Voyager 1

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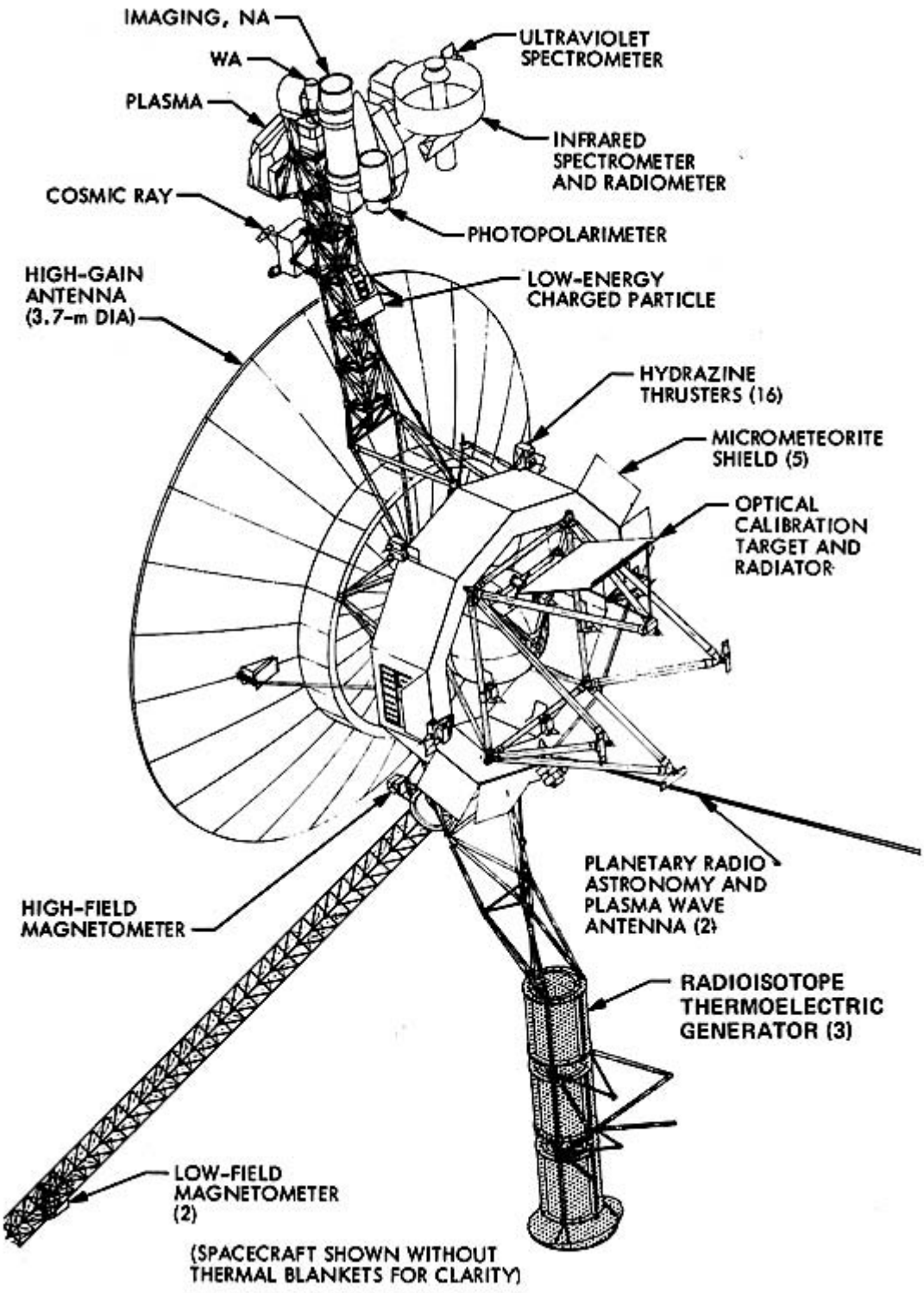
Note: In PDF format most of the images in this web paper can be enlarged for greater detail.

Voyager 1 during final assembly

Voyager 1's original mission was to explore Jupiter, Saturn, Uranus and Neptune. Launched in 1977, scientists did not imagine that the spacecraft would continue its journey for more than three and a half decades to the edge of the solar system.

Reference: *Science* 28 June 2013: Vol. 340 no. 6140 p. 1595.

