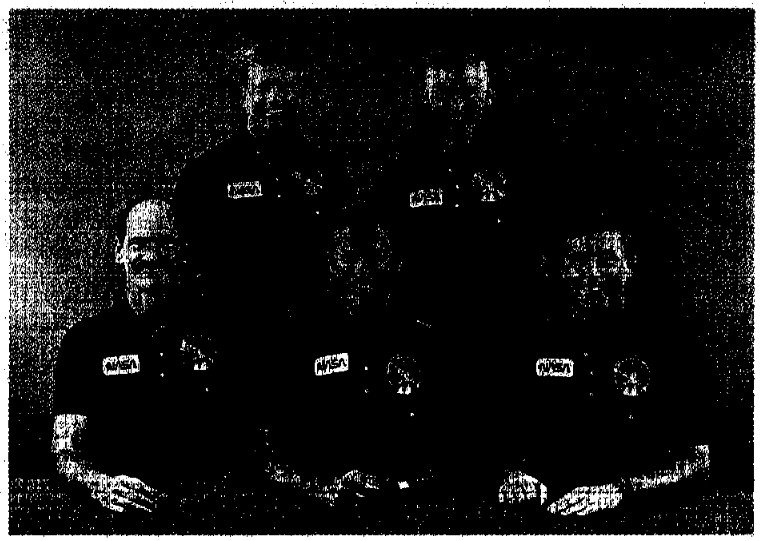

STS-27 PRESS INFORMATION

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Space Transportation
Systems Division

Office of Media Relations

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FOREWORD

STS-27 is the third flight of Atlantis (OV-104) and the 27th in the space transportation system program. This flight is a dedicated DOD mission.

The flight crew for the STS-27 mission consists of the following:

Commander: Robert L. Gibson, second space shuttle flight
Pilot: Guy S. Gardner, first space shuttle flight
Mission specialist: Richard M. Mullane, second space shuttle flight
Mission specialist: Jerry L. Ross, second space shuttle flight
Mission specialist: William M. Shepherd, first space shuttle flight

On the cover is the STS-27 flight crew portrait. Seated, from left to right, are Guy Gardner, Robert Gibson and Jerry Ross. Standing, from left to right, are William Shepherd and Richard (Mike) Mullane.

Prelaunch commentary for this mission begins at T minus 9 minutes and concludes at main engine cutoff (MECO).

The date and time of landing at Edwards Air Force Base, Calif., will be announced 24 hours before touchdown.

CONTENTS

OPERATIONAL IMPROVEMENTS AND MODIFICATIONS

The major improvements and modifications made to the STS-26 space shuttle vehicle systems and components were also incorporated into the same systems and components for the STS-27 mission. The following sections identify the major improvements and modifications made to the STS-27 orbiter, main engines and solid rocket motors (SRMs). (In addition, approximately 190 other modifications and improvements were made to Atlantis.)

ORBITER

ORBITAL MANEUVERING SYSTEM/REACTION CONTROL SYSTEM AC-MOTOR-OPERATED VALVES. The 64 valves operated by ac motors in the OMS and RCS were modified to incorporate a "sniff" line for each valve to permit monitoring of nitrogen tetroxide or monomethyl hydrazine in the electrical portion of the valves during ground operations. This new line reduces the probability of floating particles in the electrical microswitch portion of each valve, which could affect the operation of the microswitch position indicators for onboard displays and telemetry. It also reduces the probability of nitrogen tetroxide or monomethyl hydrazine leakage into the bellows of each ac-motor-operated valve.

PRIMARY RCS THRUSTERS. The wiring of the fuel and oxidizer injector solenoid valves was wrapped around each of the 38 primary RCS thrust chambers to remove electrical power from these valves in the event of a primary RCS thruster instability.

FUEL CELL POWER PLANTS. End-cell heaters on each fuel cell power plant were deleted because of potential electrical failures and replaced with Freon coolant loop passages to maintain uniform temperature throughout the power plants. In addition, the hydrogen pump and water separator of each fuel cell power plant were improved to minimize excessive hydrogen gas entrained in the power plant product water. A current measurement detector was added to monitor the hydrogen pump of each fuel cell power plant and provide an early indication of hydrogen pump overload.

The starting and sustaining heater system for each fuel cell power plant was modified to prevent overheating and loss of heater elements. A stack inlet temperature measurement was added to each fuel cell power plant for full visibility of thermal conditions.

The product water from all three fuel cell power plants flows to a single water relief control panel. The water can be directed from the single panel to the environmental control and life support system's potable water tank A or to the fuel cell power plant water relief nozzle. Normally, the water is directed to water tank A. In the event of a line rupture in the vicinity of the single water relief panel, water could spray on all three water relief panel lines, causing them to freeze and preventing water discharge.

The product water lines from all three fuel cell power plants were modified to incorporate a parallel (redundant) path of product water to ECLSS potable water tank B in the event of a freeze-up in the single water relief panel. If the single water relief panel freezes up, pressure would build up and discharge through the redundant paths to water tank B.

A water purity sensor (pH) was added at the common product water outlet of the water relief panel to provide a redundant measurement of water purity (a single measurement of water purity in each fuel cell power plant was provided previously). If the fuel cell power plant pH sensor failed in the past, the flight crew had to sample the potable water.

AUXILIARY POWER UNITS. The APUs that have been in use to date have a limited life. Each unit was refurbished after 25 hours of operation because of cracks in the turbine housing, degradation of the gas generator catalyst (which varied up to approximately 30 hours of operation) and operation of the gas generator valve module (which also varied up to approximately 30 hours of operation). The remaining parts of the APU were qualified for 40 hours of operation.

Improved auxiliary power units are scheduled for delivery in late 1988. A new turbine housing increases the life of the housing to 75 hours of operation (50 missions); a new gas generator increases its life to 75 hours; a new standoff design of the gas generator valve module and fuel pump deletes the requirement for a water spray system that was required previously for each APU upon shutdown after the first OMS thrusting period or orbital checkout; and the addition of a third seal in the middle of the two existing seals for the shaft of the fuel pump/lube oil system (previously only two seals were located on the shaft, one on the fuel pump side and one on the gearbox lube oil side) reduces the probability of hydrazine leaking into the lube oil system.

The deletion of the water spray system for the gas generator valve module and fuel pump for each APU results in a weight reduction of approximately 150 pounds for each orbiter. Upon the delivery of the improved units, the life-limited APUs will be refurbished to the upgraded design.

In the event that a fuel tank valve switch in an auxiliary power unit is inadvertently left on or an electrical short occurs within the valve electrical coil, additional protection is provided to prevent overheating of the fuel isolation valves.

MAIN LANDING GEAR. The following modifications were made to improve the performance of the main landing gear elements:

1. The thickness of the main landing gear axle was increased to provide a stiffer configuration that reduces brake-to-axle deflections and precludes brake damage experienced in previous landings. The thicker axle should also minimize tire wear.

2. Orifices were added to hydraulic passages in the brake's piston housing to prevent pressure surges and brake damage caused by a wobble/pump effect.

3. The electronic brake control boxes were modified to balance hydraulic pressure between adjacent brakes and equalize energy applications. The anti-skid circuitry previously used to reduce brake pressure to the opposite wheel if a flat tire was detected has now been removed.

4. The carbon-lined beryllium stator discs in each main landing gear brake were replaced with thicker discs to increase braking energy significantly.

