A Versatile Vehicle

The Space Shuttle Program is making the Vision for Space Exploration a reality. The first true aerospace vehicle, the Space Shuttle takes off like a rocket. The winged orbiter then maneuvers around the Earth, like a spaceship, and lands on a runway, like an airplane.

The Space Shuttle is designed to carry large and heavy payloads into space, as well as ferry resident crews to the International Space Station. But unlike earlier manned spacecraft that were good for only one flight, the Shuttle orbiter and Solid Rocket Boosters can be used again and again.

The Space Shuttle is a prime carrier of components for assembly of the International Space Station (ISS). Major elements that have been ferried to the ISS are the U.S. Lab Destiny, a robot arm, an airlock and trusses. Also, it has carried Multi-Purpose Logistics Modules that contained supplies, equipment and experiment racks.

Early in its service, the Shuttle also provided the capability to repair or service spacecraft in orbit, or return them to Earth for a more extensive overhaul and another launch. The Long-Duration Exposure Facility (LDEF), a free-flying payload, remained in orbit almost six years before it was recovered and returned to Earth, where it yielded a wealth of new data on the space environment.

An INTELSAT commercial communications satellite stranded in a useless orbit was retrieved in dramatic fashion by Shuttle astronauts, repaired and then reboosted to its proper orbit to begin operation.

The Hubble Space Telescope was successfully serviced in orbit.

Sometimes interplanetary explorers, such as the Magellan mission to Venus or the Galileo mission to Jupiter, have been launched from the Space Shuttle. They used an inertial upper stage to exit Earth orbit and begin their journeys to Earth's planetary neighbors.

A Unique Vehicle

The ability of the Shuttle to land on a runway, unlike the expensive parachute-descent and recovery-at-sea techniques used in the Mercury, Gemini and Apollo human space flight programs, saves both time and money. In addition, again unlike prior manned spacecraft, the most expensive Shuttle components can be refurbished and readied for another launch.

The complex and expensive orbiter returns to Earth and is processed for the next flight. The Solid Rocket Booster casings, engine nozzles and parachutes were built to last for 20 launches. Only the External Tank is expended on each flight. The high cargo capacity and major component reusability of the Shuttle make it unique among space vehicles.

Just after sundown, Space Shuttle Endeavour approaches touchdown on KSC's Shuttle Landing Facility Runway 33 to complete the STS-99 mission, launching the Shuttle Radar Topography spacecraft.

The orbiter is the only part of the Space Shuttle that has a name in addition to a part number. The first orbiter built was the Enterprise, which was designed for flight tests in the atmosphere rather than operations in space. It is now at the Smithsonian Museum at Dulles Airport outside Washington, D.C. Five operational orbiters were built: (in order) Columbia (OV-102), which was lost in an accident Feb. 1, 2003; Challenger (OV-099), which was lost in an accident Jan. 28, 1986; Discovery (OV-103); Atlantis (OV-104); and Endeavour (OV-105).

Parts of the Space Shuttle

The flight components of the Space Shuttle are two Solid Rocket Boosters, an External Tank and a winged orbiter. The assembled Shuttle weighs approximately 4.5 million pounds (2.041 million kilograms) at liftoff.

The orbiter carries the crew and payload. The ship is 122 feet (37 meters) long and 57 feet (17 meters) high, has a wingspan of 78 feet (24 meters), and weighs 242,000 pounds (109,771 kilograms) when it is empty. It is similar to the size and general shape of a DC-9 commercial jet airplane. Orbiters vary slightly from vehicle to vehicle.

The orbiter carries its cargo in a cavernous payload bay 60 feet (18.3 meters) long and 15 feet (4.6 meters) wide. The bay is flexible enough to provide accommodations for fully equipped scientific laboratories such as SPACEHAB. Depending on the requirements of the particular mission, a Space Shuttle can carry about 37,800 pounds (17,146 kilograms) into orbit.

An orbiter is equipped for flight with three main engines, each producing 394,260 pounds (1.754 million newtons) of thrust when operating at 104 percent at liftoff (at sea level). This figure is derived from flight experience and is 2.7 percent better than the required design minimum. The engines burn for more than eight minutes, while together drawing 64,000 gallons (242,240 liters) of propellants each minute when at full power.

Before flight, the orbiter is mated to a huge external tank, standing 154 feet (47 meters) high and 27.5 feet (8.4 meters) in diameter. The super-lightweight tank, first flown in 1998, weighs 1,648 million pounds (745,555 kilograms) at liftoff.

