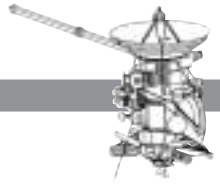

PIONEER 10

Last signal sent from RTG-powered spacecraft

Pioneer-10's mission was to explore the planet Jupiter using the 11 scientific instruments aboard the 570-lb spacecraft.

AFTER MORE THAN 30 years, it appears that the venerable *Pioneer 10* spacecraft has sent its last signal to Earth, NASA announced on February 25. *Pioneer's* last, very weak signal was received on January 22.

At last contact, *Pioneer 10* was 7.6 billion miles from Earth, or 82 times the nominal distance between the Sun and the Earth. At that distance, it takes more than 11 hours and 20 minutes for the radio signal, traveling at the speed of light, to reach Earth.

The spacecraft continued to make valuable scientific investigations in the outer regions of the solar system until routine tracking of the probe was stopped on March 31, 1997, for budgetary reasons, and NASA formally decommissioned it. Scientists subsequently made intermittent contact with it.

The agency's engineers reported that *Pioneer 10's* power source—four SNAP-19 radioisotope thermoelectric generators (RTGs)—has decayed, and may not have enough power to send additional transmissions to Earth. NASA's Deep Space Network (DSN) did not detect a signal during the last contact attempt on February 7.

The previous three contacts, including the January 22 signal, were very faint with no telemetry received. The last time a *Pioneer 10* contact returned telemetry data was on April 27, 2002. NASA has no additional contact attempts planned for the spacecraft.

"*Pioneer 10* was a pioneer in the true sense of the word," said Colleen Hartman, director of NASA's Solar System Exploration Division, at NASA headquarters, in Washington, D.C. "After it passed Mars on its long journey into deep space, it was venturing into places where nothing built by humanity had ever gone before," she observed. "It ranks among the most historic as well as the most scientifically rich exploration missions ever undertaken."

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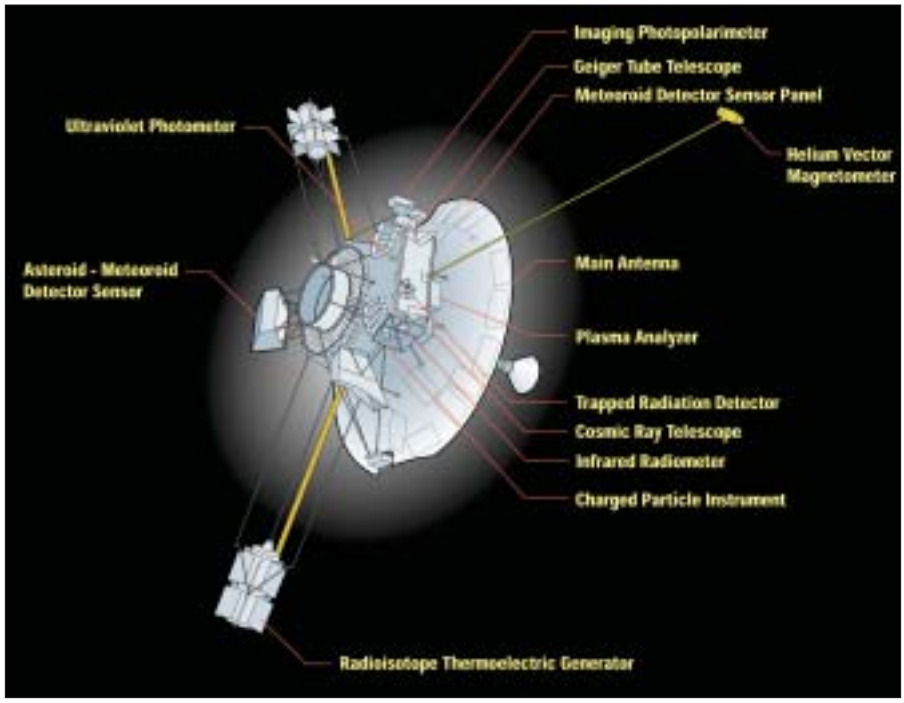


Pioneer 10's systems (NASA)

Its mission was to explore the planet Jupiter using 11 scientific instruments aboard the 570-lb spacecraft. "Originally designed for a 21-month mission, *Pioneer 10* lasted more than 30 years," said *Pioneer 10* project manager Larry Lasher. "It was a workhorse that far exceeded its warranty, and I guess you could say we got our money's worth."

The spacecraft was built by TRW Inc., in Redondo Beach, Calif., and was launched March 2, 1972, on a three-stage Atlas-Centaur rocket. *Pioneer 10* reached a speed of 32 400 mph needed for the flight to Jupiter, making it the fastest human-made object to leave Earth—fast enough to pass the moon in 11 hours and to cross Mars' orbit, about 50 million miles away, in just 12 weeks.

