Introduction to Space Craft

*** What is a spacecraft?**
A spacecraft is any machine that goes into space. It can be a rocket, a satellite, the Space Shuttle, or a robot to explore other planets. Basically, any machine that goes into space, even for a little while, is a spacecraft. They can do many different things, like carry people, watch the weather, send television signals, and explore planets. These things are called a spacecraft's mission.

*** What makes a spacecraft?**
A spacecraft is made of many different parts that work together. Each spacecraft is different and has different parts depending on its mission. The parts are grouped together into groups called subsystems. A subsystem is a set of parts that work together to do a specific task.

Some common subsystems for most spacecraft include the following:

Power Subsystem – The power subsystem provides electricity for the spacecraft. The Spacecraft needs this to operate its sensors, antennas, and computers. Some power Subsystem items include solar panels and batteries.

Communications Subsystem – The communications subsystem sends information to the controllers on earth and accepts commands. It tells the controllers how healthy the Satellite is and passes commands from the ground to the other subsystems. Some parts of a communications subsystem include antennae and electronics.

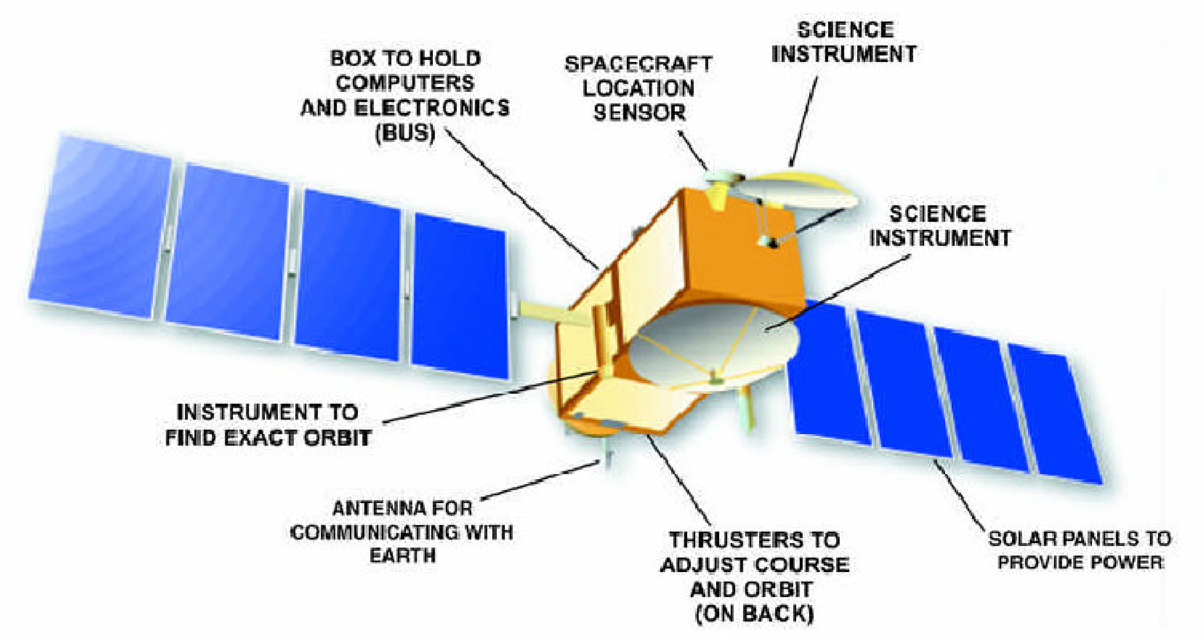
Structure Subsystem – The structure subsystem holds the spacecraft together, kind of like a skeleton. This needs to be strong and light weight. The main body of a spacecraft is part of the structure subsystem.

Payload Subsystem – The payload subsystem performs the spacecraft mission. This can be anything, from cameras that take pictures to astronauts. In the case of rockets, this can even be another spacecraft!

