Space Shuttle System

On April 12, 1981, Shuttle operations commenced with the launch of Columbia on the STS-1 mission. NASA's fleet of orbiters has comprised five ships to date: Challenger, Columbia, Discovery, Atlantis and Endeavour. Discovery, which is the chosen orbiter for the STS-121 mission has undertaken 31 missions since its first flight in August 1984 including deployment of the Hubble Space telescope in 1990 (STS-31), the STS-42 Spacelab IML-1 mission with ESA astronaut Ulf Merbold, in 1992, the third Hubble Space Telescope servicing mission (STS-103) in 1999 with ESA astronauts Claude Nicollier and Jean-Francois Clervoy, and transport of the ISS Z1 truss element (STS-92) and the European-built Multi-Purpose Logistics Module 'Leonardo' (STS-102 and STS-105) to the ISS.

Ulf Merbold as the first European and ESA astronaut on the Shuttle in 1983 in the European-developed Spacelab laboratory on the STS-9 Spacelab-1 mission. In January 1992 he flew again on the STS-42 Spacelab IML-1 mission on the Space Shuttle Orbiter Disovery. (Image: NASA)

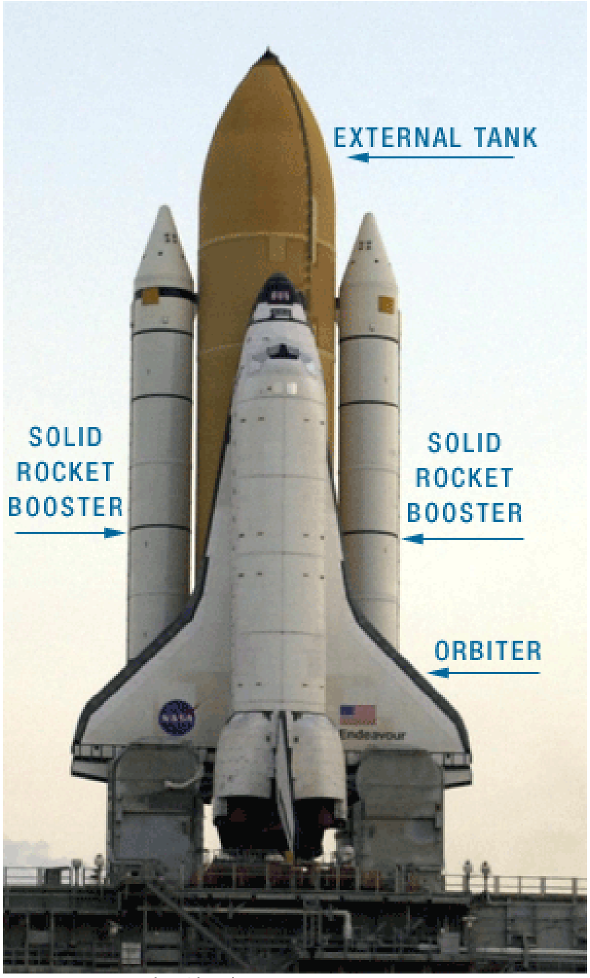
Atlantis was first launched in October 1985 and has undertaken 26 missions, which include deployment of ESA's European Retreivable Carrier (EURECA) and operation of the Tethered Satellite System on the STS-46 mission in 1992 with ESA astronaut Claude Nicollier and Italian Space Agency astronaut Franco Malerba, and transported the US Destiny laboratory, the Quest Airlock and two truss elements to the ISS on four separate missions (STS-98, STS-104, STS-110 and STS-112)

Endeavour was the fifth orbiter constructed, undertaking its first mission in 1992. Highlights of its 19 missions to date include the STS-88 mission, which transported the Unity Node as the second ISS module into orbit in December 1998, the Shuttle Radar Topography Mission (STS-99) in February 2000 with ESA astronaut Gerhard Thiele, the STS-100 mission in 2001, which brought Umberto Guidoni as the first European astronaut on mission to the ISS, and the STS-111 ISS assembly mission with ESA astronaut Philippe Perrin in June 2002.

