Most spacecraft power themselves by absorbing the sun's energy with solar panels. Beyond Earth's comfortable, brightly lit cradle, however, outer space assaults probes with deep cold, deeper darkness and intense bursts of radiation. To keep a spacecraft safely aloft ...

The Greatest Nuclear-Powered Space Missions of All Time

- By Dave Mosher
- 09.19.13
- 6:30 AM

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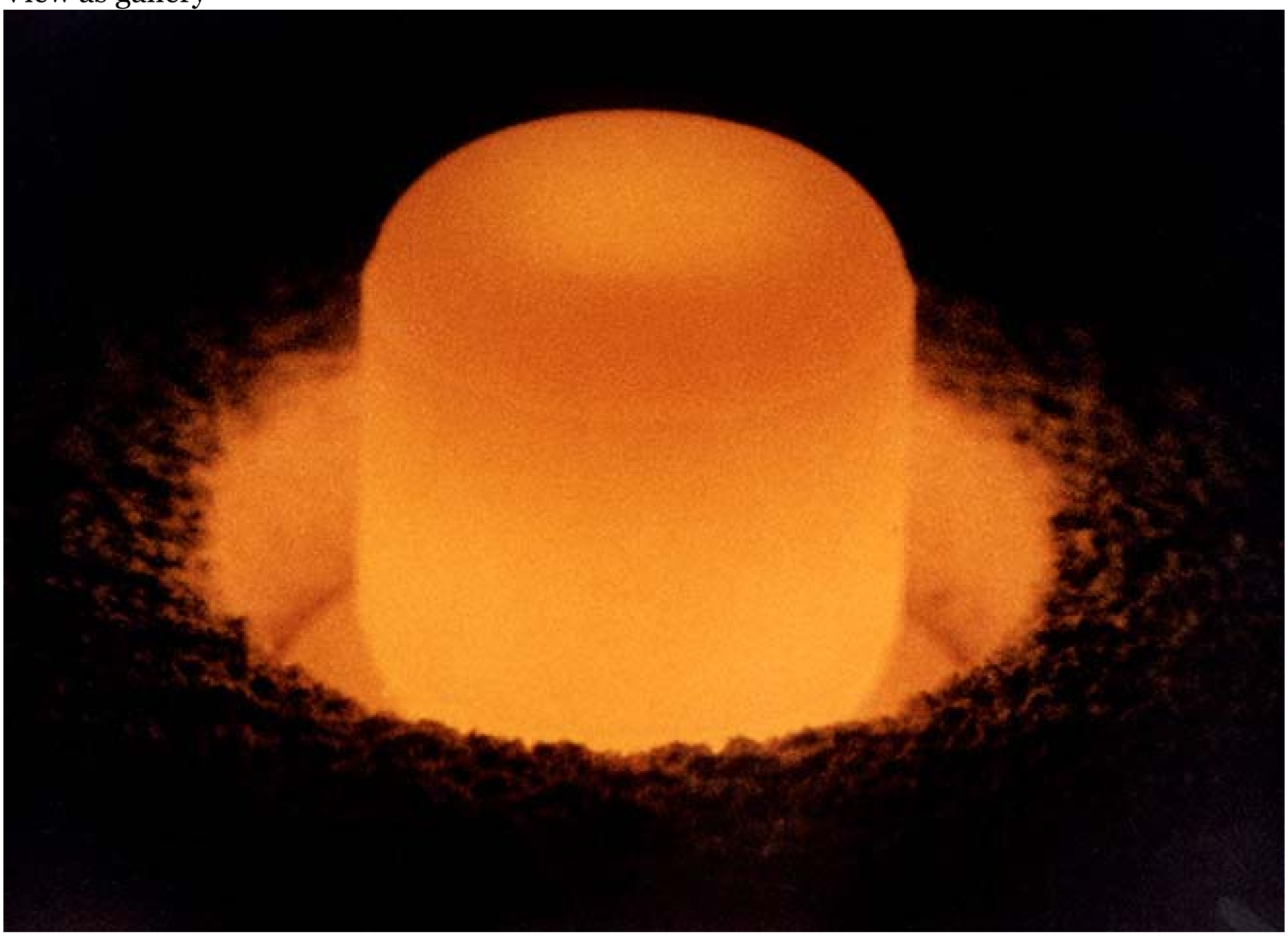
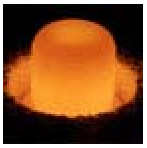


Most spacecraft power themselves by absorbing the sun's energy with solar panels. Beyond Earth's comfortable, brightly lit cradle, however, outer space assaults probes with deep cold, deeper darkness and intense bursts of radiation.

To keep a spacecraft safely aloft in the void seems to require magic. Thanks to the Cold War-era space race, U.S. engineers found some: Plutonium-238, a byproduct created during the production

of weapons-grade plutonium-239.
More on Plutonium-238:



NASA's Plutonium Problem Could End Deep-Space Exploration

How the U.S. Tested the Safety of Nuclear Batteries

Timeline: Plutonium-238's Hot and Twisted History

Unsuitable for use in weapons but perfect in a spacecraft, plutonium-238′s gradual decay gives off warmth that safeguards fragile electronics. More importantly, wrapping plutonium with heat-to-electricity converting materials, called thermoelectrics, turns the radioactive metal into a nuclear battery.

"Plutonium-238 is perhaps the main reason why other nations haven't gone as deep into space as we have," said Jim Adams, NASA's deputy chief technologist and former deputy director of the space agency's planetary science division. "They don't have access to material to make reliable, lightweight [nuclear batteries]."

Powering Cassini around Saturn, for example, would require solar panels the size of two tennis courts and weigh thousands of pounds. Barring a radical and unforeseen breakthrough in power systems, or heavy multiplying of NASA's budget (launch costs range between $5,000 and $10,000 per pound), no other energy source is as practical as a nuclear battery.

As the world's supply of plutonium-238 comes disastrously close to running out, WIRED reviews the greatest space missions of all time — some of which still phone home decades after launch and billions of miles away from Earth.

Image: A pellet of plutonium-238 glows under its own self-generated heat. (Department of Energy/Wikimedia Commons)

Transit Satellite Network

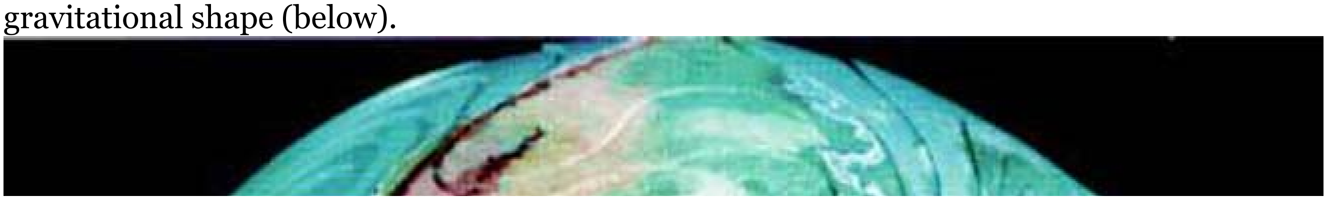
Physicist Glenn Seaborg discovered plutonium in 1940 and, just 20 years later, engineers used it to build nuclear batteries for spacecraft.