Control Subsystem – The control subsystem is used to point the spacecraft. Computers are usually used to fire thrusters to do this. The control subsystem also includes sensors that tell the spacecraft where it is and where it is pointing.

Life Support Subsystem – The life support subsystem is only used when people or animals will be on the spacecraft. This subsystem provides clean water and air to the Spacecraft occupants.

Thermal Subsystem – Many spacecraft parts have to be at a certain temperatures to operate correctly. The thermal subsystem is used to keep the spacecraft warm or, in some cases, cold. Some common thermal subsystem parts include thermal blankets and electric heaters.



*** How are spacecraft built?**

Spacecraft are built in factories on Earth. Usually, a spacecraft's life begins when somebody has an idea. This idea may be to search the universe, send television signals, or carry people to the moon. The idea becomes the mission of the spacecraft. Engineers take this idea and design a spacecraft to perform the mission. They think about the mission and decide what subsystems and parts are needed for the spacecraft.

Once the design is finished, the spacecraft is built in a factory. A spacecraft must be built very carefully so it is not damaged. Dirt, dust, and even gravity can damage a spacecraft when it is built. The factories have special clean rooms that prevent dirt and dust from getting to the spacecraft. Special structures must be built so gravity doesn't damage the spacecraft.

*** How does a spacecraft get into space?**

Once the spacecraft is finished being built, it is sent into space using rockets. The rockets take the spacecraft to a very high speed to get it into space, sometimes fast enough to visit other planets. Sending spacecraft into space using rockets takes a lot of energy and is very expensive. One day, spacecraft may be built in space on space stations or even on the moon.

***What are the different types of spacecraft?**

There is only one basic difference between shuttle and spacecraft- spacecrafts could be manned or unmanned whereas shuttles are always manned.

The different types of spacecrafts classified on basis of application are:

- ***Flyby spacecraft-*** This group of spacecraft conducted initial exploration of solar system. They followed a continuous solar orbit or escape trajectory so as not be captured in the planetary orbit. They are equipped with instruments, which are capable of observing distant targets. These equipments must be able to downlink data at high speeds. This data is then sent to earth. When the antenna of spacecraft is off the earthpoint the data is stored on-board. They have a sturdy construction, as they are required to survive long periods of interplanetary travel. Stabilization of these spacecrafts can be achieved with the help of thrusters or reaction wheels. E.g. mariner 2 sent to Venus

- ***Orbiter spacecraft***- It is a spacecraft that is designed to travel to a distant planet and enter into its orbit. It must be equipped with propulsive capability and must be able to decelerate at any moment to enter into the orbit. The spacecraft's production of electrical power can be cut off during solar occultation. (Occultation is the blockage of light due to the intervention of another object) Thus it must be designed to withstand thermal variations. Earth occultation's may also occur cutting the uplink and downlink communication with earth. They are used for the second phase of solar exploration thus enabling in-depth study of various planets. E.g. Gallileo, which entered Jupiter orbit after being released from a space shuttles cargo.

- ***Atmospheric spacecraft-*** These spacecrafts are used to study the atmospheric condition of other planets and record the data. They are designed for a relatively short mission. The spacecrafts are carried to their destination by other spacecrafts. The atmospheric spacecraft separates from the main spacecraft when it approaches close to the planet. It is equipped with an aeroshell so as to protect it from atmospheric entry and a parachute to slow its descent. Data recorded is sent to the mother-craft where it is stored and later transmitted to earth.

Balloon package are atmospheric spacecraft and are equipped with a buoyant bag to float with the wind. It is used to study wind circulation patterns. E.g. Huygen's which was carried to Saturn's moon titan by spacecraft Cassini.