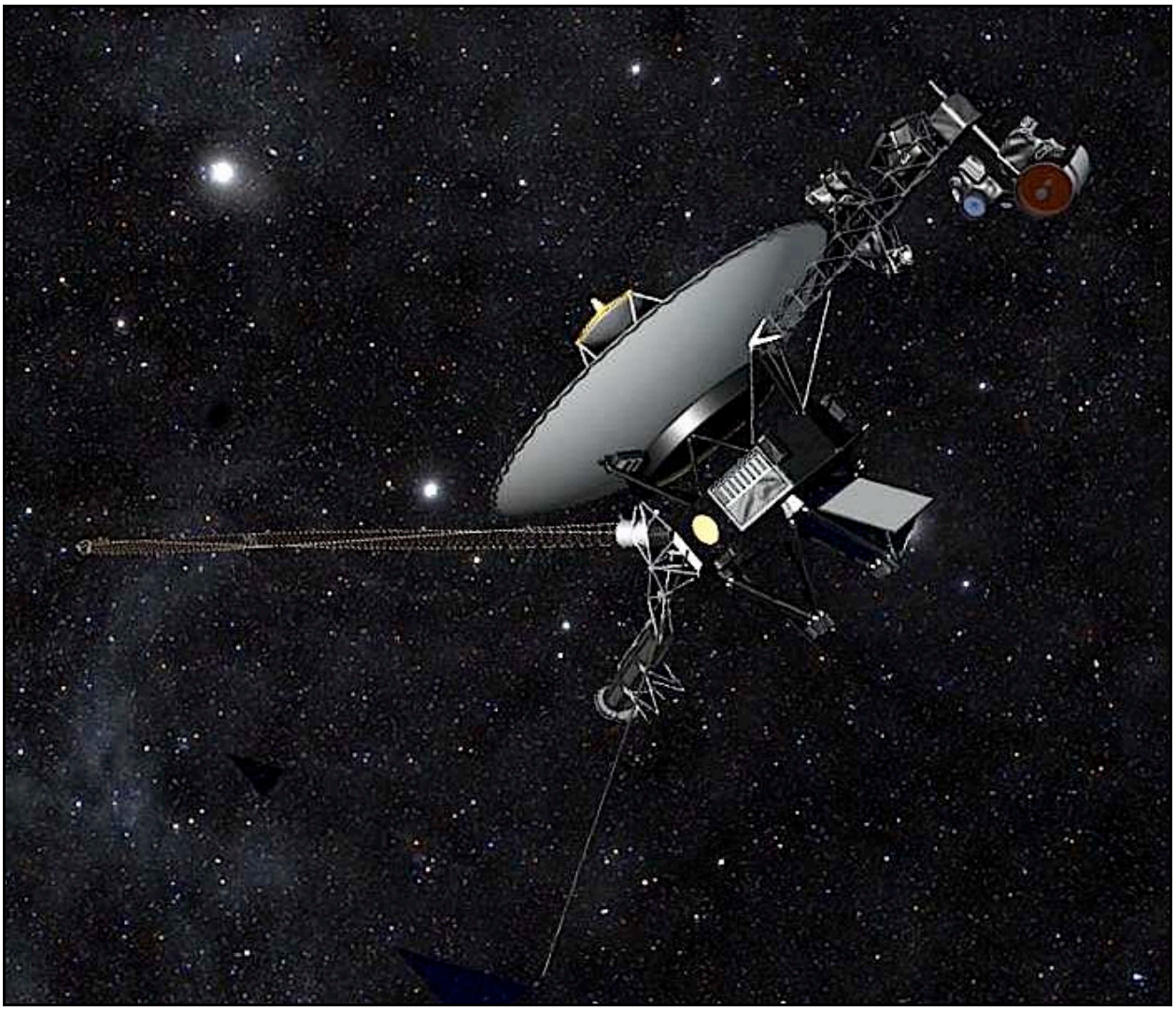
Web Reference
http://en.wikipedia.org/wiki/Voyager_1



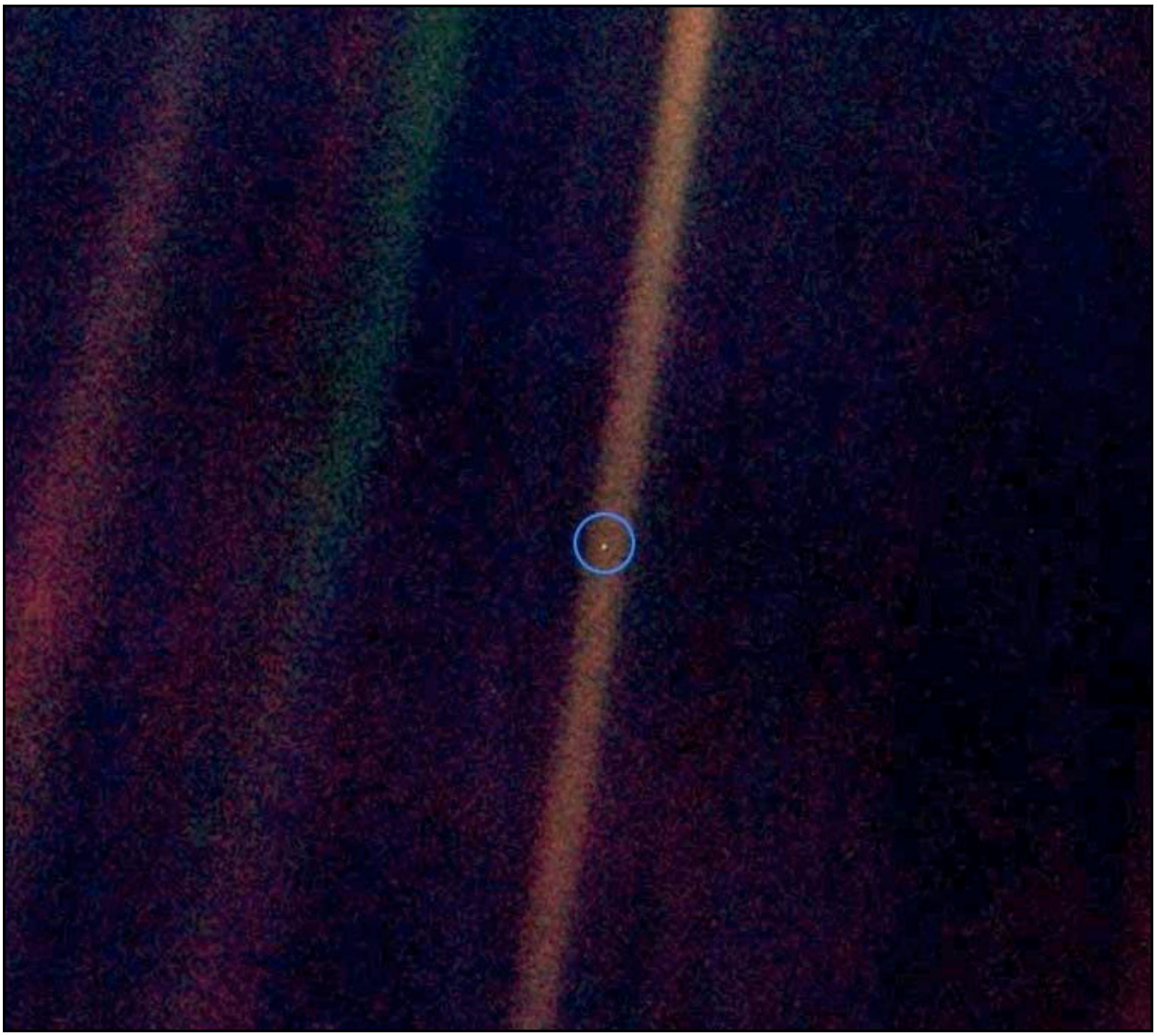
This drawing of Voyager 1 shows the locations of the satellite's components.