On July 15, 1972, *Pioneer 10* entered the asteroid belt, a doughnut-shaped area about 175 million miles wide and 50 million miles thick. The material in the belt travels at speeds up to 45 000 mph and ranges in size from dust particles to rock chunks as big as Alaska.

Pioneer 10 was the first spacecraft to pass through the asteroid belt—considered a spectacular achievement—and then headed toward Jupiter. Accelerating to a speed of 82 000 mph, the spacecraft passed by Jupiter on December 3, 1973.

It was the first spacecraft to make direct observations and obtain close-up images of Jupiter. It also charted the gas giant's intense radiation belts, located the planet's magnetic field, and established that Jupiter is predominantly a liquid planet. In 1983, *Pioneer 10* became the first human-made object to pass the orbit of Pluto.

Following its encounter with Jupiter, *Pioneer 10* explored the outer regions of the solar system, studying energetic particles from the Sun (solar wind), and cosmic rays entering our portion of the Milky Way. The spacecraft continued to make valuable scientific investigations in the outer regions of the solar system until its science mission ended on March 31, 1997.

Since that time, *Pioneer 10's* weak signal had been tracked by the DSN as part of a new advanced-concept study of communication technology in support of NASA's future Interstellar Probe mission.

As Earth's first emissary into space, the spacecraft is carrying a gold plaque that describes what humans look like, where they are, and the date when the mission began.

Pioneer 10 will continue to coast silently as a ghost ship into interstellar space. It is moving in a straight line away from the sun near the elliptic plane, heading downstream through the heliomagnetosphere toward the tail region (relative to inflowing interstellar gas), and interstellar space.

Until 126 000 years from now, when the spacecraft reaches a distance of 309 000 astronomical units (about 1.5 parsec), it will be dominated by the Sun's gravitational field. It has not yet reached the boundary of the solar wind. After that, *Pioneer 10* will be on an orbital path in the Milky Way galaxy influenced by the field of the stars that it passes. In about 2 million years, it will arrive near the red star Aldebaran, the "eye" of the constellation Taurus the Bull (about 68 light-years from Earth).

The RTGs

Pioneer 10 is powered by RTGs because sunlight is too weak beyond Jupiter to provide energy with solar cell arrays. The RTGs are held two-each about 3 m from the spacecraft's center by two three-rod trusses at an angle of about 120 degrees apart. Each RTG has six fins to provide most of its heat rejection capacity. The RTGs were built by Teledyne Energy Systems, Inc. for the Atomic Energy Commission.

In the RTGs, heat generated by the natural decay of Pu-238 dioxide fuel, which provided a total of about 160 W at launch, is converted by thermoelectric couples into electrical current, with a thermal efficiency of 5–6 percent.

The spacecraft also has a dozen radioisotope heater units (RHUs), each generating 1 W, to heat components in the cold of space. They are variously located in the Thruster Cluster Assembly, near the Sun sensor, and at the magnetometer.

Information about *Pioneer 10* is on the Internet at <spaceprojects.arc.nasa.gov/Space_Projects/pioneer/PNhome.html>.

Pioneer 11

The best components for the *Pioneer* spacecraft of that design, determined by testing, were used in *Pioneer 10*. (Four spacecraft of that design were built, but two were not flown.) The second-best components were used in *Pioneer 11*.

Pioneer 10's sister ship, *Pioneer 11*, ended its mission on September 30, 1995, when the last transmission from the spacecraft was received, as its power diminished below levels adequate to operate experiments, and daily telemetry and science operations ceased (last contact was in November 1995).

