Chapter 9. Spacecraft Classification

Objectives: Upon completion of this chapter you will be able to state the characteristics of various types of spacecraft: flyby spacecraft, orbiter spacecraft, atmospheric probe spacecraft, penetrator spacecraft, lander and surface rover spacecraft, and balloon experiments. You will be able to categorize several of JPL's spacecraft.

Spacecraft designed and constructed to achieve science data gathering are specialized systems intended to function in a specific hostile environment. Their complexity varies greatly. They may be broadly categorized according to the missions they are intended to fly. This chapter identifies a selection of different classifications.

Flyby Spacecraft

Flyby spacecraft follow a continuous trajectory, never to be captured into a planetary orbit. They must have the capability of using their instruments to observe passing targets, and ideally, compensating for the target's apparent motion in optical instruments' field of view. They must downlink data at high rates to Earth, storing data onboard during the periods when their antennas are off Earthpoint. They must be able to survive for many years of long interplanetary cruise. Examples of flyby spacecraft include Pioneers 10 and 11, Voyagers 1 and 2 (each of which have achieved solar escape velocity), and the Pluto fast-flyby mission currently being considered. Flyby spacecraft were used in the initial reconnaissance phase of solar system exploration.

Orbiter Spacecraft

A spacecraft designed to travel to a distant planet and enter into orbit must carry with it a substantial propulsive capability to decelerate it at the right moment to achieve orbit insertion. It has to be designed to live with the fact that solar occultations will occur wherein the planet shadows the spacecraft, cutting off solar panels' production of electrical power, and subjecting the vehicle to extreme thermal variation. Earth occultations will also occur, cutting off uplink and downlink communications with Earth. Orbiter spacecraft are being used in the second phase of solar system exploration, following up the initial reconnaissance with in-depth study of the planets. These include Magellan, Galileo, Mars Global Surveyor, and Cassini.

Atmospheric Probe Spacecraft

Some missions employ one or more smaller instrumented craft which separate from the main spacecraft prior to closest approach to a planet to study the gaseous atmosphere of the body as it drops through it. The atmospheric probe spacecraft is deployed by the release of springs or other devices that simply separate it from the mother ship without making significant modification to its trajectory. The mother ship typically would then execute a trajectory correction maneuver to prevent its own atmospheric entry so that it can continue on with other mission activities.

An aeroshell protects the atmospheric probe spacecraft from the thousands of degrees of heat created by atmospheric friction during entry. The shell is ejected, and a parachute then slows the craft's descent while it undertakes its agenda of scientific observations. Data are typically telemetered from the atmospheric probe to the mother craft where they are recorded onboard for later transmission to Earth.

Galileo, the Jupiter orbiter spacecraft, carried an atmospheric probe that descended into Jupiter's atmosphere during the orbiter's first pass over the planet. The Pioneer 13 spacecraft carried four atmospheric probes which radioed their data directly to Earth during descent into the Venusian atmosphere. Cassini, being designed to orbit Saturn, will carry a probe to be released into the hazy nitrogen atmosphere of Titan, Saturn's largest satellite.

Atmospheric Balloon Packages

Balloon packages are designed for suspension from a buoyant gas bag to float and travel with the wind. Tracking of the balloon's progress across the face of a planet yields data on the circulation of the planet's atmosphere. They have a limited complement of spacecraft subsystems aboard: for example, they may have no need for propulsion subsystems or attitude and articulation control system (AACS) subsystems at all. They do require a power supply, which may simply be batteries, and telecommunications equipment to permit tracking. They may also be outfitted with instrumentation for direct-sensing science experiments to take measurements of an atmosphere's composition, temperature, pressure, density, cloud content and lightning.

Lander Spacecraft

Lander spacecraft are designed to reach the surface of a planet and survive long enough to telemeter data back to Earth. Examples have been the highly successful Soviet Venera landers which survived the harsh conditions on Venus while carrying out chemical composition analyses of the rocks and relaying color images, JPL's Viking landers at Mars, and the Surveyor series of landers at Earth's moon, which carried out similar experiments. The Mars Pathfinder project, which launches in 1996, is intended to be the first in a series of landers on the surface of Mars at widely distributed locations to study the planet's atmosphere, interior, and soil. A system of actively-cooled, long-lived Venus landers designed for seismology investigations, is being studied for a possible future mission.

Surface Penetrator Spacecraft

Surface penetrators have been designed for entering the surface of a body, such as a comet, surviving an impact of hundreds of Gs, measuring, and telemetering the properties of the penetrated surface. Penetrator data would typically be telemetered to the mother craft for re-transmission to Earth. The Comet Rendezvous / Asteroid Flyby (CRAF) mission included a cometary penetrator, but the mission was cancelled in 1992 due to budget constraints. Plans for the Russian MARS '98 mission include a surface penetrator craft.

Surface Rover Spacecraft

Electrically-powered rover spacecraft are being designed and tested by JPL as part of the Mars exploration effort. Mars Pathfinder includes a small mobile instrument (rover) to be deployed on Mars. Mars rovers are also being developed by Russia with a measure of support from The Planetary Society. These rover craft will be semi-autonomous, and will be steerable from Earth, taking images and soil analyses for telemetering back to Earth.

Recap

1. ____________________ spacecraft follow a continuous trajectory, never to be captured into a planetary orbit.
2. A spacecraft designed to travel to a distant planet and enter into orbit must carry with it a substantial ______________________ capability to decelerate.
3. An aeroshell protects the __________________ _____________ spacecraft from the thousands of degrees of heat created by atmospheric friction during entry.
4. Balloon packages... have a _________________ complement of spacecraft subsystems aboard.
5. _______________ spacecraft are designed to reach the surface of a planet and survive long enough to telemeter data back to Earth.