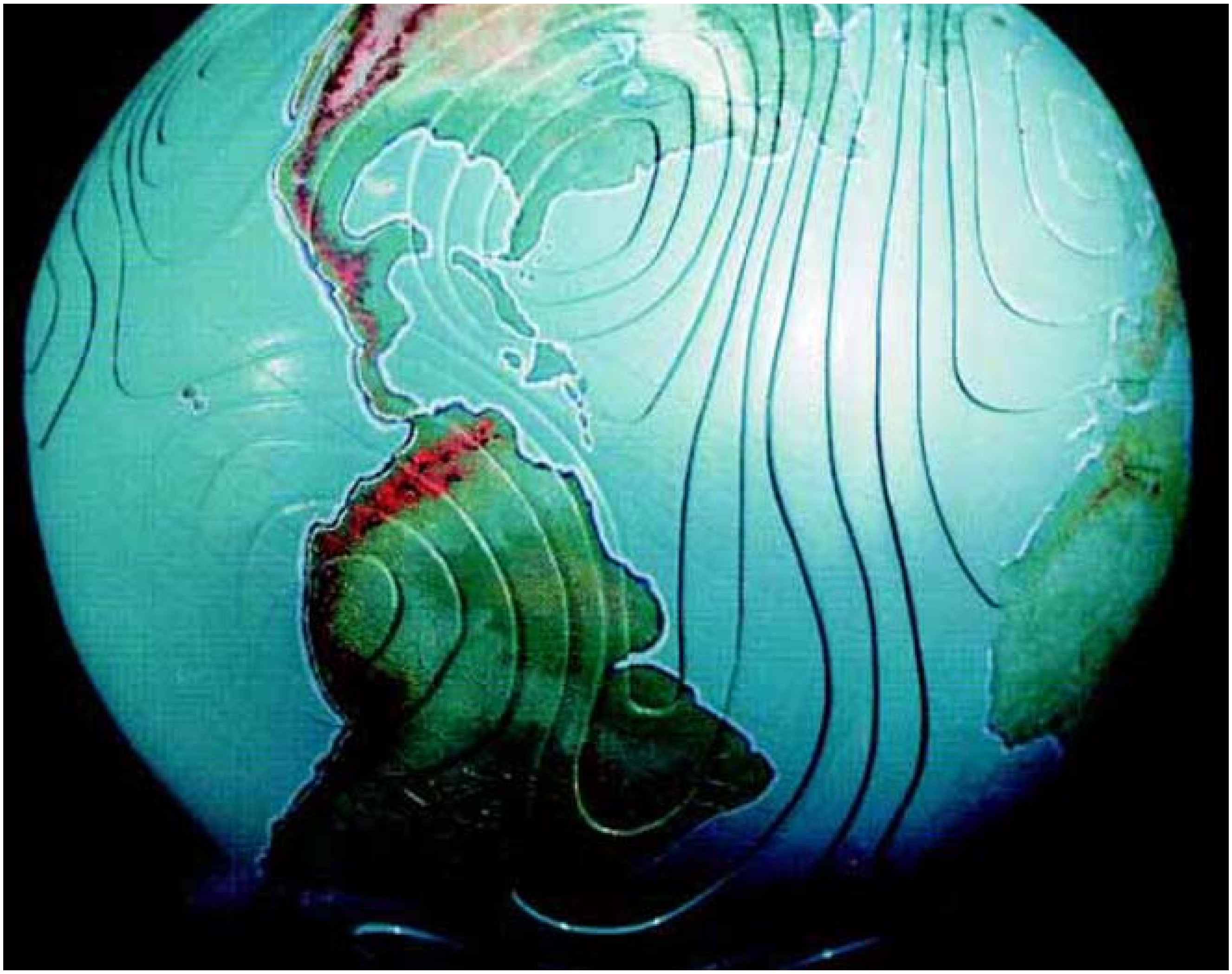
In 1960 the U.S. Navy took over an experimental plutonium-powered satellite program called TRANSIT to guide their submarines and missiles from space. The first satellite powered by plutonium, called Transit 4A (above), reached orbit on June 29, 1961. By 1988, dozens of similar spacecraft — four of them using nuclear batteries — made up a rudimentary satellite navigation network.

Each satellite beamed a unique radio signal. With multiple signals coming from different orbits, the Navy could easily pinpoint its wartime hardware.

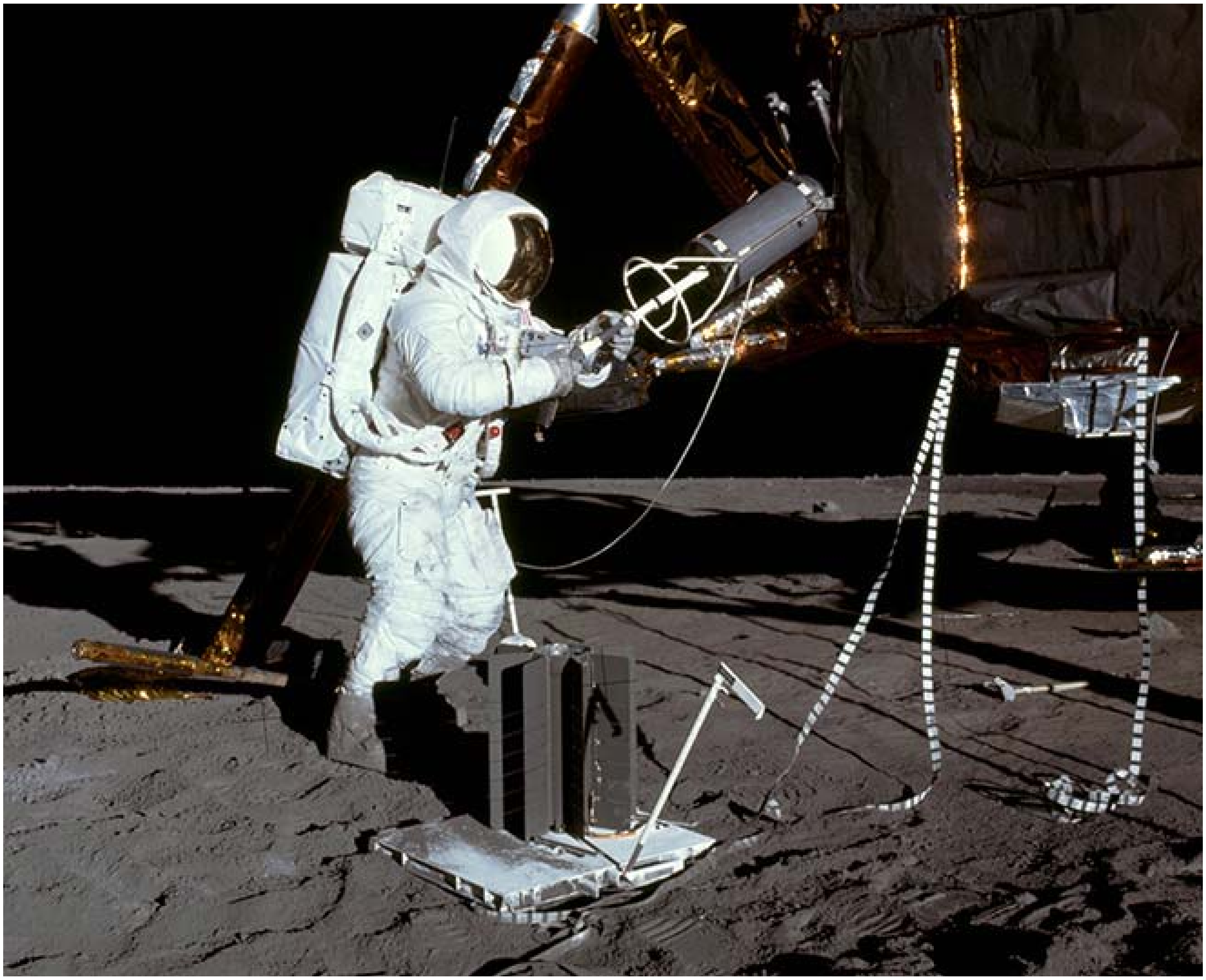
But space scientists hit a snag early on: Their data suggested that spacecraft slowed down or sped up over certain parts of Earth. When researchers mapped the anomalies, they realized that some regions of the planet were far denser than thought, and that the extra mass — and gravity — subtly affected spacecraft speed.