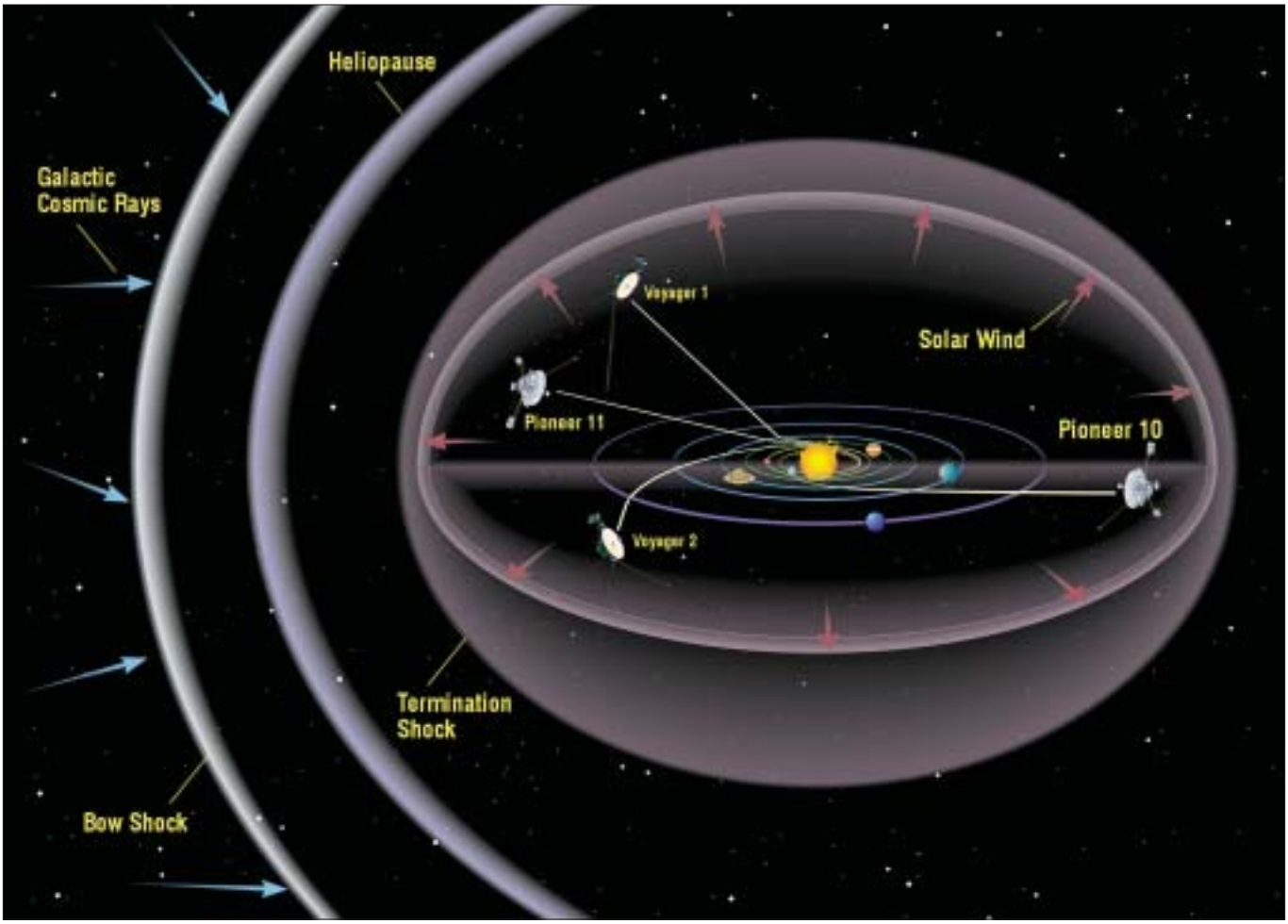
Pioneer 11 was the second spacecraft to investigate Jupiter and the first to explore Saturn. Scientists estimate that in about four million years, it may pass near the Lambda Aquila star in the constellation Aquila (the Eagle). It is heading upstream toward the nose of the heliosphere and opposite the direction of *Pioneer 10*.

Other far missions

Pioneer 10, however, is no longer the farthest human-made object in space. On February 17, 1998, NASA's *Voyager 1* spacecraft—also powered by RTGs—cruised beyond the distance of *Pioneer 10*. The two are headed in almost opposite directions away from the Sun. As of January 3, *Voyager 1* was about 8.1 billion miles from Earth and still in contact with the Jet Propulsion Laboratory/NASA. On that date, the other *Voyager* spacecraft, *Voyager 2*, was 6.4 billion miles from the Sun.

Voyager 1 and its twin, *Voyager 2*, were launched in September 1977 and August 1977, respectively. In their original mission, *Voyager 1* had close flybys of Jupiter and Saturn, and *Voyager 2* passed close to Jupiter, Saturn, Uranus, and Neptune.

The primary mission of both spacecraft has been extended into what NASA calls the Voyager Interstellar Mission. Its purpose is



The trajectories of *Pioneer 10* and *11,* and *Voyager 1* and 2. The *heliopause* is the point at which the solar wind meets the interstellar medium or solar wind from other stars. The *heliosphere* is the space within the boundary of the heliopause containing the Sun and solar system. As the heliosphere plows through the ionized interstellar gas, a *bow shock* forms, such as is formed in front of a boulder in a stream. The *termination shock* is the region where the solar wind begins to slow and large changes to the wind directions and magnetic field orientation begin to occur. Termination shock is believed to occur at around 85 ±5 astronomical units from the Sun (1 AU = average distance from Earth to the Sun = about 93 million miles). (NASA)

to expand their exploration of the solar system beyond the neighborhood of the outer planets to the outer limits of the Sun's sphere of influence, and possibly beyond.

■ The U.S. Department of Energy has awarded Russia a $32-million contract to provide Pu-238 to the U.S. space program for nuclear fuel for five years, starting next year, the French wire service AFP reported on February 26, citing an ITAR-TASS report.