

# NASA Facts

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## Space Shuttle Main Engine (SSME) Enhancements

When a NASA Space Shuttle lifts off the launch pad, it does so with the help of three reusable, high-performance rocket engines. Each of these powerful main engines is 14 feet (4.2 meters) long, weighs approximately 7,000 pounds (3,150 kilograms) and is 7.5 feet (2.25 meters) in diameter at the end of its nozzle.

Developed in the 1970s by NASA's Marshall Space Flight Center in Huntsville, Ala., the Space Shuttle Main Engine is the world's most sophisticated reusable rocket engine.

The engines operate for about eight-and-one-half minutes during liftoff and ascent—long enough to burn more than 500,000 gallons (1.9 million liters) of super-cold liquid hydrogen and liquid oxygen propellants stored in the huge external tank attached to the underside of the Shuttle. Liquid oxygen is stored at  $-298$  degrees Fahrenheit ( $-183$  degrees Celsius) and liquid hydrogen at  $-423$  degrees Fahrenheit ( $-250$  degrees Celsius). The engines shut down just before the Shuttle, traveling at about 17,000 mph (28,000 kilometers per hour), reaches orbit.

NASA continues to increase the reliability and safety of Shuttle flights through a series of enhancements to the Space Shuttle Main Engines. The engines were modified in 1988, 1995, again in 1998 and more improvements were implemented in 2001.

Modifications include new high-pressure fuel and oxidizer turbopumps, a two-duct powerhead, a single-coil heat exchanger and a large-throat main combustion chamber.



**Space Shuttle Main Engine**

## High-Pressure Turbopumps

Each engine has two new powerful high-pressure turbopumps that supply 970 pounds (440 kilograms) of liquid oxygen per second and 162 pounds (73 kilograms) of liquid hydrogen fuel per second to the engine's main combustion chamber. In this chamber, the hydrogen propellant and oxygen oxidizer mix and burn at high pressures and at temperatures exceeding 6,000 degrees Fahrenheit (3,315 degrees Celsius) to produce thrust.

The new turbopumps reduce maintenance, increase operational life, shorten turnaround time and decrease operating costs of the space shuttle main engines.

In July 1995, a redesigned oxygen turbopump first flew on STS-70. The new liquid oxygen turbopump is produced through a casting process, eliminating all but six of the 300 welds that exist in the previous pump, increasing the safety margin.

The new Pratt & Whitney high-pressure hydrogen turbopump made its debut in July 2001. STS-110 in April 2002 marks the first flight of all three main engines carrying the new hydrogen turbopump.

The primary modifications to the hydrogen turbopump are the elimination of welds by implementing a casting process for the housing, and an integral shaft/disk with hollow wall blades. The unique casting makes the pump stronger and should increase the number of flights between major overhauls. Although the new pump adds 240 pounds (109 kilograms) of weight to the Shuttle, the results are a more reliable and safer engine because of increased pump robustness.

## Two-Duct Powerhead

Considered the backbone of the engine, the powerhead consists of the main injector and two preburners, or small combustion chambers. Liquid oxygen and hydrogen are partially burned in the preburners, generating hot gases. The liquids continue to move through ducts into the main combustion chamber, while the gases created in these chambers drive the high-pressure turbopumps, which supply the engine with oxygen and hydrogen needed for thrust.

The two-duct hot gas manifold is a new powerhead design that first flew on the Shuttle in July 1995. It significantly improves fluid flows in the system by decreasing pressure and turbulence, thus reducing maintenance and enhancing the overall performance of the engine.

The previous powerhead featured five tube-like ducts—three on one side of the engine where hot gases flow from the fuel turbine, and two on the side where hot gases flow from the oxidizer turbine. The two-duct hot gas

manifold replaced the three small fuel ducts with two enlarged ducts—smoothing the fuel flow, reducing pressure and turbulence, and lowering temperatures in the engine during operation. This design reduces stress on the main injector and requires fewer welds, eliminating potential weak spots in the powerhead.

## Single-Coil Heat Exchanger

The Shuttle's engines supply pressure to the external tank, which in turn provides propellants to the engines. This pressure is produced by the engine's heat exchanger, a 40-foot-long (12-meter) piece of coiled stainless steel alloy tubing.

To pressurize the external tank, liquid oxygen is routed through the tubing, which passes through the engine's hot gas manifold. Hot exhaust from the high-pressure oxidizer turbopump turbine heats the alloy tubing. As the tubing gets hot, it vaporizes the liquid oxygen. The oxygen reaches about 500 degrees Fahrenheit (260 degrees Celsius) and supplies pressure to the ET oxygen tank. The external tank delivers liquid oxygen to the Shuttle main engines, and the oxidizer ultimately mixes with the liquid hydrogen at engine ignition.

Until mid-1995, the heat exchanger had seven welds in the 40-foot (12-meter) tube. Welding can change the properties of a metal and have flaws. The newly designed exchanger is a continuous piece of stainless steel alloy with no welds. The increased thickness of the redesigned heat exchanger reduces wear on the tube and lessens the chances of damage. It also reduces maintenance and post-flight inspections. Beginning with the STS-70 mission in July 1995, a new enhanced single-coil heat exchanger has flown on each Shuttle.

## Large Throat Main Combustion Chamber

A Shuttle engine's main combustion chamber is where the liquid hydrogen and liquid oxygen are mixed and burned to provide thrust. In January 1998, the first large throat main combustion chamber flew on the STS-89 Shuttle mission. The throat of the new chamber is about 10 percent larger than the previous design—improving the engine's reliability by reducing pressure and temperature in the chamber and throughout the engine. This allows the high-pressure pumps to operate at lower turbine temperatures and pressures. It improves chamber cooling and extends the life of the hardware. The new large throat main combustion chamber is cast from large pieces of metal, rather than constructed of smaller pieces welded together. In addition to reducing the number of welds, casting also reduces the assembly time and labor required to build and to maintain the hardware.