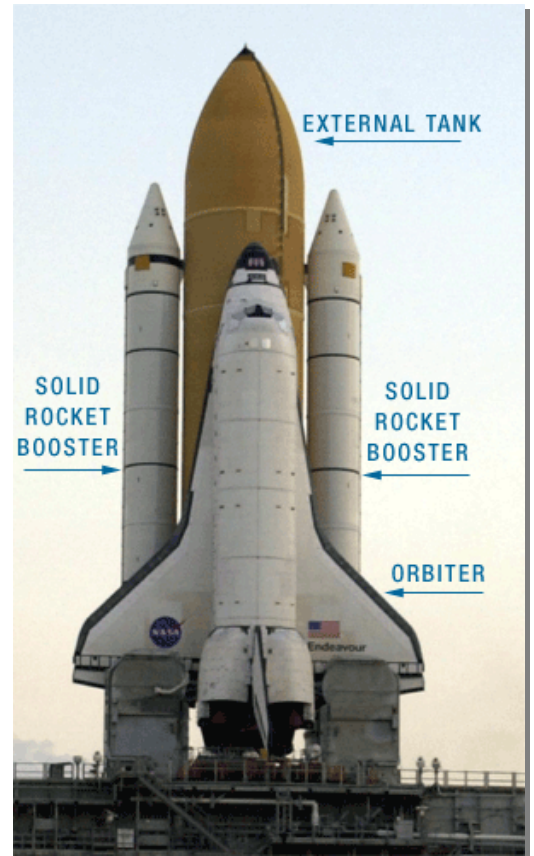


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## Space Shuttle

**Description & Purpose:** One of the most complex machines ever devised, the space shuttle is the only spacecraft capable of delivering and returning people, large payloads and scientific experiments to and from space. The shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft and lands like a glider. The space shuttles have been essential to the assembly of the International Space Station (ISS) and the space shuttle fleet will retire in 2011. Three missions will be flown in 2011 (STS-133, STS-134 & STS-135). The last flight is scheduled to fly no earlier than June 28, 2011.

**Customer:** NASA is the principle customer for the space shuttle. As the original manufacturer of the space shuttle fleet, Boeing provides design engineering and work that has supported the shuttle program since the first flight in 1981. Boeing is the major subcontractor to United Space Alliance (USA), NASA's prime contractor for space shuttle operations. Boeing Space Exploration, a division of Boeing Defense Space and Security, is headquartered in Houston and operates facilities in support of the space shuttle program in Huntington Beach and Palmdale, Calif., and Kennedy Space Center, Fla.



### General Characteristics

#### *Space Shuttle*

**Height:** 184.2 ft

**\*Gross Liftoff Weight:** 4,500,000 lbs

**Total Liftoff Thrust:** 7,145,000 lbs

**Maximum Cargo to Orbit:** 63,500 lbs

**Orbit:** 115 to 400 statute miles (185 to 643 kilometers)

**Velocity:** 17,500 mph (28,164 kph)

\* \* weight varies depending on payloads and on-board consumables.

#### *Orbiter*

**Length:** 122.17 ft (37.2 meters)

**Height:** 56.58 ft (17.2 meters)

**Wingspan:** 78.06 ft (23.8 meters)

**Landing Weight:** 242,000 lbs

**Main Engines:** (3) 375,000 lbs of thrust each at sea level

**Cargo Bay:** length - 60 ft, diameter - 15 ft

## Background

The space shuttle's main elements – the orbiter, external tank (ET) and twin Solid Rocket Boosters (SRB) – are assembled from more than 2.5 million parts, 230 miles of wire, 1,060 valves and 1,440 circuit breakers. Weighing approximately 4.5 million-pounds at launch, the space shuttle accelerates to an orbital velocity of 17,500 miles per hour – 25 times faster than the speed of sound – in just over eight minutes. Once in orbit, the orbiter protects its crew from the vacuum of space while enabling astronauts to conduct scientific research, deploy and service satellites and assemble the ISS. At the end of its mission, the shuttle uses the Earth's atmosphere as a brake to decelerate from orbital velocity to a safe landing at 220 miles per hour.

