Spacecraft

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Spacecraft

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Lageos		Earth satellite
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Luna 6	Jun. 8/65	Moon
Luna 7	Oct. 4/65	Moon
Luna 8	Dec. 3/65	Moon
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Luna 12	Oct. 22/66	Moon
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Mars 3	May 28/71	Mars
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Nadezhda 2 Rocket/Body		Earth satellite
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NOAA 7		Earth satellite
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OAO 1		Earth satellite
OAO 1 Rocket/Body		Earth satellite
OAO 2		Earth satellite
OAO 2 Rocket/Body		Earth satellite
Okean 1		Earth satellite
Okean 2		Earth satellite
Orizuru (Debut)		Earth satellite
Pageos DA		Earth satellite
Pageos H		Earth satellite
Pageos Rocket/Body		Earth satellite
Palapa 4 Rocket/Body		Earth satellite
Palapa 6 Rocket/Body		Earth satellite
Pegsat		Earth satellite
Phobos 1	Jul. 7/88	Mars

Phobos 2	Jul. 12/88	Mars
Pioneer 1	Oct. 11/58	Moon
Pioneer 2	Nov. 8/58	Moon
Pioneer 3	Dec. 6/58	Moon
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Pioneer 6	Dec. 16/65	Sun
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Pluto Fast Flyby	1999	Pluto
Polar Bear		Earth satellite
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Ranger 4	Apr. 23/62	Moon
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Ranger 6	Jan. 30/64	Moon
Ranger 7	Jul. 28/64	Moon
Ranger 8	Feb. 17/65	Moon
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RME		Earth satellite
Rosat		Earth satellite
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Sakura Rocket/Body		Earth satellite
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Seasat		Earth satellite
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Sirio Rocket/Body		Earth satellite
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Solrad 7B/Secor 3 Rocket/Body		Earth satellite
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Starlette		Earth satellite
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Surveyor 3	Apr. 17/67	Moon
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UME 2 Rocket/Body		Earth satellite

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Vanguard 1 Rocket/Body		Earth satellite
Vanguard 3		Earth satellite
Vega 1	Dec. 15/84	Venus, Comet Halley
Vega 2	Dec. 21/84	Venus, Comet Halley
Venera 1	Feb. 21/61	Venus
Venera 2	Nov. 12/65	Venus
Venera 3	Nov. 16/65	Venus
Venera 4	Jun. 12/67	Venus
Venera 5	Jan. 5/69	Venus
Venera 6	Jan. 10/69	Venus
Venera 7	Aug. 17/70	Venus
Venera 8	Mar. 27/72	Venus
Venera 9	Jun. 8/75	Venus
Venera 10	Jun. 14/75	Venus
Venera 11	Sep. 9/78	Venus
Venera 12	Sep. 14/78	Venus
Venera 13	Oct. 30/81	Venus
Venera 14	Nov. 4/81	Venus
Venera 15	Jun. 2/83	Venus
Venera 16	Jun. 7/83	Venus
Viking 1	Aug. 20/75	Mars
Viking 2	Sep. 9/75	Mars
Voyager 1	Sep. 5/77	Jupiter, Saturn, and moons of these 2 planets.
Voyager 2	Aug. 20/77	Jupiter, Saturn, Uranus, Neptune, and their moons.
Westar 6 Rocket/Body		Earth satellite
Yuri Rocket/Body		Earth satellite
Zond 1	Apr. 2/64	Venus
Zond 2	Nov. 30/64	Venus
Zond 3	Jul. 18/65	Moon
Zond 4	Jul. 18/65	Moon
Zond 5	Sep. 14/68	Moon
Zond 6	Nov. 10/68	Moon
Zond 7	Aug. 8/69	Moon

1.2 Able 1

Able 1 (38 kg) was a US spacecraft intended to go into lunar orbit. Its launch on August 17, 1958 was unsuccessful.

1.3 Able 4

Able 4 (169 kg) was a US spacecraft intended to go into lunar orbit. Its launch on November 26, 1959 was unsuccessful.

1.4 Able 5A

Able 5A (176 kg) was a US spacecraft intended to go into lunar orbit. A launch was attempted on September 25, 1960, but it was unsuccessful.

1.5 Able 5B

Able 5B (176 kg) was a US spacecraft intended for lunar orbit. Its launch on December 15, 1960 was unsuccessful.

1.6 Apollo 7

Apollo 7 was the first in the Apollo series of manned missions to the Moon. Apollo 7 never flew to the Moon itself, but rather served to prove the concept of a 3-man spacecraft in Earth orbit. Launched by the USA on October 11, 1968, it circled the Earth 163 times over a period of 10 days, 20 hours, 9 minutes before landing safely.

Apollo 7 was commanded by Wally Schirra and also carried R. Walter Cunningham and Donn F. Eisele.

1.7 Apollo 8

Apollo 8 (28883 kg) was launched on December 21, 1968 as the first manned flight to the Moon and back. Apollo 8 never landed on the surface of the Moon, but rather observed the Moon from orbit. The distinction of being the first manned landing on the Moon was to be reserved for Apollo 11.

Apollo 8 was originally intended to test Apollo equipment from within Earth orbit, as Apollo 7 had done. However, due to the successes of Apollo 7, permission was granted to allow Apollo 8 to make the first manned circumlunar flight. The public's reaction to this decision was very enthusiastic.

Commanded by Frank Borman, Apollo 8 carried him and fellow astronauts William Anders and James Lovell, Jr. on a flight that orbited the Moon 10 times on Christmas Eve and Christmas Day. The crew became the first human beings to travel around a celestial body other than the Earth. In all, the flight lasted 6 days, 3 hours, and 1 minute, ending in a successful splashdown in the Pacific Ocean. The landing craft may now be viewed at the Museum of Science & Industry in Chicago.

The crew of Apollo 8 took a dramatic picture of the Earth rising over the lunar horizon while in orbit 160 km above the surface of the Moon. In the picture, the Earth is more than 386,000 km away with Africa at the bottom of the daylight area.
View Picture from Apollo 8

1.8 Apollo 9

Apollo 9 was launched on March 3, 1969 with J. McDivitt, R. Schweickart, and David Scott on board. Unlike most of the other Apollo flights, Apollo 9 did not travel to the Moon. Instead, it orbited the Earth 151 times for a flight that lasted 10 days, 1 hour, and 1 minute.

The Apollo 9 capsule can be viewed at the Norwegian Technical Museum in Oslo, Norway.

1.9 Apollo 10

Apollo 10 (42530 kg) was launched on May 18, 1969 with John Young, Eugene Cernan, and Thomas Stafford on board. When Apollo 10 approached the Moon, Cernan and Stafford flew to within 16 km of the lunar surface in the lunar module, while Young stayed in the command module. Though they didn't land on the surface, the experience paved the way for the first manned lunar landing, Apollo 11.

The mission lasted for 8 days and 3 minutes before the crew successfully splashed down to Earth on May 26. The Apollo 10 capsule can be viewed at the Science Museum in London, England.

1.10 Apollo 11

Apollo 11 (43811 kg) is widely considered to be the most significant mission in the history of space exploration. With Apollo 11, Neil Armstrong and Edwin Aldrin became the first humans to set foot on a celestial body other than the Earth - the Moon. (The other member of the crew, Michael Collins piloted the Command Module "Columbia" in orbit around the Moon while his colleagues explored the surface).

A summary of mission events follows:

Date	Time (EDT)	Event
May 20/69		Apollo 11 launch vehicle and spacecraft (111 metres tall) left the Vehicle Assembly Building on a "crawler" at 1.5 km/hour, to launch pad 39-A.
July 3/69		Successful countdown test completed showing that everything was ready. The next launch window was scheduled for July 16/69 at 9:32 am.
July 16/69	9:32 am	Apollo 11 lift off from launch pad 39-A. View Picture
	9:35 am	First stage of Saturn V rocket separates and second stage ignites
	9:41 am	Second stage separates and third stage ignites. Spacecraft enters Earth orbit
	12:16 pm	Third stage re-ignites to send spacecraft out of Earth orbit enroute to the Moon

	12:49 pm	Command module (Columbia) and service module separate from lunar module (Eagle) and 3rd stage
	12:57 pm	Columbia and service module spin around and dock with Eagle and 3rd stage from other end.
	1:49 pm	Third stage separates.
July 17/69	12:16 pm	Minor course correction is made. View picture of Earth taken from Apollo 11
July 18/69	11:11 pm	Now 344,564 km from the Earth, Apollo passes the imaginary boundary where the gravitational pull from the Moon is stronger than that from the Earth.
July 19/69	1:21 pm	Retrorocket in service module fires to slow the spacecraft so that it enters lunar orbit.
July 20/69	1:45 pm	Armstrong and Aldrin board the Eagle and separate from Columbia. Collins stays onboard Columbia, to reunite with his crewmates when they return from their exploration of the surface.
	4:17 pm	Eagle lands on the Moon at latitude 1deg 7’N, longitude 23deg 49’E in Mare Tranquillitatis (the Sea of Tranquility), with the famous words "Houston, Tranquility Base here. The Eagle has landed". Listen to audio clip
	10:39 pm	The hatch of Eagle is opened.
	10:56 pm	Armstrong sets foot on the Moon. The first words spoken are "That’s one small step for man, one giant leap for mankind". (See note below) Listen to audio clip View Picture
	11:14 pm	Aldrin sets foot on the Moon. The astronauts collect samples of the surface and set up scientific experiments. A flag is set up, and a plaque unveiled with the inscription "Here Men From Planet Earth First Set Foot Upon the Moon. July 1969 A.D. We Came In Peace For All Mankind". This plaque is left on the Eagle’s descent stage, which remained on the Moon.
July 21/69	12:57 am	Aldrin goes back into Eagle and helps Armstrong load 21.7 kg of lunar samples.
	1:09 am	Approximately 2 hours after setting foot on the Moon, Armstrong returns to Eagle.
	1:11 am	The hatch of Eagle is closed.
	1:54 pm	21.6 hours after arrival, Eagle lifts off from the Moon.
	5:35 pm	Eagle docks with Columbia. View approach of Eagle
	7:41 pm	Astronauts board Columbia, and separate from Eagle.
July 22/69	12:55 am	Rockets in the service module fire to break Columbia out of lunar orbit for its flight back to the Earth.

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              4:01 pm     A minor course correction is made.

 July 24/69   12:20 pm    Service module is separated from Columbia.
              12:35 pm    Columbia re-enters the Earth's atmosphere.
              12:44 pm    Columbia is slowed to the point where parachutes
                          can be released without damage.
              12:50 pm    Columbia splashes down in the Pacific Ocean.
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Note: Probably the most famous quotation in space exploration is Neil Armstrong's "That's one small step for man, one giant leap for mankind" when he first set foot on the Moon. However, the speech didn't come out exactly as Armstrong had planned it. It was supposed to be: "That's one small step for *a* man, one giant leap for mankind." True enough, the usage of "man" in his actual speech does actually mean "mankind", making the sentence somewhat contradict itself. Presumably, Armstrong forgot to use the "a" in the heat of the moment.

Apollo 11's command module (Columbia) can be viewed at the Smithsonian Air & Space Museum in Washington, DC.

1.11 Apollo 12

Apollo 12 (43848 kg) was launched by the US on November 14, 1969 for a manned landing on the Moon with Charles Conrad, Alan Bean, and Richard Gordon aboard. Gordon remained onboard the command module, the "Yankee Clipper", while Conrad and Bean explored the surface from their lunar excursion module, "The Intrepid".

"The Intrepid" landed on November 19th in Oceanus Procellarum (Ocean of Storms) at latitude 3deg 12'S and longitude 23deg 23'W, approximately 180 metres from Surveyor 3. Some parts from Surveyor 3 were removed by the astronauts and returned to the Earth so that scientists could learn the effects that long term exposure on the lunar surface had to materials. They remained on the surface for 31 hours, setting up scientific experiments and collecting 34.4 kg of samples.

The crew returned to the Earth on November 24th, after a 10 day, 4 hour, and 36 minute mission. The Apollo 12 capsule can be seen at the Virginia Air and Space Center in Hampton, Virginia.

1.12 Apollo 13

Apollo 13 (43924 kg) was launched by the US on April 11, 1970 with crewmates Fred Haise, James Lovell, and John Swigert on board.

The launch was to have been man's third landing on the Moon. But 56 hours into the flight, disaster struck. An explosion caused by a short circuit destroyed the systems that supplied electricity and oxygen to the command module. The crew had to retreat into the lunar module to remain alive. Naturally, the landing on the Moon was aborted, but the crew had to remain in the lunar module for the four day flight back to the Earth.

The lunar module was never intended to provide life support for three people for four days, but through conservation measures on the part of the crew, it carried them safely back to the Earth. Their mission lasted 5 days, 22 hours, 55 minutes.

The shell of the Apollo 13 capsule can be seen in Le Bourget, France, while the seats and panels may be viewed at the Louisville Science Center in Louisville, Kentucky.

1.13 Apollo 14

Apollo 14 (44456 kg) was launched by the USA on January 31, 1971 with crewmates Alan Shepard, Edgar Mitchell, and Stuart Roosa. Once arriving at the Moon, Roosa stayed in orbit aboard the command module, while Shepard and Mitchell went down to the surface in the "Antares" - the lunar excursion module. They landed near the Fra Mauro crater (latitude 3deg 40’S, longitude 17deg 28’E) on February 5th, and conducted several scientific experiments as well as collect 42.9 kg of samples.

They later rejoined with Roosa and splashed down successfully on Earth, after a total mission time of 9 days, 2 minutes. The Apollo 14 capsule can be seen at the U.S. Air Force Museum in Dayton, Ohio.

1.14 Apollo 15

Apollo 15 (46723 kg) was launched by the USA on July 26, 1971 with crewmates David Scott, James Irwin, and Alfred Worden. Once arriving at the Moon, Worden remained in lunar orbit aboard the command module "Endeavour" while the others landed in the lunar module "Falcon" at latitude 26deg 6’N, longitude 3deg 39’E on July 30th.

The astronauts performed several scientific experiments and explored the area around a canyon called the "Hadley Rille" in the Apennine Mountains. They collected 76.8 kg of samples from the Moon, both from the surface and from depths of as great as 3 metres. In total, the astronauts spent 66 hours, 55 minutes on the lunar surface.

