

After exploring the outer planets - Jupiter, Saturn, Neptune, and Uranus - the Voyager and Pioneer spacecraft are seeking the edge of the Solar System and heading toward their final destination - interstellar space.



Voyagers and Pioneers: The Interstellar Mission

Four NASA spacecraft, **Voyager 1 and 2** and **Pioneer 10 and 11**, have successfully completed their primary missions of studying the four giant outer planets—**Jupiter, Saturn, Uranus, and Neptune**. However, NASA continues to utilize these four spacecraft for new mission objectives: to seek out the invisible edge of our **Solar System**, cross it, and then explore the **interstellar medium** of our home **galaxy, the Milky Way**. The great distances that these spacecraft have travelled since their launches in the 1970s make achieving these new mission objectives possible for the first time. These extended missions will test the hypothesis that our Solar System merges with the interstellar medium somewhere beyond the orbit of Pluto, between 9 and 15 billion kilometers from the **Sun**. When these spacecraft cross this boundary, they will be the first human-made objects to travel beyond our Solar System—the first interstellar travellers from planet **Earth**.

At present, the Pioneer and Voyager spacecraft are travelling through the so-called **interplanetary medium** of the Solar System, which dominates and fills a region of space called the **heliosphere** (*helios* is Greek for the Sun). The heliosphere is created by the **solar wind**. The solar wind is a super-thin gas (only about 5 particles per cubic centimeter by the time it passes the Earth) that originates in the Sun's outermost atmosphere, called the **solar corona**. As the solar wind expands out from the Sun, it carries with it a small portion of the Sun's **magnetic fields** like threads of a spider's web carried in a breeze. This magnetized solar wind flows continuously outward from the Sun at an average speed of 400 km per second, filling all of the heliosphere.

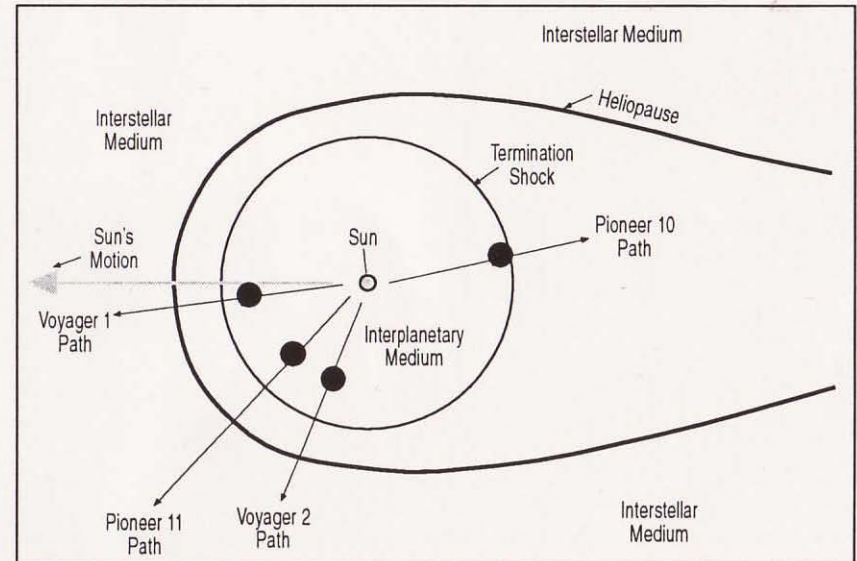
Previous Voyager and Pioneer observations show that the expansion of the solar wind continues past the orbit of Pluto. Scientists believe that this expansion continues until the pressure exerted by the magnetized solar wind on the **interstellar medium** equals the pressure of the interstellar medium itself, which is also composed of a weakly magnetized gas. The region where this pressure balance occurs is called the **heliopause** and is generally considered to be the boundary of the heliosphere. Because the Solar System is moving through the interstellar medium at approximately 27 km per second, scientists believe that the heliopause has the form of a comet-shaped bubble similar to the bow wave and wake caused by the motion of a ship through water.

Before reaching the heliopause, the solar wind is hypothesized to undergo a significant deceleration and compression where it first begins to "feel" the pressure exerted by the interstellar medium. This region of deceleration

is called the solar wind **termination shock**. The word "termination" refers to the end of high speed flow—not the end of the solar wind, which occurs at the heliopause. The instruments onboard the spacecraft will detect the slowing and compressing of the solar wind, signalling that, after decades of travel, they are finally approaching the edge of the Solar System.

For the Classroom

1. The Solar System is hypothesized to end approximately 9 to 15 billion km from the Sun. Have students calculate the approximate time required for radio signals to be transmitted from Earth to Voyager 2 at the point it is predicted to depart from the Solar System.
2. Have students research the Voyager and Pioneer spacecraft: launch dates, length of journeys to the respective planets, and pre-Space Age information compared to new findings.
3. Have students collect images of the planets and their satellites taken from Earth, from the Pioneer and Voyager spacecraft, and from the Hubble Space Telescope and discuss the differences.



A schematic view of the heliosphere and the **trajectories** of the Voyager and Pioneer spacecraft. The locations of the spacecraft in 1994 relative to the expected position of the heliopause are indicated by the dot (•) symbols.