Launch of Columbia on STS-1 mission on 12 April 1981.
(Image: NASA)

Challenger was lost on launch in January 1986 on its tenth mission and Columbia was lost prior to landing on its 28th mission in February 2003.

The Space Shuttle or Space Transportation system (STS) consists of three major component parts: The orbiter, which most people refer to as the Space Shuttle, the external tank, which holds the orbiter's propellant and the solid rocket boosters which provide the most lift during the first two minutes of flight. Together they have a length of 56 metres and weigh more than 2,000 tonnes at lift-off. The Space Shuttle has a lift-off thrust of over 3,240 tonnes and is capable of carrying a cargo of just over 28 tonnes into orbit. A normal mission lasts between 5 and 16 days. Since 1981 more than 600 astronauts have flown on Shuttle and it has put more than 1.36 million kilograms into orbit. Since the Columbia accident in February 2003 there have been improvements made to all elements of the Shuttle.



Major Shuttle components. (Image: NASA)

The Orbiter

The 37-metre long orbiter is the element of the Space Shuttle system which contains the crew and returns the crew to earth at the end of their orbital mission. It also contains relevant equipment and supplies, either for use by the Shuttle crew on a non-ISS Shuttle mission, or additionally by the ISS Expedition Crew when on an ISS mission. To protect the orbiter from the up to 1600 °C temperatures during re-entry, all surfaces are covered with thermally protective materials. The main types of thermal materials used are Reinforced Carbon-Carbon (RCC), low- and high-temperature reusable surface insulation tiles, felt reusable surface insulation blankets and fibrous insulation blankets. RCC is used amongst other places on the wing leading edges where improvements have been made to prevent heat flow getting inside the wing structure.

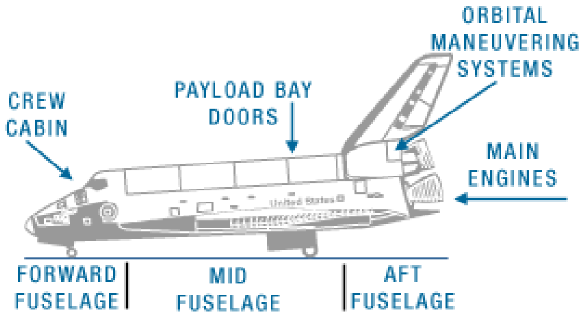
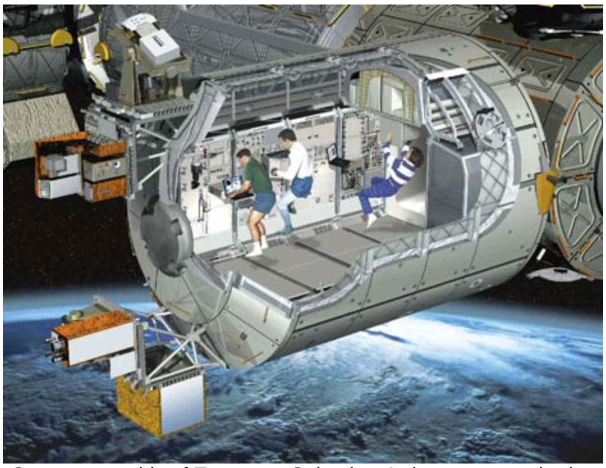


Diagram of main orbiter sections. (Image: NASA)

The forward fuselage contains the 65.8 m^3 crew station module. This pressurised three-section compartment contains areas for working, living and stowage. It consists of the flight deck, the middeck/equipment bay and an airlock. Four crew members seats are on the flight deck. On the forward flight deck there are more than 2000 displays and controls with the commander's seat positioned on the left and the pilot's seat on the right. The middeck contains the three other crew seats together with provisions and stowage facilities, four crew sleep stations the waste management system, the personal hygiene station and the work/dining table. Outside the aft bulkhead of the crew module in the payload bay, a docking



Cutaway graphic of European Columbus Laboratory attached to the ISS. A subsequent Shuttle mission will transport this laboratory in the Shuttle's cargo bay. (Image: ESA/D. Ducros) module and a transfer tunnel with an adapter can be fitted to allow crew and equipment transfer for docking, Spacelab and extravehicular operations.