Apollo 15 was the first manned mission to exploit a "lunar rover". This vehicle carried them 28.2 kilometers, enabling them to explore a bit beyond the immediate vicinity of the "Falcon".

After rejoining with Worden in orbit, the crew returned to Earth after a total mission time of 12 days, 7 hours, 12 minutes.

1.15 Apollo 16

Apollo 16 (46733 kg) was launched by the USA on April 16, 1972 with crewmates Charles Duke, Thomas Mattingly, and John Young. Once arriving at the Moon on April 21, Mattingly remained in lunar orbit aboard the command module "Casper", while the others landed in the lunar module "Orion" at latitude 9deg 0’N, longitude 15deg 31’E.

The astronauts explored the Descartes region of the Moon, performed several scientific experiments, and collected 94.7 kg of samples from the lunar surface. They remained on the Moon for 71 hours, enjoying the use of a lunar rover to carry them about the surface, logging a total distance of 26.7 km.

After rejoining with Mattingly in orbit, the crew returned to Earth after a total mission time of 11 days, 1 hour, 51 minutes. The Apollo 16 capsule can be seen at the Space and Rocket Center in Huntsville, Alabama.

View Apollo 16 landing site, imaged by Clementine

1.16 Apollo 17

Apollo 17 (46743 kg) was launched by the USA on December 7, 1972 as the last of the extremely successful manned landing missions to the Moon. On December 12th, crewmates Eugene Cernan and Harrison Schmitt landed on the surface in the lunar excursion module "Challenger" (at latitude 20deg 10’N, longitude 30deg 46’E), while Ronald Evans remained aboard the command module in orbit.

The astronauts carried out a variety of scientific experiments in the Taurus-Littrow region, and collected more samples from the surface of the Moon than had ever been obtained before - 110.5 kg. They used a lunar rover to help them move about the surface of the Moon to do their work, remaining there for 75 hours, and travelling 33.8 km.

After rejoining with Evans in orbit, the crew returned to Earth after a total mission time of 12 days, 13 hours, 52 minutes. The Apollo 17 capsule can be seen at the Johnson Space Center in Houston, Texas.

1.17 Cassini

Cassini (5630 kg) is a US mission to study Saturn, scheduled for launch on October 6, 1997. Named for the French astronomer Jean Cassini, it will be launched aboard a Titan IV-Centaur rocket from Florida, using a gravity-assisted trajectory to bring it to Saturn with a minimum expenditure of fuel. It will fly twice past Venus, then by the Earth and Jupiter before arriving at the ringed planet.

Upon reaching Saturn, the probe will swing to within only 20,000 km of the planet’s surface before beginning a four year mission. In late 2004, Cassini will release the "Huygens" probe (built by the European Space Agency). Much like the atmospheric descent probe in the Galileo mission, it will descend slowly through the atmosphere of Titan, radioing scientific data to the spacecraft for relay back to Earth. It is hoped that the probe will survive its descent and land safely on the surface. Since many scientists believe that Titan may be covered by oceans of methane or ethane, the probe is designed to function even if it lands in a liquid.

The orbiter will proceed to study Saturn and its moons, making more than 30 close flybys of Titan and several dozen more distant flybys of other moons. The orbit of the spacecraft will allow observations of both Saturn’s polar and

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equatorial regions.

A rough timeline for events in the Cassini mission is as follows:

 Oct.  6/97 - Launch
 Apr. 21/98 - Gravity assist from Venus
 Jun. 20/99 - Gravity assist from Venus
 Aug. 16/99 - Gravity assist from Earth
 Dec. 30/00 - Gravity assist from Jupiter
 Jun. 25/04 - Arrival at Saturn
 Nov.  6/04 - Huygens probe separation
 Nov. 27/04 - Entry of Huygens into the atmosphere of Titan
 Jun. 25/08 - End of primary mission
The spacecraft will carry the following instruments:

 Orbiter
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 - Cameras to take pictures in visible, near ultraviolet, and near
   infrared light.
 - Radar to map the surface of Titan.
 - Using the radio transmitter as a probe to detect features of the
   rings, atmosphere, and gravity fields of Saturn and its moons,
   as well as attempt to search for gravitational waves.
 - Ion and neutral mass spectrometer to learn more about the upper
   atmospheres and ionospheres of Saturn and its satellites.
 - Visual and infrared mapping spectrometer, to help identify the
   chemical composition of the surfaces, atmospheres, and rings of
   Saturn and its satellites.
 - Composite infrared spectrometer, to study the temperature and
   composition of Saturn and its moons.
 - Cosmic dust analyzer, to study ice and dust grains in space near
   Saturn.
 - Radio and plasma wave experiments to study natural emissions of
   radio energy in the system, as well as dust.
 - Plasma spectrometer to investigate plasma within and near Saturn's
   magnetic field.
 - Ultraviolet imaging spectrograph, to study the structure, chemistry,
   and composition of the atmospheres and rings of Saturn and its
   satellites.
 - Magnetospheric imaging instrument, to study the extent and
   behaviour of Saturn's magnetosphere.
 - Dual technique magnetometer, to study the interaction of Saturn's
   magnetic field with the solar wind, the rings, and the satellites
   of Saturn.

 Huygens Probe
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 - Descent imager and spectral radiometer, to take pictures and
   measure temperatures in its descent to the surface of Titan.
 - Atmospheric structure instrument, to study the structure and physical
   properties of Titan's atmosphere.
 - Gas chromatograph and mass spectrometer, to determine the chemical
   composition of gases and dust in Titan's atmosphere.
 - Aerosol collector pyrolyzer, to examine clouds and dust in Titan's
   atmosphere.
 - Surface science package, to investigate the physical properties of
   Titan's surface.
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- Doppler wind experiment, to study Titan's winds during the probe's descent to the surface.

1.18 Clementine

After the Apollo 17 mission, the moon lay all but neglected by the USA for the next 20 years. Clementine (424 kg), launched by the US Department of Defense ended that period.

Clementine was different from previous spacecraft in two fundamental ways. First, it was not developed with traditional spacecraft design techniques. Many components of the spacecraft were never before flown in the harsh environment of space. As well, the entire mission was designed using aggressive engineering methods and attitudes. As a result, the project cost a comparatively inexpensive $100 million, and took only two years from initial concept to launch.

A brief timeline of events in the Clementine mission follows:

Mar. 24/92	Design process begun
Jan. 25/94	Spacecraft launched
Feb. 3/94	Departure from low Earth orbit after eight day checkout period
Feb. 19/94	Clementine injected into lunar orbit
Feb. 26/94	Mapping process begun
Mar. 24/94	First mapping pass completed
May 5/94	Clementine leaves lunar orbit
May 7/94	Clementine malfunction

During the period in which Clementine was carrying out a systematic mapping of the Moon, over 1,500,000 images were returned. This is the first such mapping attempted and will occupy scientists and lunar geologists for many years to come.

View Apollo 16 landing site, imaged by Clementine

After leaving lunar orbit, Clementine was to rendezvous with the asteroid 1620 Geographos on August 31/94. Unfortunately, on May 7th at 9:39 am EST, the satellite suffered a malfunction. The computer which controls most of Clementine's systems activated several thrusters during a 20 minute loss in telemetry with the Earth. As a result, all the fuel in the tanks for the Attitude Control System (ACS) was depleted and the spacecraft could no longer be controlled.

Yet, it appears as though the Clementine spacecraft may still be alive, even if its trajectory and orientation cannot be controlled. On February 20, 1995, a 70 metre antenna in NASA's Deep Space Network detected radio emissions from the spacecraft, and was able to maintain a lock on the signal for 50 minutes. It is hoped that at some point in the future, enough electricity is gathered by the solar cell arrays to reboot the onboard computer.

Clementine contains the following scientific instruments:

Star Tracker Camera
UV/Visible Camera
Near IR Camera
Long Wave IR Camera
High Resolution Camera

Laser Transmitter
Charged Particle Telescope
Dosimeters
Radiation Experiment
Orbital Meteoroid and Debris Experiment
Particle Counting Experiment

1.19 Explorer 33

Explorer 33 (93 kg) was launched by the USA on July 1, 1966 to orbit the Moon. Unfortunately, it failed in its attempt to establish lunar orbit and is currently in orbit around the Earth.

1.20 Explorer 35

Explorer 35 (104 kg) was launched by the USA on July 19, 1967. It successfully entered lunar orbit and acquired field and particle data.

1.21 Explorer 49

Explorer 49 (328 kg) was launched by the USA on June 10, 1973 to study the Sun from an orbit around the Moon. It also explored low frequency radiation originating from the Sun, Earth, and Jupiter, as well as that from sources both within and outside of our galaxy.

1.22 Galileo (spacecraft)

Named after the famous astronomer Galileo, this probe (2222 kg) was launched by the USA on October 18, 1989 in a mission to study Jupiter. Arriving at the planet in late 1995, it will study Jupiter’s atmosphere, satellites and surrounding magnetosphere in a 2 year observation period. Germany is a partner in the mission, having provided the spacecraft propulsion subsystem, scientific instrumentation, and mission operations support.

Galileo consists of both an orbiter and an atmospheric probe. When arriving at Jupiter, the probe will be released and enter the Jovian atmosphere while the orbiter will continue a survey of the system from orbit. Spacecraft characteristics are as follows:

	Orbiter	Probe
Mass, kg	2223	339
Propellant, kg	925	0
Size, meters	6.15	0.86
# of instruments	11	6
Payload mass, kg	118	30
Power supply	RTGs, 470-570 watts	Lithium sulfur battery, 730 watt-hours.

Galileo was originally designed for a direct flight of 2.5 years to Jupiter. However, changes at NASA after the space shuttle Challenger accident made this impossible. Therefore, mission planners conceived of a new orbital path. In order to save propellant on the flight to Jupiter, Galileo is using a 'gravity assisted' trajectory. By swinging behind a planet or other solar system object a spacecraft is able to pick up additional speed from the object as it enters its gravitational field. This "slingshot" effect enables spacecraft to attain higher speeds with less propellant. The gravity assisted trajectory of Galileo carried it past Venus, twice past the Earth, and past two asteroids on its route to Jupiter.

The primary mission events for the Galileo spacecraft are as follows:

Launch	October 18, 1989
Trajectory change manoeuvre	November 9-11, 1989
Venus flyby	February 10, 1990
Venus data playback	November 19-21, 1990
Earth flyby # 1	December 8, 1990
Gaspra flyby	October 29, 1991
Earth flyby # 2	December 8, 1992
Ida flyby	August 28, 1993
Ida data playback completed	June 26, 1994
Comet SL9 impact observation	July, 1994
Course adjustment	April 12, 1995
Course adjustment	June 23, 1995
Probe release	July 13, 1995
Orbiter deflection manoeuvre	July 20, 1995
Jupiter arrival	December 7, 1995
Io Encounter	December 7, 1995
Ganymede Encounter	July 4, 1996
Ganymede Encounter	September 6, 1996
Callisto Encounter	November 4, 1996
Europa Encounter	November 4, 1996
Europa Encounter	December 19, 1996
Europa Encounter	January 20, 1997
Europa Encounter	February 20, 1997
Europa Encounter	April 4, 1997
Ganymede Encounter	April 5, 1997
Callisto Encounter	May 6, 1997
Ganymede Encounter	May 7, 1997
Callisto Encounter	June 25, 1997
Ganymede Encounter	June 26, 1997
Callisto Encounter	September 17, 1997
Europa Encounter	November 6, 1997

Launch

On October 18, 1989 Galileo was launched by the space shuttle Atlantis. It, along with its Inertial Upper Stage (IUS) booster was deployed from the cargo bay. After reaching a safe distance from the shuttle, the IUS was ignited to propel Galileo out of Earth orbit on a flight path to Venus.

Venus encounter

On February 9, 1990 Galileo approached Venus from the night side of the planet. It then passed into the sunlight and made its closest approach of 16,000 km at 1:00 am EST, February 10. Scientists commanded Galileo to collect measurements on charged particles, magnetic fields, and infrared and ultraviolet spectrae, as well as take 81 pictures with its video camera.

Since Galileo was originally designed to fly directly between the Earth and Jupiter, it was exposed to a much hotter environment by taking the indirect route via Venus. In order to protect the fragile high gain (main) antenna, it was furled for the Venus encounter. As a result, communications with the spacecraft were restricted to a much smaller antenna. The data observed at Venus was recorded onto tape for later playback when Galileo became nearer to the Earth on November 19-21, 1990.

Earth Encounter # 1

As Galileo approached the Earth, it measured the magnetic field to extend far beyond the night side of our planet. It was also able to observe both the near and far sides of the Moon, compiling maps of mineral composition. After making its closest approach of only 1000 km on December 8, 1990, Galileo swung into the sunlit side and took several images of the Earth while receding.

Problems with the High Gain Antenna

After Galileo's encounter with the Earth, the spacecraft would no longer be passing nearer to the Sun than it was originally designed for. As a result, commands were sent in April, 1991 to unfurl the main antenna. Unfortunately, the antenna failed to fully deploy. A team was organized on the ground to assess the problem and suggest a method of correcting it. After extensive analysis, they concluded that three of the antenna's 18 umbrella-like ribs were stuck in the closed position. Despite several attempts to free the stuck ribs, the antenna remains closed and it is likely that the mission will have to continue with only the low gain antenna. The lower power of this antenna means that data will have to be sent at a much slower rate (10 bits per second). However, with the use of data compression and upgrades to the Deep Space Network of radio telescopes used on the Earth to communicate with the probe, it is expected that 70% of the original science objectives will still be achieved. Long term monitoring of the weather systems on Jupiter will suffer the most, since it required a great deal of data in the form of images to be transmitted to the Earth.

Gaspra Encounter

Read summary of findings at Gaspra

Earth Encounter # 2

On December 8, 1992, Galileo made its second flyby of the Earth, passing within only 300 km of the surface. The Earth's gravitational pull changed the flight path to direct the spacecraft towards Jupiter, and increased its velocity by about 13,000 km/hour. As Galileo departed, it was able to obtain images of the north pole of our moon - a region never studied properly before.

View Earth-Moon system as observed from Galileo

Ida Encounter

Read summary of findings at Ida

Galileo observes Comet SL9 impact

In July and August 1994, Comet Shoemaker-Levy 9 collided with Jupiter. Astronomers around the world were excited to learn as much as possible about the event (it is believed by some that similar events with the Earth may be responsible for ice ages or mass extinctions). Unfortunately, the fragments of the comet hit the side of Jupiter facing away from the Earth, so direct observation from here was impossible. In pictures taken from Earth, scientists had to be content with observing the impact sites as they rotated into view several minutes later.