The map of the anomalies became the first of Earth's geoid, a representation of the planet's true gravitational shape (below).





Images: Johns Hopkins University Applied Physics Laboratory



Apollo Surface Experiments

Astronauts in 1969 dropped off about 1.2 ounces of plutonium-238 on the moon. The material sat inside a device called the Apollo Lunar Radioisotopic Heater, or ALRH, and it kept a seismic monitoring station warm during half-month-long lunar nights dipped surface temperatures to -243 degrees Fahrenheit.

All subsequent Apollo missions also used plutonium, yet kept theirs inside of nuclear batteries to provide 70 watts of power, which is on par with an incandescent light bulb's energy use — and just enough to charge the electronics of surface experiments. Above, astronaut Alan L. bean pulls a plutonium fuel cask from the lunar lander during Apollo 12′s first extravehicular excursion.

A similar nuclear battery from NASA’s flubbed Apollo 13 mission survived reentry to Earth orbit. NASA suspects it landed somewhere in the bottom of the Tonga Trench in the South Pacific Ocean. To this day, no release of plutonium-238 has ever been detected.

Image: NASA

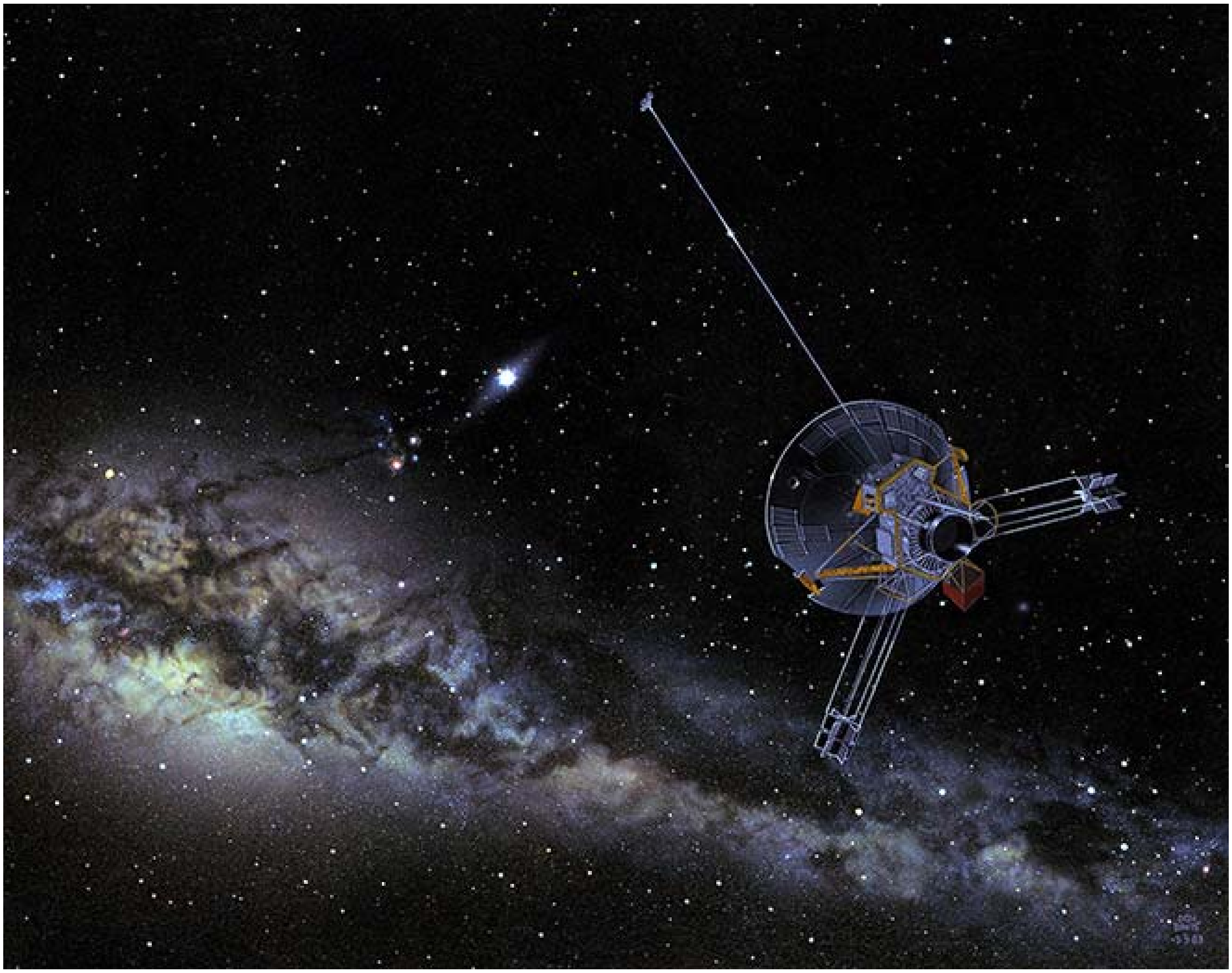
Nimbus-B-1

One of the most important space missions powered by plutonium-238 was a disaster.

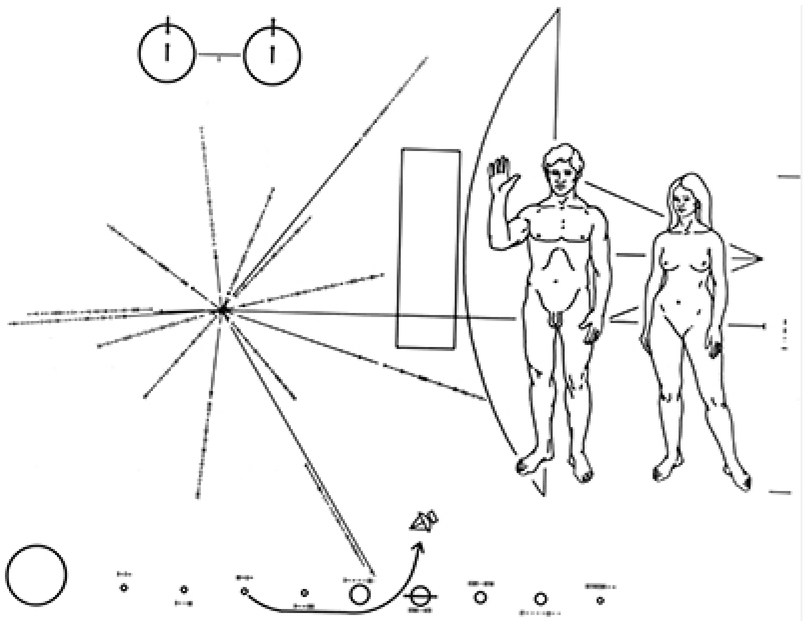
The Nimbus-B-1 satellite was supposed to use its nuclear battery to measure Earth's surface temperatures from space, through both day and night. But when it launched on May 18, 1968, a booster failed and mission control blew up the rocket and spacecraft over the Pacific Ocean.