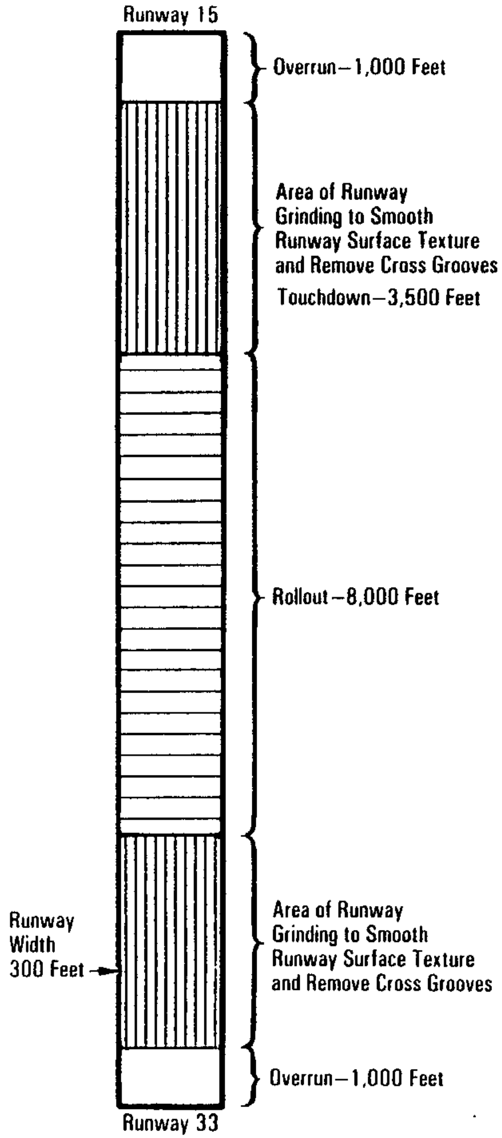
5. A long-term structural carbon brake program is in progress to replace the carbon-lined beryllium stator discs with a carbon configuration that provides higher braking capacity by increasing maximum energy absorption.

6. Strain gauges were added to each nose and main landing gear wheel to monitor tire pressure before launch, deorbit and landing.

Other studies involve arresting barriers at the end of landing site runways (except lake bed runways), installing a skid on the landing gear that could preclude the potential for a second blown tire on the same gear after the first tire has blown, providing "roll on rim" for a predictable roll if both tires are lost on a single or multiple gear and adding a drag chute.

Studies of landing gear tire improvements are being conducted to determine how best to decrease tire wear observed after previous Kennedy Space Center landings and how to improve crosswind landing capability.

Modifications were made to the Kennedy Space Center shuttle landing facility runway. The full 300-foot width of 3,500-foot sections at both ends of the runway were ground to smooth the runway surface texture and remove cross grooves. The modified corduroy ridges are smaller than those they replaced and run the length of the runway rather than across its width. The existing landing zone light fixtures were also modified, and the markings of the entire runway and overruns were repainted. The primary purpose of the modifications is to enhance safety by reducing tire wear during landing.



Shuttle Landing Facility Runway Modifications at Kennedy Space Center

NOSE WHEEL STEERING. The nose wheel steering system was modified on Columbia (OV-102) for the 61-C mission, and Discovery (OV-103) and Atlantis (OV-104) are being similarly modified before their return to flight. The modification allows a safe high-speed engagement of the nose wheel steering system and provides positive lateral directional control of the orbiter during rollout in the presence of high crosswinds and blown tires.

THERMAL PROTECTION SYSTEM. The area aft of the reinforced carbon-carbon nose cap to the nose landing gear doors has sustained damage (tile slumping) during flight operations from impact during ascent and overheating during re-entry. This area, which previously was covered with high-temperature reusable surface insulation tiles, will now be covered with reinforced carbon-carbon.

The low-temperature thermal protection system tiles on Columbia's midbody, payload bay doors and vertical tail were replaced with advanced flexible reusable surface insulation blankets.

Because of evidence of plasma flow on the lower wing trailing edge and elevon landing edge tiles (wing/elevon cove) at the outboard elevon tip and inboard elevon, the low-temperature tiles are being replaced with fibrous refractory composite insulation (FRCI-12) and high-temperature (HRSI-22) tiles along with gap fillers on Discovery and Atlantis. On Columbia only gap fillers are installed in this area.

WING MODIFICATION. Before the wings for Discovery and Atlantis were manufactured, a weight reduction program was instituted that resulted in a redesign of certain areas of the wing structure. An assessment of wing air loads from actual flight data indicated greater loads on the wing structure than predicted. To maintain positive margins of safety during ascent, structural modifications were incorporated into certain areas of the wings.

MIDFUSELAGE MODIFICATIONS. Because of additional detailed analysis of actual flight data concerning descent-stress thermal-gradient loads, torsional straps were added to tie all the lower midfuselage stringers in bays 1 through 11 together in a manner similar to a box section. This eliminates rotational (torsional) capabilities to provide positive margins of safety.

Also, because of the detailed analysis of actual descent flight data, room-temperature vulcanizing silicone rubber material was bonded to the lower midfuselage from bays 4 through 11 to act as a heat sink, distributing temperatures evenly across the bottom of the midfuselage, reducing thermal gradients and ensuring positive margins of safety.

GENERAL-PURPOSE COMPUTERS. New, upgraded general-purpose computers (AP-101S) will replace the existing GPCs aboard the space shuttle orbiters in late 1988 or early 1989. The upgraded computers allow NASA to incorporate more capabilities into the orbiters and apply advanced computer technologies that were not available when the orbiter was first designed. The new computer design began in January 1984, whereas the older design began in January 1972. The upgraded GPCs provide 2.5 times the existing memory capacity and up to three times the existing processor speed with minimum impact on flight software. They are half the size, weigh approximately half as much, and require less power to operate.

INERTIAL MEASUREMENT UNITS. The new high-accuracy inertial navigation system will be phased in to augment the present KT-70 inertial measurement units in 1988-89. These new IMUs will result in lower program costs over the next decade, ongoing production support, improved performance, lower failure rates and reduced size and weight. The HAINS IMUs also contain an internal dedicated microprocessor with memory for processing and storing compensation and scale factor data from the vendor's calibration, thereby reducing the need for extensive initial load data for the orbiter's computers. The HAINS is both physically and functionally interchangeable with the KT-70 IMU.

CREW ESCAPE SYSTEM. The in-flight crew escape system is provided for use only when the orbiter is in controlled gliding flight and unable to reach a runway. This would normally lead to ditching. The crew escape system provides the flight crew with an alternative to water ditching or to landing on terrain other than a landing site. The probability of the flight crew surviving a ditching is very small.

The hardware changes required to the orbiters would enable the flight crew to equalize the pressurized crew compartment with the outside pressure via a depressurization valve opened by pyrotechnics in the crew compartment aft bulkhead that would be manually activated by a flight crew member in the middeck of the crew compartment; pyrotechnically jettison the crew ingress/egress side hatch in the middeck of the crew compartment; and bail out from the middeck of the orbiter through the ingress/egress side hatch opening after manually deploying the escape pole through, outside and down from the side hatch opening. One by one, each crew member attaches a lanyard hook assembly, which surrounds the deployed escape pole, to his parachute harness and egresses through the side hatch opening. Attached to the escape pole, the crew member slides down the pole and off the end. The escape pole provides a trajectory that takes the crew members below the orbiter's left wing.

Changes were also made in the software of the orbiter's general-purpose computers. The software changes were required for the primary avionics software system and the backup flight system for transatlantic-landing and glide-return-to-launch-site aborts. The changes provide the orbiter with an automatic-mode input by the flight crew through keyboards on the commander's and/or pilot's panel C3, which provides the orbiter with an automatic stable flight for crew bailout.

EMERGENCY EGRESS SLIDE. The emergency egress slide provides orbiter flight crew members with a means for rapid and safe exit through the orbiter middeck ingress/egress side hatch after a normal opening of the side hatch or after jettisoning the side hatch at the nominal end-of-mission landing site or at a remote or emergency landing site.

The emergency egress slide replaces the emergency egress side hatch bar, which required the flight crew members to drop approximately 10.5 feet to the ground. The previous arrangement could have injured crew members or prevented an already-injured crew member from evacuating and moving a safe distance from the orbiter.