However, Galileo was in a position to observe the impacts directly. It took many images of the impact, but due to the fact that the high gain antenna on the spacecraft cannot be used, it took a long time for the majority to make it to Earth for analysis.

One such sequence of images depict the collision of a fragment known as 'W', and were taken on July 22, 1994. At this time, Galileo was approximately 238,000,000 km from Jupiter. Four images in visible light were taken, at intervals of 2.3 seconds.

In the first image, taken at 8:06:10 GMT, no impact can be observed. In the next three, a point of light appears, brightens dramatically, and then fades. In addition, dark spots from previous impacts can be seen to the right of the flash, on the day side of Jupiter. It is not yet known whether the flash observed by Galileo is due to the fragment burning as it entered the atmosphere of Jupiter, or whether it is a view of the subsequent explosion and fireball.

View SL-9W impact from Galileo

More information on Comet SL9 impact

Probe separation

On July 13, 1995 Galileo will undergo a probe separation manoeuvre. The spacecraft will precisely adjust its trajectory so that it is on a collision course with Jupiter. It will then turn so that the probe will enter the atmosphere of the planet at the correct angle, and then spin at 10 RPM. The spin-stabilized probe will be released, and a few days later (July 20) the orbiter will again adjust its trajectory so that it will not collide with Jupiter itself.

Jupiter arrival

By December 7, 1995 the Galileo orbiter and probe will arrive at Jupiter separately. In a period of about seven hours many events will occur. First, the orbiter will pass within 33,000 km of Europa and 1,000 km of Io. A few hours later the probe will enter the upper atmosphere of Jupiter, 6 degrees north of the equator. Travelling at about 160,000 km/hour it will slow down in the atmosphere for about 2 minutes before deploying its parachute and ejecting its heat shielding. It is hoped to then float 200 km down through the clouds in the next 75 minutes, transmitting data to the orbiter for later relay to Earth. By the time it has lasted 75 minutes, the batteries in the probe are expected to give out and contact will be lost (even if the batteries lasted longer, the probe itself would not be able to withstand the immense atmospheric pressure as it continued to descend. It is designed to withstand an atmospheric pressure of about 25 times that of the Earth, but no more).

After the demise of the probe, the orbiter will thrust with its main engine to go into orbit around Jupiter. It will then undergo a complex orbital dance, using the gravitational field of one moon to bring it to another, all the while obtaining scientific data for scientists back on Earth. It is hoped that the orbiter survives at least 2 years in the Jovian system. If so, the closest approaches to the Galilean satellites will range from 1000 km (in the case of Io) to 416 km (for Callisto). The resolution in the images is expected to be better than 80 metres/pixel.

1.23 Giotto

Giotto (512 kg) was launched by the ESA (European Space Agency) on July 2, 1985 to explore Comet Halley and Comet Grigg-Skjellerup. The spacecraft carried ten scientific instruments, including a color camera, and returned a great deal of data until just before its closest approach. On March 13, 1986, it came to within 540 km of the nucleus of Comet Halley. Some of its instruments were severely damaged by dust during the encounter, so it was placed into hibernation shortly afterwards.

Then in April, 1990 the ESA reactivated Giotto. Three instruments were fully operational, four partly operational, and the remainder (including the camera) unusable. On July 2, 1990 Giotto flew quickly past the Earth, and then flew to a rendezvous with Comet Grigg-Skjellerup. It approached to within 200 km of the comet on July 10, 1992.

1.24 Helios 1

Helios 1 (370 kg) was a spacecraft constructed by the USA and West Germany. It was launched on December 10, 1974 to study the Sun from solar orbit. It passed within 47,000,000 km of the Sun.

1.25 Helios 2

Helios 2 (376 kg) was launched by West Germany on January 15, 1976 to study the Sun. It got as close as 43,000,000 km to its target.

1.26 Hiten

Hiten (195 kg, formerly called Muses-A) was a lunar probe launched by Japan in January 1990. It was the first non-USA or USSR probe to reach the Moon.

Two months after launch, a 12 kg satellite named Hagoromo was placed into lunar orbit. After making several close flybys, Hiten itself entered orbit on February 15, 1992.

On April 10, 1993, the mission ended when Hiten crashed into the lunar surface near the crater Furnerius.

1.27 ICE (International Cometary Explorer)

The International Cometary Explorer (479 kg) was launched by the USA on August 12, 1978. Originally named the "International Sun-Earth Explorer 3", its initial goal was to study the environment between the Earth and the Sun. But when scientists realized that the spacecraft could be diverted to rendezvous with a comet, they jumped at the opportunity (and renamed the spacecraft appropriately). It became the first spacecraft sent to a comet.

On September 11, 1985, ICE passed within 8,000 km of the nucleus of Comet Giacobini-Zinner. Hundreds of microscopic dust particles hit ICE at speeds of 21 km/second, but the spacecraft suffered no apparent damage. The spacecraft returned a great deal of data helping scientists to understand more about the structure of comets.

1.28 Kosmos 21

Kosmos 21 (950 kg) was launched by the USSR on November 11, 1963 in an attempt to reach Venus. Though its launch was successful, it failed to leave Earth orbit.

1.29 Kosmos 27

Kosmos 27 (950 kg) was launched by the USSR on March 26, 1964 in an attempt to reach Venus. Unfortunately, it failed to leave Earth orbit, and as a result the mission was unsuccessful.

1.30 Kosmos 60

Kosmos 60 (1470 kg) was launched by the USSR on March 12, 1965 in an attempt to reach the Moon. Though the launch was successful, it failed to leave Earth orbit.

1.31 Kosmos 96

Kosmos 96 (960 kg) was launched by the USSR on November 23, 1965 in an attempt to reach Venus. Unfortunately, it failed to leave Earth orbit.

1.32 Kosmos 111

Kosmos 111 (1600 kg) was a spacecraft launched by the USSR on March 1, 1966 in an attempt to pass by the far side of the Moon. Though the launch was successful, the probe failed to leave Earth orbit.

1.33 Kosmos 146

Kosmos 146 (5600 kg) was launched by the USSR on March 10, 1967. This circumlunar probe failed to leave Earth orbit.

1.34 Kosmos 154

Kosmos 154 (5600 kg) was launched by the USSR on April 8, 1967 in an attempt to pass beyond the Moon and back. Unfortunately, it failed to leave Earth orbit.

1.35 Kosmos 167

Kosmos 167 (1100 kg) was launched by the USSR on June 17, 1967 in an attempt to reach and study Venus. However, the mission was unsuccessful as the spacecraft failed to leave Earth orbit.

1.36 Kosmos 300

Kosmos 300 (5600 kg) was launched by the USSR on September 23, 1969 in an effort to reach the Moon, land softly on the surface, and return samples back to the Earth. Unfortunately, the craft failed to leave Earth orbit.

1.37 Kosmos 305

Kosmos 305 (5600 kg) was launched by the USSR on October 22, 1969 in an attempt to reach the Moon and return samples to Earth. However, the mission was unsuccessful, as the craft failed to leave Earth orbit.

1.38 Kosmos 382

Kosmos 382 (5600 kg) was launched by the USSR on December 2, 1970 in an attempt to orbit around the far side of the Moon. Unfortunately, the spacecraft failed to leave Earth orbit.

1.39 Kosmos 419

Kosmos 419 (4650 kg) was launched by the USSR on May 10, 1971. The spacecraft was intended to travel to Mars, orbit around the planet and land upon the surface. Unfortunately, the spacecraft failed to leave Earth orbit (a problem which seemed to be common to the Kosmos series).

1.40 Kosmos 482

Kosmos 482 (1180 kg) was launched by the USSR on March 31, 1972 in an effort to reach and study Venus. Unfortunately, the spacecraft failed to leave Earth orbit.

1.41 Luna 1

Luna 1 (361 kg) was the first spacecraft with a destination of the Moon. Launched by the USSR on Jan. 2, 1959, it missed the Moon and thus became the first spacecraft to orbit the Sun.

1.42 Luna 2

Luna 2 (387 kg) was launched by the USSR on September 12, 1959. It became the first man-made object to strike the surface of another object in our solar system when it crash landed (intentionally) on the Moon on September 15.

1.43 Luna 3

Luna 3 (278.5 kg) was launched by the USSR on October 4, 1959. Encountering the Moon on October 7, it became the first probe to send back a picture to Earth of what the far side of the Moon looked like. The probe is now in a decaying orbit taking it between the Earth and Moon.

1.44 Luna 4

The Luna 4 designation is often given to two separate spacecraft designed and built by the USSR. On April 12, 1960, a 300 kg spacecraft destined for the Moon suffered a launch failure. As a result, it did not receive an official "Luna" designation, although it was originally intended to be Luna 4.

The next Soviet probe to be launched inherited the name Luna 4 from its predecessor. This 1422 kg craft was launched on April 2, 1963 to study the Moon. It was originally intended to crash land on the surface, but failed in its attempt. It is now in solar orbit.

1.45 Luna 5

Luna 5 (1474 kg) was launched by the USSR on May 9, 1965 with the intention of being the first vehicle to make a soft landing on the Moon (previous probes had simply crash landed). Unfortunately, the probe failed and impacted with the Moon like most of the others before it.

1.46 Luna 6

Luna 6 (1440 kg) was launched by the USSR on June 8, 1965 with the intention of being the first vehicle to make a soft landing on the Moon. Unfortunately, the probe missed the Moon altogether and is now in solar orbit.

1.47 Luna 7

Luna 7 (1504 kg) was launched by the USSR on October 4, 1965 with the intention of being the first vehicle to make a soft landing on the Moon. The probe failed and impacted with the Moon, as most previous probes had done.

1.48 Luna 8

Luna 8 (1550 kg) was launched by the USSR on December 3, 1965 with the intention of being the first vehicle to make a soft landing on the Moon. Like most previous probes, it failed and impacted with the lunar surface.

1.49 Luna 9

Luna 9 (1580 kg) was launched by the USSR on January 31, 1966. Unlike a series of unsuccessful probes in the Luna series before it, on February 3, Luna 9 managed to make a soft landing on the Moon (and was the first such spacecraft to do so). It sent 27 television pictures to the Earth, and survived for 3 days.

1.50 Luna 10

Luna 10 (1597 kg) was launched by the USSR on March 31, 1966 to orbit the Moon. On April 3, it became the first spacecraft to do so - and it is still in lunar orbit. It remained operational until May 30th of that year.

1.51 Luna 11

Luna 11 (1638 kg) was launched by the USSR on August 24, 1966 to orbit the Moon. It was successful in its attempt and remains in orbit to this day. Data was returned until October 1st, 1966.

1.52 Luna 12

Luna 12 (1620 kg) was launched by the USSR on October 22, 1966. It arrived at the Moon a few days later and entered lunar orbit, where it remains. During its lifetime, it transmitted several television pictures of the Moon back to the Earth.

1.53 Luna 13

Luna 13 (1700 kg) was launched by the USSR on December 21, 1966. It made a successful landing on the surface of the Moon a few days later. Photographs were returned, as well as data from a soil density experiment.

1.54 Luna 14

Luna 14 (1700 kg) was launched by the USSR on April 7, 1968 to study the Moon, the Moon's gravitational field, and the Earth-Moon mass relationship. It is now in solar orbit.

1.55 Luna 15

Luna 15 (2718 kg) was launched on July 13, 1969 by the USSR to land on the Moon, collect samples of the lunar soil, and return them to Earth. Unfortunately, it failed in its landing attempt and crashed on July 21st, after a flight time of 204 hours, 56 minutes.

Had Luna 15 succeeded, it would have beat the historic Apollo 11 flight in being the first spacecraft to return samples of another body in the solar system to the Earth.

1.56 Luna 16

Luna 16 (5600 kg) was launched by the USSR on September 12, 1970. This unmanned lunar probe landed successfully on September 20 at Mare Fecunditatis (The Sea of Fertility, 0deg 41' S, 56deg 18' E) and collected 100 grams of samples from the lunar surface. On September 21, it blasted off from the Moon and arrived at the Earth with its precious cargo 3 days later.

Two samples of lunar regolith (soil) and a small fleck of basalt from Luna 16 were sold for $442,500 at an auction at Sotheby's in New York City on December 11, 1993.

1.57 Luna 17

Luna 17 (5600 kg) was launched by the USSR on November 10, 1970. This unmanned lunar probe landed successfully on November 17. The mission was unique in that it was the first to carry an automated vehicle (the Lunokhod 1 Rover). This rover was piloted via remote control from the Earth and explored the surface of the Moon.

1.58 Luna 18

Luna 18 (5600 kg) was launched by the USSR on September 2, 1971. Like Luna 16, its mission was to land softly on the Moon and return samples of the lunar surface back to Earth. Unfortunately, it crashed on September 11th while making its landing attempt.

1.59 Luna 19

Luna 19 (5600 kg) was launched by the USSR on September 28, 1971 to explore and photograph the Moon from orbit. It remains in orbit.

1.60 Luna 20

Luna 20 (5600 kg) was launched by the USSR on February 14, 1972. Like Luna 16, this probe’s mission was to obtain samples from the lunar surface and return them to Earth. On February 21, it landed successfully in the Apollonius highlands (3deg 32’ N, 56deg 33’ E) and obtained 30 grams of lunar soil. It managed to depart from the lunar surface and bring the samples to Earth.

1.61 Luna 21

Luna 21 (4850 kg) was launched by the USSR on January 8, 1973 to study the Moon. Like Luna 17, it carried a lunar rover (Lunokhod 2) which ground controllers operated by remote control to explore the surface.

Luna 21 landed on January 16th in crater Lemogneir at the eastern edge of Mare Serenitatis.

1.62 Luna 22

Luna 22 (5600 kg) was launched by the USSR on May 29, 1974. It successfully entered lunar orbit and made observations of the lunar surface.

1.63 Luna 23

Luna 23 (5600 kg) was launched by the USSR on October 28, 1974. It was intended to make a soft landing on the surface of the Moon, but unfortunately crashed in the attempt.

1.64 Luna 24

Luna 24 (4800 kg) was the last in the USSR’s "Luna" series of lunar exploration probes. Launched on August 9, 1976, it made a successful landing in the Mare Crisium (12deg 45’ N, 60deg 12’ E). 170 grams of samples were retrieved from the lunar surface and returned to the Earth.

