previous programs and during the testing of 4.1.1.1 and 4.1.2. No further testing will be conducted to verify conformance to these requirements. (TBS)

4.1.3.3 Demonstrations. Not applicable.

4.1.3.4 Tests. The following requirements in Section 3 shall be verified during the preliminary qualification tests of 4.1.2: (TBS)

4.1.4 Reliability Tests and Analysis. At the start of the acquisition phase a reliability mathematical model shall be presented to justify reliability failure allocations for the various CEI components. The results of tests, failure reports, and conclusions as to system reliability shall be presented to the customer throughout the acquisition program. No special testing shall be specifically conducted to satisfy the provisions of 3.1.2.1.

4.1.5 Engineering Critical Component Qualification. Not applicable.

4.1.6. Interface Testing.

4.1.6.1 System Interfaces. Conformance to the requirement of paragraph 3.2.1.2.1 "System Interface" shall be verified by comparative analysis of engineering documentation developed under previous programs and during selected testing according to 4.1.1.1 and 4.1.2 as follows:

4.1.6.1.1 Parametric Interfaces. SRM seal-level ballistic and TVC performance as specified in (TBS) shall be verified to the extent analyzed by 4.1.3.2 and 4.1.3.4.

4.1.6.1.2 Structural and Dynamic Load Interfaces. These interfaces as specified in (TBS), shall be verified only to the extent that mass property requirements shall be verified as appropriate according to 4.1.3.2.

4.1.6.1.3 Electrical Interfaces. These interfaces as specified in (TBS) shall be tested as defined by (TBS). (ref: 4.1.6.1.4)

4.1.6.1.4 Testing Interfaces. These interfaces, as specified in (TBS) shall be verified to the extent where UTC electrical test requirements are applicable to the testing of 4.1.1.1 and 4.1.2. (reference 4.1.6.1.8 for fluid systems verifications.)

4.1.6.1.5 Physical Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.6 Electrical Interfaces. These interfaces, as specified in (TBS), shall be verified by testing as defined by (TBS). (ref.: 4.1.6.1.4)

4.1.6.1.7 Envelope Interface. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.8 Fluid Interfaces. To the extent that the fluid interfaces are required for the testing of 4.1.1.1 and 4.1.2, the interfaces (mechanical, fluid quantity and fluid quality) used for static test will be consistent with the requirements of (TBS) and thereby verify adequacy of requirements.

4.1.6.1.9 Installation Interfaces. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.2 Category II Test Program. The requirements of 3.3.9 shall be verified by tests to be performed after the SRM stage has been integrated into an assembled launch vehicle. The solid rocket motors shall demonstrate the following minimum vehicle centerline vacuum web action time total impulse when assembled and launched as a Stage of the space shuttle launch vehicle in accordance with MIL-STD-471: (TBS)

5. PREPARATION FOR DELIVERY. (TBS)

6. NOTES.

6.1 Supplemental Information. Maximum use shall be made of components qualified under other programs.

6.1.1 Definitions. For purposes of this specification the following definitions shall apply:

6.1.1.1 Web Action Time. Web action time shall be defined as follows: The start of web action time shall be that point in the pressure/time trace at which the head end pressure has reached 75 percent of maximum. The end of web action time shall be defined by the following geometric construction. Extend the general shape of the pressure time curve prior to and immediately after the beginning of tail-off. Then bisect the angle formed by this extension. Extend this bisector to intersect the pressure/time trace. The time that corresponds to this intersection point is the end of web action time.

6.1.1.2 Action Time. Action time is defined as beginning when the pressure has risen to 75 percent of the maximum chamber pressure and ending when the head end pressure has fallen to 10 percent of the maximum chamber pressure.

6.1.1.3 Delivered Specific Impulse. The delivered specific impulse shall be defined as the total impulse along the nozzle centerline delivered during web action time divided by the weight of propellant expended during web action time. Delivered specific impulse at plant site shall be extrapolated to specific impulse at vacuum conditions. The methods used to determine the weight of expended propellant and to extrapolate the data shall be presented subject to customer approval.

6.1.1.4 Regressivity. Regressivity is defined as the maximum vacuum thrust minus the vacuum thrust at end of web action time divided by the maximum vacuum thrust. All thrusts are taken along the nozzle centerline.

6.1.1.5 Action Time Total Impulse. Action time total impulse is defined as the integrated thrust along the nozzle centerline over the action time.

6.1.1.6 Initial Vacuum Thrust. Initial vacuum thrust is defined as that vacuum thrust along with the nozzle centerline at the completion of ignition. Initial vacuum thrust may be calculated from sea level data by adding 183,603 lb_f to the measured sea level nozzle centerline thrust.

6.1.1.7 Web Action Time Total Impulse. Web action time total impulse is defined as the integrated thrust along the nozzle centerline over the web action time.

6.1.1.8 Ignition Delay. Ignition delay is defined as the time interval between fire signal and when the motor chamber pressure reaches 75 percent of the initial peak pressure.

6.1.1.9 Tailoff. Tailoff is defined as the time interval between web action time and action time.

6.1.1.10 Total Prelaunch Weight (Nominal). Total prelaunch weight is defined as the sum of all motor weights which includes propellants and inerts.

6.1.1.11 Expendable Weight. Expendable weight is defined as the weight of those items that are expended from the motor which include propellant, insulation and liner, nozzle, igniter charge, and weather seal.

6.1.1.12 <u>Weight Empty</u>. Weight empty is defined as the total of inert motor component weights excluding R&D instrumentation.

6.1.1.13 <u>Burnout Motor Weight</u>. Total prelaunch weight minus expendables is burnout condition. A definition of burnout weight is prelaunch weight minus inert expendable weight excluding expended propellant and igniter charge weight.

6.1.1.14 <u>Loaded Propellant Weight</u>. Loaded propellant weight is defined as all solid propellant weight in the rocket motor.

6.1.1.15 <u>Nominal Inert Motor Weight</u>. Nominal inert motor weight includes the following: The motor case with nozzle, thrust termination port covers and stacks, skirts, igniter, and internal insulation. It does not include the TVC system and its attachments, instrumentation, ordnance system, power supplies, other electrical systems, external insulation, all vehicle attachment and aerodynamic fairings.

6.1.1.16 <u>Mass Fraction</u>. The nominal propellant mass fraction ($\lambda \rho$) is determined by the following method:

$$\lambda \rho = W_p / (W_p + W_i)$$

Where: W_p = Loaded Propellant Weight

W_i = Nominal Inert Motor Weight

6.1.1.17 <u>Resolution</u>. Resolution is defined as the minimum change in input voltage necessary to produce a change in generated side force, in the same direction as the previous change.

6.1.1.18 <u>Hysteresis</u>. Hysteresis is defined as the difference in input voltage required to produce a change in generated thrust vector moment arm (TVMA) when the direction of the TVMA is changed due to command voltage reversals.

6.1.1.19 <u>Deflection Angle</u>. Deflection angle is defined as the arctan of the side thrust measured perpendicular to the nozzle centerline divided by the axial thrust measured along the nozzle centerline.

6.1.1.20 <u>Launch Reaction Time</u>. Launch reaction time is defined as the time required to prepare to launch a vehicle following the completion of prelaunch checkout.

