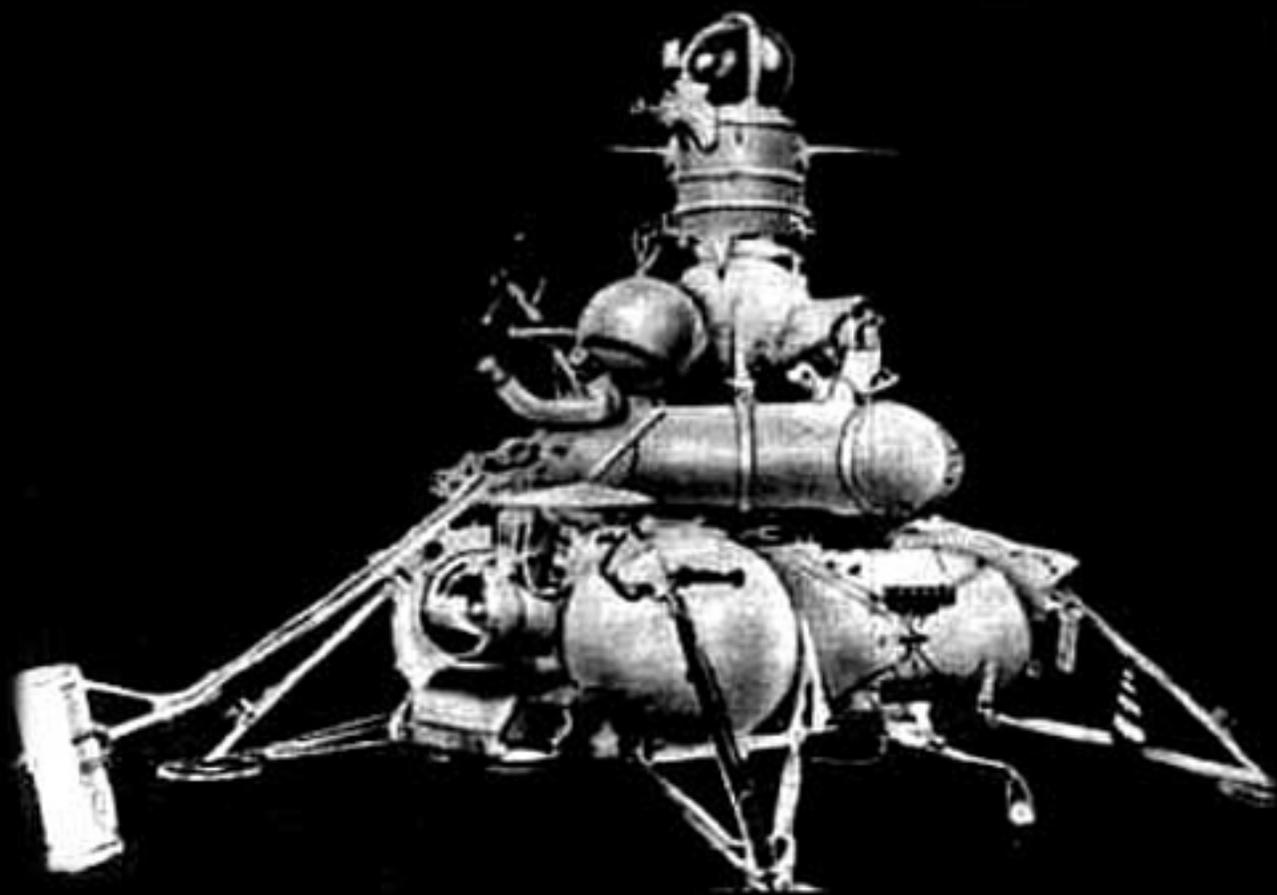


Handbook of
Space and Solar System
Exploration in 1970s



Stewart Griffith

First Edition, 2012

ISBN 978-81-323-2385-3

© All rights reserved.

Published by:

Library Press

4735/22 Prakashdeep Bldg,

Ansari Road, Darya Ganj,

Delhi - 110002

Email: info@wtbooks.com

Table of Contents

Chapter 1 - Space and Solar System Exploration in 1970

Chapter 2 - Space and Solar System Exploration in 1971

Chapter 3 - Space and Solar System Exploration in 1972

Chapter 4 - Space and Solar System Exploration in 1973

Chapter 5 - Space and Solar System Exploration in 1974

Chapter 6 - Space and Solar System Exploration in 1975

Chapter 7 - Space and Solar System Exploration in 1977

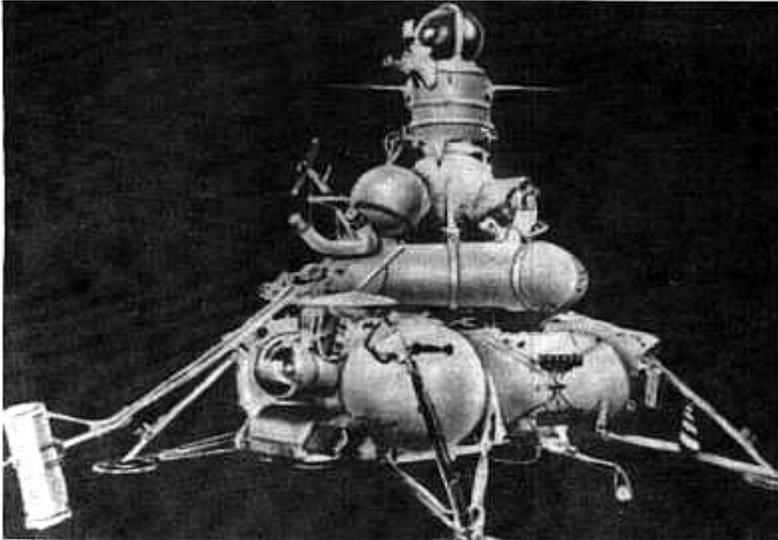
Chapter 8 - Space and Solar System Exploration in 1978

Chapter- 1

Space and Solar System Exploration in 1970

Luna E-8-5 No.405

Luna E-8-5 No.405



A Luna E-8-5 spacecraft

Major contractors	NPO Lavochkin
Bus	Luna E-8-5
Mission type	Lunar lander Sample return
Launch date	6 February 1970 04:16:06 UTC
Carrier rocket	Proton-K/D 8K82K s/n 247-01
Launch site	Baikonur Site 81/23

Mass 5,600 kilograms (12,000 lb)

Luna E-8-5 No.405, also known as **Luna Ye-8-5 No.405**, and sometimes identified by NASA as **Luna 1970A**, was a Soviet spacecraft which was lost in a launch failure in 1970. It was a 5,600-kilogram (12,000 lb) Luna E-8-5 spacecraft, the fifth of eight to be launched. It was intended to perform a soft landing on the Moon, collect a sample of lunar soil, and return it to the Earth.

Luna E-8-5 No.405 was launched at 04:16:06 UTC on 6 February 1970 atop a Proton-K 8K78K carrier rocket with a Blok-D upper stage, flying from Site 81/23 at the Baikonur Cosmodrome. The rocket malfunctioned, and the spacecraft failed to achieve orbit. Prior to the release of information about its mission, NASA correctly identified that it had been an attempted sample return mission.

Venera 7

Venera 7 (3V (V-70))



Model of Venera 7 Descent Capsule

Mission type Lander

Satellite of	Venus
Orbital insertion date	Landed on December 15, 1970
Launch date	August 17, 1970
Launch vehicle	Molniya Booster Plus Upper Stage and Escape Stages
Mission duration	August 17, 1970 to December 15, 1970
Orbital decay	N/A
COSPAR ID	1970-060A
Mass	1180 kg

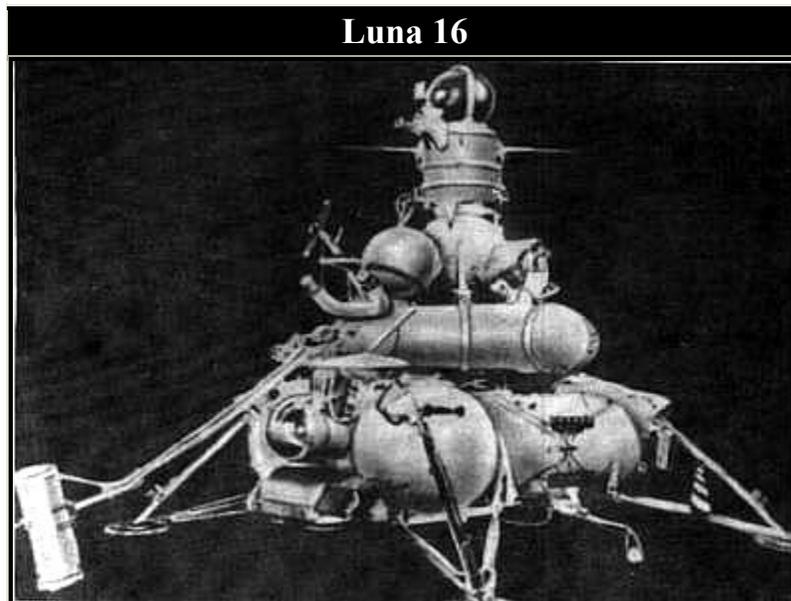
The **Venera 7** (Russian: Венера-7) (manufacturer's designation: 3V (V-70)) was a Soviet spacecraft, part of the Venera series of probes to Venus. When it landed on the Venusian surface, it became the first man-made spacecraft to successfully land on another planet and to transmit data from there back to Earth.

- Launch date/time: 1970 August 17 at 05:38 UTC
- On-orbit dry mass: 1180 kg
- Lander mass: 495 kg

It entered the atmosphere of Venus on December 15, 1970 and landed on the planet at 05:34:10 UTC of the same day. Landing coordinates are 5°S 351°E / 5°S 351°E.

The capsule antenna was extended, and signals were returned for 35 minutes. Venera 7 suddenly went silent. However, recording tapes kept rolling. A few weeks later, another 23 minutes of very weak signals were found on them. The spacecraft had landed on Venus, probably bounced onto its side on landing, and the medium gain antenna was not pointed correctly for strong signal transmission to Earth.

Luna 16



Organization:	Soviet Union
Major Contractors:	GSMZ Lavochkin
Mission Type:	Planetary Science Lunar Sample Return
Satellite of:	Moon
Launch:	September 12, 1970 at 13:25:53 UTC
Launch Vehicle:	Proton 8K82K + Blok D
Mission Highlight:	101-gram sample returned on September 24, 1970, 05:25 UTC 80 km SE of Dzhezkazgan, Kazakhstan.
Mission Duration:	12-days
Mass:	5,600 kg
NSSDC ID:	1970-072A
Webpage:	NASA NSSDC Master Catalog
Orbital elements	
Semimajor Axis:	6,488.8 km
Eccentricity:	0
Inclination:	70°

Orbital Period:	119 minutes
Aposelene:	111 km
Periselene:	111 km
Orbits:	~36
Lunar Landing:	September 20, 1970, 05:18 UTC
Landing coordinates:	0°41' S, - 56°18' E.
Lunar liftoff:	September 21, 1970, 07:43 UTC
Instruments	
Stereo imaging system:	Lunar photography
Remote arm for sample collection:	collect lunar material
Radiation detector:	Lunar radiation environment

Luna 16 (Ye-8-5 series) was an unmanned space mission, part of the Soviet Luna program.

Luna 16 was the first robotic probe to land on the Moon and return a sample of lunar soil to Earth. It represented the first lunar sample return mission by the Soviet Union, and was the third lunar sample return mission overall, following the Apollo 11 and Apollo 12 missions.

The spacecraft consisted of two attached stages, an ascent stage mounted on top of a descent stage. The descent stage was a cylindrical body with four protruding landing legs, fuel tanks, a landing radar, and a dual descent engine complex.

A main descent engine was used to slow the craft until it reached a cutoff point which was determined by the onboard computer based on altitude and velocity. After cutoff a bank of lower thrust jets was used for the final landing. The descent stage also acted as a launch pad for the ascent stage.

The ascent stage was a smaller cylinder with a rounded top. It carried a cylindrical hermetically sealed soil sample container inside a re-entry capsule.

The spacecraft descent stage was equipped with a television camera, radiation and temperature monitors, telecommunications equipment, and an extendable arm with a drilling rig for the collection of a lunar soil sample.

Mission profile

The Luna 16 automatic station was launched toward the Moon from a preliminary Earth orbit and after one mid-course correction on 13 September it entered a circular 111 km with 70° inclination lunar orbit on September 17, 1970.

The lunar gravity was studied from this orbit. After two orbital adjustments were performed on 18 September and 19 September the perilune was decreased to 15.1 km, as well as the inclination altered in preparation for landing. At perilune at 05:12 UT on 20 September, the main braking engine was fired, initiating the descent to the lunar surface. Six minutes later at 05:18 UT, the spacecraft safely soft-landed in its target area at 0°41' south latitude and 56°18' east longitude, in the northeast area of the Sea of Fertility, approximately 100 kilometers east of Webb crater. This was the first landing made in the lunar night side, as the Sun had set about 60 hours earlier. The main descent engine cut off at an altitude of 20 m and the landing jets cut off at 2 m height at a velocity less than 2.4 m/s, followed by vertical free-fall. The mass of the spacecraft at landing was 1,880 kilograms. Less than an hour after landing, at 06:03 UT, an automatic drill penetrated the lunar surface to collect a soil sample. After drilling for 7 minutes, the drill reached a stop at 35 centimeters depth and then withdrew its sample and lifted it in an arc to the top of the spacecraft, depositing the lunar material in a small spherical capsule mounted on the main spacecraft bus. The column of regolith in the drill tube was then transferred to the soil sample container.

Finally, after 26 hours and 25 minutes on the lunar surface at 07:43 UT on 21 September, the spacecraft's upper stage lifted off from the Moon. The lower stage of Luna 16 remained on the lunar surface and continued transmission of lunar temperature and radiation data. Three days later on 24 September, after a direct ascent traverse with no midcourse corrections, the capsule, with its 101 grams of lunar soil, reentered Earth's atmosphere at a velocity of 11 kilometers per second. The capsule parachuted down 80 kilometers southeast of the town of Jezkazgan in Kazakhstan at 05:25 UT on 24 September 1970. Analysis of the dark basalt material indicated a close resemblance to soil recovered by the American Apollo 12 mission.

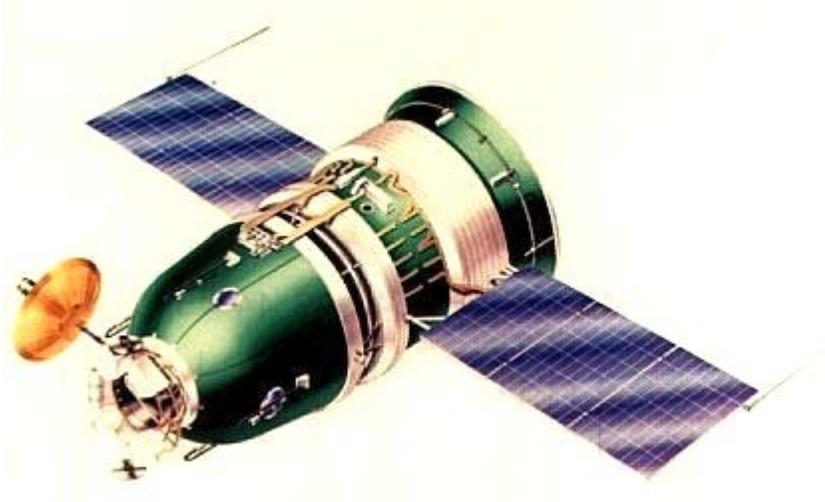
According to the Bochum Radio Space Observatory in the Federal Republic of Germany, strong and good quality television pictures were returned by the spacecraft.

Luna 16 was a landmark success for the Soviets in their deep space exploration program; the mission accomplished the first fully automatic recovery of soil samples from the surface of an extraterrestrial body.

- Launch Date/Time: 1970-09-12 at 13:25:53 UTC
- On-orbit dry mass: 5600 kg

Zond 8

Zond 8



Zond 8

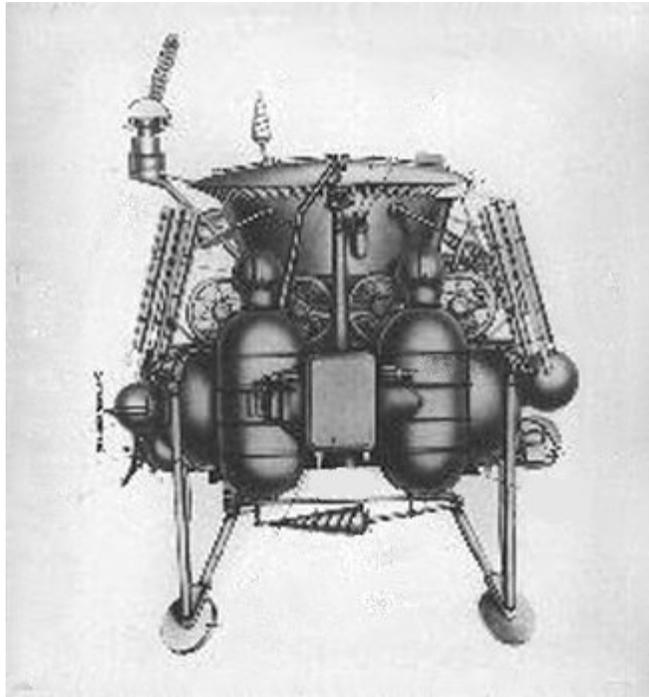
Major contractors	OKB-1
Bus	Soyuz 7K-L1
Mission type	Lunar flyby Spacecraft test
Launch date	20 October 1970 19:55:39 UTC
Carrier rocket	Proton-K/D
Launch site	Baikonur
Landing site	730 km SE of the Chagos Archipelago, Indian Ocean
Mass	5,375 kilograms (11,850 lb)

Zond 8, a formal member of the Soviet Zond program and unmanned version of Soyuz 7K-L1 manned moon-flyby spacecraft, was launched from an Earth orbiting platform, Tyazheliy Sputnik (70-088B), towards the Moon. The announced objectives were investigations of the moon and circumlunar space and testing of onboard systems and units. The spacecraft obtained photographs of Earth on October 21 from a distance of 64,480 km. The spacecraft transmitted flight images of Earth for three days. Zond 8 flew past the Moon on October 24, 1970, at a distance of 1110.4 km and obtained both black and white and color photographs of the lunar surface. Scientific measurements were also

obtained during the flight. Zond 8 reentered Earth's atmosphere and splashed down 730 km SE of the Chagos Archipelago, in the Indian Ocean on October 27, 1970, 24 km from the USSR recovery ship Taman. The Chagos Archipelago is south of the Maldives Islands.

- Launch Date/Time: 1970-10-20 at 19:55:39 UTC
- Launch Site: Tyuratam (Baikonur Cosmodrome), U.S.S.R
- On-orbit dry mass: 5375 kg

Luna 17



Luna 17 diagram

Luna 17 (Ye-8 series) was an unmanned space mission of the Luna program, also called Lunik 17.

Luna 17 was launched from an Earth parking orbit towards the Moon and entered lunar orbit on 15 November 1970. The spacecraft softly landed on the Moon in the Sea of Rains. The spacecraft had dual ramps by which the payload, Lunokhod 1, descended to the lunar surface. Lunokhod 1 was a lunar vehicle formed of a tub-like compartment with a large convex lid on eight independently powered wheels. Lunokhod was equipped with a cone-shaped antenna, a highly directional helical antenna, four television cameras, and special extendable devices to impact the lunar soil for soil density and mechanical property tests. An x-ray spectrometer, an x-ray telescope, cosmic-ray detectors, and a

laser device were also included. The vehicle was powered by a solar cell array mounted on the underside of the lid. Lunokhod was intended to operate through three lunar days but actually operated for eleven lunar days. The operations of Lunokhod officially ceased on 4 October 1971, the anniversary of Sputnik 1, after having travelled over 10.5 kilometers while taking pictures and performing numerous tests.

Luna 17 continued the spate of successes in Soviet lunar exploration begun by Luna 16 and Zond 8. Luna 17 carried Lunokhod 1, the first in a series of robot lunar roving vehicles whose conception had begun in the early 1960s, originally as part of the piloted lunar landing operations. This was the second attempt to land such a vehicle on the Moon after a failure in February 1969. The descent stage was equipped with two landing ramps for the “ascent stage,” that is, the rover, to disembark onto the Moon’s surface. The 756-kilogram rover stood about 1.35 meters high and was 2.15 meters across. Each of its eight wheels could be controlled independently for two forward and two reverse speeds. Its top speed was about 100 meters per hour, with commands issued by a five-man team of “drivers” on Earth who had to deal with the 5-second delay. The set of scientific instruments was powered by solar cells (installed on the inside of the hinged top lid of the rover) and chemical batteries. After two midcourse corrections en route to the Moon, Luna 17 entered lunar orbit and then landed on the lunar surface at 03:46:50 UT on 17 November 1970 at 38°17' north latitude and 35° west longitude, about 2,500 kilometers from the Luna 16 site in the Sea of Rains. The Lunokhod 1 rover rolled over the ramps and onto the lunar surface at 06:28 UT. The rover had an expected lifetime of three lunar days but operated for eleven. During its 322 Earth days of operation, the rover traveled 10.54 kilometers and returned more than 20,000 TV images and 206 high-resolution panoramas. In addition, Lunokhod 1 performed twenty-five soil analyses with its RIFMA x-ray fluorescence spectrometer and used its penetrometer at 500 different locations. Controllers finished the last communications session with Lunokhod 1 at 13:05 UT on 14 September 1971. Attempts to reestablish contact were finally discontinued on 4 October.

In March 2010, the Lunar Reconnaissance Orbiter photographed the landing site of Luna 17, showing the lander and tracks of the rover. In April 2010, the Apache Point Observatory Lunar Laser-ranging Operation team announced that with the aid of these photos, they had found the long lost Lunokhod 1 rover and had received returns from the laser retroreflector.

- Launch Date/Time: 1970-11-10 at 14:44:01 UTC
- On-orbit dry mass: 5600 kg

Chapter- 2

Space and Solar System Exploration in 1971

Apollo 14

Apollo 14

Mission insignia



Mission statistics

Mission name	<i>Apollo 14</i>
	CM-110
Command Module	callsign <i>Kitty Hawk</i> mass 29,240 kg
Service Module	SM-110 LM-8
Lunar Module	callsign <i>Antares</i> mass 15,264 kg
Crew size	3
Booster	Saturn V SA-509

Launch pad	LC 39A Kennedy Space Center Florida, USA
Launch date	January 31, 1971 21:03:02 UTC
Lunar landing	February 5, 1971 09:18:11 UTC Fra Mauro 3°38'43.08"S 17°28'16.90"W / 3.6453°S 17.471361°W (based on the IAU Mean Earth Polar Axis coordinate system)
Lunar EVA duration	First 04:47:50 Second 04:34:41 Total 09:22:31
Lunar surface time	1 d 09 h 30 m 29 s
Lunar sample mass	42.28 kg (93.21 lb)
Total CSM time in lunar orbit	2 d 18 h 35 m 39 s
Landing	February 9, 1971 21:05:00 UTC  27°1'S 172°39'W / 27.017°S 172.65°W
Mission duration	9 d 00 h 01 m 58 s

Crew photo



Left to right: Roosa, Shepard, Mitchell

Related missions

Previous mission



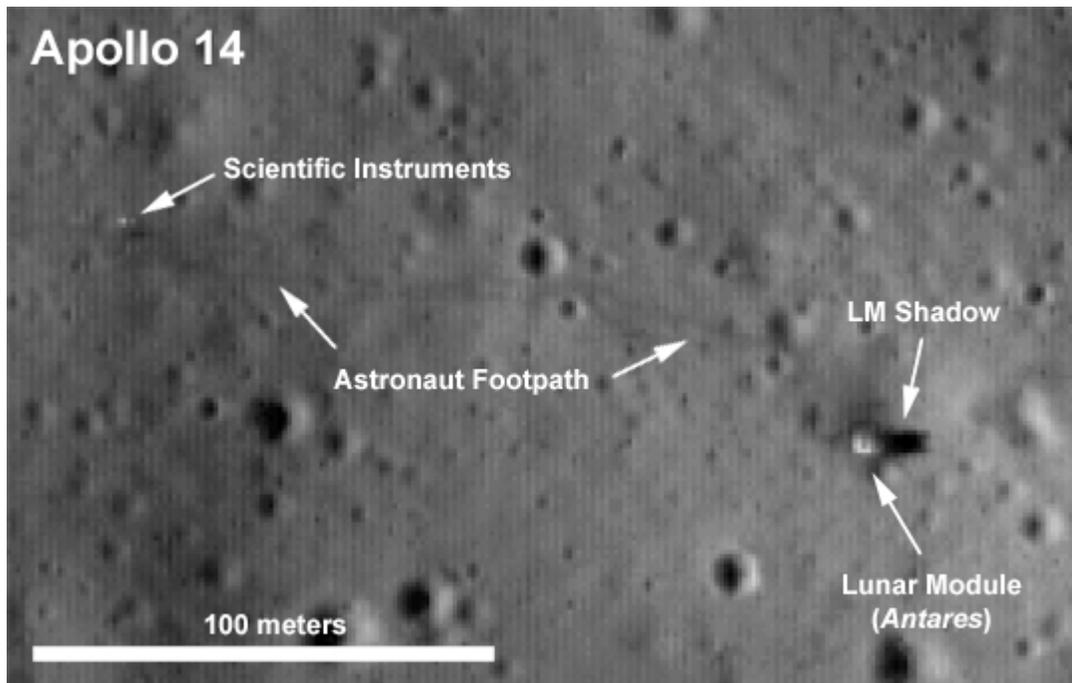
Apollo 13

Subsequent mission

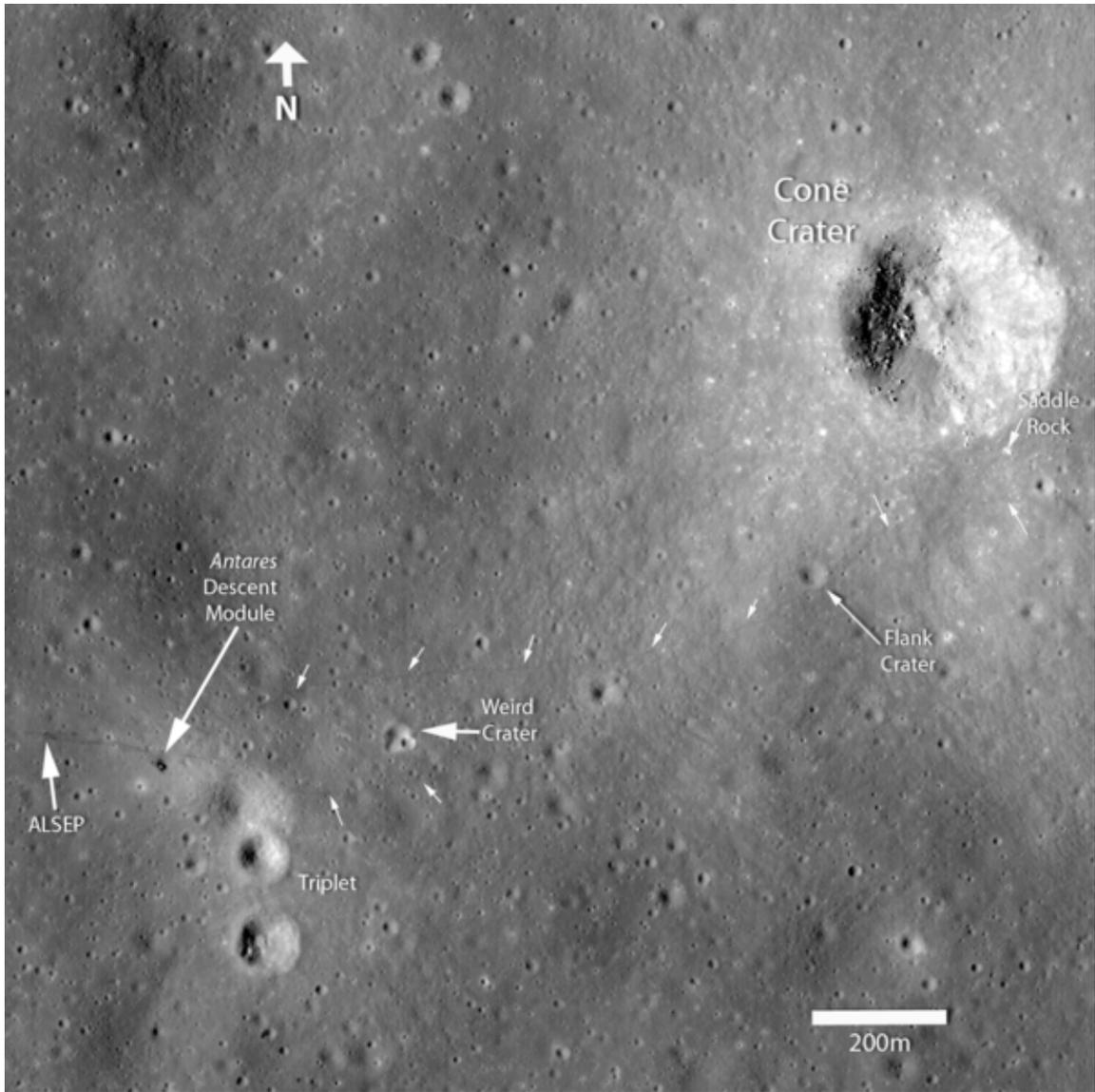


Apollo 15

Apollo 14 was the eighth manned mission in the American Apollo program, the third to land on the Moon. It was the last of the "H missions", targeted landings with two-day stays on the Moon with two lunar EVA's, or moonwalks.



