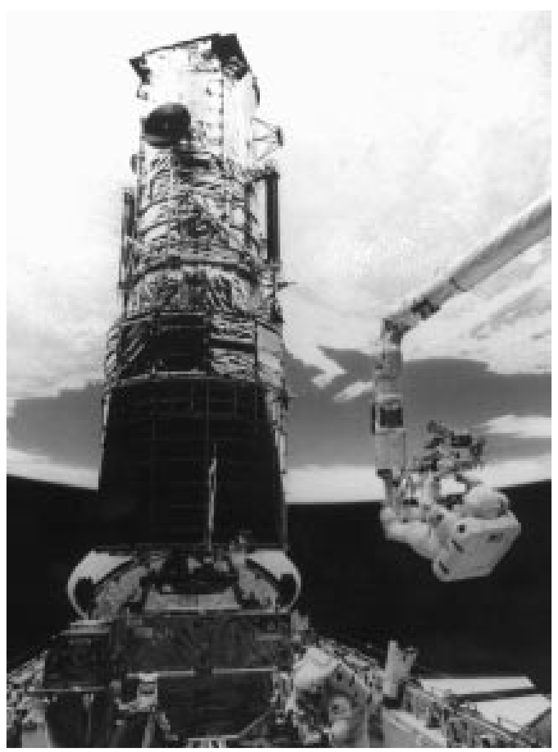
A Versatile Vehicle

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 Earth orbit. But unlike earlier manned spacecraft, which were good for only one flight, the Shuttle orbiter and solid rocket boosters can be used again and again.

The Shuttle also provides a new 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 re-boosted to its proper orbit to begin operation. The Hubble Space Telescope was successfully serviced in orbit and has helped unlock many of the mysteries of the universe since the repairs and improvements were made.



The Shuttle's usefulness as a platform for on-orbit servicing of spacecraft was demonstrated during the STS-61 Hubble servicing mission in 1993. Spacewalking astronauts successfully completed repairs and upgrades to the Hubble telescope while it was temporarily stored in the orbiter Endeavour's payload bay.

Satellites today play a major role in the fields of environmental protection, energy, weather forecasting, navigation, fishing, farming, mapping, oceanography and many other space-borne applications. Satellites also provide worldwide communications, linking the people and nations of the world together. A single channel, one out of 24 on many communications satellites, can provide television coverage to most entire nations. Satellites have become an indispensable part of the modern world.

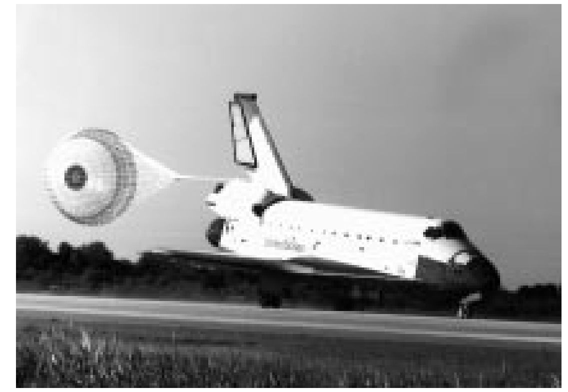
All satellites released from a Space Shuttle initially enter low Earth orbit — about 115 to 250 miles (185-402 meters) altitude. Some, such as Hubble or the environment-monitoring Upper Atmosphere Research Satellite, remain there throughout their working lives.

Many spacecraft, such as the weather and communications satellites that can "see" a third of the world at once, operate at a much higher level known as geosynchronous orbit. This is a flight path about 22,300 miles (35,888 kilometers) above and aligned with the equator, with a speed in orbit that matches that of the Earth's surface below. From the ground such satellites appear to hang motionless in the sky. Spacecraft reach this altitude by firing an attached propulsion unit, such as an Inertial Upper Stage (IUS), or the smaller Payload Assist Module (PAM), after deployment from the Shuttle orbiter. At altitude an on-board engine fires to "circularize" the orbit.

Sometimes interplanetary explorers, such as the Magellan mission to Venus or the Galileo mission to Jupiter, are launched from the Space Shuttle. They also use the IUS to exit Earth orbit and begin their journey to Earth's planetary neighbors.

