Space Transportation System
Space Shuttle Main Engine

Orbiter Discovery just after launch of STS-63 from Kennedy Space Center, Florida. Image courtesy of NASA Johnson Space Center. Photographer unknown

The Space Shuttle used three Space Shuttle Main Engines (SSMEs) mounted to the orbiter. The SSME was designed and developed under a contract with the NASA Marshall Space Flight Center, Huntsville, Alabama. The contract was awarded in 1971 to the Rocketdyne Division of North American Rockwell Corp., Canoga Park, California. In late 2005, Pratt & Whitney purchased Rocketdyne from the Boeing Company. Rocketdyne was combined with the rocket engine contingent of Pratt & Whitney, West Palm Beach, Florida to form a division named Pratt & Whitney Rocketdyne.

The SSME was a large reusable liquid rocket engine which used liquid hydrogen as fuel and liquid oxygen as oxidizer. Both propellants were stored in the External Tank. The SSME operated using the staged-combustion cycle, meaning propellants were initially burned in preburners in order to power the high-pressure turbopumps and were then burned again at a higher mixture ratio in the main combustion chamber. This cycle yielded a specific impulse substantially higher than previous rocket engines thus minimizing volume and weight for the integrated vehicle. Along with high efficiency and low weight came system complexity, high turbopump speeds, high chamber pressures, and a high thrust-to-weight ratio of sixty-six at full power level.

The SSME had a nominal burn time in flight of approximately 8.5 minutes. The engines were required to operate at any power level between 67% and 109% of rated power level (RPL), though the majority of ascent was spent at 104.5% RPL. The engine was throttled down early in ascent to minimize the structural loads on the vehicle when maximum dynamic pressure was reached. The engines throttled down again near Main Engine Cut-Off when the thrust was reduced in order not to exceed a 3G (three times the force of gravity) acceleration on the crew and cargo. Operation at 109% RPL was required for several abort modes which were never used in flight. The engine employed closed-loop control on both chamber pressure and mixture ratio. The control system employed redundancy known as fail-op/fail-safe which required the engines to operate normally for the first control failure (fail operational or fail-op) and then to shut down safely for the second failure (fail safe).

The SSMEs were attached to the vehicle's thrust structure via a gimbal bearing. This bearing provided an attachment point while allowing the engine to pivot on two axes. Each engine had two hydraulic actuators attached from the SSME main combustion chamber to the Orbiter's thrust structure. These were used for vehicle steering (roll, pitch, and yaw) movements. Vehicle steering was accomplished using both the SSMEs and Reusable Solid Rocket Boosters (RSRBs) during first stage operation and by the SSMEs alone after separation of the RSRBs.

The SSMEs operated successfully during all 135 flights due in large part to extensive ground testing which was used to fully characterize performance and to establish acceptable life limits. Over a million seconds of test and flight time were accumulated. The majority of the testing occurred at Stennis Space Center (SSC). Post-flight inspections and data assessment were integral to understanding in-flight performance of the hardware.

This recording project is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. The Space Transportation System recording project was cosponsored during 2011 by the Space Shuttle Program Transition and Retirement Office of the Johnson Space Center (JSC), with the guidance and assistance of Barbara Severance, Integration Manager, JSC, Jennifer Groman, Federal Preservation Officer, NASA Headquarters and Ralph Allen, Historic Preservation Officer, Marshall Space Flight Center. The field work and measured drawings were prepared under the general direction of Richard O'Connor, Chief, Heritage Documentation Programs, National Park Service. The project was managed by Thomas Behrens, HAER Architect and Project Leader. The Space Transportation System Recording Project consisted architectural delineators, John Wachtel, Iowa State and Joseph Klimek, Illinois Institute of Technology. This documentation is based on high-definition laser scans provided by Smart GeoMetrics, Houston, Texas and documentation provided by NASA's Headquarters, Johnson Space Center and Marshall Space Flight Center. Written historical and descriptive data was provided by Archaeological Consultants Inc., Sarasota, Florida. Large-format photographs were produced by NASA's Imaging Lab at Johnson Space Center in Houston Texas with supplimental images provided by Jet Lowe, HAER photographer.