Completed Voyager assembly before being encapsulated for launch.

(Note the gray thermal blankets installed.)



An artist's image of how the Voyager would look fully deployed in space.



The Pale Blue Dot

In this image taken by Voyager 1 in 1990 from about 6 billion kilometers (3.7 billion miles) away, Earth appears as a tiny dot, the bluish-white speck approximately halfway down the brown band of light to the right, within the darkness of deep space. In his book "Pale Blue Dot: A Vision of the Human Future in Space", Sagan related his thoughts on a deeper meaning of the images taken by Voyager 1.

"From this distant vantage point, the Earth might not seem of any particular interest. But for us, it's different. Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor

and explorer, every teacher of morals, every corrupt politician, every "superstar," every "supreme leader," every saint and sinner in the history of our species lived there – on a mote of dust suspended in a sunbeam.

The Earth is a very small stage in a vast cosmic arena. Think of the rivers of blood spilled by all those generals and emperors so that in glory and triumph they could become the momentary masters of a fraction of a dot. Think of the endless cruelties visited by the inhabitants of one corner of this pixel on the scarcely distinguishable inhabitants of some other corner. How frequent their misunderstandings, how eager they are to kill one another, how fervent their hatreds. Our posturings, our imagined self-importance, the delusion that we have some privileged position in the universe, are challenged by this point of pale light. Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity – in all this vastness – there is no hint that help will come from elsewhere to save us from ourselves.

The Earth is the only world known, so far, to harbor life. There is nowhere else, at least in the near future, to which our species could migrate. Visit, yes. Settle, not yet. Like it or not, for the moment, the Earth is where we make our stand. It has been said that astronomy is a humbling and character-building experience. There is perhaps no better demonstration of the folly of human conceits than this distant image of our tiny world. To me, it underscores our responsibility to deal more kindly with one another and to preserve and cherish the pale blue dot, the only home we've ever known."

"Carl Sagan, Pale Blue Dot: A Vision of the Human Future in Space 1997, pp. xv–xvi."

Web References

http://en.wikipedia.org/wiki/Carl_Sagan

http://en.wikipedia.org/wiki/Pale_Blue_Dot

http://www.youtube.com/watch?v=p86BPM1GV8M

http://en.wikipedia.org/wiki/Pale_Blue_Dot:_A_Vision_of_the_Human_Future_in_Space

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Image Reference

Voyager 1 Observes Low-Energy Galactic Cosmic Rays in a Region Depleted of Heliospheric Ions. E. C. Stone, A. C. Cummings, F. B. McDonald, B. C. Heikkila, N. Lal, and W. R. Webber. *Science* 12 July 2013: 150-153.