1.65 Lunar Orbiter 1

Lunar Orbiter 1 (386 kg) was launched by the USA on August 10, 1966 to study the Moon. On August 14, it entered lunar orbit and photographed the far side as well as future landing sites. Under command from mission control, it impacted with the lunar surface on October 29th.

Through analyzing the orbital paths of the 5 Lunar Orbiter probes, scientists learned that the Moon’s gravitational field is irregular. In addition, the probes photographed 98% of the lunar surface and proved that the surface would support the weight of manned landing craft.

1.66 Lunar Orbiter 2

Lunar Orbiter 2 (390 kg) was launched by the USA on November 6, 1966 to study the Moon. As with Lunar Orbiter 1, it entered lunar orbit and photographed the far side as well as future landing sites, returning some 205 photographs. Under command from mission control, it impacted with the lunar surface on October 11, 1967.

Through analyzing the orbital paths of the 5 Lunar Orbiter probes, scientists learned that the Moon’s gravitational field is irregular. In addition, the probes photographed 98% of the lunar surface and proved that the surface would support the weight of manned landing craft.

1.67 Lunar Orbiter 3

Lunar Orbiter 3 (385 kg) was launched by the USA on February 5, 1967 to study the Moon. It entered lunar orbit and photographed the far side of the Moon as well as the future landing site for Apollo 12, returning some 182 images. On October 9th, it impacted with the lunar surface upon command from mission control.

Through analyzing the orbital paths of the 5 Lunar Orbiter probes, scientists learned that the Moon’s gravitational field is irregular. In addition, the probes photographed 98% of the lunar surface and proved that the surface would support the weight of manned landing craft.

1.68 Lunar Orbiter 4

Lunar Orbiter 4 (390 kg) was launched by the USA on May 4, 1967 to study the Moon. Unlike previous probes, it obtained images of the lunar surface from polar orbit, returning some 163 pictures back to Earth via radio. It was commanded to crash land on the surface on October 6th.

Through analyzing the orbital paths of the 5 Lunar Orbiter probes, scientists learned that the Moon’s gravitational field is irregular. In addition, the probes photographed 98% of the lunar surface and proved that the surface would support the weight of manned landing craft.

1.69 Lunar Orbiter 5

Lunar Orbiter 5 (389 kg) was launched by the USA on August 1, 1967 to study the Moon. Like Lunar Orbiter 4, it circled the Moon in a polar orbit. After obtaining several high resolution pictures of important sites, it was commanded to crash land on the lunar surface on January 31, 1968.

Through analyzing the orbital paths of the 5 Lunar Orbiter probes, scientists learned that the Moon’s gravitational field is irregular. In addition, the probes photographed 98% of the lunar surface and proved that the surface would support the weight of manned landing craft.

1.70 Magellan

View deployment of Magellan from shuttle mission STS-30

Magellan (3545 kg) was launched by the USA on May 4, 1989 to make extremely detailed radar maps of Venus. Lasting longer than anticipated, it also fulfilled secondary mission objectives of making a map of Venus’ gravity field and testing a new manoeuvering technique called "aerobraking", which uses the planet’s atmosphere to steer or slow a spacecraft.

The 4.6 metre long spacecraft was constructed partially from spare parts from other missions. The high gain antenna, used both for communication with the Earth and retrieving radar echoes from the surface of Venus, was a spare from the Voyager missions to the outer planets. It had previously been on public display at the National Air and Space Museum in Washington, D.C. The main structure and a set of thrusters also originated in the Voyager project. The command data computer system, attitude control computer and power distribution units were salvaged from spares of the Galileo mission to Jupiter. As well, the medium gain antenna originated from the Mariner 9 project.

Magellan was powered by two solar panels, 2.5 metres long and generating 1200 watts at the beginning of the mission. Throughout time, their efficiency degraded as expected, but they were sufficient to power the spacecraft for the duration of its mission.

Launched by the space shuttle Atlantis on May 4, 1989, it became the first interplanetary spacecraft to use the shuttle to assist it on its journey. After separating from the shuttle to a safe distance, it used a solid fuel rocket motor called the Inertial Upper Stage (IUS) to propel it on its 15 month journey to Venus. Once arriving on August 10, 1990, it fired another solid fuel motor to slow it down into polar orbit around the planet.

The orbit of Magellan was highly elliptical, ranging from 294 km from the surface of Venus at closest approach to 8,543 km at furthest. During a typical orbit of 3.25 hours, Magellan used its sophisticated imaging radar to map a swath 17 to 28 km wide during its closest approach. Then, as Magellan swung further from the planet for the remainder of the orbit, it radioed the data back to the Earth. As Venus slowly rotated under the spacecraft, a different swath was mapped. At the end of a 243 Earth-day period (the length of one Venusian day), 84% of the surface had been mapped.

In the process of mapping the planet, an active volcano (Maat Mons) was discovered. Active volcanoes are only known to exist on two planets in the solar system - Earth and Venus (though there are also volcanoes on the moons Io and Triton).

Since the spacecraft was still performing well, two more mapping cycles were conducted, ending in September 1992. At their completion, 98% of the surface had been observed - much of it more than once, which enabled scientists to look for any changes.

During Magellan’s fourth 243-day orbital cycle, it did not use its radar mapper. Instead, it transmitted a continuous radio signal to Earth. When passing over an area of Venus with higher than normal gravity, the spacecraft would slightly speed up in its orbit. By measuring the doppler shift with highly sensitive antennas on the ground, such variations in velocity could be detected. Powerful computers were then used to construct a detailed gravity map of the planet.

By May 1993, Magellan had completed its fourth cycle of orbits and had already lasted longer than anyone had hoped. Low on manoeuvering fuel, flight controllers decided to try an untested technique known as "aerobraking" to lower the orbit. By changing the lowest point of the orbit slightly so that it skimmed the upper regions of the atmosphere of Venus, the velocity of the spacecraft was decreased so that the high point of the orbit got lower and lower. This technique is hoped to be used by the upcoming Mars Surveyor and Mars Pathfinder missions.

By August 3, 1993 the orbit had been changed to take the probe within 180 km of the surface on closest approach and 541 km on furthest. In addition, Magellan circled the planet much more quickly - completing one orbit in 94 minutes. This faster and more circular orbit allowed Magellan to return even more accurate data on Venus’ gravitational field. In April 1994, Magellan began its sixth orbital cycle to do exactly that.

In September of 1994, Magellan began its final experiment. Its orbit was lowered further in a test known as the "windmill experiment". In this test, the solar panels of the spacecraft were turned in a configuration resembling that of a windmill, and flight engineers measured how much effort was required to keep the spacecraft from spinning. This gave new data on the upper atmosphere of Venus, and was able to provide engineers with useful information in designing future spacecraft.

On October 11, 1994, mission controllers sent commands to Magellan to further lower its orbit. Dipping further into the atmosphere of Venus, Magellan's signal was lost at 3:02 AM PDT on October 12. It is expected that although much of the spacecraft burned up on descent, some parts hit the surface of the planet by 1:00 PM PDT, October 13, 1994. This was the first intentional crash landing by an interplanetary orbiter and signalled the end of an extremely successful mission, generating more digital data than that of all previous U.S. planetary missions combined.

View sample Magellan radar image of Venus' surface
View Magellan radar mosaic of Venus

1.71 Mariner 1

Mariner 1 (202 kg) was to have been the the first US spacecraft to visit the inner solar system. Unfortunately, a transcription error in the guidance software caused its launch vehicle to stray from the safe flight path shortly after its launch on July 22, 1962. It was consequently destroyed by the Range Safety Officer.

1.72 Mariner 2

Mariner 2 (201 kg) was launched by the USA on August 27, 1962 to explore Venus and the interplanetary medium (the region in space between the planets). Launched aboard an Atlas/Agena rocket, it was as much an experiment for the rocket's capabilities as it was for Mariner 2 itself.

The first discovery made was that of the solar wind. Long suspected by astronomers, measurements by Mariner 2 confirmed its existence.

While enroute to Venus, Mariner 2 suffered several unanticipated events. It lost its attitude orientation, one of its two solar panels failed, the temperature rose dangerously high as it approached nearer the Sun, and the computer/sequencer became erratic. But with some help from the engineers on the ground, the probe managed to recover from all the obstacles.

On December 14, 1962, Mariner 2 passed within 34,760 km of Venus and scanned its surface with infrared and microwave radiometers. The data obtained proved that the surface of Venus was extremely hot (about 425 degrees C). As well, the probe indicated that Venus either had a very weak or nonexistent magnetic field; in either case, nothing was picked up with its instrumentation. About three weeks later, on January 3, 1963, communication was lost with the spacecraft. It is now in a solar orbit.

1.73 Mariner 3

Mariner 3 (260 kg) was launched by the USA on November 5, 1964 in an attempt to fly past Mars. Contact was lost when its protective shroud failed to eject. Unable to collect light from the Sun to power its solar cells, the spacecraft died when its batteries ran out. It is currently in solar orbit.

1.74 Mariner 4

Mariner 4 (260 kg) was launched by the USA on November 28, 1964 to study Mars. It arrived on July 14, 1965, and sent back 22 photographs of the planet as it flew within 9844 km of the surface.

The pictures returned by the spacecraft revealed that Mars had meteor craters - something which had never been seen from telescopes on the Earth. In addition, it showed that Mars had no detectable magnetic field. Images and data returned from the spacecraft indicated that Mars had no canals or detectable forms of life.

Ground controllers directed Mariner 4 to fly behind Mars, and used the radio signal from the spacecraft to act as a probe of the planet's atmosphere as it disappeared from view. Using this information, they were able to determine that the atmospheric surface pressure was less than 1% that of the Earth - much less than previously thought. Following its close flyby, Mariner 4 left the planet and is now in solar orbit.

In addition to studying Mars, Mariner 4 returned useful information to scientists about the conditions in space between the planets.

1.75 Mariner 5

Mariner 5 (244 kg) was launched by the USA on June 14, 1967 to explore Venus. It flew within 3990 km of Venus on October 19, 1967, reporting a large concentration of carbon dioxide in the planet's atmosphere. It is now in solar orbit.

1.76 Mariner 6

Mariner 6 (412 kg) was launched by the USA on February 24, 1969 to study Mars. It returned 75 photographs of the surface of the planet, closing to within 3410 km of the surface on July 31, 1969.

After flying past Mars, Mariner 6 entered a solar orbit where it currently remains.

1.77 Mariner 7

Mariner 7 (412 kg) was launched by the USA on March 27, 1969 to study Mars. Arriving on August 5th, it photographed the surface of the planet from within 3520 km of the surface, and provided the first high quality images of the southern polar cap.

After flying past Mars, Mariner 7 entered a solar orbit where it currently remains.

1.78 Mariner 8

Mariner 8 (1031 kg) was intended to orbit and study Mars. Unfortunately, its launch by the USA on May 8, 1971 was a failure and the mission was unsuccessful.

1.79 Mariner 9

Mariner 9 (974 kg) was launched by the USA on May 30, 1971 to study Mars. It entered orbit on November 14, 1971 at an altitude of about 1600 km above the Martian surface. It returned a great deal of data and 7,329 images of the planet and its two moons (Deimos and Phobos), revealing huge volcanoes, canyon systems, and evidence that water once flowed on the planet. It also succeeded in photographing a widespread dust storm on the surface.

Though no longer operational, the probe is still in orbit about Mars.

1.80 Mariner 10

View picture of spacecraft
View mosaic of Mercury taken by Mariner 10
View surface of Mercury taken by Mariner 10

Mariner 10 (526 kg), launched in the evening of November 3, 1973 on an Atlas Centaur launch vehicle, was the first spacecraft to visit more than one planet. Until the end of its mission in March, 1975, it transmitted over 12,000 images of the Moon, Mercury and Venus.

Mariner 10 required more course corrections than any previous probe, and was the first spacecraft to use the gravitational pull of one planet (Venus) to help it reach another (Mercury). In addition, it was the first to use the solar wind in order to assist with course corrections. When the probe began to run low on thruster fuel, mission scientists used its solar panels as sails to make minor adjustments to its trajectory.

On February 5, 1974, Mariner 10 returned the first close up images of the atmosphere of Venus in ultraviolet, revealing previously unseen details. It made the discovery that the entire cloud system circled the planet in four Earth days. After using the gravity of Venus to assist it further towards the Sun, the probe was able to make three flybys of Mercury before running out of attitude control gas, rendering the spacecraft unable to change its orientation. On March 29, 1974 it passed within 750 km of the surface. On September 21st it passed within 48,000 km, and on March 16, 1975, it returned to within 300 km.

Mariner 10 is the only spacecraft thus far to have visited Mercury, and returned a wealth of images from the surface. Mercury was revealed to be a heavily cratered planet, with a mass much greater than previously thought. Mariner 10 managed to map only about 45% of the planet’s surface, and discovered a thin atmosphere and magnetic field.

Mariner 10 is still orbiting the Sun, though as a dead spacecraft - its electronics systems have probably been destroyed by solar radiation.

1.81 Mars 1

Mars 1 (893 kg) was launched by the USSR on November 1, 1962 as the first spacecraft to explore Mars. It failed en route.

1.82 Mars 2

Mars 2 (4650 kg) was launched by the USSR on May 19, 1971 to study Mars. It consisted of two components - an orbiter and a lander. Unfortunately, the lander crashed to the surface and failed to yield any data, but gained the distinction of being the first human artifact on Mars.

The orbiter returned images and data of Mars until August 1972. It is still in orbit about the planet.

The sister ship of Mars 2 (Mars 3) succeeded in bringing its lander to a soft touchdown on the surface.

1.83 Mars 3

Mars 3 (4643 kg) was launched by the USSR on May 28, 1971 to study Mars. It consisted of two components - an orbiter and a lander. The lander made its descent on December 2, 1971 and succeeded in making a soft touchdown (the first such probe to do so). Unfortunately, it only returned data for 20 seconds.

The orbiter successfully returned data and images of the surface of Mars. It is still in orbit about the planet.

1.84 Mars 4

Mars 4 (4650 kg) was launched by the USSR on July 21, 1973 to study Mars from orbit. Unfortunately, its engines never fired to slow down the spacecraft sufficiently, and it flew right past. However, it returned several useful images and data during its closest approach.