6.1.1.21 <u>Abort Recycle Time</u>. Abort recycle time is defined as the time required to launch a vehicle following an abortive launch attempt.

6.1.1.22 <u>The SRM Pitch (Yaw) Thrust Vector Angle</u>. The angle between the SRM motor centerline and the projection of the SRM thrust vector into the SRM pitch (yaw) plane.

6.1.1.23 SRM Pitch (Yaw) Plane. The plane defined by the SRM motor centerline and a line which is normal to the SRM centerline and parallel to the vehicle pitch (yaw) plane.

6.1.1.24 The SRM Pitch (Yaw) Thrust Vector Moment Arm. The length of the perpendicular line from the SRM motor centerline at missle station (TBS) to the SRM projection of the thrust vector into the pitch (yaw) plane.

6.1.1.25 Solid Rocket Motor Centerline. The line joining the center of the aft closure-to-nozzle throat bolt circle to the center of the forward closure in the plane of the forward attach structure.

6.1.1.26 Nozzle Centerline. The line joining the center of the nozzle throat to the center of the nozzle exit.

6.1.1.27 Stage Centerline. The line joining the center of the stage/orbiter assembly joint bolt circle and the center of the aft structure support structure.

6.1.1.28 SRM Thrust Vector. The force vector whose magnitude and variability is defined by paragraph 3.1.1.1.1, and whose direction and variability is defined by paragraph 3.1.1.1.2.

6.1.1.29 Stage Roll Plane. A plane perpendicular to the stage centerline which intersects the stage centerline at missile station (TBS).

6.1.1.30 Stage Roll Control Moment. The resultant moment about the stage centerline of the sum of the SRM thrust vectors projected into the stage roll plane.

10. APPENDIX

10.1 Test Configuration. The static test configuration of the SRM shall conform to UTC drawing (TBS). This drawing shows several obvious differences from the flight configuration. These differences shall not affect performance but are related to ordance, structural, and instrumentation measurements which pertain directly to the static test program.

Specific differences shall include the following areas: (TBS)

The following figures are to be supplied:

Figure 1. Ignition Transient 156-Inch Thrust Versus Time & Nozzle Sea Level at 60°F

Figure 2. Ignition Transient 156-Inch Pressure Versus Time at 60°F

Figure 3. Vacuum Thrust Versus Time, 40°F

Figure 4. Vacuum Thrust Versus Time, 60°F

Figure 5. Vacuum Thrust Versus Time, 70°F

Figure 6. Vacuum Thrust Versus Time, 90°F

Figure 7. Sea Level Thrust Versus Time, 40°F

Figure 8. Sea Level Thrust Versus Time, 60°F

Figure 9. Sea Level Thrust Versus Time, 70°F

Figure 10. Sea Level Thrust Versus Time, 90°F

Figure 11. Forward Head Pressure Versus Time, 40°F

Figure 12. Forward Head Pressure Versus Time, 60°F

Figure 13. Forward Head Pressure Versus Time, 70°F

Figure 14. Forward Head Pressure Versus Time, 90°F

Figure 15. Aft End Pressure Versus Time, 40°F

Figure 16. Aft End Pressure Versus Time, 60°F

Figure 17. Aft End Pressure Versus Time, 70°F

Figure 18. Aft End Pressure Versus Time, 90°F

Figure 19. Aft to Forward Head Pressure Ratio Versus Time

Figure 20. Thrust Vector Angle Versus Command Voltage and Chamber Pressure

Figure 21. Thrust Vector Moment Arm Versus Command Voltage and Nominal Chamber Pressure

Figure 22. Roll Control Moment Versus Roll Command Voltage and Nominal Chamber Pressure

Figure 23. Frequency Response

Figure 24. Slew Rates

Figure 25. Net Thrust Versus Time from Thrust Termination Actuation

Figures 26 through 30. Schematic Arrangements of SRM Electrical Systems

(PRELIMINARY)

PRIME ITEM DEVELOPMENT SPECIFICATION

SOLID ROCKET MOTOR, SPACE SHUTTLE BOOSTER, S6-120

Basic Approved by__________________
(United Technology Center)

Basic Approved by______________________

Date______________________________

Date______________________________

1. SCOPE. This specification establishes the performance, design, development, and test requirements for the S6-120 space shuttle booster stage prime item.

2. APPLICABLE DOCUMENTS. The following documents form a part of this specification to the extent specified herein. In the event of conflict between documents referenced here and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

SPECIFICATIONS

Military

MIL-E-5272	Environmental Testing, Aeronautical and Associated Equipment, General Specification for
MIL-H-6083	Hydraulic Fluid, Petroleum Base, Preservative
MIL-I-8500	Interchangeability and Replaceability of Component Parts for Aircraft and Missiles

United Technology Center

(TBS)	Forward Section, Rocket Motor
(TBS)	Mechanical Hardware Set, Rocket Motor
(TBS)	Ordnance Set, Rocket Motor
(TBS)	Segment Assembly, Rocket Motor
(TBS)	Aft Section, Rocket Motor
(TBS)	Extension, Nozzle Exit Cone
(TBS)	Nose Section, Rocket Motor
(TBS)	Aft Structure, Rocket Motor
(TBS)	Interstage Structure
(TBS)	Flight Instrumentation Set, Rocket Motor
(TBS)	Battery Set (31 July 1964)

STANDARDS

Military

MIL-STD-130	Identification Marking of US Military Property
MIL-STD-447	Definitions of Interchangeability, Substitute and Replacement Items
MIL-STD-470	Maintainability Program Requirements (for Systems and Equipment)
MIL-STD-471	Maintainability Demonstration Requirements
MIL-STD-778	Maintainability Terms and Definitions
MS33586	Metals, Definition of Dissimilar

DRAWINGS

United Technology Center

C09006	Rocket Motor Assembly
(TBS)	Electrical System - Interconnect Diagram

OTHER PUBLICATIONS

AFM 127-100	Explosives Safety Manual
(TBS)	Range Safety Manual
(TBS)	Policies, Procedures, and Criteria
(TBS)	Facility Contract End Item and Interface Specification, Performance, Design and Interface Requirements for Space Shuttle Booster
(TBS)	Interface Specification, Solid Rocket Motor to Launch Vehicle System - Parametric Interfaces (Performance, Environmental and Flight Control)
(TBS)	Interface Specification, Solid Rocket Booster Stage Orbiter Vehicle System - Structural and Dynamic Loading Interfaces
(TBS)	Interface Specification, Solid Rocket Booster Stage to Orbiter Vehicle System - Electrical Interfaces

(TBS)	Interface Specification, Solid Rocket Booster Stage to Orbiter Vehicle System - Testing Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Physical Interfaces (Mechanical & Structural)
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiert Vehicle System - Electrical Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Envelope Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Orbiter Vehicle System - Fluid Interfaces
(TBS)	Interface Control Drawing, Solid Rocket Booster Stage to Launch Orbiter Vehicle System
(TBS)	Electromagnetic Compatibility (EMC) Control Plan
(TBS)	System Effectiveness Management Plan
(TBS-NASA)	Space Shuttle Booster System Performance/ Design Requirements, General Specification

3. REQUIREMENTS

3.1 Performance.

3.1.1 Functional Characteristics. The solid Rocket Motor (SRM) booster stage shall conform to thefollowing functional characteristics from sea level to 200,000 feet (when ignited in air at altitudes up to 2500 feet) for motor mean bulk temperatures of (TBS) degrees Fahrenheit (°F) to (TBS). The design temperature for all calculations and reporting shall be (TBS). Thrust vector characteristics are specified relative to the motor centerline at missile station (TBS).