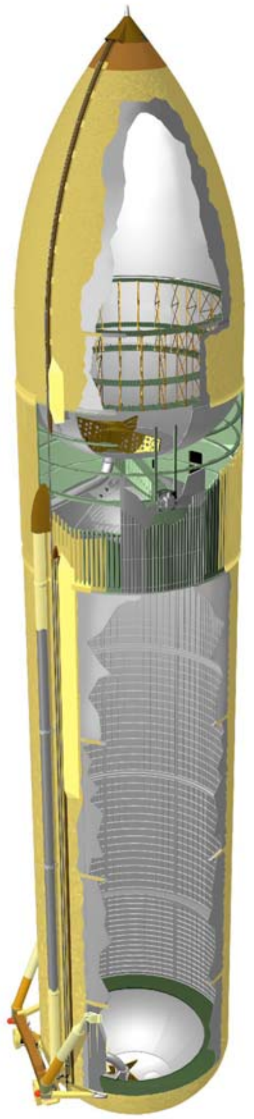
The 18-metre long, 5-metre wide mid fuselage is the location of the payload bay and payload bay doors. It is in this cargo area that the European Columbus Laboratory will be carried to the ISS and in which the MPLM's are carried as pressurised cargo containers for resupplying the ISS. The payload bay is the location of the Shuttle's Remote Manipulator System or robotic arm which is controlled from the flight deck. This allows payloads to be deployed out of the payload bay or payloads to be grappled and secured in the payload bay for return to Earth.

The 5.5 metre long aft fuselage consists of the left and right orbital maneuvering systems, Space Shuttle main engines, body flap, vertical tail and orbiter/external tank rear attachments. The orbiter has a wingspan of 24 metres and, on the runway, a height of 17 metres. It has an in-orbit altitude of between 185 and 643 kilometres, with a velocity of 28,000 km/h. The orbiter's engines exert a thrust of over 170 tonnes at sea level.

External Tank

The External Tank is the fuel tank for the orbiter. It contains the propellants used by the Space Shuttle main engines. It has been redesigned in the past two years to eliminate the possibility of foam coming off during launch which could potentially damage the Shuttle. When it's empty the External Tank weighs more than 35 tonnes and can carry almost 720 tonnes of propellant, more than 616 tonnes of liquid oxygen and nearly 103 tonnes of liquid hydrogen.

The External Tank is 47 metres long and acts as the "backbone" of the Shuttle during the launch, providing structural support for attachment with the solid rocket boosters and orbiter. The tank is the only component of the Space Shuttle that is not reused. Approximately 8.5 minutes into the flight, with its propellant used, the tank is jettisoned at an altitude of approximately 110 kilometres above the Earth. The now nearly empty tank separates and falls in a preplanned trajectory with the majority of it disintegrating in the atmosphere and the rest falling into the ocean.



Graphic representation of External Tank. (Image: NASA)

The three main components of the External Tank are an oxygen tank holding a volume of more than 540,000 litres of liquid oxygen, located in the forward position, an aft-positioned hydrogen tank holding more than 1,450,000 litres of liquid hydrogen and a collar-like intertank, which connects the two propellant tanks, houses instrumentation and processing equipment, and provides the attachment structure for the forward end of the solid rocket boosters.

The hydrogen tank is 2.5 times larger than the oxygen tank but weighs only one-third as much when filled to capacity. The reason for the difference in weight is that liquid oxygen is 16 times heavier than liquid hydrogen.