17-INCH ORBITER/EXTERNAL TANK DISCONNECTS. Each mated pair of 17-inch disconnects contains two flapper valves: one on the orbiter side and one on the external tank side. Both valves in each disconnect pair are opened to permit propellant flow between the orbiter and the external tank. Prior to separation from the external tank, both valves in each mated pair of disconnects are commanded closed by pneumatic (helium) pressure from the main propulsion system. The closure of both valves in each disconnect pair prevents propellant discharge from the external tank or orbiter at external tank separation. Valve closure on the orbiter side of each disconnect also prevents contamination of the orbiter main propulsion system during landing and ground operations.

Inadvertent closure of either valve in a 17-inch disconnect during main engine thrusting would stop propellant flow from the external tank to all three main engines. Catastrophic failure of the main engines and external tank feed lines would result.

To prevent inadvertent closure of the 17-inch disconnect valves during the space shuttle main engine thrusting period, a latch mechanism was added in each orbiter half of the disconnect. The latch mechanism provides a mechanical backup to the normal fluid-induced-open forces. The latch is mounted on a shaft in the flowstream so that it overlaps both flappers and obstructs closure for any reason.

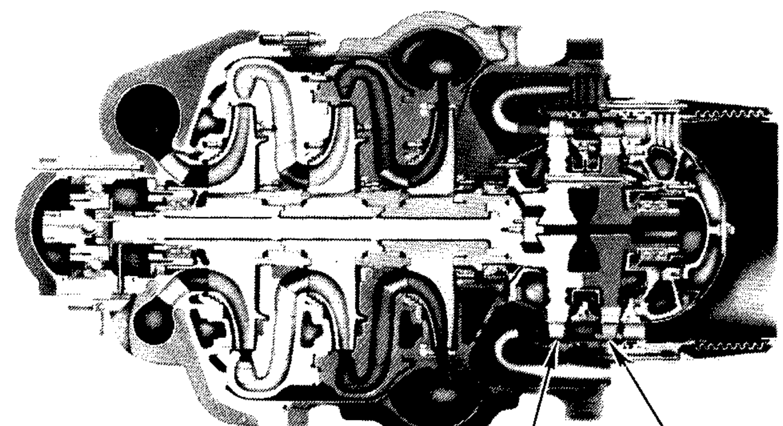
In preparation for external tank separation, both valves in each 17-inch disconnect are commanded closed. Pneumatic pressure from the main propulsion system causes the latch actuator to rotate the shaft in each orbiter 17-inch disconnect 90 degrees, thus freeing the flapper valves to close as required for external tank separation.

A backup mechanical separation capability is provided in case a latch pneumatic actuator malfunctions. When the orbiter umbilical initially moves away from the external tank umbilical, the mechanical latch disengages from the external tank flapper valve and permits the orbiter disconnect flapper to toggle the latch. This action permits both flappers to close.

SPACE SHUTTLE MAIN ENGINE MARGIN IMPROVEMENT PROGRAM

Improvements to the SSMEs for increased margin and durability began with a formal Phase II program in 1983. Phase II focused on turbomachinery to extend the time between high-pressure turbopump overhauls by reducing the operating temperature in the high-pressure fuel turbopump and by incorporating margin improvements to the HPFT rotor dynamics (whirl), turbine blade and HPFT bearings. Phase II certification was completed in 1985, and all the changes have been incorporated into the SSMEs for STS-26 and STS-27.

In addition to the Phase II improvements, additional changes in the SSMEs have been incorporated to further extend the



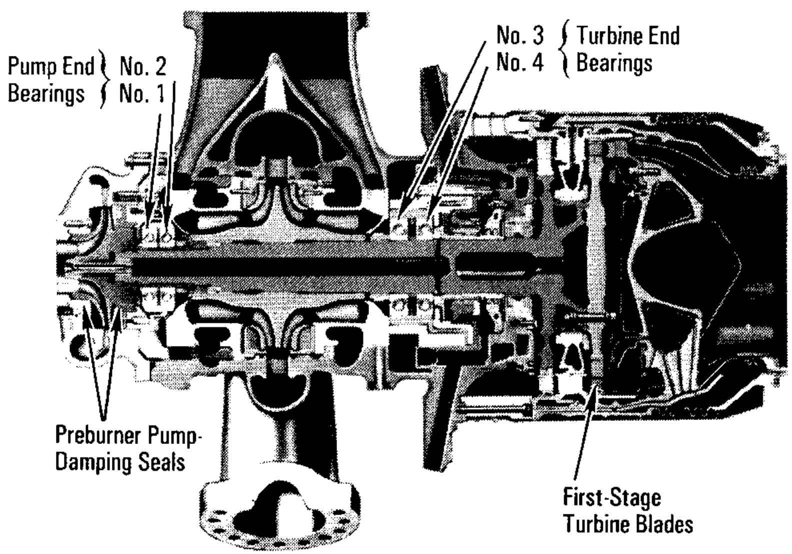
Phase II—High-Pressure Fuel Turbopump

engines' margin and durability. The main changes were to the high-pressure turbomachinery, main combustion chamber, hydraulic actuators and high-pressure turbine discharge temperature sensors. Changes were also made in the controller software to improve engine control.

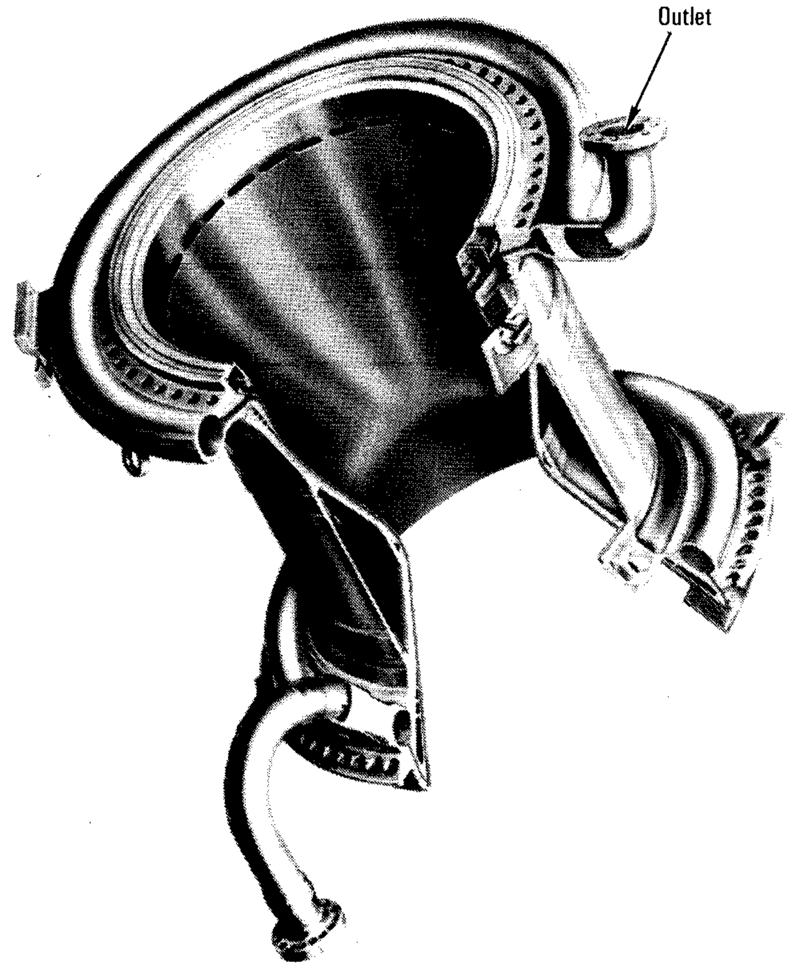
Minor high-pressure turbomachinery design changes resulted in margin improvements to the turbine blades, thereby extending the operating life of the turbopumps. These changes included applying surface texture to important parts of the fuel turbine blades to improve the material properties in the presence of hydrogen and incorporating a damper into the high-pressure oxidizer turbine blades to reduce vibration.

Main combustion chamber life has been increased by plating a welded outlet manifold with nickel. Margin improvements have also been made to five hydraulic actuators to preclude a loss in redundancy on the launch pad. Improvements in quality have been incorporated into the servocomponent coil design along with modifications to increase margin. To address a temperature sensor in-flight anomaly, the sensor has been redesigned and extensively tested without problems.