Each orbiter is about the size of a small commercial airliner and typically carries a crew of seven, including a commander, pilot and five mission or payload specialists. The spacecraft can accommodate a payload the size of a school bus. The space shuttles were designed and manufactured by Rockwell International, located in Downey and Palmdale, Calif. In 1996, The Boeing Company purchased the aerospace assets of Rockwell International, and later moved the Downey operation to Huntington Beach, Calif.

NASA has put five orbiters into operational service: *Columbia*, OV-102; *Challenger*, OV-099; *Discovery*, OV-103; *Atlantis*, OV-104; and *Endeavour*, OV-105. The first orbiter built, *Enterprise*, was never flown in space, but was instrumental in achieving the early atmospheric flight test program objectives.

On September 17, 1976, the first orbiter, ***Enterprise***, was rolled out and became crucial to the development of the Space Shuttle Program. Its series of approach and landing tests in 1977 proved the shuttle could fly in the atmosphere and land like a glider. After those tests, *Enterprise* was flown to NASA's Marshall Space Flight Center in Huntsville, Ala., where it was mated with an ET and SRBs and subjected to a series of vertical ground vibration tests. *Enterprise* was also sent to the Kennedy Space Center in Florida, where it was rolled out to the launch pad to act as a "stand-in" as NASA prepared for the first shuttle launch. *Enterprise* is now the centerpiece of the McDonnell Space Hangar at the National Air and Space Museum's Steven F. Udvar-Hazy Center in Chantilly, Va.



On April 12, 1981, ***Columbia (OV-102)*** roared into a deep blue sky as the nation's first reusable space shuttle. With Rockwell's contract award on July 26, 1972, *Columbia* was rolled out of its Palmdale, Calif., facility on March 8, 1979. It proved the operational

concept of a winged, reusable spaceship by successfully completing the Orbital Flight Test Program - missions STS-1 through STS-4. Named after the first American ocean vessel to circle the globe and the command module for the Apollo 11 Moon landing, *Columbia* continued this heritage of intrepid exploration. The heaviest of NASA's shuttles, *Columbia* weighed too much and lacked the necessary equipment to assist with assembly of the ISS. Despite its limitations, the shuttle's legacy is one of groundbreaking scientific research and notable "firsts" in space flight. Space shuttle mission STS-9, launched in late November 1983, was the maiden flight for Spacelab. Designed to be a space-based science lab, Spacelab was launched into orbit from inside the shuttle's cargo bay.



*Columbia* and its crew were tragically lost during STS-107 in 2003. As the space shuttle lifted off from Kennedy Space Center in Florida on January 16, a small portion of foam broke away from the orange external fuel tank and struck the shuttle's left wing. The resulting damage created a hole in the wing's leading edge, which caused the vehicle to break apart during re-entry to Earth's atmosphere on February 1.

First called STA-099, ***Challenger*** was built to serve as a test vehicle for the Space Shuttle Program. *Challenger* was named after the British Naval research vessel HMS *Challenger* that sailed the Atlantic and Pacific oceans during the 1870s. But despite its Earth-bound beginnings, STA-099 was destined for space. In the late 1970s, NASA strived for a lighter weight shuttle, but a test vehicle was needed to ensure the lighter airframe could handle the stress of space flight. Computer software at the time wasn't yet advanced enough to accurately predict how STA-099's new, optimized design would respond to intense heat and stress. The best solution was to submit the vehicle to a year of intensive vibration and thermal testing. NASA awarded the contract on July 26, 1972, and *Challenger* rolled out from the Palmdale facility on Feb. 14, 1978.

On January 29, 1979, NASA awarded the contract to convert STA-099 to a space-rated orbiter, OV-099. The vehicle's conversion began late that year and roll-out from Palmdale was on June 30, 1982. Although the job was easier than it would have been to convert NASA's first shuttle, *Enterprise*, it was a major process that involved the disassembly and replacement of many parts and components.

