How Voyager Works

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At this moment, two spacecraft that were launched from Earth in 1977 hurtle through space at more than 30,000 mph (48,280 km/h). They are both several billion miles away, farther from Earth than any other man-made object. On Aug. 25, 2012, one of them crossed into interstellar space, making the first spacecraft to leave the solar system

Voyager 1 and 2 carry coded messages to potential alien civilizations. They have already taught scientists a great deal about the **heliosheath**, the outermost layer of the solar system. But none of this is even what they were designed for.

The Voyager spacecrafts were built to fly past the outer planets (Jupiter, Saturn, Neptune and Uranus) and study them closely, the first time in human history they'd been observed up close. The spacecraft succeeded magnificently, advancing planetary science by vast leaps. It was only after they'd accomplished their primary mission that they continued on to become Earth's most far-ranging explorers.

Yet it was a matter of extremely good luck and timing that the missions were possible at all -- and an equal stroke of bad luck that almost scuttled the Voyager project before it ever left the ground. These ambitious missions were the product of new advances in the science and math of orbital trajectories, but they were almost cast by the wayside in favor of the expensive space shuttle program. Virtually every unmanned space mission undertaken today relies on knowledge and experience gained by the Voyagers.

We'll take a close look at the ungainly Voyager space probes and all the technical equipment they carry on board. We'll trace their trajectory from the development stages to their ultimate fate light years away from Earth. There will be stops at the largest planets in our solar system along the way. And if you're wondering what's on the golden records each Voyager carries as messages for alien life forms, we'll give them a spin. Will any aliens ever find them?

Contents

Voyager 1 and 2: The Grand Tour

The 1970s were a transitional period for the U.S. space effort. The Apollo program was coming to a close, and NASA was trying to figure out what form manned spaceflight would take. The Mariner missions expanded our knowledge of the inner planets by sending space probes to fly past (and in some cases orbit) Mars, Venus and Mercury. There were tentative plans to send a Mariner mission to visit some of the outer planets, but using chemical rocket propulsion, such a trip would take 15 years or more.

At the same time, important advances were being made in the science of **gravity-assisted orbital trajectories**. While the math and physics involved are pretty complicated, the basic idea is that a spacecraft can use the gravity of a nearby planet to give it a large boost in velocity as long as the spacecraft follows the proper orbit. The higher the mass of the planet, the stronger the gravitational force, and the bigger the boost. That meant that once a space probe reached Jupiter (the most massive planet in our solar system), it could use Jupiter's gravity like a slingshot and head out to explore the more distant planets.

In 1965, an engineer named Gary Flandro noticed that in the mid-1970s, the outer planets would be aligned in such a way as to make it possible for a spacecraft to visit them all using a series of gravity-assisted boosts [source: Evans]. This particular alignment wasn't just a once-in-a-lifetime event -- it wouldn't occur again for another 176 years. It was an amazing coincidence that the technical ability to accomplish such a mission was developed a few years before the planets lined up to allow it.

Initially, the ambitious project, known as the **Grand Tour,** would have sent a series of probes to visit all the outer planets. In 1972, however, budget projections for the project were approaching $900 million, and NASA was planning development of the space shuttle [source: Evans]. With the immense shuttle development costs looming, the Grand Tour was cancelled and replaced with a more modest mission profile. This would be an extension of the Mariner program, referred to as the **Mariner Jupiter-Saturn mission (MJS)**. Based on the Mariner platform and improved with knowledge gained from Pioneer 10's 1973 fly-by of Jupiter, the new probes eventually took the name Voyager. Design was completed in 1977. Optimistic NASA engineers thought they might be able to use gravity-assisted trajectories to reach Uranus and Neptune if the initial mission to visit Jupiter and Saturn (and some of their moons) was completed successfully. The idea of the Grand Tour flickered back to life.