3.1.1.1 Primary Performance Characteristics.

3.1.1.1.1 Propulsion System Performance Characteristics.

3.1.1.1.1.1 Ignition Transient. Ignition delay shall be (TBS) to (TBS) milliseconds for motor mean bulk temperatures of (TBS) to (TBS) inclusive. The motor chamber pressure at ignition from 50 percent to 100 percent of maximum chamber pressure shall be such that the differential chamber pressure between any two motors simultaneously ignited shall not exceed (TBS) percent of the maximum chamber pressure. Predicted igniter nominal performance is depicted in Figures 1 and 2.

3.1.1.1.1.2 Vacuum and Sea Level Performance. Each SRM shall have a vacuum (vac) and sea level (SL) performance rating as specified in Table I. The limits specified in Table I apply to a nominal established by the maximum number of test firings available. This actual nominal may vary from the nominal of Table I by the percentages specified in the column headed "Percent 3-Sigma Variation of Nominal".

3.1.1.1.1.3 Thrust Characteristics. Each SRM thrust versus time shall be as shown in Figures 3 through 10. The actual nominal established by the maximum number of test firings available shall fall within the dotted lines of Figures 3 through 10. The 3 σ dispersion on the actual nominal shall be ±95,000 pounds, except during tail-off when paragraph 3.1.1.1.9 shall apply. Estimated head end motor pressure is shown in Figures 11 through 14. Estimated aft end stagnation pressure is shown in Figures 14 through 18. Figure 19 shows the estimated relationship between head end pressure and aft end stagnation pressure for mean bulk temperature of 40°, 60°, 70°, and 90°F.

TABLE I. SHUTTLE BOOSTER PERFORMANCE SUMMARY 60°F

		Nominal Rating	Percent 3-Sigma Variation of Nominal
Web Time, sec		124.0	2.16
Average Pressure, psia		652	
Average Thrust (SL), lb_f	$x10^6$	1.050	
Average Thrust (vac), lb_f	$x10^6$	1.231	
Average Specific Impulse (SL), sec		232.4	0.7
Average Specific Impulse (vac), sec		272.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	130.2	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	152.6	1.0
Propellant Consumed, lb	$x10^3$	560.2	
Action Time, sec		135.7	3.11
Average Pressure, psia		627	
Average Thrust (SL), lb_f	$x10^6$	1.006	
Average Thrust (vac), lb_f	$x10^6$	1.187	
Average Specific Impulse (SL), sec		231.1	0.7
Average Specific Impulse (vac), sec		272.5	0.7
Total Impulse (SL), lb_f-sec	$x10^6$	136.6	1.0
Total Impulse (vac), lb_f-sec	$x10^6$	161.0	1.0
Propellant Consumed, lb	$x10^3$	591.0	
Duration, sec		137.0	
Maximum Pressure, psi		834	
Initial Thrust (SL), lb_f	$x10^6$	1.213	6.0
Maximum Thrust (vac), lb_f	$x10^6$	1.431	
Total Impulse (vac), lb_f-sec	$x10^6$	161.3	1.0
Propellant Consumed, lb	$x10^3$	591.8	

3.1.1.1.1.4 Maximum Expected Operating Chamber Pressure. The maximum expected operating chamber pressure (MEOP) shall be 1,000 pounds per square inch gage (psig).

3.1.1.1.1.5 SRM Thrust Vector. Solid rocket motor thrust performance is defined for a motor whose nozzle centerline is coincident with the motor centerline. Alignment and movement of the thrust vector is defined in 3.1.1.1.2.

3.1.1.1.1.6 Stage Thrust Vector. Stage thrust vector performance is defined for the thrust vector sum of the individual solid rocket motors. The stage thrust vector location, alignment and movement is defined in 3.1.1.1.2 relative to the stage centerline and to the intersection of the stage centerline with the stage/orbiter separation plane, MS (TBS).

3.1.1.1.1.7 Nozzle Characteristics. (TBS)

3.1.1.1.1.8 Propellant. (TBS)

3.1.1.1.1.9 Thrust Decay (TBS)

3.1.1.1.2 Primary Thrust Vector Control (TVC) System Performance Characteristics. The TVC system shall provide the performance indicated below during stage operation under initial prelaunch temperature of 25°F to 100°F. The TVC system shall utilize moveable nozzles on each SRM to provide omni-axial thrust vector orientation in accordance with pitch, yaw, and roll command signals from the vehicle guidance system. The TVC performance of the individual SRMs and combined stage shall be as specified in the TVC Math Model, specification (TBS).

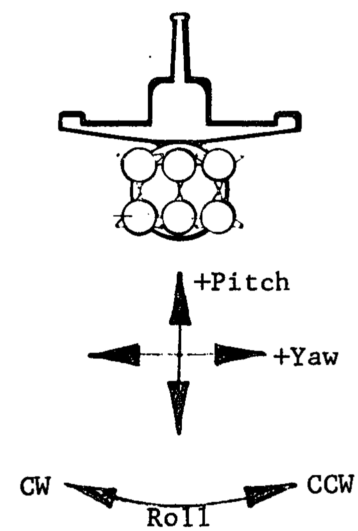
3.1.1.1.2.1 TVC System Operation. The stage TVC system shall consist of omni-directional moveable nozzles. Each SRM shall have a single moveable nozzle operated by two servo-controlled hydraulic actuators located in mutually perpendicular planes. The actuators shall position the SRM nozzles in accordance with pitch, yaw, and roll commands from the vehicle guidance system. Nozzle rotation shall be limited electronically to prevent overtravel in any axis. Control axes interactions and actuator cross coupling shall be defined and compensation provided as required to obtain vehicle response in accordance with command control moments within the control variation defined herein.

3.1.1.1.2.2 Booster Stage Axes Definition. Table II shows the stage axes definition and indicates the command voltages and polarities required to provide control moments about the roll, pitch, and yaw axes.

3.1.1.1.2.3 Stage Thrust Vectoring. The nominal stage pitch (yaw) thrust vector angle as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure and described in the TVC Math Model, for all stage thrust vector angles between ±10 degrees.

3.1.1.1.2.4 Stage Thrust Vector Moment Arm. The nominal stage pitch (yaw) thrust vector moment arm as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure and as described in the TVC Math Model, for all thrust vector moment arms within ± (TBS) meters.

Table II. Axes Definition and Command Voltage



Booster SRM Axes Definition Looking Forward

Command Voltage Relative to its individual corresponding return	Externally Directed Force
-10 to +10 volts on pitch command lines (three redundant pairs)	Pitch of same polarity as command
-10 to +10 volts on yaw command lines (three redundant pairs)	Yaw of same polarity as command
-10 to +10 volts on roll command lines (three redundant pairs)	Roll CW for (+) commands and CCW for (-) commands

3.1.1.1.2.3 SRM Thrust Vectoring. The nominal SRM pitch (yaw) thrust vector angle, as a function of command voltage and nominal motor chamber pressure, shall be as shown in Figure 20 and as described in the TVC Math. Model, for all SRM thrust vector angles between ±10 degrees.