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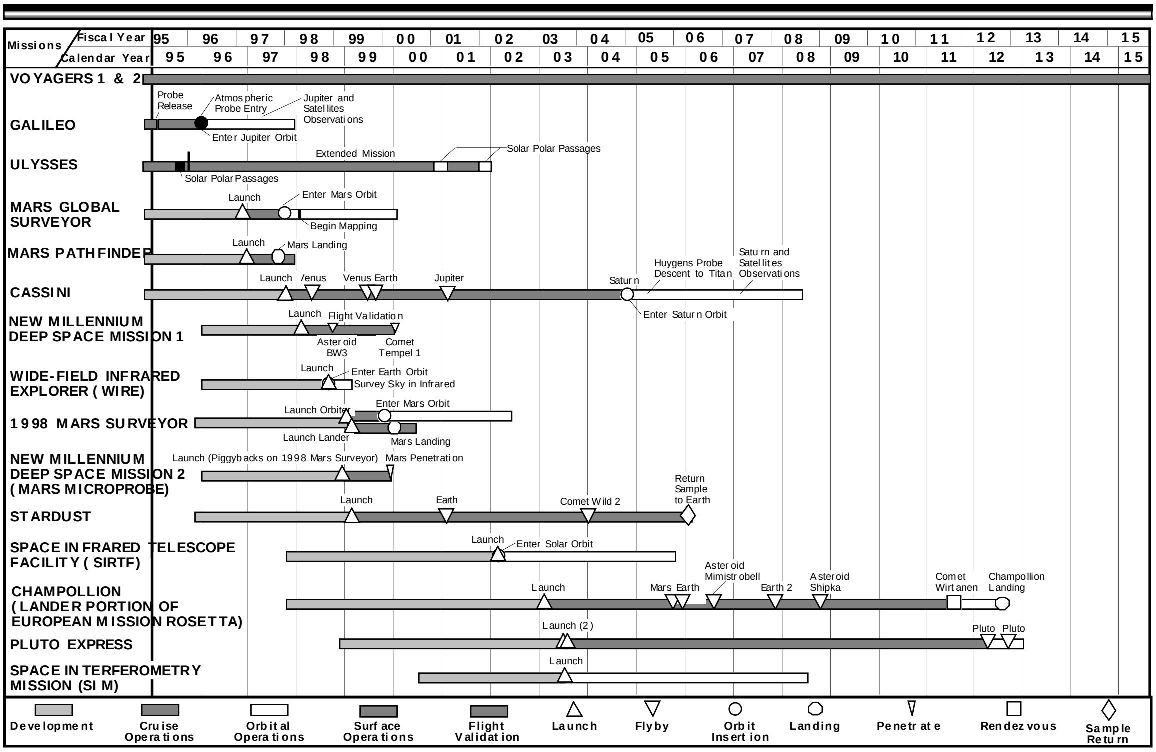
1. Flyby *2. propulsive* *3. atmospheric probe* *4. limited* *5. Lander*

The following is a list of space flight projects currently funded at JPL as of fiscal year1996. Drawings on subsequent pages illustrate a sampling of various classifications of spacecraft connected with JPL in the past, present, and future. These drawings are not to scale with each other. Detailed models of many of them, as well as other spacecraft, may be found in the Von Kármán Museum, JPL Building 186, and in the Spacecraft Assembly Facility (SAF) north viewing gallery, Building 179.

Current Space Science Missions at JPL:



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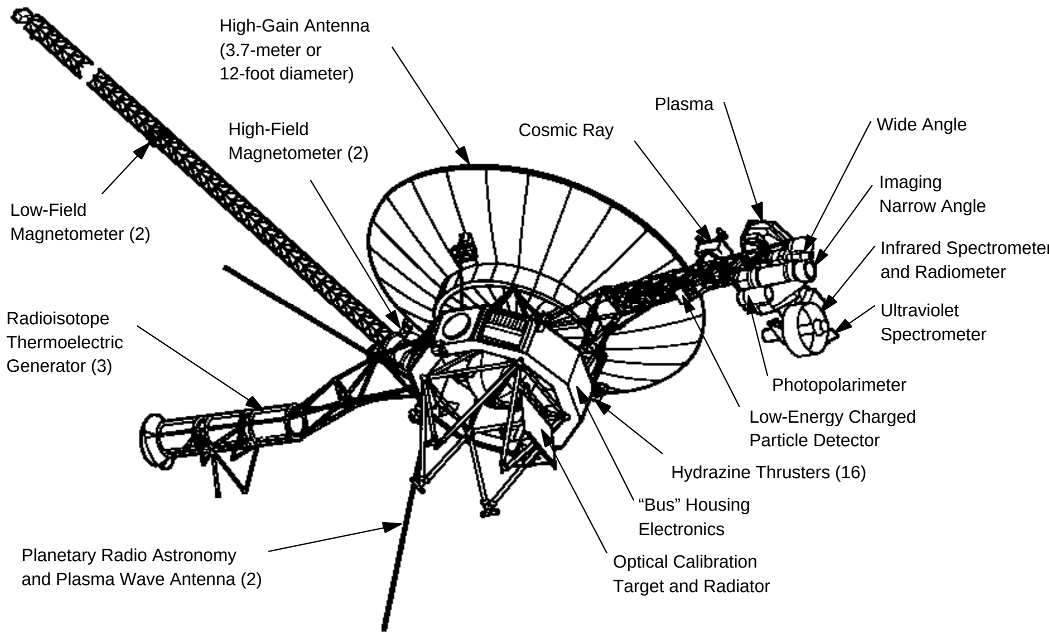
Projects Currently Being Studied at JPL:

To be added.