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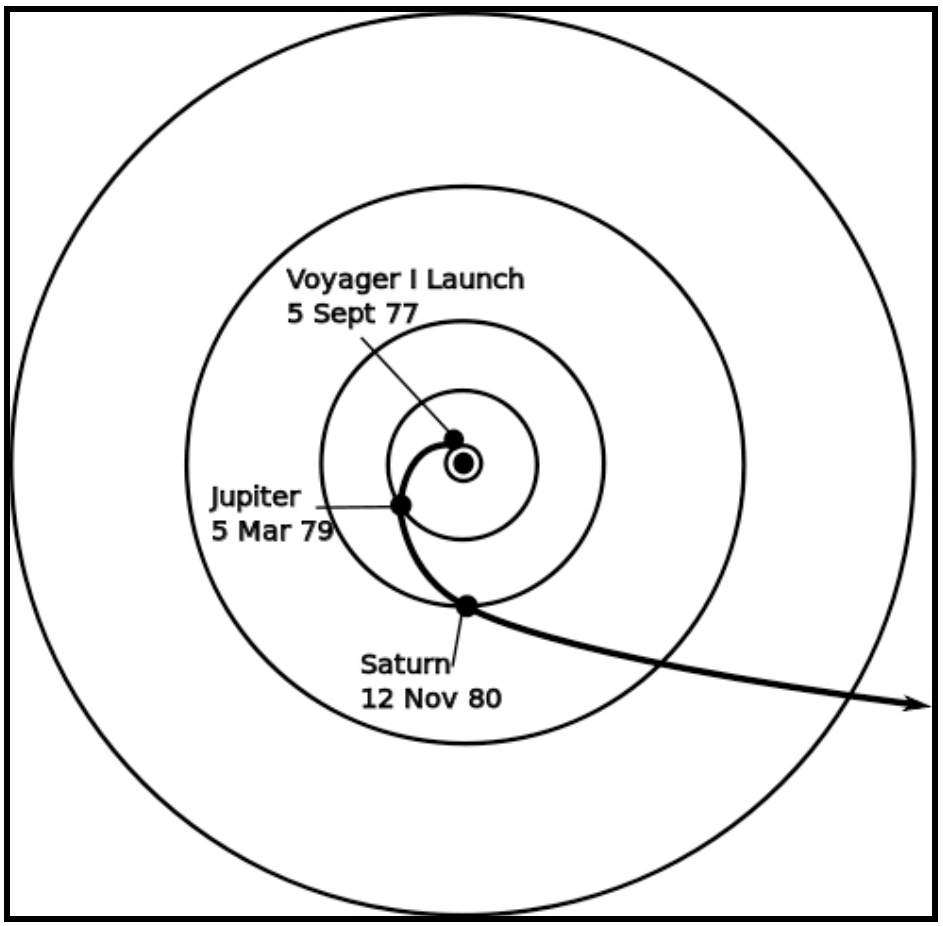
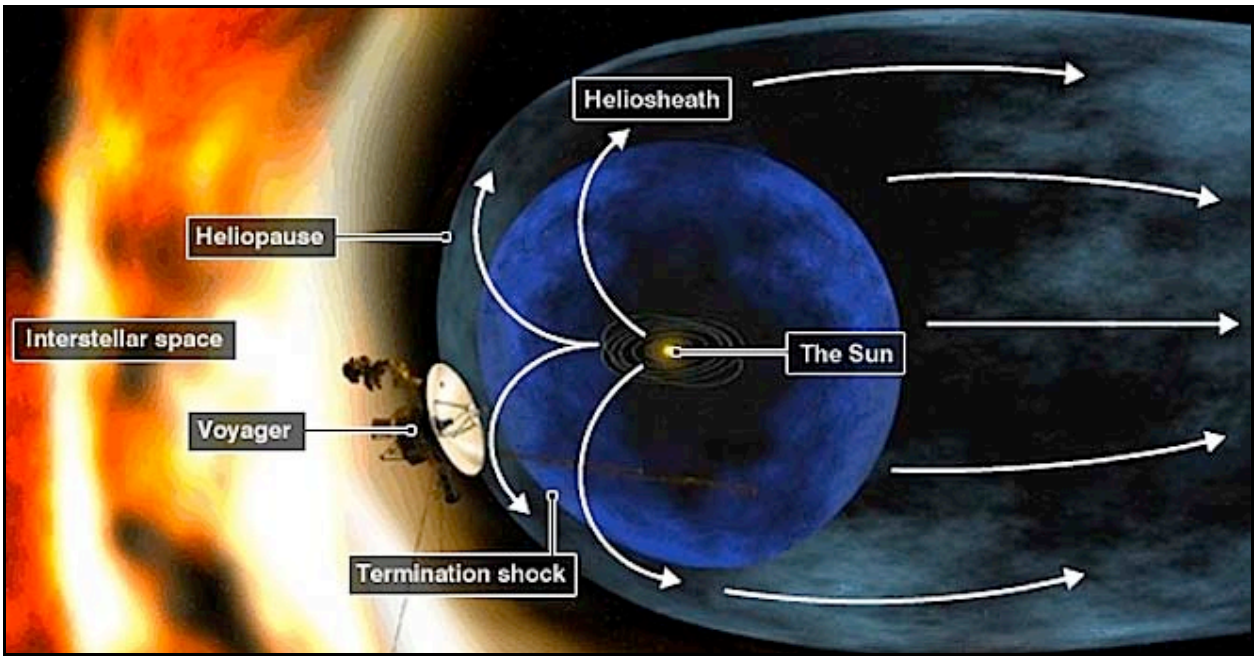
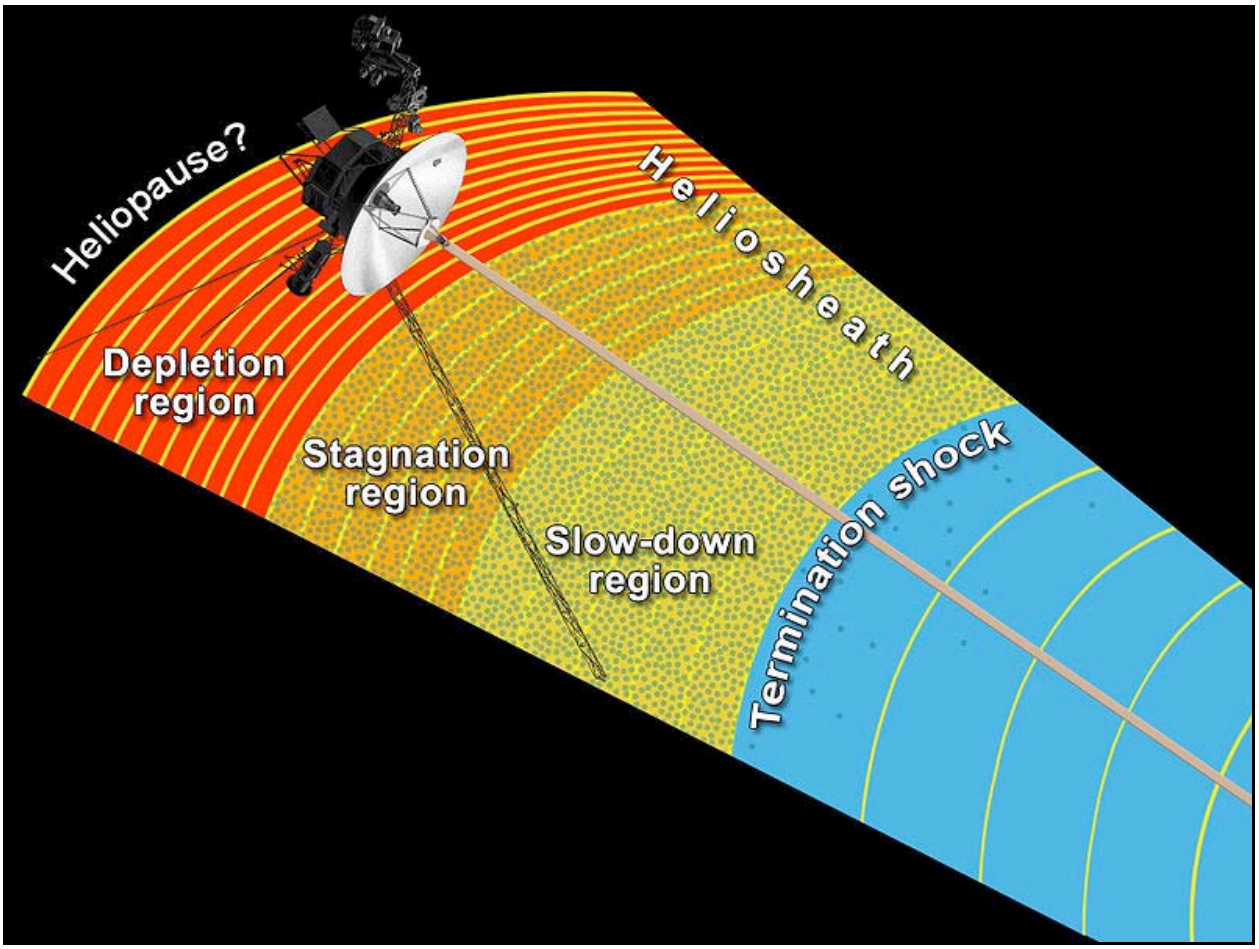
http://www.bbc.co.uk/news/science-environment-21866532