3.1.1.1.2.4 SRM Thrust Vector Moment Arm. The nominal SRM pitch (yaw) thrust vector moment arm as a function of command voltage and nominal motor chamber pressure shall be as shown in Figure 21 and as described in the TVC Math. Model, for all thrust vector moment arms within ± (TBS)inches.

3.1.1.1.2.5 TVC Hysteresis. Three-sigma deviations from nominal TVC relationships in 3.1.1.1.2.3 and 3.1.1.1.2.4 due to command voltage reversals shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or the greater of ±(TBS)% or ±(TBS) inches, respectively, from ignition to web action time; and shall not exceed the greater of ±(TBS)% or ±(TBS) degrees, or ±(TBS)% or ±(TBS) inches, respectively, from web action time to action time.

3.1.1.1.2.6 TVC Variability. Three-sigma variability of the stage thrust vector angle shall not exceed the greater of ±(TBS)% or ±(TBS) degree, and variability of the slope of the command voltage to thrust vector moment arm relationship shall not exceed the greater of ±(TBS)% or ±(TBS) inches/volt from ignition to web action times; and shall not exceed ±(TBS) degrees, and the greater of ±(TBS)% or ±(TBS) inches/volt, respectively, from web action time to action time. This variability shall include all deviations, tolerances, and cross-coupling effects excepting variations in the nominal motor chamber pressure with stage mean bulk temperature.

3.1.1.1.2.7 Roll Control Moments. The nominal stage roll control moment as a function of roll command voltage and nominal motor chamber pressure shall be as shown in Figure 22 and as described in the TVC Math Model. Three-sigma variations shall not exceed the greater of ±(TBS)% or ±(TBS) Newton meters from ignition to web action time; or the greater of ±(TBS)% or ±(TBS) inch-pounds from web action time to action time. Three-sigma deviations from the nominal command voltage-to-roll control moment relationship due to command voltage reversal shall not exceed ±(TBS) inch-pounds from ignition to web action time; and ±(TBS) inch-pounds from web action time to action time.

3.1.1.1.2.8 Resolution. The TVC system resolution within the range of ±10 degrees of SRM thrust vector angle shall not exceed (TBS) volts from ignition to web action time and (TBS) volts from web action time to action time.

3.1.1.1.2.9 Frequency Response. The total thrust vector control system frequency response at any ambient voltage command level in the defined nozzle axes for motor chamber pressures between (TBS) and (TBS) psia shall be as specified by the upper and lower limits of the amplitude ratio and phase lag given in Figure 23. This curve is valid as long as the maximum command voltage does not exceed 10 VDC, the velocity or rate of change of the command voltage is below the minimum slew rates specified in Figure 24, and the minimum command is greater than (TBS) VDC.

3.1.1.1.2.10 Slew Rate. The TVC system shall be capable of changing the vehicle thrust vector angle at a minimum slew rate of 5 degrees per second throughout motor operating time. This requirement shall apply for all motor and actuation system operating conditions in conjunction with external nozzle loads and environments as specified in (TBS). Slew rate is defined as the instantaneous rate of change of thrust vector angle for command changes exceeding (TBS) volts at a rate exceeding (TBS) volts per second. The minimum and maximum slew rate limits as a function of flight time shall be as shown in Figure 24. Minimum slew rate is derived assuming nominal SRM performance combined with minus 3-sigma control system performance and plus 3-sigma external nozzle loads. Maximum slew rates is derived assuming nominal SRM performance combined with plus 3-sigma control system performance and minus 3-sigma external nozzle loads.

3.1.1.1.3 SRM Ignition. Each stage of the booster stage shall provide an integral igniter motor that shall perform the function of initiating stage ignition. Simultaneous ignition of each stage of the booster stage shall be accomplished by receipt of simultaneous command signals, from the orbiter or from ground equipment, to the ordnance electrical system of each stage.

3.1.1.1.4 Staging Performance. (TBS) staging motors per stage, (TBS) in the nose section and (TBS) in the aft section, shall supply the lateral staging impulse to each SRM to fulfill the requirements of the shuttle booster general system specification (TBS). Staging ignition initiation shall be accomplished by the stage ordnance electrical system upon receipt of command from the orbiter.

3.1.1.1.5 Flight Safety. To preclude or limit hazard to personnel and/or equipment, each SRM of the booster stage shall incorporate: 1) a thrust termination system with provisions for activation when commanded by the orbiter vehicle or upon detection of an inadvertent separation of an SRM from the launch vehicle, and, 2) an inadvertent separation detection system (ISDS), and 3) an emergency detection system for monitoring critical booster parameters and providing signals to the orbiter crew. The design of these systems shall be in accordance with the requirements of Range Safety Manual (TBS), Shuttle Booster General System Specification (TBS) and Component CEI Specifications.

3.1.1.1.5.1 Thrust Termination Performance. A two-port thrust termination system shall be provided on each solid rocket motor. The thrust termination system shall effectively neutralize the axial thrust of each SRM by venting the combustion chamber at the forward end of each SRM. Each solid rocket motor and its thrust termination system shall be capable of surviving the environments created by thrust termination for a period of (TBS) seconds after the initiation of thrust termination. The thrust termination performance for a single solid rocket motor is shown in Figure 25.

3.1.1.1.5.2 Emergency Detection System. The emergency detection system shall provide the following output signals to the orbiter.

(a) Fast Failure: A signal shall be present when an emergency condition exists which will result in motor failure with (TBD) seconds and an immediate abort is required.

(b) Slow Failure: A signal shall be present when an emergency condition exists which will result in motor failure after at least (TBD) seconds from initial detection.

(c) Unverified Failure: A signal shall be present when an emergency condition is sensed by only one of a pair of redundant transducers.

(d) Emergency Detection System Self Check: a signal shall be present when all Malfunction Detection System self check circuits are indicating proper operation.

An emergency detection system input shall be provided such that the system can be disabled on command from the orbiter.

3.1.1.1.5.3 Inadvertent Separation Detection System (ISDS). Each SRM of the booster stage shall provide an ISDS that shall detect the inadvertent loss of electrical cabling between the orbiter/launch vehicle and automatically initiate thrust termination prior to receipt of a disable command from the orbiter. The ISDS shall be an integral part of the booster ordnance electrical system.

3.1.1.1.6 Electrical Power, Control, and Distribution. Each SRM of the booster stage shall provide the airborne power, switching capability from ground power to airborne power, and the distribution of all airborne power to the TVC system, ordnance system, emergency detection system, and flight instrumentation system. The electrical systems of the booster stage shall receive and distribute ground power for SRM systems ground operation and checkout. All systems shall operate from 28 VDC (nominal) power sources.

3.1.1.2 Secondary Performance Characteristics.

3.1.1.2.1 Instrumentation System Performance Characteristics. The booster stage instrumentation system shall provide signal outputs to the orbiter for the purpose of verification and evaluation of booster stage status and performance prior to and during flight. The functional status of specified redundancy features included in the other booster stage systems shall be indicated by discrete output signals to the orbiter.