The final Voyager mission plan looked like this: Two spacecraft (Voyager 1 and Voyager 2) would be launched a few weeks apart. Voyager 1 would fly past Jupiter and several of Jupiter's moons from a relatively close distance, scanning and taking photos. Voyager 2 would also fly past Jupiter, but at a more conservative distance. If all went well, both probes would be catapulted toward Saturn by Jupiter's gravity. Voyager 1 would then investigate Saturn, specifically the rings, as well as the moon Titan. At that point, Voyager 1's trajectory would take it out of the solar system's **ecliptic** (the plane of the planets' orbits), away from all other planets, and eventually out of the solar system itself.

Meanwhile, Voyager 2 would visit Saturn and several of Saturn's moons. If it was still functioning properly when that was completed, it would be boosted by Saturn's gravity to visit Uranus and Neptune before also leaving the ecliptic and exiting the solar system. This was considered a long shot, but amazingly, everything worked as planned.

Next, what kind of hardware did the Voyagers carry into space?

Voyager Equipment

Both Voyager spacecraft are identical. They don't have a sleek, aerodynamic design because there's no aerodynamic friction in space to worry about. Weighing 1,592 pounds (722 kilograms), they're made up of a main bus, a high-gain antenna, three booms that held scientific instruments and the power supply, and two other antennae.

The main bus is the body of the Voyager. It's a 10-sided box 5.9 feet (1.8 meters) across, and it contains some scientific instruments, electronics and a fuel tank for the rocket thrusters. The thrusters are used to reorient the craft as it moves through space.

Mounted on top of the main bus, the high-gain antenna is 12 feet (3.7 meters) across and looks like a satellite dish. This antenna is how the Voyagers receive commands from Earth and send the data they gather back. No matter where a Voyager spacecraft flies, the high-gain antenna always points toward Earth.

One of the booms extending off of the main bus carries Voyager's **radioisotope thermoelectric power supply**. Pellets of plutonium dioxide release heat through natural decay. This heat is converted into electricity using a series of thermocouples. Although the power output isn't very strong, it powers the electronics and instruments on board the Voyagers for a very long time. Power isn't expected to deplete completely until 2020. The power supply was placed on a boom to keep the radiation from interfering with the other scientific instruments.

The other two booms carry a series of instruments. These include:

- Magnetometer
- Cosmic ray detector
- Plasma detector
- Photopolarimeter
- Infrared interferometer
- Spectrometer
- Radiometer
- Ultraviolet spectrometer
- Low energy charged particle detector
- Plasma wave detector

[source: Evans, Dethloff & Schorn]

Perhaps the most significant instruments on board the Voyagers, as far as the public is concerned, are the cameras. Also mounted on the instrument boom, the cameras have a resolution of 800x800, with both wide-angle and narrow-field versions. The cameras returned unprecedented photos of the outer planets and gave us views of our solar system that we had never before witnessed (including the famous departure shot showing both Earth and Earth's moon in the same frame). The boom carrying the cameras could be moved independently from the rest of the craft.

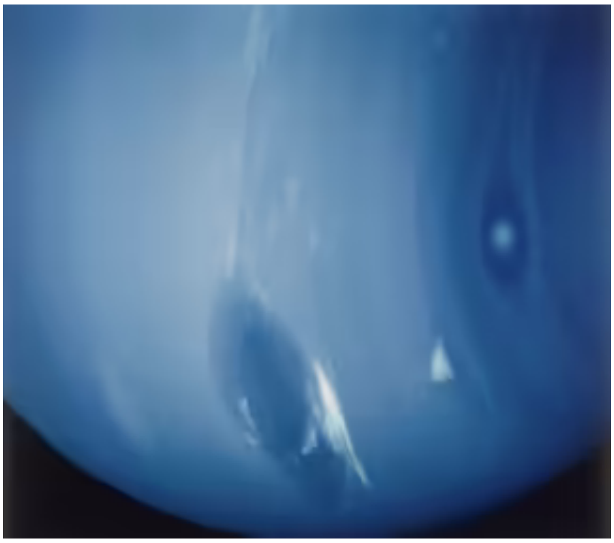
The Voyager's computer system was very impressive as well. Knowing the craft would be on its own much of the time, with the lag between command and response from Earth growing longer the farther the craft went into space, engineers developed a **self-repairing computer system**. The computer has multiple modules that compare the data they receive and the output instructions they decide on. If one module differs from the others, it's assumed to be faulty and is eliminated from the system, replaced by one of the backup modules. It was tested shortly after launch, when a delay in boom deployment was misread as a malfunction. The problem was corrected successfully.