All was not lost. A crew recovered the battery's fully intact fuel casks (right) between California's Jalama Beach and San Miguel Island, demonstrating their robust safety design. Nuclear engineers

recycled the plutonium fuel into a new battery, which was used in the follow-up Nimbus III mission (one of the very first navigation satellites to aid search-and-rescue operations).
Images: NASA



Pioneer Probes

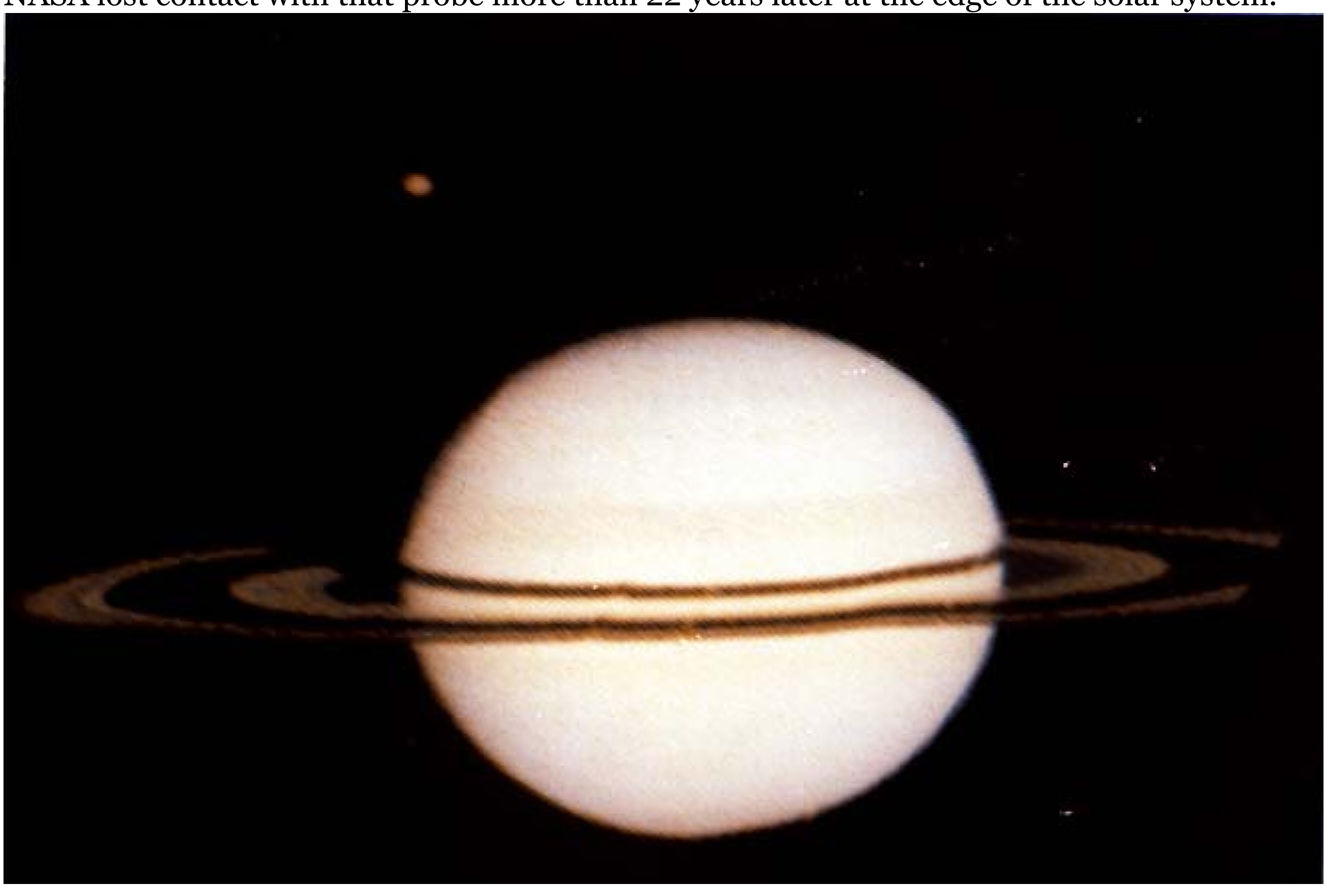


Just in case the probes bump into intelligent aliens, each one carries a plaque to communicate basic information about the spacecraft's origin and creators. Image: NASA

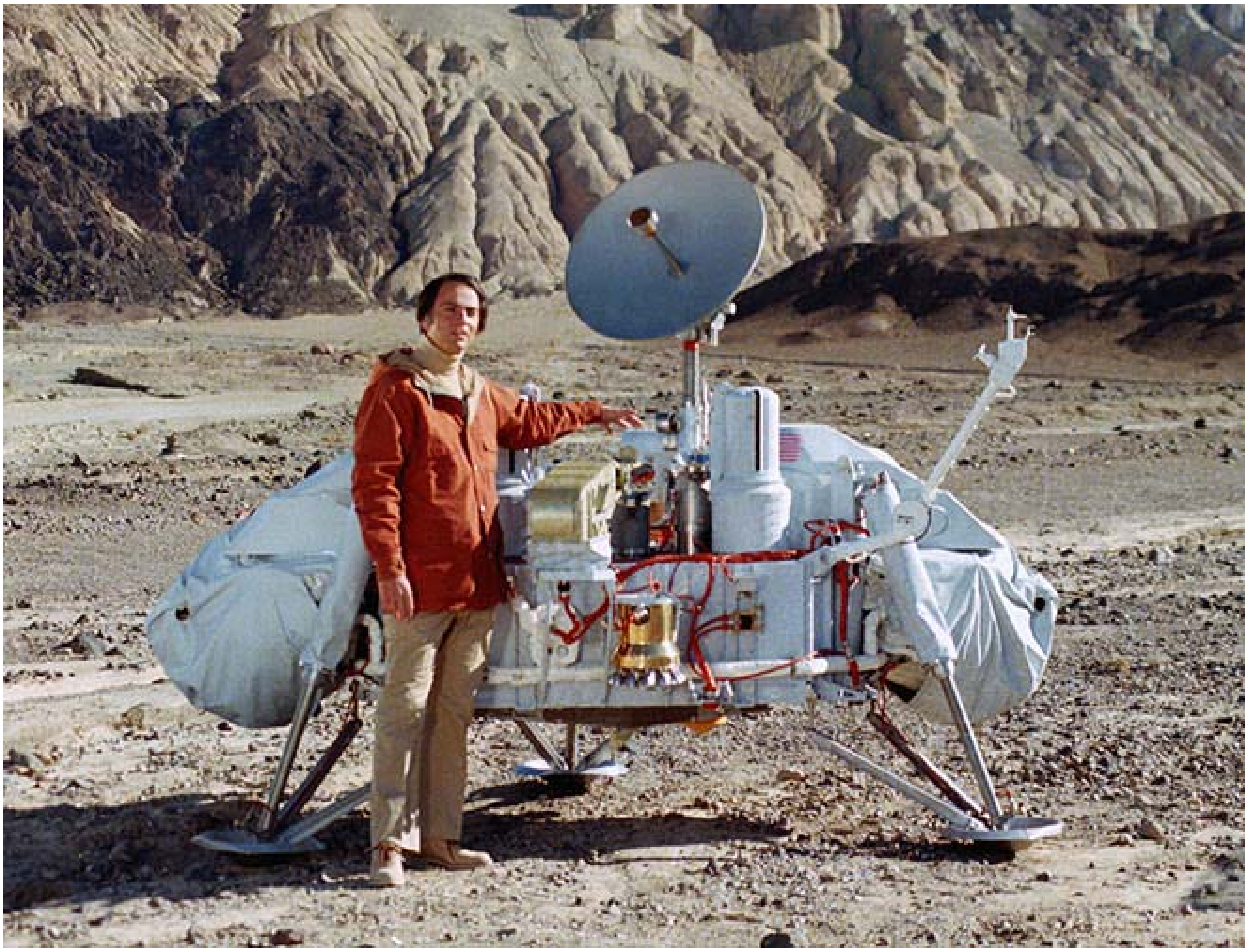
NASA intended its Pioneer program of more than a dozen spacecraft to explore the moon, visit Venus and monitor space weather. But most people remember Pioneer 10 and Pioneer 11 for their daring flybys of never-before-visited outer planets.