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 spaceflight programs, saves both time and money. In addition, again unlike prior manned spacecraft, the most expensive Shuttle components can be refurbished and made ready for another launch. The complex and expensive orbiter is designed to last 100 flights minimum, and the solid rocket booster casings, engine nozzles, parachutes, etc., 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.

The orbiter is the only part of the Space Shuttle which 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, Challenger (lost in an accident Jan. 28, 1986), Discovery, Atlantis and Endeavour (Challenger's replacement).



The orbiter Columbia returns to Kennedy's Shuttle Landing Facility, completing Mission STS-62 on March 18, 1994. All four orbiters in the Shuttle fleet are now equipped with a drag chute that is deployed during landing to assist in stopping and to provide greater stability in the event of a flat tire or steering problem.

The 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 about 4.5 million pounds (2.041 million kilograms) at liftoff.

The orbiter carries the crew and payload. It is 122 feet (37 meters) long and 57 feet (17 meters) high, has a wingspan of 78 feet (24 meters), and weighs from 168,000 to 175,000 pounds (76,000 to 79,000 kilograms) empty. It is about the size and general shape of a DC-9 commercial jet airplane. Orbiters may vary slightly from unit to unit.

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 unmanned spacecraft in a variety of shapes and sizes, and for fully equipped scientific laboratories such as the Spacelab or 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 400,500 pounds (1.781 million newtons) of thrust when operating at 104 percent at liftoff (at sea level). This figure is derived from flight experience and is about 2.7 percent better than the required design minimum. The engines burn for over eight minutes, while together drawing 64,000 gallons (242,240 liters) of propellants each minute when at full power.

The orbiter is mated to the huge external tank, standing 154 feet (47 meters) long and 28 feet (8.5 meters) in diameter. The tank weighs a total of 1.68 million pounds (762,048 kilograms) at liftoff. Two inner tanks provide a maximum of 145,000 gallons (659,170 liters) of liquid oxygen and 390,000 gallons (1.773 million liters) of liquid hydrogen. The tank feeds these propellants to the main engines of the orbiter throughout the ascent into orbit, and is then discarded.

Most of the Shuttle's power at liftoff is provided by its two solid rocket boosters. Each booster is 149.1 feet (45.4 meters) high and 12.2 feet (3.7 meters) in diameter, and each weighs 1.3 million pounds (589,670 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 they produce about 2.908 million pounds (12.935 million newtons) of thrust each for the first few seconds after ignition, 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 7.0175 million pounds (31.2 million newtons).

In-orbit maneuvering capability is provided by two smaller Orbital Maneuvering System (OMS) 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 to slow the vehicle for re-entry at the end of the mission.

Crew Accommodations

Nominal crew size for a Shuttle flight is up to seven people; 10 could be carried in an emergency. 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. Mission operations displays and controls are on the right side of the cabin, and payload controls on the left. The latter are often operated by payload specialists, who are usually not career NASA astronauts. The living, eating and sleeping area for off-duty crew members, called the middeck, is located below the flight deck. It contains pre-packaged food, a toilet, bunks and other amenities. Experiments for the flight also may be stowed in middeck lockers.

On the first Space Shuttle flight — STS-1 in 1981 — Pilot Robert Crippen floats effortlessly in the microgravity of space, inside the middeck of the orbiter Columbia.

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

Payload specialists are persons other than NASA astronauts — including foreign citizens — who have specialized onboard duties. They may be added to Shuttle crews if activities that have unique requirements are involved.

Orbiter Insulation

A special silicon-based insulation in the form of 100 square-inch (average) tiles 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 1,260 degrees Celsius (2,300 degrees Fahrenheit). 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. They tended to be heavy and were not reusable.

Shuttle crews experience a designed maximum gravity load of 3g during launch, and less than 1.5g 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 and are assembled and checked out in special buildings before being loaded into the orbiter. Each Shuttle arrives as a set of component parts. 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 checked out in the Orbiter Processing Facility, then moved to the VAB and attached to the external tank. A giant crawler-transporter picks up the 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 refilled with propellant.

The orbiter continues into space — a total of over 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 OMS engines then fire long enough to stabilize and circularize the orbit. On some missions the OMS engines also are fired soon 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 by the needs of the mission. A typical Shuttle flight lasts about ten days, but modifications now being performed will enable some orbiters to stay in space for up to 16 days.