3.1.1.2.2 Checkout Provisions. Provisions shall be made to allow the following booster stage verification tests to be performed on an assembled launch vehicle via the airborne and ground electrical interfaces.

(a) Detailed functional tests, as specified in (TBS), of all electrical and mechanical subsystems including operational status of redundant features.

(b) System operability (quick look) tests, as specified in (TBS) of the flight critical active systems, providing go/no go signals, including checks of redundant features.

(c) Integrated-system test, as specified in (TBS), performed as a simulated countdown and flight with the complete launch system.

(d) Booster stage component malfunction isolation and component checkout tests as specified in (TBS).

During these tests, airborne items which are not operated due to safety, one operation capability, reduced hold capability, or physical difficulty will be checked in a non-operating mode to verify operable status and proper installation. No non-flight hardware will be connected to the stage for these tests except the normal ground umbilical cable.

3.1.1.2.3 Mass Property Requirements. Nominal values of mass, center of gravity (cg) location, and momemnts of inertia shall be determined as a function of flight characteristics. Three-sigma tolerances on the prelaunch values shall be as follows:

		Individual SRMs	Stage
cg location -	longitudinal	±7.7 inches	±
	pitch plane	±1.6 inches	±
	yaw plane	±1.7 inches	±
Mass		±3,600 pounds	±

Moments of inertia - ±10 percent

The mass fraction of the stage shall be (TBS) minimum using the inch motor definition in Section 6.

3.1.1.2.4 Hold and Reaction Time Requirements. The booster stage shall be capable of maintaining a launch hold at T-(TBS) minutes for 30 days without environmental protection (shall allow electrical maintenance of batteries via the ground umbilical cable during the hold). The booster stage shall be capable of a launch reaction time of TBS hours after integrated system test and a system abort recycle time for causes external to the vehicle of TBS hours. The booster stage shall be capable of proceeding to T-(TBS) seconds returning to T-(TBS) minutes and holding for 30 days.

3.1.2 Operability. The SRM booster stage conform to the following operability requirements.

3.1.2.1 Reliability. The reliability of the SRM booster stage shall be as specified in the shuttle booster general system specification (TBS).

3.1.2.2 Maintainability. The SRM booster stage shall meet the maintainability requirements of MIL-STD-470. Quantitative requirements shall be established for the contributions to system downtime considering the AGE, facilities, and airborne portions of the vehicle system. The maintainability apportionment shall be consistent with the probability of launch-on-time requirements. Downtime shall be interpreted as active downtime defined in MIL-STD-778 and shall not be greater than (TBS) hours mean active time to restore. Mean maintenance-downtime (M) is described for corrective-maintenance functions as:

$$\bar{M}_{ct} = \frac{\sum_{1}^{N_c} M_{ct}}{N_c} = \bar{M} \text{ hours}$$

Where:

$\bar{M}_{ct}$ = mean maintenance correction-time for sub-system (arithmetic mean)

N_c = number of corrective maintenance-functions for modular remove/replace maintenance concept

M_{ct} = active maintenance correction-time per corrective maintenance task

The quantitative $\bar{M}$ allocations shall be as follows:

(TBS)

The M allocations do not apply on a lower level of assembly because maintenance or test results pertinent to a requirement for maintenance only occurs at the fully assembled level. The above subsystems are defined in the UTC System Effectiveness Plan, (TBS).

3.1.2.2.1 Maintenance and Repair Cycles. Maintainability analyses shall establish time goals for the completion of maintenance activities and the associated design and procedural approaches. This data will be incorporated into equipment specifications and, thus, constitute objectives to be accomplished during the design process. Maintenance functions for support of the SRM are corrective-maintenance functions. Preventive maintenance is not considered in the maintenance concept.

3.1.2.2.2 Service and Access. Access shall be provided so all interface connections and maintenance operations can be performed. The ordnance and TVC subsystems shall be capable of checkout and servicing while installed in the booster stage SRM. Access requirements shall be evaluated to ascertain performance of corrective-maintenance tasks upon which active maintenance downtime is based, and which are organizational level remove/replace maintanance functions.

3.1.2.3 Useful Life. The SRM booster stage shall comply with shuttle booster general system specification (TBS). The SRM booster stage shall meet the requirements of this specification after exposure to the environment specified in 3.1.2.4 for a period of one year. Cyclic life limitations shall be as defined in the component CEI specifications (see 3.3.1.3).

3.1.2.4 Environmental.

3.1.2.4.1 Prelaunch. The SRM booster stage shall perform as specified herein after exposure to the following environments.

(a) Temperature - Surrounding air temperatures between 25° and 100°F with mean bulk propellant temperatures of 40° to 90°F for periods up to 60 days.

(b) Humidity - Relative humidities of up to 100 percent including condensation in the form of water or frost for periods up to 60 days.

(c) Fungus - Exposure to fungi equivalent to 28 days of exposure to selected fungi as described in Specification MIL-E-5272. As a design goal materials which are fungus nutrients shall not be used.

(d) Sand and dust - Exposure to windblown graded sand and dust equivalent to exposure for 6 hours in a sand-and-dust chamber as described in Specification MIL-E-5272.

(e) Sunshine - Normally exposed, non-metallic materials shall withstand the deteriorating effects of direct sunlight for periods up to 60 days.

(f) Salt fog - Exposure to salt fog equivalent to exposure to a 20-percent salt spray for:

(i) 10 hours for internally-mounted equipment

(ii) 50 hours for externally-mounted equipment

(g) Rain - Exposure to rain equivalent to 4 inches per hour for 2 hours.

(h) Wind and gusts - Exposure to the wind and gusts prevalent at the launch base as defined in (TBS).

(i) Propellant compatibility - (TBS)

(j) Loads - Exposure to loads induced by the winds and gusts specified in (h) above.

(k) Overpressure - Exposure to overpressures induced by an incident on an adjacent launch pad as defined in (TBS).

3.1.2.4.2 Launch and Flight. The SRM booster stage shall perform as specified herein during and after exposure to the environment specified in the shuttle booster general system specification (TBS).

3.1.2.4.3 Storage. The SRM booster stage shall perform as specified herein when its components CEIs are stored at mean bulk temperatures between 40°F and 90°F with propellant surfaces protected from humidity in excess of 50 percent RH.

3.1.2.5 Transportability. The assembled SRM booster stage will not be transported. Transportation environments will be within the limits specified in 3.1.2.4. The forward section, segments, and aft section shall be transportable in the clevis-down or horizontal position without degradation of the propellant or bonding to the extent that would preclude the booster stage from performing as specified herein. Component CEIs shall be designed so that only passive means of environmental protection are required during transportation.

3.1.2.6 Human Performance. The SRM booster stage and associated ground equipment shall meet the human-performance requirements of (TBS).

3.1.2.7 Safety.

3.1.2.7.1 Flight Safety. Design of airborne systems shall meet the requirements of applicable Range Safety Specification (TBS).

3.1.2.7.2 Ground Safety. The SRM shall be compatible with the shuttle booster general specification (TBS).

3.1.2.7.3 Nuclear Safety. Not applicable.

3.1.2.7.4 Personnel Safety. Provisions for personnel safety shall be in accordance with the shuttle booster general specification (TBS).