Voyagers 1 & 2



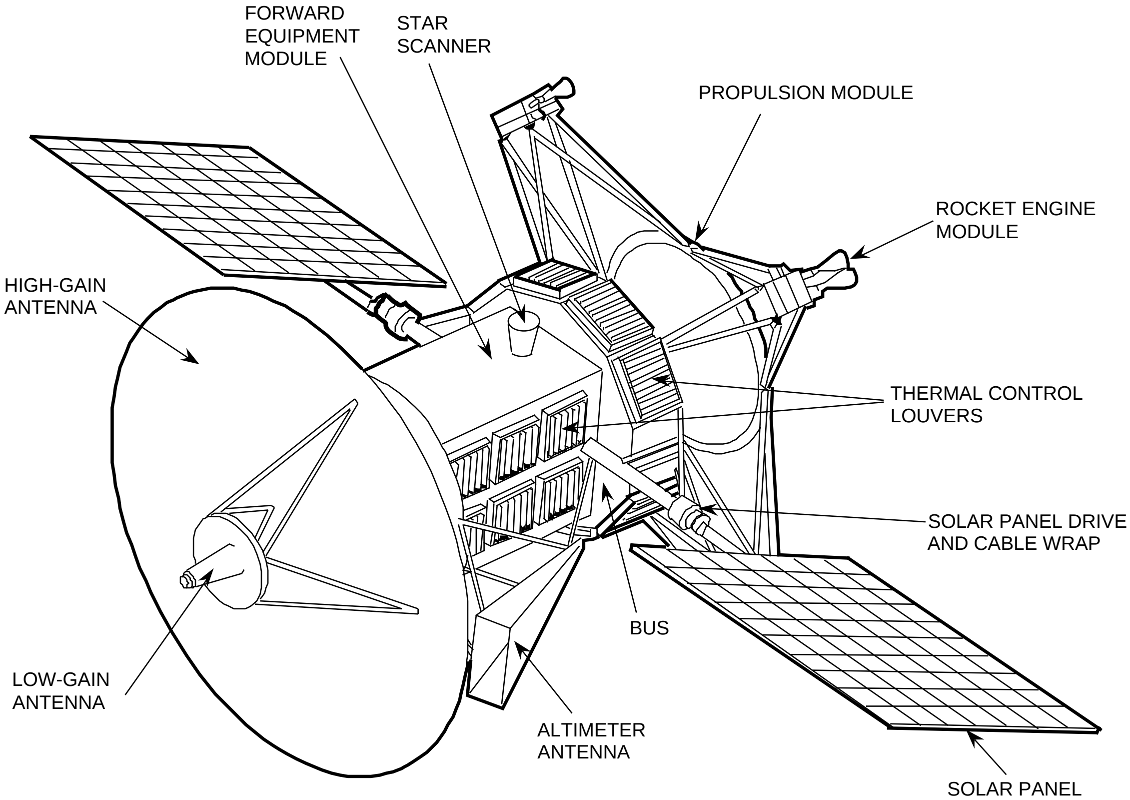
Classification: Flyby spacecraft

Mission: Jovian planets and interstellar space

Features: The Voyager 1 and Voyager 2 spacecraft were launched in late 1977 aboard Titan III launch vehicles with Centaur upper stages. They completed highly successful prime mission flybys of Jupiter in 1979 and Saturn in 1980 and 1981. Voyager 2's extended mission succeeded with flybys of Uranus in 1986 and Neptune in 1989. Both spacecraft are still healthy in 1995, and are conducting studies of interplanetary space enroute to interstellar space. Voyager 1 and Voyager 2 recently identified low frequency radio emissions from the heliopause, estimated to be about 50 AU away from the spacecraft. Science data return is expected to continue well into the next century.

Stabilization: Three-axis stabilized via thrusters.

Magellan



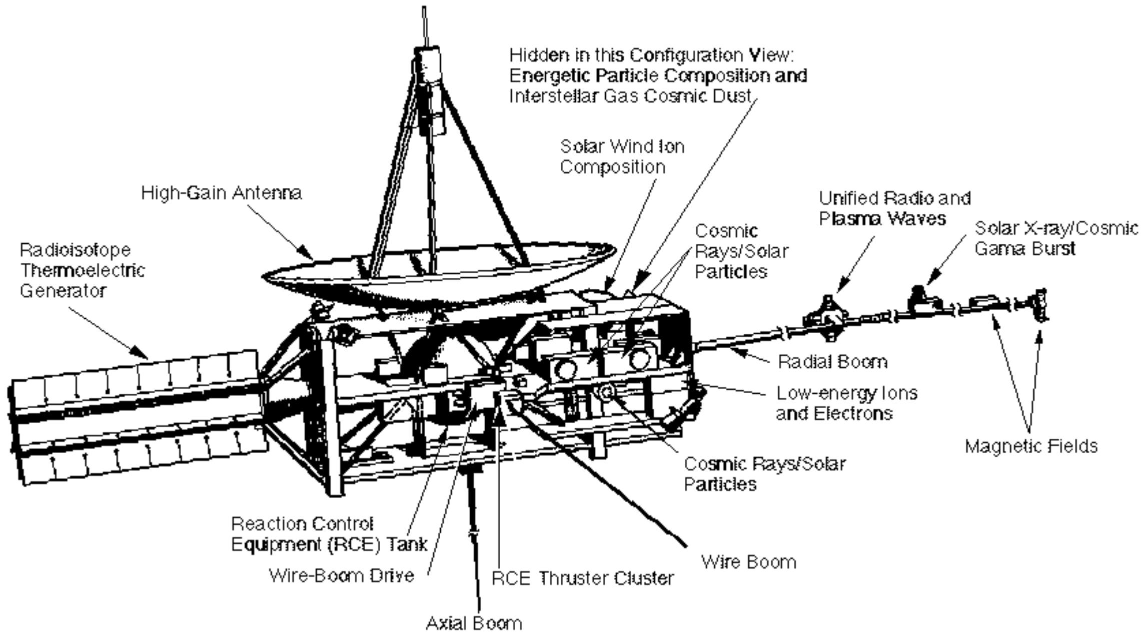
Classification: Orbiter spacecraft

Mission: Venus mapping

Features: The Magellan spacecraft was launched in early 1989 via the Space Shuttle Atlantis and an IUS upper stage. By the end of its fourth Venus-rotation cycle (243 days each) four years after launch, Magellan had mapped 98% the surface of Venus with imaging, altimetry, and radiometry, performed several radio science experiments, and had surveyed the gravity field at low latitudes all the way around the planet. The imaging resolution was about 100 m, close enough to discern the various geologic processes for the first time. Magellan's periapsis was lowered into Venus's atmosphere for a thousand orbits, aerobraking into a nearly circular orbit. Magellan's periapsis was then raised out of the atmosphere, and it completed high-resolution mapping of the planet's gravity field from low circular orbit. Magellan was then intentionally flown to its destruction in Venus's atmosphere in October 1994, all the while carrying out additional experiments.