Apollo 14 landing site, photograph by LRO



Later photo of landing site taken by LRO



Alan Shepard on lunar surface

Commander Alan Shepard, Command Module Pilot Stuart Roosa, and Lunar Module Pilot Edgar Mitchell launched on their nine-day mission on January 31, 1971. Shepard and Mitchell made their lunar landing on February 5 in the Fra Mauro formation; this had originally been the target of the aborted Apollo 13 mission. During the two lunar EVA's, 42 kilograms (93 lb) of Moon rocks were collected and several surface experiments, including seismic studies, were carried out. Commander Alan Shepard famously hit two golf balls on the lunar surface with a make-shift club he had brought from Earth. Shepard and Mitchell spent about 33 hours on the Moon, with about 9½ hours on EVA.

While Shepard and Mitchell were on the surface, Stuart Roosa remained in lunar orbit aboard the Command/Service Module, performing scientific experiments and photographing the Moon. He took several hundred seeds on the mission, many of which were germinated on return resulting in the so-called Moon trees. Shepard, Roosa, and Mitchell landed in the Pacific Ocean on February 9.

Crew

Position	Astronaut
Commander	Alan B. Shepard, Jr Second spaceflight
Command Module Pilot	Stuart A. Roosa First spaceflight
Lunar Module Pilot	Edgar D. Mitchell First spaceflight

Shepard was the oldest U.S. astronaut when he made his trip aboard Apollo 14. He is the only astronaut from Project Mercury (the original Mercury Seven astronauts) to reach the Moon. Another of the original seven, L. Gordon Cooper, had originally been scheduled to command the mission, but according to Chaikin, his casual attitude toward training, along with problems with NASA hierarchy (reaching all the way back to the Mercury-Atlas 9 flight) resulted in his removal.

The mission was a personal triumph for Shepard, who had battled back from Ménière's disease which grounded him from 1964 to 1968. He and his crew were originally scheduled to fly on Apollo 13, but in 1969 NASA Administrators switched the scheduled crews for Apollo 13 and 14. This was done to place the more experienced Apollo 8 veteran Jim Lovell in command of what would have been the first lunar landing mission if both Apollo 11 and Apollo 12 had failed to successfully land.

As of 2011, Mitchell is the only surviving member of the crew; Roosa died in 1994 from pancreatitis and Shepard in 1998 from leukemia.

Backup crew

Position	Astronaut
Commander	Eugene A. Cernan
Command Module Pilot	Ronald E. Evans, Jr
Lunar Module Pilot	Joseph H. Engle

James McDivitt, the commander of Apollo 9, who would have been either the prime crew Lunar Module Pilot or the backup crew commander, was unwilling to take a secondary role in the mission.

Support crew

- Philip K. Chapman
- Bruce McCandless, II
- William R. Pogue
- C. Gordon Fullerton

Flight directors

- Pete Frank, Orange team
- Glynn Lunney, Black team
- Milton Windler, Maroon team
- Gerry Griffin, Gold team

Mission parameters

- **Mass:** CSM 29,240 kg; LM 15,264 kg
- **Perigee:** 183.2 km
- **Apogee:** 188.9 km
- **Inclination:** 31.12°
- **Period:** 88.18 min

- **Perilune:** 108.2 km
- **Apolune:** 314.1 km
- **Inclination:** °
- **Period:** 120 min
- **Landing Site:** 3.64530° S – 17.47136° W or
3° 38' 43.08" S – 17° 28' 16.90" W

LM – CSM docking

- **Undocked:** February 5, 1971 – 04:50:43 UTC
- **Docked:** February 6, 1971 – 20:35:42 UTC

EVAs

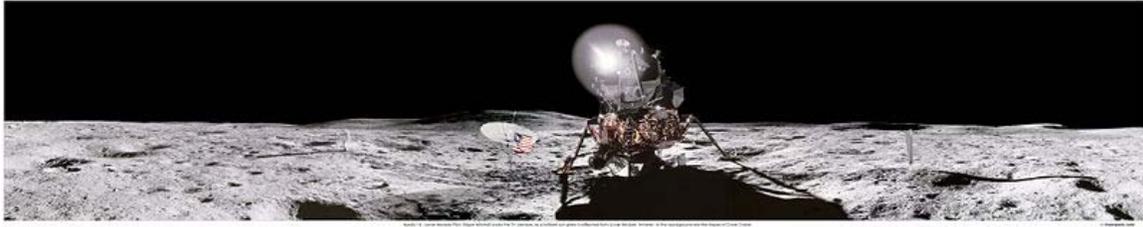
EVA 1 start: February 5, 1971, 14:42:13 UTC

- *Shepard* – EVA 1
- **Stepped onto moon:** 14:54 UTC
- **LM ingress:** 19:22 UTC

- *Mitchell* – EVA 1
- **Stepped onto moon:** 14:58 UTC
- **LM ingress:** 19:18 UTC

- **EVA 1 end:** February 5, 19:30:50 UTC
 - **Duration:** 4 hours, 47 minutes, 50 seconds

EVA 2 start: February 6, 1971, 08:11:15 UTC



Panoramic Assembly of Fra Mauro – Apollo 14 Landing Site

- *Shepard* – EVA 2
- **Stepped onto moon:** 08:16 UTC
- **LM ingress:** 12:38 UTC

- *Mitchell* – EVA 2
- **Stepped onto moon:** 08:23 UTC
- **LM ingress:** 12:28 UTC

- **EVA 2 end:** February 6, 12:45:56 UTC
 - **Duration:** 4 hours, 34 minutes, 41 seconds

Mission highlights

Transfer and descent



Launch of Apollo 14

At the beginning of the mission, the CSM *Kitty Hawk* had difficulty achieving capture and docking with the LM *Antares*. Repeated attempts to dock went on for 1 hour and 42 minutes, until it was suggested that pilot Roosa hold *Kitty Hawk* against *Antares* using its thrusters, then the docking probe would be retracted out of the way, hopefully triggering the docking latches. This attempt was successful, and no further docking problems were encountered during the mission.

After separating from the command module in lunar orbit, the LM *Antares* also had two serious problems. First, the LM computer began getting an ABORT signal from a faulty switch. NASA believed that the computer might be getting erroneous readings like this if a tiny ball of solder had shaken loose and was floating between the switch and the contact, closing the circuit. The immediate solution—tapping on the panel next to the switch—did work briefly, but the circuit soon closed again. If the problem recurred after the descent engine fired, the computer would think the signal was real and would initiate an auto-abort, causing the Ascent Stage to separate from the Descent Stage and climb back into orbit. NASA and the software teams at MIT scrambled to find a solution, and determined the fix would involve reprogramming the flight software to ignore the false signal. The software modifications were transmitted to the crew via voice communication, and Mitchell manually entered the changes (amounting to over 80 keystrokes on the LM computer pad) just in time.

A second problem occurred during the powered descent, when the LM radar altimeter failed to lock automatically onto the moon's surface, depriving the navigation computer of vital information on the vehicle altitude and groundspeed. This was later determined to be an unintended consequence of the software patch. After the astronauts cycled the landing radar breaker, the unit successfully acquired a signal near 50,000 feet (15,000 m), again just in the nick of time. Shepard then manually landed the LM closer to its intended target than any of the other six moon landing missions. Mitchell believes that Shepard would have continued with the landing attempt without the radar, using the LM inertial guidance system and visual cues. But a post-flight review of the descent data showed the inertial system alone would have been inadequate, and the astronauts probably would have been forced to abort the landing as they approached the surface.

EVA's

Shepard and Mitchell named their landing site *Fra Mauro Base*, and this designation is recognized by the International Astronomical Union (depicted in Latin on lunar maps as *Statio Fra Mauro*).

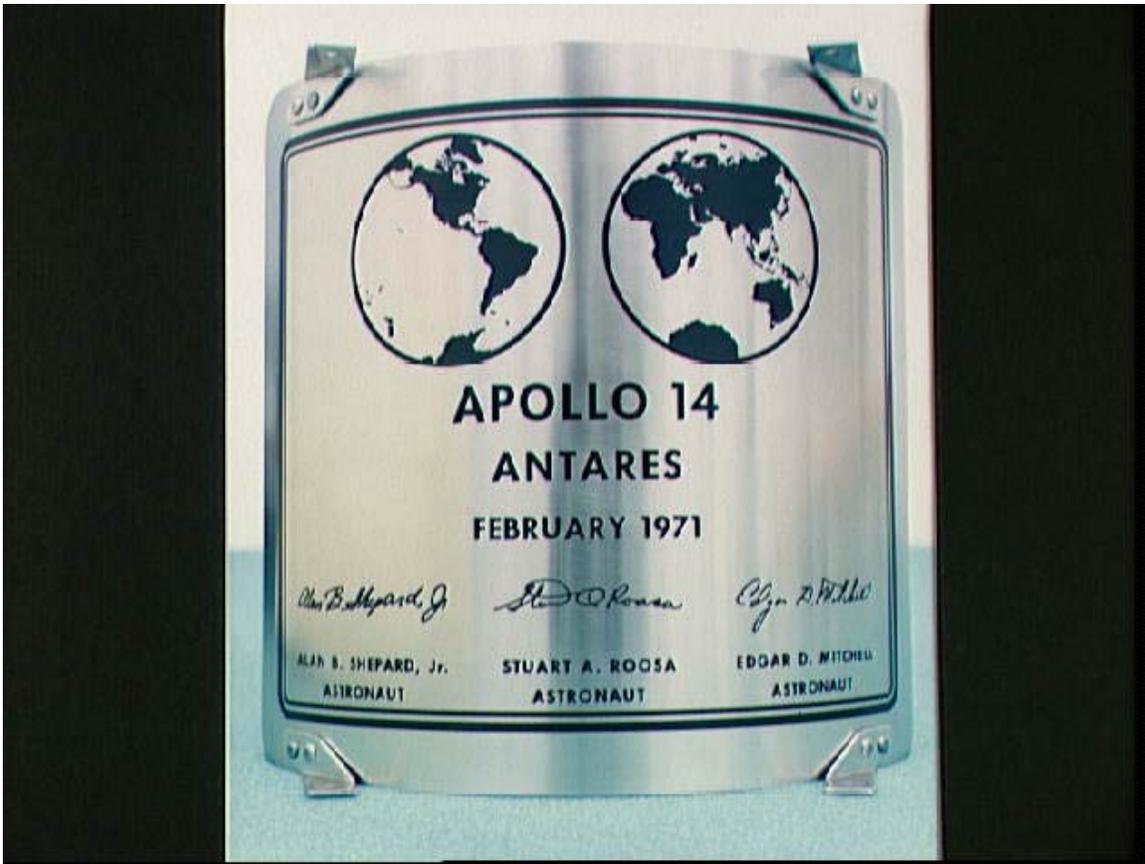
Shepard's first words, after taking his first step onto the lunar surface, were "And it's been a long way, but we're here." Unlike Apollo 11's Neil Armstrong and Apollo 12's Pete Conrad, Shepard had already gotten off the ladder and was a few meters from the LM before he spoke.



This TV image shows Alan Shepard golfing on the Moon

Shepard's moonwalking suit was the first to utilise red bands on the arms and legs and a red stripe on the top of the lunar EVA sunshade "hood", so as to allow easy identification of the commander while on the surface; on the Apollo 12 pictures, it had been almost impossible to distinguish between the two crewmen, causing a great deal of confusion. This feature was included on Jim Lovell's Apollo 13 suit, but because of the accident on that mission, it was not used. It was used on the remaining three Apollo flights and is used on both the U.S. and Russian spacesuits on both the Space Shuttle and International Space Station.

After landing in the Fra Mauro formation—the destination for Apollo 13—Shepard and Mitchell took two moon walks, adding new seismic studies to the by now familiar Apollo experiment package, and using the Modularized Equipment Transporter (MET), a pull cart for carrying equipment and samples, referred to as a "lunar rickshaw". Roosa, meanwhile, took pictures from on board command module *Kitty Hawk* in lunar orbit.



The plaque left on the Moon by Apollo 14

The second moonwalk, or EVA, was intended to reach the rim of the 1,000 foot (300 m) wide Cone Crater. However, the two astronauts were not able to find the rim amid the rolling terrain of the crater's slopes. Later analysis, using the pictures that they took, determined that they had come within an estimated 65 feet (20 m) of the crater's rim. Images from the Lunar Reconnaissance Orbiter show the tracks of the astronauts and the MET come to within 30 m of the rim.

Shepard and Mitchell deployed and activated various scientific instruments and experiments and collected almost 100 pounds (45 kg) of lunar samples for return to earth. Other Apollo 14 achievements included: the only use of MET; longest distance traversed by foot on the lunar surface; first use of shortened lunar orbit rendezvous techniques; first use of color TV with new vidicon tube on lunar surface and the first extensive orbital science period conducted during CSM solo operations.



Command Module *Kitty Hawk* on display at the Saturn V Center at Kennedy Space Center

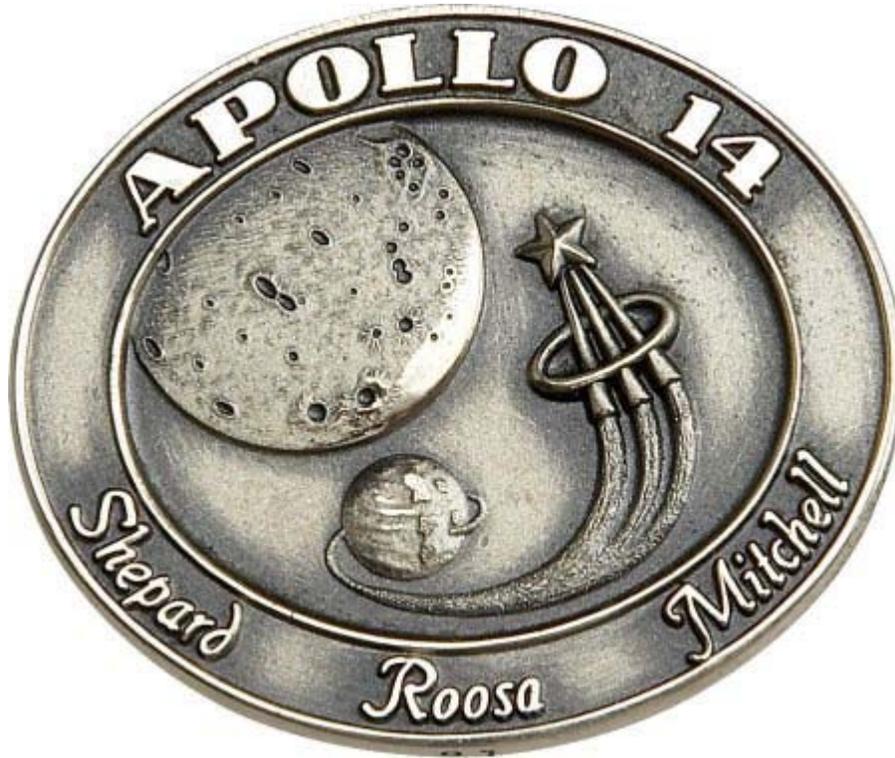
The astronauts also engaged in less serious activities. Shepard brought a makeshift six iron golf club and two golf balls to the Moon, and took several swings (one-handed, due to the limited flexibility of the EVA suit). He exuberantly, and somewhat whimsically, exclaimed that the second ball went "miles and miles and miles" in the lunar gravity, but later estimated it actually went 200 to 400 yards (180 to 370 m). Mitchell then used a lunar scoop handle as a javelin, creating the first 'Lunar Olympics'. Before the flight, backup crew members Cernan, Evans and Engle played a joke on the astronauts by stashing their own crew patches in every single locker and compartment in the spacecraft. Whenever one of the patches would float out of a locker during the mission, Shepard would say "Tell Cernan, BEEP-BEEP my ass!"

Return

On the way back to Earth, the crew conducted the first U.S. materials processing experiments in space. The Apollo 14 astronauts were the last lunar explorers to be quarantined on their return from the Moon.

Roosa, who worked in forestry in his youth, took several hundred tree seeds on the flight. These were germinated after the return to Earth, and widely distributed around the world as commemorative Moon Trees.

Mission insignia



Robbins Medallion flown on Apollo 14

The oval insignia shows a gold NASA Astronaut Pin, given to U.S. astronauts upon completing their first space flight, traveling from the Earth to the Moon. A gold band around the edge includes the mission and astronaut names. The designer was Jean Beaulieu.

The backup crew spoofed the patch with its own version, with revised artwork showing the Road Runner cartoon character on the moon, holding a U.S. flag and a flag labeled "1st Team," as a gray-bearded (for Shepard, who was 47 at the time of the mission and the oldest man on the Moon), pot bellied (for Mitchell, who had a pudgy appearance), red furred (for Roosa's red hair) Wile E. Coyote flies in place of the astronaut pin. The flight name is replaced by "BEEP BEEP" and the backup crew's names are given. Several were left as "gotchas" on the *Kitty Hawk*.

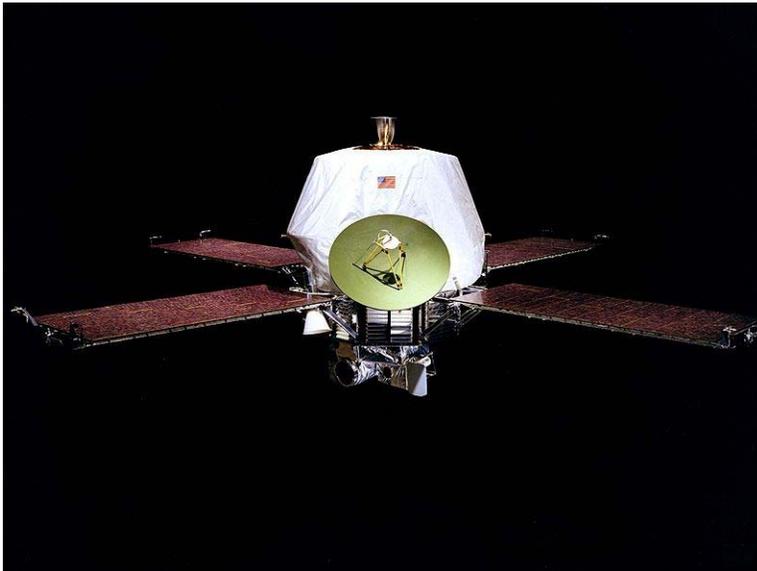
Spacecraft location

The Apollo 14 Command Module *Kitty Hawk* is on display at the Saturn V Center building at KSC after being on display at the Astronaut Hall of Fame, Titusville, Florida for several years.

The ascent stage of Lunar Module *Antares* impacted the Moon 7 February 1971 at 00:45:25.7 UT (6 February, 7:45 PM EST) 3°25'S 19°40'W / 3.42°S 19.67°W. Antares' descent stage and the mission's other equipment remain at Fra Mauro at 3°39'S 17°28'W / 3.65°S 17.47°W; they are, by far, the most visible Apollo hardware in the photographs from the Lunar Reconnaissance Orbiter released on 17 July 2009, owing to particularly good lighting conditions when the images were captured.

Mariner 9

Mariner 9



Operator	NASA
Mission type	Orbiter
Satellite of	Mars
Orbital insertion date	November 13, 1971
Launch date	May 30, 1971 at 22:23:00 UTC

Launch vehicle	Atlas-Centaur SLV-3C launch vehicle
Mission duration	May 30, 1971 to October 27, 1972
COSPAR ID	1971-051A
Mass	558.8 kg
Power	500 W

Orbital elements

Eccentricity	.6014
Inclination	64.4°
Apoapsis	16,860 kilometres (10,480 mi)
Periapsis	1,650 kilometres (1,030 mi)
Orbital period	719.47 m

Mariner 9 (Mariner Mars '71 / Mariner-I) was a NASA space orbiter that helped in the exploration of Mars and was part of the Mariner program. Mariner 9 was launched toward Mars on May 30, 1971 from Cape Canaveral Air Force Station and reached the planet on November 13 of the same year, becoming the first spacecraft to orbit another planet — only narrowly beating Soviet Mars 2 and Mars 3, which both arrived within a month. After months of dust-storms it managed to send back clear pictures of the surface.

Objectives



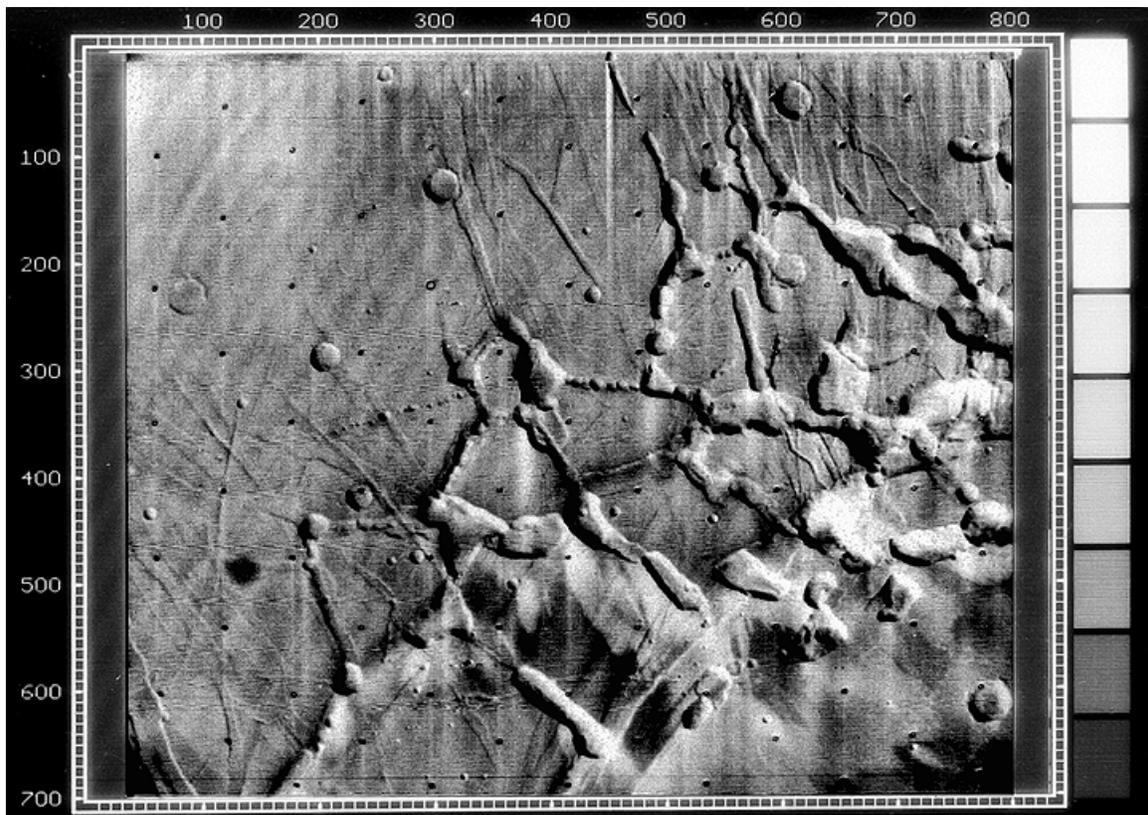
Mariner 9 launch

Mariner 9 was designed to continue the atmospheric studies begun by Mariner 6 and 7, and to map over 70% of the Martian surface from the lowest altitude (1,500 kilometers (930 mi) and at the highest resolutions (from 1 kilometer per pixel to 100 meters per pixel) of any Mars mission up to that point. An infrared radiometer was included to detect heat sources in search of evidence of volcanic activity. It was to study temporal changes in the Martian atmosphere and surface. Mars' two moons were also to be analyzed. Mariner 9 more than met its objectives.

Experiments

1. Ultraviolet Spectrometer (UVS)
2. Infrared Interferometer Spectrometer (IRIS)
3. Celestial Mechanics (not a separate instrument; it relied upon tracking measurements including range, range rate, and Doppler)
4. S-Band Occultation (not a separate instrument; experiment observed the attenuation of the communication signal as the orbiting satellite passed out of view)
5. Infrared Radiometer (IRR)
6. Visual Imaging System

Achievements



Mariner 9 view of the Noctis Labyrinthus "labyrinth" at the western end of Valles Marineris.

Mariner 9 was the first spacecraft to orbit another planet. It carried an instrument payload similar to Mariner 6 and 7, but, because of the need for a larger propulsion system to control the spacecraft in Mars orbit, it weighed more than Mariners 6 and 7 combined. When Mariner 9 arrived at Mars, the atmosphere was so dusty that the surface was obscured. This unexpected situation made a strong case for the desirability of studying a planet from orbit rather than merely flying past. Mariner 9's computer was thus programmed from Earth to delay imaging of the surface for a couple of months until the

dust settled. After 349 days in orbit, Mariner 9 had transmitted 7,329 images, covering 100% of Mars' surface. The images revealed river beds, craters, massive extinct volcanoes (such as Olympus Mons, the largest known volcano in the Solar System), canyons (including the Valles Marineris, a system of canyons over about 2,500 miles (4,020 km) long), evidence of wind and water erosion and deposition, weather fronts, fogs, and more. Mars' tiny moons, Phobos and Deimos, were also photographed. The findings from the Mariner 9 missions underpinned the later Viking program.

The enormous Valles Marineris canyon system is named after Mariner 9 in honor of its achievements.

After depleting its supply of attitude control gas, the spacecraft was turned off on October 27, 1972.

Construction

The ultraviolet spectrometer aboard Mariner 9 was constructed by the Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder, Colorado. The ultraviolet spectrometer team was led by Professor Charles Barth.

The Infrared Interferometer Spectrometer (IRIS) team was led by Dr. Rudolf A. Hanel from NASA Goddard Spaceflight Center (GSFC). The IRIS instrument was built by Texas Instruments, Dallas, Texas.

The Infrared Radiometer (IRR) team was led by Professor Gerald Neugebauer from the California Institute of Technology (Caltech).

Error Correction Codes achievements

A Hadamard code was used during the 1971 Mariner 9 mission to correct for picture transmission errors. The data words used during this mission were 6 bits long, which represented 64 grayscale values.

Because of limitations of the quality of the alignment of the transmitter the maximum useful data length was about 30 bits. Instead of using a repetition code, a [32, 6, 16] Hadamard code was used. Errors of up to 7 bits per word could be corrected using this scheme.

Compared to a 5-repetition code, the error correcting properties of this Hadamard code are much better, yet its rate is comparable. The efficient decoding algorithm was an important factor in the decision to use this code. The circuitry used was called the "Green Machine". It employed the fast Fourier transform which can increase the decoding speed by a factor of 3.

Present location

Mariner 9 will remain in a stable Mars orbit until at least 2022, after which the spacecraft will enter the Martian atmosphere.

Mars 2

Mars 2

Operator	USSR
Mission type	Orbiter and lander
Orbital insertion date	November 27, 1971
Orbits	362
Launch date	1971-05-19 at 16:22:44 UTC
Launch vehicle	Proton K with Blok D
Mission duration	22 August 1972
COSPAR ID	1971-045A
Mass	4650 kg

Orbital elements

Eccentricity	.71178
Inclination	48.9°
Apoapsis	24940 km
Periapsis	1380 km
Orbital period	17.96 h

The **Mars program** was a series of Mars unmanned landers and orbiters launched by the Soviet Union in the early 1970s.

The Mars 2 and Mars 3 missions consisted of identical spacecraft, each with an orbiter and an attached lander; they were the first human artifacts to impact the surface of Mars. They were launched by Proton K heavy launch vehicle with a Block D upper stage.