Using a 155-watt nuclear battery, Pioneer 10 became the first spacecraft to cross the Asteroid Belt, visit Jupiter and beam back images of the gas giant. The spacecraft launched on March 2, 1972, but NASA was able to maintain contact with it until 2003, when at a distance of 7.5 billion miles its radio signal became too weak to detect.

Pioneer 11, which launched on April 6, 1973, became the first spacecraft to visit Saturn (below). NASA lost contact with that probe more than 22 years later at the edge of the solar system.



Images: 1) An illustration of a Pioneer probe. (NASA Ames Research Center) 2) One of Pioneer 11's first images of Saturn and one of its moons, Titan (top left). (NASA/GRIN)



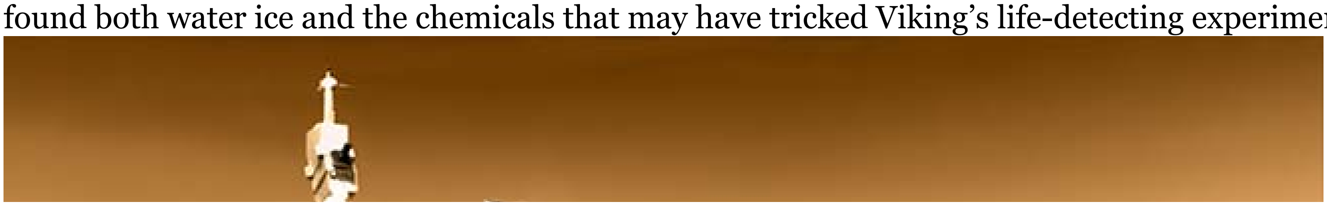
Viking Landers

By the time sunlight reaches Mars, it's about 50 percent less intense than on Earth. Combined with a dusty and windblown environment, solar panels become a liability for surface spacecraft.

To touch down on the Martian surface for the first time in 1976, NASA built a pair of Viking orbiters and a plutonium-238-powered lander for each one.

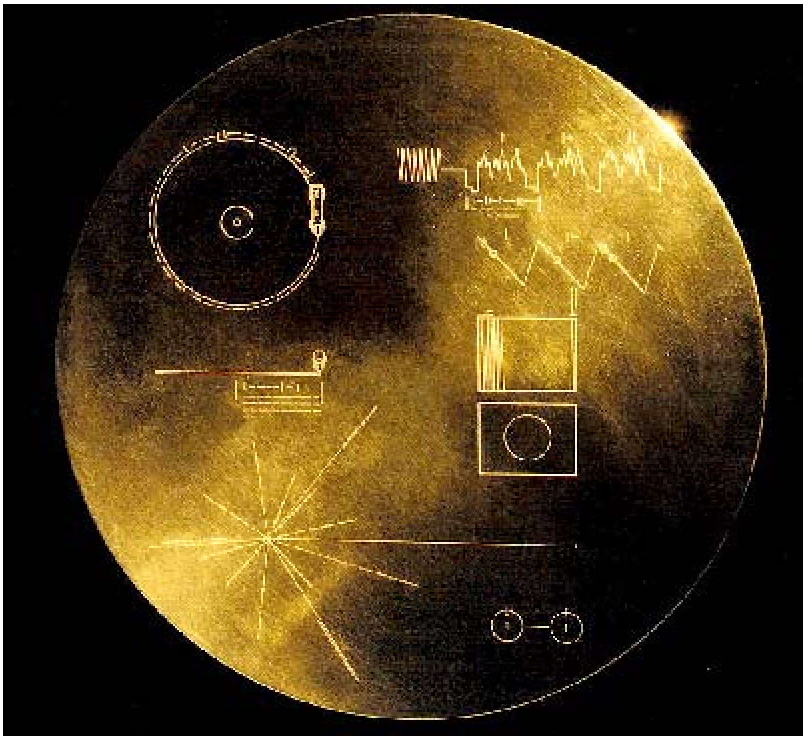
Both landers carried stereoscopic cameras, a weather station, a shovel and a soil-sampling chamber to sniff out signs of life 140 million miles from Earth. Neither lander dug deep enough to find water ice and the soil experiment failed to detect organic molecules, even though it sniffed out carbon dioxide — a gas emitted by most active lifeforms — when it introduced a nutrient-rich liquid to the soil.

Although non-biological soil chemistry likely caused the anomalous result, the Viking landers didn't labor in vain. In addition to returning stunning views of the red planet (below), the landers made the case for NASA to send a flotilla of spacecraft to visit Mars — including the Phoenix lander, which found both water ice and the chemicals that may have tricked Viking's life-detecting experiments.



Images: 1) Carl Sagan stands next to a Viking lander model in Death Valley. (NASA/JPL-Caltech) 2) A view of Mars' surface from Viking 2 (E. Vandencbulek/NASA)