Stabilization: Three-axis stabilized via reaction wheels and thrusters.

Ulysses



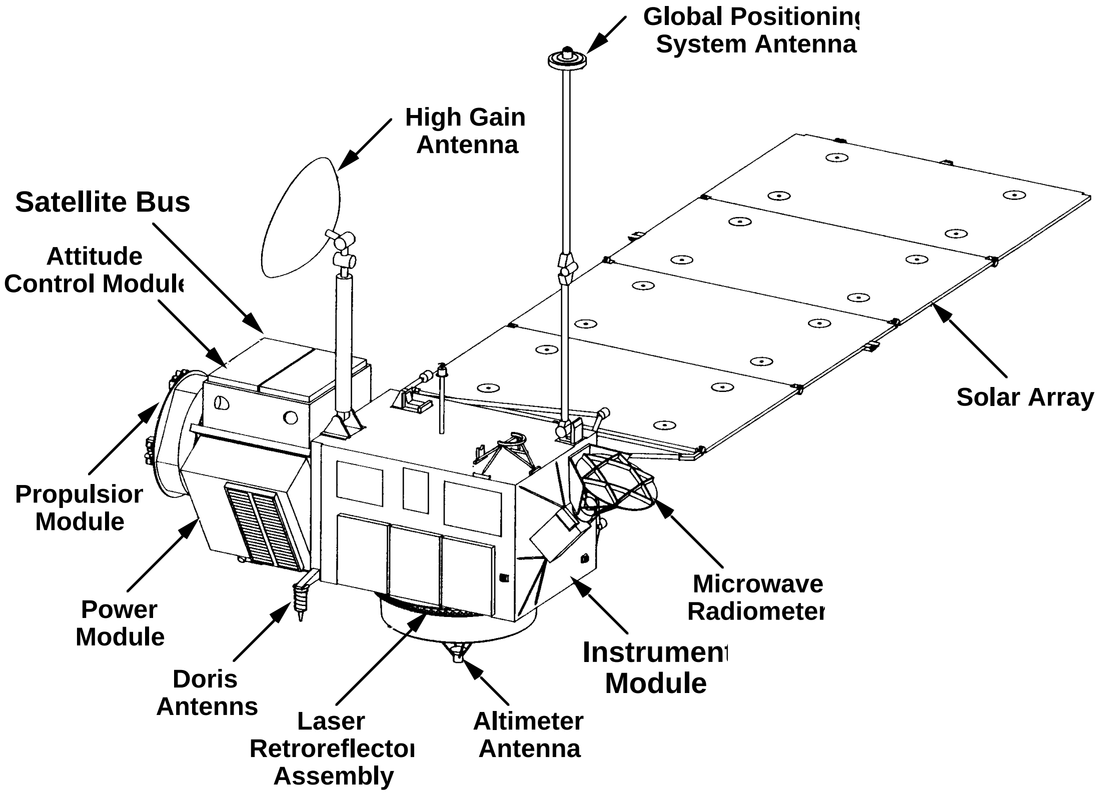
Classification: Orbiter spacecraft

Mission: Study the sun from solar polar latitudes

Features: The Ulysses spacecraft is a joint project between NASA and the European Space Agency (ESA). It was launched in late 1990 via the Space Shuttle with an IUS upper stage and Payload Assist Module (PAM-S). It encountered Jupiter early in 1992 for a gravity assist to achieve a trajectory at nearly right angles to the ecliptic plane. It explored the Sun's high southern latitudes during June through October 1994. It passed over the Sun's north polar region between June and September 1995. At no time will it approach less than 1 AU from the sun. While within Jupiter's environs for its gravity assist, it made significant observations of the Jovian system. Ulysses carries fields and particles instruments. Its U.S. counterpart, a second spacecraft with imaging instruments, designed to travel simultaneously over the opposite Solar poles, was cancelled by the U.S.

Stabilization: Spin stabilized.