- Launch Date/Time:
 - Mars 2: 1971-05-19 at 16:22:44 UTC
- Launch mass (including fuel):
 - Combined: 4650 kg
 - Orbiter: 3440 kg
 - Lander: 1210 kg
- On-orbit dry mass: 2265 kg
- Dimensions: 4.1 meters tall, 2 meters across (5.9 meters across with solar panels deployed)

Orbiter

The orbiter engine performed a burn to put the spacecraft into a 1380 x 24,940 km, 18 hour orbit about Mars with an inclination of 48.9 degrees. Scientific instruments were generally turned on for about 30 minutes near periapsis

The orbiter primary scientific objectives were to image the Martian surface and clouds, determine the temperature on Mars, study the topography, composition and physical properties of the surface, measure properties of the atmosphere, monitor the solar wind and the interplanetary and Martian magnetic fields, and act as communications relays to send signals from the landers to Earth.

The Mars 2 orbiter sent back a large volume of data covering the period from December 1971 to March 1972, although transmissions continued through August. It was announced that Mars 2 had completed their mission by 22 August 1972, after 362 orbits. The probe, combined with Mars 3, sent back a total of 60 pictures. The images and data revealed mountains as high as 22 km, atomic hydrogen and oxygen in the upper atmosphere, surface temperatures ranging from -110 °C to +13 °C, surface pressures of 5.5 to 6 mbar (0.55 to 0.6 kPa), water vapor concentrations 5000 times less than in Earth's atmosphere, the base of the ionosphere starting at 80 to 110 km altitude, and grains from dust storms as high as 7 km in the atmosphere. The images and data enabled creation of surface relief maps, and gave information on Martian gravity and magnetic fields.

Lander

The lander crashed on the Martian surface and was lost.

The Mars 2 descent module was mounted on the bus/orbiter opposite the propulsion system. It consisted of a spherical 1.2 m diameter landing capsule, a 2.9 m diameter conical aerodynamic braking shield, a parachute system and retro-rockets.

The entire descent module had a fueled mass of 1210 kg, the spherical landing capsule accounting for 358 kg of this. An automatic control system consisting of gas micro-engines and pressurized nitrogen containers provided attitude control. Four "gunpowder" engines were mounted to the outer edge of the cone to control pitch and yaw.

The main and auxiliary parachutes, the engine to initiate the landing, and the radar altimeter were mounted on the top section of the lander. Foam was used to absorb shock within the descent module. The landing capsule had four triangular petals which would open after landing, righting the spacecraft and exposing the instrumentation.

The lander was equipped with two television cameras with a 360 degree view of the surface as well as a mass spectrometer to study atmospheric composition; temperature, pressure, and wind sensors; and devices to measure mechanical and chemical properties of the surface, including a mechanical scoop to search for organic materials and signs of life. It also contained a pennant with the Soviet coat of arms.

Four aerials protruded from the top of the sphere to provide communications with the orbiter via an onboard radio system. The equipment was powered by batteries which were charged by the orbiter prior to separation. Temperature control was maintained through thermal insulation and a system of radiators. The landing capsule was sterilized before launch to prevent contamination of the martian environment.

The descent module separated from the orbiter on 27 November 1971 about 4.5 hours before reaching Mars. After entering the atmosphere at approximately 6 km/s, the descent system on the module malfunctioned, possibly because the angle of entry was too steep. The descent sequence did not operate as planned and the parachute did not deploy. Mars 2 was the first manmade object to reach the surface of Mars. The landing site is unknown.

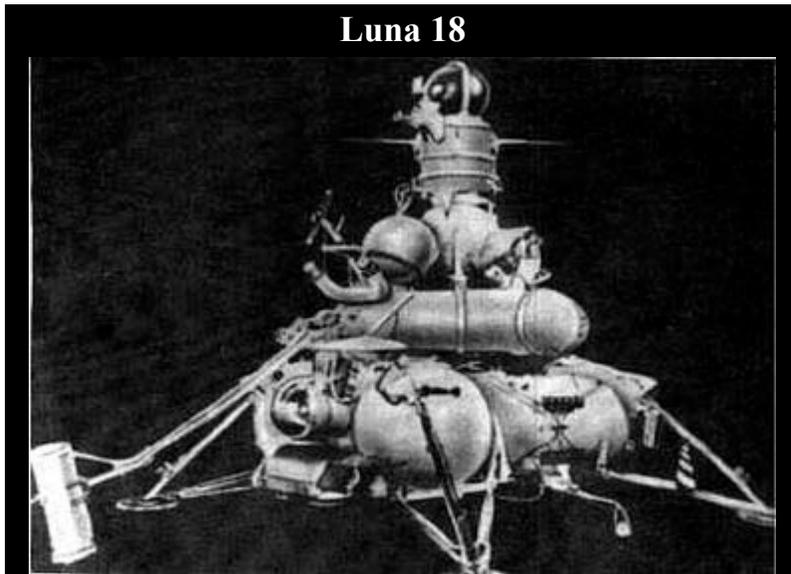
Prop-M Rover

Mars 2 lander had a small 4.5 kg Mars 'rover' on board, which would move across the surface on skis while connected to the lander with a 15-meter umbilical. Two small metal rods were used for autonomous obstacle avoidance, as radio signals from Earth would take too long to drive the rovers using remote control. The rover carried a dynamic penetrometer and a radiation densitometer.

The main PROP-M frame was a squat box with a small protrusion at the center. The frame was supported on two wide flat skis, one extending down from each side elevating the frame slightly above the surface. At the front of the box were obstacle detection bars.

The rover was planned to be placed on the surface after landing by a manipulator arm and to move in the field of view of the television cameras and stop to make measurements every 1.5 meters. The traces of movement in the martian soil would also be recorded to determine material properties.

Luna 18



Organization:	Soviet Union
Major Contractors:	GSMZ Lavochkin
Mission Type:	Planetary Science Lunar Sample Return
Satellite of:	Moon
Launch:	September 2, 1971 at 13:40:40 UTC
Launch Vehicle:	Proton 8K82K + Blok D
Mission Highlight:	Lunar impact on September 11, 1971, 07:48 UTC at 3° 34' N, - 56° 30' E.
Mission Duration:	9-days
Mass:	5,750 kg
NSSDC ID:	1971-073A
Webpage:	NASA NSSDC Master Catalog

Orbital elements

Semimajor Axis:	6,477.8 km
Eccentricity:	.001361
Inclination:	35°
Orbital Period:	119 minutes
Aposelene:	100 km
Periselene:	100 km
Orbits:	~48 - then attempted landing and Lunar impact

Instruments

Stereo imaging system:	Lunar photography
Remote arm for sample collection:	collect lunar material
Radiation detector:	Lunar radiation environment
Radio altimeter:	Density of lunar topsoil

Luna 18 (Ye-8-5 series) was an unmanned space mission of the Luna program, also called Lunik 18. Luna 18 was placed in an earth parking orbit after it was launched and was then sent towards the Moon. On September 7, 1971, it entered lunar orbit. The spacecraft completed 85 communications sessions and 54 lunar orbits before it was sent towards the lunar surface by use of braking rockets. It impacted the Moon on September 11, 1971, at 3 degrees 34 minutes N, 56 degrees 30 minutes E (selenographic coordinates) in a rugged mountainous terrain. Signals ceased at the moment of impact.

This mission was the seventh Soviet attempt to recover soil samples from the surface of the Moon and the first after the success of Luna 16. After two midcourse corrections on 4 September and 6 September 1971, Luna 18 entered a circular orbit around the Moon on 7 September at 100 kilometers altitude with an inclination of 35°. After several more orbital corrections, on 11 September, the vehicle began its descent to the lunar surface. Unfortunately, contact with the spacecraft was abruptly lost at 07:48 UT at the previously determined point of lunar landing. Impact coordinates were 3°34' north latitude and 56°30' east longitude, near the edge of the Sea of Fertility. Officially, the Soviets announced that "the lunar landing in the complex mountainous conditions proved to be unfavorable." Later, in 1975, the Soviets published data from Luna 18's continuous-wave radio altimeter that determined the mean density of the lunar topsoil.

- Launch Date/Time: 1971-09-02 at 13:40:40 UTC
- On-orbit dry mass: 5600 kg

Luna 19

Luna 19



Operator	Soviet Union
Major contractors	GSMZ Lavochkin
Mission type	Planetary Science Lunar orbiter
Satellite of	Moon
Orbits	~4,315
Launch date	September 28, 1971 at 10:00:22 UTC
Launch vehicle	Proton 8K82K + Blok D
Mission duration	~388-days ~October 20, 1972
Mission highlight	Entered lunar orbit on October 3, 1971
COSPAR ID	1971-082A
Homepage	NASA NSSDC Master Catalog
Mass	5,700 kg (5,600 kg dry)

Orbital elements

Semimajor axis	6,517.8 km
Eccentricity	0.18
Inclination	40.58°
Apoapsis	140 km
Periapsis	140 km
Orbital period	121.13 min

Instruments

Imaging system, Gamma-ray spectrometer, Radio altimeter,
 Meteoroid detectors, Magnetometer, Cosmic-ray detectors,
 Radiation detectors

Luna 19 (a.k.a. Lunik 19) (Ye-8-LS series), was an unmanned space mission of the Luna program. Luna 19 extended the systematic study of lunar gravitational fields and location of mascons (mass concentrations). It also studied the lunar radiation environment, the gamma-active lunar surface, and the solar wind. Photographic coverage via a television system was also obtained.

Luna 19 was the first of the “advanced” lunar orbiters whose design was based upon the same Ye-8-class bus used for the lunar rovers and the sample collectors. For these orbiters, designated Ye-8LS, the basic “lander stage” was topped off by a wheelless Lunokhod-like frame that housed all scientific instrumentation in a pressurized container.

Luna 19 was launched into an earth parking orbit on 28 September, and, from this orbit, was sent toward the Moon. Luna 19 entered an orbit around the Moon on 2 October 1971 after two midcourse corrections on 29 September and 1 October. Initial orbital parameters were 140 x 140 kilometers at 40.58° inclination.

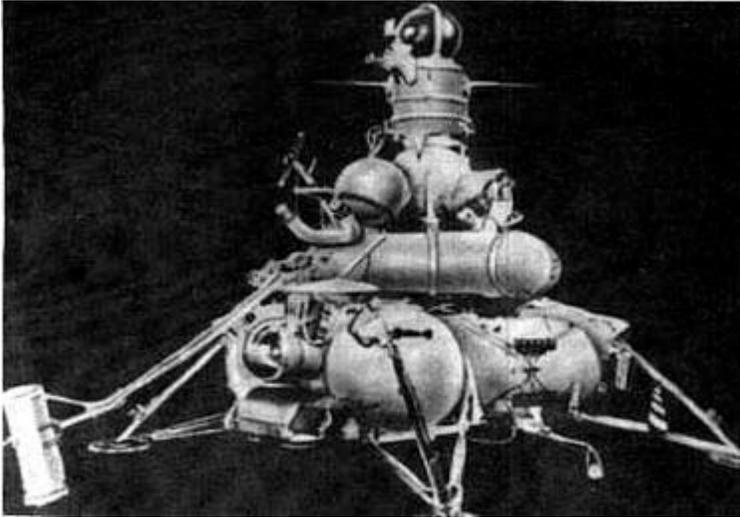
Soon afterward, the spacecraft began its main imaging mission — providing panoramic images of the mountainous region of the Moon between 30° and 60° south latitude and between 20° and 80° east longitude. Other scientific experiments included extensive studies on the shape and strength of the lunar gravitational field and the locations of the mascons. Occultation experiments in May and June 1972 allowed scientists to determine the concentration of charged particles at an altitude of 10 kilometers. Additional studies of the solar wind were evidently coordinated with those performed by the Mars 2 and 3 orbiters and Veneras 7 and 8. Communications with Luna 19 were terminated some time between 3 and 20 October 1972, after a year of operation and more than 4,000 orbits around the Moon.

Chapter- 3

Space and Solar System Exploration in 1972

Luna 20

Luna 20



Operator	Soviet Union
Major contractors	GSMZ Lavochkin
Mission type	Planetary Science Lunar Sample Return
Satellite of	Moon
Orbits	~36
Launch date	February 14, 1972 at 03:27:59 UTC

Launch vehicle	Proton 8K82K + Blok D
Mission duration	11 days
Mission highlight	55-gram Lunar sample returned to Earth on February 25, 1972, 19:19 UTC 40 km north of Dzhezkazgan, Kazakhstan
COSPAR ID	1972-007A
Homepage	NASA NSSDC Master Catalog
Mass	5,727 kg (5,600 kg dry)

Orbital elements

Semimajor axis	6,477.8 km
Eccentricity	0.0
Inclination	65°
Apoapsis	100 km
Periapsis	100 km
Orbital period	119 min

Lunar landing

Date	February 21, 1972, 19:19 UTC
Coordinates	3° 32' N, -56° 33' E
Departure	February 22, 1972, 22:58 UTC

Instruments

Stereo imaging system
Remote arm for sample collection
Radiation detector

Luna 20 (Ye-8-5 series) was the second of three successful Soviet lunar sample return missions. It was flown as part of the Luna program, also called Lunik 20, as a robotic competitor to the six successful Apollo lunar sample return missions. Luna 20 was placed in an intermediate Earth parking orbit and from this orbit was sent towards the Moon. It entered lunar orbit on February 18, 1972. On February 21, 1972, Luna 20 soft landed on the Moon in a mountainous area known as the Apollonius highlands near Mare Fecunditatis (Sea of Fertility), 120 km from where Luna 16 had landed. While on the lunar surface, the panoramic television system was operated. Lunar samples were obtained by means of an extendable drilling apparatus. The ascent stage of Luna 20 was launched from the lunar surface on 22 February 1972 carrying 55 grams of collected lunar samples in a sealed capsule. It landed in the Soviet Union on 25 February 1972. The lunar samples were recovered the following day.

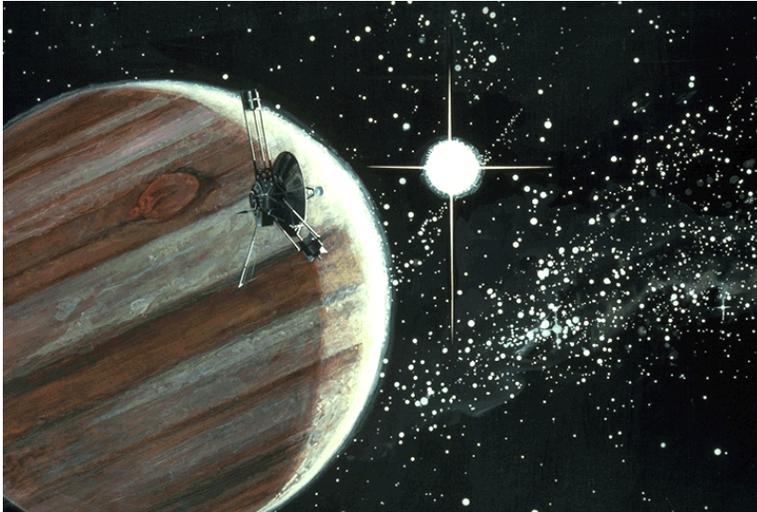
This was the eighth Soviet spacecraft launched to return lunar soil to Earth. It was evidently sent to complete the mission that Luna 18 had failed to accomplish. After a 4.5-day flight to the Moon, which included a single midcourse correction on 15 February, Luna 20 entered orbit around the Moon on 18 February. Initial orbital parameters were 100 x 100 kilometers at 65° inclination. Three days later, at 19:13 UT, the spacecraft fired its main engine for 267 seconds to begin descent to the lunar surface. A second firing further reduced velocity before Luna 20 set down safely on the Moon at 19:19 UT on 21 February 1972 at coordinates 3°32' north latitude and 56°33' east longitude, only 1.8 kilometers from the crash site of Luna 18. After collecting a small sample of lunar soil, the spacecraft's ascent stage lifted off at 22:58 UT on 22 February and quickly accelerated to 2.7 kilometers per second velocity—sufficient to return to Earth. The small spherical capsule eventually parachuted down safely on an island in the Karkingir River, 40 kilometers north of the town of Jezkazgan in Kazakhstan, at 19:19 UT on 25 February 1972.

Lunar Mission	Sample Returned	Year
Luna 16	101 g	1970
Luna 20	55 g	1972
Luna 24	170 g	1976

The 55-gram soil sample differed from that collected by Luna 16 in that the majority (50 to 60 %) of the rock particles in the newer sample were ancient lunar highlands anorthosite (which consists largely of feldspar) rather than the basalt of the earlier one (which contained about 1 to 2 % of anorthosite). The American Apollo 16 mission returned similar highlands material two months later. Like the Luna 16 soil, samples of the Luna 20 collection were shared with American and French scientists.

Pioneer 10

Pioneer 10

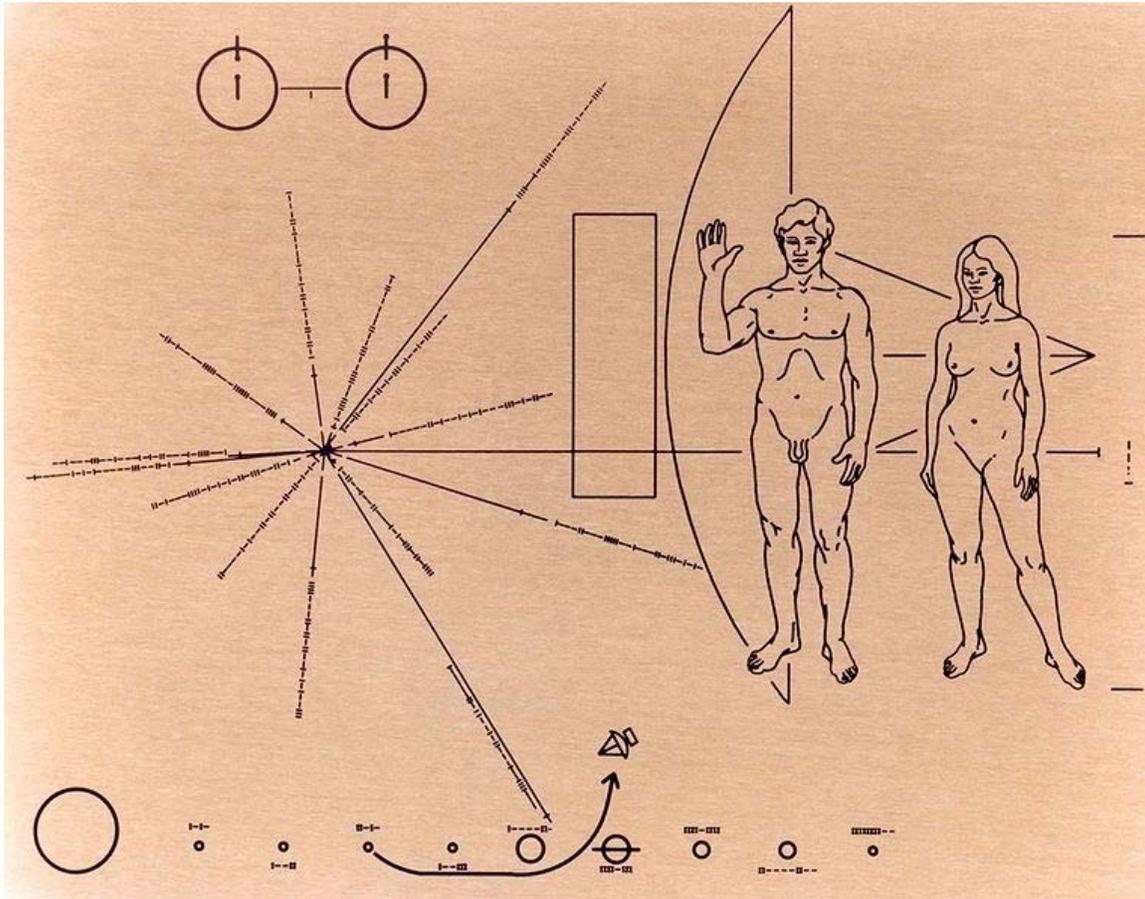


An artist's concept of the Jupiter encounter.

Operator	ARC / NASA
Major contractors	TRW
Mission type	Flyby
Flyby of	Jupiter
Launch date	1972-03-02 01:49:00 UTC (38 years, 10 months, and 11 days ago)
Launch vehicle	Atlas/Centaur/TE364-4
Launch site	Space Launch Complex 36A Cape Canaveral Air Force Station
Mission duration	March 2, 1972 - January 23, 2003 (lost communication) Jupiter flyby (completed 1973-12-04)
COSPAR ID	1972-012A
Homepage	NASA Archive
Mass	258 kg (569 lb)

Power

165.0 W (4 SNAP-19 RTGs)



The *Pioneer 10* (also known as *Pioneer F*) spacecraft is a 258-kilogram (569 lb) robotic space probe launched by NASA on March 2, 1972 to study Jupiter and eventually interstellar space. While the spacecraft is believed to still operate properly, communication has been lost since January 23, 2003. Prior to this, the spacecraft was in extended mission to study the dynamics of the solar system boundary including, interplanetary magnetic fields, solar wind, cosmic rays, and the heliosphere. The primary mission ended in December 1973, encountering the Jovian system. It was the first probe to traverse the asteroid belt and the first to encounter Jupiter.

Mission background

History

Approved in February 1969, *Pioneer 10* and twin probe *Pioneer 11*, were the first to be designed for exploring the outer solar system. Yielding to multiple proposals throughout the 1960s, early mission objectives were defined as:

- Explore the interplanetary medium beyond the orbit of Mars

- Investigate the nature of the asteroid belt from the scientific standpoint and assess the belt's possible hazard to missions to the outer planets.
- Explore the environment of Jupiter.

Later development-stage objectives also included the probe closely approaching Jupiter to provide data on the effect the environmental radiation surrounding Jupiter would have to the instruments on the spacecraft.

The Pioneer Project Office at Ames Research Center was selected to oversee the project and aerospace contractor, TRW was selected for construction of the probes.

Spacecraft design

Pioneer 10 was built with six thrusters (first pair used to maintain a constant spin-rate of 4.8-rpm, second pair used for thrust, third pair used for attitude control), a star sensor able to reference Canopus, and two sun sensors. Combined, these systems would allow the space probe to maintain pointing of the high-gain antenna toward Earth autonomously. The probe carried a scientific payload of 11 instruments that would provide data for 13 experiments during the mission.

Communications

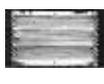
The space probe included a redundant system of receivers, one attached to the high-gain antenna, the other to an omni antenna and medium-gain antenna. Each receiver is 8 watts and transmits data across the S-band using 2110 MHz for the uplink from Earth and 2292 MHz for the downlink to Earth with the Deep Space Network tracking the signal. Prior to transmitting data, the probe was built with error correction utilizing a convolutional encoder to avoid sending corrupted data.

Power

Pioneer 10 utilized 4 SNAP-19 Radioisotope Thermoelectric Generators(RTGs). They are positioned on 2 three-rod trusses, each 3 meters (10 feet) in length and 120 degrees apart. This was expected to be a safe distance from the sensitive scientific experiments carried on board. Combined, the RTGs provided 155w at launch and would decay to 140w in transit to Jupiter. The spacecraft required 100w to power all systems.

Scientific instruments

Instrument Name	Abr.	Image	Description
Helium Vector Magnetometer	(HVM)		Measures the fine structure of the interplanetary magnetic field, maps the Jovian magnetic field, and provides magnetic field measurements to evaluate solar wind interaction with Jupiter.

Quadrispherical Plasma Analyzer		Peers through a hole in the large dish-shaped antenna to detect particles of the solar wind originating from the Sun.
Charged Particle Instrument	(CPI)	
Cosmic Ray Telescope	(CRT)	Detects cosmic rays in the Solar System.
Geiger Tube Telescope	(GTT)	
Trapped Radiation Detector	(TRD)	
Meteoroid Detectors		Surveys the intensities, energy spectra, and angular distributions of electrons and protons along the spacecraft's path through the radiation belts of Jupiter.
Asteroid/Meteoroid Detector	(AMD)	Includes an <i>unfocused Cerenkov counter</i> that detects the light emitted in a particular direction as particles pass through it recording electrons of energy, 0.5 to 12 MeV, an <i>electron scatter detector</i> for electrons of energy, 100 to 400 keV, and a <i>minimum ionizing detector</i> consisting of a solid-state diode that measures minimum ionizing particles (<3 MeV) and protons in the range of 50 to 350 MeV.
Ultraviolet Photometer		Twelve panels of pressurized cell detectors mounted on the back of the main dish antenna record penetrating impacts of small meteoroids.
Imaging Photopolarimeter	(IPP)	
		Meteoroid-asteroid detector looks into space with four non-imaging telescopes to track particles ranging from close-by bits of dust to distant large asteroids.
		Ultraviolet light is sensed to determine the quantities of hydrogen and helium in space and on Jupiter.
		The imaging experiment relies upon the spin of the spacecraft to sweep a small telescope across the planet in narrow strips only 0.03 degrees wide, looking at the planet in red and blue light. These strips were then processed to build up a visual image of the planet.

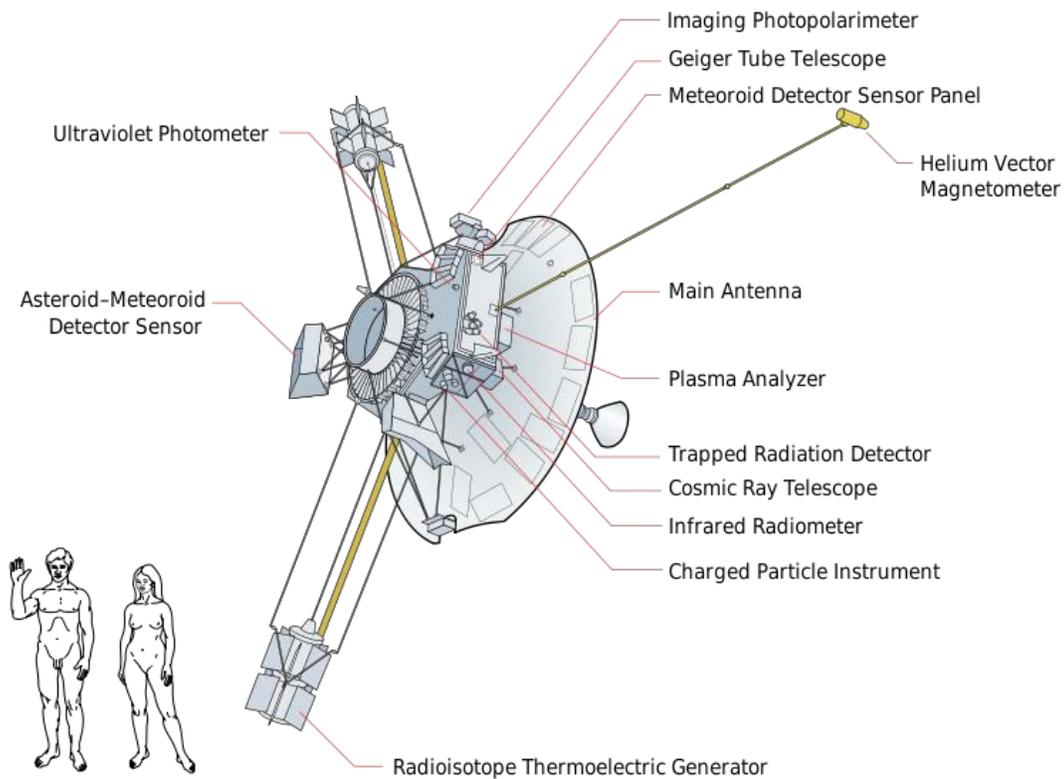
Infrared Radiometer



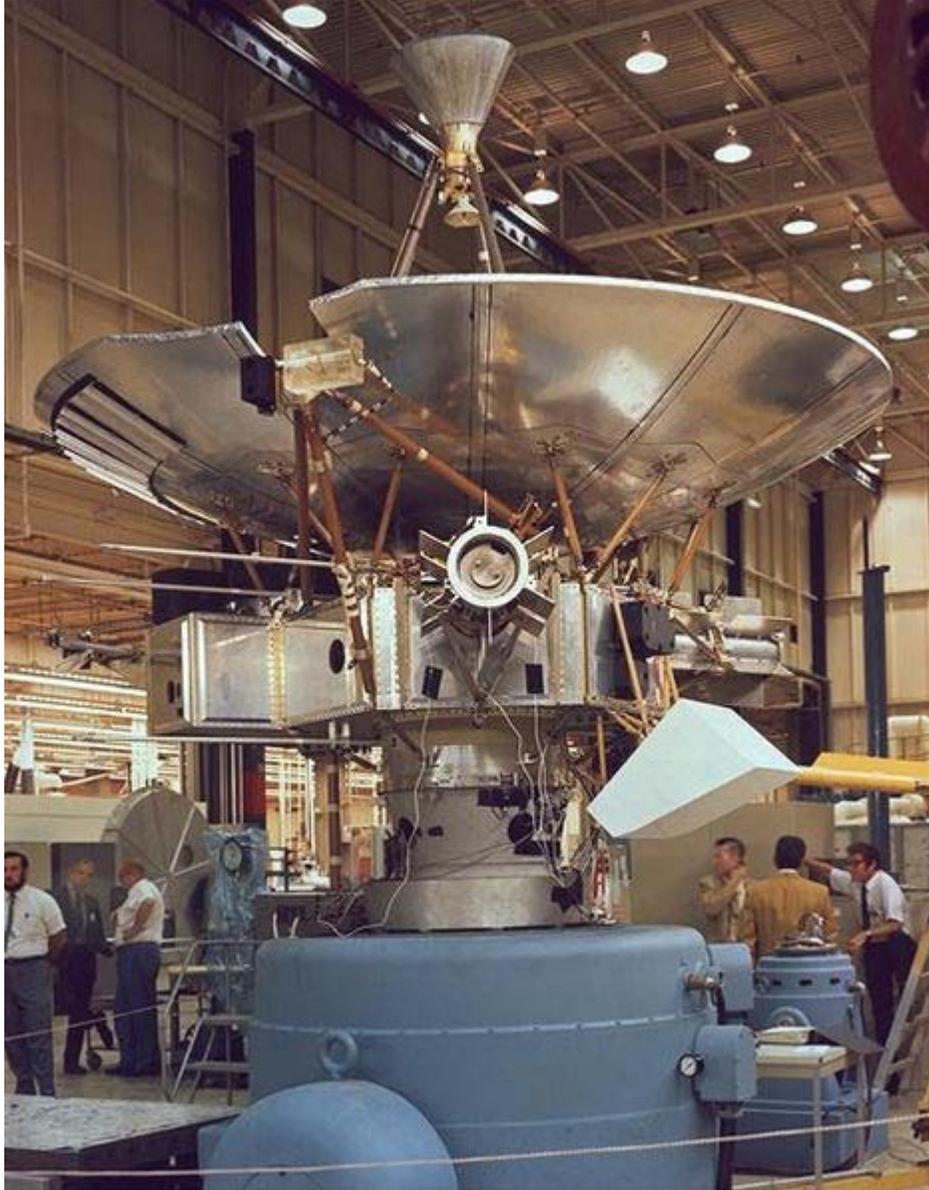
Provides information on cloud temperature and the output of heat from Jupiter.

