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NASAFACTSHEET

THE 21ST CENTURY SPACE SHUTTLE

A Familiar Workhorse Evolves into a Safer, More Capable Spacecraft

Hidden beneath its familiar shape, the Space Shuttle has undergone a metamorphosis. From the inside out, thousands of advances in technology and enhanced designs have been incorporated into the Shuttle since it first launched. Today's Shuttle is a safer, more powerful and more efficient spacecraft. When the Shuttle Atlantis launches this year, it will be the most up-to-date Space Shuttle ever. From a new "glass cockpit" to main engines estimated threefold safer, Atlantis is far different than when it first flew in 1985.

This year also will see the 100th Space Shuttle launch in history, a milestone for a workhorse that has taken over 600 passengers and 3 million pounds of cargo to orbit. The Shuttle fleet has spent almost two and a half years in space. But even the most-traveled Shuttles remain young in the lifetimes for which they were built. NASA is preparing for the possibility of flying the Space Shuttle for at least another decade. Future upgrades will make this American cornerstone of world spaceflight even better — toward a goal of doubling its launch safety by 2005.

Tomorrow's Shuttle: Cutting Risks in Half by 2005

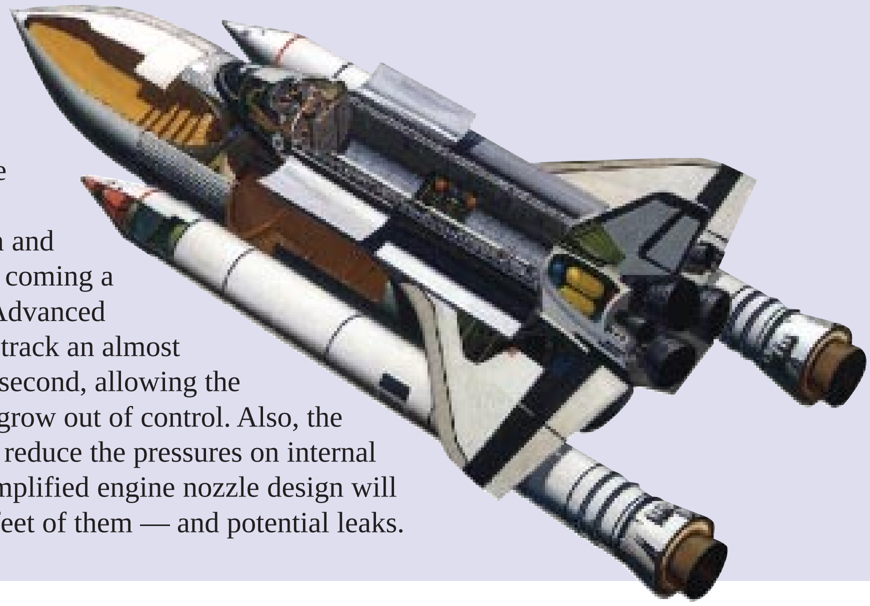
Enhancements now under development could double the Shuttle's safety by 2005: New sensors and computer power in the main engines will "see" trouble coming a split second before it can do harm, allowing a safe engine shut down. A new engine nozzle will eliminate the need for hundreds of welds and potential leaks. Electric generators for the Shuttle's hydraulics will replace the highly volatile rocket fuel that now powers the system. And a next-generation "smart cockpit" will reduce the pilot's workload in an emergency, allowing the crew to better focus on critical tasks. Other improvements will make steering systems for the solid rockets more reliable, make the manufacturing of solid propellant safer and increase the strength of external fuel tank welds.

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.

A BETTER SPACE SHUTTLE TAKES SHAPE

Better Main Engines



The Space Shuttle's main engines operate at greater extremes of temperature and pressure than any other machine. Since 1981, three overhauls to the original design have more than tripled estimates of their safety. Now, a fourth major overhaul is planned that will make them even safer by 2005. The planned improvements include a high-tech optical and vibration sensor system and computing power in the engines that will "see" trouble coming a fraction of a second before it can do harm. Called the Advanced Health Monitoring System, the sensors will detect and track an almost microscopic flaw in an engine's performance in a split second, allowing the engine to be safely shut down before the situation can grow out of control. 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 Units, generators that power the Shuttle's hydraulics. Today, those generators use a highly volatile and toxic rocket fuel. But recent advances in battery and electrical power technology — much of it developed by the automotive industry — will 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, will be developed to power the Shuttle's hydraulic system, providing greater reliability for astronauts in flight and providing a safer workplace for ground crews.