Voyager Twins



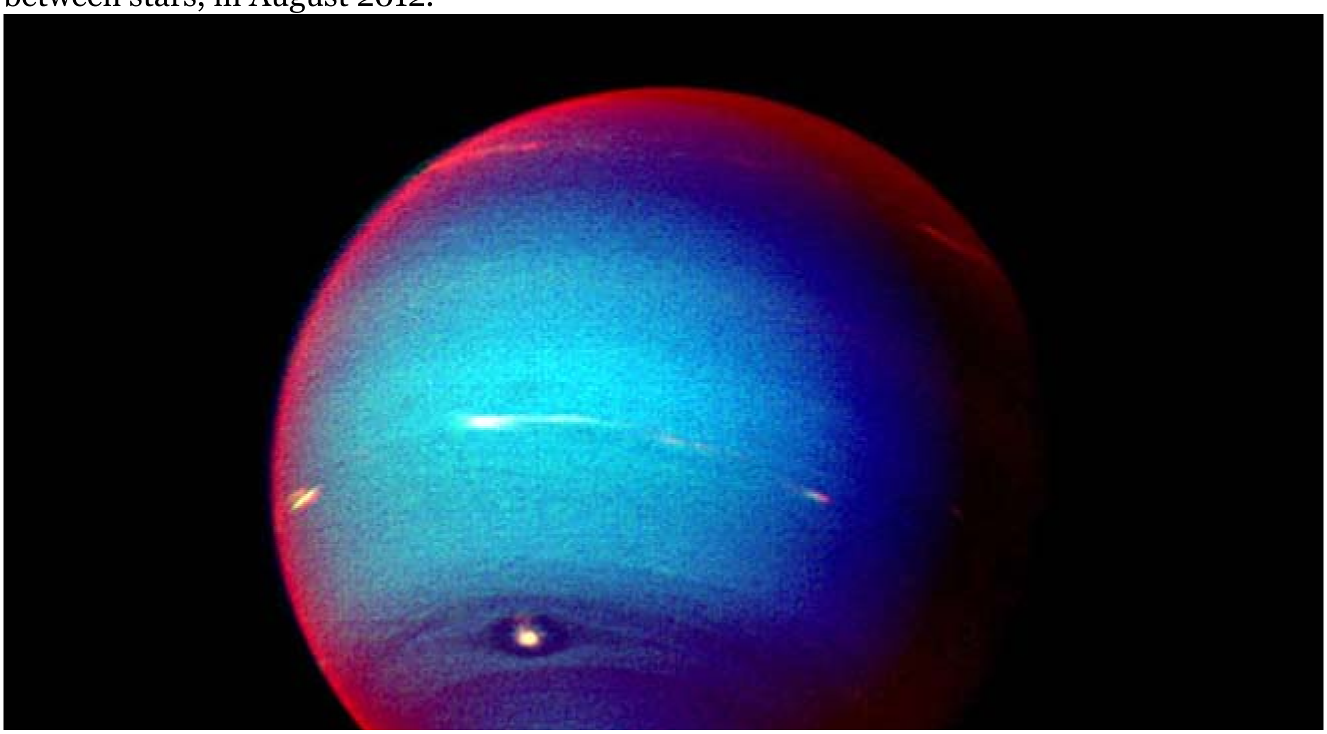
Instructions to decode Voyager's gold record were etched on the surface. Image: NASA/JPL-Caltech

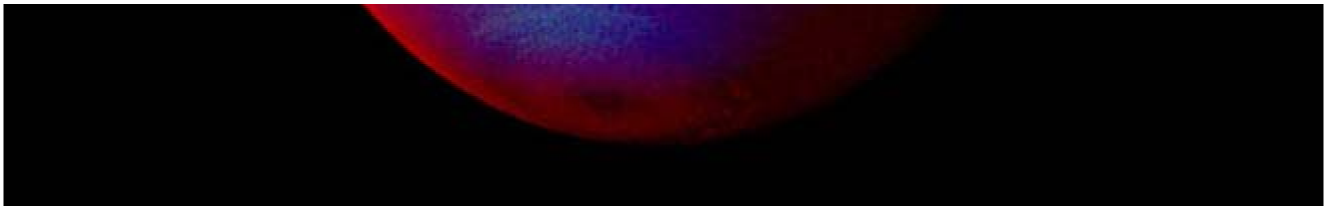
The Voyager probes capitalized on years of improvements in electronics over their predecessors, Pioneer 10 and Pioneer 11, to return stunning views of the solar system — including a view of the Earth from 4 billion miles away that Carl Sagan championed.

Voyager 1 and Voyager 2 also launched with a more advanced message for any intelligent life they encountered: A golden record (right) full of images, audio and other information about Earth and its lifeforms.

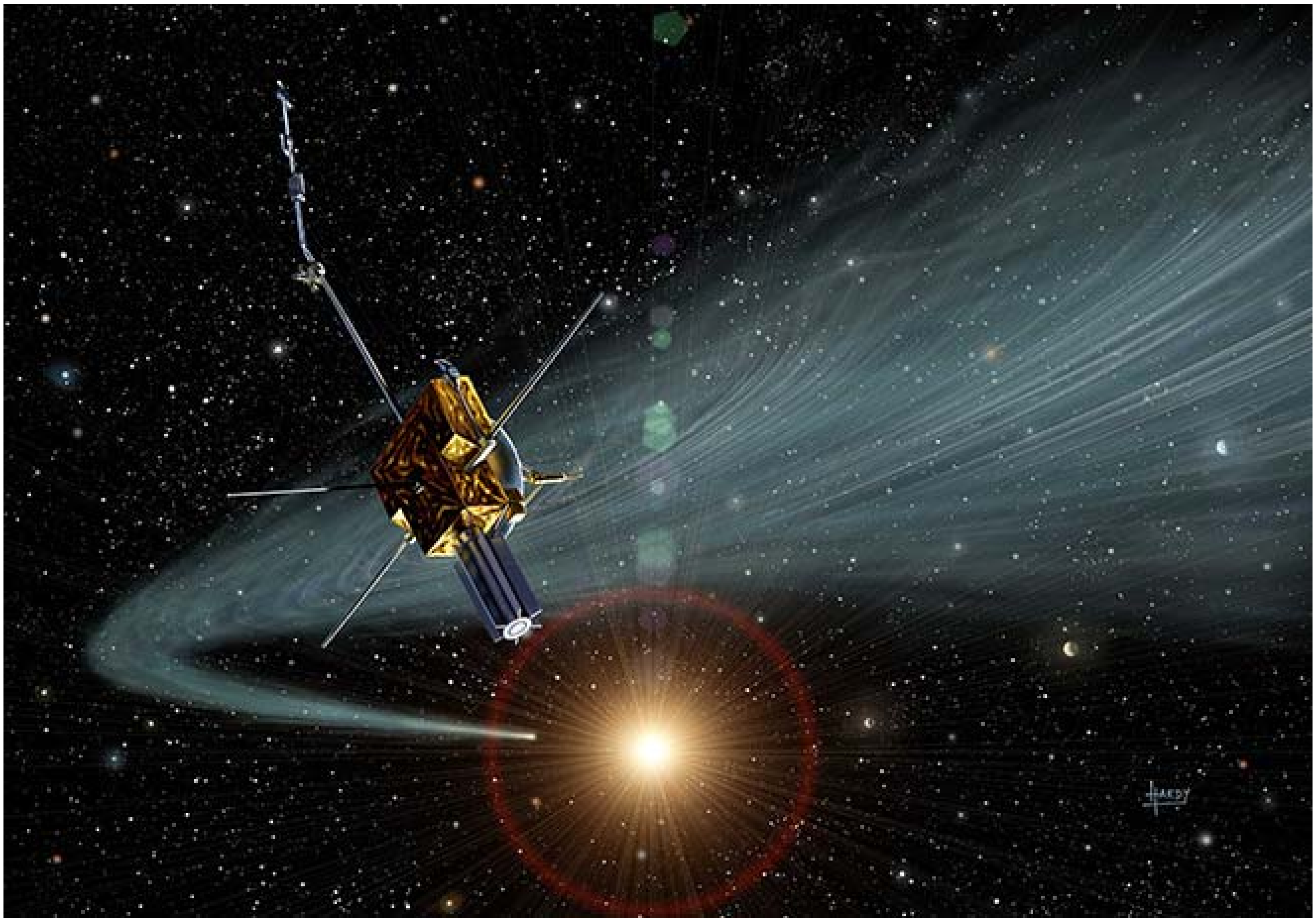
At 11.7 billion miles and counting, Voyager 1 is the farthest human-made object from Earth. Despite the vast distances and 36 years of operation, each of Voyager's three plutonium-238-filled nuclear batteries allow the spacecraft to continue communicating with ground stations on Earth.