Pioneer plaque

Pioneer 10 and Pioneer 11 carry a gold-anodized aluminium plaque in the event that either spacecraft is ever found by intelligent life-forms from other planetary systems. The plaques feature the nude figures of a human male and female along with several symbols that are designed to provide information about the origin of the spacecraft.



Pioneer 10 and Pioneer 11 spacecraft design



Pioneer 10 in the final stages of construction



The Pioneer plaque fixed to the space probe



Pioneer 10 on a kick motor just prior to be encapsulated for launch

Mission profile



Pioneer 10 launching from Space Launch Complex 36A

Launch and trajectory

The *Pioneer 10* probe was launched on March 3, 1972 at 01:49:00 UTC by the National Aeronautics and Space Administration from Space Launch Complex 36A at Cape Canaveral, Florida aboard an Atlas/Centaur launch vehicle. The launch vehicle accelerated the probe for 17 minutes, reaching a velocity of 51,682 kilometers/hour (32,114 miles/hour) passing by the moon in 11 hours and becoming the fastest man-made object at that time. Twin probe, Pioneer 11, would launch a year later on April 4, 1973.

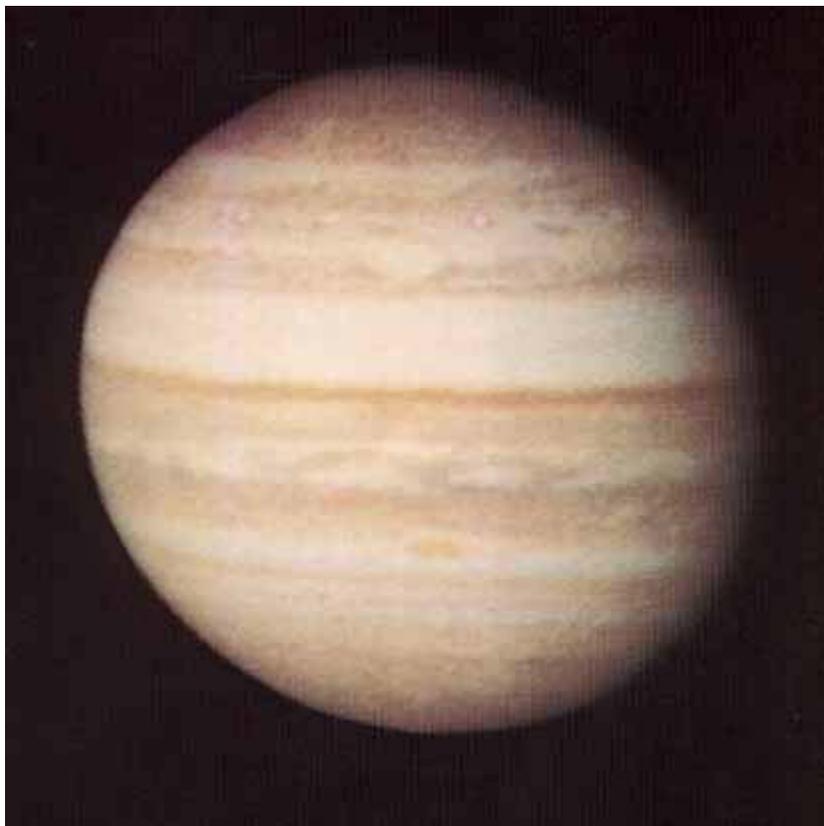
Timeline of travel

Date	Event
1972-03-03	Spacecraft launched.
1972-06-	Crossed orbit of Mars.
1972-07-15	Entered the asteroid belt.
1973-12-03 / 1973-12-04	Encounter with Jovian system.

Encounter with Jupiter

In November and December 1973, *Pioneer 10* began transmitting images of Jupiter back to Earth. 500 images of Jupiter had been received by December 2, 1973, revealing little detail. However, within the 48 hours prior to closest approach, the probe exceeded the resolution of Earth based observations, revealing many previously unseen details.

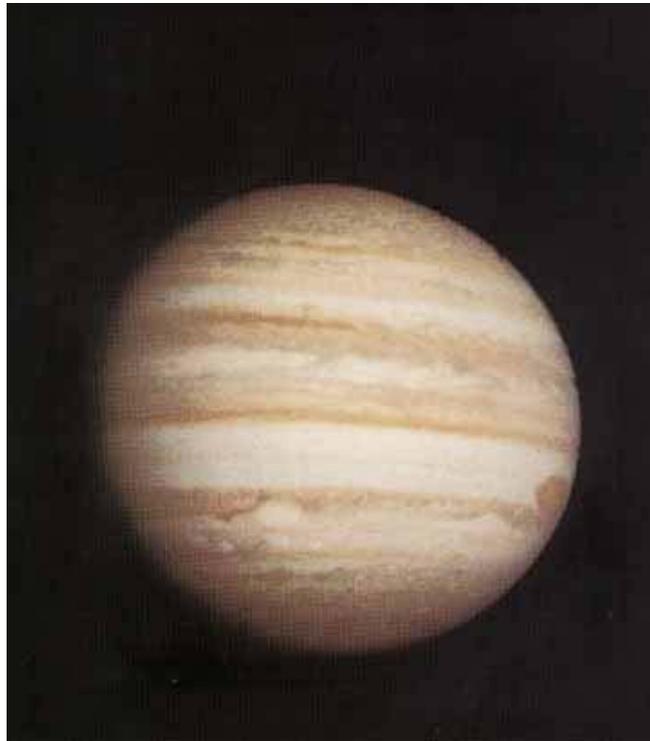
On December 4, 1973, *Pioneer 10* reached closest approach to Jupiter, passing 200,000 kilometers (124,274 miles) above the cloud tops.



Jupiter encounter (frame 1)



Jupiter encounter (frame 2)



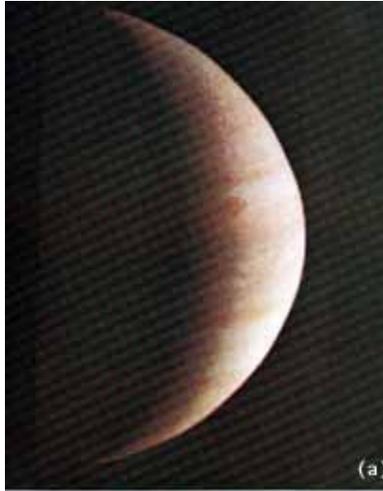
Jupiter encounter (frame 3)



Jupiter encounter (frame 4)



Highest detailed image of the *Pioneer 10* encounter of Jupiter



Sunrise on a crescent-shaped Jupiter



Ganymede as seen from *Pioneer 10*



Europa appeared as a mostly featureless disk

Interstellar mission

Pioneer anomaly

Analysis of the radio tracking data from the *Pioneer 10* and *11* spacecraft at distances between 20–70 AU from the Sun has consistently indicated the presence of a small but anomalous Doppler frequency drift. The drift can be interpreted as due to a constant acceleration of $(8.74 \pm 1.33) \times 10^{-10} \text{ m/s}^2$ directed towards the Sun. Although it is suspected that there is a systematic origin to the effect, none has been found. As a result, there is growing interest in the nature of this anomaly.

Current status

Pioneer 10's weak signal continued to be tracked by the Deep Space Network. After 1997, the probe was used in the training of flight controllers on how to acquire radio signals from space. There was an Advanced Concepts study applying chaos theory to extract coherent data.

The last successful reception of telemetry was on April 27, 2002; subsequent signals were barely strong enough to detect. Loss of contact was probably due to a combination of increasing distance and the spacecraft's steadily weakening power source, rather than structural failure of the craft.

The last, very weak signal from *Pioneer 10* was received on January 23, 2003, when it was 12 billion kilometers (80 au) from Earth.

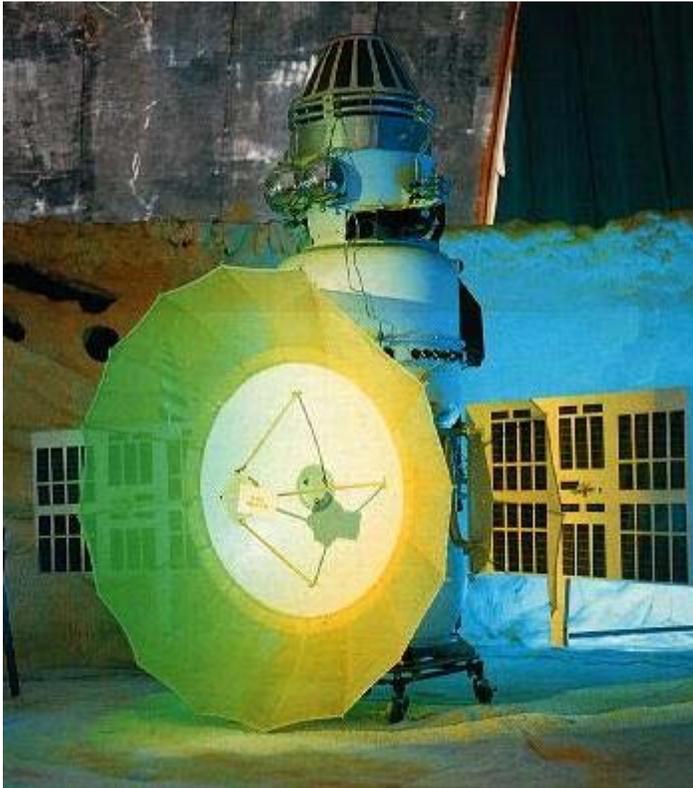
A contact attempt on February 7, 2003 was unsuccessful.

One final attempt was made on the evening of March 4, 2006, the last time the antenna would be correctly aligned with Earth. No response was received from *Pioneer 10*.

Pioneer 10 is heading in the direction of the star Aldebaran in the constellation Taurus at roughly 2.6 AU per year. If Aldebaran had zero relative velocity, it would take *Pioneer 10* about 2 million years to reach it.

Venera 8

Venera 8 (3V (V-72))



Venera 8

Operator	USSR
Mission type	Lander
Satellite of	Venus
Orbital insertion date	Landed on 22 July 1972
Launch date	1972-03-27 at 04:15:01 UTC
Launch vehicle	Proton Booster Plus Upper Stage and

Escape Stages

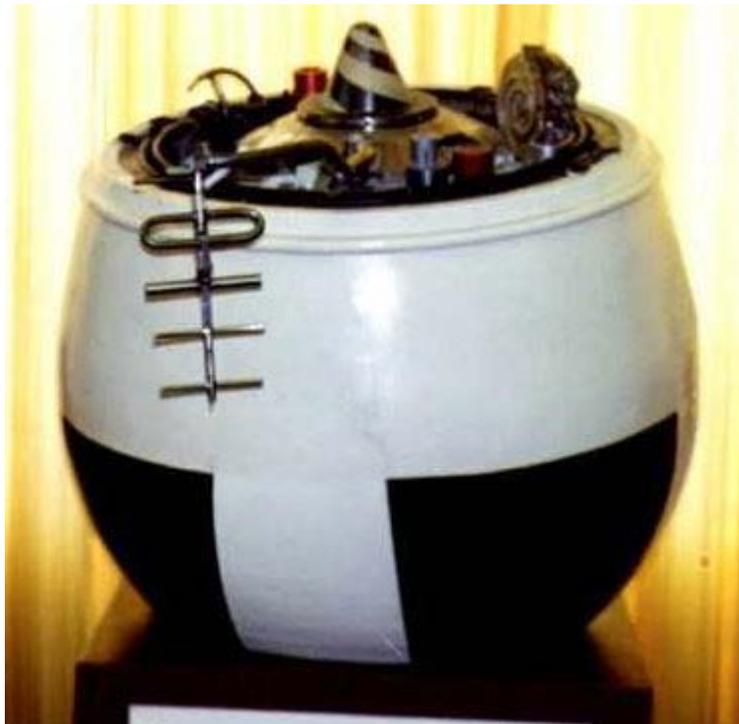
Mission duration 1972-03-27 to 22 July 1972

COSPAR ID 1972-021A

Mass 1180 kg

Venera 8 (Russian: Венера-8) (manufacturer's designation: 3V (V-72)) was a probe in the Soviet Venera program for the exploration of Venus.

Venera 8 was a Venus atmospheric probe and lander. Its instrumentation included temperature, pressure, and light sensors as well as an altimeter, gamma ray spectrometer, gas analyzer, and radio transmitters. The spacecraft took 117 days to reach Venus with one mid-course correction on 6 April 1972, separating from the bus (which contained a cosmic ray detector, solar wind detector, and ultraviolet spectrometer) and entering the atmosphere on 22 July 1972 at 08:37 UT. A refrigeration system attached to the bus was used to pre-chill the descent capsule's interior prior to atmospheric entry in order to prolong its life on the surface. Descent speed was reduced from 41,696 km/h to about 900 km/h by aerobraking. The 2.5 meter diameter parachute opened at an altitude of 60 km.



Venera 8 landing capsule

Venera 8 transmitted data during the descent. A sharp decrease in illumination was noted at 35 to 30 km altitude and wind speeds of less than 1 km/s were measured below 10 km.

Venera 8 landed at 09:32 UT in what is now called Vasilisa Regio, within 150 km radius of 10°42'S 335°15'E / 10.70°S 335.25°E, in sunlight, about 500 km from the morning terminator. The lander mass was 495 kg. It continued to send back data for 50 minutes, 11 seconds after landing before failing due to the harsh surface conditions. The probe confirmed the earlier data on the high Venus surface temperature and pressure (470 degrees Celsius, 90 atmospheres) returned by Venera 7, and also measured the light level as being suitable for surface photography, finding it to be similar to the amount of light on Earth on an overcast day with roughly 1 km visibility.

Venera 8's photometer measurements showed for the first time that the Venusian clouds end at a high altitude, and the atmosphere was relatively clear from there down to the surface. The on-board gamma ray spectrometer measured the uranium/thorium/potassium ratio of the surface rock, indicating it was similar to granite.

Kosmos 482

Kosmos 482 (Russian: Космос 482 meaning **Cosmos 482**), launched March 31, 1972 at 04:02:33 UTC, was an attempted Venus probe which failed to escape low Earth orbit.

Beginning in 1962, the name Kosmos was given to Soviet spacecraft which remained in Earth orbit, regardless of whether that was their intended final destination. The designation of this mission as an intended planetary probe is based on evidence from Soviet and non-Soviet sources and historical documents. Typically Soviet planetary missions were initially put into an Earth parking orbit as a launch platform with a rocket engine and attached probe. The probes were then launched toward their targets with an engine burn with a duration of roughly 4 minutes. If the engine misfired or the burn was not completed, the probes would be left in Earth orbit and given a Kosmos designation.

Kosmos 482 was launched by an SL-6/A-2-e launcher on March 31, 1972, 4 days after the Venera 8 atmospheric probe and may have been similar in design and mission plan. After achieving an Earth parking orbit, the spacecraft made an apparent attempt to launch into a Venus transfer trajectory. It separated into four pieces, two of which remained in low Earth orbit and decayed within 48 hours into south New Zealand (known as the *Ashburton balls incident*), and two pieces (presumably the payload and detached engine unit) went into a higher 210 x 9800 km orbit. It is thought that a malfunction resulted in an engine burn which did not achieve sufficient velocity for the Venus transfer and left the payload in this elliptical Earth orbit.

At 1 am on April 3, 1972, four red-hot 13.6kg titanium alloy balls landed within a 16km radius of each other just outside Ashburton, New Zealand. The 38cm-diameter spheres scorched holes in crops and made deep indentations in the soil, but no one was injured. A similarly shaped object was discovered near Eifelton, New Zealand, in 1978.

Space law required that the space junk be returned to its national owner, but the Soviets denied knowledge or ownership of the satellite. Ownership therefore fell to the farmer upon whose property the satellite fell. Kosmos 482 was thoroughly analysed by New Zealand scientists which determined that they were Soviet in origin because of manufacturing marks and the high-tech welding of the titanium. The scientists concluded that they were probably gas pressure vessels of a kind used in the launching rocket for a satellite or space vehicle and had decayed in the atmosphere.

Apollo 16

Apollo 16

Mission insignia



Mission statistics

Mission name	<i>Apollo 16</i>
	CM-113
Command Module	callsign <i>Casper</i> mass 30,395 kg
Service Module	SM-113 LM-11
Lunar Module	callsign <i>Orion</i> mass 16,445 kg
Crew size	3
Booster	Saturn V SA-511 LC 39A
Launch pad	Kennedy Space Center Florida, USA
Launch date	April 16, 1972 17:54:00 UTC
Lunar landing	April 21, 1972 02:23:35 UTC

	Descartes Highlands
	8°58'22.84"S 15°30'0.68"E /
	8.9730111°S 15.5001889°E
	(based on the IAU
	Mean Earth Polar Axis coordinate
	system)
	First 07:11:02
Lunar EVA	Second 07:23:09
duration	Third 05:40:03
	Total 20:14:14
Lunar surface time	2 d 23 h 02 m 13 s
Lunar Roving	
Vehicle	LRV-2
CMP EVA duration	01:23:42
Lunar sample mass	95.71 kg (211 lb)
Total CSM time in	
lunar orbit	5 d 05 h 49 m 32 s
	April 27, 1972
Landing	19:45:05 UTC
	 0°43'S 156°13'W / 0.717°S
	156.217°W
Mission duration	11 d 01 h 51 m 05 s

Crew photo



Left to right: Mattingly, Young, Duke

Related missions

Previous mission

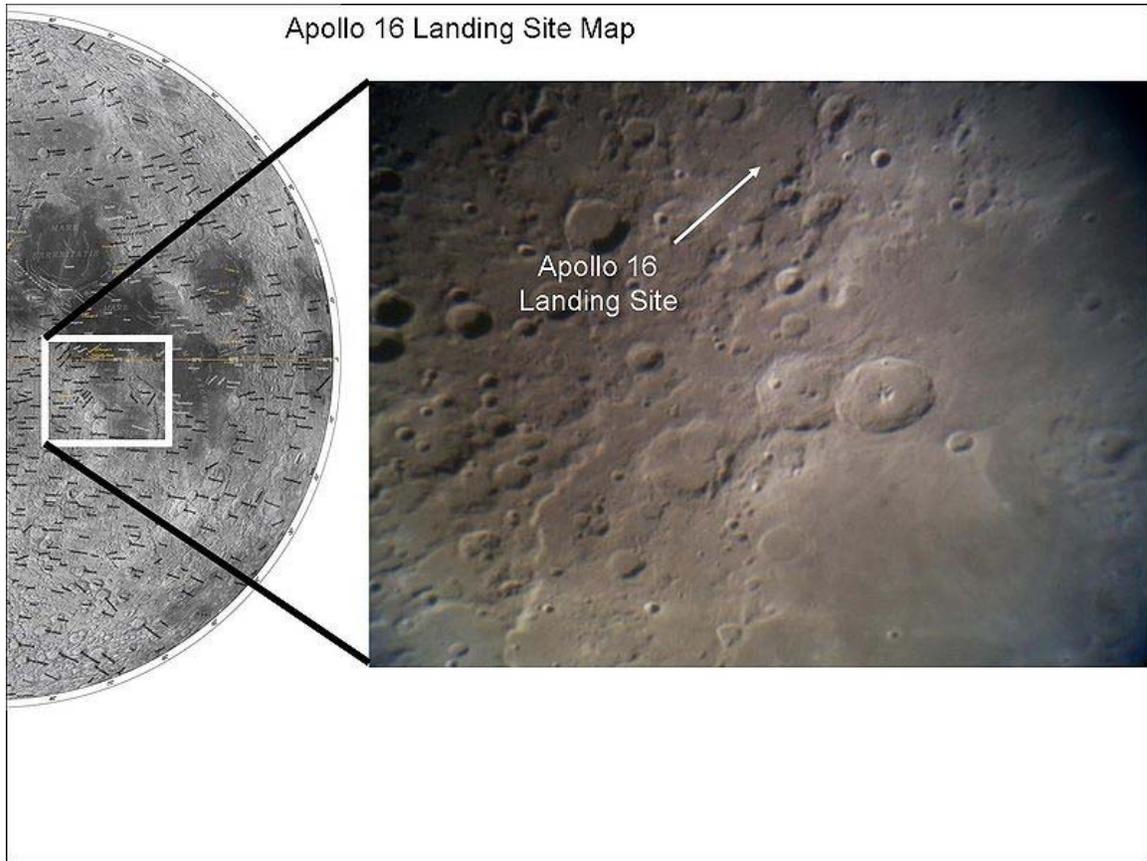


Apollo 15

Subsequent mission



Apollo 17



Location of the Apollo 16 landing site

Apollo 16 was the tenth manned mission in the Apollo program. It was the fifth mission to land on the Moon and the first to land in a highlands area. The mission was launched on April 16, 1972, and concluded on April 27. It was a J-class mission, featuring a Lunar Rover and brought back 94.7 kg of lunar samples. It included three lunar EVA: 7.2 hours, 7.4 hours, 5.7 hours and one trans-earth EVA of 1.4 hours.

The Apollo 16 subsatellite was launched from the CSM while it was in lunar orbit. The subsatellite carried out experiments on magnetic fields and solar particles. It was launched April 24, 1972 at 21:56:09 UTC and orbited the Moon for 34 days and 425 revolutions. It had a mass of 80 lb (36 kg) and consisted of a central cylinder and three 1.5 m booms.

En route to the Moon, the Apollo 16 astronauts took several photos of Earth, one of which was with North America in the background, with much of the northern portion of the continent under extensive cloud cover.

Despite a malfunction in the Command Module which almost aborted the lunar landing, Apollo 16 landed successfully in the Descartes Highlands on April 21.

Crew

Position	Astronaut
Commander	John W. Young Fourth spaceflight
Command Module Pilot	T. Kenneth Mattingly Jr. First spaceflight
Lunar Module Pilot	Charles M. Duke Jr. First spaceflight

Young and Duke served as the backup crew to Apollo 13; Mattingly was slated as the Apollo 13 command module pilot until being pulled from the mission due to his exposure to rubella by Duke.

Backup crew

Position	Astronaut
Commander	Fred W. Haise, Jr
Command Module Pilot	Stuart A. Roosa
Lunar Module Pilot	Edgar D. Mitchell

Although not officially announced, the original backup crew consisted of Fred Haise (CDR), William R. Pogue (CMP) and Gerald Carr (LMP) who were targeted for the prime crew assignment on Apollo 19. However, after the widely-expected cancellations of Apollo 18 and Apollo 19 were finalized in September 1970 it meant that this crew would not rotate to a lunar mission as planned. Subsequently, Roosa and Mitchell were recycled to serve as members of the backup crew after returning from Apollo 14 while Pogue and Carr were re-assigned to the Skylab program where they later flew on Skylab 4.

Support crew

- Philip K. Chapman
- Anthony W. England
- Henry W. Hartsfield, Jr
- Robert F. Overmyer

Mission parameters

- **Mass:**
 - Launch mass: 2,921,005 kg
 - Total spacecraft: 46,782 kg
 - CSM mass: 30,354 kg, of which CM was 5840 kg, SM 24,514 kg
 - LM mass: transposition and docking 36,252 lb (16,444 kg), separation for landing 36,743 lb (16,666 kg), ascent stage at lunar liftoff 10,949 lb (4,966 kg)
- **Earth orbits:** 3 before leaving for Moon, about one on return
- **Lunar orbits:** 64

- **Perigee:** 166.7 km
- **Apogee:** 176.0 km
- **Inclination:** 32.542°

- **Period:** 87.85 min

- **Perilune:** 107.6 km
- **Apolune:** 315.4 km
- **Inclination:** 168°

- **Period:** 120 min
- **Landing Site:** 8.97301° S - 15.50019° E or

8° 58' 22.84" S - 15° 30' 0.68" E

LM - CSM docking

- **Undocked:** April 20, 1972 - 18:07:31 UTC
- **Docked:** April 24, 1972 - 03:35:18 UTC

EVA's

- ***Young and Duke*** - EVA 1
- **EVA 1 Start:** April 21, 1972, 16:47:28 UTC
- **EVA 1 End:** April 21, 23:58:40 UTC
- **Duration:** 7 hours, 11 minutes, 02 seconds

- ***Young and Duke*** - EVA 2
- **EVA 2 Start:** April 22, 1972, 16:33:35 UTC
- **EVA 2 End:** April 22, 23:56:44 UTC
- **Duration:** 7 hours, 23 minutes, 09 seconds

- ***Young and Duke*** - EVA 3

- **EVA 3 Start:** April 23, 1972, 15:25:28 UTC
- **EVA 3 End:** April 23, 21:05:31 UTC
- **Duration:** 5 hours, 40 minutes, 03 seconds

- **Mattingly** (*Duke - Stand up*) - Transearth EVA 4

- **EVA 4 Start:** April 25, 1972, 20:33:46 UTC
- **EVA 4 End:** April 25, 21:57:28 UTC
- **Duration:** 1 hour, 23 minutes, 42 seconds

Mattingly's EVA was only the second trans-earth EVA ever and was used to bring in film from exterior cameras and conduct an experiment on microbial survival.