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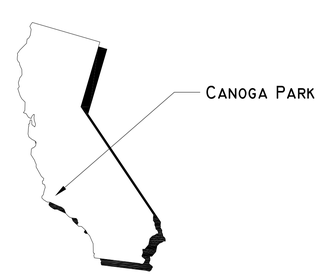

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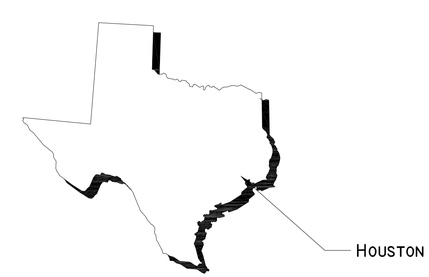

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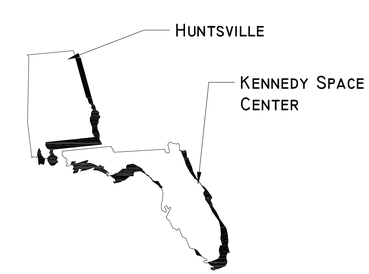

ALABAMA FLORIDA

DELINEATED BY: THOMAS M. BEHRENS

SPACE TRANSPORTATION SYSTEM RECORDING PROJECT
NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

SPACE TRANSPORTATION SYSTEM, SPACE SHUTTLE MAIN ENGINE
JOHNSON SPACE CENTER, 2101 NASA PARKWAY
HARRIS COUNTY
HOUSTON TEXAS

SHEET 1 OF 2

HISTORIC AMERICAN ENGINEERING RECORD
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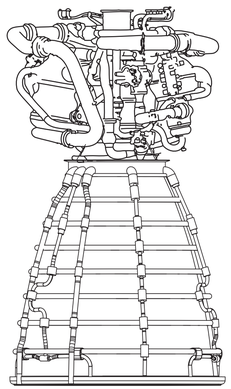
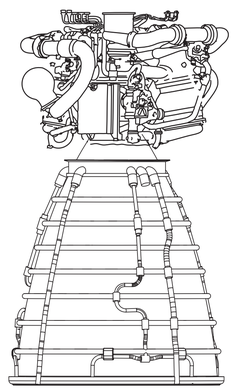


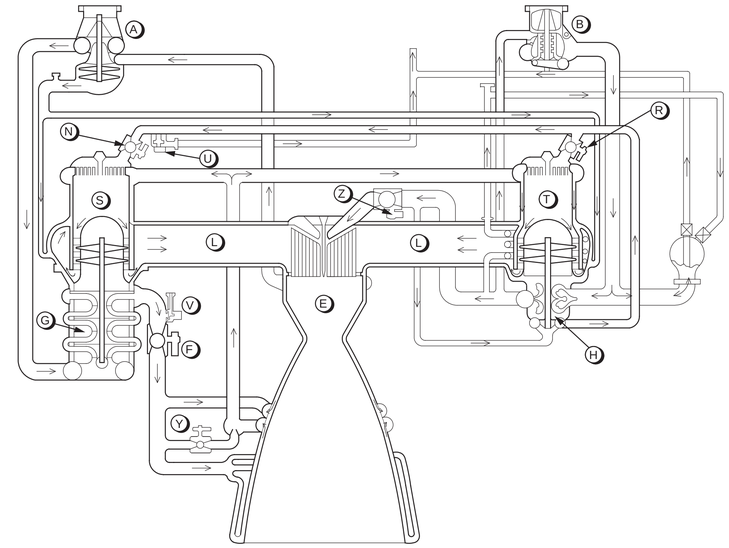
SSME LOW PRESSURE
OXYGEN TURBOPUMP ELEVATION



SSME LOW PRESSURE
FUEL TURBOPUMP ELEVATION

SSME COMPONENTS

A LOW-PRESSURE FUEL TURBOPUMP	G HIGH-PRESSURE FUEL TURBOPUMP	M CONTROLLER	T OXIDIZER PREBURNER
B LOW-PRESSURE OXIDIZER TURBOPUMP	H HIGH-PRESSURE OXIDIZER TURBOPUMP	N FUEL PREBURNER OXIDIZER VALVE	U LOX BLEED VALVE
C LOW-PRESSURE OXIDIZER DUCT	I LPFTP TURBINE DRIVE DUCT	O PNEUMATIC CONTROL ASSEMBLY	V FUEL BLEED VALVE
D LOW-PRESSURE FUEL DUCT	J LPOTP TURBINE DRIVE DUCT	P HIGH PRESSURE LOX DUCT	W HGM COOLANT DUCT
E MAIN COMBUSTION CHAMBER	K LPFTP TURBINE DISCHARGE DUCT	Q HIGH PRESSURE FUEL DUCT	X OPB LOX SUPPLY DUCT
F MAIN FUEL VALVE	L HOT-GAS MANIFOLD	R OXIDIZER PRE-BURNER OXIDIZER VALVE	Y CHAMBER COOLANT VALVE
		S FUEL PREBURNER	Z MAIN OXIDIZER VALVE