- ***Lander spacecraft*** - These spacecrafts are designed to land on the surface of a planet and sent data back to the earth. E.g. Mars pathfinder. Mars Pathfinder spacecraft had two major components
    - the lander
    - a small rover

- ***Penetrator spacecraft*** -These spacecrafts are designed for penetrating the surface of a body, such as a comet. These spacecrafts must be designed to survive the impact of hundreds of Gs. The measured properties of the penetrated surface are then telemetered to the mother-craft, which is then transmitted to earth. E.g. twin Deep space 2 penetrators

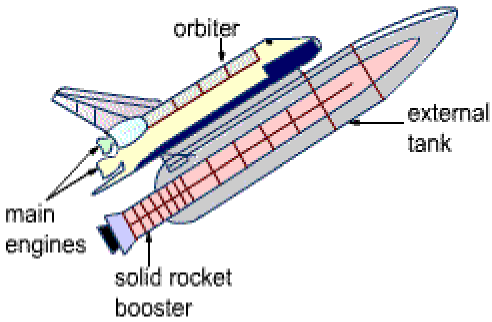
- ***Rover spacecraft*** -They are semi-autonomous roving vehicle that are steerable from earth. They are sent to the planet for taking images and analysing soil. The collected information is then telemetered to earth. E.g. sojourner rover

- ***Observatory spacecraft***- As the name suggests it is a spacecraft that does not travel to a destination but occupies earth or solar orbit. It observes the distant targets. Its vision is not hampered due to the obscuring and blurring effects of the earth's atmosphere. E.g. jpl sirft project

- ***Communication spacecraft-*** These are earth orbiting communication spacecrafts, which are used to transfer data. These spacecrafts in future may be sent to other planets to communicate with the orbiters, rovers, penetrators and atmospheric spacecraft in their vicinity. E.g. – TDRS 10

Introduction to Space Shuttle

Rockets- a space vehicle consisting of propellants, which are burned using a suitable propulsion technique, to generate thrust.



Shuttle

Let us now see what shuttles are and how they have helped in exploring space

Space shuttles are manned, recoverable spacecraft designed to be used as a launch vehicle for Earth-orbiting experiments and as a short-term research platform.

Earlier rockets were used for placing astronauts and equipments in the outer space. But rockets could be used only once i.e. they were not reusable. The idea of reusable "space shuttle" that could be launched like rocket and made to enter the earth's atmosphere like an airplane appealed NASA. It began designing and evaluating cost of space shuttle.

Finally, after many years of construction and testing, the shuttle was ready to fly. Four shuttles were developed. These were

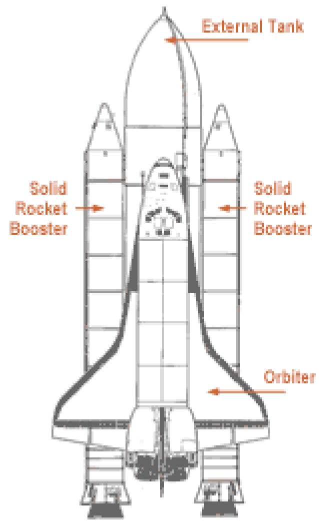
- Columbia
- Discovery
- Atlantis
- Challenger

The first flight was in 1981 with the space shuttle Columbia, piloted by astronauts John Young and Robert Crippen. Columbia performed well and the other shuttles soon made several successful flights.

As we now have a basic idea about the shuttles, let us go into detail and understand the working of the main parts of the shuttle.

*** What are the main parts of space shuttle?**

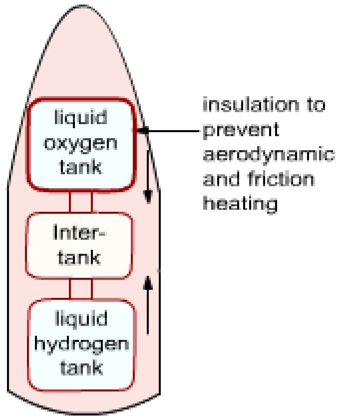
Solid rocket booster- The Solid Rocket Boosters (SRB) are solid rockets that provide most of the main force or thrust (71 percent) needed to lift the space shuttle off the launch pad. In addition, the SRBs support the entire weight of the space shuttle orbiter and fuel tank on the launch pad. Because the SRBs are solid rocket engines, once they are ignited, they cannot be shut down. Therefore, they are the last component to light at launch.