The second shuttle to join NASA's fleet, OV-099 arrived at NASA's Kennedy Space Center in Florida in July 1982. *Challenger* launched on her maiden voyage, STS-6, on April 4, 1983. *Challenger's* service to America's Space Program ended in tragedy on Jan. 28, 1986. Just 73 seconds into mission STS 51-L, a booster failure caused an explosion that resulted in the loss of seven astronauts, as well as the vehicle.



NASA awarded the build contract for its third space shuttle, **Discovery (OV-103)**, on Jan. 29, 1979, and it was rolled out of the Palmdale plant on Oct. 16, 1983. *Discovery* is named for two famous sailing ships; one sailed by Henry Hudson in 1610-11 in search of a northwest passage between the Atlantic and Pacific Oceans, and the other by James Cook on a voyage during which he discovered the Hawaiian Islands. In addition, two British Royal Geographical Society ships have carried the name "*Discovery*" as they sailed on expeditions to the North Pole and the Antarctic.

The *Discovery* orbiter arrived for the first time at the Kennedy Space Center in Florida on November 9, 1983. After checkout and processing, it was launched on Aug. 30, 1984, for its first mission, 41-D, to deploy

three communications satellites. Later missions included NASA's return-to-flight missions after the loss of *Challenger* (September 1988) and *Columbia* (July 2005), the launch of the Hubble Space Telescope in April 1990, the final Shuttle/Mir docking mission in June 1998, and Senator John Glenn's shuttle flight in October 1998. With *Discovery* retirement in 2011, it has flown 39 missions, more than any other shuttle.

NASA's fourth space shuttle, **Atlantis (OV-104)**, was named after the two-masted boat that served as the primary research vessel for the Woods Hole Oceanographic Institute in Massachusetts from 1930 to 1966. Following the contract award on Jan. 29, 1979, construction of the shuttle *Atlantis* began on March 3, 1980. Thanks to lessons learned in the construction and testing of shuttles *Enterprise*, *Columbia* and *Challenger*, *Atlantis* was completed in about half the man-hours spent on building *Columbia*. This is largely attributed to the use of large thermal protection blankets on the shuttle's upper body, rather than individual tiles requiring more attention. Weighing in at 151,315 pounds when it rolled out of the assembly plant in Palmdale, Calif., on March 6, 1985, *Atlantis* was nearly 3.5 tons lighter than *Columbia*.



With a contract award on July 31, 1987, and authorization to construct the fifth space shuttle as a replacement for *Challenger*, **Endeavour (OV-105)** rolled out of the Palmdale assembly facility on April 25, 1991, and arrived at Kennedy Space Center's Shuttle Landing Facility on May 7, 1991, piggy-backed on top of NASA's Space Shuttle Carrier Aircraft. *Endeavour* was named after a ship chartered to traverse the South Pacific in 1768 and captained by 18th century British explorer James Cook, an experienced seaman, navigator and amateur astronomer. *Endeavour* first flew on STS-

49 on May 7, 1992. It became the first space shuttle to use a drag chute during a landing -- only one of many technical improvements made to *Endeavour*.

## Miscellaneous

Boeing's Space Exploration Space Program Operations Contract, is valued at \$1.4 billion through September 2011 (total Shuttle value \$40.8 billion). Boeing provides design engineering and support that has supported the shuttle fleet since the first flight in 1981. This activity has been a process of continuous design improvement that will continue until flight of the next generation launch system. Boeing engineers are actively involved in the design and development work required to fulfill America's space vision, using existing shuttle experience and knowledge as a stepping-stone to the next space exploration launch vehicle.

Boeing's space shuttle work is organized into the following areas:

**Sustaining Engineering:** Boeing serves as the technical expert to NASA and USA on the design and operation of the space shuttle fleet to ensure its continued safety, flight-readiness, efficiency and overall mission success. Activities range from designing new system modifications and upgrades to resolving day-to-day issues and mission anomalies.