Mars 4 was the sister ship of Mars 5.

1.85 Mars 5

Mars 5 (4650 kg) was launched by the USSR on July 25, 1973 to study Mars from orbit. It was the sister ship of Mars 4, but unlike its sibling, was able to enter orbit in February, 1974.

1.86 Mars 6

Mars 6 (4650 kg) was launched by the USSR on August 5, 1973 to study Mars. It was intended to make a soft landing on the Martian surface, but ended up crashing in March, 1974, instead. Despite the mishap, it did return useful data during its descent.

1.87 Mars 7

Mars 7 (4650 kg) was launched by the USSR on August 9, 1973 to study Mars. It consisted of two parts - a lander and an orbiter. Unfortunately, it failed to enter orbit about Mars and is now in solar orbit.

1.88 Mars 96

Originally scheduled for launch in 1994 (and named "Mars 94"), Mars 96 is a mission planned to explore Earth's neighbour. It is in serious budget difficulty at the moment, but if all goes well, it will be launched in 1996 by the CIS (Commonwealth of Independent States - the former USSR).

The mission will carry out a variety of experiments to help us learn more about Mars. Part of payload is a French-Soviet balloon experiment. Mars 96 will deploy several balloon-borne instrument packages into the atmosphere. The packages will transmit data on the composition and content of the atmosphere to the orbiting spacecraft, for later transmission to the Earth.

The mission will enlist the assistance of the Mars Surveyor probe in returning its data to the Earth.

1.89 Mars 98

Originally scheduled for launch in 1996 (and named "Mars 96"), Mars 98 is a mission planned to explore Earth's neighbour. It is in serious budget difficulty at the moment, but if all goes well, it will be launched in 1998 by the CIS (Commonwealth of Independent States - the former USSR).

If Mars 98 gets off the ground, it is possible that it will include balloon packages (like the Mars 96 mission), and a Mars rover which will land and explore the surface.

The mission will enlist the assistance of the Mars Surveyor probe in returning its data to the Earth.

1.90 Mars 1969A & Mars 1969B

Mars 1969A and Mars 1969B (3500 kg) were Soviet spacecraft intended to explore Mars. They consisted of two main parts - a flyby section and a lander.

On March 27, 1969, Mars 1969A was launched. However, the Proton rocket booster powering the spacecraft exploded midway to achieving Earth orbit. A similar fate is believed to have happened to Mars 1969B, launched on April 14, 1969.

There was a third spacecraft in the series (Mars 1969C), though its launch does not appear to have been attempted.

1.91 Mars Observer

Mars Observer (2500 kg) was launched by the USA on September 25, 1992 to explore the red planet. The following mission objectives were planned:

- map the planet for a full Martian year (687 Earth days) in order to see how the planet varies throughout its seasons.
- Determine global composition of the surface material.
- Establish whether a magnetic field exists.
- Determine where and when dust appears in the atmosphere.
- Investigate the structure and circulation of the atmosphere.

In order to carry out these objectives, seven instrument packages were placed onboard the orbiter:

- gamma ray spectrometer to measure the abundance of elements on the surface.
- thermal emission spectrometer to map the mineral content of surface rocks, frost, and the composition of clouds.
- line scan camera to make low resolution images of Mars on a daily basis for climatological studies. It would also make high resolution images of selected areas to study surface geology and the interactions of the surface with the atmosphere.
- laser altimeter to determine the topography of the surface.
- pressure-modulator infrared radiometer to measure dust in the atmosphere, as well as obtain profiles of temperature, water vapour, and dust opacity as they change with latitude, longitude, and season.
- Ultra stable radio oscillator to measure atmospheric refraction as it varies with altitude to determine a temperature profile of the atmosphere. In addition doppler shifts would help to generate a gravity map of Mars.
- magnetometer and electron reflectometer to determine the nature

of the magnetic field of Mars, and its interactions with the solar wind.

Unfortunately, none of these ambitious experiments were carried out. On August 21, 1993 the flight team was working to pressurize the propellant tanks in preparation for the main engine firing that would be required in 3 days to bring the spacecraft in orbit around Mars. To accomplish this, several valves needed to be opened using little explosive charges. These charges send off small shock waves through the spacecraft. The amplifier tubes in the spacecraft's radio transmitter are sensitive to these shock waves, so standard procedure (as had been done previously during Mars Observer's mission) was to instruct the onboard computer to shut down the transmitter, fire the charges, wait for the vibrations to settle down, and then switch the transmitter on again. The initial events occurred on schedule, and the transmitter was shut off - but never heard from again.

A post-mortem analysis revealed it likely that there was an unintentional mixing of propulsion fuel and oxidizer in the pressurization system tubing causing a small explosion. This resulted in a rupture of the tubing, spewing liquid helium, liquid fuel, and oxidizer over the spacecraft. This would cause the spacecraft to spin out of control, as well as cause shorts in the electrical wiring. As the solar panels were no longer pointing at the Sun, it would only be a matter of time before the batteries were depleted and power lost to the spacecraft.

Assuming this scenario, it is likely that the probe did not go into orbit about Mars, but rather flew past in orbit about the Sun. Despite numerous attempts to re-establish communication with the spacecraft, the Mars Observer mission was declared lost. Mars Surveyor, a replacement mission meant to recover most of the lost scientific goals of Mars Observer, is scheduled to launch in 1996.

1.92 Mars Pathfinder

Mars Pathfinder is a US mission currently planned for launch in December 1996. It is intended to use the technique of aerobraking (first tested by Magellan) to slow down once arriving and enter the atmosphere. At 10 km above the surface, parachutes will be deployed, but since the Martian atmosphere is quite thin, this will not be enough to ensure a soft landing. At 100 metres from the surface, solid rockets will be fired and air bags deployed to cushion the landing. Once the spacecraft has landed, "petals" will open to upright the lander in case it tips over when contact is made with the surface.

Within a few hours after landing, panoramic images of the Martian surface will be transmitted back to the Earth. Next a rover will be deployed - similar in concept, though different in design from the lunar rovers employed by astronauts on the Apollo missions. The rover will perform mobility tests, take images of its surroundings, and place an alpha proton X-ray spectrometer against rocks to make measurements of their composition.

It is hoped that the rover lasts one week, and the lander one month on the Martian surface.

1.93 Mars Surveyor

The Mars Global Surveyor mission is currently planned for launch by the USA in November 1996. It will be a polar orbiting spacecraft designed to provide global maps of the surface topography of Mars, determine the distribution of minerals, and study global weather patterns.

After launch from a Delta II vehicle, Mars Surveyor will spend 10 months journeying to Mars. Once arriving, it will be inserted into an elliptical capture orbit. Through a combination of thruster firings and aerobraking techniques (first demonstrated by the Magellan orbiter), the spacecraft will eventually reach a low, circular, polar orbit. In late January, 1998, the mapping process is expected to begin.

The spacecraft will carry much of the instrumentation launched on Mars Observer, a probe which never managed to fulfill any of its scientific objectives before it was lost. It is hoped to last at least one Martian year to observe the changes that appear as the planet goes through its cycle of seasons.

Mars Surveyor will also serve as a data relay station for the Mars 96 and Mars 98 CIS spacecraft.

1.94 Phobos 1

Phobos 1 (5000 kg) was launched by the USSR on July 7, 1988 to study Mars and its moons along with its sister ship Phobos 2. It was carried aloft by a four stage Proton launch vehicle from the Baikonur Cosmodrome near Tyuratum in the southern part of the USSR.

Scheduled to arrive on January 25, 1989, the probe observed the Sun and the conditions of interplanetary space, communicating the results to Earth every five days. However in late September, contact was lost with the spacecraft. It is expected that an erroneous command was sent from the Earth, causing the craft to lose its lock on the Sun. When the solar panels were no longer pointed in the proper direction to provide electricity, the probe shut down.

The spacecraft was to have landed a probe on Mars' moon Phobos, and to have obtained an unprecedented amount of data from the Martian system.

1.95 Phobos 2

Phobos 2 (5000 kg) was launched by the USSR on July 12, 1988 to study Mars and its moons along with its sister ship Phobos 1.

It was carried aloft by a four stage Proton launch vehicle from the Baikonur Cosmodrome near Tyuratum in the southern part of the USSR.

During its flight to Mars, the probe observed the Sun and the conditions of interplanetary space, communicating the results to Earth every five days. On January 29, 1989 the spacecraft was put into orbit around Mars. The orbit ranged from 875 km at closest approach and 80,000 km at furthest, with a period of 77 hours. This orbit was maintained for ten days, and then slowly lowered to a circular orbit taking the probe to within 30km of Mars' moon Phobos.

During Phobos 2's voyage to Mars, several technical problems arose. The television imaging system failed, making it impossible for controllers to manoeuvre the spacecraft closer to Phobos. The spacecraft lost power from one of its 50 watt power supplies. In an effort to conserve power, the high gain radio link to Earth was cut off and the on-board computers were commanded to control the probe while it was collecting data (the remaining 5 watt radio receiver was too slow to accept such commands from the ground). Then on March 27, 1989 the computer failed and the craft began to tumble out of control - making it rely totally on its batteries. But the batteries had a lifetime of only ten hours, and when the mission controllers on the ground failed to regain control in that time, the mission was lost.

The spacecraft was to have landed two probes on Phobos - one fixed in place and the other using spring loaded legs to hop 20 metres at a time in the weak gravity. In addition, the main probe was to have passed within 30 metres of the moon's surface. Unfortunately, contact was lost before any of these exciting events could come to pass.

The mission was not a total loss though. Dust and water ice were observed in the atmosphere of Mars. The atmospheric layers themselves were defined more clearly. Measurements showed that minerals on the surface of Phobos have even less water bound into their structure than had been previously thought. There is still the possibility that water exists within the moon's interior, however.

1.96 Pioneer 1

Pioneer 1 (38 kg) was launched by the USA on October 11, 1958 in an effort to place the spacecraft in orbit around the Moon. However, it failed in its mission, attaining an altitude of 118,000 km.

1.97 Pioneer 2

Pioneer 2 (39 kg) was launched by the USA on November 8, 1958 in an effort to place the spacecraft in orbit around the Moon. It failed in its mission, attaining an altitude of only 1600 km.

1.98 Pioneer 3

Pioneer 3 (6 kg) was launched by the USA on December 6, 1958. It was intended to fly past the Moon but was unsuccessful, reaching an altitude of 106,000 km.

1.99 Pioneer 4

Pioneer 4 (5.9 kg) was launched by the USA on March 3, 1959 to make a distant flyby of the Moon. After its encounter, it became the first US probe to orbit the Sun.

1.100 Pioneer 6

Pioneer 6 (63.4 kg) was launched by the USA on December 16, 1965 to study the Sun from solar orbit. It is still operational.

1.101 Pioneer 7

Pioneer 7 (63 kg) was launched by the USA on August 17, 1966 to study the Sun from solar orbit. It has been recently turned off.

1.102 Pioneer 8

Pioneer 8 (63 kg) was launched by the USA on December 13, 1967 to study the Sun and its radiation from solar orbit. It is still operational.

1.103 Pioneer 9

Pioneer 9 (63 kg) was launched by the USA on November 8, 1968 to study the Sun and its radiation from solar orbit. Operating for more than 18 years, it lasted until March 3, 1987 before its signal was lost.

1.104 Pioneer 10

Pioneer 10 (259 kg) was the first spacecraft to accomplish a variety of different things. Launched by the USA at 8:49 pm EST on March 3, 1972, it became the first probe to cross the asteroid belt, and the first to fly past Jupiter and return pictures and data (doing so on December 1, 1973, at a minimum distance of 130,000 km).

The findings at Jupiter were substantial - Pioneer 10 charted the planet’s intense radiation belts, discovered its magnetic field, and measured the masses of Io, Ganymede, Callisto, and Europa. In addition, it discovered that Jupiter was primarily a liquid planet, and determined the relative amount of hydrogen and helium in the atmosphere.

At this point, the spacecraft had completed its primary mission. However, since it was still operating perfectly, scientists reprogrammed the probe for an indefinite mission to explore the outer solar system and beyond. After the Jupiter encounter, the trajectory of Pioneer 10 was not sufficient to carry the spacecraft near any other planets, but it continued to study interplanetary space.

In its travels outward, Pioneer 10 measured the solar wind to see how it varied with distance from the Sun. On June 13, 1983, the spacecraft became the first to reach a distance further from the Sun than that of Pluto. When this occurred, some astronomers considered the probe to have left the solar system. But the boundaries of our solar system are not well defined. Most scientists consider the edge of the solar system to be the region where the solar wind is overpowered by a similar 'stellar wind' from nearby stars. This imaginary boundary is termed the heliopause. It is hoped that Pioneer 10 survives long enough to let us know when it travels through the heliopause. Project manager Richard Fimmel expects that contact will be maintained with the probe until the end of the 1990s, when the power supply will fall below the level required to maintain communications. In the meantime, scientists are carefully studying the position of the probe in an attempt to detect 'gravity waves' - tiny 'jiggles' in the fabric of space itself. As well, the exact position of the probe can be used to help determine if a possible tenth planet to our system (Planet X) might exist, and if so, where it is located.

Pioneer 10 is the most distant manmade object in existence. As of 1995, it is located more than 9 billion km from the Earth, requiring more than 8 hours for its radio signals, travelling at the speed of light, to reach us. It is estimated that in January 1998, Voyager 1's faster velocity will cause it to become further from the Sun than Pioneer 10, giving it the title of the furthest man-made object in space.

In case inhabitants from other star systems intercept Pioneer 10 millions of years from now, a pictoral message has been placed on the probe attempting to describe who we are and where we live. The picture is engraved into a gold-anodized aluminum plate measuring 152 x 229 mm, and attached to the antenna support struts in such a manner as to shield it from erosion by interstellar dust. The plaque may be viewed by clicking on the button at the bottom of this text - a description of the various elements in the picture follow.

First of all, a method of describing measurements is required. It would do little good to describe dimensions in metres or inches to an alien mind. This base measurement scale is represented by (1) in the diagram. The figure is meant to represent a reversal in the direction of spin of the electron in a hydrogen atom. This reversal causes the atom to emit a radio wave 21 cm long, so the indication is that 21 cm is our base length.

