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Space Exploration

Space Shuttle Backgrounder

Description & Purpose: The space shuttle is the world's first reusable spacecraft, and the first spacecraft in history that can carry large satellites to and from orbit. The shuttle launches like a rocket, maneuvers in Earth orbit like a spacecraft and lands like a glider. The space shuttle fleet is essential to complete assembly of the International Space Station (ISS) before its scheduled retirement in 2010.

Customer: NASA is the principle customer for the space shuttle. As the original manufacturer of the orbiter fleet, Boeing provides design engineering and support 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's Space Exploration, a division of Boeing Integrated Defense Systems, is headquartered in Houston and operates facilities in support of the space shuttle in Huntington Beach and Palmdale, Calif., and Kennedy Space Center, Fla.

General Characteristics

Space Shuttle

Height: 184.2 feet

***Gross Liftoff Weight:** 4,500,000 pounds

Total Liftoff Thrust: 7,145,000 pounds

Maximum Cargo to Orbit: 63,500 pounds

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

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

Orbiter

Length: 122.17 feet (37.2 meters)

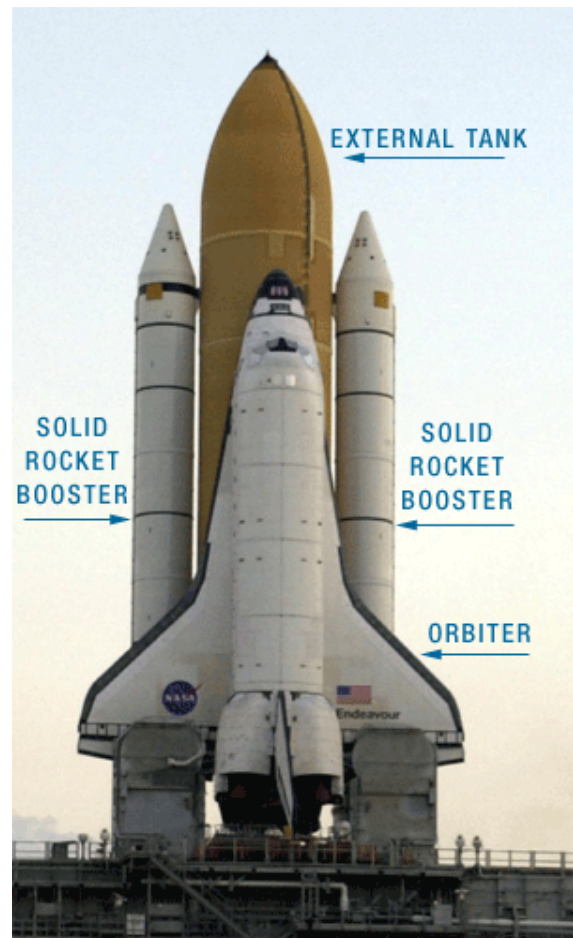
Height: 56.58 feet (17.2 meters)

Wingspan: 78.06 feet (23.8 meters)

Landing Weight: 242,000 pounds

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

Cargo Bay: length - 60 feet, diameter - 15 feet



* * weight will vary depending on payloads and on board consumables.

Boeing is a major subcontractor under the Space Program Operations Contract (SPOC), which runs from Oct 1, 2006 until Sept. 30, 2010.

Background

The space shuttle is one of the most complex machines ever devised. Its main elements – the orbiter, Space Shuttle Main Engines (SSME), external tank (ET), and 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 on orbit, the orbiter must protect 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, dissipating in the process all the energy it gained on its way into orbit.

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.

The orbiter is about the size of a small commercial airliner. The orbiter normally carries a crew of seven, including a commander, pilot, and five mission or payload specialists. The Orbiter can accommodate a payload the size of a school bus weighing between 38,000 and 56,300 pounds depending on what orbit it is launched into. The space shuttle orbiter was designed and manufactured by Rockwell International, located primarily 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., as part of a consolidation of facilities.