In the next section, we'll find out what we learned from the Voyager missions.

To Neptune and Beyond

Although the lifetime mission cost for Voyager exceeded $750 million, by 1989 the spacecrafts had returned enough scientific data to fill 6,000 editions of the Encyclopedia Britannica [source: Evans]. The science modules on board were chosen from proposals submitted by research teams across the United States. The information about Jupiter, Saturn, Uranus and Neptune (and many of their moons) that we learned from the Voyager missions wasn't just vast in quantity, but also in influence. It shaped science textbooks in schools across the U.S., informed public perceptions of the solar system and laid the foundation for the modern space program. Much of what we know about the outer planets came from Voyager. That's not to mention the thousands of photographs taken from vantage points humans had never experienced before. Those brilliant images of Jupiter and Saturn fired the public's imagination and fueled enthusiasm for future space exploration.

From Voyager, we learned more about the weather on Jupiter; the rings around Jupiter, Saturn and Uranus; volcanic activity on Jupiter's moon Io; the masses and densities of Saturn's moons; the atmospheric pressure on Titan, Saturn's largest moon; the magnetic field of Uranus; and a persistent weather system on Neptune as large as Earth, known as the **Great Dark Spot**. By the time Voyager 2 reached Neptune, it was 1989. More than 10 years had passed since launch, and many of the scientists working on the original mission had moved on. Voyager had passed by Jupiter, Saturn and Uranus in 1979, 1981 and 1986, respectively.



The Great Dark Spot on the surface of Neptune, as observed by the Voyager 2 spacecraft in 1989. The spot, thought to be a swirling mass of gases, had disappeared by 1994, to be replaced by a similar spot in a different location.

Space Frontiers/Hulton Archive/Getty Images

So where are they now? The two Voyagers aren't together. Voyager 1 is moving north (relative to the orientation of Earth out of the solar system), while Voyager 2 is moving south. In 2007, they both entered the heliosheath, the outermost section of the solar system. There, the solar wind meets interstellar magnetic fields and forms a boundary with a shock wave. The Voyagers traversed the shock wave and sent data back, giving astronomers their first idea of the shape and location of the heliosheath. On Sept. 21, 2013, Voyager scientists reported that Voyager 1 left the solar system on Aug. 25, 2012.

Although some instruments on the Voyagers are no longer working, they do continue to send back important information. Imagine a car that has been on the road continuously since 1977, and you'll get some idea of how amazing these spacecraft are. At their current distance, it takes radio signals traveling at the speed of light more than 14 hours to reach Earth. The craft are running low on fuel for their orienting thrusters and will have to power down some instruments in the coming years as their plutonium runs out as well. By 2020, they will be dark and silent.

Yet they will continue on their current trajectory, moving over 30,000 mph (48,280 km/h), arcing out into the Milky Way for tens of thousands of years. With no atmosphere in space, they will never corrode, and there is little for them to crash into in interstellar space. It will take them about 40,000 years before they even come within light years of another star. The Voyagers may be traveling for hundreds of thousands or even millions of years.

What if the Voyagers meet an intelligent alien civilization some day? We've left a message for them.