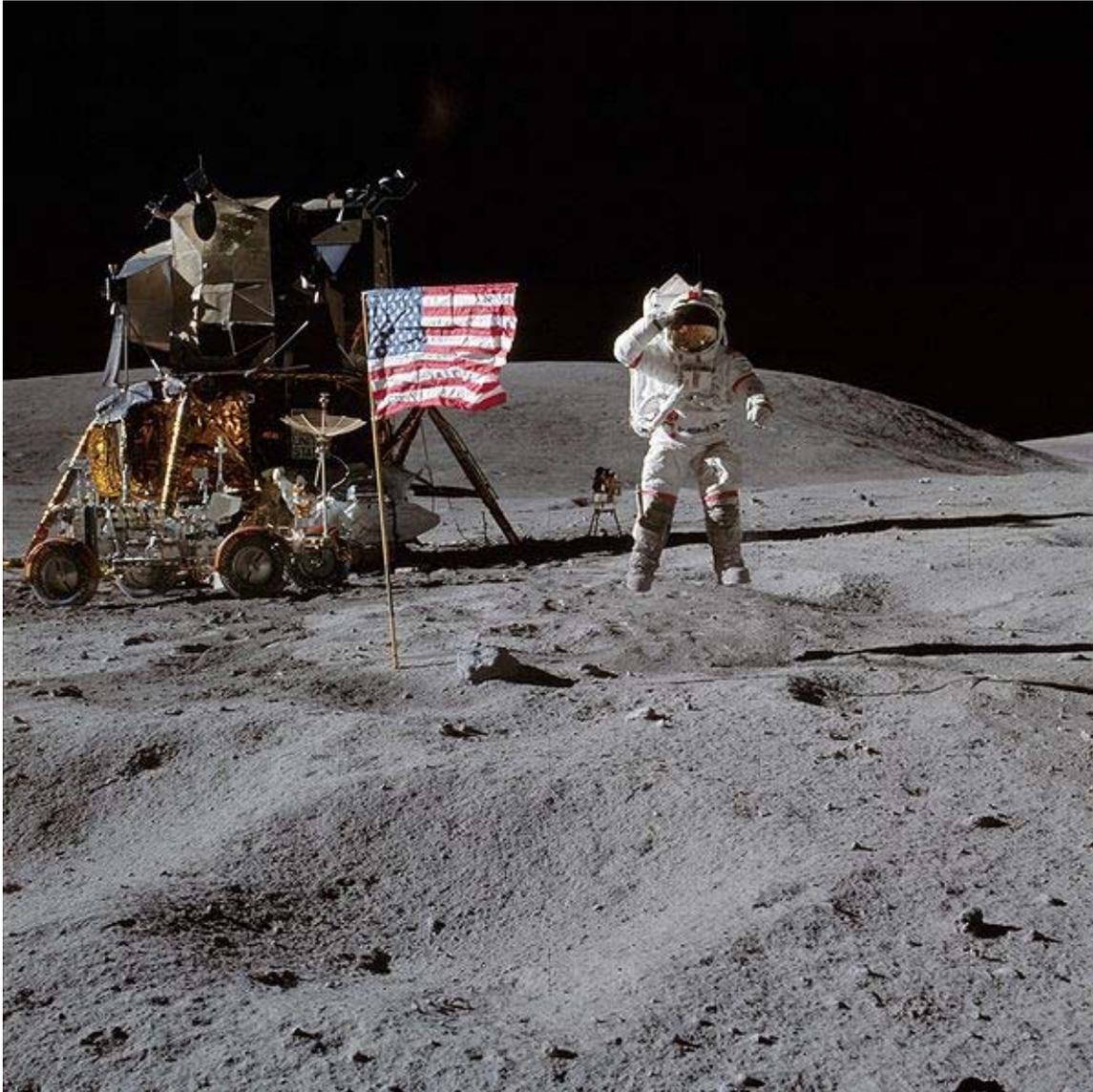
The splashdown point was 0 deg 43 min S, 156 deg 13 min W, 215 miles (346 km) southeast of Christmas Island (Kiritimati) and 5 km (3.1 mi) from the recovery ship USS *Ticonderoga*.

Mission highlights



The Saturn V launches Apollo 16 to the Moon

A malfunction in a backup yaw gimbal servo loop in the main propulsion system of the CSM *Casper* caused concerns about firing the engine to adjust the CSM's lunar orbit, and nearly caused the Moon landing to be aborted. After a delayed first landing attempt, it was determined that the malfunction presented relatively little risk, and Young and Duke (who were already undocked, and flying LM *Orion* when the problem occurred) were permitted to land on the Moon.



John Young jumps while saluting the American flag

Young and Duke spent three days exploring the Descartes highland region, while Mattingly circled overhead in *Casper*. This was the only one of the six Apollo landings to target the lunar highlands. On the first day of the test, news was relayed to them that Congress approved the Space Shuttle program for use. Young stated that it was needed. The astronauts discovered that what was thought to have been a region of volcanism was

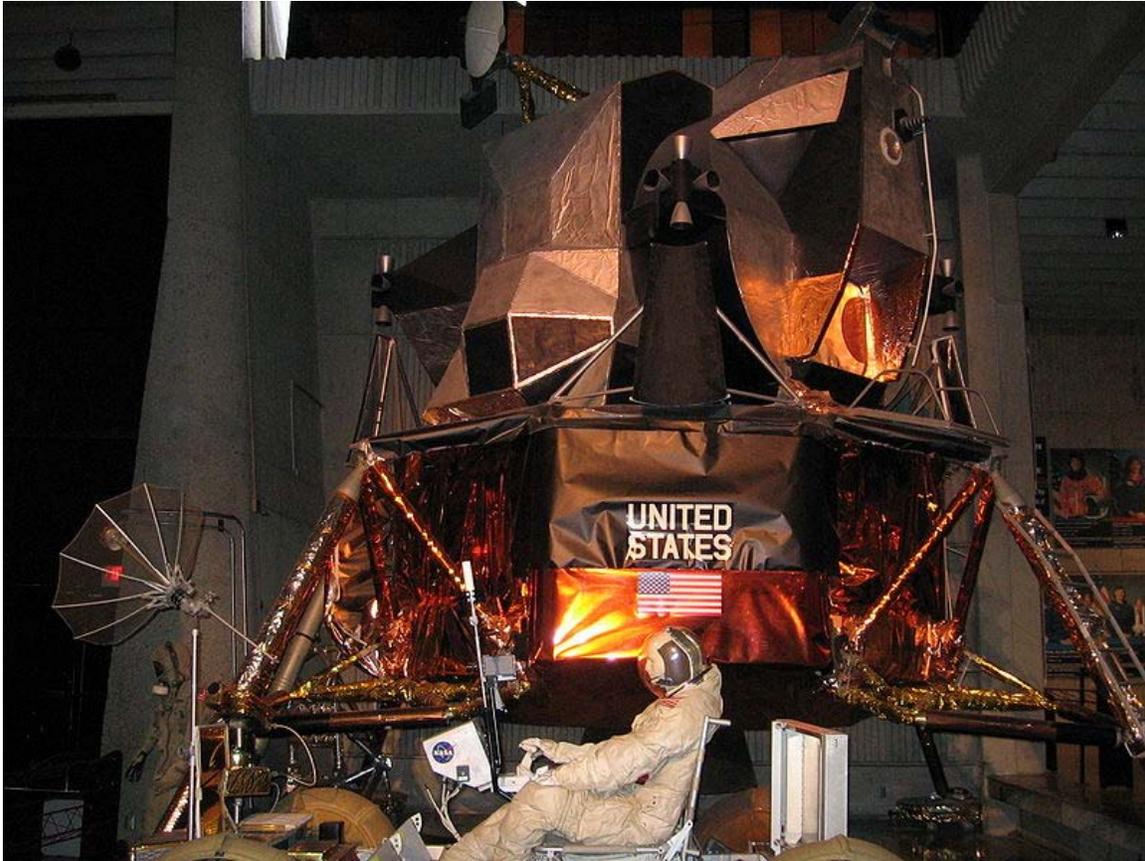
actually a region full of impact-formed rocks (breccias). Their collection of returned specimens included a 25 pound (11 kg) chunk that was the largest single rock returned by the Apollo astronauts (nicknamed "Big Muley" after Bill Muehlberger, principal investigator for the mission's geology activities). The scientific results of Apollo 16 caused planetary geologists to revise previous interpretations of the lunar highlands, concluding that meteorite impacts were the dominant agent in shaping the Moon's ancient surfaces.

The Apollo 16 astronauts also conducted performance tests with the lunar rover, at one time getting up to a top speed of eleven miles per hour (eighteen kilometers per hour), which still stands as the record speed for any wheeled vehicle on the Moon (listed as such in the Guinness Book of Records).

Apollo 16 was originally scheduled for splashdown at 3:30pm EST on April 28. The mission was shortened by a day (reducing the time in orbit around the Moon after the LM left the Moon and docked with the CSM) because of the problems with the command module prior to landing. As Charlie Duke described on the Apollo Lunar Surface Journal website: "The more you waited up there - if you did have a problem - the less time you had to think of something brilliant to fix it. They got a little nervous and brought us home a day early, I think, just to make sure we could have some ample time to fix any problems." There were no problems encountered during the return flight.

Subsatellite

The subsatellite (PFS-2) was a 78 cm x 36 cm hexagonal cylinder weighing 36.3 kg. Launched from the Service Module while in orbit around the Moon, the subsatellite's mission was to measure plasma, energetic particle intensities and the lunar magnetic fields. The craft was launched through a spring action, which generated a relative velocity of around 1.2 m/s and a spin of 120 rpm. It returned data from 24 April to 29 May 1972 with an orbital period of around 120 minutes. It was launched into a sub-optimal inclination and the orbit decayed earlier than anticipated, with impact occurring after 425 revolutions.



Mock-up of *Orion* on display at the U.S. Space & Rocket Center

Spacecraft locations

The Apollo 16 command module *Casper* is currently on display at the U.S. Space & Rocket Center, in Huntsville, Alabama. The lunar module ascent stage separated 24 April 1972 but a loss of attitude control rendered it out of control. It orbited the Moon for about a year. Its impact site on the Moon is unknown.

Charles Duke donated some flown items, including a lunar map, to Kennesaw State University in Kennesaw, Georgia. Duke left two items on the Moon, both of which he photographed. The most famous is a plastic-encased photo portrait of his family on the Moon (NASA Photo AS16-117-18841). The reverse of the photo is signed by Duke's family and bears this message: "This is the family of Astronaut Duke from Planet Earth. Landed on the Moon, April 1972." The other item was a commemorative medal issued by the United States Air Force, which was celebrating its 25th anniversary in 1972. He took two medals, leaving one on the Moon and donating the other to the Wright-Patterson Air Force Base museum.

Mission insignia



Robbins Medallion from Apollo 16

The circular patch featured an eagle with wings outstretched, perched atop a red, white, and blue shield, over a lunar surface. The vector symbol from the NASA logo was placed on top of the shield, and then across the shield were written the words APOLLO 16. The artwork was bordered in white, with a blue band carrying 16 stars and the crew names. There was a gold border. The patch was designed by NASA artist Barbara Matelski.

Quotes

"I mean, I haven't eaten this much citrus fruit in 20 years! And I'll tell you one thing, in another 12 fucking days, I ain't never eating any more."—John Young in an air-to-ground transmission, reacting to stomach problems caused by drinking potassium-enriched orange juice (to prevent an electrolyte deficiency identified in the crew of Apollo 15). He was unaware that his microphone was still transmitting after a recent conversation with Mission Control.

Chapter- 4

Space and Solar System Exploration in 1973

Luna 21

Luna 21 (Ye-8 series) was an unmanned space mission of the Luna program, also called Lunik 21. The Luna 21 spacecraft landed on the Moon and deployed the second Soviet lunar rover (Lunokhod 2). The primary objectives of the mission were to collect images of the lunar surface, examine ambient light levels to determine the feasibility of astronomical observations from the Moon, perform laser ranging experiments from Earth, observe solar X-rays, measure local magnetic fields, and study mechanical properties of the lunar surface material.

The SL-12/D-1-e launcher put the spacecraft into Earth parking orbit followed by translunar injection. On 12 January 1973, Luna 21 was braked into a 90×100 km orbit about the Moon. On 13 and 14 January, the perilune was lowered to 16 km altitude. On 15 January after 40 orbits, the braking rocket was fired at 16 km altitude, and the craft went into free fall. At an altitude of 750 meters the main thrusters began firing, slowing the fall until a height of 22 meters was reached. At this point the main thrusters shut down and the secondary thrusters ignited, slowing the fall until the lander was 1.5 meters above the surface, where the engine was cut off. Landing occurred at 23:35 UT in Le Monnier crater at 25.85° N, 30.45° E. The lander carried a bas relief of Lenin and the Soviet coat-of-arms.

Luna 21 carried the second successful Soviet lunar rover, Lunokhod 2, and was launched less than a month after the last Apollo lunar landing. After a midcourse correction the day after launch, Luna 21 entered orbit around the Moon on 12 January 1973. Parameters were 100×90 kilometers at 60° inclination. On 15 January, the spacecraft deorbited and, after multiple engine firings, landed on the Moon at 22:35 UT the same day, inside the LeMonnier crater at $25^\circ 51'$ north latitude and $30^\circ 27'$ east longitude, between Mare Serenitatis and the Taurus Mountains. Less than 3 hours later, at 01:14 UT on 16 January, the rover disembarked onto the lunar surface. The 840-kilogram Lunokhod 2 was an improved version of its predecessor and was equipped with a third TV camera, an improved eight-wheel traction system, and additional scientific instrumentation. By the end of its first lunar day, Lunokhod 2 had already traveled further than Lunokhod 1 in its entire operational life. On 9 May, the rover inadvertently rolled into a crater and dust

covered its solar panels and radiators, disrupting temperatures in the vehicle. Attempts to save the rover failed, and on 3 June, the Soviet news agency announced that its mission was over. Before last contact, the rover took 80,000 TV pictures and 86 panoramic photos and had performed hundreds of mechanical and chemical surveys of the soil. The Soviets later revealed that during a conference on planetary exploration in Moscow, 29 January to 2 February 1973 (that is, after the landing of Luna 21), an American scientist had given photos of the lunar surface around the Luna 21 landing site to a Soviet engineer in charge of the Lunokhod 2 mission. These photos, taken prior to the Apollo 17 landing, were later used by the "driver team" to navigate the new rover on its mission on the Moon.

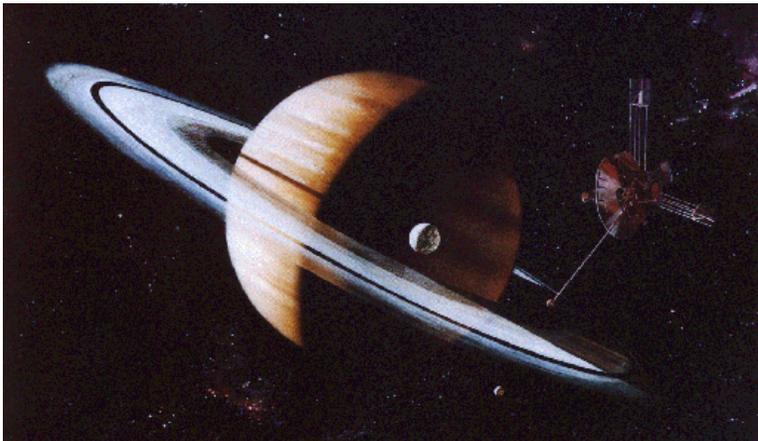
- Launch Date/Time: 1973-01-08 at 06:55:38 UTC
- On-orbit dry mass: 4850 kg

Present ownership

Both Luna 21 and Lunokhod 2 were purchased by Richard Garriott in December of 1993 at a Sotheby's auction in New York.

Pioneer 11

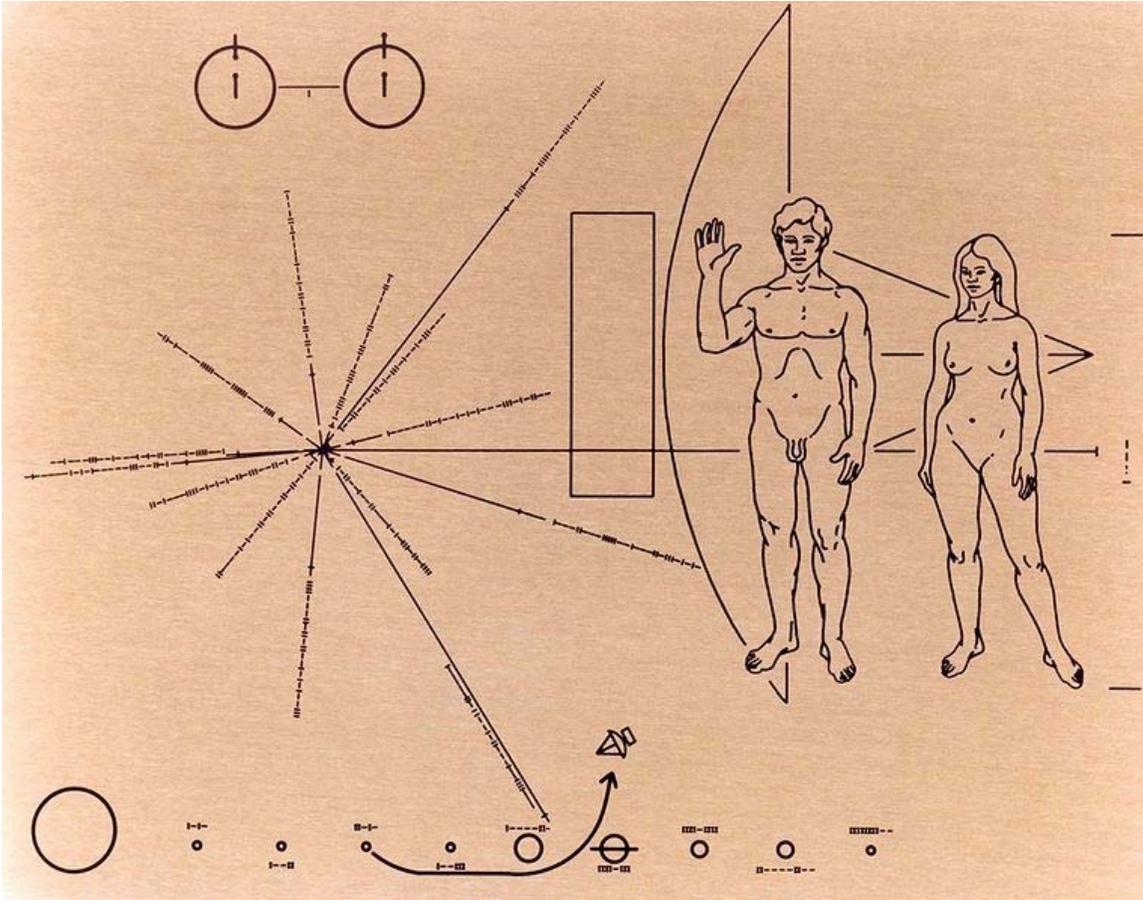
Pioneer 11



Pioneer 11 at Saturn (artist's impression)

Operator	ARC / NASA
Major contractors	TRW
Mission type	Flyby

Flyby of	Jupiter, Saturn
Launch date	1973-04-06 02:11:00 UTC (37 years, 9 months, and 8 days ago)
Launch vehicle	Atlas/Centaur/TE364-4
Launch site	Space Launch Complex 36A Cape Canaveral Air Force Station
Mission duration	December 2, 1974 - September 30, 1995 (lost communication) Jupiter flyby <i>(completed 1974-12-03)</i> Saturn flyby <i>(completed 1979-09-01)</i>
COSPAR ID	1973-019A
Homepage	NASA Archive
Mass	259 kg (571 lb)
Power	165.0 W (4 SNAP-19 RTGs)



The *Pioneer 11* (also known as *Pioneer G*) spacecraft is a 259-kilogram (569 lb) robotic space probe launched by NASA on April 6, 1973 to study Jupiter, Saturn and eventually interstellar space. While the spacecraft is believed to still operate properly, communication has been lost since November 30, 1995. Prior to this, the spacecraft was in extended mission to study the dynamics of the solar system boundary including, interplanetary magnetic fields, solar wind, cosmic rays, and the heliosphere. The primary mission ended in September 1973, after encountering the Jovian system and the Saturnian System. It was the first probe to encounter Saturn.

Mission background

History

Approved in February 1969, *Pioneer 11* and twin probe *Pioneer 10*, were the first to be designed for exploring the outer solar system. Yielding to multiple proposals throughout the 1960s, early mission objectives were defined as:

- Explore the interplanetary medium beyond the orbit of Mars
- Investigate the nature of the asteroid belt from the scientific standpoint and assess the belt's possible hazard to missions to the outer planets.
- Explore the environment of Jupiter.

Subsequent planning for an encounter with Saturn added many more goals:

- Map the magnetic field of Saturn and determine its intensity, direction, and structure.
- Determine how many electrons and protons of various energies are distributed along the trajectory of the spacecraft through the Saturn system.
- Map the interaction of the Saturn system with the solar wind.
- Measure the temperature of Saturn's atmosphere and that of Titan, the large satellite of Saturn.
- Determine the structure of the upper atmosphere of Saturn where molecules are expected to be electrically charged and form an ionosphere.
- Map the thermal structure of Saturn's atmosphere by infrared observations coupled with radio occultation data.
- Obtain spin-scan images of the Saturnian system in two colors during the encounter sequence and polarimetry measurements of the planet.
- Probe the ring system and the atmosphere of Saturn with S-band radio waves at occultation.
- Determine more precisely the masses of Saturn and its larger satellites by accurate observations of the effects of their gravitational fields on the motion of the spacecraft.
- As a precursor to the Mariner Jupiter/Saturn mission, verify the environment of the ring plane to find out where it may be safely crossed by the Mariner spacecraft without serious damage.

The Pioneer Project Office at Ames Research Center was selected to oversee the project and aerospace contractor, TRW was selected for construction of the probes.

Spacecraft design

Pioneer 11 was built with six thrusters (first pair used to maintain a constant spin-rate of 4.8-rpm, second pair used for thrust, third pair used for attitude control), a star sensor able to reference Canopus, and two sun sensors. Combined, these systems would allow the space probe to maintain pointing of the high-gain antenna toward Earth autonomously. The probe carried a scientific payload of 11 instruments that would provide data for 13 experiments during the mission.

Communications

The space probe included a redundant system of receivers, one attached to the high-gain antenna, the other to an omni antenna and medium-gain antenna. Each receiver is 8 watts and transmits data across the S-band using 2110 MHz for the uplink from Earth and 2292 MHz for the downlink to Earth with the Deep Space Network tracking the signal. Prior to transmitting data, the probe was built with error correction utilizing a convolutional encoder to avoid sending corrupted data.

Power

Pioneer 11 utilized 4 SNAP-19 Radioisotope Thermoelectric Generators (RTGs). They are positioned on 2 three-rod trusses, each 3 meters (10 feet) in length and 120 degrees apart. This was expected to be a safe distance from the sensitive scientific experiments carried on board. Combined, the RTGs provided 155w at launch and would decay to 140w in transit to Jupiter. The spacecraft required 100w to power all systems.

Scientific instruments

Instrument Name	Abr.	Image	Description
Helium Vector Magnetometer	(HVM)		Measures the fine structure of the interplanetary magnetic field, maps the Jovian magnetic field, and provides magnetic field measurements to evaluate solar wind interaction with Jupiter.
Quadrispherical Plasma Analyzer			Peers through a hole in the large dish-shaped antenna to detect particles of the solar wind originating from the Sun.
Charged Particle Instrument	(CPI)		Detects cosmic rays in the Solar System.
Cosmic Ray Telescope	(CRT)		Collects data on the composition of the cosmic ray particles and their energy ranges.
Geiger Tube Telescope	(GTT)		Surveys the intensities, energy spectra, and angular distributions of electrons and protons along the spacecraft's path through the radiation belts of Jupiter.
Trapped Radiation Detector	(TRD)		Includes an <i>unfocused Cerenkov counter</i> that detects the light emitted in a particular direction as particles pass through it recording electrons of energy, 0.5 to 12 MeV, an <i>electron scatter detector</i> for electrons of energy, 100 to 400 keV, and a <i>minimum ionizing detector</i> consisting of a solid-state diode that measures minimum ionizing particles (<3 MeV) and protons in the range of 50 to 350 MeV.
Meteoroid Detectors			Twelve panels of pressurized cell detectors mounted on the back of the main dish antenna record penetrating

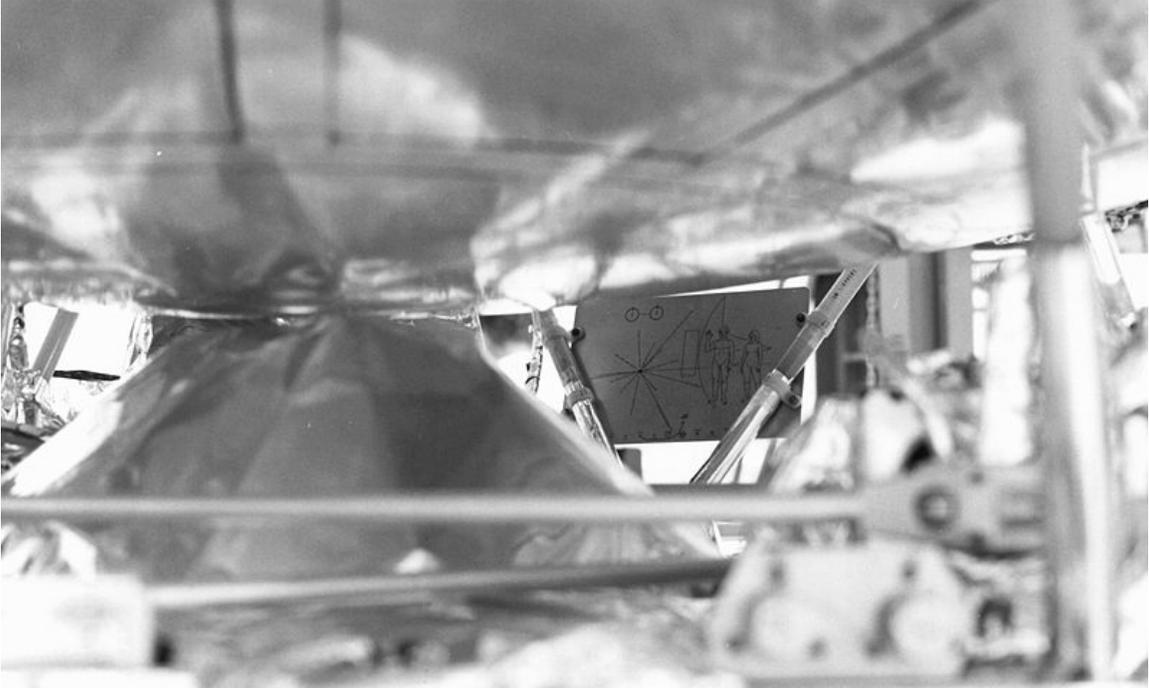
Asteroid/Meteoroid Detector	(AMD)		<p>impacts of small meteoroids. Meteoroid-asteroid detector looks into space with four non-imaging telescopes to track particles ranging from close-by bits of dust to distant large asteroids.</p>
Ultraviolet Photometer			<p>Ultraviolet light is sensed to determine the quantities of hydrogen and helium in space and on Jupiter.</p>
Imaging Photopolarimeter	(IPP)		<p>The imaging experiment relies upon the spin of the spacecraft to sweep a small telescope across the planet in narrow strips only 0.03 degrees wide, looking at the planet in red and blue light. These strips were then processed to build up a visual image of the planet.</p>
Infrared Radiometer			<p>Provides information on cloud temperature and the output of heat from Jupiter.</p>

Pioneer plaque

Pioneer 10 and Pioneer 11 carry a gold-anodized aluminium plaque in the event that either spacecraft is ever found by intelligent life-forms from other planetary systems. The plaques feature the nude figures of a human male and female along with several symbols that are designed to provide information about the origin of the spacecraft.



Pioneer 11 spin stabilization testing



The Pioneer plaque fixed to the space probe



Pioneer 11 being encapsulated for launch

Mission profile



Pioneer 11 launching from Space Launch Complex 36A

Launch and trajectory

The *Pioneer 11* probe was launched on April 6, 1973 at 02:11:00 UTC, by the National Aeronautics and Space Administration from Space Launch Complex 36A at Cape Canaveral, Florida aboard an Atlas/Centaur launch vehicle. Twin probe, Pioneer 10, had previously launched a year before on March 3, 1972.