On September 17, 1976, the first orbiter, *Enterprise*, was rolled out. *Enterprise* was crucial to the space shuttle program. Its series of approach and landing tests in 1977 proved the orbiter could fly in the atmosphere and land like an airplane, except without power -- like a glider. After those tests, *Enterprise* was flown to NASA's Marshall Space Flight Center in Huntsville, Ala., where it was mated with



the ET and SRBs and subjected to a series of vertical ground vibration tests. The orbiter 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 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. Boeing was awarded the contract on July 26, 1972 and *Columbia*

was rolled out of its Palmdale 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 orbiters, *Columbia* weighed too much and lacked the necessary equipment to assist with assembly of the ISS. Despite its limitations, the orbiter'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 installed inside the orbiter'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 orbiter'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. Space shuttle orbiter *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 orbiter, 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. Boeing received the contract on July 26, 1972 and rollout from Palmdale was Feb. 14, 1978.

On January 29, 1979, NASA awarded Boeing a 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 orbiter, *Enterprise*, it was a major process that involved the disassembly and replacement of many parts and components.

The second orbiter to join NASA's Space Shuttle 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.



Boeing received the contract to build NASA's third space shuttle Orbiter **Discovery (OV-103)** Jan. 29, 1979 and it was rolled out of the Palmdale plant on Oct. 16, 1983. *Discovery* 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. Since that inaugural flight, *Discovery* has completed 31 successful missions -- more than any other orbiter in NASA's fleet. Just like all of the orbiters, it has undergone some major modifications over the years. *Discovery* has the distinction of being chosen as the Return to Flight orbiter twice. The first was for STS-26 in 1988, and its most recent flight was for STS-114 in 2005. *Discovery* is named for two famous sailing ships; one sailed by Henry Hudson in 1610-11 to search for 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.

NASA's fourth space-rated space shuttle orbiter, **OV-104 "Atlantis,"** 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 contract award on Jan. 29, 1979, construction of the orbiter *Atlantis* began on March 3, 1980. Thanks to lessons learned in the construction and testing of orbiters *Enterprise*, *Columbia* and *Challenger*, *Atlantis* was completed in about half the time in man-hours spent on *Columbia*. This is largely attributed to the use of large thermal protection blankets on the orbiter'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. OV-105 became the first space shuttle orbiter to use a drag chute during a landing -- only one of many technical improvements made to *Endeavour*.

There are seven remaining shuttle missions scheduled until retirement. Of those seven, four are space station assembly missions, one shuttle flight to service the Hubble Space

Telescope, and two contingency flights to provide mandatory spares and components to keep the station viable. There is one additional mission called the Alpha Magnetic Spectrometer (AMS) that is still waiting for funding from Congress

Miscellaneous:

Boeing provides design engineering and support that has supported the shuttle fleet since the first flight in 1981. This has been a process of continuous design improvement that will continue until we begin to fly the next generation vehicle. Boeing engineers are actively involved in the design and development work required to fulfill America's space vision, using the 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 orbiter 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 modifications, 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.

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 were:

- 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



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.

(greater than Mach 15). It is the first of three missions to test this effect and the size of the protuberance will increase with each mission and the data will be used for the design of future spacecraft.

- During the November 2008 STS-126 mission, Space Shuttle *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 orbiter's ability to return to Earth unmanned.
- For the STS-124 mission in May 2008, *Discovery* was the final orbiter 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 microchip measures the amount of oxygen and nitrogen being supplied. They also provide early insight into any possible 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 on ISS by facilitating space station annunciation of selected shuttle alarms. The shuttle capability is expected to come on line in 2008 when compatible ISS software is completed.
- Also in 2007 during the August STS-118 Space Shuttle *Endeavour* mission, NASA successfully used the Boeing-built Station-Shuttle Power Transfer System (SSPTS) for the first time to extend a shuttle mission. The Space Shuttle *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 its 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 orbiter 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; the advance time depends on the mission's complexity.

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