Space Shuttle
(launch configuration)

External fuel tank-

The external tank is the only non-reusable element of space shuttle. It is also the largest part of the space shuttle and provides structural backbone of the entire system. The chief purpose of external tank is to carry the fuels necessary to provide power for the orbiters main engines.



External Tank

It mainly consists of three tanks –

1) Liquid oxygen tank located at the top

2) Liquid hydrogen tank located at the bottom

3) Intertank connecting the liquid oxygen and liquid hydrogen tank

The Intertank, connecting hydrogen and oxygen tank, is 22 feet, 6 inches long by 27 feet, 7 inches wide and its purpose is to distribute all the thrust loads that the Solid rocket boosters produce during launch and flight.

Since, the fuels stored in tank should be at low temperature to prevent explosion, hence these tank requires thermal protection from sunrays and friction due to atmosphere of earth. This is done by a one-inch layer of spray-on foam insulation applied over the forward portion of the liquid oxygen tank, the Intertank and the sides and bottoms of the liquid hydrogen tank.

The foam insulation not only provides insulation from aerodynamic heating and friction heating but also reduces ice formation on the tank, which could increase the weight of the external tank and that can become hazardous to the space shuttle during launch. The ET also contains systems that are necessary for its operation like system to regulate tank pressure, environmental conditioning system, electrical system to provide and distribute power etc.

At launch, ET is attached to orbiter and SRBs. After launch, ET empties about 8.5 minutes after which it gets detached from the orbiter, breaks up and falls on the earth.

Space shuttle main engine- Space shuttle main engine burns a combination of liquid oxygen and liquid hydrogen fed from the space shuttle external tank. The combustion process takes place in two steps, firstly the fuel is burnt at high pressure and low temperature and then it is burned completely at high pressure and high temperature.

Due to this staged burning of fuel, amount of fuel required would be comparatively less and hence, SSME's efficiency to produce thrust is about 99%. The space shuttle main engines are controlled during flight by digital computer systems mounted on each engine.

These operate in conjunction with engine sensors, valve actuators and spark igniters. These devices help in monitoring engine control, checkout and status of the combustion process of fuel.

Each SSME has one main engine controller consisting of two digital computers and their related electronics.

Orbiter-Orbiter is the home of the crew members during the space mission. The major parts of the orbiter are:

1. The Forward Fuselage is made up of lower and upper sections that form a clam like shell around a pressurized crew compartment. It houses the support equipments of crew compartment and supports Orbiter/External Tank attachment etc.

2. The Crew Compartment is a pressurized compartment, intended to support all astronaut activities aboard the Orbiter.

The Crew Compartment has 11 windows, including six forward windows, two overhead rendezvous observation windows, two aft payload bay viewing windows and a single side hatch window. Three panes make up each window. At a total width of nearly three inches, these are the thickest windows ever designed for see-through flight applications.

The Crew Compartment contains three levels, including a flight deck located at the top, a mid deck in the centre and a lower level equipment bay. The Crew Compartment is pressurized at 14.7 pounds per square-inch with an atmosphere of 80% nitrogen and 20% oxygen.

3. The Payload Bay Doors, which are opened shortly after orbit is achieved to allow heat to be released from the Orbiter. The two Payload Bay Doors are hinged at the port of the Midfuselage.

Thermal seals on the Payload Bay Doors provide a relatively airtight environment within the payload bay when the doors are closed. Each Payload Bay Door is 60 feet long by 15 feet wide.

4. The Airlock is typically housed in the crew compartment mid deck. The Airlock is 83 inches long and has a diameter of 63 inches. Two pressurized sealing hatches are contained in the Airlock. Each sealing hatch has a four-inch diameter observation window.