3.1.2.7.5 Explosive and/or Ordnance Safety. The system shall comply with the requirements of paragraph 3.1.2.7.4 of this CEI Specification and the shuttle booster general specification (TBS) to the extent specified in the component CEI Specifications. The explosive classification of each assembled SRM of the booster stage shall be Class 2 in accordance with AFM-127-100.

3.2 CEI Definition.

3.2.1 Interface Requirements.

3.2.1.1 Schematic Arrangement. The SRM booster stage shall conform to the dimensions shown in UTC Drawing C09006. The schematic arrangement of the overall system and each electrical system shall be as shown in Figures 26 through 30 and UTC Drawing (TBS).

3.2.1.2 Detailed Interface Definition.

3.2.1.2.1 System Interfaces. All interfaces between the SRM booster stage and the orbiter vehicle and facility will be defined and controlled by the following interface documents:

(TBS)

3.2.1.2.2 AGE Interfaces. Necessary interfaces for the SRM booster stage launch pad testing shall be provided for mating with the following equipment:

(TBS)

3.2.2 Component Definition.

3.2.2.1 Customer-Furnished-Property List. The following items, which are to be furnished by the customer, are required for flight CEI operation:

(a) Component CEIs (see 3.3.1.3) of each SRM

3.2.2.2 Engineering-Critical-Components List. Engineering critical components are listed in the component CEI specifications.

3.2.2.3 Logistics Critical Components List. Logistics critical components are listed in the component CEI specifications.

3.3 Design and Construction.

3.3.1 General Design Features.

3.3.1.1 General Design and Construction Requirements. The SRM design shall comply with the shuttle booster general system specification (TBS).

3.3.1.2 Description.

3.3.1.2.1 Solid Rocket Booster Stage. The solid rocket booster stage shall consist of six solid rocket motors attached together by their attach structure, and the various systems required by this specification. Each motor shall be a (TBS)-segment 120-inch diameter motor with spherical end closures at each end. The segments and closures are joined with a pressure sealing clevis joint. The attach structure also serves to collect the thrust and steering loads from each of the solid rocket motors and applies them to the orbiter at the interstage structure.

3.3.1.2.2 Segments and Closures. Each segment is insulated with rubber and cast with composite, aluminized propellant in the form of a hollow cylinder. One end of the grain is restricted from burning by a rubber restrictor and a tapering of the central perforation provides the required tailoff thrust characteristics. The forward closure is insulated with rubber and propellant is cast in the form of an eight-point star with ports provided to allow for thrust termination. The aft closure is rubber insulated and has a circular port grain configuration.

3.3.1.2.3 Nozzle and Exit Cone. To the aft closure is attached a 50-inch diameter ablative throat and a 20°-conical ablative exit cone with an expansion ratio of 12.7:1.

3.3.1.2.4 Thrust Vector Control System. Thrust vector control is provided by moveable nozzles on each SRM. Each nozzle is supported by a constant-volume-fluid-filled bearing which transmits the nozzle blowoff loads and thrust vectoring loads to the SRM by means of two annular rolling convolutes. Movement of the nozzle, within the limits of the fluid bearing, is provided by actuators placed in mutually perpendicular planes. Hydraulic power for the actuators is provided by a regulated pressure supply system using a solid propellant gas generator as the energy source. Actuator position control is accomplished by an electronic control unit, which resolves and conditions vehicle guidance system steering commands into the appropriate control responses.

3.3.1.2.5 Attach Structure. The attach structure consists of a thrust transmission structure and an aft skirt for each SRM. The aft skirt provides ground support during buildup of a single SRM and ground support for the assembled launch vehicle. The thrust transmission structure transmits the SRM thrust to the interstage structure described in UTC Specification (TBS). Provisions for mounting staging motors are provided in the thrust transmission structure and in the aft skirts. The interstage structure interfaces with the orbiter stage and includes the system required to separate the booster stage after SRM burnout.

3.3.1.2.6 Emergency Detection System. Detection of impending SRM booster failures necessitating a mission abort is provided by this system. The output of various pairs of redundant transducers are compared to predetermined criteria to determine presence of an impending failure situation. Parallel redundancy is utilized in this system to reduce the possibility of occurrence of an inadvertent mission abort.

3.2.1.2.7 Instrumentation System. The instrumentation system shall monitor pertinent booster stage parameters and supply conditioned signals to the orbiter telemetry system to verify and evaluate booster stage status and performance prior to and during flight. The system also provides signal input and output via the ground umbilical cable, required to accomplish verification tests on the booster stage. The design of the instrumentation system component failure will result in performance degradation of any other booster stage system such that the limits of this specification are exceeded.

3.3.1.2.8 Ordnance System. The ordnance systems for the SRM booster stage provided the capability of performing the functions of booster ignition, staging, thrust termination, and inadvertent separation detection by initiation of ordnance devices. The ordnance electrical system provides the power and control of the firing units. Firing unit charging and triggering is accomplished upon command from the orbiter vehicle or ground station.

3.3.1.2.9 Interstage Structure. The interstage structure shall transmit and distribute axial force, shear, and bending movement between the individual SRMs of the booster stage to the hydrogen-oxygen tank and shall provide sufficient separation between the SRM stage and the orbiter vehicle to allow SRM thrust termination port covers to clear the orbiter if the thrust termination system is activated. The interstage structure shall provide an equipment bay for housing some electrical components of the TVC, ordnance, emergency detection and flight instrumentation systems. Provisions for compartment environmental control shall be made as necessary.

3.3.1.2.10 Redundancy. Redundancy shall be utilized, to the maximum extent practicable, in all systems to exclude the possibility of a single non-structural failure causing out-of-specification performance.

3.3.1.2.11 Weight. The predicted component weights are given in table III.

3.3.1.3 Component CEIs. The following sub-paragraphs identify the component CEIs which form each SRM of the booster stage.

3.3.1.3.1 Forward Section, Rocket Motor. Each booster forward section shall be in accordance with UTC Specification (TBS).

3.3.1.3.2 Aft Section, Rocket Motor. The booster aft section shall be in accordance with UTC Specification (TBS).

3.3.1.3.3 Segment Assembly, Rocket Motor. The booster segment assembly shall be in accordance with UTC Specification (TBS).

3.3.1.3.4 Nose Section, Rocket Motor. The booster nose section shall be in accordance with UTC Specification (TBS).

3.3.1.3.5 Extension, Nozzle Exit Cone. The nozzle exit cone extension shall be in accordance with UTC Specification (TBS).

3.3.1.3.6 Battery Set. All flight batteries shall be in accordance with UTC Specification (TBS).

3.3.1.3.7 Ordnance Set, Rocket Motor. The booster ordnance set shall be in accordance with UTC Specification (TBS).

3.3.1.3.8 Mechanical Hardware Set, Rocket Motor. The booster mechanical hardware set shall be in accordance with UTC Specification (TBS).