This schematic shows Voyager 1's journey through our solar system.



The Heliosphere and Voyager 1's relative position to the Sun in 2013.

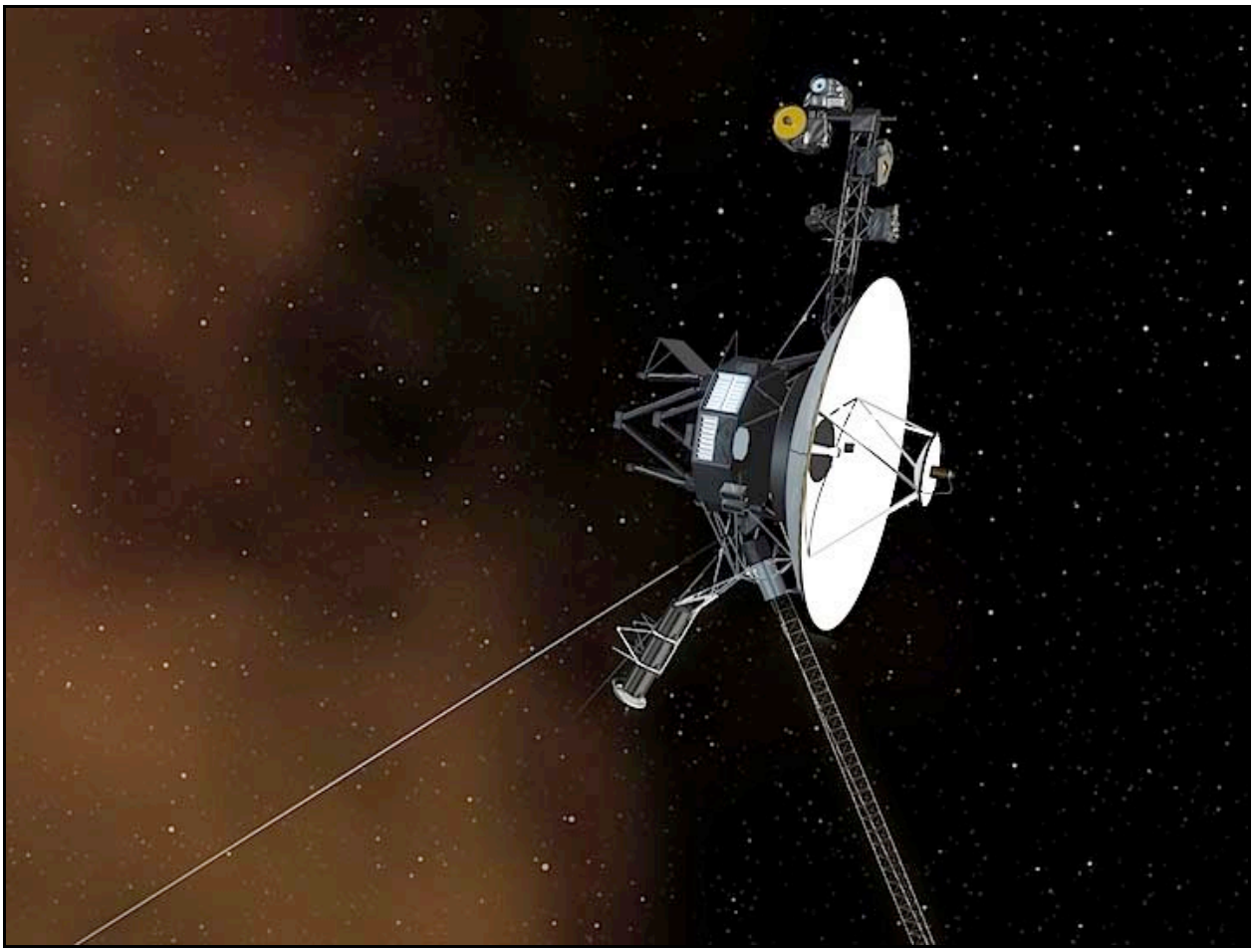


Moving into Interstellar Space

This artist's concept shows the outer layers of our solar bubble, or heliosphere, and nearby interstellar space. NASA's Voyager 1 is currently exploring a region of interstellar space, which is the space between stars that still feels charged particle and magnetic field influences from the heliosphere. The magnetic field lines (yellow arcs) appear to lie in the same general direction as the magnetic field lines emanating from our sun.