Depending on the mission application, the Airlock can be positioned in either the crew compartment or the payload bay in support of space walk activities.

5. The Wings provide an aerodynamic lifting surface to produce conventional lift and control for the Orbiter. The left and right Wings an intermediate section that includes the main landing gears.

6. The Midfuselage provides a structural interface for the forward fuselage, aft fuselage and wings. It supports the payload bay doors, hinges as well as various Orbiter system components. The Midfuselage provides the structural foundation for the payload bay doors.

7. The Orbital Manoeuvring System/Reaction Control System Pods are attached to the upper aft fuselage left and right sides and contain all of the Orbital Manoeuvring

System (OMS) and Reaction Control System (RCS) propulsion elements that are located at the aft of the Orbiter. (These systems have been explained in the subsystems of space shuttle).

8. The Body Flap provides a thermal shield for the three Space Shuttle Main Engines during re-entry and provides the Orbiter with pitch control trim during atmospheric flight.

9. The Vertical Tail consists of a structural fin surface, a rudder/speed brake surface, a tip and a lower trailing edge. The Vertical Tail provides aerodynamic stability for the Orbiter during flight, and its rudder can be split into two halves to act as a speed brake during landing

10. The Aft Fuselage consists of an outer shell, thrust structure and internal secondary structure. The Aft Fuselage supports and interfaces with the orbital manoeuvring system/reaction control system pods.

The Aft Fuselage also supports and interfaces with the wings, Midfuselage, Orbiter/External Tank rear attachments, Space Shuttle Main Engines, aft heat shield, body flap, vertical tail and two pre-launch umbilical panels.

The Aft Fuselage outer shell allows access to systems installed within the structure. The Aft Fuselage thrust structure supports the three Space Shuttle Main Engines and their hardware. The internal secondary structure houses hardware and wiring for auxiliary power unit, hydraulics, ammonia boiler and flash evaporator systems.

Mission Stages

As we now have an idea about the construction and working of shuttles. Let us see the various steps involved in launching a shuttle, orbiting it around a planet/moon and then bringing the shuttle safely to earth.

**** Ascent***

Pre-launch preparation- As the shuttle rests on the pad fully fuelled, it weighs about 4.5 million pounds or 2 million kg and it is supported on the solid rocket boosters (explained in construction of shuttle). The pre-launch preparations begin at T minus 31 seconds:

1. T minus 31 s - the on-board computers take over the launch sequence.
2. T minus 6.6 s - the shuttles main engines are ignited one at a time (0.12 s apart). The engines build up to more than 90 percent of their maximum thrust.
3. T minus 3 s - shuttle main engines are in lift-off position.
4. T minus 0.3 s -the SRBs are ignited and the shuttle lifts off the pad.

First stage- The first stage extends from the SRB ignition to its separation.

The space shuttle lifts off the pad at 0.3s after the SRB ignition and rises vertically in altitude till it is approximately at a height of 41 feet. The vehicle manoeuvres into position with the orbiter head down, with wings level and aligned with the launch pad. The orbiter flies upside down during the ascent phase. SRB separation occurs six seconds after the SRB separation sequence software detects both SRB chamber pressures below 50 psi (pound per square inch). At SRB separation, the first stage is complete, and the software automatically shifts to second stage.

Second Stage- Second-stage ascent begins at SRB separation and extends up until main engine cut-off and external tank separation. The main engines are commanded to begin throttling at 10-percent thrust per second to 65-percent thrust. This is held for approximately 6.7 seconds, and the engines are shut down. The vehicle altitude is frozen. During this time a signal is generated which confirms that main engine has been shutdown.

The external tank software sends the commands to close the 17-inch orbiter/external tank line feeding liquid oxygen and hydrogen and disconnects valves. The onboard general-purpose computers perform ET separation automatically.