"Smart Cockpit"

The new "glass cockpit" that will be initiated when *Atlantis* launches on STS-101 sets the stage for the next cockpit improvement, planned to fly by 2005: a "smart cockpit" that reduces the pilots' workload during critical periods. The enhanced displays won't fly the Shuttle, but they will do much of the deductive reasoning required for a pilot to respond to a problem. By simplifying the pilots' job, this "smart cockpit" will allow astronauts to better focus on critical tasks in an emergency.

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.

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.

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.

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 an improved toilet, 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.

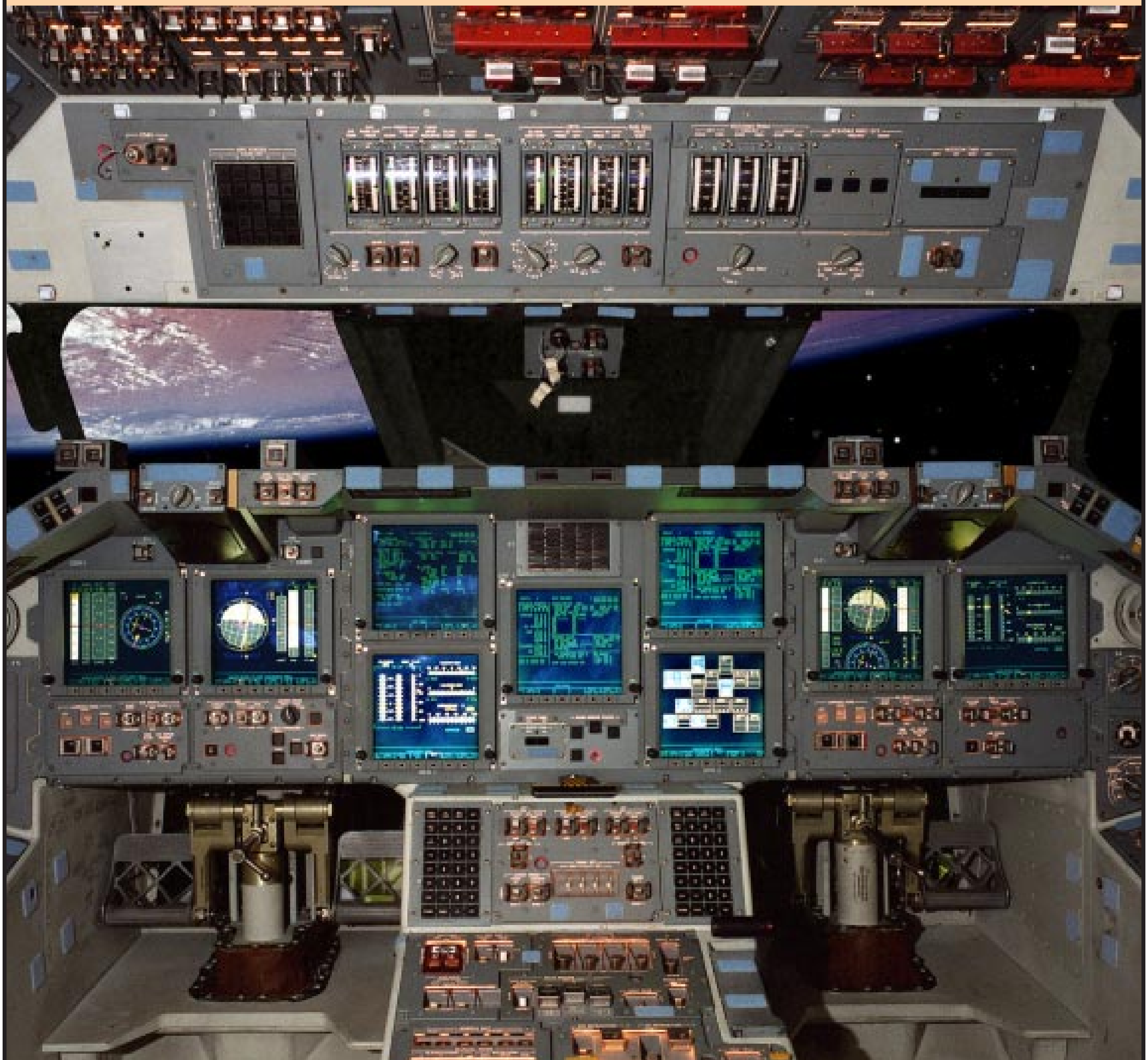
June 1995, STS-71

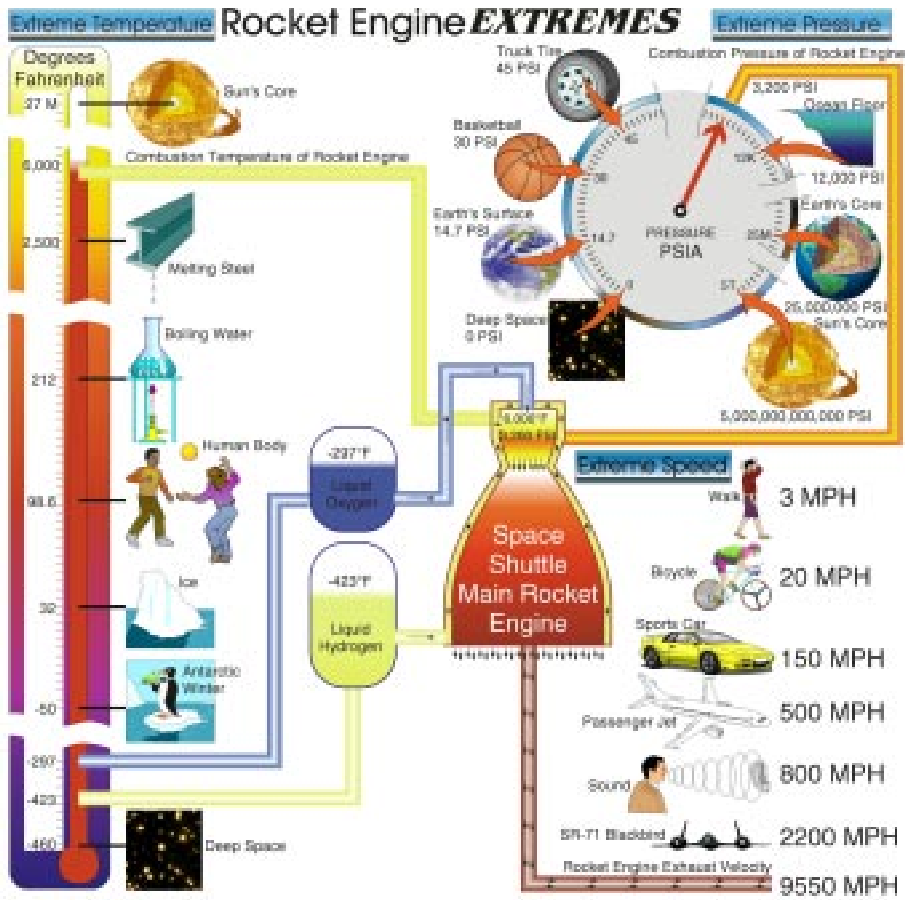
International Space Station Assembly

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 International Space Station, 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.