Researchers this month announced that Voyager 1 had reached the insterstellar medium, or space between stars, in August 2012.





Images: 1) NASA/JPL-Caltech 2) A false-color view of Neptune from Voyager 2 that reveals a haze of methane gas in red. (NASA/JPL-Caltech)



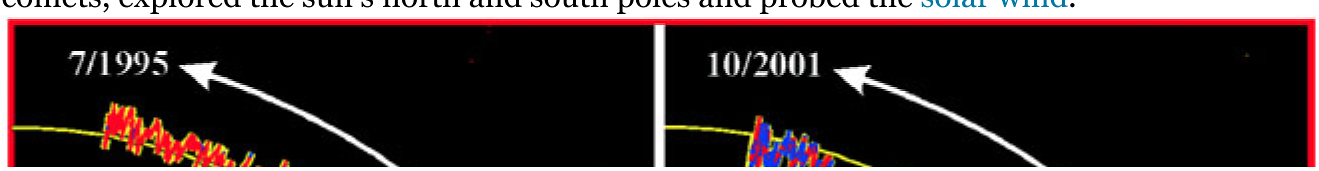
Ulysses

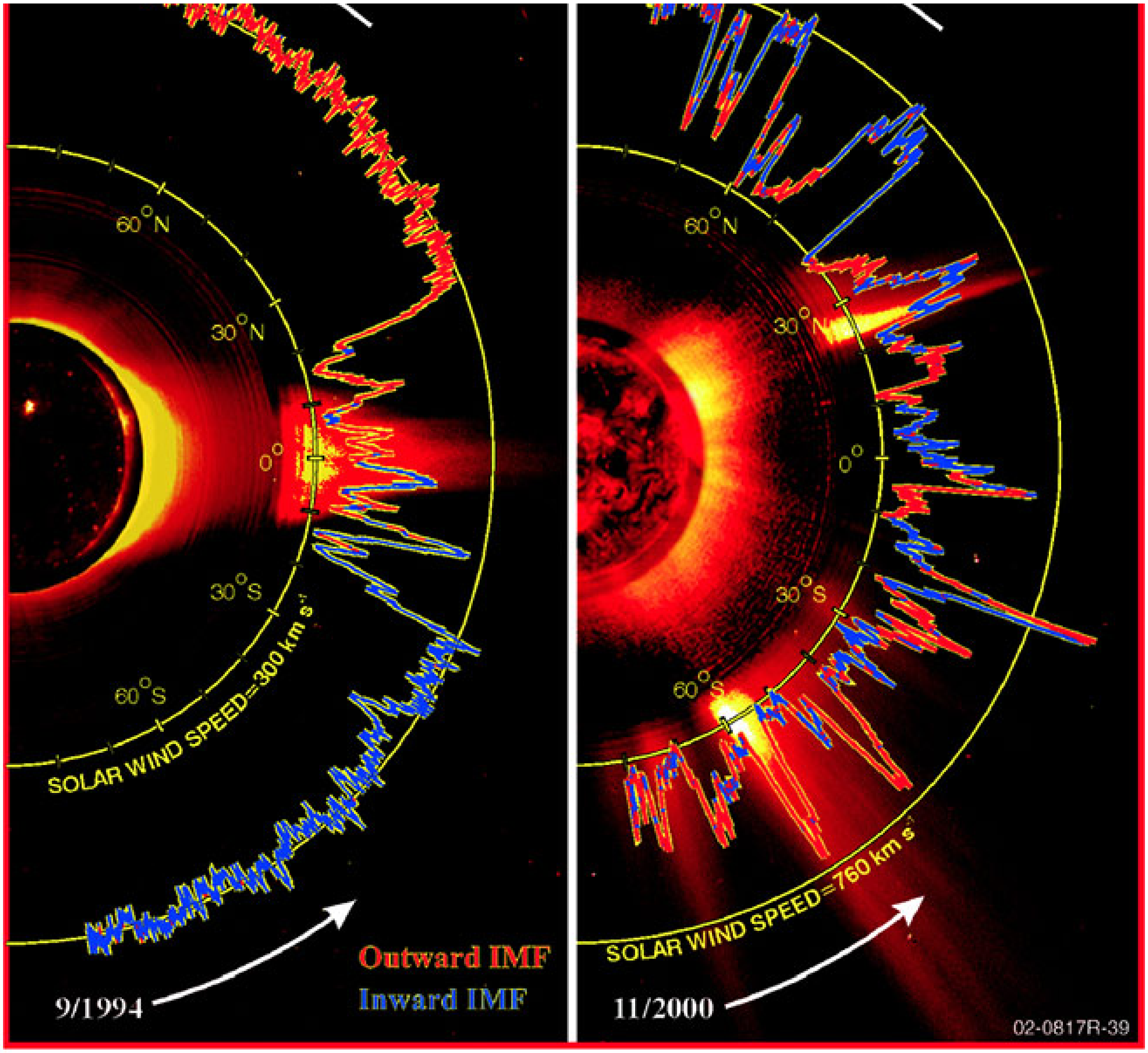
To get into a peculiar orbit above and below the sun to study its poles, designers of the Ulysses spacecraft met a paradox: a sun-probing machine that couldn't rely on solar power.

Achieving Ulysses' orbit required flying to Jupiter, then using the gas giant's gravity to slingshot the spacecraft into a proper trajectory. Sunlight is 25 times dimmer at Jupiter than at Earth, and solar panels would have doubled the spacecraft's weight — 2,500 pounds of arrays versus a 124-pound nuclear battery.

Ulysses launched in 1990, pulled off the Jupiter gravity assist two years later and began a mission in 1994 that would last until 2009. That's when the decaying plutonium-238′s warmth faded enough that it couldn't keep Ulysses' hydrazine propellent from freezing.

Before it perished after nearly 19 years of service, however, Ulysses flew through the tails of several comets, explored the sun's north and south poles and probed the solar wind.





Images: 1) An artist's depiction of Ulysses encountering the tail of comet Hyakutake in May 1996. (ESA/NASA) 2) The differences in solar wind recorded by Ulysses at two different times in the sun's 11-year-long cycle of activity. (SwRI/NASA)