In the outer layers of the solar bubble — labeled here the "slow-down region" and the "stagnation region"— the magnetic field lines generated by our sun are piling up and intensifying. The green dots are the low-energy charged particles that are accelerated in the heliosphere's turbulent outer layer.

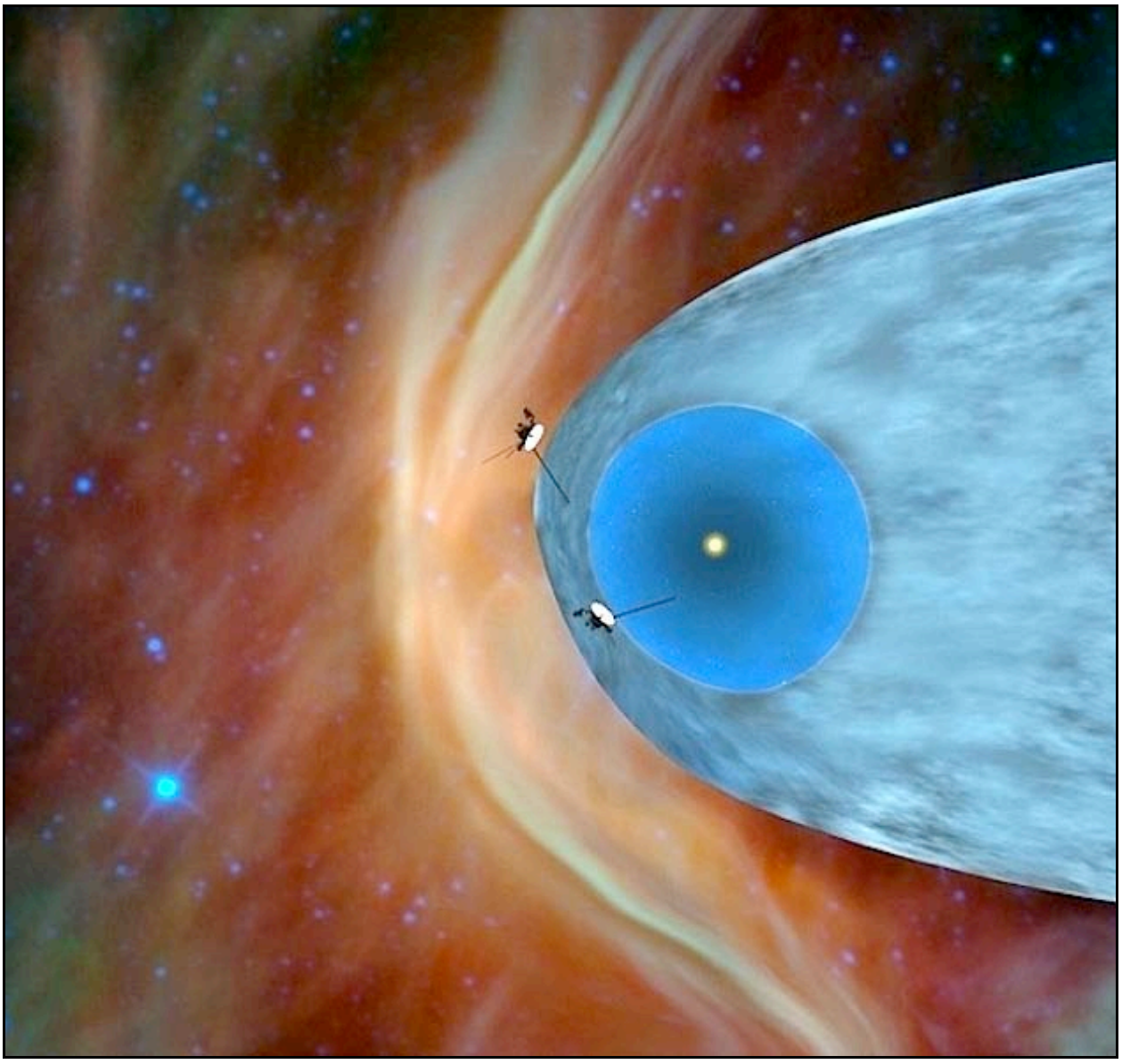
The heliosheath, or the outer layer of our solar bubble, begins at the termination shock, where the wind of plasma that streams off the sun abruptly slows down from supersonic speeds and becomes turbulent. In the slow-down region, the solar wind slows down and stops moving outward in the stagnation region. Previously, scientists thought there was a layer in our solar bubble called the depletion region, where these low-energy charged particles from the heliosheath disappeared. With new data, scientists now know that the depletion region was actually the beginning of interstellar space.



Voyager 1 Entering Interstellar Space

This artist's concept depicts NASA's Voyager 1 spacecraft entering interstellar space, or the space between stars. Interstellar space is dominated by the plasma, or ionized gas, that was ejected by the death of nearby giant stars millions of years ago. The environment inside our solar bubble is dominated by the plasma exhausted by our sun, known as the solar wind.