**System and Payload Integration:** Boeing identifies overall shuttle system (orbiter, Space Shuttle Main Engines, External Tank and Solid Rocket Boosters) and payload requirements during all shuttle operations phases: ground operations and checkout, ascent, on-orbit operations, reentry, landing and ferry flight activities. It also ensures the complementary operation of shuttle system elements, payloads and ground systems. Activities range from evaluating external structural loads, aerodynamics, heating and guidance to developing payload support hardware.

**Orbiter Maintenance and Modifications:** A technical team at Kennedy Space Center, Fla., supports periodic orbiter major maintenance, during which each vehicle receives a comprehensive structural inspection and modifications designed to reduce program maintenance costs, expand shuttle mission capabilities and improve operations, safety and reliability.



This "fish-eye" view illustrates Multifunction Electronic Display Subsystem (MEDS), otherwise known as "glass cockpit." It represents a number of important modifications that have been accomplished on the Orbiter's flight deck.

**Shuttle Upgrades:** Boeing, together with NASA and USA, has worked on a number of significant upgrades to the shuttle orbiter fleet to improve safety and reliability, lower program costs, enhance performance and benefit future missions. Among some of the upgrades are:

- During the STS-119 mission, the space shuttle flew with a special tile that has a protuberance under one of its wings to measure increase heating and pressure during reentry and to better understand the “boundary layer” effect at high Mach numbers (greater than Mach 15). This was the first of three missions to test this effect and the size of the protuberance increased with each mission. The data will be used for the design of future spacecraft.
- During the November 2008 STS-126 mission, *Endeavour* debuted with updated flight software that provides enhanced survivability to the shuttle crew in the event of abort launch and landing scenarios. Called Operational Increment 33 (OI-33), the upgrade has been performed on the entire shuttle fleet and improves 30 areas in the flight software, including safety modifications for engine-out scenarios, External Tank separation during a mission abort after launch and the shuttle’s ability to return to Earth unpowered.
- For the STS-124 mission in May 2008, *Discovery* was the final space shuttle to receive the Boeing Reusable Insulation (BRI), used in the area surrounding *Discovery*’s landing gear, lower surface carrier and external tank doors to protect them from foam and ice during ascent. *Atlantis* and *Endeavour* underwent the application process earlier.
- In February 2008, *Atlantis* used a new microchip technology flow sensor panels during the STS-122 mission. The panels control nitrogen and oxygen pressurization of the crew module to maintain a habitable environment. The technology measures the supply of oxygen and nitrogen and also provides early insight into potential cabin atmosphere changes. In October 2007, during the STS-120 mission, new software was added that, among other things, improves a shuttle crew’s ability to detect critical shuttle faults while docked with ISS, by facilitating space station annunciation of selected shuttle alarms.
- Also in 2007, during the August STS-118 *Endeavour* mission, NASA successfully used the Boeing-built Station-Shuttle Power Transfer System (SSPTS) for the first



time to extend a shuttle mission. *Discovery* was the last of the two shuttles to be upgraded; *Endeavour* was the first. The upgrade allows the space shuttle's electrical power system to connect into the International Space Station's solar arrays to transfer power from the space station to the orbiter, resulting in a lower consumption rate of liquid hydrogen and oxygen used for making electricity by the orbiter's fuel cells. The SSPTS upgrade allows the orbiter to increase time docked to the station from 6-8 to 9-12 days depending on the mission configuration.

**Payload Operations:** Under the Checkout, Assembly and Payload Processing Services Contract at NASA's Kennedy Space Center, Boeing performs engineering and facilities support and maintenance activities related to preparing payloads for launch in the shuttle's payload bay. Processing a human space flight payload involves complex scheduling and logistics and precise testing to ensure the payload can communicate with the space shuttle and ground stations. The payloads can include scientific instruments, interplanetary spacecraft, research laboratory modules and elements of the ISS. Processing activities begin years before a mission is scheduled to fly; depending on the mission's complexity.

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