Two inner tanks provide a maximum of 141,750 gallons (541,482 liters*)* of liquid oxygen and 384,071 gallons (1,450,000 liters) of liquid hydrogen. The tank feeds these propellants to the main engines of the orbiter throughout the ascent into orbit, and the tank is then discarded.

Most of the Shuttle's power at liftoff is provided by its two Solid Rocket Boosters. Each booster is 149.2 feet (45.5 meters) high and 12.2 feet (3.7 meters) in diameter, and each weighs 1.38 million pounds (6.3 million kilograms). Their solid propellant consists of a mixture of aluminum powder as the fuel, aluminum perchlorate as the oxidizer, and iron oxide as a catalyst, all held together by a polymer binder.

Flight experience indicates that within 0.7 seconds after ignition, the boosters each produce about 2.908 million pounds (12.935 million newtons) of thrust before gradually declining for the remainder of a two-minute burn. Together with the orbiter's three main engines firing at 104 percent, total thrust of the Space Shuttle at liftoff is 6.999 million pounds (31.131 million newtons).

In-orbit maneuvering capability is provided by two smaller Orbital Maneuvering System engines located on the orbiter. They burn nitrogen tetroxide as the oxidizer and monomethyl-hydrazine as the fuel, from on-board tanks carried in two pods at the upper rear. The OMS engines are used for major maneuvers in orbit, and for slowing the vehicle during re-entry at the end of the mission.

Crew Accommodations

Normal crew size for a Shuttle flight is seven people. The crew occupies a two-level cabin at the forward end of the orbiter. They operate the vehicle from the upper level, the flight deck, with the flight controls for the mission commander and pilot located in the front.

A station at the rear, overlooking the payload bay through two windows, contains the controls a mission specialist astronaut uses to operate the Remote Manipulator System arm which handles elements in the payload bay.

Astronaut James F. Reilly, STS-104 mission specialist, looks over supplies in the Quest Airlock aboard the International Space Station (ISS). Reilly was one of two assigned spacewalkers on the STS-104 mission. The third extravehicular activity utilized the new airlock, marking its first usage.

Mission operations displays and controls are on the right side of the cabin, and payload controls are on the left. The latter are sometimes operated by payload specialists, who are usually not career NASA astronauts.

The living, eating and sleeping area for off-duty crew members, called the mid-deck, is located below the flight deck. It contains prepackaged food, a toilet, bunks and other amenities. Experiments for the flight also may be stowed in mid-deck lockers.

A typical Shuttle crew includes a commander and pilot, mission specialists and occasionally payload specialists. The commander and pilot are selected from the pilot astronaut corps, highly qualified individuals with at least 1,000 hours of pilot-in-command time in jet aircraft, and they must meet other rigorous qualifications. Mission specialists are scientists, physicians or other highly qualified specialists.

Payload specialists are persons other than NASA astronauts – including international citizens – who have specialized on-board duties. They may be added to Shuttle crews if activities are involved that have unique requirements.

Shuttle crews experience a maximum gravity load of 3 g's during launch, and less than 1.5 g's during re-entry. These accelerations are about one-third the levels experienced on previous U.S. human spaceflights. Many other features of the Space Shuttle, such as a standard sea-level atmosphere, make spaceflight more comfortable for the astronaut.

Typical Shuttle Mission

The rotation of the Earth has a significant effect on the payload capabilities of the Space Shuttle. A due-east launch from the Kennedy Space Center in Florida uses the Earth's rotation as a launch assist, since the ground is turning to the east at that point at a speed of 915 miles (1,473 kilometers) per hour.

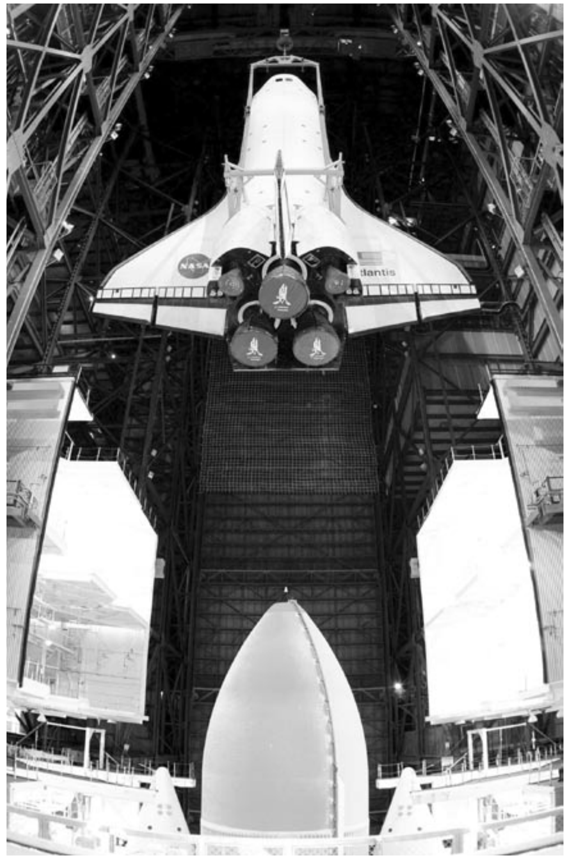
Spacecraft and other payload items arrive at the Kennedy Space Center for final processing and are checked out in special buildings before being loaded into the orbiter. Each Shuttle arrives at the pad as a set of assembled components.