During second-stage ascent, the flight crew monitors the onboard systems to ensure that the major events occur correctly and on time.

At time t plus 10.5 minutes orbital manoeuvring system (OMS) engine fires to place the space shuttle into low earth orbit and at time t plus 45 minutes OMS engine fires again to place the vehicle into higher, circular orbit.

The space shuttle is now in outer space and continues with its mission.

Abort modes

Sometimes it may become necessary to abort the mission if a there is a failure that affects the vehicle performance such as failure of main engine or orbital manoeuvring system failure.

There are two basic types of ascent abort modes for space shuttle missions:

- <u>Intact aborts</u>
- Contingency aborts.

An intact abort would provide a safe return of the orbiter to a planned landing site. On the other hand a contingency abort is designed to permit the crew to survive severe failures when an intact abort is not possible.

Orbit insertion

This stage helps to insert the shuttle (orbiter) into the planet's orbit to carry out the mission.

The orbiter's velocity and altitude are varied depending upon the mission's requirement. Two thrusting periods help to boost the orbiter to the orbit. The first thrusting period is referred to as OMS-1 and boosts the orbiter to the desired apogee (farthest point from the earth); the second thrusting period is called OMS-2 and it circularizes the orbit.

The optimal orbital altitude (the altitude that satisfies mission and payload goals) is determined before launch. To achieve the orbit computer maintains an accurate targets and initiates manoeuvres to specified attitudes and positions. These activities are planned with several constraints in mind, including fuel consumption, vehicle thermal limits, payload requirements and rendezvous/proximity operations considerations.

Deorbit

After the shuttle has completed its mission, to return back to earth it has to deorbit- i.e. free itself from the influence of planet's gravity.

In returning home, the orbiter must be sufficiently decelerated by an OMS (Orbital manoeuvring system) so that when it enters the atmosphere, it maintains control and glides to the landing site. For the nominal end of mission, a retrofiring of approximately 2.5 minutes is performed at the appropriate point in the vehicle's trajectory. For this manoeuvre, the orbiter is positioned in a tail-first thrusting attitude. Deorbit thrusting is nominally accomplished with the two OMS engines.

About one hour before deorbit, the crewmembers take their seats. The spacecraft is then manually manoeuvred to the deorbit attitude. About 30 minutes before deorbit, the OMS is prepared for deorbit thrusting.

The deorbit phase of the mission includes deorbit preparations, execution and monitoring, and manoeuvring to approximately 400,000 feet. This point is called the entry interface.

Entry

After the space shuttle has reached the entry interface, the next step is to enter the earth's atmosphere and ensure a safe landing.

Overcoming gravity is one of the important problems while getting into space. While coming back, space shuttle must lose speed instead of gaining it. During entry, space shuttle has to slow down considerably. There are 2 possible ways of landing:

> **Vertical landing**- A space shuttle will land with help of rocket power generated by fuel. There is one disadvantage of vertical landing. That it cannot use the atmosphere alone to slow down. Parachutes and parasail have to be employed, but they will help only for small capsules. Splitting it into two parts at the time of re-entry can bring down a large vehicle. Each part can be brought separately with the help of parachute.
>
> **Horizontal landing**- this technique effectively utilizes the atmosphere for landing. It has been used in the U.S. space shuttle since 1981.

Future Space Travel

Today the applications of space travel have increased. All this is due to the refined technologies and advancements made in the design of space shuttles. Keeping in mind all these factors the future of space travel is glorious. The applications of space travel are very much beyond our wildest imaginations.

The day may come when human beings explore and inhabit the distant reaches of space and unravel the mysteries of the universe and of life within it. Let us have a look at these possibilities, which may be possible in near future. Some of them include:

- Inflatable spacecraft
- Self-healing spacecraft
- Space elevator
- Space Power
- Space Colonies
- Space Tourism

(http://library.thinkquest.org/03oct/02144/basics/univ.htm)