The interstellar plasma is shown with an orange glow similar to the color seen in visible-light images from NASA's Hubble Space Telescope that show stars in the Orion nebula traveling through interstellar space. Image credit: NASA/JPL-Caltech



One Voyager Out, One Voyager In

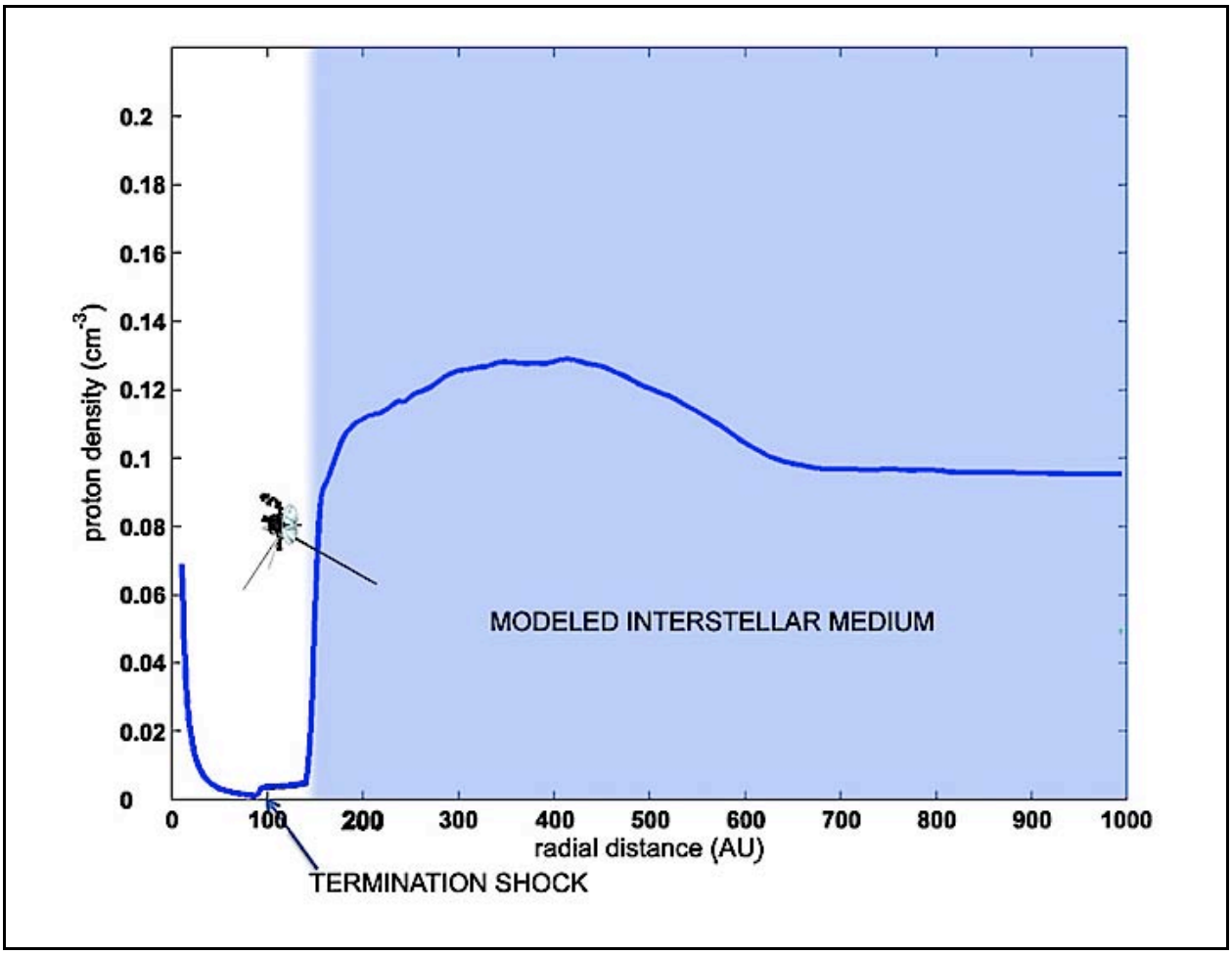
This artist's concept shows the general locations of NASA's two Voyager spacecraft. Voyager 1 (top) has sailed beyond our solar bubble into interstellar space, the space between stars. Its environment still feels the solar influence. Voyager 2 (bottom) is still exploring the outer layer of the solar bubble. Image credit: NASA/JPL-Caltech

A painting of Voyager 1 just outside of our Solar System, September 12, 2013 ~ 18.7 billion kilometers (11.6 billion miles) from Earth.

"Voyager is in interstellar space — the space between the stars."
— Dr. Ed Stone, Voyager Project Scientist

"PASADENA, Calif. — NASA's Voyager 1 spacecraft officially is the first human-made object to venture into interstellar space. The 36-year-old probe is about 12 billion miles (19 billion kilometers) from our sun. New and unexpected data indicate Voyager 1 has been traveling for about one year through plasma, or ionized gas, present in the space between stars. Voyager is in a transitional region immediately outside the solar bubble, where some effects from our sun are still evident. A report on the analysis of this new data, an effort led by Don Gurnett and the plasma wave science team at the University of Iowa, Iowa City, is published in Thursday's edition of the journal *Science*. "Now that we have new, key data, we believe this is mankind's historic leap into interstellar space," said Ed Stone, Voyager project scientist based at the California Institute of Technology, Pasadena. "The Voyager team needed time to analyze those observations and make sense of them. But we can now answer the question we've all been asking — 'Are we there yet?' Yes, we are."