The aluminium skin of the External Tank is covered with a thermal protection system that is a 2.5-centimetres thick coating of polyisocyanurate foam. The purpose of the thermal protection system is to maintain the propellants at an acceptable temperature, to protect the skin surface from aerodynamic heat and to minimize ice formation.

The External Tank includes a propellant feed system to duct the propellants to the orbiter engines, a pressurisation and vent system to regulate the tank pressure, an environmental conditioning system to regulate the temperature and render the atmosphere in the intertank area inert, and an electrical system to distribute power and instrumentation signals and provide lightning protection.

The tank's propellants are fed to the orbiter through a 43-centimeter diameter connection that branches inside the orbiter to feed each main engine.

Solid Rocket Boosters

The two Solid Rocket Boosters (SRBs) operate in parallel with the main engines for the first two minutes of flight to provide the additional thrust needed for the orbiter to escape the gravitational pull of the Earth. Each booster is over 45 metres long and weighs about 590 tonnes at lift-off. At an altitude of approximately 45 km, the boosters separate from the orbiter/external tank, descend on parachutes, and land in the Atlantic Ocean where they are recovered and thereafter refurbished for reuse. The boosters also assist in guiding the entire vehicle during initial ascent. Thrust of both boosters is equal to 2,400 tonnes.

In addition to the solid rocket motor, the booster contains the structural, thrust vector control, separation, recovery, and electrical and instrumentation subsystems.

The solid rocket motor is composed of a segmented motor case loaded with solid propellants, an ignition system, a movable nozzle and the necessary instrumentation and integration hardware. Each solid rocket motor contains more than 450 tonnes of propellant, which requires an extensive mixing and casting operation. The solid fuel is actually powdered aluminium, mixed with oxygen provided by a chemical called ammonium perchlorate.

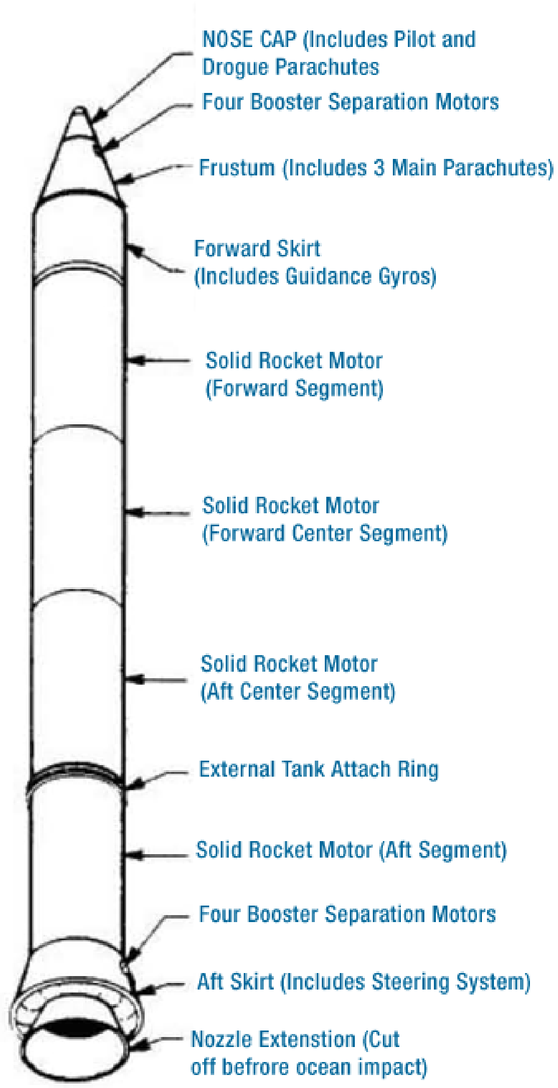


Diagram of Solid Rocket Booster. (Image: NASA)

Following the Columbia accident there have been redesigns of the bolt catchers which catch part of the bolts that hold the boosters to the external tank during booster separation and the booster separation motors which push the boosters away from the external tank during separation.