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UPDATES

"With the advanced monitoring, we have hopes of being able to take out from 30 to 40 percent of the potential catastrophic engine failures by being able to detect them and shut the engine down before they occur," McHenry said. Also, the engine's main combustion chamber will be enlarged to reduce the pressures on internal components without reducing the thrust, and a new, simplified engine nozzle design will eliminate the need for hundreds of welds – over 500 feet of them – and potential leaks.

Safer Hydraulic Power – Aside from the main engines and solid rockets, the single highest-risk equipment on the space shuttle are the Auxiliary Power

Interior of a Super Lightweight External Tank.

Units, generators that power the shuttle's hydraulics. Today, those generators run on hydrazine, a highly volatile and toxic rocket fuel. But recent advances in battery and electrical power technology – much of it developed by the automotive industry – may replace that system by 2005, eliminating many hazards not only in flight but also on the ground. Electric motors, powered by a bank of lightweight batteries, may be developed to power the shuttle's hydraulic system, providing greater reliability for astronauts in flight as well as providing a safer workplace for ground crews.

Landing Gear, Solid Rockets and External Tank Upgrades – Future improvements for the Solid Rocket Boosters include a redesign of several valves, filters and seals in the steering system to enhance their reliability as well as studies of the potential for an electrical system to power the booster hydraulics. Also, changes to the solid rocket propellant manufacturing process will make the workplace safer for shuttle technicians. For the External Tank, a new friction-stir welding technique will produce stronger and more durable welds throughout the tank. Another minor upgrade in work at present is a strengthening of the shuttle's main landing gear tires and wheels.

Safety Enhancements Under Study – In addition to the top-priority improvements planned during the next five years, other shuttle improvements are being studied, McHenry said. "For the rest of this year, we are looking at the shuttle's crew escape system and studying improvements, if any, that could be made to it. We also are looking at the orbiter's thermal protection system for potential improvements," McHenry said. "We have no plans right now to implement anything in those areas, but we're looking into any possibilities. We'll decide by the end of the year what we may want to do, if anything." ■

Major space shuttle improvements

A brief history

April 1983, STS-6: A Lighter Fuel Tank – A redesigned Lightweight External Tank, 10,000 pounds lighter than the original design, flew on STS-6 in 1983, increasing the shuttle's cargo capacity by the same amount. In 1998, a Super Lightweight External Tank flew on STS-91, further reducing the tank's weight by 7,500 pounds and again increasing the shuttle's cargo capacity by the same amount. The new Super Lightweight Tank is manufactured from a Lockheed Martin-developed aluminum-lithium alloy that is not only lighter, but also is 30 percent stronger than the previous tank design.

September 1988, STS-26: The Return to Flight – When *Discovery* returned the shuttle fleet to space following the *Challenger* accident, more than 200 safety improvements and modifications were ushered in. The improvements included a major redesign of the solid rockets, the addition of a crew escape and bailout system, stronger landing gear, more powerful flight control computers, updated inertial navigation equipment, and several updated avionics units.

May 1992, STS-49: *Endeavour*'s Maiden Voyage – *Endeavour*'s first flight in 1992 marked the debut of many shuttle improvements, including a drag chute to assist braking during landing, improved nosewheel steering, lighter and more reliable hydraulic power units, and updates to a variety of avionics equipment.

June 1992, STS-50: Extended Duration Flights – *Columbia* was the first shuttle to be modified to allow long-duration flights, and flew the first such mission in 1992. The modifications included a regenerative system to remove carbon dioxide from the air, connections for a pallet of additional hydrogen and oxygen tanks to be mounted in the cargo bay, and extra stowage room in the crew cabin.

June 1995, STS-71: International Space Station Assembly – The first docking of a shuttle with the Russian Mir Space Station debuted changes made to the shuttle that allowed it to dock with Mir and prepare for assembly of the International Space Station. To allow docking with Mir and with the ISS, the shuttle's airlock was relocated from inside the cabin to the cargo bay on all orbiters except *Columbia*. Reductions in weight also were developed, including lightweight lockers, seats and other cabin equipment. Those changes, coupled with the super lightweight external tank and performance improvements, increased the cargo capacity for the shuttle by 16,000 pounds since 1992.

July 1995, STS-70: Space Shuttle Main Engines – The shuttle main engines have had three major redesigns that have more than tripled estimates of their safety. With its first flight in 1995, the first redesign, called the Block I engine, included design changes to strengthen the oxygen turbopump and engine powerhead. The second overhaul, called the Block IIA engine, included a larger throat to the main combustion chamber and first flew on STS-89 in January 1998. The third redesign, called the Block II engine, includes a stronger fuel turbopump and will fly for the first time in 2000. A fourth major overhaul is now planned to fly by 2005. Called the Block III engine, it will include further improvements to the combustion chamber and a simplified nozzle design.

Today's Space Shuttle – Since 1992: Not only has the cargo capacity of the shuttle increased by 8 tons, the annual cost of operating the shuttle has decreased by 40 percent. Improvements to the main engines and other systems have reduced the estimated risks during launch by over 80 percent. And the number of all actual problems experienced by the shuttle in flight has decreased by 70 percent. Although they have flown for almost 20 years, the space shuttle fleet has used only about a quarter of the lifetime for which it was designed. *Discovery*, the most flown shuttle, has completed 27 trips to space out of 100 flights originally designed for each shuttle. ■