TOPEX/Poseidon



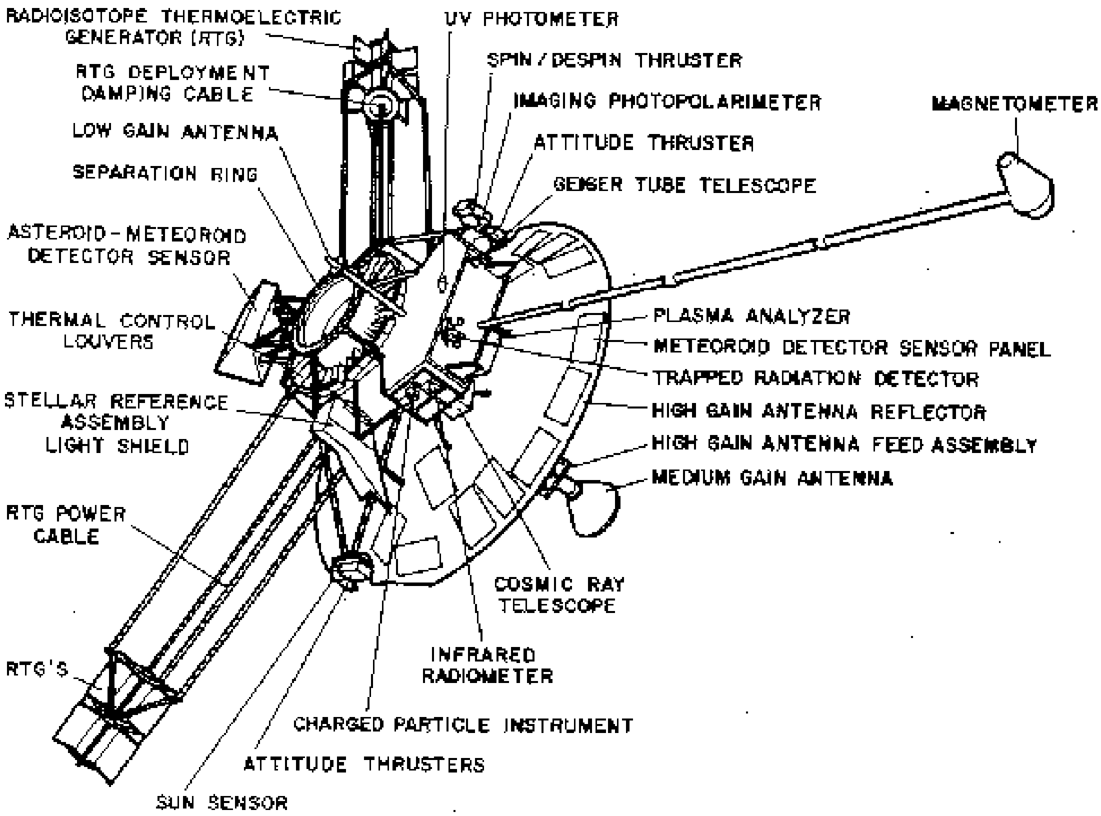
Classification: Orbiter spacecraft

Mission: Global view of Earth’s oceans

Features: Topex/Poseidon is a joint project between NASA and Centre National d’Études Spatiales (CNES) launched in mid 1992 aboard an Ariane 4. The spacecraft occupies a 1336-km-high Earth orbit inclined 66°. Revealing minute differences in the oceans’ heights, Topex/Poseidon’s data should lead to improved understanding of oceanic circulation and forecasting of global environment.

Stabilization: Three-axis stabilized via reaction wheels and thrusters.

Pioneers 10 & 11



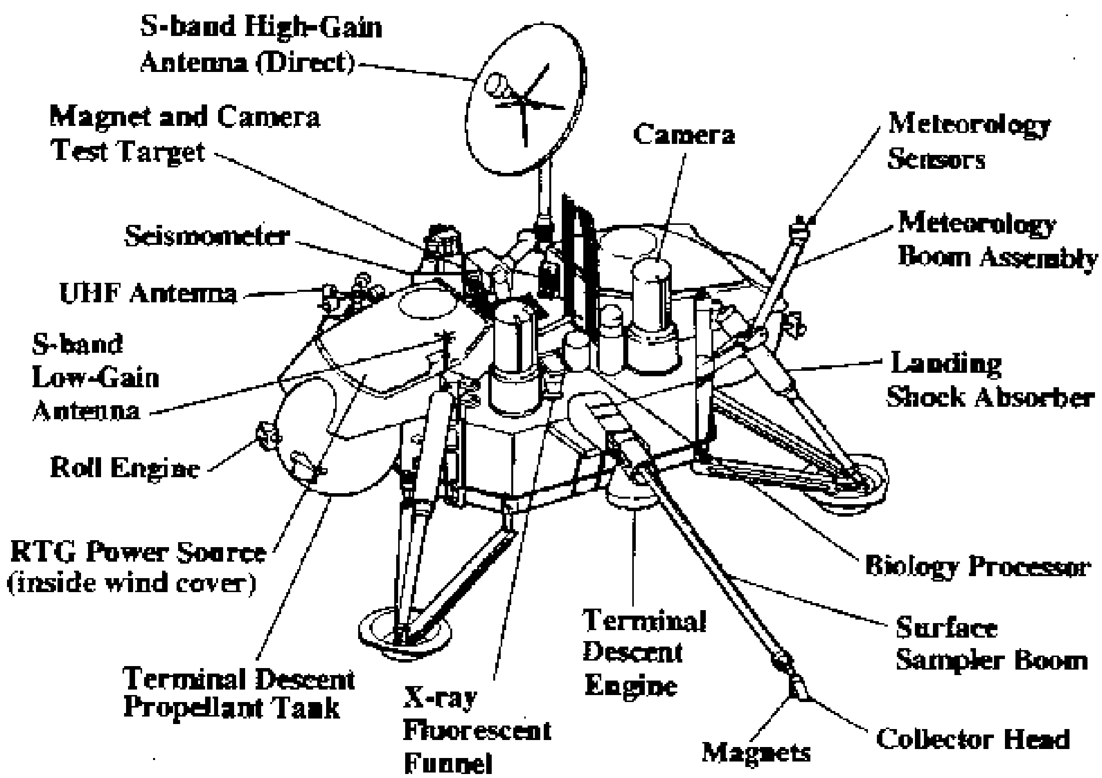
Classification: Flyby spacecraft

Mission: Jupiter, Saturn, and interstellar space

Features: Pioneer 10 and 11 launched in 1972 and 1973, and penetrated the asteroid belt. Pioneer 10 was the first spacecraft to study Jupiter and its environment, and obtain spin-scan images of the planet. Pioneer 11 also encountered Jupiter, and went on to become the first to encounter Saturn, its rings and moons. Pioneer 10 and 11 are still operative in the far reaches of the outer solar system, and are still being tracked in November 1995. Pioneer 11 has run out of sufficient electrical power to continue operations and is expected to lose communications with Earth within a few months. It is likely that Pioneer 10 will follow suit within a few years.

Stabilization: Spin stabilized.