Timeline of travel

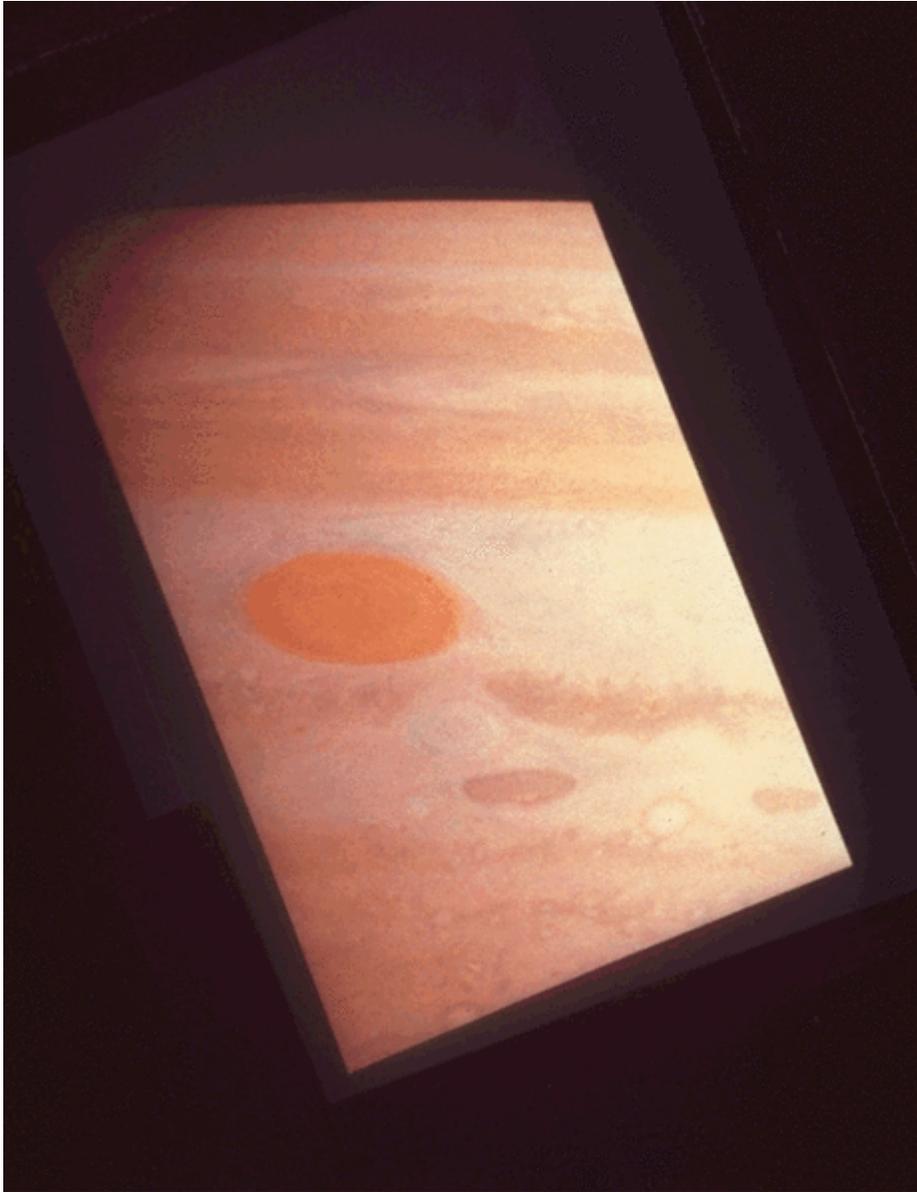
Date	Event
1973-04-06	Spacecraft launched at 02:11:00.
1974-04-19	Passage through the asteroid belt.
1974-12-02 / 1974-12-03	Encounter with Jovian system.
1979-08-29 / 1979-09-02	Encounter with Saturnian system.

Encounter with Jupiter

In November and December 1974, During its closest approach, December 2, 1974, *Pioneer 11* reached closest approach to Jupiter, passing 42,828 kilometers (26,612 miles) above the cloud tops. The probe obtained detailed images of the Great Red Spot, transmitted the first images of the immense polar regions, and determined the mass of Jupiter's moon Callisto. Utilizing the gravitational pull of Jupiter, a gravity assist was used to alter the trajectory of the probe, towards Saturn.



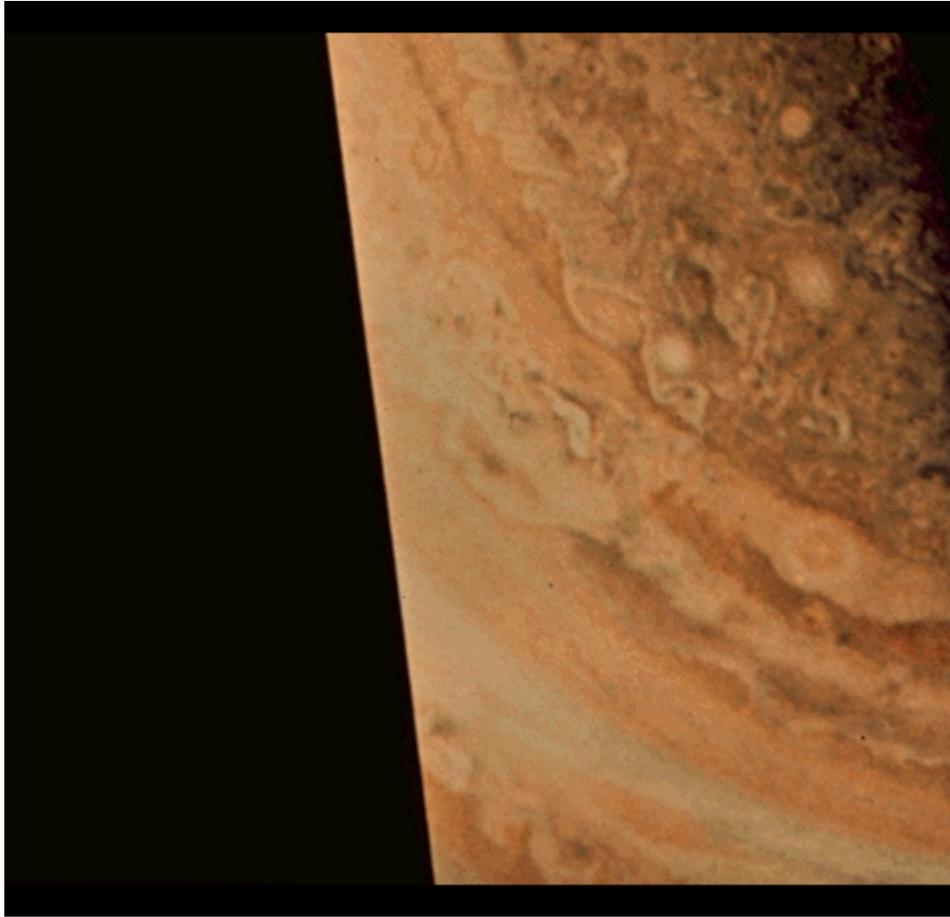
Approach on Jupiter



The Great Red Spot imaged by *Pioneer 11*



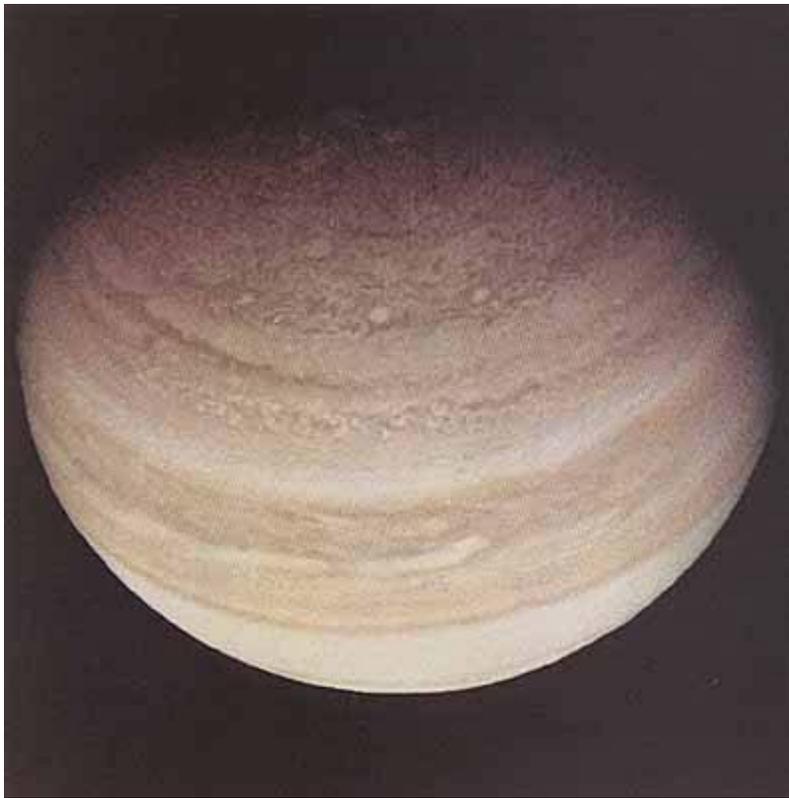
The Great Red Spot prior to closest approach



Cloud bands along the edge of Jupiter



Beginning polar gravity assist



Jupiter polar region from 1,079,000 km



Io imaged from 756,000 km

Saturn encounter



Pioneer 11 and Saturn rings on September 1, 1979 (artist's impression)

Pioneer 11 passed by Saturn on September 1, 1979, at a distance of 21,000 km from Saturn's cloud tops.

By this time Voyager 1 and Voyager 2 had already passed Jupiter and were also en route to Saturn, so it was decided to target Pioneer 11 to pass through the Saturn ring plane at the same position that the soon-to-come Voyager probe would use in order to test the route before Voyager arrived. If there were faint ring particles that could damage a probe in that area, mission planners felt it was better to learn about it via Pioneer. Thus, Pioneer 11 was acting as a "pioneer" in a true sense of the word; if danger was detected, then the Voyager probes could be rerouted further away from the rings, but missing the opportunity to visit Uranus and Neptune in the process.

Pioneer 11 imaged and nearly collided with one of Saturn's small moons, passing at a distance of no more than 2500 miles. The object was tentatively identified as Epimetheus, a moon discovered the previous day from Pioneer's imaging, and suspected from earlier observations by Earth-based telescopes. After the Voyager flybys, it became known that there are two similarly-sized moons (Epimetheus and Janus) in the same orbit, so there is some uncertainty about which one was the object of Pioneer's near-miss. Pioneer 11

encountered Janus on September 1, 1979 at 14:52 UTC at a distance of 2500 km and Mimas at 16:20 UTC the same day at 103000 km.

Besides Epimetheus, instruments located another previously undiscovered small moon and an additional ring, charted Saturn's magnetosphere and magnetic field and found its planet-size moon, Titan, to be too cold for life. Hurtling underneath the ring plane, Pioneer 11 sent back amazing pictures of Saturn's rings. The rings, which normally seem bright when observed from Earth, appeared dark in the Pioneer pictures, and the dark gaps in the rings seen from Earth appeared as bright rings.

Interstellar mission

Pioneer anomaly

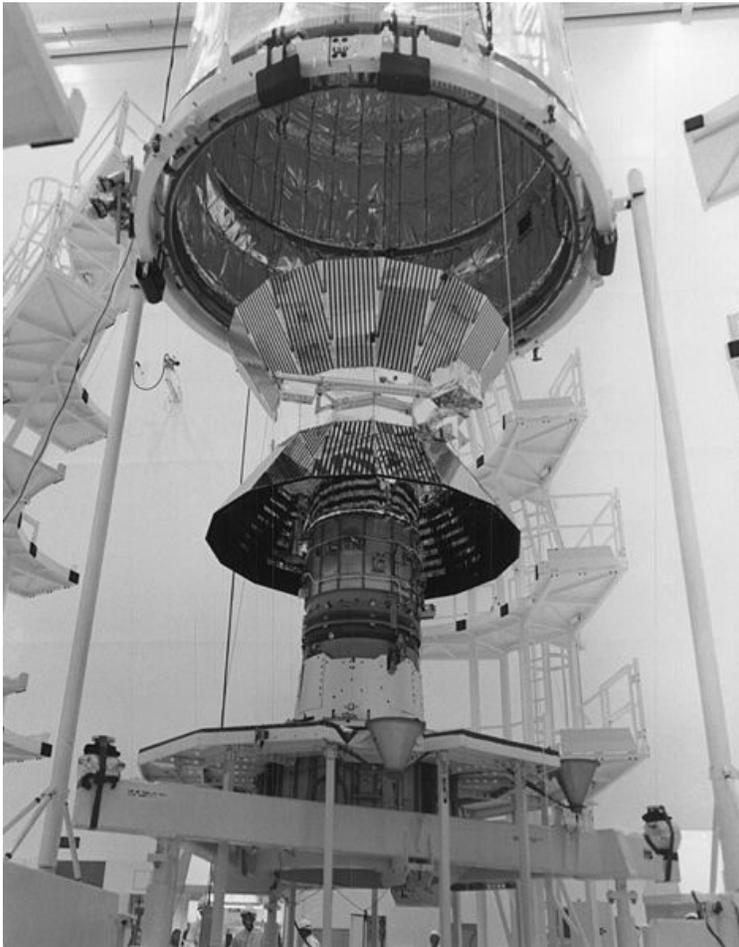
Analysis of the radio tracking data from the Pioneer 10 and 11 spacecraft at distances between 20–70 AU from the Sun has consistently indicated the presence of an anomalous, small Doppler frequency drift. The drift can be interpreted as being due to a constant acceleration of $(8.74 \pm 1.33) \times 10^{-10} \text{ m/s}^2$ directed towards the Sun. Although it is suspected that there is a systematic origin to the effect, none has been found. As a result, the nature of this anomaly has become of growing interest.

Chapter- 5

Space and Solar System Exploration in 1974

Helios (spacecraft)

Helios A / Helios B



Prototype of the Helios spacecraft

Operator

NASA / FRG

Major contractors	MBB
Mission type	Orbiters
Satellite of	Sun
Launch date	Helios-A: 1974-11-10 07:11:01 UTC (36 years, 2 months, and 4 days ago) Helios-B: 1976-01-15 05:34:00 UTC (34 years, 11 months, and 30 days ago)
Launch vehicle	Titan IIIE / Centaur
Launch site	Space Launch Complex 41 Cape Canaveral Air Force Station
Mission duration	Helios-A: January 16, 1975 to February 18, 1985 Helios-B: July 21, 1976 to December 23, 1979
COSPAR ID	Helios-A: 1974-097A Helios-B: 1976-003A
Homepage	Helios-A: NASA Solarsystem Exploration page Helios-B: NASA Solarsystem Exploration page
Mass	370 kg (816 lb)
Power	(solar array)

Helios-A and *Helios-B* (also known as *Helios 1* and *Helios 2*), were a pair of probes launched into heliocentric orbit for the purpose of studying solar processes. A joint venture of the Federal Republic of Germany (West Germany) and NASA, the probes were launched from the John F. Kennedy Space Center at Cape Canaveral, Florida, on Dec. 10, 1974, and Jan. 15, 1976, respectively.

The probes are notable for having set a maximum speed record among spacecraft at 252,792 km/h (157,078 mi/h or 43.63 mi/s or 70.22 km/s or 0.000234c). Helios 2 flew three million kilometers closer to the Sun than Helios 1, achieving perihelion on 17 April 1976 at a record distance of 0.29 AU (or 43.432 million kilometers), slightly inside the

orbit of Mercury. Helios 2 was sent into orbit 13 months after the launch of Helios 1. The Helios space probes completed their primary missions by the early 1980s, but they continued to send data up to 1985. The probes are no longer functional but still remain in their elliptical orbit around the Sun.

Mission background

Scientific instruments

Instrument Name	Description
Plasma Experiment Investigation	Measures the velocity and distribution of the solar wind plasma.
Flux-gate Magnetometer	Measures the field strength and direction of low frequency magnetic fields in the Sun's environment.
Search Coil Magnetometer	Compliments the Flux-Gate Magnetometer by measuring the magnetic fields between 0 and 3 kHz.
Plasma Wave Investigation	
Cosmic Radiation Investigation	Measures protons, electrons and x-rays to determine the distribution of cosmic rays.
Low-Energy Electron and Ion Spectrometer	Investigates the higher energy portion of the crossover region between the solar wind particles and the cosmic rays.
Zodiacal Light Photometer	Measures the scattering of sunlight by interplanetary dust particles.
Micrometeoroid Analyser	Investigates the composition, charge, mass, velocity and direction of interplanetary dust particles.

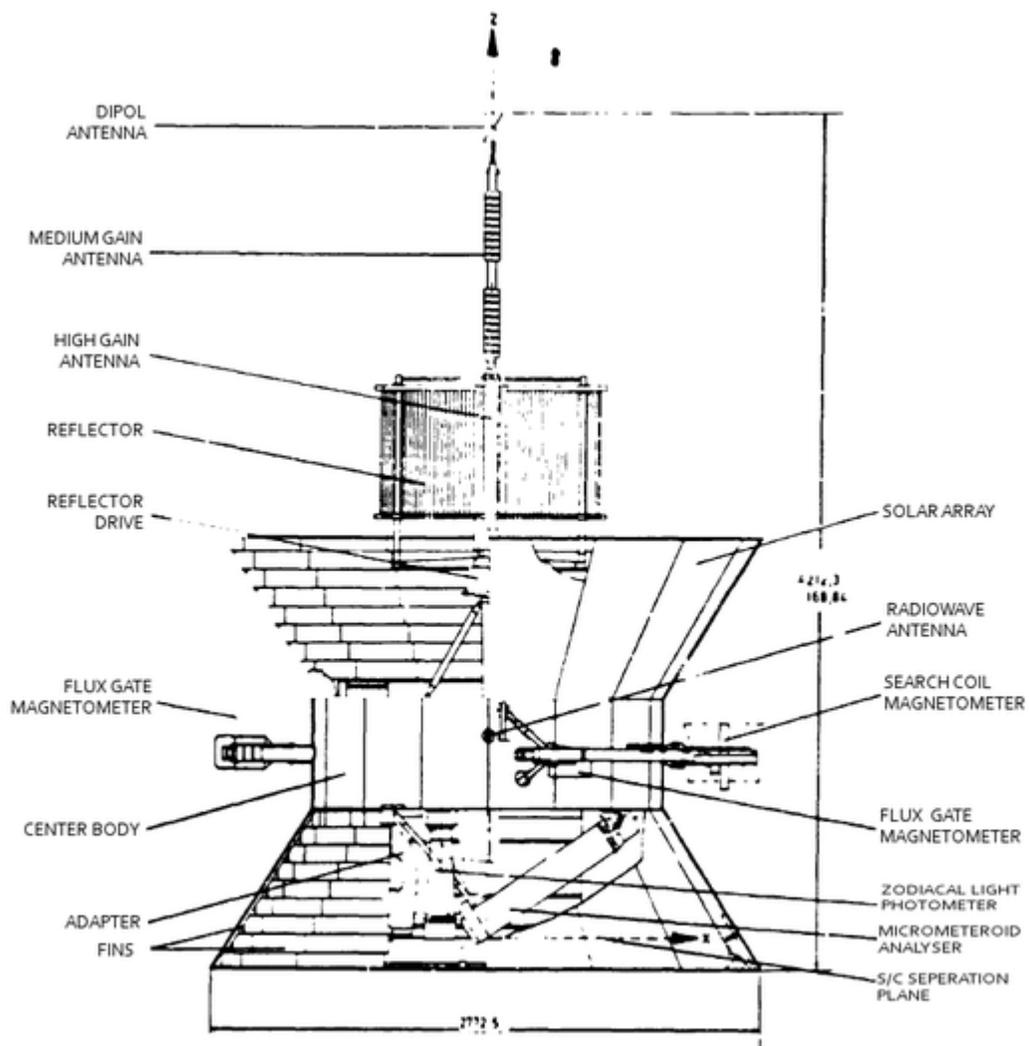
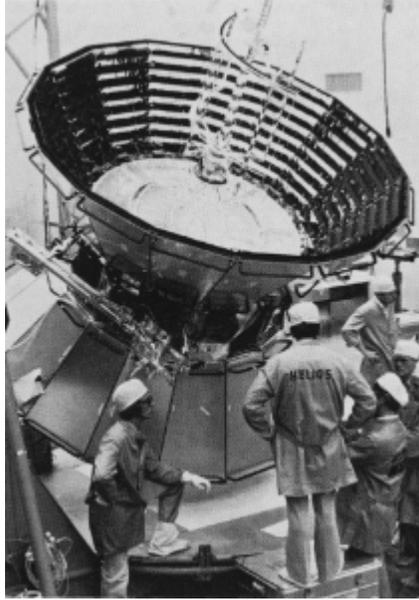


Figure 1 Spacecraft Launch Configuration

Launch configuration diagram



A technician stands next to one of the twin Helios spacecraft



Inspection of *Helios-B*



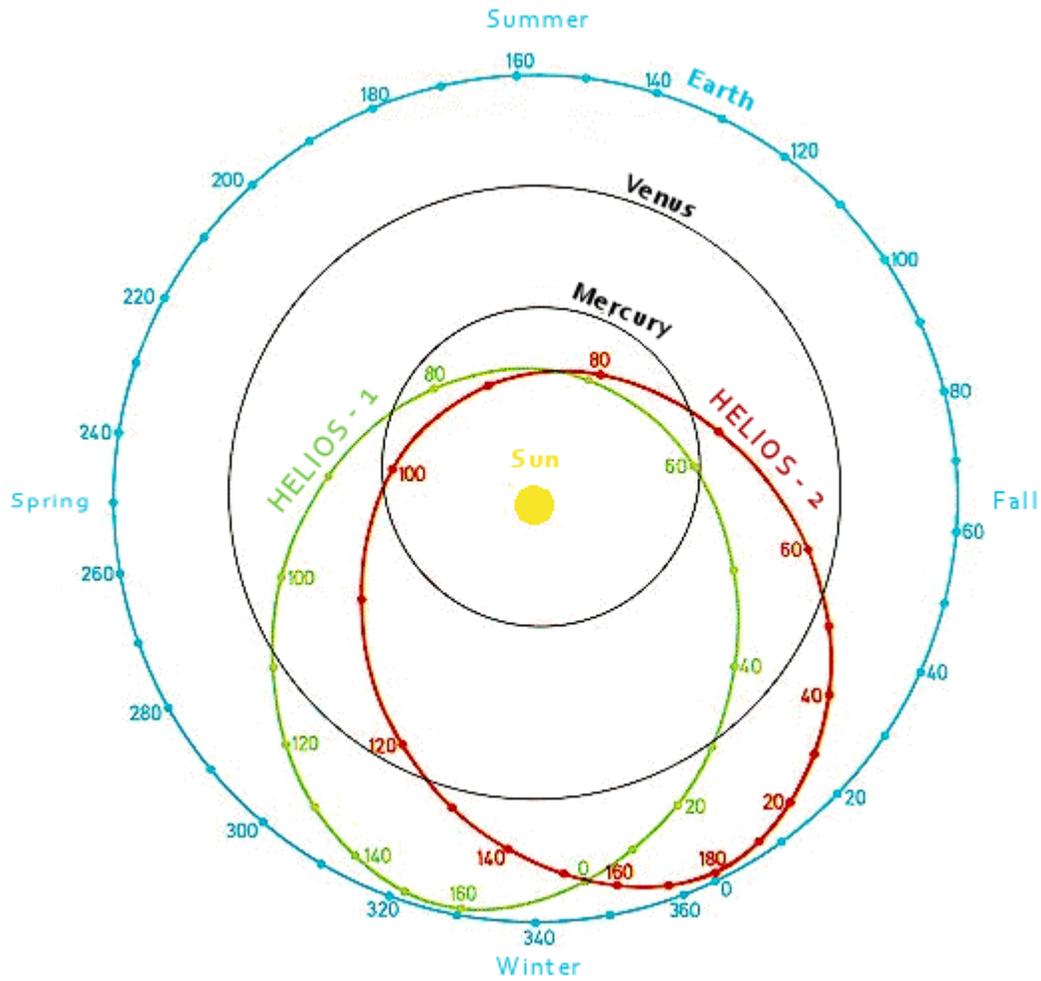
A Helios probe being encapsulated for launch

Mission profile



Helios-A sitting atop the Titan III-C / Centaur launch vehicle

Launch and trajectory



Trajectory of the Helio space probes

Timeline of travel

Date	Event
1974-11-10	Launch of <i>Helios-A</i>
1976-01-15	Launch of <i>Helios-B</i>
1976-04-17	Closest flyby of the Sun of any spacecraft performed by <i>Helios II</i> .

Luna 23

Luna 23	
Organization:	Soviet Union
Major Contractors:	GSMZ Lavochkin
Mission Type:	Planetary Science Lunar Sample Return
Satellite of:	Moon
Launch:	October 28, 1974 at 14:30:32 UTC
Launch Vehicle:	Proton 8K82K + Blok D
Mission Highlight:	Landed on moon November 6, 1974 at ~12°N 62°E / 12°N 62°E Failed to return sample.
Mission Duration:	12-days November 9, 1974
Mass:	5,800 kg
NSSDC ID:	1974-084A
Webpage:	NASA NSSDC Master Catalog
Orbital elements	
Semimajor Axis:	6,476.8 km
Eccentricity:	?
Inclination:	138°
Orbital Period:	~119 minutes
Apogee:	104 km
Perigee:	94 km
Orbits:	~48
Entered Lunar orbit:	November 2, 1974
Lunar Landing:	November 6, 1974
Landing coordinates:	~12° N - ~62° E.
Instruments	
Stereo imaging system:	Lunar photography

Improved drill/arm sample collector:	collect lunar material
Radiation detector:	Lunar radiation environment

Luna 23 (Ye-8-5M series) was an unmanned space mission of the Luna program, also called Lunnik 23. Luna 23 was a Moon lander mission which was intended to return a lunar sample to Earth. Launched to the Moon by a Proton SL-12/D-1-e booster, the spacecraft was damaged during landing in Mare Crisium (Sea of Crises). The sample collecting apparatus could not operate and no samples were returned. The lander continued transmissions for 3 days after landing. In 1976, Luna 24 landed several hundred meters away and successfully returned samples.

Luna 23 was the first modified lunar sample return spacecraft, designed to return a deep core sample of the Moon's surface (hence the change in index from Ye-8-5 to Ye-8-5M). While Luna 16 and 20 had returned samples from a depth of 0.3 meters, the new spacecraft was designed to dig to 2.5 meters. After a midcourse correction on 31 October, Luna 23 entered orbit around the Moon on 2 November 1974. Parameters were 104 x 94 kilometers at 138° inclination. Following several more changes to the orbit, the spacecraft descended to the lunar surface on 6 November and landed in the southernmost portion of Mare Crisium. Landing coordinates were 13° north latitude and 62° east longitude. During landing in "unfavorable" terrain, the lander's drilling device was evidently damaged, preventing fulfillment of the primary mission, the return of lunar soil to Earth. Scientists devised a makeshift plan to conduct a limited science exploration program with the stationary lander. Controllers maintained contact with the spacecraft until 9 November 1974.

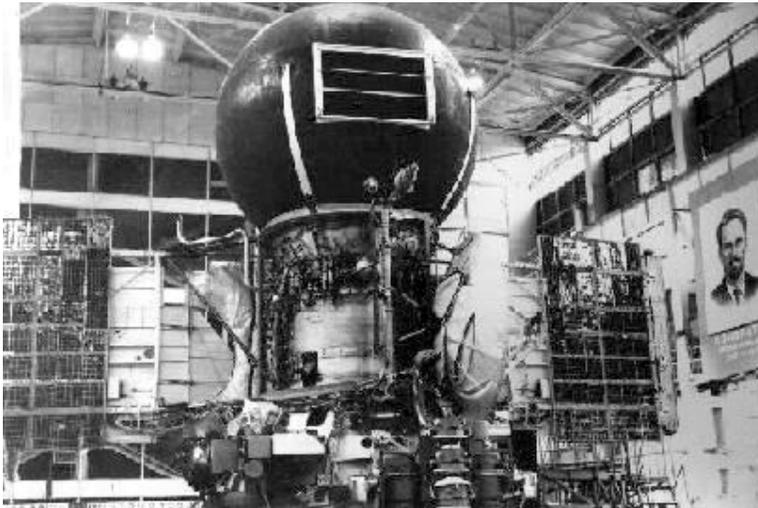
- Launch Date/Time: 1974-10-28 at 14:30:32 UTC
- On-orbit dry mass: 5600 kg

Chapter- 6

Space and Solar System Exploration in 1975

Venera 9

Venera 9 (4V-1 No. 660)



Venera 9 orbiter

Operator	USSR
Mission type	Orbiter and Lander
Satellite of	Venus
Orbital insertion date	October 20, 1975
Launch date	June 8, 1975 from Baikonur Cosmodrome Site 81
Launch vehicle	Proton Booster Plus Upper Stage and Escape Stages

Mission duration June 8, 1975 to ~December 25, 1975?