3.3.1.3.9 Aft Structure, Rocket Motor. The booster aft section shall be in accordance with UTC Specification (TBS).

TABLE III. COMPONENT WEIGHTS

Component	
Attach Structure	(8,942)
Forward	2,116
Aft	6,826
Separation System	--
Solid Motor (Empty)	(73,938)
Case	(49,252)
Forward Closure	5,928
Segments (Total)	38,780
Aft Closure	4,196
Assembly Hardware	348
Insulation	(12,230)
Forward Closure	1,710
Segments (Total)	9,345
Aft Closure	1,175
Igniter	378
Thrust Termination	1,556
Nozzle	(10,522)
Moveable	8,252
Fixed	2,264
Actuation System	930
Electrical & Instrumentation	634
Weight Empty	84,444
Solid Propellant	591,800
Single Loaded Motor - Total	676,244
Interstage Structure	32,800
Stage Elect. & Inst.	855
STAGE TOTAL	4,091,119

3.3.1.3.10 Flight Instrumentation Set, Rocket Motor. The rocket motor flight instrumentation set shall be in accordance with UTC Specification (TBS).

3.3.1.3.11 Interstage Structure. The rocket motor booster interstage structure shall be in accordance with UTC Specification (TBS).

3.3.2 Selection of Specifications and Standards. The selection of specifications and standards shall be in accordance with shuttle booster general system specification (TBS).

3.3.3 Materials, Parts, and Processes. Materials, parts and processes used in each SRM shall conform to the applicable requirements as specified in shuttle booster general system specification (TBS) as further defined by component CEI Specifications referenced in paragraph 3.3.1.

3.3.4 Standard and Commercial Parts. Standard and commercial parts shall be in accordance with shuttle booster general system specification (TBS).

3.3.5 Moisture and Fungus Resistance. Materials used in this CEI shall comply with the requirements of the shuttle booster general specification (TBS).

3.3.6 Corrosion of Metal Parts. All metal parts used in fabrication of the SRM shall be corrosion resistant or suitably treated to resist corrosion when exposed to the environmental conditions specified in 3.1.2.4. Wherever practical, the use of dissimilar metals, as defined in Standard MS33586, in contact with each other shall be avoided.

3.3.7 Interchangeability and Replaceability. The interchangeability and replaceability, as specified in MIL-STD-447, of the SRM components shall be in accordance with MIL-I-8500.

3.3.8 Workmanship. The SRM shall be fabricated and finished in such a manner that criteria of appearnce, fit, and adherence to specified tolerances shall be observed. Particular attention shall be given to the neatness and thoroughness of soldering, wiring, marking of parts and assemblies, plating, painting, riveting, machine-screw assemblage, welding and brazing, and freedom of parts from burrs and sharp edges.

3.3.9 Electromagnetic Interference. The SRM shall meet the electromagnetic interference requirements of Electromagnetic Compatibility Control Plan (TBS).

3.3.10 Identification and Marking. The SRM shall be identified and marked in accordance with MIL-STD-130 and (TBS).

3.3.11 Storage. The assembled SRM booster stage and its components shall conform to the storage requirements of 3.1.2.3 and 3.1.2.4, as applicable.

3.3.12 Cleanliness. The SRM booster stage and its components shall meet the cleanliness requirements (TBS).

4. QUALITY ASSURANCE PROVISIONS.

4.1 Category I Test. Category I tests as used herein shall be defined as contractor performed component, subsystem and full scale static level tests. Records and documentation of results of all Category I testing shall be maintained in comprehensive, legible format.

4.1.1 Engineering Test and Evaluation. Engineering tests and evaluations shall be conducted to provide maximum assurance of successful completion of the qualification and category II system tests specified below.

4.1.1.1 Development Testing. (TBS) motor firing tests shall be conducted at a UTC test facility during the development phase, (TBS) vertical at UTC and (TBS) horizontal thrust termination test. Motors shall be instrumented during these firings to evaluate the internal ballistic performance, TVC performance, and electrical system performance. Test configuration shall be as specified in (TBS).

4.1.2 Preliminary Qualification Tests. (TBS) rocket motors identical in configuration to the final flight configuration will be fired in a preliminary flight rating test (PFRT) program to be conducted at a UTC test facility. The differences in configuration will be limited to those required for the inverted-from-flight attitude firings and are defined in (TBS). Successful completion of these firings will constitute the preliminary qualification test program.

4.1.3 Formal Qualification Tests. The following subparagraphs specify the requirements for, and methods of, formally verifying that each requirement in Section 3 has been satisfied.

4.1.3.1 Inspection. The following requirements of Section 3 shall be verified by an inspection at a time and place to be determined mutually by the customer and UTC: (TBS)

4.1.3.2 Analysis. Conformance to the following requirements shall be verified by comparative analysis of engineering documentation developed under previous programs and during the testing of 4.1.1.1 and 4.1.2. No further testing will be conducted to verify conformance to these requirements. (TBS)

4.1.3.3 Demonstrations. Not applicable.

4.1.3.4 Tests. The following requirements in Section 3 shall be verified during the preliminary qualification tests of 4.1.2: (TBS)

4.1.4 Reliability Tests and Analysis. At the start of the acquisition phase a reliability mathematical model shall be presented to justify reliability failure allocations for the various CEI components. The results of tests, failure reports, and conclusions as to system reliability shall be presented to the customer throughout the acquisition program. No special testing shall be specifically conducted to satisfy the provisions of 3.1.2.1.

4.1.5 Engineering Critical Component Qualification. Not applicable.

4.1.6. Interface Testing.

4.1.6.1 System Interfaces. Conformance to the requirement of paragraph 3.2.1.2.1 "System Interface" shall be verified by comparative analysis of engineering documentation developed under previous programs and during selected testing according to 4.1.1.1 and 4.1.2 as follows:

4.1.6.1.1 <u>Parametric Interfaces</u>. SRM seal-level ballistic and TVC performance as specified in (TBS) shall be verified to the extent analyzed by 4.1.3.2 and 4.1.3.4.

4.1.6.1.2 <u>Structural and Dynamic Load Interfaces</u>. These interfaces as specified in (TBS), shall be verified only to the extent that mass property requirements shall be verified as appropriate according to 4.1.3.2.

4.1.6.1.3 <u>Electrical Interfaces</u>. These interfaces as specified in (TBS) shall be tested as defined by (TBS). (ref: 4.1.6.1.4)

4.1.6.1.4 <u>Testing Interfaces</u>. These interfaces, as specified in (TBS) shall be verified to the extent where UTC electrical test requirements are applicable to the testing of 4.1.1.1 and 4.1.2. (reference 4.1.6.1.8 for fluid systems verifications.)

4.1.6.1.5 <u>Physical Interfaces</u>. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.6 <u>Electrical Interfaces</u>. These interfaces, as specified in (TBS), shall be verified by testing as defined by (TBS). (ref.: 4.1.6.1.4)

4.1.6.1.7 <u>Envelope Interface</u>. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.1.6.1.8 <u>Fluid Interfaces</u>. To the extent that the fluid interfaces are required for the testing of 4.1.1.1 and 4.1.2, the interfaces (mechanical, fluid quantity and fluid quality) used for static test will be consistent with the requirements of (TBS) and thereby verify adequacy of requirements.

4.1.6.1.9 <u>Installation Interfaces</u>. Dimensional requirements only, as specified in (TBS), shall be verified according to the inspections of 4.1.3.1.