Viking Lander

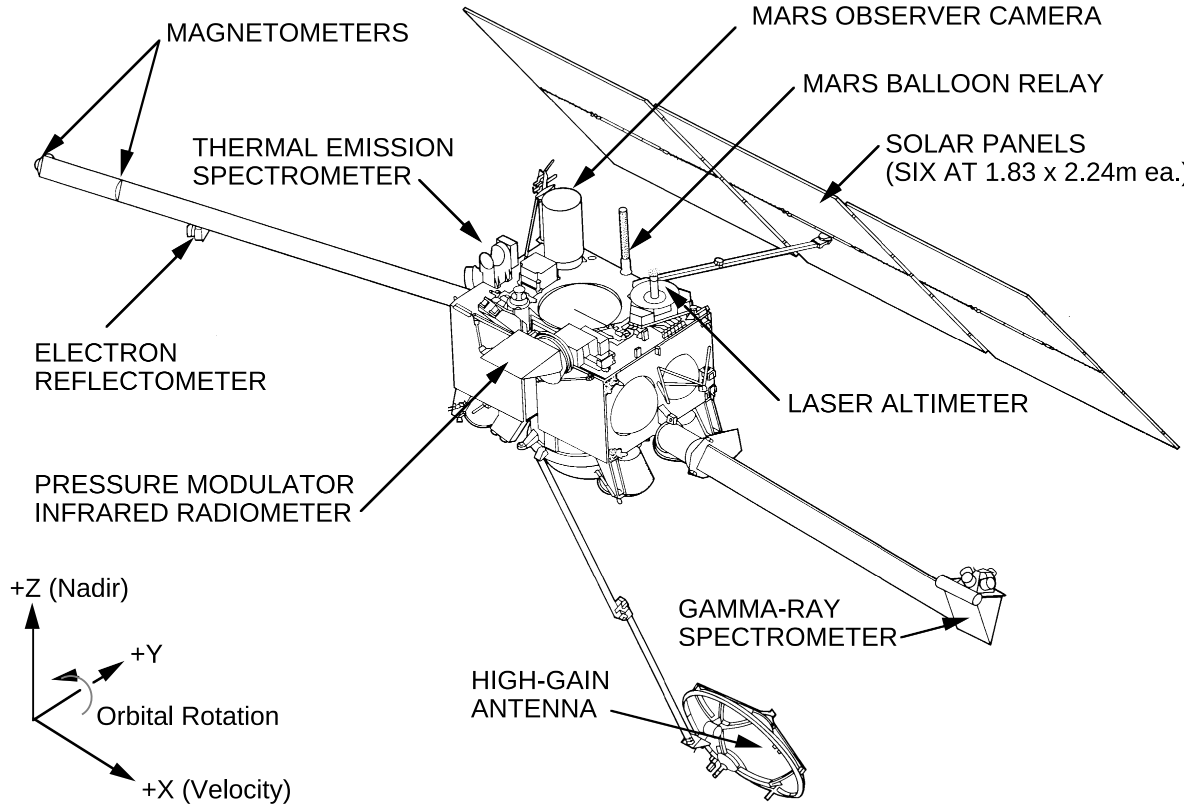


Classification: Lander spacecraft

Mission: Survey Martian landscape

Features: The Viking Lander 1 spacecraft touched down on Mars in July 1976, followed by the Viking 2 Lander the following month. These automated scientific laboratories photographed their surroundings, and gathered data on the structure, surface, and atmosphere of the planet, and carried out an investigation into the possibility of past and present life forms.

Mars Observer



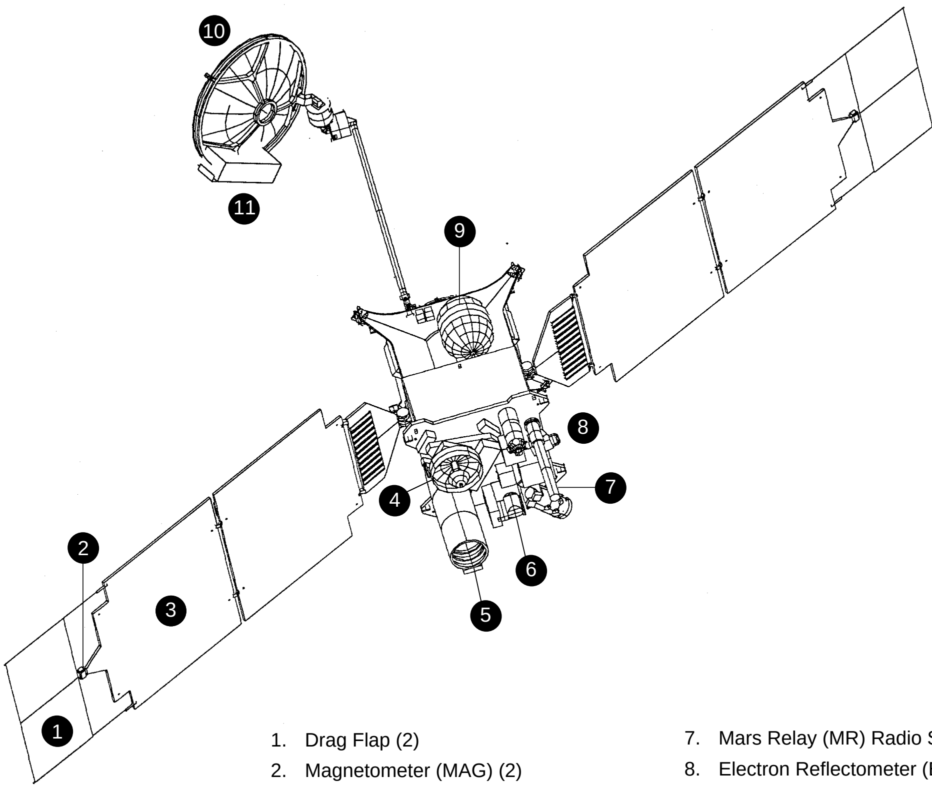
Classification: Orbiter spacecraft

Mission: Mars mapping

Features: The Mars Observer spacecraft was launched in 1992 aboard a Titan III with a Transfer Orbit Upper Stage. Unfortunately, communications with the spacecraft were lost just before its orbit insertion maneuver. Based upon the design for an Earth-orbiting spacecraft, it was to observe Mars for one continuous Martian year (687 Earth days), studying surface mineralogy and morphology, topography, atmospheric circulation and the movement of water, dust, fog and frost. It was to characterize the gravitational field and the magnetic field. It also would have provided Earth relay capability for Russian landers and the Mars Balloon.