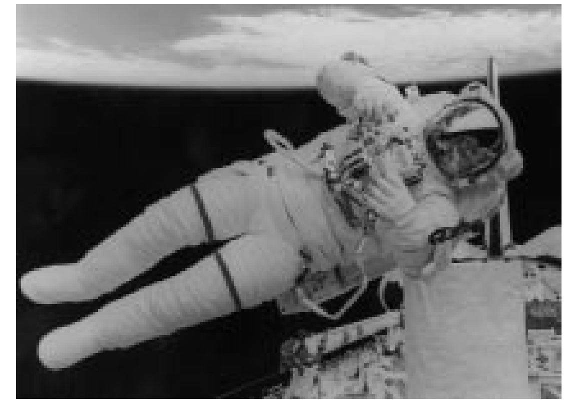
After completing mission objectives, which might include deploying a spacecraft, operating onboard scientific instruments or conducting experiments, the orbiter re-enters the atmosphere and lands. Kennedy Space Center is considered the prime end-of-mission landing site, while Edwards Air Force Base, 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 off 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 Developed for Shuttle

An improved space suit and an independent rescue unit have been developed for the Shuttle by the Johnson Space Center, Houston, Tex. Johnson is responsible for mission planning, and provides ground control and support during each flight. The space suit is for use 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 the back.

A Simplified Aid for Extravehicular Activity Rescue (SAFER) has been 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 space walker 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 Russian Mir space station or to the international space station. The SAFER was first flown on STS-64 in September 1994.



During the first untethered space walk in 10 years, Mission Specialist Mark Lee tests the new Simplified Aid for Extravehicular Rescue (SAFER) system. The 28th space walk of the Shuttle program took place on Mission STS-64 in September 1994.

Spacelab and SPACEHAB: Science in Orbit

Periodically the Shuttle is scheduled to carry a complete scientific laboratory into Earth orbit. Two configurations are available, the Spacelab and the SPACEHAB. These modules are similar to a small but well-equipped laboratory on Earth, but designed for zero-gravity operation. They provide a shirt-sleeve, pressurized environment where crew members can perform scientific tests utilizing the high vacuum and microgravity of orbital space. They also can make astronomical observations above the Earth's obscuring atmosphere.

Two complete Spacelabs (plus instrument-carrying platforms exposed to space, called "pallets") have been built by the European Space Agency (ESA), which paid for the development expense and manufacturing costs of the first one. NASA purchased the second unit.

Spacelab experiments for a particular mission may be sponsored and/or organized by a nation, such as the German D-1 and D-2 flights and the Spacelab-J mission jointly sponsored by Japan and NASA. Or they may be oriented around a particular field, such as the Spacelab Life Sciences-1 and -2 missions which focused on life science research in microgravity. Sometimes Spacelab flies as an all-pallet configuration, where all the instruments are exposed to space and operated from inside the orbiter.

The SPACEHAB module was commercially developed by McDonnell Douglas Aerospace-Huntsville, under contract to SPACEHAB, Inc. The module offers up to 61 standard lockers, such as those found in the orbiter middeck, and two single or double racks for experiments. In addition, there is access to the exterior of the module for experiments requiring exposure to the space environment. Two SPACEHAB modules have been built.

The Spacelab or SPACEHAB remain in the orbiter payload bay throughout the mission. After landing, the laboratory is removed and preparations begin to configure it for its next flight.

Space Station and Space Applications

The Space Shuttle is scheduled to carry many of the component parts of the international space station into orbit and to provide an initial base for assembly operations. At 290 feet (88.4 meters) long and 361 feet (110 meters) across, the space station will be the largest assembly ever erected in space. It 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 produce products difficult or impossible to make on Earth, such as power generation from sunlight. In addition, such an orbiting platform can provide astronomers and other scientists with an excellent vantage point above the distorting atmosphere from which they can study the composition and structures of our universe in ways not possible on the ground.

Other applications are the economical manufacturing in zero gravity of presently very expensive medical drugs, or glass for lenses, or electronic crystals of unrivaled purity and size, as well as various alloys, composites and metallic materials impossible to produce on Earth. Drugs, metals, glass, and protein and electronic crystals will first be manufactured in pilot programs on board various Shuttle missions, proving the concept before larger scale operations begin.

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

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Information Summaries

Space Shuttle

Space Shuttle Discovery, STS-26, September 1988

National Aeronautics and Space Administration
John F. Kennedy Space Center