NOWFLYING:ATLANTIS'**GLASS**COCKPIT

Flying for the first time on *Atlantis* on mission STS-101, eleven new full-color, flat-panel display screens in the Shuttle cockpit replace 32 gauges and electromechanical displays and four cathode-ray tube displays. The new "glass cockpit" is 75 pounds lighter and uses less power than before, and its color displays provide easier pilot recognition of key functions. The new cockpit will be installed in all Shuttles by 2002, and it sets the stage for the next cockpit improvement planned to fly by 2005: a "smart cockpit" that reduces the pilots' workload during critical periods. On STS-101, *Atlantis* will fly as the most updated Space Shuttle ever, with more than 100 new modifications incorporated during a 10-month period at Boeing's Palmdale, Calif., Shuttle factory in 1998. *Atlantis*' airlock was relocated to the payload bay to prepare for International Space Station assembly flights; the communications system was updated; several weight reduction measures were installed; enhancements were made to provide additional protection to the cooling system; and the crew cabin floor was strengthened. The Shuttle *Columbia* is at the Palmdale factory this year receiving many of the same upgrades, including installation of the new "glass cockpit."





The Amazing Space Shuttle

- The most complex machine ever built, the Space Shuttle has more than 2.5 million parts, including almost 230 miles of wire, more than 1,060 plumbing valves and connections, over 1,440 circuit breakers, and more than 27,000 insulating tiles and thermal blankets.
- In eight and a half minutes after launch, the Shuttle accelerates from zero to about nine times as fast as a rifle bullet, or 17,400 miles per hour, to attain Earth orbit.
- The Space Shuttle weighs more than 4.5 million pounds at launch — over 3.5 million pounds are propellants entirely consumed in the next eight and a half minutes.
- If the Shuttle’s main engines pumped water instead of fuel, they would drain an average-sized swimming pool every 25 seconds.
- Because liquid hydrogen and liquid oxygen fuel the main engines, the majority of exhaust produced is water vapor.
- At launch, the Shuttle’s two solid rockets consume more than 10 tons of fuel each second and produce 44 million horsepower, equal to 14,700 locomotives.
- The three Shuttle main engines produce power equivalent to 23 times that produced by the Hoover Dam.
- The Shuttle's solid rockets burn powdered aluminum as fuel — a different form of the same type of material that is used as a foil wrap in most kitchens.
- The temperatures inside the Shuttle’s main engines and solid rockets reach more than 6,000 degrees Fahrenheit, higher than the boiling point of iron, yet the main engine’s fuel, liquid hydrogen, is the second coldest liquid on Earth at minus -423 degrees Fahrenheit.
- The discharge pressure of a Shuttle main engine turbopump could send a column of liquid hydrogen 36 miles into the air.
- Temperatures experienced by the Shuttle range from as low as minus -250 degrees Fahrenheit in space to as high as 3,000 degrees Fahrenheit as it reenters the atmosphere.

BY THE TIME IT TURNS 100...

Now at the dawn of the 21st Century, the Space Shuttle is about to launch for the 100th time when *Discovery* lifts off this year on STS-92, an International Space Station assembly flight. By that time, the Space Shuttle will have launched about 3 million pounds of cargo into space and 624 passengers. The Shuttle fleet will cumulatively have spent almost two and a half years in orbit and amassed almost 15 years of passenger-hours in flight. More than 850 payloads will have flown, and the Shuttle will have deployed more than 60 payloads and retrieved more than two dozen. The Shuttle has supported two space stations; made three maintenance flights to the Hubble Space Telescope; launched planetary missions to study Jupiter, Venus and the Sun; and conducted hundreds of studies of the effects of weightlessness on materials, plants, animals and human beings in onboard laboratories. Although flying for two decades, the Shuttle still will have more than three-quarters of its design lifetime available. Out of 100 flights designed for each orbiter, when STS-92 — the 100th overall flight for the program — is completed, *Discovery* will be the most-flown Shuttle with 28 flights to its credit. *Columbia* will be second with 26 flights. *Atlantis* will have made 22 trips to space and *Endeavour* will have completed 14 flights.

"The exploration of space will never be without risk. But it is mandatory that we use the best technology, human expertise and human dedication available to minimize that risk at all times. And it is certain that the benefits to humanity are worth the risk we cannot avoid."

— Astronaut John Young, Assistant Director, Johnson Space Center, and Commander of the first Space Shuttle mission