The radiating lines (3) represent a type of map to describe how to find our solar system. The varying lines define the direction and relative distances to a variety of pulsars in the Milky Way. Little tick marks near the lines denote the periods of these pulsars in binary form. The horizontal bar (2), used at the same scale as the other radiating lines indicates our distance from the center of our galaxy. Since pulsars are known to be slowing down, the combination of direction, distance, and pulsar periods described in the diagram may help aliens to determine our position not only in space, but also in time.

At the bottom of the drawing (4), we find a representation of our solar system. The ticks nearby each planet indicates, in binary form, the relative distances of the planets from the Sun. Pioneer 10 is drawn as having originated from the third planet - the Earth.

At the far right, the tick marks (5) show the height of the woman. The other marks (6) indicate the number 8 in binary form. Thus, the woman can be considered to be 8 times 21 cm (the base length) for a total of 168 cm tall. If this seems a little obscure, the size of the couple can also be determined from comparing their sizes to the scale drawing of the Pioneer 10 probe (7).

View Pioneer 10 plaque

1.105 Pioneer 11

Pioneer 11 (259 kg) was launched by the USA on April 6, 1973 to study Jupiter and Saturn.

On December 1, 1974 it flew to within 42,000 km of the Jovian cloud tops - much closer than had its predecessor, Pioneer 10. It provided the first photographs of the polar regions of the planet, and obtained a great deal of information about the Great Red Spot, as well as measured the temperature and magnetic field of Jupiter. In addition, it took the first measurements of Amalthea.

Flying past Jupiter at the unprecedented speed of 180,000 km/h Pioneer 11 shot onwards to Saturn. Arriving on September 1, 1979, the spacecraft was the first to visit the ringed planet. It flew within 21,400 km of the surface and took the first close up pictures. Two previously undetected moons were discovered, as well as an additional ring. Pioneer 11 charted Saturn's magnetosphere and magnetic field, as well as determined that Titan was much too cold for life.

After the encounter with Saturn, Pioneer 11 continued its outward journey. On February 23, 1990 the probe became further from the Sun than Neptune (currently the furthest planet from the Sun), and was considered by some to have left the solar system. But many astronomers feel that the boundary is best defined by the heliopause - the region in space where the solar wind is overcome by the 'stellar wind' from nearby stars. It was hoped that contact with the probe could be maintained until it reached this boundary, but the outlook is doubtful. The spacecraft's power has become too low to operate instruments and transmit data. On September 30, 1995, NASA ceased daily communications with the spacecraft. Instead, they plan to listen to it once or twice a month until the transmitter falls silent completely (predicted to be some time in late 1996). By learning more about this "fade-down" process, they will be able to better understand the future fate of Pioneer 10.

As with Pioneer 10, Pioneer 11 contains a plaque onboard describing where the spacecraft came from and what humans are like, in the event that it is ever discovered by an alien culture in the far future. For details on this plaque, see the entry for Pioneer 10.

1.106 Pioneer 12 (Pioneer Venus)

Pioneer Venus (582 kg) was launched by the USA on May 20, 1978 to study Venus. Placed into orbit on December 4, 1978, it became the first probe to penetrate the thick clouds covering the planet and create a map of the surface using a radar altimeter. It completed some 4000 orbits before ending its mission 14 years later on October 8, 1992.

Scientists carefully timed radar pulses from the spacecraft as they bounced off the surface and returned. They used this data to create topographical maps of Venus accurate to an altitude of approximately 200 meters. The orbit of Pioneer Venus allowed it to map approximately 93% of the planet's surface, missing only a small area at the north and south poles.

These maps revealed that most of Venus is covered by low, rolling plains varying less than 900 meters in altitude. A few basins and mountains exceed this variation, but in general Venus exhibits a relatively flat surface.

In addition to producing a radar map of the surface, the Pioneer Venus orbiter also studied the planet's atmosphere. When it first arrived in 1978, it discovered that sulfur dioxide gas, a major product of volcanic eruptions, was abundant. Over the next few years however, the sulfur dioxide gradually decreased while airborne dust particles increased. It is believed that the orbiter arrived shortly after a major volcanic eruption occurred. It also discovered a curious 'V' structure in the cloud patterns around Venus which is believed to be caused by the winds rotating around the planet faster at the equator than at the poles.
View cloud features of Venus taken by Pioneer Venus

An analysis of radio signal data indicated that there is as much, if not more, lightning activity within the thick cloud layers as there is on the Earth. It is suspected that the lightning is produced in the same manner - by the building up of opposite charges in the clouds.

For the first 19 months of the mission, NASA researchers used the spacecraft's hydrazine propellant to keep the orbit's lowest point (the periapsis) at 155 km above the planet's surface. Then, with only 10% of the propellant left, they allowed the Sun's gravity to slowly raise periapsis to 2500 km before returning it to a lower altitude.

At 3:22 PM EDT on October 8, 1992, when Pioneer Venus passed through a particularly low periapsis of 128 km, radio contact was lost. It is suspected that the spacecraft was disabled by the heat of friction with Venus' atmosphere.

1.107 Pioneer E

The Pioneer E (67 kg) spacecraft was intended to study the Sun. Unfortunately, its launch by the USA on August 27, 1969 was a failure and the mission was unsuccessful.

1.108 Pluto Fast Flyby

The Pluto Fast Flyby mission is intended to study Pluto - the only planet which has not yet been visited by spacecraft. If approved, this relatively inexpensive 110-150 kg spacecraft would launch in 2000 or 2001, arriving at Pluto between 2007-2010.

The spacecraft would not stop at the planet, but rather fly past at 12-18 km/second (43,000-65,000 km/hour), at a closest approach of 15,000 km. Data and images would be collected by the spacecraft during its encounter, and be transmitted slowly back to the Earth over the next year or so.

Scientific objectives for the mission include studying the geology of Pluto and its moon Charon, mapping the surface of each object, and studying Pluto's atmosphere. To accomplish this last objective, it is critical that the mission is launched as soon as possible. Pluto is currently moving further from the Sun, and as it does so, the cooler temperatures will cause the atmosphere to freeze and fall to the surface as "snow". If we miss this chance, we will have to wait until the year 2250 for a similar opportunity.

1.109 Ranger 3

Ranger 3 (327 kg) was a lunar probe launched by the USA on January 26, 1962. Meant to impact the Moon, it missed its target, and is now in solar orbit.

1.110 Ranger 4

Ranger 4 (328 kg) was a lunar probe launched by the USA on April 23, 1962. It managed to crash land on the Moon, as hoped. Unfortunately, it failed to send television pictures of the surface during its descent.

1.111 Ranger 5

Ranger 5 (340 kg) was a lunar probe launched by the USA on October 18, 1962. It made a flyby of the Moon, as intended, and is now in solar orbit.

1.112 Ranger 6

Ranger 6 (361.8 kg) was a lunar probe launched by the USA on January 30, 1964. As intended, it crash landed upon the lunar surface.

1.113 Ranger 7

Ranger 7 (362 kg) was a lunar probe launched by the USA on July 28, 1964. On July 31, it arrived at its target and managed to send 4,308 television pictures of the Moon before crash landing on the surface.

1.114 Ranger 8

Ranger 8 (366 kg) was a lunar probe launched by the USA on February 17, 1965. It crash landed, intentionally, on the Moon while relaying 7,137 pictures of the lunar surface back to Earth on its descent.

1.115 Ranger 9

Ranger 9 (366 kg) was a lunar probe launched by the USA on March 21, 1965. It crash landed, intentionally, in Alphonsus crater on the Moon while relaying 5,814 television pictures of the lunar surface back to Earth on its descent.

1.116 Sakigake

Sakigake (141 kg) was launched by Japan on January 7, 1985 to explore Comet Halley. It made its closest approach on March 1, 1986, studying the vast cloud of hydrogen surrounding the comet.

1.117 Sputnik7

Sputnik 7 (640 kg) was launched by the USSR on February 4, 1961 in an attempt to study Venus. Unfortunately, it failed to leave Earth orbit.

1.118 Suisei

Suisei (141 kg) was launched by Japan on August 18, 1985 to explore Comet Halley. It made its closest approach on March 8, 1986, studying the vast cloud of hydrogen surrounding the comet.

1.119 Surveyor 1

Surveyor 1 (269 kg) was launched by the USA on Apr 30, 1966 to study the Moon. On June 2 it landed, and during its lifetime on the lunar surface sent 11,237 television pictures back to the Earth. Contact was lost with the probe on July 13, 1966.

1.120 Surveyor 2

Surveyor 2 (292 kg) was launched by the USA on September 20, 1966 to study the Moon. Unfortunately, it failed in its attempt at landing and crashed to the surface.

1.121 Surveyor 3

Surveyor 3 (283 kg) was launched by the USA on April 17, 1967 to study the Moon. It made a successful landing, performed tests on a variety of soil samples, and returned photographs until May 3rd.

Pieces of Surveyor 3 were brought back by the Apollo 12 mission, to analyze what effects long term exposure on the lunar surface have on spacecraft.

1.122 Surveyor 4

Surveyor 4 (283 kg) was launched by the USA on July 14, 1967 to study the Moon. Unfortunately, it failed in its attempt at landing and crashed to the surface.

1.123 Surveyor 5

Surveyor 5 (279 kg) was launched by the USA on September 8, 1967 to study the Moon. Landing successfully, it performed tests on the lunar soil, sending the data back to the Earth for analysis. In addition, 19000 television images of the lunar surface were returned.

1.124 Surveyor 6

Surveyor 6 (280 kg) was launched by the USA on November 7, 1967 to study the Moon. It managed to land successfully, as well as depart from the surface.

1.125 Surveyor 7

Surveyor 7 (1036 kg) was launched by the USA on January 7, 1968 to study the Moon. It landed successfully on the lunar surface on January 10th.

1.126 Ulysses

Ulysses (370 kg) was a spacecraft designed by NASA and the ESA (European Space Agency), launched on October 6, 1990 to study the poles of the Sun and interplanetary space in the region above and below the ecliptic. The orientation of the Sun is such that the poles are never clearly visible from our location on Earth, requiring studies to be done from a spacecraft. Ulysses will observe the Sun at nearly all solar latitudes, but the regions near the poles have the most scientific value, simply because they have never been observed before.

When engineers design spacecraft to leave the Earth’s gravity, they usually launch them more or less in the direction that the Earth is moving in its orbit around the Sun. By doing so, the vehicle’s velocity comes from that of the Earth as well as rockets, and a considerable fuel savings may be obtained. Consequently, most interplanetary probes orbit near the plane of the Earth’s orbit (the ecliptic), and do not have the opportunity to study the regions outside of this plane. In order to attain an orbit out of the ecliptic, Ulysses used the strong gravitational field of Jupiter to swing its orbit around to pass within 10 degrees of the solar poles. Similar deflections were used successfully in the past to change an object’s orbit advantageously - perhaps made most famous by the Voyager probes in their exploration of the outer solar system.

The current orbit of Ulysses carries it from 1.5 AU at perihelion to 5.2 AU at aphelion.

A brief mission timeline for Ulysses is as follows:

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Event                            Date
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Launch from "Discovery"          Oct. 6/90
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 Jupiter Encounter                 Feb. 8/92
 Passage near south solar pole    Sep. 13/94
 Cross solar equator              Mar. 12/95
 Passage near north solar pole    Jul. 31/95
 Scheduled end of mission         Oct. 1/95
The spacecraft carries a number of experiments on board:

 - A pair of magnetometers to measure changes in the interplanetary
   magnetic field at different heliographic latitudes.
 - A low energy charged particle detector to measure the abundances
   of interplanetary ions and electrons.
 - A cosmic dust experiment to provide observations of the
   interactions between dust particles and the solar wind.
 - A radio and plasma wave experiment to determine the direction
   and polarization of charged particles in the solar wind that
   emit bursts of radio noise.  It will also study waves in clouds
   of ionized particles in the solar wind.
 - An experiment to determine the relationship between the relative
   abundances of electrons, protons, and heavy ions and their distance
   from the Sun and heliographic latitude.
 - A cosmic ray and solar particle instrument to attempt to resolve
   some problems in solar, interplanetary, and cosmic ray physics.
 - An X-ray and gamma burst experiment to measure electrons in solar
   flares and determine the direction of bursts of gamma ray radiation
   from within the galaxy.
 - An ion composition spectrometer to study the composition and mean
   temperatures of ions in the solar wind.
 - An energetic particle composition experiment to measure the
   intensities and energies of interplanetary ions to determine their
   masses and observe helium from interstellar space.
In addition, precise observations of the radio signal from Ulysses allow
scientists to measure density, turbulence, and velocity of the plasma in the
Sun's corona, as well as attempt to detect gravity waves.

Many significant discoveries about the Sun and the solar wind have already been
made by Ulysses.  Some of these findings include:

 - Ulysses has verified global differences in the speed of the wind
   flowing out from the Sun at different latitudes.  Most notably,
   solar winds at high southern latitudes traveled at roughly double
   the speed found in the equatorial zone.  The solar winds flow at
   approximately two million miles per hour (800 kilometers per second)
   at high southern latitudes, while dropping in velocity to about one
   million miles per hour (400 kilometers) near the equator.
 - As the spacecraft approached the equator, the solar wind continued to
   be very fast until around 20 degrees south latitude, at which time an
   abrupt transition to the low-speed, low-latitude solar wind was seen.
   Large variations in the solar wind speed and other properties then
   continued until the spacecraft reached 20 degrees north latitude, at
   which time only the fast solar wind was again observed continuously.
 - The loss of material from the Sun over the south pole, caused by the
   flow of the solar wind, is roughly one million tons per second.  This
   matter consists of hydrogen, helium and a small fraction of metals and
   heavy atoms.  Results of the southern pass also revealed the outward
   pressure of the solar wind to be much greater over the pole than it is
   around the equator.  As a consequence, the shape of the heliosphere - that
   region of space dominated by solar particles and electromagnetic
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fields - may be elongated in the polar direction, extending much farther out into interstellar space than it does near the equator.
- High energy cosmic radiation entering the inner solar system and, eventually, Earth's atmosphere, from the galaxy is controlled at all latitudes by the level of solar activity, which is determined by each phase of the Sun's 11-year sunspot cycle. The findings suggest the Sun's control over how much cosmic radiation enters the solar system is just as effective in the polar regions as it is near the equator.
- Plasma waves - electrical and magnetic fields that result from unstable distributions in the particles making up the solar wind - play a role in regulating the behavior of solar wind particles and were expected to be found at nearly identical levels in both hemispheres of the Sun. However, as Ulysses crossed the Sun's equator and entered the northern hemisphere, observations revealed significantly higher levels of several varieties of plasma waves in the northern region of the Sun, compared to their presence in the southern hemisphere. The cause of this asymmetry is not yet understood, but plasma wave measurements will continue to be used as a diagnostic tool for studying the local properties of the solar wind along the spacecraft's trajectory.