To certify the improvements to the SSMEs and demonstrate their reliability through margin (or limit testing), an aggressive ground test program was initiated in December 1986. From December 1986 to December 1987, 151 tests and 52,363 seconds of



Phase II—High-Pressure Oxygen Turbopump

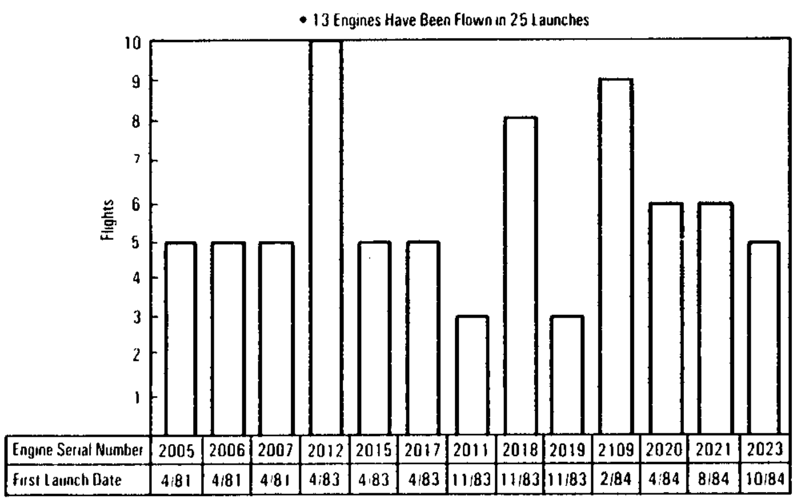


Main Combustion Chamber

operation (equivalent to 100 shuttle missions) were performed. The SSMEs have exceeded 300,000 seconds total test time, the equivalent of 615 space shuttle missions. These hot-fire ground tests are performed at the single-engine test stands at NASA's John C. Stennis Space Center in Mississippi and at Rockwell International's Rocketdyne Division's Santa Susana Field Laboratory in California.

SSME FLIGHT PROGRAM

By January 1986, there had been 25 flights (75 engine launches with three SSMEs per flight) of the SSMEs. A total of 13 engines were flown, and SSME reusability was demonstrated. One engine (serial number 2012) has been flown 10 times; 10 other engines have flown between five and nine times. Two off-nominal conditions were experienced on the launch pad and one during flight. Two fail-safe shutdowns occurred on the launch pad during engine start but before solid rocket booster ignition. In each case, the controller detected a loss of redundancy in the hydraulic actuator system and commanded engine shutdown in keeping with the launch commit criteria. Another loss of redundancy occurred in flight with a loss of a redline temperature sensor and its backup.



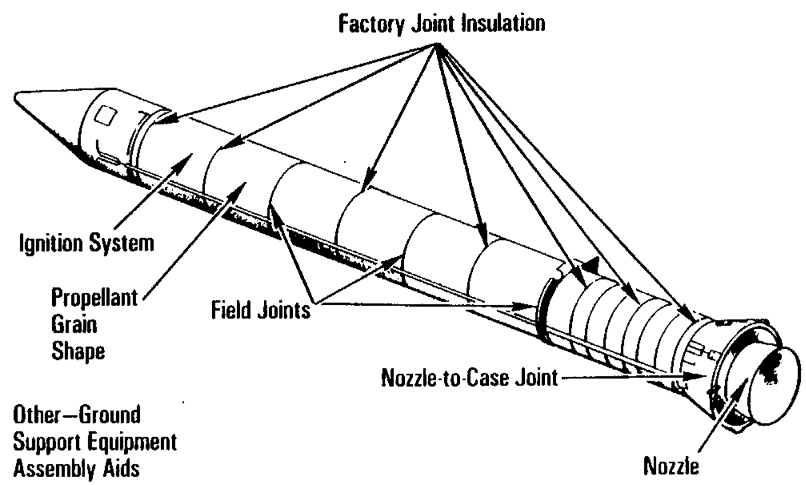
SSME Flight Experience Demonstrates Reusability (Through Feb. 1, 1986)

The engine was commanded to shut down, but the other two engines safely delivered the space shuttle to orbit. A major upgrade of these components was implemented to prevent a recurrence of these conditions and were incorporated for STS-26 and STS-27.

SOLID ROCKET MOTOR REDESIGN

On June 13, 1986, President Reagan directed NASA to implement, as soon as possible, the recommendations of the Presidential Commission on the Space Shuttle Challenger Accident. NASA developed a plan to provide a redesigned solid rocket motor. The primary objective of the redesign effort was to provide an SRM that is safe to fly. A secondary objective was to minimize impact on the schedule by using existing hardware, to the extent practical, without compromising safety. A joint redesign team was established that included participation from Marshall Space Flight Center, Morton Thiokol and NASA centers as well as individuals from outside NASA.

An "SRM Redesign Project Plan" was developed to formalize the methodology for SRM redesign and requalification. The plan provided an overview of the organizational responsibilities



Solid Rocket Booster Redesign and Reassessment and relationships, the design objectives, criteria and process; the verification approach and process; and a master schedule. The companion "Development and Verification Plan" defined the test program and analyses required to verify the redesign and the unchanged components of the SRM.

All aspects of the existing SRM were assessed, and design changes were required in the field joint, case-to-nozzle joint, nozzle, factory joint, propellant grain shape, ignition system and ground support equipment. No changes were made in the propellant, liner or castable inhibitor formulations. Design criteria were established for each component to ensure a safe design with an adequate margin of safety. These criteria focused on loads, environments, performance, redundancy, margins of safety and verification philosophy.

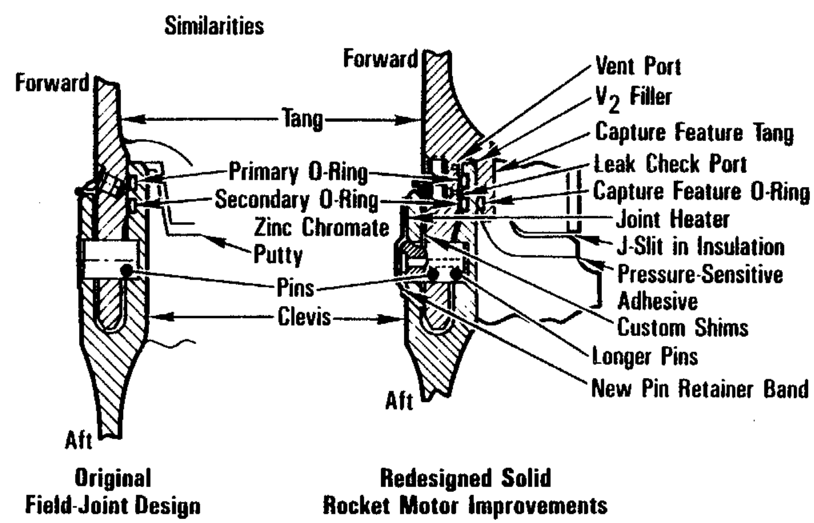
The criteria were converted into specific design requirements during the Preliminary Requirements Reviews held in July and August 1986. The design developed from these requirements was assessed at the Preliminary Design Review held in September 1986 and baselined in October 1986. The final design was approved at the Critical Design Review held in October 1987. Manufacture of the redesigned solid rocket motor test hardware and the first flight hardware began prior to the PDR and continued in parallel with the hardware certification program. The Design Certification Review examined the analyses and test results versus the program and design requirements to certify the redesigned SRM was ready to fly.

ORIGINAL VERSUS REDESIGNED SRM FIELD JOINT. The SRM field-joint metal parts, internal case insulation and seals were redesigned, and a weather protection system was added.