COSPAR ID 1975-050D

Mass 2015 kg

Orbital elements

Eccentricity .89002

Inclination 29.5°

Apoapsis 19.51 RV

Periapsis 1.26 RV

Orbital period 48.3 h

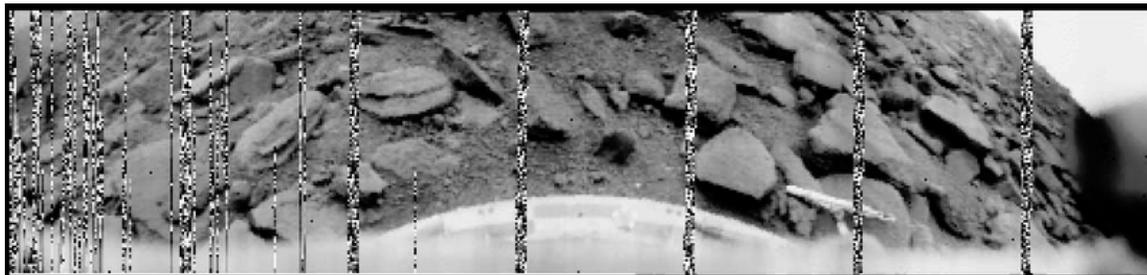
Venera 9 (Russian: Венера-9) (manufacturer's designation: 4V-1 No. 660) was a USSR unmanned space mission to Venus. It consisted of an orbiter and a lander. It was launched on June 8, 1975 02:38:00 UTC and weighed 4,936 kg (10,884 lb). The orbiter was the first spacecraft to orbit Venus, while the lander was the first to return images from the surface of another planet.

Orbiter

The orbiter consisted of a cylinder with two solar panel wings and a high gain parabolic antenna attached to the curved surface. A bell-shaped unit holding propulsion systems was attached to the bottom of the cylinder, and mounted on top was a 2.4 meter sphere which held the lander.

The orbiter entered Venus orbit on October 20, 1975. Its mission was to act as a communications relay for the lander and to explore cloud layers and atmospheric parameters with several instruments and experiments. It performed 17 survey missions from October 26, 1975 to December 25, 1975.

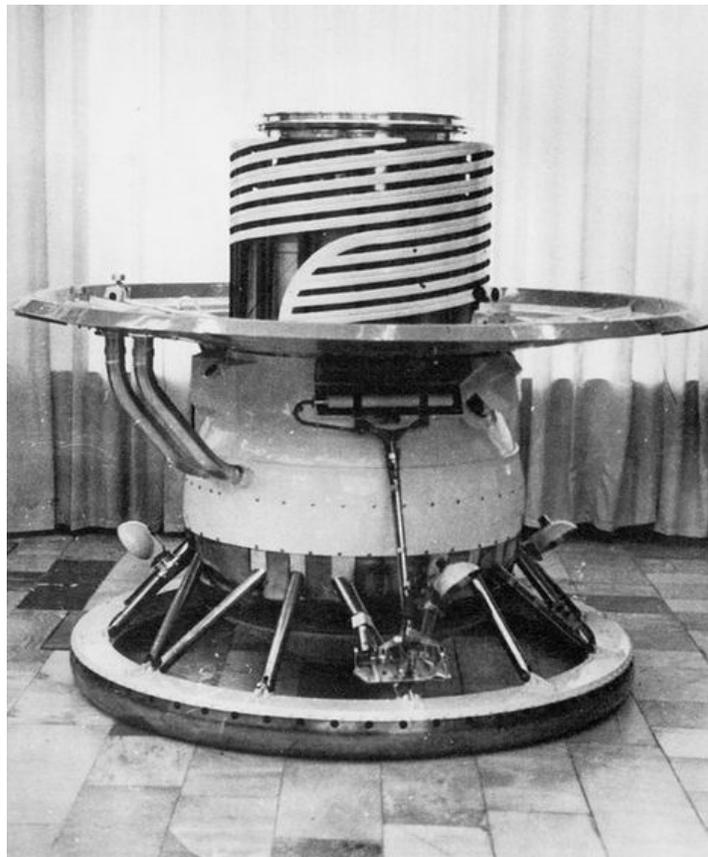
List of orbiter instruments and experiments



180-degree panorama taken by Venera 9 of the surface of Venus

- 1.6-2.8 μm IR Spectrometer
- 8-28 μm IR Radiometer
- 352 nm UV Photometer
- 2 Photo-polarimeters (335-800 nm)
- 300-800 nm Spectrometer
- Lyman- α H/D Spectrometer
- Bistatic Radar Mapping
- CM, DM Radio Occultations
- Triaxial Magnetometer
- 345-380 nm UV Camera
- 355-445 nm Camera
- 6 Electrostatic Analyzers
- 2 Modulation Ion Traps
- Low-Energy Proton / Alpha detector
- Low-Energy Electron detector
- 3 Semiconductor Counters
- 2 Gas-Discharge Counters
- Cherenkov Detector

Lander



Venera 9 lander

On October 20, 1975, the lander spacecraft was separated from the orbiter, and landing was made with the Sun near zenith at 05:13 UTC on October 22. Venera 9 landed within a 150 km radius of 31°01'N 291°38'E / 31.01°N 291.64°E, near Beta Regio, on a steep (20°) slope covered with boulders (suspected to be the slope of the tectonic rift valley, Aikhulu Chasma). The entry sphere weighed 1,560 kg (3,440 lb) and the surface payload 660 kg (1,455 lb).

It was the first spacecraft to return an image from the surface of another planet. The Soviet space program had far more success with Venus landers than Mars landers, possibly because the mechanics of landing on Venus involve fewer steps than Mars due to the much thicker atmosphere.

A system of circulating fluid was used to distribute the heat load. This system, plus pre-cooling prior to entry, permitted operation of the spacecraft for 53 minutes after landing, at which time radio contact with the orbiter was lost. During descent, heat dissipation and deceleration were accomplished sequentially by protective hemispheric shells, three parachutes, a disc-shaped drag brake, and a compressible, metal, doughnut-shaped landing cushion. The landing was about 2,200 km from the Venera 10 landing site.

Venera 9 measured clouds that were 30–40 km thick with bases at 30–35 km altitude. It also measured atmospheric chemicals including hydrochloric acid, hydrofluoric acid, bromine, and iodine. Other measurements included surface pressure of about 90 atmospheres (9 MPa), temperature of 485 °C, and surface light levels comparable to those at Earth mid-latitudes on a cloudy summer day. Venera 9 was the first probe to send back black and white television pictures from the Venusian surface showing shadows, no apparent dust in the air, and a variety of 30 to 40 cm rocks which were not eroded. Planned 360-degree panoramic pictures could not be taken because one of two camera lens covers failed to come off, limiting pictures to 180 degrees. This failure recurred with Venera 10.

Lander Payload

- Temperature and pressure sensors
- Accelerometer
- Visible / IR photometer - IOV-75
- Backscatter and multi-angle nephelometers - MNV-75
- P-11 Mass spectrometer - MAV-75
- Panoramic telephotometers (2, with lamps)
- Anemometer - ISV-75
- Gamma ray spectrometer - GS-12V
- Gamma ray densitometer - RP-75
- Radio Doppler experiment

Image processing

Don P. Mitchell recently came across the original Venera imaging data while researching the Soviet Venus program, and reconstructed the images using modern image processing software.

Venera 10

Venera 10



Venera 10 orbiter

Operator	USSR
Mission type	Orbiter and Lander
Satellite of	Venus
Orbital insertion	October 23, 1975

date**Launch date** May 14, 1975**Launch vehicle** Proton Booster Plus Upper Stage and
Escape Stages**COSPAR ID** 1975-054D**Mass** 2300 kg**Orbital elements****Eccentricity** .8798**Inclination** 29.5°**Apoapsis** 19.82 RV**Periapsis** 1.27 RV**Orbital period** 49.4 h

Venera 10 (Russian: Венера-10) was a USSR unmanned space mission to Venus. It consisted of an orbiter and a lander. It launched on June 14, 1975 03:00:31 UTC.

Orbiter

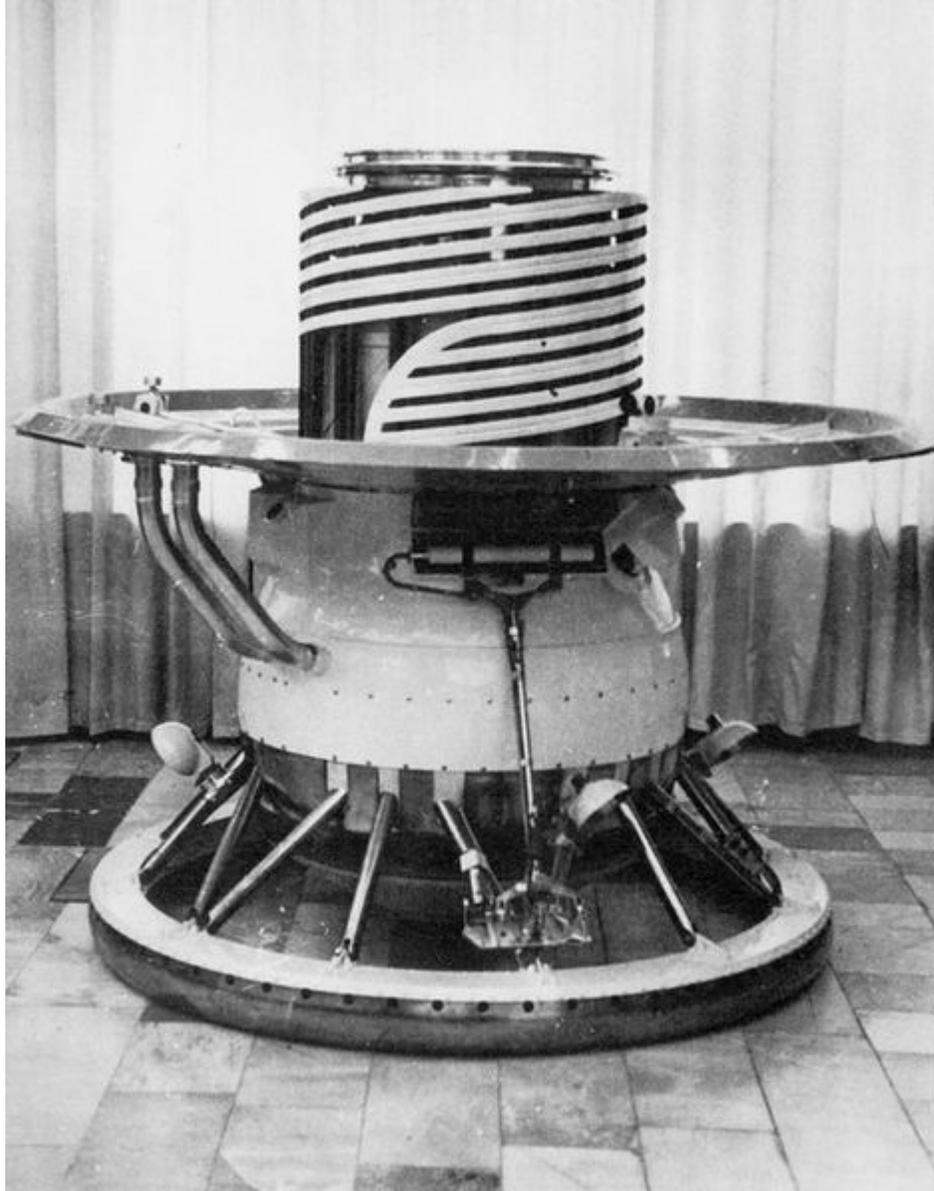
The orbiter entered Venus orbit on October 23, 1975. Its mission was to serve as a communications relay for the lander and to explore cloud layers and atmospheric parameters with several instruments and experiments:

- 1.6-2.8 μm IR Spectrometer
- 8-28 μm IR Radiometer
- 352 nm UV Photometer
- 2 Photopolarimeters (335-800 nm)
- 300-800 nm Spectrometer
- Lyman- α H/D Spectrometer
- Bistatic Radar Mapping
- CM, DM Radio Occultations
- Triaxial Magnetometer
- 345-380 nm UV Camera
- 355-445 nm Camera
- 6 Electrostatic Analyzers
- 2 Modulation Ion Traps
- Low-Energy Proton / Alpha detector
- Low-Energy Electron detector
- 3 Semiconductor Counters

- 2 Gas-Discharge Counters
- Cherenkov Detector

The orbiter consisted of a cylinder with two solar panel wings and a high gain parabolic antenna attached to the curved surface. A bell-shaped unit holding propulsion systems was attached to the bottom of the cylinder, and mounted on top was a 2.4 meter sphere which held the landers.

Lander



Venera 10 lander

On October 23, 1975, this spacecraft was separated from the Orbiter, and landing was made with the sun near zenith, at 0517 UT, on October 25.

A system of circulating fluid was used to distribute the heat load. This system, plus precooling prior to entry, permitted operation of the spacecraft for 65 min after landing. During descent, heat dissipation and deceleration were accomplished sequentially by protective hemispheric shells, three parachutes, a disk-shaped drag brake, and a compressible, metal, doughnut-shaped, landing cushion.



Landing area of Venera 10 as mapped by the Magellan orbiter

It landed 2200 km from Venera 9 (within a 150 km radius of $15^{\circ}25'N$ $291^{\circ}31'E$ / $15.42^{\circ}N$ $291.51^{\circ}E$), three days after its touchdown. Venera 10 measured a surface windspeed of 3.5 m/s. Other measurements included atmospheric pressure at various heights, and

temperature, and surface light levels. Venera 10 was the second probe to send back black and white television pictures from the Venusian surface (after Venera 9). Venera 10 photographs showed lava rocks of pancake shape with lava or other weathered rocks in between. Planned 360 degree panoramic pictures could not be taken because, as with Venera 9, one of two camera lens covers failed to come off, limiting pictures to 180 degrees.

Lander Payload:

- Temperature and pressure sensors
- Accelerometer
- Visible / IR photometer - IOV-75
- Backscatter and multi-angle nephelometers - MNV-75
- P-11 Mass spectrometer - MAV-75
- Panoramic telephotometers (2, with lamps)
- Anemometer - ISV-75
- Gamma ray spectrometer - GS-12V
- Gamma ray densitometer - RP-75
- Radio Doppler experiment

Image processing

Researcher Don P. Mitchell recently rediscovered the original Venera imaging data. Using modern software he has been able to reproduce images with far greater clarity than the versions previously available.

Chapter- 7

Space and Solar System Exploration in 1977

Voyager 2

Voyager 2



Voyager spacecraft

Operator	NASA / JPL
Mission type	Flyby
Flyby of	Jupiter, Saturn, Uranus, Neptune
Launch date	1977-08-20 14:29:00 UTC (33 years, 4 months, and 26 days ago)
Launch vehicle	Titan IIIE / Centaur
Launch site	Space Launch Complex 41

Cape Canaveral Air Force Station

In Progress (Interstellar mission)

(31 years, 6 months, and 6 days elapsed)

Jupiter flyby

(completed 1979-08-05)

Saturn flyby

(completed 1981-09-25)

Uranus flyby

(completed 1986-02-25)

Neptune flyby

(completed 1989-10-02)

Mission duration

COSPAR ID

1977-076A

Homepage

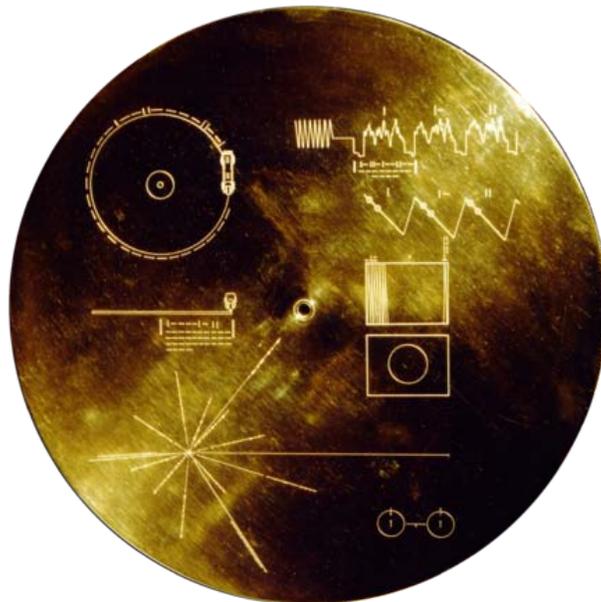
NASA *Voyager* website

Mass

721.9 kg (1,592 lb)

Power

420 W (3 RTGs)



The *Voyager 2* spacecraft is a 722-kilogram (1,592 lb) robotic space probe launched by NASA on August 20, 1977 to study the outer Solar System and eventually interstellar space. Operating for 33 years, 4 months, and 26 days, the spacecraft receives routine commands and transmits data back to the Deep Space Network. Currently in extended mission, the spacecraft is tasked with locating and studying the boundaries of the Solar System, including the Kuiper belt, the heliosphere and interstellar space. The primary mission ended December 31, 1989 after encountering the Jovian system in 1979, Saturnian system in 1980, Uranian system in 1986, and the Neptunian system in 1989. It was the first probe to provide detailed images of the outer ice giants.

Mission background

History

Conceived in the 1960s, a Grand Tour proposal to study the outer planets, prompted NASA to begin work on a mission in the early 1970s. The development of the interplanetary probes coincided with an alignment of the planets, making possible a mission to the outer Solar System by taking advantage of the then-new technique of gravity assist.

It was determined that utilizing gravity assists would enable a single probe to visit the four gas giants (Jupiter, Saturn, Uranus, and Neptune) while requiring a minimal amount of propellant and a shorter transit duration between planets. Originally, *Voyager 2* was planned as *Mariner 12* of the Mariner program however, due to congressional budget cuts, the mission was scaled back to be a flyby of Jupiter and Saturn, and renamed the Mariner Jupiter-Saturn probes. As the program progressed, the name was later changed to Voyager as the probe designs began to differ greatly from previous Mariner missions.

Upon a successful flyby of the Saturnian moon Titan, by Voyager 1, *Voyager 2* would get a mission extension to send the probe on towards Uranus and Neptune.

Spacecraft design

Constructed by the Jet Propulsion Laboratory, *Voyager 2* included 16 hydrazine thrusters, three-axis stabilization, gyroscopes and celestial referencing instruments (sun sensor/Canopus Star Tracker) to maintain pointing of the high-gain antenna toward Earth. Collectively these instruments are part of the Attitude and Articulation Control Subsystem (AACS) along with redundant units of most instruments and 8 backup thrusters. The spacecraft also included 11 scientific instruments to study celestial objects as it traveled through space.

Communications

Built with the intent for eventual interstellar travel, *Voyager 2* included a large, 3.7-meter parabolic, high-gain antenna to transceive data with the Deep Space Network on Earth. Communications are conducted over the S-band (13 cm wavelength) and X-band (3.6 cm

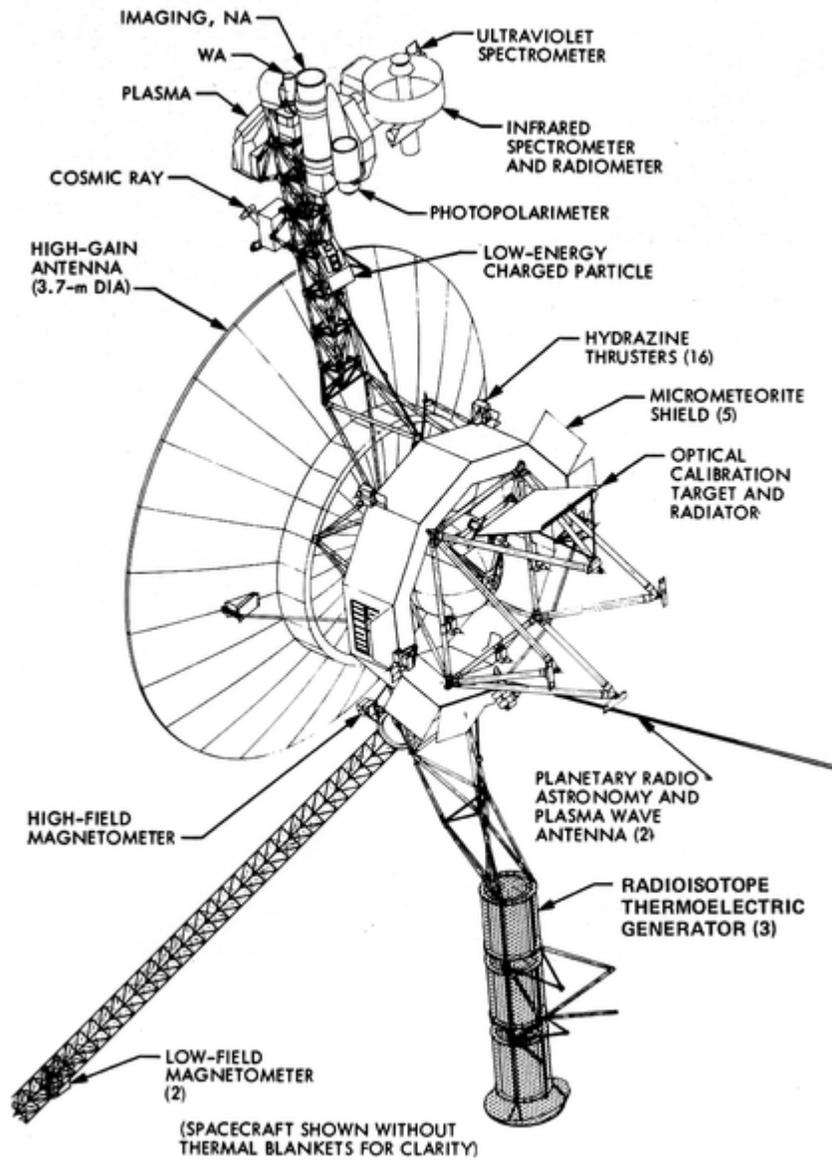
wavelength) providing bandwidth as high as 115.2 kilobits per second. When the spacecraft is unable to communicate with Earth, the Digital Tape Recorder (**DTR**) is able to record up to 62,500-kilobytes of data to later transmit when communication is reestablished.

Power

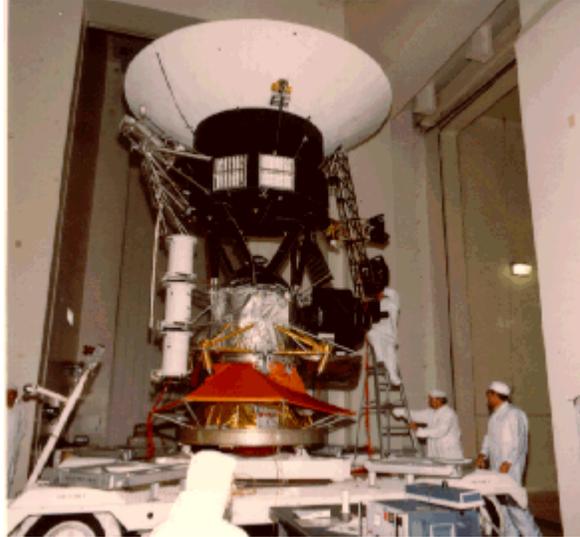
The spacecraft was built with 3 Multihundred-Watt radioisotope thermoelectric generators (**MHW RTG**). Each RTG includes 24 pressed plutonium oxide spheres and provide enough heat to generate approximately 157 Watts of power at launch. Collectively, the RTGs supply the spacecraft with 470 Watts at launch and will allow operations to continue until at least 2020.

Golden record

Each *Voyager* space probe carries a gold-plated audio-visual disc in the event that either spacecraft is ever found by intelligent life-forms from other planetary systems. The discs carry photos of the Earth and its lifeforms, a range of scientific information, spoken greetings from the people (e.g. the Secretary-General of the United Nations and the President of the United States, and the children of the Planet Earth) and a medley, "Sounds of Earth", that includes the sounds of whales, a baby crying, waves breaking on a shore, and a variety of music.



Voyager spacecraft structure



Voyager in transport to a solar thermal test chamber



Gold-Plated Record is attached to *Voyager*



Voyager 2 awaiting payload entry into a Titan/Centaur-6 rocket

Mission profile



Voyager 2 launch on August 20, 1977 with a Titan IIIE/Centaur

Launch and trajectory

The *Voyager 2* probe was launched on August 20, 1977, by the National Aeronautics and Space Administration from Space Launch Complex 41 at Cape Canaveral, Florida, aboard a Titan IIIE/Centaur launch vehicle. Two weeks later, the twin *Voyager 1* probe would be launched on September 5, 1977. However, *Voyager 1* would reach both Jupiter and Saturn sooner, as *Voyager 2* had been launched into a longer, more circular trajectory.

Encounter with Uranus

The closest approach to Uranus occurred on January 24, 1986, when *Voyager 2* came within 81,500 kilometers (50,600 miles) of the planet's cloud tops. *Voyager 2* also discovered 10 previously unknown moons of Uranus; studied the planet's unique atmosphere, caused by its axial tilt of 97.8°; and examined the Uranian ring system.

Uranus is apparently the third largest (Neptune has a larger mass, but a smaller volume) planet in the Solar System. It orbits the Sun at a distance of about 2.8 billion kilometers (1.7 billion miles), and it completes one orbit every 84 years. The length of a day on Uranus as measured by *Voyager 2* is 17 hours, 14 minutes. Uranus is unique among the planets in that its axial tilt is about 90°, meaning that its axis is roughly parallel, not perpendicular to the plane of the ecliptic. This extremely large tilt of its axis is thought to be the result of a collision between the accumulating planet Uranus with another planet-sized body early in the history of the Solar System. Given the unusual orientation of its axis, with the polar regions of Uranus exposed for periods of many years to either continuous sunlight or darkness, planetary scientists were not at all sure what to expect when observing Uranus.

Voyager 2 found that one of the most striking effects of the sideways orientation of Uranus is the effect on the tail of the planetary magnetic field. This is itself tilted about 60 degrees from the Uranian axis of rotation. The planet's magneto tail was shown to be twisted by the rotation of Uranus into a long corkscrew shape following the planet. The presence of a significant magnetic field for Uranus was not at all known until *Voyager's 2* arrival.

The radiation belts of Uranus were found to be of an intensity similar to those of Saturn. The intensity of radiation within the Uranian belts is such that irradiation would "quickly" darken—within 100,000 years—any methane that is trapped in the icy surfaces of the inner moons and ring particles. This kind of darkening might have contributed to the darkened surfaces of the moons and the ring particles, which are almost uniformly dark gray in color.

A high layer of haze was detected around the sunlit pole of Uranus. This area was also found to radiate large amounts of ultraviolet light, a phenomenon that is called "dayglow." The average atmospheric temperature is about 60 K (−350 degrees Fahrenheit/−213 degrees Celsius). Surprisingly, the illuminated and dark poles, and most of the planet, exhibit nearly the same temperatures at the cloud tops.

The Uranian moon Miranda, the innermost of the five large moons, was discovered to be one of the strangest bodies yet seen in the Solar System. Detailed images from *Voyager 2's* flyby of Miranda showed huge canyons made from geological faults as deep as 20 kilometers (12 miles), terraced layers, and a mixture of old and young surfaces. One hypothesis suggests that Miranda might consist of a reaggregation of material following an earlier event when Miranda was shattered into pieces by a violent impact.