4.2 <u>Category II Test Program</u>. The requirements of 3.3.9 shall be verified by tests to be performed after the SRM stage has been integrated into an assembled launch vehicle. The solid rocket motors shall demonstrate the following minimum vehicle centerline vacuum web action time total impulse when assembled and launched as a Stage of the space shuttle launch vehicle in accordance with MIL-STD-471: (TBS)

5. <u>PREPARATION FOR DELIVERY</u>. (TBS)

6. NOTES.

6.1 <u>Supplemental Information</u>. Maximum use shall be made of components qualified under other programs.

6.1.1 <u>Definitions</u>. For purposes of this specification the following definitions shall apply:

6.1.1.1 Web Action Time. Web action time shall be defined as follows: The start of web action time shall be that point in the pressure/time trace at which the head end pressure has reached 75 percent of maximum. The end of web action time shall be defined by the following geometric construction. Extend the general shape of the pressure time curve prior to and immediately after the beginning of tail-off. Then bisect the angle formed by this extension. Extend this bisector to intersect the pressure/time trace. The time that corresponds to this intersection point is the end of web action time.

6.1.1.2 Action Time. Action time is defined as beginning when the pressure has risen to 75 percent of the maximum chamber pressure and ending when the head end pressure has fallen to 10 percent of the maximum chamber pressure.

6.1.1.3 Delivered Specific Impulse. The delivered specific impulse shall be defined as the total impulse along the nozzle centerline delivered during web action time divided by the weight of propellant expended during web action time. Delivered specific impulse at plant site shall be extrapolated to specific impulse at vacuum conditions. The methods used to determine the weight of expended propellant and to extrapolate the data shall be presented subject to customer approval.

6.1.1.4 Regressivity. Regressivity is defined as the maximum vacuum thrust minus the vacuum thrust at end of web action time divided by the maximum vacuum thrust. All thrusts are taken along the nozzle centerline.

6.1.1.5 Action Time Total Impulse. Action time total impulse is defined as the integrated thrust along the nozzle centerline over the action time.

6.1.1.6 Initial Vacuum Thrust. Initial vacuum thrust is defined as that vacuum thrust along with the nozzle centerline at the completion of ignition. Initial vacuum thrust may be calculated from sea level data by adding 183,603 lb_f to the measured sea level nozzle centerline thrust.

6.1.1.7 Web Action Time Total Impulse. Web action time total impulse is defined as the integrated thrust along the nozzle centerline over the web action time.

6.1.1.8 Ignition Delay. Ignition delay is defined as the time interval between fire signal and when the motor chamber pressure reaches 75 percent of the initial peak pressure.

6.1.1.9 Tailoff. Tailoff is defined as the time interval between web action time and action time.

6.1.1.10 Total Prelaunch Weight (Nominal). Total prelaunch weight is defined as the sum of all motor weights which includes propellants and inerts.

6.1.1.11 Expendable Weight. Expendable weight is defined as the weight of those items that are expended from the motor which include propellant, insulation and liner, nozzle, igniter charge, and weather seal.

6.1.1.12 <u>Weight Empty</u>. Weight empty is defined as the total of inert motor component weights excluding R&D instrumentation.

6.1.1.13 <u>Burnout Motor Weight</u>. Total prelaunch weight minus expendables is burnout condition. A definition of burnout weight is prelaunch weight minus inert expendable weight excluding expended propellant and igniter charge weight.

6.1.1.14 <u>Loaded Propellant Weight</u>. Loaded propellant weight is defined as all solid propellant weight in the rocket motor.

6.1.1.15 <u>Nominal Inert Motor Weight</u>. Nominal inert motor weight includes the following: The motor case with nozzle, thrust termination port covers and stacks, skirts, igniter, and internal insulation. It does not include the TVC system and its attachments, instrumentation, ordnance system, power supplies, other electrical systems, external insulation, all vehicle attachment and aerodynamic fairings.

6.1.1.16 <u>Mass Fraction</u>. The nominal propellant mass fraction ($\lambda\rho$) is determined by the following method:

$$\lambda\rho = W_p / (W_p + W_i)$$

Where: W_p = Loaded Propellant Weight

W_i = Nominal Inert Motor Weight

6.1.1.17 <u>Resolution</u>. Resolution is defined as the minimum change in input voltage necessary to produce a change in generated side force, in the same direction as the previous change.

6.1.1.18 <u>Hysteresis</u>. Hysteresis is defined as the difference in input voltage required to produce a change in generated thrust vector moment arm (TVMA) when the direction of the TVMA is changed due to command voltage reversals.

6.1.1.19 <u>Deflection Angle</u>. Deflection angle is defined as the arctan of the side thrust measured perpendicular to the nozzle centerline divided by the axial thrust measured along the nozzle centerline.

6.1.1.20 <u>Launch Reaction Time</u>. Launch reaction time is defined as the time required to prepare to launch a vehicle following the completion of prelaunch checkout.

6.1.1.21 <u>Abort Recycle Time</u>. Abort recycle time is defined as the time required to launch a vehicle following an abortive launch attempt.

6.1.1.22 <u>The SRM Pitch (Yaw) Thrust Vector Angle</u>. The angle between the SRM motor centerline and the projection of the SRM thrust vector into the SRM pitch (yaw) plane.

6.1.1.23 SRM Pitch (Yaw) Plane. The plane defined by the SRM motor centerline and a line which is normal to the SRM centerline and parallel to the vehicle pitch (yaw) plane.

6.1.1.24 The SRM Pitch (Yaw) Thrust Vector Moment Arm. The length of the perpendicular line from the SRM motor centerline at missle station (TBS) to the SRM projection of the thrust vector into the pitch (yaw) plane.

6.1.1.25 Solid Rocket Motor Centerline. The line joining the center of the aft closure-to-nozzle throat bolt circle to the center of the forward closure in the plane of the forward attach structure.

6.1.1.26 Nozzle Centerline. The line joining the center of the nozzle throat to the center of the nozzle exit.

6.1.1.27 Stage Centerline. The line joining the center of the stage/orbiter assembly joint bolt circle and the center of the aft structure support structure.

6.1.1.28 SRM Thrust Vector. The force vector whose magnitude and variability is defined by paragraph 3.1.1.1.1, and whose direction and variability is defined by paragraph 3.1.1.1.2.

6.1.1.29 Stage Roll Plane. A plane perpendicular to the stage centerline which intersects the stage centerline at missile station (TBS).

6.1.1.30 Stage Roll Control Moment. The resultant moment about the stage centerline of the sum of the SRM thrust vectors projected into the stage roll plane.

10. APPENDIX

10.1 Test Configuration. The static test configuration of the SRM shall conform to UTC drawing (TBS). This drawing shows several obvious differences from the flight configuration. These differences shall not affect performance but are related to ordance, structural, and instrumentation measurements which pertain directly to the static test program.

Specific differences shall include the following areas: (TBS)

The following figures are to be supplied:

Figure 23. Frequency Response

Figure 24. Slew Rates

Figure 25. Net Thrust Versus Time from Thrust Termination Actuation

Figures 26 through 30. Schematic Arrangements of SRM Electrical Systems