In the STS 51-L design, the application of actuating pressure to the upstream face of the O-ring was essential for proper joint sealing performance because large sealing gaps were created by pressure-induced deflections, compounded by significantly reduced O-ring sealing performance at low temperature. The major change in the motor case is the new tang capture feature to provide a positive metal-to-metal interference fit around the circumference of the tang and clevis ends of the mating segments. The interference fit limits the deflection between the tang and clevis O-ring sealing surfaces caused by motor pressure and structural loads. The joints are designed so that the seals will not leak under twice the expected structural deflection and rate.

The new design, with the tang capture feature, the interference fit and the use of custom shims between the outer surface of the tang and inner surface of the outer clevis leg, controls the O-ring sealing gap dimension. The sealing gap and the O-ring seals are designed so that a positive compression (squeeze) is always on the O-rings. The minimum and maximum squeeze requirements include the effects of temperature, O-ring resiliency and compression set, and pressure. The clevis O-ring groove dimension has been increased so that the O-ring never fills more than 90 percent of the O-ring groove and pressure actuation is enhanced.

The new field-joint design also includes a new O-ring in the capture feature and an additional leak check port to ensure that the primary O-ring is positioned in the proper sealing direction at ignition. This new, or third, O-ring also serves as a thermal barrier in case the sealed insulation is breached.

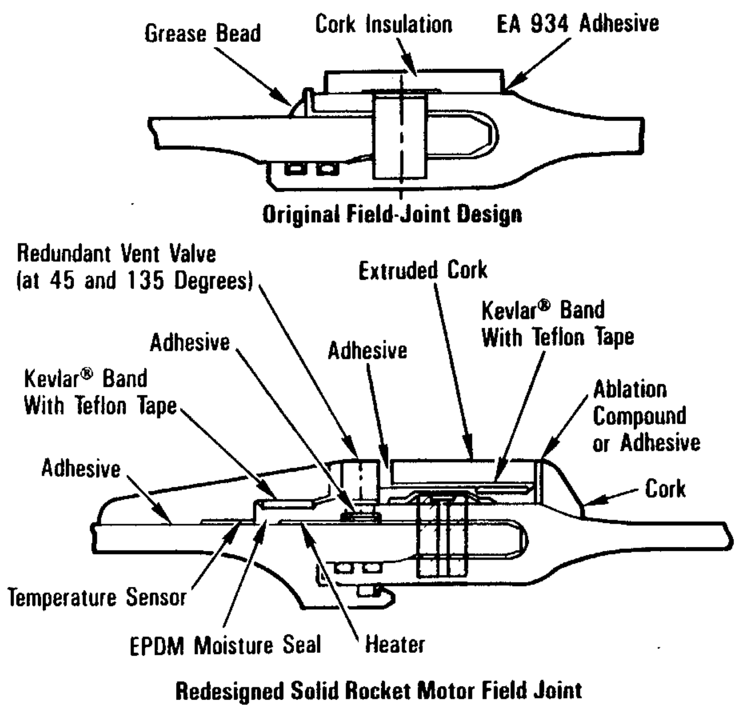


Field-Joint Comparision

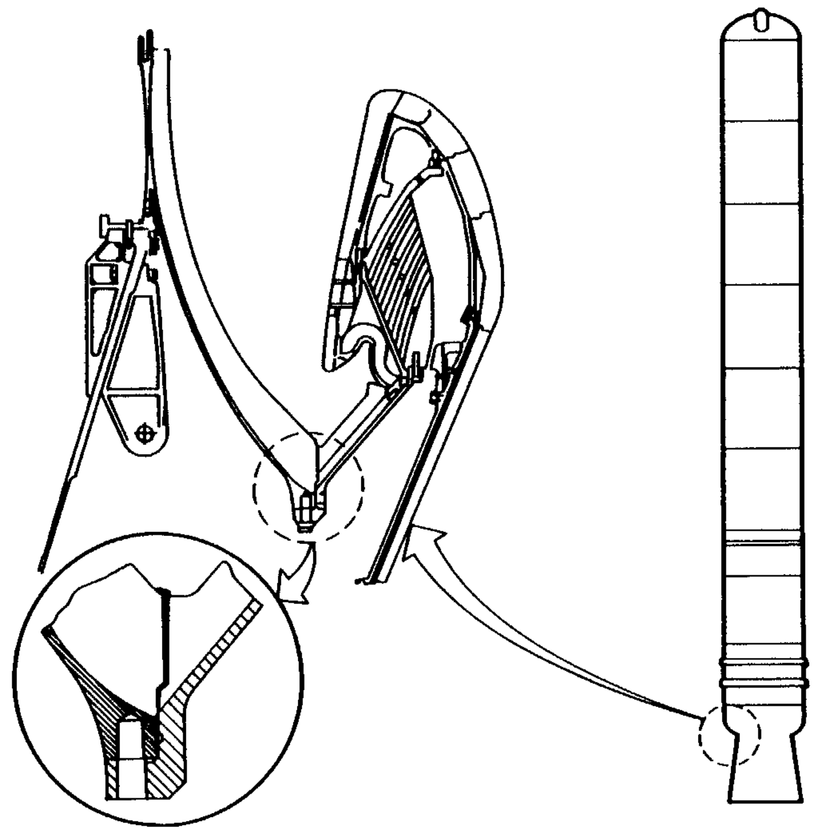
The field-joint internal case insulation was modified to be sealed with a pressure-actuated flap called a J-seal, rather than with putty as in the STS 51-L configuration.

Longer field-joint-case mating pins, with a reconfigured retainer band, were added to improve the shear strength of the pins and increase the metal parts' joint margin of safety. The joint safety margins, both thermal and structural, are being demonstrated over the full ranges of ambient temperature, storage compression, grease effect, assembly stresses and other environments. External heaters with integral weather seals were incorporated to maintain the joint and O-ring temperature at a minimum of 75 F. The weather seal also prevents water intrusion into the joint.

ORIGINAL VERSUS REDESIGNED SRM CASE-TO-NOZZLE JOINT. The SRM case-to-nozzle joint, which experienced several instances of O-ring erosion in flight, has been redesigned to satisfy the same requirements imposed upon the case field joint. Similar to the field joint, case-to-nozzle joint modifications have been made in the metal parts, internal insulation and O-rings. Radial bolts with Stat-O-Seals were added to minimize the joint sealing gap opening. The internal insulation was modified to be sealed adhesively, and a third O-ring was included. The third O-ring serves as a dam or wiper in front of the primary O-ring to prevent the polysulfide adhesive from being extruded into the primary O-ring groove. It also serves as a thermal barrier in case the polysulfide adhesive is breached. The polysulfide adhesive replaces the putty used in the 51-L joint. Also, an additional



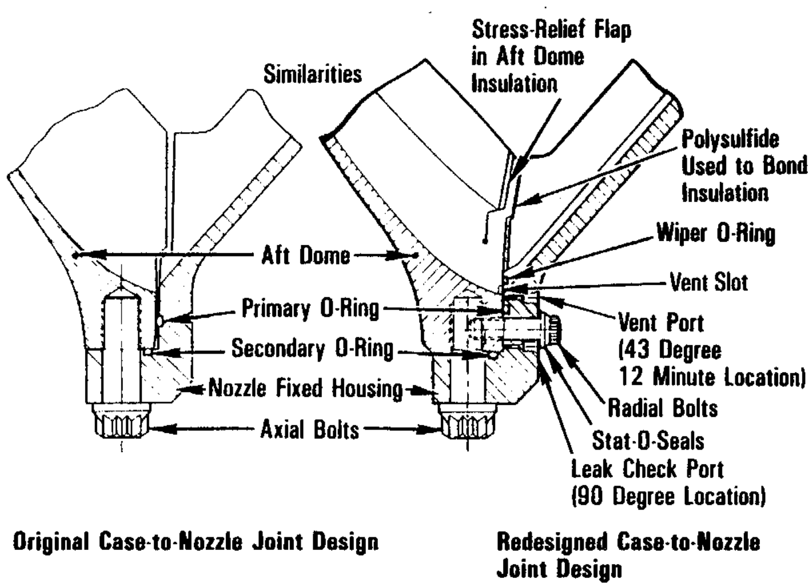
Field-Joint Protection System



Nozzle-to-Case Joint

leak check port was added to reduce the amount of trapped air in the joint during the nozzle installation process and to aid in the leak check procedure.