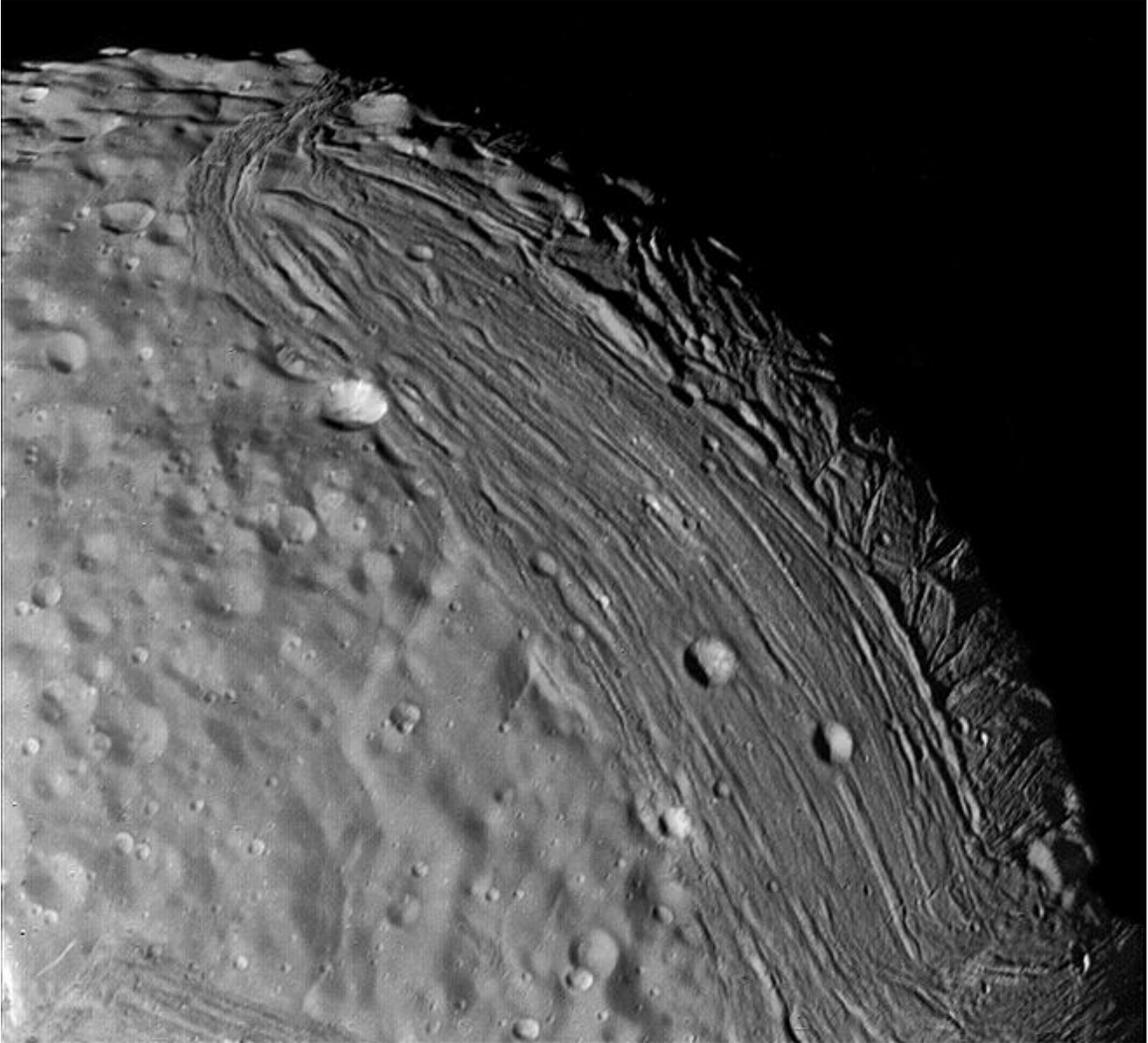
All nine of the previously known Uranian rings were studied by the instruments of *Voyager 2*. These measurements showed that the Uranian rings are distinctly different from those at Jupiter and Saturn. The Uranian ring system might be relatively young, and it did not form at the same time that Uranus did. The particles that make up the rings might be the remnants of a moon that was broken up by either a high-velocity impact or torn up by tidal effects.



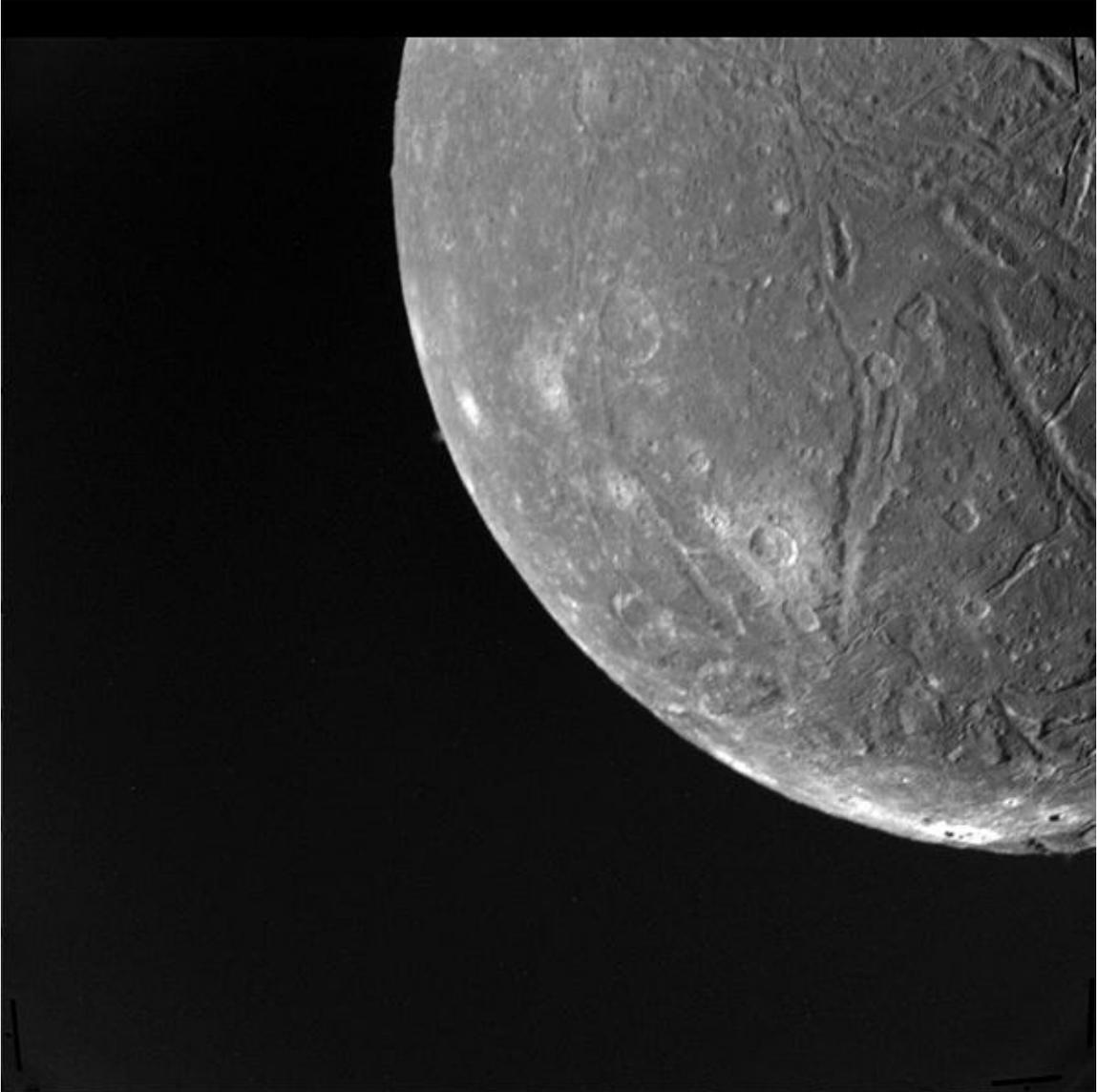
Uranus viewed from 18 million kilometers



Departing image of crescent Uranus



Fractured surface of Miranda



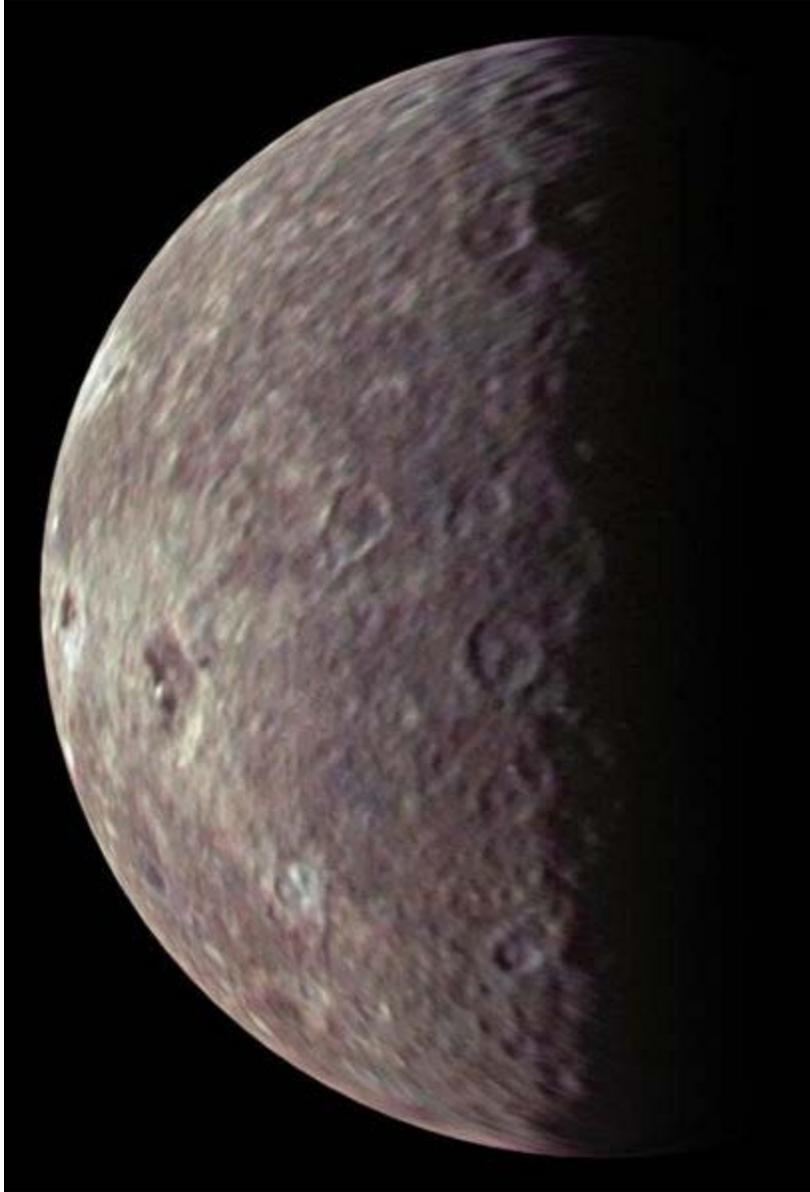
Ariel as imaged from 130,000 km



Color composite of Titania from 500,000 km



Umbriel (moon) imaged from 550,000 km



Color composite of Oberon



Voyager 2 photo of the Rings of Uranus

Encounter with Neptune

Voyager 2's closest approach to Neptune occurred on August 25, 1989. Since this was the last planet of our Solar System that *Voyager 2* could visit, the Chief Project Scientist, his staff members, and the flight controllers decided to also perform a close fly-by of Triton, the larger of Neptune's two originally known moons, so as to gather as much information on Neptune and Triton as possible, regardless of what angle at which *Voyager 2* would fly away from Neptune. This was just like the case of *Voyager 1's* encounters with Saturn and its massive moon Titan.

Through repeated computerized test simulations of trajectories through the Neptunian system conducted in advance, flight controllers determined the best way to route *Voyager 2* through the Neptune-Triton system. Since the plane of the orbit of Triton is tilted significantly with respect to the plane of the ecliptic, through mid-course corrections, *Voyager 2* was directed into a path several thousand miles over the north pole of

Neptune. At that time, Triton was behind and below (south of) Neptune (at an angle of about 25 degrees below the Ecliptic), close to the apoapsis of its elliptical orbit. The gravitational pull of Neptune bent the trajectory of *Voyager 2* down in the direction of Triton. In less than 24 hours, *Voyager 2* traversed the distance between Neptune and Triton, and then it observed the northern hemisphere of Triton as *Voyager 2* passed over the north pole of Triton.

The net and final effect on the trajectory of *Voyager 2* was to bend its trajectory south below the plane of the Ecliptic by about 30 degrees. *Voyager 2* is on this path permanently, and hence, it is exploring space south of the plane of the Ecliptic, measuring magnetic fields, charged particles, etc., there, and sending the measurements back to the Earth via telemetry.

While in the neighborhood of Neptune, *Voyager 2* discovered the "Great Dark Spot", which has since disappeared, according to observations by the Hubble Space Telescope. Originally thought to be a large cloud itself, the "Great Dark Spot" was later hypothesized to be a hole in the visible cloud deck of Neptune.

Neptune's atmosphere consists of hydrogen, helium, and methane. The methane in Neptune's upper atmosphere absorbs the red light from the Sun, but it reflects the blue light from the sun back into space. This is why Neptune looks blue.

For decades, beginning in the late 19th century, it was widely thought that an unseen planet (dubbed "Planet X") was influencing the orbits of Uranus and Neptune, by perturbing them, since their observed positions differed somewhat from the positions predicted by calculations. This notion might have brought about the 1930 discovery of Pluto, but the actual discovery of Pluto by Clyde Tombaugh in 1930 was an accidental one that occurred while a few astronomers were scanning areas of the sky for "Planet X".

The notion of a "Planet X" has persisted, because over the decades since 1930, it became increasingly clear that Pluto has insufficient mass to account for the observational discrepancies. When *Voyager 2* flew-by Neptune, it took very precise measurements of Neptune's mass. Neptune was evaluated at about 0.5 percent less massive than previous estimates — a difference comparable to a planet with the mass of Mars. When the orbits of Uranus and Neptune orbits were recalculated using the more accurate mass figure, it was found that the imprecise number for Neptune — and not the gravity of an unseen planet — caused the orbital discrepancies that had long perplexed planetary astronomers.

With the decision of the International Astronomical Union to reclassify Pluto as a "plutoid" in 2008, the flyby of Neptune by *Voyager 2* in 1989 became the point when every known planet in the Solar System had been visited at least once by a space probe.

Chapter- 8

Space and Solar System Exploration in 1978

Pioneer Venus project

Pioneer Venus Orbiter



Pioneer Venus Orbiter

Operator	Ames Research Center - NASA
Mission type	Orbiter
Satellite of	Venus
Orbital insertion date	December 4, 1978
Launch date	May 20, 1978
Launch vehicle	Atlas-Centaur
Mission duration	May 20, 1978 to August, 1992

Orbital decay	August, 1992
COSPAR ID	1978-051A
Homepage	National Space Science Data Center (NASA)
Mass	517 kg
Power	312 W

Orbital elements

Eccentricity	.842
Inclination	105°
Apoapsis	1.03 RV
Periapsis	12.01 RV
Orbital period	24 h

The **Pioneer mission** to Venus consisted of two components, launched separately. Pioneer Venus 1 or *Pioneer Venus Orbiter* was launched in 1978 and studied the planet for more than a decade after orbital insertion in 1978. Pioneer Venus 2 or *Pioneer Venus Multiprobe* sent four small probes into the Venusian atmosphere. This was managed by NASA Ames Research Center as part of the Pioneer series of spacecraft that included Pioneer 10 and Pioneer 11.

Pioneer Venus Orbiter

- Launch date: May 20, 1978
- Launch vehicle: Atlas-Centaur
- On-orbit mass: 517 kg
- Power system: solar array of 312 W

The Pioneer Venus Orbiter was inserted into an elliptical orbit around Venus on December 4, 1978. The Orbiter was a flat cylinder 2.5 m in diameter and 1.2 m high. All instruments and spacecraft subsystems were mounted on the forward end of the cylinder, except the magnetometer, which was at the end of a 4.7 m boom. A solar array extended around the circumference of the cylinder. A 1.09 m despun dish antenna provided S and X band communication with Earth. It was manufactured by Hughes Aircraft Company.

The Pioneer Venus Orbiter carried 17 experiments (with a total mass of 45 kg):

- a **cloud photo-polarimeter (OCP)** to measure the vertical distribution of the clouds, similar to Pioneer 10 and Pioneer 11 imaging photo-polarimeter (IPP)

- a **surface radar mapper (ORAD)** to determine topography and surface characteristics. Observations could only be conducted when the probe was closer than 4700 km over the planet. A 20 Watt S-band signal (1.757 gigahertz) was sent to the surface that reflected it, with the probe analyzing the echo. Resolution at periapsis was 23 x 7 km.
- an **infrared radiometer (OIR)** to measure IR emissions from Venus' atmosphere
- an airglow **ultraviolet spectrometer (OUVS)** to measure scattered and emitted UV light
- a **neutral mass spectrometer (ONMS)** to determine the composition of the upper atmosphere
- a solar wind **plasma analyzer (OPA)** to measure properties of the solar wind
- a **magnetometer (OMAG)** to characterize the magnetic field at Venus
- an **electric field detector (OEFD)** to study the solar wind and its interactions
- an **electron temperature probe (OETP)** to study the thermal properties of the ionosphere
- an **ion mass spectrometer (OIMS)** to characterize the ionospheric ion population
- a **charged particle retarding potential analyzer (ORPA)** to study ionospheric particles
- two radio science experiments to determine the gravity field of Venus
- a radio occultation experiment to characterize the atmosphere
- an atmospheric drag experiment to study the upper atmosphere
- a radio science atmospheric and solar wind turbulence experiment
- a **gamma ray burst (OGBD)** detector to record gamma ray burst events

From Venus orbit insertion to July 1980, periapsis was held between 142 and 253 km (at 17 degrees north latitude) to facilitate radar and ionospheric measurements. The spacecraft was in a 24 hour orbit with an apoapsis of 66,900 km. Thereafter, the periapsis was allowed to rise (to 2290 km at maximum) and then fall, to conserve fuel. In 1991 the Radar Mapper was reactivated to investigate previously inaccessible southern portions of the planet, in conjunction with the recently-arrived Magellan probe. In May 1992 Pioneer Venus began the final phase of its mission, in which the periapsis was held between 150 and 250 km, until the fuel ran out and atmospheric entry destroyed the spacecraft the following August.

Pioneer Venus Multiprobe



Pioneer Venus Multiprobe



Pioneer Venus Large Probe

- Launch date: August 8, 1978
- Launch vehicle: Atlas-Centaur
- Mass: 290 kg (bus), 315 kg (large probe), 90 kg (each small probe)
- Power system: solar array of 241 W (bus); batteries (probes)

The Pioneer Venus Multiprobe consisted of a bus which carried one large and three small atmospheric probes. None of these atmospheric probes had photographic imaging capabilities and were not designed for soil analysis. They were not even designed for a soft landing; the large probe had a parachute that was designed to cut loose at a certain altitude, and the small probes had no parachute at all. Survival to the surface was

considered a bonus. All the entry probes survived the density of the Venusian atmosphere at least until impact, but only one probe survived for a significant period after impact.

The large probe was released on November 16, 1978 and the three small probes on November 20. All four probes entered the Venusian atmosphere on December 9, followed by the bus.

Pioneer Venus probes and bus: atmospheric entry and impacts (all times in UT)

	Large Probe	North Probe	Day Probe	Night Probe	Bus
Entry time (200 km)	18:45:32	18:49:40	18:52:18	18:56:13	20:21:52
Impact time	19:39:53	19:42:40	19:47:59	19:52:05	(signal lost at 110 km altitude)
Loss of signal	19:39:53	19:42:40	20:55:34	19:52:07	20:22:55
Impact coordinates	4°24'N 304°00'E / 4.4°N 304.0°E	59°18'N 4°48'E / 59.3°N 4.8°E	31°18'S 317°00'E / 31.3°S 317.0°E	28°42'S 56°42'E / 28.7°S 56.7°E	37°54'S 290°54'E / 37.9°S 290.9°E (estimated)
Solar Zenith Angle	65.7	108.0	79.9	150.7	60.7
Local Venus time	7:38	3:35	6:46	0:07	8:30

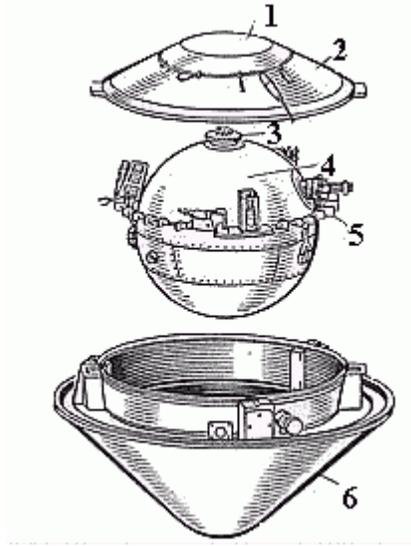
Bus

The **Pioneer Venus bus** portion of the spacecraft was targeted to enter the Venusian atmosphere at a shallow entry angle and transmit data until destruction by the heat of atmospheric friction. The objective was to study the structure and composition of the atmosphere down to the surface, the nature and composition of the clouds, the radiation field and energy exchange in the lower atmosphere, and local information on the atmospheric circulation pattern.

The bus was a 2.5 m diameter cylinder weighing 290 kg, and afforded us our only direct view of the upper Venus atmosphere, as the probes did not begin making direct measurements until they had decelerated lower in the atmosphere.

With no heat shield or parachute, the bus made upper atmospheric measurements with two instruments, an Ion Mass Spectrometer (BIMS) and a Neutral Mass Spectrometer (BNMS), down to an altitude of about 110 km before disintegrating on December 9, 1978.

Large probe



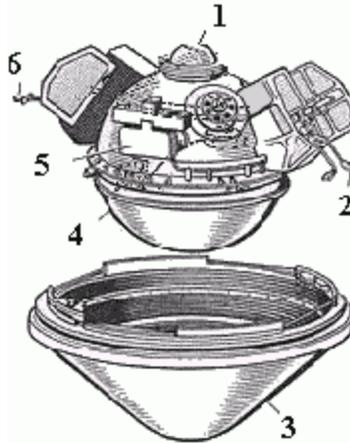
Large probe (1-radio-transparent window, 2-tail protection, 3-antenna, 4-hermetic container, 5-sensors, 6-frontal protection)

The **Pioneer Venus Large probe** was equipped with 7 science experiments, contained within a sealed spherical pressure vessel. The science experiments were:

- a neutral mass spectrometer to measure the atmospheric composition
- a gas chromatograph to measure the atmospheric composition
- a solar flux radiometer to measure solar flux penetration in the atmosphere
- an infrared radiometer to measure distribution of infrared radiation
- a cloud particle size spectrometer to measure particle size and shape
- a nephelometer to search for cloud particles
- temperature, pressure, and acceleration sensors

This pressure vessel was encased in a nose cone and aft protective cover. After deceleration from initial atmospheric entry at about 11.5 km/s near the equator on the Venus night side, a parachute was deployed at 47 km altitude. The large probe was about 1.5 m in diameter and the pressure vessel itself was 73.2 cm in diameter.

Small probes



Small probe. (1-antenna, 2-temperature sensor, 3-frontal protection, 4-hermetic container, 5-nephelometer, 6-radiometer)

The three small probes were identical to each other, 0.8 m in diameter. These probes also consisted of spherical pressure vessels surrounded by an aeroshell, but unlike the large probe, they had no parachutes and the aeroshells did not separate from the probe.

Each small probe carried a nephelometer and temperature, pressure, and acceleration sensors, as well as a net flux radiometer experiment to map the distribution of sources and sinks of radiative energy in the atmosphere. The radio signals from all four probes were also used to characterize the winds, turbulence, and propagation in the atmosphere.

The small probes were each targeted at different parts of the planet and were named accordingly.

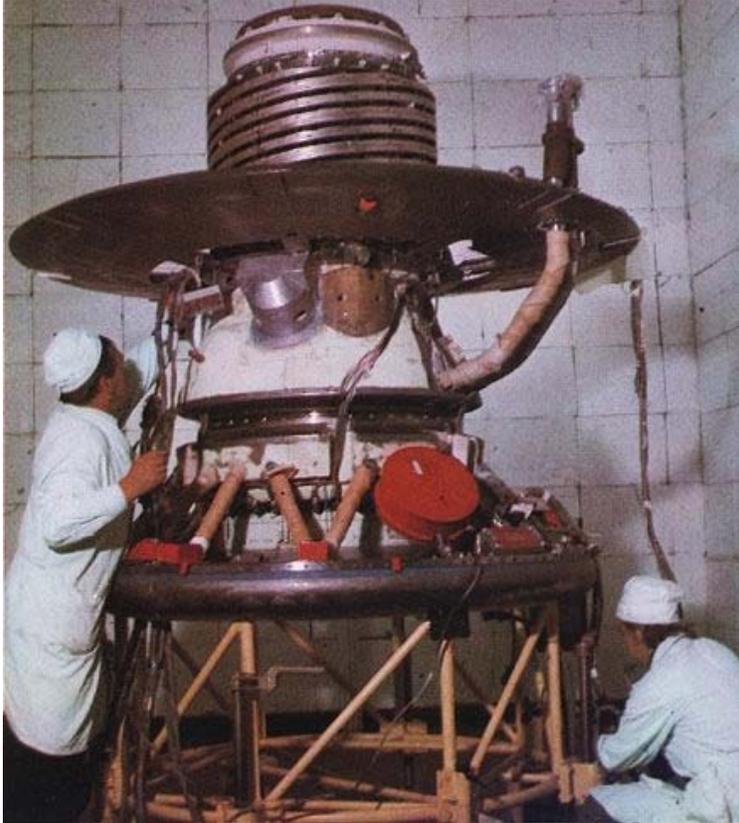
- The **North probe** entered the atmosphere at about 60 degrees north latitude on the day side.
- The **Night probe** entered on the night side.
- The **Day probe** entered well into the day side, and was the only one of the four probes which continued to send radio signals back after impact, for over an hour.

Halley's Comet in 1986

Pioneer Venus Orbiter orbiting Venus had a front row seat when Halley's Comet was more or less hidden behind the Sun during February 1986. Its UV-spectrometer observed the water loss when Halley's Comet was at perihelion February 9.

Venera 12

Venera 12



Venera 11 lander

Operator	USSR
Mission type	Flyby and Lander
Flyby date	December 19, 1978
Satellite of	Venus
Launch date	14 September 1978 02:25:13 UTC
Launch vehicle	Proton Booster Plus Upper Stage and Escape Stages
COSPAR ID	1978-086A
Mass	4940 kg

Orbital elements

Periapsis 6.62 RV (flight platform)

The **Venera 12** (Russian: Венера-12) was an USSR unmanned space mission to explore the planet Venus. Venera 12 was launched on 14 September 1978 at 02:25:13 UTC. Separating from its flight platform on December 19, 1978, the lander entered the Venus atmosphere two days later at 11.2 km/s. During the descent, it employed aerodynamic braking followed by parachute braking and ending with atmospheric braking. It made a soft landing on the surface at 06:30 Moscow time (0330 UT) on 21 December after a descent time of approximately 1 hour. The touchdown speed was 7–8 m/s. Landing coordinates are 7°S 294°E / 7°S 294°E. It transmitted data to the flight platform for 110 minutes after touchdown until the flight platform moved out of range. Identical instruments were carried on Venera 11 and 12.

Flight platform

Venera 12 flight platform carried solar wind detectors, ionosphere electron instruments and two gamma ray burst detectors - the Soviet-built KONUS and the French-built SIGNE 2. The SIGNE 2 detectors were simultaneously flown on Venera 12 and Prognoz 7 to allow triangulation of gamma ray sources. Before and after Venus flyby, Venera 11 and Venera 12 yielded detailed time-profiles for 143 gamma-ray bursts, resulting in the first ever catalog of such events. The last gamma-ray burst reported by Venera 12 occurred on January 5, 1980. Venera 12 used its ultraviolet spectrometer to study Comet Bradfield on 13 February 1980, and reported spectrophotometric data until 19 March 1980.

List of flight platform instruments and experiments:

- 30-166 nm Extreme UV Spectrometer
- Compound Plasma Spectrometer
- KONUS Gamma-Ray Burst Detector
- SNEG Gamma-Ray Burst Detector
- Magnetometer
- 4 Semiconductor Counters
- 2 Gas-Discharge Counters
- 4 Scintillation Counters
- Hemispherical Proton Telescope

The mission ended in April, 1980.

Lander

The Venera 12 descent craft carried instruments designed to study the detailed chemical composition of the atmosphere, the nature of the clouds, and the thermal balance of the atmosphere. Among the instruments on board was a gas chromatograph to measure the composition of the Venus atmosphere, instruments to study scattered solar radiation and

soil composition, and a device named Groza which was designed to measure atmospheric electrical discharges. Results reported included evidence of lightning and thunder, a high $\text{Ar}^{36}/\text{Ar}^{40}$ ratio, and the discovery of carbon monoxide at low altitudes. Both Venera 11 and Venera 12 had landers with two cameras, each designed for color imaging. Each failed to return images when the lens covers did not separate after landing due to a design flaw.

List of lander experiments and instruments:

- Backscatter Nephelometer
- Mass Spectrometer - MKh-6411
- Gas Chromatograph - Sigma
- X-Ray Fluorospectrometer
- 360° Scanning Photometer - IOAV
- Spectrometer (430-1170 nm)
- Microphone/Anemometer
- Low-Frequency Radio Sensor
- 4 Thermometers
- 3 Barometers
- Accelerometer - Bizon
- Penetrometer - PrOP-V
- Soil Analysis Device
- 2 Color Cameras
- Small solar batteries – MSB