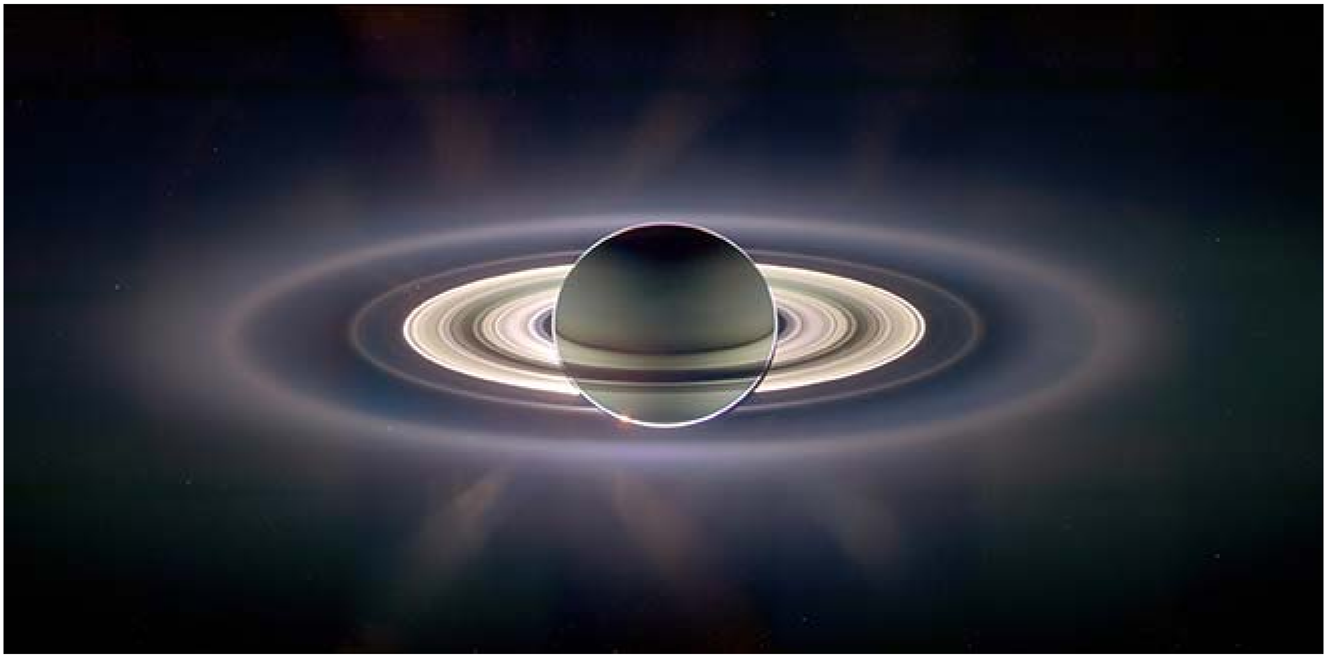
Galileo

Launched from the payload bay of space shuttle Atlantis in 1995, Galileo used two nuclear batteries to give it 570 watts of power.

About enough to run a dorm room microwave, the initial output allowed Galileo to study Jupiter and its four large moons Io, Callisto, Ganymede and Europa (below).

Space scientists operated Galileo for 14 years total, eight of which were spent around Jupiter. To safeguard potentially life-supporting Jovian moons from any stray Earthly bacteria stuck to the spacecraft, NASA plunged it into Jupiter's thick atmosphere at about 100,000 mph in 2003.

Images: 1) NASA 2) The Jovian moons Io, Europa, Ganymede and Callisto as seen by the Galileo spacecraft. (NASA/JPL/DLR)



Cassini

Carrying a whopping 72 pounds of nuclear material, the most plutonium-238 of any spacecraft ever launched, Cassini faced heated public opposition before its 1997 launch toward Saturn. A public information campaign and additional safety tests eventually quelled fears, and today the spacecraft's three nuclear batteries allow it to beam back more data than any previous deep-space probe.

Since Cassini arrived at Saturn on Christmas day in 2004, it has dropped a lander named Huygens on the moon Titan, has discovered moonlets, recorded Saturn's polar auroras, flown through and "sniffed" the icy jets of the moon Enceladus and more.

The spacecraft could explore Saturn for many more years. The only question is how long NASA chooses to fund the team of humans that controls it from 890 million miles away.

Some plans include careening Cassini into Saturn's atmosphere to destroy it, Galileo-style, while others call for parking it in orbit around Titan or other gas giants like Uranus, Neptune or Jupiter.

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HD

Image: Cassini's view from within the shadow of Saturn in 2006. The Earth is visible as dot at left-center. (Cassini Imaging Team/SSI/JPL/ESA/NASA)
Video: Chris Abbas/Vimeo

New Horizons

In just a few short years, the dwarf planet Pluto and its ensemble of moons will receive the first-ever Earth visitor.

Due for the rendezvous is the New Horizons spacecraft, which launched in 2006 toward Pluto at roughly 36,000 mph. That's far too fast to dip into orbit around Pluto, but the spacecraft should still get a solid 6 months of observations around its flyby date of July 14, 2015. In the two weeks before and after that date, New Horizon's view will far exceed the Hubble space telescope's view of Pluto from low-Earth orbit.

New Horizons' single nuclear battery will enable observations of the dwarf planet and its five known moons — Charon, Nix, Hydra, P1 and P2. When the spacecraft passes Pluto in the summer of 2015 and enters the Kuiper Belt, it may spot strange new planetary objects in deep-freeze.

Images: 1) New Horizons being prepared for launch in 2005. The black finned object at left is the nuclear battery. (NASA) 2) An artist's depiction of the view from above Pluto's surface, looking at the moon Charon. (Dan Durda/SwRI)

Curiosity (Mars Science Laboratory)

NASA's new car-sized rover landed safely on Mars on August 5, 2012 after surviving a harrowing descent known to engineers as the "7 minutes of terror" (below). The robot is equipped with everything from a stereoscopic camera and a powerful microscope to a rock-zapping infrared laser and an X-ray spectrometer to perform advanced science on the red planet.

Unlike previous wheeled rovers on Mars, which only used bits of plutonium-238 to warm their circuit boards (and relied entirely on solar power), one 125-watt nuclear battery feeds Curiosity. The power source should be strong enough to keep the rover rolling around Mars' mountainous Gale Crater for about 14 years.

Unfortunately, Curiosity harbors some of the last plutonium-238 in NASA's reserves. The spacecraft uses about 7.7 pounds, leaving the space agency with roughly 36 pounds.

The 2012 and 2013 budgets provided $10 million and $14.5 million, respectively, to the U.S. Department of Energy to research plutonium-238 production. But that's about half the funding the agency initially requested. Even if production began in earnest today — it hasn't as of yet — the wait for the first spacecraft-ready shipment of plutonium is expected to take between 5 and 7 years.

Image: Illustration of the Curiosity Mars Science Laboratory. (NASA/JPL-Caltech)
Video: JPLnews/YouTube

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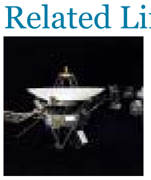


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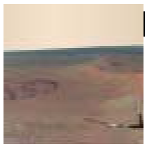

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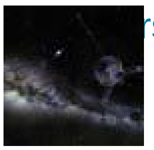

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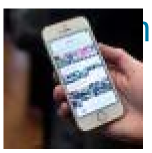

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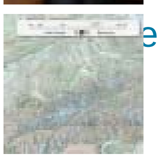

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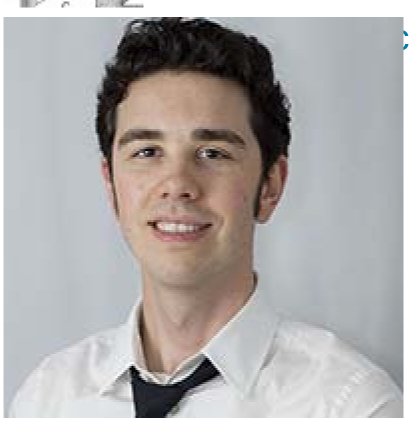

Dave Mosher is a science journalist obsessed with space, physics, biology, technology and more. He lives in New York City. G+
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