NOZZLE. The internal joints of the nozzle metal parts have been redesigned to incorporate redundant and verifiable O-rings at each joint. The nozzle steel fixed housing part has been redesigned to permit the incorporation of the 100 radial bolts that attach the fixed housing to the case's aft dome. Improved bonding techniques are being used for the nozzle nose inlet, cowl/boot and aft exit cone assemblies. The distortion of the nose inlet assembly's metal-part-to-ablative-parts bond line has been eliminated by increasing the thickness of the aluminum nose inlet housing and improving the bonding process. The tape-wrap angle of the carbon cloth fabric in the areas of the nose inlet and throat assembly parts was changed to improve the ablative insulation's erosion tolerance. Some of these ply-angle changes were in progress prior to STS 51-L. The cowl and outer boot ring has additional structural support with increased thickness and contour changes to increase their margins of safety. Additionally, the outer boot ring's ply configuration was altered.



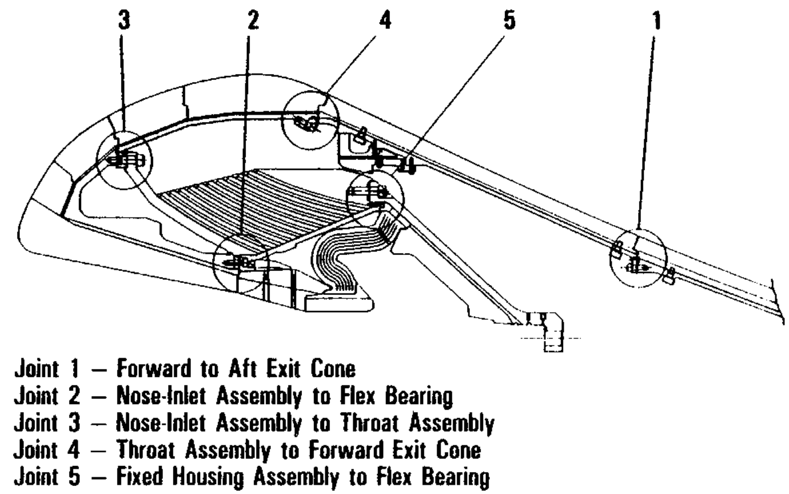
Case-to-Nozzle Joint Design

FACTORY JOINT. Minor modifications were made in the case factory joints by increasing the insulation thickness and layup to increase the margin of safety on the internal insulation. Longer pins were also added, along with a reconfigured retainer band and new weather seal to improve factory joint performance and increase the margin of safety. Additionally, the O-ring and O-ring groove size was changed to be consistent with the field joint.

PROPELLANT. The motor propellant forward transition region was recontoured to reduce the stress fields between the star and cylindrical portions of the propellant grain.

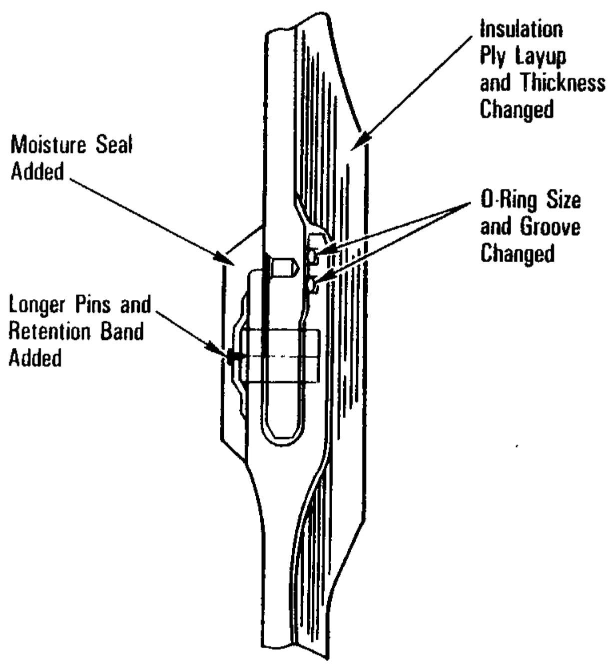
IGNITION SYSTEM. Several minor modifications were incorporated into the ignition system. The aft end of the igniter steel case, which contains the igniter nozzle insert, was thickened to eliminate a localized weakness. The igniter internal case insulation was tapered to improve the manufacturing process. Finally, although vacuum putty is still being used at the joint of the igniter and case forward dome, it was changed to eliminate asbestos as one of its constituents.

GROUND SUPPORT EQUIPMENT. The GSE has been redesigned to (1) minimize the case distortion during handling at the launch site; (2) improve the segment tang and clevis joint mea-



Redesigned Solid Rocket Motor Nozzle Internal Seals surement system for more accurate reading of case diameters to facilitate stacking; (3) minimize the risk of O-ring damage during joint mating; and (4) improve leak testing of the igniter, case and nozzle field joints. A GSE assembly aid guides the segment tang into the clevis and rounds the two parts with each other. Other GSE modifications include transportation monitoring equipment and lifting beam.

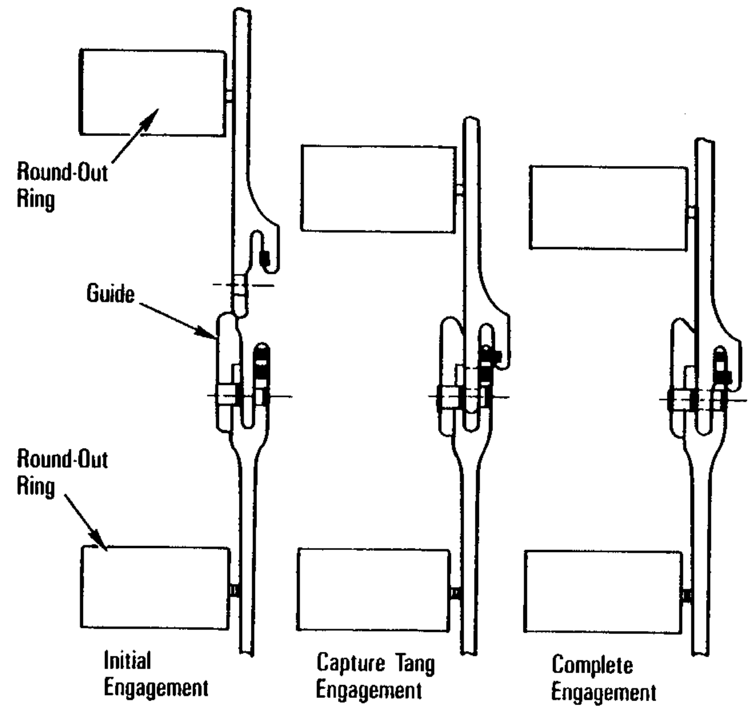
DESIGN ANALYSIS SUMMARY. Improved, state-of-the-art analyses related to structural strength, loads, stress, dynamics, fracture mechanics, gas and thermal dynamics, and material characterization and behavior were performed to aid the field joint, nozzle-to-case joint and other designs. Continuing these analyses will ensure that the design integrity and system compatibility adhere to design requirements and operational use. These analyses were verified by tests, whose results were correlated with pretest predictions.



Redesigned Factory Joint

VERIFICATION/CERTIFICATION TEST. The verification program demonstrated that the redesigned solid rocket motor met all design and performance requirements, and that failure modes and hazards have been eliminated or controlled. The verification program encompassed the following program phases: development, certification, acceptance, preflight checkout, flight and postflight.

Redesigned SRM certification was based on formally documented results of development motor tests, qualification motor tests and other tests and analyses. The certification tests were conducted under strict control of environments, including thermal and structural loads; assembly, inspection and test procedures; and Safety, Reliability, Maintainability and Quality Assurance surveillance to verify that flight hardware met the specified performance and design requirements. The "Development and Verification



Ground Support Equipment Assembly Aids

Plan" stipulated that the test program follow a rigorous sequence wherein successive tests are built on the results of previous tests and lead to formal certification.