The Solid Rocket Booster propellant segments are received and checked out in a special facility, then taken to the Vehicle Assembly Building (VAB) and stacked on a Mobile Launcher Platform to form two complete rockets. The External Tank is received and prepared for flight in the VAB, then mated to the solid rockets.

An orbiter is prepared in the Orbiter Processing Facility, then moved to the VAB and attached to the External Tank. A giant Crawler-transporter picks up the

Orbiter Insulation

A special silica-based insulation in the form of tiles and blankets serves as the primary heat shield for the orbiter. This material sheds heat so readily that one side can be held in bare hands while the opposite side is red-hot. These lightweight tiles are made to survive temperatures of up to 2,500 degrees Fahrenheit (1,260 degrees Celsius). Previous crewed spacecraft used heat shields that ablated – flaked away in small pieces to carry off heat from the surface – during the fiery entry into Earth's atmosphere. In 1996 a fourth tile material was introduced, using small quantities of alumina fiber. Fibrous Insulation Blankets, made of silica felt sandwiched between silica fabric and S-Glass fabric, also replaced a majority of the white tiles on the upper surface. Currently, each orbiter has about 24,300 tiles and 2,300 flexible insulation blankets.



Suspended from an overhead crane, the orbiter Atlantis is lowered toward the Solid Rocket Booster and External Tank below for mating before rollout to the launch pad for mission STS-112.

Mobile Launcher Platform and the assembled Shuttle and takes them to the pad. The Shuttle remains on the platform until liftoff.

The orbiter's main engines ignite first and build to full power before the huge solid rockets ignite and liftoff occurs. The solid rockets burn out after about two minutes, are separated from the tank, and parachute into the ocean about 160 miles (258 kilometers) from the launch site. Two special recovery ships pull the parachutes out of the water and tow the rocket casings to land, where they are refurbished and sent back to the manufacturer to be filled again with propellant.

The orbiter continues into space – a total of more than eight minutes of burn-time on the three main engines – and then separates from the external tank. The latter breaks up as it re-enters the atmosphere over an uninhabited area of the Indian Ocean.

On most missions, the orbiter enters an elliptical orbit, then coasts around the Earth to the opposite side. The Orbital Maneuvering System (OMS) engines then fire long enough to stabilize and circularize the orbit.

On some missions the OMS engines also are fired after the External Tank separates if more velocity is needed to reach the desired altitude for the burn that circularizes the orbit. Later OMS burns can raise or adjust this orbit, if required.

A typical Shuttle flight lasts about 10 days, but may be able to stay in space up to 16 days or longer. After completing mission objectives, such as deploying a Space Station module, operating on-board scientific instruments or conducting experiments, the orbiter re-enters the atmosphere and lands.

Kennedy Space Center is considered the prime end-of-mission landing site, while Edwards Air Force Base, Calif., is the alternate. Unlike prior crewed spacecraft, which followed a ballistic trajectory upon re-entry, the orbiter has a cross-range capability (can move to the right or left of the straight line of its entry path) of about 1,270 miles (2,045 kilometers).

The landing speed is from about 212 to 226 miles (341 to 364 kilometers) per hour. The orbiter is immediately "safed" by a ground crew with special equipment, the first step in the process which will result in another launch of this particular orbiter.

Improved Space Suit and Unique Rescue System for Spacewalkers

An improved space suit and an independent rescue unit were developed for the Shuttle by the Johnson Space Center in Houston. Johnson is responsible for mission planning and provides ground control and support during each flight. The space suit has been used when a crew member is working outside the pressurized crew cabin, Spacelab or SPACEHAB modules.

Unlike earlier suits, each of which was tailored to an astronaut's specific measurements, the Shuttle-era space suits come in small, medium and large sizes, and can be adjusted to fit both men and women. A suit comes in two parts — upper torso and pants — and each part is pressure-sealed, unlike previous suits that were zipper-sealed at the waist. The material used for the elbow, knee and other joints is a fabric that allows easier movement, and costs and weighs less than the neoprene rubber joints of earlier units. Each suit has an integral Primary Life Support System, rather than the previously required set of connected tanks carried on astronauts' backs.