1.127 Unannounced spacecraft

Exploration always carries with it a risk of danger, and space travel is no exception. Since 1958, several lunar and interplanetary spacecraft have failed on launch or at some other point in their mission.

The former Soviet Union has not revealed the official designations for many of their failed missions. This section provides a short description for all known "unannounced" spacecraft.

Launch Date	Weight (kg)	Mission	Reason for failed mission
May 1, 1958	350	Lunar probe	Launch failure
Jun 25, 1958	350	Lunar probe	Launch failure
Sep 24, 1958	350	Lunar probe	Launch failure
Nov 15, 1958	350	Lunar probe	Launch failure
Jan 9, 1959	375	Lunar probe	Launch failure
Jun 16, 1959	375	Lunar probe	Launch failure
Apr 12, 1960	375	Lunar probe	Launch failure
Oct 10, 1960	640	Mars probe	Launch failure
Oct 14, 1960	640	Mars probe	Launch failure
Oct 24, 1960	640	Mars probe	Launch failure (see below)
Aug 25, 1962	890	Venus probe	Failed to leave Earth orbit
Sep 1, 1962	890	Venus probe	Failed to leave Earth orbit
Sep 12, 1962	890	Venus probe	Failed to leave Earth orbit
Oct 24, 1962	890	Mars probe	Failed to leave Earth orbit
Nov 4, 1962	890	Mars probe	Failed to leave Earth orbit
Jan 4, 1963	1400	Lunar lander	Failed to leave Earth orbit
Feb 3, 1963	1400	Lunar lander	Launch failure
Feb 27, 1964	950	Venus probe	Launch failure
Mar 4, 1964	950	Venus probe	Launch failure
Apr 9, 1964	1425	Lunar lander	Launch failure
Mar 27, 1967	950	Mars probe	Launch failure
Nov 22, 1967	5600	Lunar probe	Launch failure
Apr 22, 1968	5600	Lunar probe	Launch failure

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 Jan  5, 1969      5600      Lunar probe   Launch failure
 Apr 15, 1969      5600      Lunar sampler Launch failure
 Jun 12, 1969      5600      Lunar sampler Launch failure
 Feb 19, 1970      5600      Lunar sampler Launch failure
 Oct 13, 1975      5600      Lunar sampler Launch failure
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According to the April 1989 issue of the Russian magazine "Ogonyok", the world's greatest disaster in the history of space exploration may have occurred with the October 24, 1960 attempted launch of a spacecraft for Mars.

Shortly before scheduled liftoff, an electrical problem with the rocket had created a fuel leak. Field Marshall Mitrofan Nedelin, Commander in Chief of the Strategic Rocket Forces and the official in charge of the project, was under immense scientific and political pressure to launch the spacecraft with minimal delay. Standard procedure called for emptying the fuel from the rocket before attempting repairs, but he decided to forego these safety measures. While installing an electrical distributor, the second stage of the rocket suddenly ignited. In the matter of a few seconds, the flames from the second stage ignited the first stage, resulting in a tremendous explosion. Nedelin and dozens (perhaps hundreds) of technicians were instantly killed, and the launch pad was destroyed.

1.128 Vega 1 & 2

Vega 1 (5000 kg) was launched by the USSR on December 15, 1984 on a combined mission to study Venus and Halley's Comet. It, along with its sister ship "Vega 2" (also 5000 kg, launched December 21, 1984) reached Venus in June 1985. They both dropped landing craft that recorded data as they descended and while on the surface. Then, they continued on towards Halley's Comet, reaching it in March 1986.

Cameras and sensors onboard the spacecraft revealed that the nucleus of the comet was potato-shaped and larger than expected. It is approximately 15 km long and 8 km wide, rotating once in every 53 hours. There are spots on the surface which spew out gas and dust as the Sun strikes them, like a geyser.

Measurements from Vega 1 revealed that the black nucleus had a temperature of 77 degrees C. Since this temperature is much hotter than required for ice to vaporize in the vacuum of space, scientists believe that the surface layer must be an insulating crust of dark matter (possibly rock dust) covering the ice.

View nucleus of Comet Halley from Vega 2

1.129 Venera 1

Venera 1 (643.5 kg) was launched by the USSR on February 12, 1961. It was the first probe to fly past Venus. No longer operational, it is now in solar orbit.

1.130 Venera 2

Venera 2 (962 kg) was the fourth spacecraft to explore Venus. Launched by the USSR on November 12, 1965 it passed within 40,200 km of the planet on February 27, 1966. Unfortunately, its communication system failed just before its arrival. It is now in solar orbit.

1.131 Venera 3

Venera 3 (958 kg) was launched by the USSR on November 16, 1965 to explore Venus. It was meant to enter the atmosphere, returning data as it descended. Unfortunately, communications failed just before atmospheric entry. It crashed to the surface on March 1, 1966.

1.132 Venera 4

Venera 4 (1104 kg) was launched by the USSR on June 12, 1967 to explore Venus. On October 18, it dropped a capsule of instruments into Venus' atmosphere by parachute. It managed to return data until it was crushed by the intense atmospheric pressure on Venus. Venera 4 was the first space probe to give us direct evidence on the state and composition of the Cytherean (Venusian) atmosphere, reporting a high concentration of carbon dioxide.

1.133 Venera 5

Venera 5 (1128 kg) was launched by the USSR on January 5, 1969 to explore Venus. An atmospheric probe like Venera 4, it returned data until crushed on May 5, 1969, by the atmospheric pressure at 26 km from the surface of Venus. Venera 5 was a sister ship of Venera 6.

1.134 Venera 6

Venera 6 (1128 kg) was a sister ship to Venera 5. Launched by the USSR on January 10, 1969 to explore Venus, it returned data on the atmosphere of Venus as it descended towards the surface of the planet on May 17, 1969. It reached to within 11 km of the surface, at which point it was crushed by the intense atmospheric pressure.

1.135 Venera 7

Venera 7 (1180 kg) was launched by the USSR on August 17, 1970 to explore Venus. On December 15, 1970 it made a soft landing on the surface, being the first spacecraft to successfully land on another planet. It returned data for 23 minutes until it was overcome by the intense heat and atmospheric pressure.

1.136 Venera 8

Venera 8 (1180 kg) was launched by the USSR on March 27, 1972 to explore Venus. On July 22nd, it made a successful soft landing on the surface, and returned data for 50 minutes until it was overcome by the intense heat and atmospheric pressure.

1.137 Venera 9

Venera 9 (4936 kg) was launched by the USSR on June 8, 1975 to explore Venus. It separated into two parts - an orbiter which remained in Venus orbit and a lander which made a successful descent to the planet's surface on October 22, 1975. Venera 9 landed on a slope inclined by about 30 degrees. The lander had the distinction of being the first device to return an image of the surface of another planet, and operated for 53 minutes before being overcome by the intense heat and pressure at the surface of the planet.

Data returned from Venera 9 and Venera 10 showed that the clouds of Venus are surprisingly thin - more like a haze than heavy clouds. As a result, the surface is much brighter than had been previously expected. It is comparable to that of the Earth on an overcast day.

In addition, the probes returned evidence that the clouds are actually composed of tiny droplets of sulfuric acid.

1.138 Venera 10

Venera 10 (5033 kg) was launched by the USSR on June 14, 1975 to explore Venus. It separated into two parts - an orbiter which remained in Venus orbit and a lander which made a successful descent to the planet's surface on October 25, 1975. Venera 10 landed on a slope inclined by about 8 degrees. The lander survived for 65 minutes before being overcome by the intense heat and atmospheric pressure of Venus, returning an image and other data.

Data returned from Venera 10 and Venera 9 showed that the clouds of Venus are surprisingly thin - more like a haze than heavy clouds. As a result, the surface is much brighter than had been previously expected. It is comparable to that of the Earth on an overcast day.

In addition, the probes returned evidence that the clouds are actually composed of tiny droplets of sulfuric acid.

1.139 Venera 11

Venera 11 (4940 kg) was launched by the USSR on September 9, 1978 to explore Venus. It successfully landed on the surface on December 25, 1978, managing to return pictures and data for 95 minutes before being overcome by the intense heat and pressure at the surface.

An alternate purpose of Venera 11 and Venera 12 was to investigate the possibility of an Earth to Venus route for future spacecraft.

1.140 Venera 12

Venera 12 (4940 kg) was launched by the USSR on September 14, 1978 to explore Venus. It successfully landed on the surface on December 21, 1978, managing to return pictures and data for 110 minutes before being overcome by the intense heat and pressure at the surface.

An alternate purpose of Venera 11 and 12 was to investigate the possibility of an Earth to Venus route for future spacecraft.

1.141 Venera 13

Venera 13 (5000 kg) was launched by the USSR on October 31, 1981 to explore Venus. Landing on March 1, 1982, it became the first space probe to return a color picture of Venus’ surface.

Venera 13 and its sister probe Venera 14 returned several color and black & white photographs, as well as data from a detailed chemical analysis of the planet. Soviet geophysicists reporting on the results of the mission at the Lunar and Planetary Science Conference in Houston on March 18th said that the photographs yielded "convincing proof" that the sky of Venus is reddish-orange in color. Additionally, the sandy and rocky area in which Venera 13 landed is dark brown. It is suspected that the surface is basaltic, like volcanic rock on the Earth. Such a finding reveals that the chemical processes at work on Venus and Earth are similar, leading scientists to look for other reasons to explain why the two planets have had such a different evolutionary history.

Venera 13 transmitted data for more than two hours before being overcome by the intense heat and pressure at the surface of Venus.

The pictures returned by the Venera probes appear to have been taken through a "fisheye" lens. This is an extreme wide angle lens, distorting the edges of the image substantially, but allowing more to be observed in a single frame. Thus, in Venera images, one can see the base of the spacecraft in the lower center region, with the horizon appearing curved at the far left and right edges.

The picture of the Venusian surface provided with "The Digital Universe" is not one of the color pictures returned by Venera 13, but instead a black and white image showing greater detail.
View surface of Venus taken by Venera 13

1.142 Venera 14

Venera 14 (5000 kg) was launched by the USSR on November 4, 1981 to explore Venus. It successfully landed on the surface on March 5, 1982.

Venera 14 and its sister probe Venera 13 returned several color and black & white photographs and data from a detailed chemical analysis of the planet. Soviet geophysicists reporting on the results of the mission at the Lunar and Planetary Science Conference in Houston on March 18th said that the photographs yielded "convincing proof" that the sky of Venus is reddish-orange in color. It is suspected that the surface is basaltic, like volcanic rock on the Earth. Such a finding reveals that the chemical processes at work on Venus and Earth are similar, leading scientists to look for other reasons to explain why the two planets have had such a different evolutionary history.

Venera 14 transmitted data for approximately one hour before being overcome by the intense heat and pressure at the surface of Venus.

1.143 Venera 15

Venera 15 (5000 kg) was launched by the USSR on June 2, 1983 to explore Venus. It arrived at Venus on October 10, 1983, at which time it began a radar mapping mission from orbit.

At a March 15, 1984 conference in Houston, Alexei T. Basilevsky presented data from Venera 15 and Venera 16. He revealed that land having the physical characteristics of volcanoes is present all over the surface. Unlike the Moon and Mercury, which are literally scarred by thousands of craters, only 57 could be found on Venus. Presumably, most craters have been covered over by lava flows from these volcanoes.

1.144 Venera 16

Venera 16 (5000 kg) was launched by the USSR on June 7, 1983 to explore Venus. It arrived at Venus on October 14, 1983, at which time it began a radar mapping mission from orbit.

At a March 15, 1984 conference in Houston, Alexei T. Basilevsky presented data from Venera 15 and Venera 16. He revealed that land having the physical characteristics of volcanoes is present all over the surface. Unlike the Moon and Mercury, which are literally scarred by thousands of craters, only 57 could be found on Venus. Presumably, most craters have been covered over by lava flows from these volcanoes.

1.145 Viking 1

View picture of spacecraft

Viking 1 (3399 kg) was launched by the USA on August 20, 1975 to study Mars. It consisted of two parts - a lander and an orbiter. Viking 2 was its sister ship.

The spacecraft successfully entered orbit on June 19, 1976. It returned a wealth of images of the planet’s surface. In viewing these images, the Viking team decided that the original intended landing site was unsafe, and changed the flight plan of the lander. It successfully touched down at latitude 22.3deg N, longitude 48.0deg, on the western side of Cryse Planitia (the Plains of Gold) on July 20th.

The Viking spacecraft were hoped to last 90 days after the landing. In fact, they both lasted far longer than that, with the Viking 1 orbiter surviving for some 4 years. In the end, it ran out of attitude control gas and was commanded to shut down on August~7, 1980 after completing 1,489 orbits. It is expected to crash to the planet's surface by the year 2025.

The lander also performed remarkably well. With the exception of a seismometer, all instruments worked as expected. Several experiments were carried out. Biology experiments detected unexpected chemical activity in the Martian soil, but gave no clear evidence for the presence of living microorganisms. It is currently believed that a combination of solar ultraviolet radiation and extreme dryness prevents the formation of living organisms. It is still unknown as to whether life may have existed on Mars in the far distant past, though. After the loss of the orbiter, the lander was switched into a weather reporting mode in which it was hoped to continue sending data to the Earth until 1994. Unfortunately, a command was accidentally sent to the lander on November 13, 1982 telling it to shut down until further notice. Contact was never restored.

It was found that barometric pressure varies at both landing sites on a semiannual basis. This is because in the winter, carbon dioxide in the atmosphere freezes to form a huge polar cap at the pole. In the summer, this cap evaporates once again. It was found that a small polar cap of water ice remains in the northern hemisphere during the summer.
View picture of Mars' south polar cap

The landers returned some 4,500 images of the planet's surface, while the orbiters returned some 52,000 pictures. In total, 97% of the surface of Mars was mapped.