The test activities included laboratory and component tests, subscale tests, full-scale simulation and full-scale motor static test firings. Laboratory and component tests were used to determine component properties and characteristics. Subscale motor firings were used to simulate gas dynamics and thermal conditions for components and subsystem design. Full-scale hardware simulators were used to verify analytical models; determine hardware assembly characteristics; determine joint deflection characteristics; determine joint performance under short-duration hot-gas tests, including joint flaws and flight loads; and determine redesigned hardware structural characteristics.

Fourteen full-scale joint assembly demonstration vertical mate/demate tests, with eight interspersed hydrotests to simulate flight hardware refurbishment procedures, were completed early for the redesigned capture feature hardware. Assembly loads were as expected, and the case growth was as predicted with no measurable increase after three hydroproof tests.

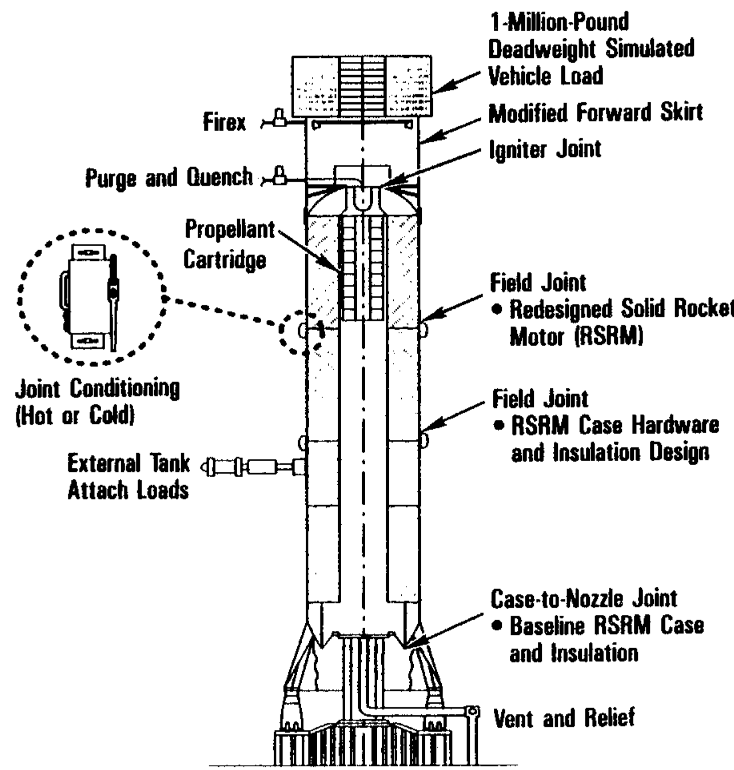
Flight-configuration aft and center segments were fabricated, loaded with live propellant, and used for assembly test article stacking demonstration tests at Kennedy Space Center. These tests were pathfinder demonstrations for the assembly of flight hardware using newly developed GSE.

In a long-term stack test, a full-scale casting segment, with live propellant, was mated vertically with a J-seal insulation segment and underwent temperature cycling. This determined the compression set of the J-seal, aging effects and long-term propellant slumping effects.

The structural test article (STA-3), consisting of flight-type forward and aft motor segments and forward and aft skirts, was subjected to extensive static and dynamic structural testing, including maximum prelaunch, lift-off and flight (maximum dynamic pressure) structural loads.

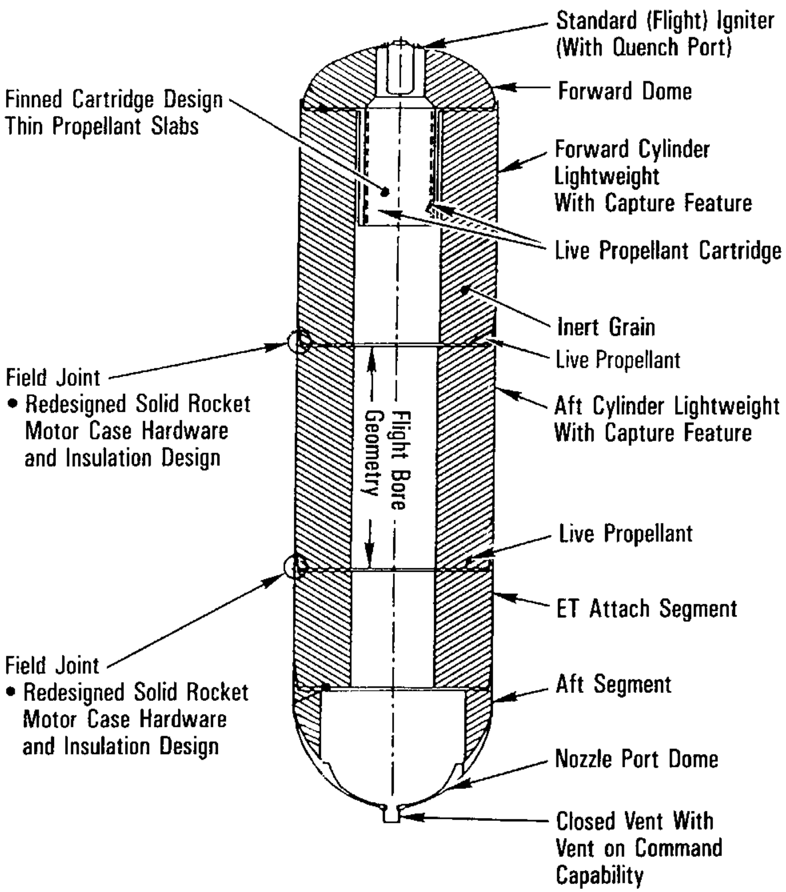
Redesigned SRM certification included testing the actual flight configuration over the full range of operating environments and conditions. The joint environment simulator, transient pressure test article, and the nozzle joint environment simulator test programs all utilized full-scale flight design hardware and subjected the redesigned SRM design features to the maximum expected operating pressure, maximum pressure rise rate and temperature extremes during ignition tests. Additionally, the TPTA was subjected to ignition and lift-off loads as well as maximum dynamic pressure structural loads.

Four TPTA tests were completed to subject the redesigned case field and case-to-nozzle joints to the above-described condi-



Transient Pressure Test Article (TPTA) Configuration tions. The field and case-to-nozzle joints were temperature-conditioned to 75 F and contained various types of flaws in the joints so that the primary and secondary O-rings could be pressure-actuated, joint rotation and O-ring performance could be evaluated and the redesigned joints could be demonstrated as fail-safe.

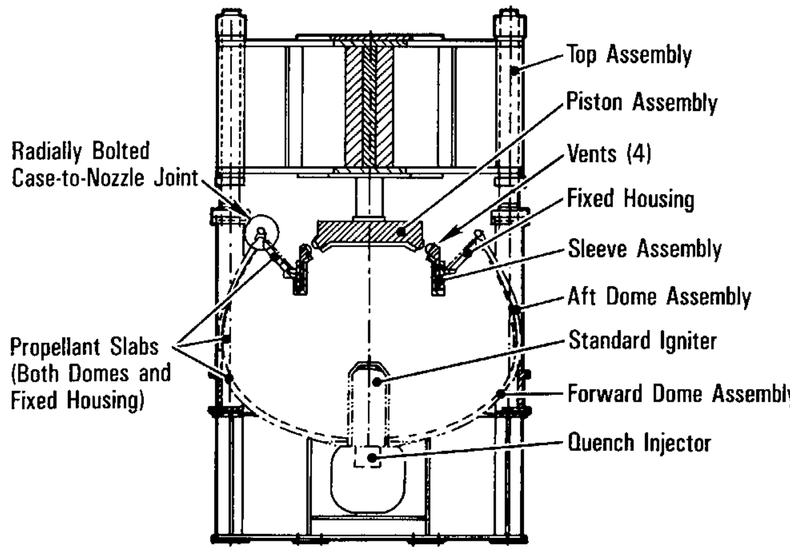
Seven joint environment simulator tests were completed. The JES test program initially used the STS 51-L configuration hardware to evaluate the joint performance with prefabricated blow-holes through the putty. The JES-1 test series, which consisted of two tests, established a structural and performance data base for the STS 51-L configuration with and without a replicated joint failure. The JES-2 series, two tests, also used the STS 51-L case metal-part joint but with a bonded labyrinth and U-seal insulation that was an early design variation of the J-seal. Tests were conducted with and without flaws built into the U-seal joint insulation; neither joint showed O-ring erosion or blowby. The JES-3 series, three tests, used an almost exact flight-configuration hardware, case field-joint capture feature with interference fit and J-seal insulation.



