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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-long, weighs approximately 7,000 pounds and is seven-and-one-half feet in diameter at the end of its nozzle.

These Space Shuttle Main Engines will be modified with several enhancements beginning in 1995, the first modifications since 1988. These modifications are expected to increase the reliability and safety of Space Shuttle flights.

The engines are liquid hydrogen/liquid oxygen engines which fire for about eight-and-one-half minutes during liftoff and ascent — long enough to burn more than one-half-million gallons of super-cold cryogenic liquid propellants stored in the huge external tank attached to the underside of the orbiter. (Liquid oxygen is minus 298 degrees Fahrenheit and liquid hydrogen is minus 423 degrees Fahrenheit). The engines shut down just before the Shuttle reaches low-earth orbit.

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

The modifications being made to the Shuttle's engines include new High Pressure Fuel and Oxidizer Turbopumps, a Two-Duct Powerhead, a Single Coil Heat Exchanger, and a Large Throat Main Combustion Chamber.

High-Pressure/Liquid Oxygen Turbopump

Each engine has two powerful high-pressure turbopumps which supply up to 970 pounds of liquid oxygen (the oxidizer) per second and up to 162 pounds of liquid hydrogen (the fuel) per

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second to the engine's main combustion chamber. In this chamber the propellants mix and burn at high pressures and at temperatures exceeding 6,000 degrees Fahrenheit to produce thrust.

The current turbopump design requires frequent maintenance between flights since 20-year-old technology is used. The new pump incorporates the latest state of the art in turbomachinery design.

The newly designed pump requires fewer parts overall, with 50 percent fewer rotating parts. The new turbopump's improved durability will significantly increase the number of missions between major overhauls.

The current design features welded construction. The new design uses a unique casting process to eliminate welds, which require meticulous inspections. In addition, the current design requires special coatings for thermal protection. These coatings are no longer necessary in the new turbopump design because the hardware is constructed of materials which are more heat tolerant and less sensitive to the hydrogen environment.

Also incorporated into the improved pump design is a new bearing. Bearings separate high speed rotating parts from stationary parts and prevent friction between the two. Currently the bearings must be replaced after two flights. The new balls are made of silicon nitride. This material is 30 percent harder and 40 percent lighter than steel and has an ultra-smooth finish which produces less friction during pump operation.

A new liquid oxygen turbopump in one Shuttle main engine flew on STS-70 in July of 1995. Plans are underway to enhance the liquid hydrogen turbopump which was put on hold in 1991 due to budget constraints. Completion and the first flight of this new pump is expected in 1997.

Two-Duct Powerhead

Considered the backbone of the engine, the powerhead consists of the main injector and two preburners, or small combustion chambers. The preburners generate hot gases that drive the turbines in the high-pressure turbopumps, which pump liquid oxygen and liquid hydrogen to the engines. The Two-Duct Hot Gas Manifold is a new powerhead design which significantly improves fluid flows in the system by decreasing pressure and turbulence, thus reducing maintenance and enhancing the overall performance of the engine.

The current powerhead features five tube-like openings called ducts — three on one side of the engine through which the hot gases from the fuel turbine flow, and two on the side through which the hot gases from the oxidizer turbine flow. The hot gases are generated in the preburners, where the fuel-rich mixture is partially burned. The fluids continue to move through the ducts into the main combustion chamber. The gas that is created in this chamber drives the high-pressure turbopumps which give the Shuttle thrust.

The Two Duct Hot Gas Manifold will replace the three small fuel ducts in the current design with two enlarged ducts. This should smooth the fuel flow and reduce pressure, turbulence, lower temperatures in the engine during operation. This environment will reduce stress on the main injector. In addition, the two-duct powerhead will be constructed with fewer welds, eliminating potential weak spots.

Single Coil Heat Exchanger

Another enhancement to the engine powerhead will improve the engine's heat exchanger. Shuttle engines must supply pressure to the Shuttle's External Tank, which in turn provides propellants at the correct pressures to the engines. This pressure is produced by the engine's heat exchanger, a 40-foot-long piece of coiled stainless steel alloy tubing. In order to pressurize the external tank, liquid oxygen is routed through the tubing, which passes through the engine's hot gas manifold. There hot exhaust from the high pressure oxidizer turbopump turbine heats the alloy tubing. As the tubing gets hot, so does the liquid oxygen. The oxygen reaches about 500 degrees and supplies pressure to the external tank. The external tank delivers liquid oxygen at the correct pressures to the Shuttle main engines which will ultimately mix with the liquid hydrogen fuel at engine ignition.

The current heat exchanger has seven welds in the 40-foot-tube. Welding can change the properties of a metal and leave flaws. The new single coil heat exchanger is a continuous piece of stainless steel alloy with no welds. The new design will be thicker to reduce wear on the tube and lessen the chances of damage. It also will reduce maintenance and post-flight inspections. The updated powerhead and single-coil heat exchanger was flown with the new liquid oxidizer turbopump on STS-70 in July of 1995.

Large Throat Main Combustion Chamber

The Shuttle engine main combustion chamber is where the liquid hydrogen and liquid oxygen are mixed and burned to provide thrust. The current chamber design requires frequent maintenance. The new Large Throat Main Combustion Chamber will be cast from large pieces of metal, rather than being made from smaller pieces welded together. In addition to reducing the number of welds, casting also reduces the assembly time and labor required to build and maintain the hardware.

The throat of the new chamber is 11 percent larger than the current design, improving the engine by reducing pressure in the chamber and in the rest of the engine. This lowers turbine temperatures and speeds, improves cooling, reduces overall maintenance and extends the life of the hardware. The enhancements to the main combustion chamber are expected in 1997.

Block I Space Shuttle Main Engines:

First Flight - STS-70, July 1995 (1 engine)
- New High-Pressure Oxidizer Turbopump
- Single-Coil Heat Exchanger
- Two-Duct Powerhead

Block II Space Shuttle Main Engines:

First Flight - 1997
- New High-Pressure Fuel Turbopump
- Large Throat Main Combustion Chamber