Stabilization: Three-axis stabilized via reaction wheels and thrusters.

Mars Global Surveyor



1. Drag Flap (2)
2. Magnetometer (MAG) (2)
3. Solar Array (4 Panels)
4. Mars Orbiter Laser Altimeter (MOLA)
5. Mars Orbiter Camera (MOC)
6. Thermal Emission Spectrometer (TES)
7. Mars Relay (MR) Radio System
8. Electron Reflectometer (ER)
9. Propellant Tank (3)
10. High-Gain Antenna/Radio Science Investigation
11. Radio-Frequency Power Amplifiers

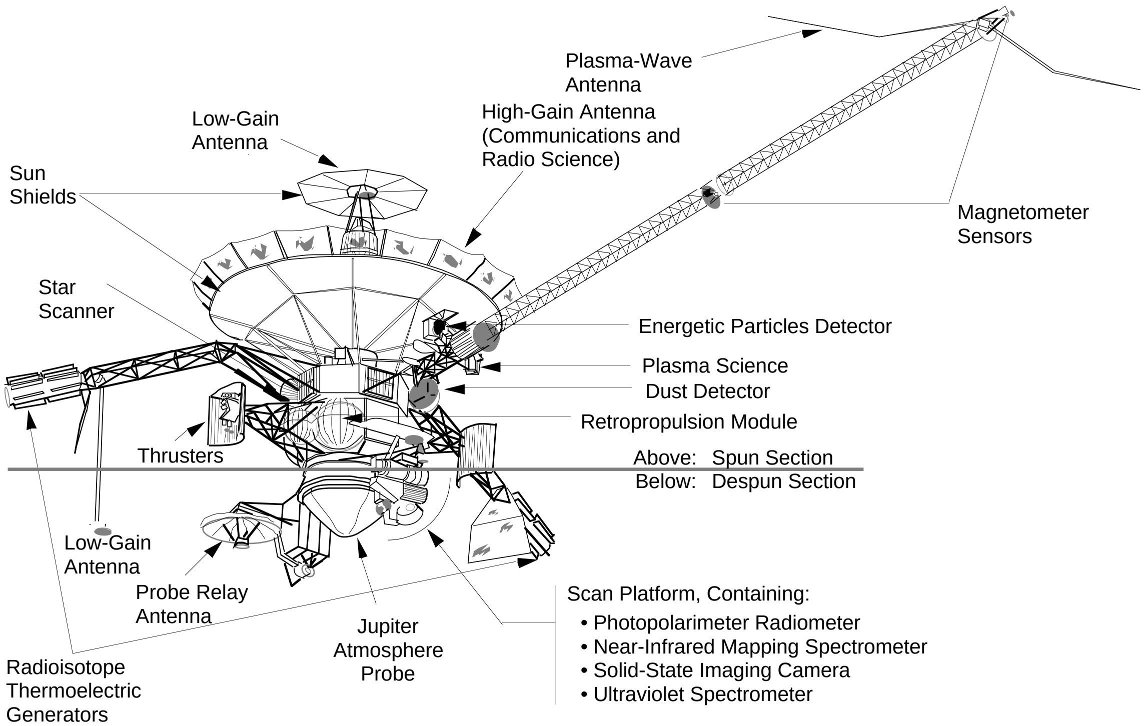
Classification: Orbiter spacecraft.

Mission: Mars mapping

Features: The Mars Global Surveyor spacecraft will be launched in November 1996 on a Delta 7925 launch vehicle. It will carry all but two of the eight science instruments that were aboard Mars Observer, providing high-resolution, global maps of the Martian surface, profiling the planet's atmosphere, and studying the nature of the magnetic field. Mars Global Surveyor will take ten months to reach Mars, entering a polar orbit around the planet in September 1997.

Stabilization: Three-axis stabilized via reaction wheels and thrusters.

Galileo Orbiter



Classification: Orbiter spacecraft

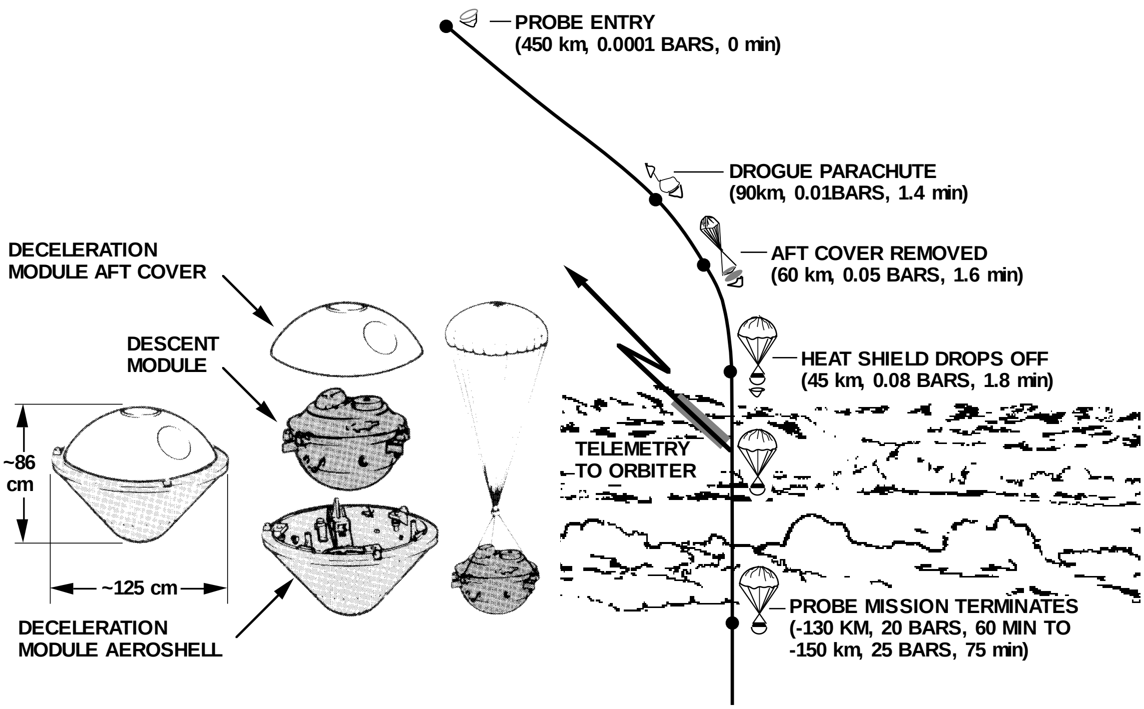
Mission: Investigate Jupiter's atmosphere, magnetosphere, and satellites.