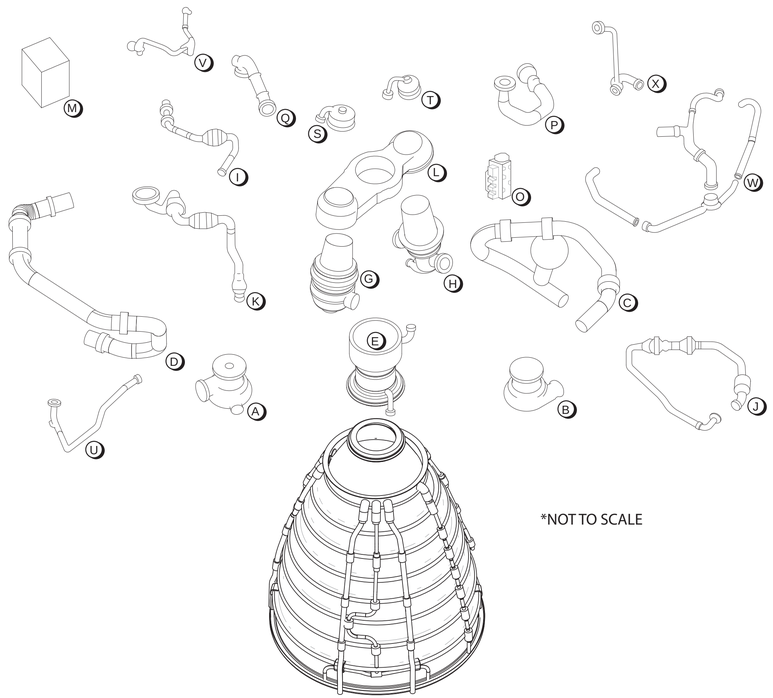
SSME PROPELLANT FLOW SCHEMATIC

0 2 4 8 FEET
0 1 2 METERS
SCALE: 3/8" = 1'-0"

The SSME was designed for 55 missions. The engines were generally referred to as the center (engine 1), left (engine 2), and right (engine 3). The SSMEs were 14 feet long and 7.5 feet in diameter at the nozzle exit. Each nozzle had an area ratio of 77.5:1. Each SSME weighed approximately 7,000 pounds.

The SSME utilized four turbopumps to boost the pressure of its cryogenic propellants for preburner and main combustion chamber injection. The design incorporated a controller with a health management system. The five main control valves operated under hydraulic pressure and had redundant pneumatic control for failure scenarios. Additionally, the engine featured a passive on-engine POGO oscillation suppression system attached to the low-pressure oxidizer duct (LPOD) to damp and prevent coupling of vehicle-to-engine low-cycle pressure oscillations.

Throughout its history, the SSME incorporated many design improvements. Most large changes were incorporated in block upgrades. Many limitations of the first manned orbital flight (FMOF) engines were addressed by the Phase I design, which first flew on STS-6. Post-Challenger Return-to-Flight (STS-26R) brought the first flight of Phase II, which included modifications to the turbopumps, main combustion chamber, and avionics. The Block I configuration which followed incorporated a new high-pressure oxygen turbopump, an improved powerhead, and a new heat exchanger. The Block I configuration was first flown on STS-70. Block IIA was first flown on STS-89. It incorporated a large-throat main combustion chamber reducing system internal pressures and temperatures. The last block upgrade was Block II, which added a new high-pressure fuel turbopump. Block II first flew on STS-104. The cumulative effects of these modifications were increased safety and reduced maintenance costs between flights. Predicted reliability improved by a factor of four over the life of the program, and maintenance on the Block II engine was 57% less than on the Phase II engines.



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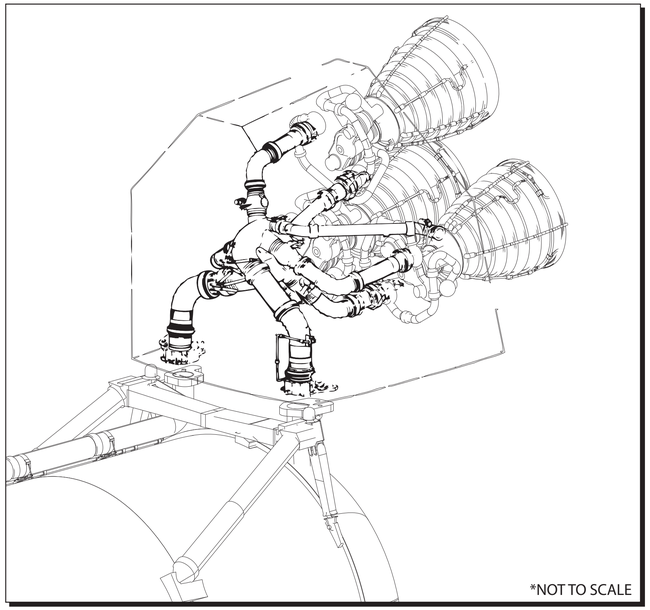
COMPONENT ISOMETRIC

SSME CLUSTER UMBILICAL ATTACHMENT TO EXTERNAL TANK



*NOT TO SCALE

SPACE SHUTTLE MAIN ENGINE

DELINEATED BY: JOHN WACHTEL, JOSEPH KLIMEK

SPACE TRANSPORTATION SYSTEM
RECORDING PROJECT
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