View craters and cliffs on Mars from orbit
View image of Deimos taken from Viking
View image of Phobos taken from Viking
View image of Olympus Mons from Viking
View hemisphere of Mars, showing Schiaparelli crater

1.146 Viking 2

View picture of spacecraft

Viking 2 (3399 kg) was launched by the USA on September 9, 1975 to study Mars. It consisted of two parts - a lander and an orbiter. Viking 1 was its sister ship.

The spacecraft successfully entered orbit on August 7, 1976. It returned a wealth of images of the planet's surface. In viewing these images, the Viking team decided that the original intended landing site was unsafe, and changed the flight plan of the lander. It successfully touched down at latitude 47.7deg N, longitude 48.0deg, at Utopia Planitia on September 3rd.

The Viking spacecraft were hoped to last 90 days after the landing. In fact, they both lasted far longer than that. Contact was lost with the Viking 2 orbiter on July 25, 1978 when it ran out of attitude control gas to control its orientation in space. Its orbit is decaying, and the orbiter is expected to crash into the planet's surface by the year 2025.

The lander also performed remarkably well, with all instruments working as expected. Several experiments were carried out, and one small "marsquake" appeared to have been detected with the onboard seismometer. Much later, researchers attributed this event with wind buffeting and not ground movement. This does not necessarily mean, however, that Mars is geologically inactive, since the seismometer was only sensitive enough to pick up a quake of 3 on the Richter scale if the epicenter were within 200 km of the lander. If a magnitude 8 quake were to occur on the opposite side of the planet, it would go unnoticed.

Biology experiments detected unexpected chemical activity in the Martian soil, but gave no clear evidence for the presence of living microorganisms. It is currently believed that a combination of solar ultraviolet radiation and extreme dryness prevents the formation of living organisms. It is still unknown as to whether life may have existed on Mars in the far distant past, though. Contact was lost with the lander on April 12, 1980.

It was found that barometric pressure varies at both landing sites on a semiannual basis. This is because in the winter, carbon dioxide in the atmosphere freezes to form a huge polar cap at the pole. In the summer, this cap evaporates once again. It was found that a small polar cap of water ice remains in the northern hemisphere during the summer. It was observed that a thick layer of water frost covered the ground around Viking 2 each winter.
View picture of Mars' south polar cap
View summer picture of Mars' surface from Viking 2 lander
View winter picture of Mars' surface from Viking 2 lander

The landers returned some 4,500 images of the planet's surface, while the orbiters returned some 52,000 pictures. In total, 97% of the surface of Mars was mapped.

View craters and cliffs on Mars from orbit
View image of Deimos taken from Viking
View image of Phobos taken from Viking
View image of Olympus Mons from Viking
View hemisphere of Mars, showing Schiaparelli crater

1.147 Voyager 1

View picture of Voyager spacecraft

Voyager 1, and its sister ship Voyager 2 were two of the most highly successful interplanetary explorers of the American space program. Launched on September 5, 1977, this 800 kg spacecraft was designed to obtain as much information as possible about Jupiter, Saturn, and the moons associated with each planet (Voyager 2 went on to explore Uranus and Neptune as well). It was then sent in a long journey out of the solar system, and is still returning valuable data about the nature of space beyond the orbit of Pluto.

Voyager 2 was actually launched before Voyager 1, but since the latter was on a faster trajectory, it reached its targets earlier.

Voyagers 1 and 2 are identical spacecraft. They contain 10 different experiment packages, including cameras, infrared and ultraviolet sensors, magnetometers, plasma detectors, and cosmic ray and charged particle sensors. As well, the signal received from the spacecraft's radio was extensively studied to reveal a great deal of additional information.

The Voyager probes traveled too far from the Sun to use conventional solar panels - at the distances they achieved, the Sun was simply not bright enough to produce a sufficient amount of energy. So they used devices known as radioisotope thermoelectric generators (RTGs) which convert the heat produced from the natural radioactive decay of plutonium into electricity.

The trajectory taken by the Voyager probes took advantage of a rare geometric arrangement of the outer planets that only occurs every 189 years. This arrangement allowed the spacecraft to use the gravitational field of one planet to propel it on towards the other without the need for large rocket engines to alter its course. As a result, between the two spacecraft, all four of the gas giant planets in the solar system were studied, resulting in a considerable savings both in money and time.

Since most of our current knowledge of Jupiter, Saturn, Uranus, and Neptune was obtained from the highly successful Voyager probes, detailed explanations of the findings are not presented here. Instead, links are provided to obtain the information directly from the database of information known about the various objects encountered.

The following timeline of events associated with Voyager 1 is provided:

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 Sep.  5/77 - Launch aboard a Titan/Centaur rocket.

 Mar.  5/79 - Closest approach to Jupiter, at 348,890 km.
 Mar.  5/79 - Closest approach to Io, at 20,570 km.
 Mar.  5/79 - Closest approach to Ganymede, at 114,710 km.
 Mar.  5/79 - Closest approach to Europa, at 734,000 km.
 Mar.  6/79 - Closest approach to Callisto, at 126,400 km.
            - 19,000 pictures were taken during the Jupiter encounter

 Nov. 11/80 - Closest approach to Titan, at 4000 km.
 Nov. 12/80 - Closest approach to Saturn, at 184,300 km.
 Nov. 12/80 - Closest approach to Tethys, at 415,670 km.
 Nov. 12/80 - Closest approach to Mimas, at 88,440 km.
 Nov. 12/80 - Closest approach to Enceladus, at 202,040 km.
 Nov. 12/80 - Closest approach to Dione, at 161,520 km.
 Nov. 12/80 - Closest approach to Rhea, at 73,980 km.
 Nov. 13/80 - Voyager 1 left the Saturnian system in its long voyage
              out of the solar system.

 May, 1993  - Mission scientists declared that the plasma wave
              experiments were beginning to pick up radio emissions
              from the heliopause.
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It is hoped that scientists will remain in contact with Voyager 1 for at least another 25 to 30 years. After that time, the increasing distance coupled with the reduced power of the radio transmitter will render the signal too weak to be detected.

Significant discoveries by the Voyager probes include:

- 26 new moons were discovered: 3 at Jupiter, 7 at Saturn, 10 at Uranus, and 6 at Neptune. In addition, one satellite of Saturn (Janus), originally discovered in 1966 was revealed to actually consist of 2 different satellites, travelling in similar orbits.
- Io was found to have active volcanoes. It is the only body in the solar system other than the Earth with this feature.
- Triton was discovered to have active geysers and an atmosphere.
- Aurorae were discovered near the poles of Jupiter, Saturn, and Neptune.
- Jupiter was discovered to have rings. Thousands of additional rings were found in Saturn's system. The rings of Uranus and Neptune were thought to only exist as 'arcs', but Voyager 2 revealed them to be complete structures.
- 'Spokes' appear in the rings of Saturn.
- The magnetic fields of Uranus and Neptune are highly inclined and offset from the planets' axes of rotation. This suggests that their sources are significantly different from the magnetic fields observed elsewhere.
- A large dark spot was observed in the atmosphere of Neptune. This was surprising, since it was previously thought that Neptune was too cold to support such large scale storms.

It is estimated that in January 1998, Voyager 1's faster velocity will cause it to become further from the Sun than Pioneer 10, giving it the title of the furthest man-made object in space.

Further details on these (and more) discoveries are available by obtaining information on the various planets studied by the Voyagers.

Voyager 1 is currently headed towards the star Rasalhague in the constellation of Ophiuchus. Its first encounter with a star will occur 40,270 years from now when it passes within 1.6 light years of an 11th magnitude small, cool red star known only as AC+79 3888, in the constellation of Camelopardalis.

1.148 Voyager 2

View picture of Voyager spacecraft

Voyager 2, and its sister ship Voyager 1 were two of the most highly successful interplanetary explorers of the American space program. Launched on August 20, 1977, this 800 kg spacecraft was designed to obtain as much information as possible about Jupiter, Saturn, and the moons associated with each planet. After performing remarkably well, mission controllers sent it out to perform the extended mission of a flyby of Uranus and Neptune. It succeeded, and is currently on its way out of the solar system, still returning useful data about the nature of space beyond the orbit of Pluto.

Voyager 2 was actually launched before Voyager 1, but since the latter was on a faster trajectory, it reached its targets earlier.

Voyagers 1 and 2 are identical spacecraft. They contain 10 different experiment packages, including cameras, infrared and ultraviolet sensors, magnetometers, plasma detectors, and cosmic ray and charged particle sensors. As well, the signal received from the spacecraft's radio was extensively studied to reveal a great deal of additional information.

The Voyager probes traveled too far from the Sun to use conventional solar panels - at the distances they achieved, the Sun was simply not bright enough to produce a sufficient amount of energy. So they used devices known as radioisotope thermoelectric generators (RTGs) which convert the heat produced from the natural radioactive decay of plutonium into electricity.

The trajectory taken by the Voyager probes took advantage of a rare geometric arrangement of the outer planets that only occurs every 189 years. This arrangement allowed the spacecraft to use the gravitational field of one planet to propel it on towards the other without the need for large rocket engines to alter its course. As a result, between the two spacecraft, all four of the gas giant planets in the solar system were studied, resulting in a considerable savings both in money and time.

Since most of our current knowledge of Jupiter, Saturn, Uranus, and Neptune was obtained from the highly successful Voyager probes, detailed explanations of the findings are not presented here. Instead, links are provided to obtain the information directly from the database of information known about the various objects encountered.

The following timeline of events associated with Voyager 2 is provided:

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 Aug. 20/77 - Launch aboard a Titan/Centaur rocket.

 Jul.  8/79 - Closest approach to Callisto, at 214,930 km.
 Jul.  9/79 - Closest approach to Ganymede, at 62,130 km.
 Jul.  9/79 - Closest approach to Europa, at 205,720 km.
 Jul.  9/79 - Closest approach to Jupiter, at 722,000 km.
 Jul.  9/79 - Closest approach to Io, at 1,130,000 km.
            - 33,000 pictures were taken during the Jupiter encounter

 Aug. 24/81 - Closest approach to Titan, at 666,190 km.
 Aug. 25/81 - Closest approach to Saturn, at 161,000 km.
 Aug. 25/81 - Closest approach to Iapetus, at 908,680 km.
 Aug. 25/81 - Closest approach to Hyperion, at 431,370 km.
 Aug. 25/81 - Closest approach to Enceladus, at 87,010 km.
 Aug. 25/81 - Closest approach to Tethys, at 93,010 km.
 Aug. 25/81 - Closest approach to Phoebe, at 2,100,000 km.

 Jan. 24/86 - Closest approach to Uranus, at 81,500 km.

 Aug. 25/89 - Closest approach to Neptune, at 5,000 km.

 May, 1993  - Mission scientists declared that the plasma wave
              experiments were beginning to pick up radio emissions
              from the heliopause.
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It is hoped that scientists will remain in contact with Voyager 2 for at least another 25 to 30 years. After that time, the increasing distance coupled with the reduced power of the radio transmitter will render the signal too weak to be detected.

Significant discoveries by the Voyager probes include:

- 26 new moons were discovered: 3 at Jupiter, 7 at Saturn, 10 at Uranus, and 6 at Neptune. In addition, one satellite of Saturn (Janus), originally discovered in 1966 was revealed to actually consist of 2 different satellites, travelling in similar orbits.

- Io was found to have active volcanoes. It is the only body in the solar system other than the Earth with this feature.
- Triton was discovered to have active geysers and an atmosphere.
- Aurorae were discovered near the poles of Jupiter, Saturn, and Neptune.
- Jupiter was discovered to have rings. Thousands of additional rings were found in Saturn's system. The rings of Uranus and Neptune were thought to only exist as 'arcs', but Voyager 2 revealed them to be complete structures.
- 'Spokes' appear in the rings of Saturn.
- The magnetic fields of Uranus and Neptune are high inclined and offset from the planets' axes of rotation. This suggests that their sources are significantly different from the magnetic fields observed elsewhere.
- A large dark spot was observed in the atmosphere of Neptune. This was surprising, since it was previously thought that Neptune was too cold to support such large scale storms.

Further details on these (and more) discoveries are available by obtaining information on the various planets studied by the Voyagers.

Voyager 2 is currently headed towards the southern portion of the constellation Pavo. Over the next million years, it will pass by 13 stars, though at substantial distances. The years of closest approach, as well as the associated distances, are summarized in the following table:

		Distances in light years		
Star	Year	Voyager-Star	Sun-Voyager	Sun-Star
Barnard's Star	8,571	4.03	0.42	3.80
Proxima Centauri	20,319	3.21	1.00	3.59
Alpha Centauri	20,629	3.47	1.02	3.89
Lalande 21185	23,274	4.65	1.15	4.74
Ross 248	40,176	1.65	1.99	3.26
DM-36 13940	44,492	5.57	2.20	7.39
AC+79 3888	46,330	2.77	2.29	3.76
Ross 154	129,084	5.75	6.39	8.83
DM+15 3364	129,704	3.44	6.42	6.02
Sirius	296,036	4.32	14.64	16.58
DM-5 4426	318,543	3.92	15.76	12.66
44 Ophiuchi	442,385	6.72	21.88	21.55
DM+27 1311	957,963	6.62	47.38	47.59

1.149 Zond 1

Zond 1 (890 kg) was launched by the USSR on April 2, 1964 to explore Venus. No longer operational, it is now in solar orbit.

1.150 Zond 2

Zond 2 (890 kg) was launched by the USSR on November 30, 1964 to explore Venus. It failed while en route to the planet.

1.151 Zond 3

Zond 3 (959 kg) was launched by the USSR on July 18, 1965 to study the Moon. While flying past the Moon, it returned pictures of the far side. It is now in solar orbit.

1.152 Zond 4

Zond 4 (5600 kg) was launched by the USSR on March 2, 1968 as a test flight to measure conditions in space on a journey to the Moon. It is now in solar orbit.

1.153 Zond 5

Zond 5 (5375 kg) was launched by the USSR on September 14, 1968. It was the first probe to orbit the Moon and return to a soft landing on the Earth. It returned on September 21st, and splashed down in the Indian Ocean.

1.154 Zond 6

Zond 6 (5375 kg) was launched by the USSR on November 10, 1968. Like Zond 5, it orbited the Moon and returned to a soft landing on the Earth (in the USSR).

1.155 Zond 7

Zond 7 (5979 kg) was launched by the USSR on August 8, 1969. It flew around the Moon and returned to a soft landing on the Earth (in the USSR) on August 14th.