Voyager 1 first detected the increased pressure of interstellar space on the heliosphere, the bubble of charged particles surrounding the sun that reaches far beyond the outer planets, in 2004. Scientists then ramped up their search for evidence of the spacecraft's interstellar arrival, knowing the data analysis and interpretation could take months or years. Voyager 1 does not have a working plasma sensor, so scientists needed a different way to measure the spacecraft's plasma environment to make a definitive determination of its location. A coronal mass ejection, or a massive burst of solar wind and magnetic fields, that erupted from the sun in March 2012 provided scientists the data they needed. When this unexpected gift from the sun eventually arrived at Voyager 1's location 13 months later, in April 2013, the plasma around the spacecraft began to vibrate like a violin string. On April 9, Voyager 1's plasma wave instrument detected the movement. The pitch of the oscillations helped scientists determine the density of the plasma. The particular oscillations meant the spacecraft was bathed in plasma more than 40 times denser than what they had encountered in the outer layer of the heliosphere.



Density of this sort is to be expected in interstellar space. The plasma wave science team reviewed its data and found an earlier, fainter set of oscillations in October and November 2012. Through extrapolation of measured plasma densities from both

events, the team determined Voyager 1 first entered interstellar space in August 2012. "We literally jumped out of our seats when we saw these oscillations in our data — they showed us the spacecraft was in an entirely new region, comparable to what was expected in interstellar space, and totally different than in the solar bubble," Gurnett said.

"Clearly we had passed through the heliopause, which is the long-hypothesized boundary between the solar plasma and the interstellar plasma." The new plasma data suggested a timeframe consistent with abrupt, durable changes in the density of energetic particles that were first detected on **August 25, 2012**. The Voyager team generally accepts this date as the date of interstellar arrival. The charged particle and plasma changes were what would have been expected during a crossing of the heliopause.

"The team's hard work to build durable spacecraft and carefully manage the Voyager spacecraft's limited resources paid off in another first for NASA and humanity," said Suzanne Dodd, Voyager project manager, based at NASA's Jet Propulsion Laboratory, Pasadena, Calif. "We expect the fields and particles science instruments on Voyager will continue to send back data through at least 2020. We can't wait to see what the Voyager instruments show us next about deep space."

Voyager 1 and its twin, Voyager 2, were launched 16 days apart in 1977. Both spacecraft flew by Jupiter and Saturn. Voyager 2 also flew by Uranus and Neptune. Voyager 2, launched before Voyager 1, is the longest continuously operated spacecraft. It is about 9.5 billion miles (15 billion kilometers) away from our sun. Voyager mission controllers still talk to or receive data from Voyager 1 and Voyager 2 every day, though the emitted signals are currently very dim, at about 23 watts -- the power of a refrigerator light bulb. By the time the signals get to Earth, they are a fraction of a billion-billionth of a watt. Data from Voyager 1's instruments are transmitted to Earth typically at 160 bits per second, and captured by 34- and 70-meter NASA Deep Space Network stations. Traveling at the speed of light, a signal from Voyager 1 takes about 17 hours to travel to Earth. After the data are transmitted to JPL and processed by the science teams, Voyager data are made publicly available.

"Voyager has boldly gone where no probe has gone before, marking one of the most significant technological achievements in the annals of the history of science, and adding a new chapter in human scientific dreams and endeavors," said John Grunsfeld, NASA's associate administrator for science in Washington. "Perhaps some future deep space explorers will catch up with Voyager, our first interstellar envoy, and reflect on how this intrepid spacecraft helped enable their journey."

Scientists do not know when Voyager 1 will reach the undisturbed part of interstellar space where there is no influence from our sun. They also are not certain when Voyager 2 is expected to cross into interstellar space, but they believe it is not very far behind. JPL built and operates the twin Voyager spacecraft. The Voyagers Interstellar Mission is a part of NASA's Heliophysics System Observatory, sponsored by the Heliophysics Division of NASA's Science Mission Directorate in Washington. NASA's Deep Space Network, managed by JPL, is an international network of antennas that supports interplanetary spacecraft missions and radio and radar astronomy observations for the exploration of the solar system and the universe.

The cost of the Voyager 1 and Voyager 2 missions— including launch, mission operations and the spacecraft's nuclear batteries, which were provided by the Department of Energy—is about $988 million through September. For a sound file of the oscillations detected by Voyager in interstellar space, animations and other information, visit: http://www.nasa.gov/voyager and http://www.jpl.nasa.gov/interstellarvoyager/ . For an image of the radio signal from Voyager 1 on February 21st by the National Radio Astronomy Observatory's Very Long Baseline Array, which links telescopes from Hawaii to St. Croix, visit: http://www.nrao.edu.

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Dr. Allan Chapman of Oxford University wrote this tribute to Voyager 1 for the BBC.

"Farewell Voyager, after your magnificent work teaching us more about the other worlds of the Solar System. You were the latest 'upgrade' in optical and mechanical technology, which began in 1609 when first Thomas Harriot and then Galileo brought home to mankind that our ancestral five natural senses could be strengthened - indeed, unimaginably strengthened -by ingenious devices.

Two spectacle lenses in a tube began the saga, 404 years ago. Then, once the penny had dropped, we quickly learned how to create ever greater magnifications. Then came photography, then spectroscopy—and then computing and imaging. And then, how to send our 'artificial organs' of seeing into the very depths of space, and still stay in touch with you.

And now, you have more than earned your keep, and deserve the long, long rest that awaits you as you glide for evermore through realms of light and energy.

***Vola in Pace* - 'Fly in Peace'. "**