A Simplified Aid For Extravehicular Activity Rescue (SAFER) was developed by Johnson for emergency situations. A scaled-down version of the Manned Maneuvering Unit (MMU) flown aboard Shuttle missions in 1984, the SAFER is designed for self-rescue use by a spacewalker in the event the Shuttle is unable or unavailable to retrieve a detached, drifting crew member. Examples of such times may include a mission where the Shuttle is docked to the International Space Station. The SAFER was first flown on STS-64 in September 1994.

International Space Station

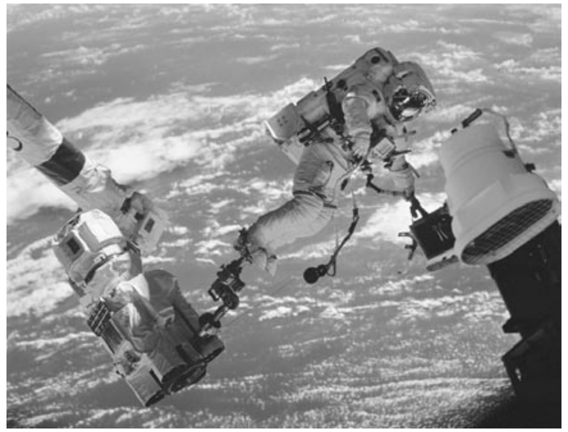
The Space Shuttle has carried many of the component parts of the International Space Station into orbit for assembly in space, and has provided an initial base for assembly operations. Phase 1 of construction was completed in 2003 . The installation of NASA's Node 2 will signify the U.S. Core Complete stage of International Space Station assembly and increase the living and working space inside the station to approximately 18,000 cubic feet. Other U.S. elements installed include the Unity module, Destiny laboratory, Node 1 and port and starboard trusses, as well as the Quest Joint Airlock. The airlock is the primary path for International Space Station spacewalk entry and departure for U.S. spacesuits, which are known as Extravehicular Mobility Units, or EMUs. In addition, the Joint Airlock is designed to support the Russian Orlan spacesuit for spacewalks.

Elements of the Space Station provided by Russia include the Zvezda service module, Zarya control module, and the Pirs docking port.

At 290 feet (88.4 meters) long and 361 feet (110 meters) across, the finished Space Station will be the largest structure ever assembled in space. Its current weight is 404,069 pounds. The habitable volume is 15,000 cubic feet. Its height is 90 feet.

The Space Station also represents the largest cooperative scientific program in space history, and will include contributions from NASA, Japan, Canada, the member nations of the European Space Agency and Russia.

People operating inside the microgravity of a Space Station can create products difficult or impossible to make on Earth, such as regular and perfect forms of protein crystals. In addition, such a platform orbiting above the distorting atmosphere can provide astronomers and other scientists an excellent vantage point to study the composition and phenomena of our universe.



STS-112 Mission Specialist David A. Wolf is anchored to a foot restraint on the Canadarm2 as he carries the Starboard One (S1) outboard nadir external camera to the S1 Truss on the International Space Station.

Other applications are the economical manufacturing in zero gravity of presently very expensive medical drugs, glass for lenses, electronic crystals of unrivaled purity and size, as well as various alloys, composites and metallic materials impossible to produce on Earth.

The Space Shuttle is overall the most capable vehicle built since the space program began. It is the major means of providing humanity with the limitless benefits available from space exploration and space utilization.

Spacelab and SPACEHAB: Science in Orbit

The Shuttle was used to carry a complete scientific laboratory into Earth orbit. Two configurations were used: the Spacelab, until 1993, and the SPACEHAB.

The Spacelab modules were similar to small, well-equipped laboratories on Earth, but designed for zero-gravity operation.

Two complete Spacelabs (plus instrument-carrying platforms exposed to space, called "pallets") were built by the European Space Agency.

The two SPACEHAB modules were commercially developed by McDonnell Douglas Aerospace-Huntsville, under contract to SPACEHAB, Inc.

The module offered up to 61 standard lockers, such as those found in the orbiter mid-deck, and two single or double racks for experiments.

IS-2005-06-021-KSC John F. Kennedy Space Center

National Aeronautics and Space Administration

Space Shuttle

A fish-eye view shows Space Shuttle Discovery moments after liftoff from Launch Pad 39B on the historic Return to Flight mission STS-114 on July 26, 2005.

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