Features: Galileo was launched aboard the Space Shuttle in October 1989. It executed science observations during gravity-assist flybys of Venus and Earth, as well as during two asteroid flybys. It observed Comet Shoemaker-Levy 9's impact with Jupiter in July 1994. Galileo entered Jovian orbit December 1995 shortly after receiving the data from its atmospheric probe, which entered Jupiter's atmosphere.

Stabilization: Spin stabilized.

Note: See also the detailed foldout illustration of the Galileo Orbiter in Chapter 11.

Galileo Atmospheric Probe



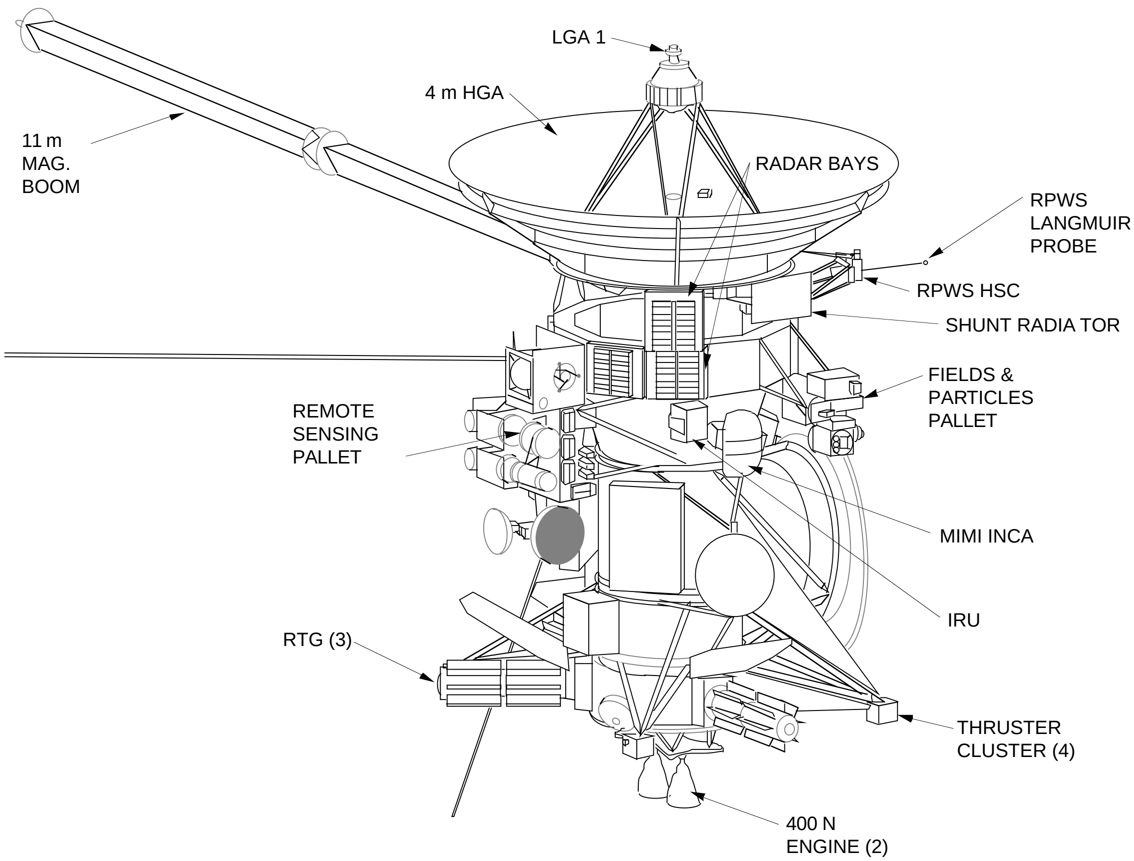
Classification: Atmospheric probe spacecraft

Mission: Investigate Jupiter's atmosphere

Features: The Galileo Atmospheric Probe was released from the Galileo orbiter spacecraft in July 1995, about 100 days before arrival at Jupiter. Atmospheric entry took place on 7 December 1995 as the orbiter tracked the probe and recorded its data for later relay to Earth. Probe instruments investigated the chemical composition and the physical state of the atmosphere. The probe returned data for just over an hour before it was overcome by the pressure of Jupiter's atmosphere.

Stabilization: Spin stabilized.

Cassini



Classification: Orbiter spacecraft

Mission: Explore Saturnian system

Features: Cassini is scheduled for launch aboard a Titan IV with a Centaur upper stage in 1997. It will encounter Venus, Earth and Jupiter for gravity assists, and will reach Saturn in 2004. It will spend four years conducting a detailed examination of Saturn's atmosphere, rings, and magnetosphere, and close-up studies of its satellites. It will radar map portions of Titan's surface. Cassini will also carry the Huygens probe which will be deployed into the atmosphere of Titan.

Stabilization: Three-axis stabilized via reaction wheels and thrusters.