Joint Environment Simulator (JES) Configuration

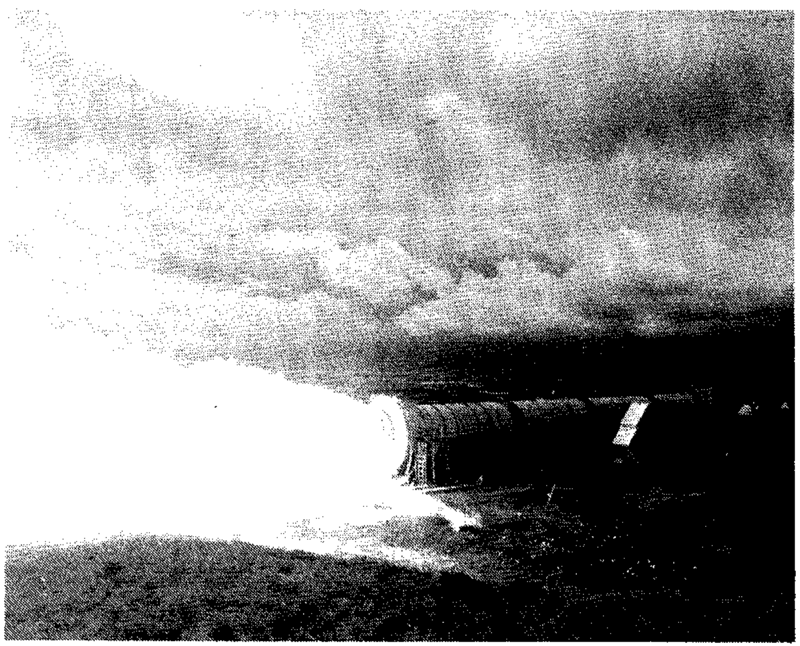
Five nozzle JES tests were successfully conducted. The STS 51-L hardware configuration hydrotest confirmed predicted case-to-nozzle joint deflection. The other three tests used the radially bolted redesigned SRM configuration.

Seven full-scale, full-duration motor static tests were conducted to verify the integrated redesigned SRM performance. These included one engineering test motor used to (1) provide a data base for STS 51-L-type field joints, (2) evaluate new seal 13



Nozzle Joint Environment Simulator Configuration material, (3) evaluate the ply-angle change in the nozzle parts, (4) evaluate the effectiveness of graphite composite stiffener rings to reduce joint rotation and (5) evaluate field-joint heaters. There were two development motor tests and three qualification motor tests for final flight configuration and performance certification. There was one flight production verification motor that contained intentionally induced defects in the joints to demonstrate joint performance under extreme worse-case conditions. The QM-7 motor was subjected to lift-off and maximum dynamic pressure structural loads, and was temperature-conditioned to 90 F. QM-8 will be temperature-conditioned to 40 F and subjected to lift-off and maximum dynamic pressure structural loads.

An assessment was conducted to determine the full-duration static firing test attitude necessary to certify the design changes completely. The assessment included establishing test objectives, defining and quantifying attitude-sensitive parameters, and evaluating attitude options. Both horizontal and vertical (nozzle up and down) test attitudes were assessed. In all three options, consideration was given to testing with and without externally applied loads. This assessment determined that the conditions influencing the joint and insulation behavior could best be tested to design extremes in the horizontal attitude. In conjunction with the horizontal attitude for the redesigned SRM full-scale testing, it was decided to incorporate externally applied loads. A second horizontal test stand for certification of the redesigned SRM was constructed at Morton Thiokol. This new stand, designated as the T-97 Large Motor Static Test Facility, is used to simulate environmental stresses, loads and temperatures experienced during an actual shuttle launch and ascent. The new test stand also provided redundancy for the existing stand.



Full-Duration Test Firing

NON-DESTRUCTIVE EVALUATION. The shuttle 51-L and Titan 34D-9 vehicle failures, both of which occurred in 1986, resulted in major reassessments of each vehicle's design, processing, inspection and operations. While the shuttle SRM insulation/ propellant integrity was not implicated in the 51-L failure, the intent was to preclude a failure similar to that experienced by Titan. The redesigned SRM field joint is quite tolerant of unbonded insulation. It has sealed insulation to prevent hot combustion products from reaching the insulation-to-case bond line. The bonding processes have been improved to reduce contamination potential, and the new geometry of the tang capture feature inherently provides more isolation of the edge insulation area from contaminating agents. A greatly enhanced NDE program for the redesigned SRM has been incorporated. The enhanced nondestructive testing includes ultrasonic inspection and mechanical testing of propellant and insulation bonded surfaces. All segments were X-rayed for the first flight and also will be X-rayed for near-term subsequent flights.

CONTINGENCY PLANNING. To provide additional program confidence, both near- and long-term contingency planning was implemented. Alternative designs, which might be incorporated into the flight program at discrete decision points, include field-joint graphite-composite overwrap bands and alternative seals for the field joint and case-to-nozzle joint. Alternative designs for the nozzle include a different composite layup technique and a steel nose inlet housing.

Alternative designs with long-lead-time implications were also developed. These designs focus on the field joint and case-to-nozzle joint. Since fabrication of the large steel components dictates the schedule, long-lead procurement of maximum-size steel ingots was initiated. This allowed machining of case joints to either the new baseline or to an alternative design configuration. Ingot processing continued through forging and heat treating. At that time, the final design was selected. A principal consideration in this configuration decision was the result of verification testing on the baseline configuration.

INDEPENDENT OVERSIGHT. As recommended in the Presidential Commission report and at the request of the NASA administrator, the National Research Council established an Independent Oversight Panel chaired by Dr. H. Guyford Stever, who reports directly to the administrator. Initially, the panel was given introductory briefings on the shuttle system requirements, implementation and control, the original design and manufacturing of the SRM, mission 51-L accident analyses and preliminary plans for the redesign. The panel met with major solid rocket motor manufacturers and vendors, and visited some of their facilities. The panel frequently reviewed the redesigned SRM design criteria, engineering analyses and design, and certification program planning. Panel members continuously reviewed the design and testing for safe operation, selection and specifications for material, and quality assurance and control. The panel continued to review the design as it progressed through certification and the manufacturing and assembly of the first-flight redesigned SRM. Panel members participated in major program milestones, Project Requirements Review, and Preliminary Design Review; they will also participate in future reviews. The panel has submitted six written reports to the NASA administrator.

In addition to the NRC, the redesign team has a design review group of 12 expert senior engineers from NASA and the aerospace industry. They have advised on major program decisions and serve as a sounding board for the program.

Additionally, NASA requested the four other major solid rocket motor companies—Aerojet Strategic Propulsion Company, Atlantic Research Corporation, Hercules Incorporated and United Technologies Corporation's Chemical Systems Division—to participate in the redesign efforts by critiquing the design approach and providing experience on alternative design approaches.

STS-26 REDESIGNED SRM RESULTS

Upon recovery and retrieval of the STS-26 solid rocket boosters and disassembly at Cape Canaveral (Hangar AF), the SRMs showed no signs of gas leakage. Also in disassembly, all six field joints and the two case-to-nozzle joints were visually inspected, and it was confirmed that the joints performed as expected.