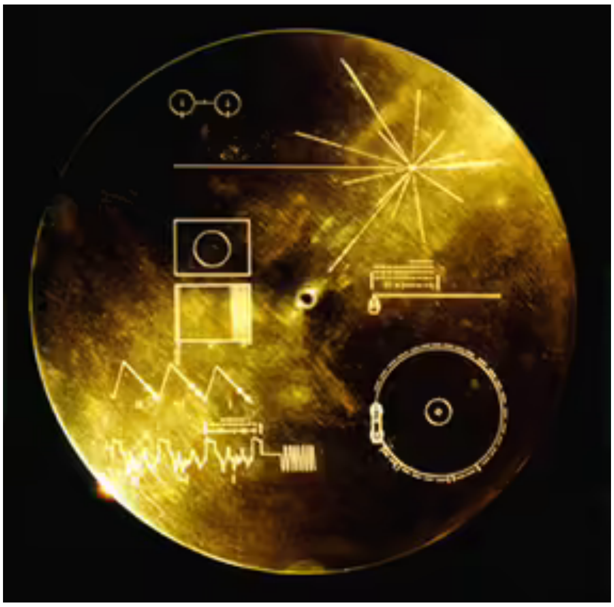
Voyager Golden Record

When NASA realized that the Voyagers would eventually travel beyond the edge of our solar system, they decided it might be a good idea to include some kind of message to any intelligent aliens who might some day find them. A committee headed by astronomer **Carl Sagan** put these messages together. They're contained on gold-plated copper discs, which are engraved much like a vinyl record album. A portion of the disc contains audio information, including a variety of music, greetings spoken in 55 different languages (including some that are very obscure or long extinct) and a selection of nature sounds. The discs also include 122 images, encoded as vibrations on the disc with instructions for decoding.

On each disc's cover plate are several symbols that depict the method of playing back the record (a stylus and mounting platter are included as well). The image decoding instructions are revealed, describing the "image start" signal, the aspect ratio of the images, and a reproduction of the first image, so the aliens would know if they got it right. A star map clearly showing the location of Earth completes the picture.

If the aliens wonder how long the Voyager they find has been traveling, they can examine the piece of uranium-238 attached to the main bus near the record. Examining the isotope ratios (assuming they know the half-life of uranium-238), they could then deduce how long the sample had been in space.

What music will the aliens hear when they play the record? Mostly traditional music from a variety of cultures, such as Native Americans chants, Scottish bagpipes and African ritual music. It is also something of a "greatest hits" collection of classical music. The most contemporary songs are "Johnny B. Goode" by Chuck Berry and a jazz number by Louis Armstrong.


The decoding instructions and map on the cover of the golden record

Courtesy NASA/JPL-Caltech

The images on the record are varied, and include maps of Earth, images of the other planets in our solar system, pictures of various animals and several images of humans. Carl Sagan wrote a book about the record, called "Murmurs of Earth." A companion CD-ROM was released decades later.

The Voyager discs are similar to a plaque that was placed aboard Pioneer 10 and Pioneer 11, although the creators of the Voyager discs spent a lot of time making sure the aliens could decode it. Many Earth scientists could not decode the information on the Pioneer plaque. At the time, some voiced concerns that any hostile aliens finding the Voyager disc would have a map leading them directly to Earth. However, the Voyagers will spend tens of thousands of years in interstellar space before they are anywhere near another star, so the matter isn't really an immediate concern. If the discs are ever found, it may be so far in the future that humans no longer exist.

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Voyager Space FAQ

What is the temperature of interstellar space?

Interstellar space â€" the space between the stars in a galaxy â€" is about as cold as it gets. Sciencing.com reports the temperature is 3 kelvins, which is not much above absolute zero, the coldest anything can ever get.

How far away is Voyager 2?

According to its NASA mission log, of January 2021 Voyager 2 was 11.8 billion miles from Earth.

How far away is Voyager 1?

According to its NASA mission log, of January 2021 Voyager 1 was 14.1 billion miles from Earth.

Do the Voyagers have a camera?

Yes, they are perhaps the most significant instruments on board the Voyagers, as far as the public is concerned. The cameras have taken unprecedented photos of the outer planets with both wide-angle and narrow-field lenses.

What is the difference between Voyager 1 and 2?

Both Voyager spacecraft are identical, though they launched on different dates. Voyager 1 was the first to reach interstellar space, but Voyager 2 is the only spacecraft to study all four of the solar system's giant planets at close range.

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