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Voyager: Venturing Outside the Solar System

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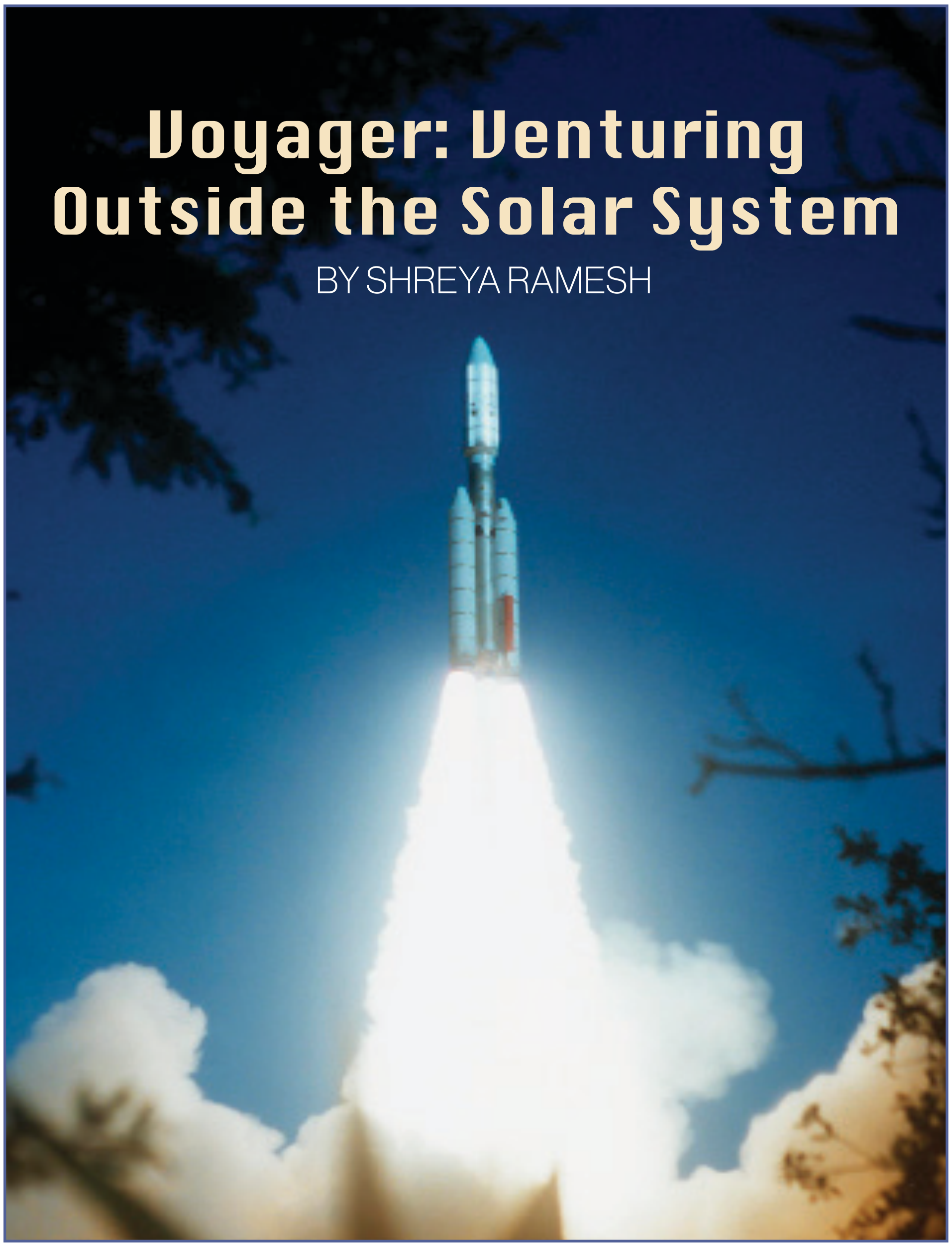

We often wonder how many questions about our universe have yet to be answered, but we forget to consider the questions that remain unanswered within our very own solar system. In the past 45 years, the Voyager probes have been among the first to venture out into the solar system, making discoveries and answering questions about the gas giants in the outer solar system. Only recently have the Voyager missions progressed beyond the depths of the solar system and far into interstellar space. Even after so long, these probes continue to relay never-before-seen information about the past, present, and future of our universe.

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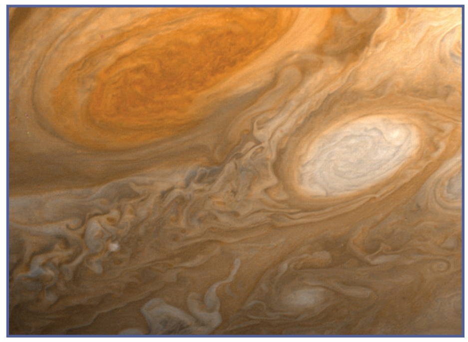

Figure 1: Images of Jupiter's surface captured by the Voyager missions (colorized).

HISTORY OF THE MISSIONS

The Voyager missions were one of NASA's earliest projects. In 1965, scientists discovered that the alignment of the planets would allow probes to be launched in the late 1970s to visit the outer planets, a phenomenon that occurs once every 176 years.[1] This alignment would let the probes venture out into space by swinging forward with the gravitational assistance from the planets, saving fuel and energy in the process. NASA scientists designed and constructed the probes over the next decade, and the Voyager missions were launched in 1977. Voyager 2 was launched in August 1977, followed by Voyager 1 in September 1977 due to differences in trajectories on their way to the outer planets and interstellar space. Once both missions passed the Asteroid Belt between the orbits of Mars and Jupiter after a few years, Voyager 1 and Voyager 2 flew by Jupiter in 1979 and took many pictures of Jupiter, allowing researchers to discover new moons and rings.[2]

Throughout the 1980s, the probes made numerous fly-bys of Uranus and Neptune, making many discoveries along the way. For example, they discovered that Uranus and Neptune are ice giants and that Neptune has partial rings just like many other gas giants in our solar system. The probes took plenty of photos of the gas giants and of the solar system as they moved out into interstellar space. In 1990, Voyager 1 turned on its camera one last time to take a photo of the solar system and Earth. The image, now dubbed "The Pale Blue Dot," captured Earth nearly 3.7 billion miles away, showing us how far we have ventured out into the solar system.[3] After 35 years of nonstop travel and exploration, Voyager 1 finally passed the heliopause, a region of the solar system protected by the

Figure 2: "The Pale Blue Dot," as captured by Voyager 1. The blue dot on the right-most band in the image is Earth.

Sun from high-energy cosmic rays, and entered interstellar space on August 25, 2012.[4] Shortly after, Voyager 2 entered interstellar space on November 5, 2018.[5] Now, both of the probes could make measurements and collect data about the intensity of cosmic rays and the interstellar magnetic field of interstellar space. Such measurements are critical for us to deepen our understanding of our universe and its origins, such as how the Sun influences our solar system and outer space around it as well as the compositions of planets we have never visited before.[6]

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ENGINEERING AND DESIGN

Currently, five instruments are actively collecting data of magnetic fields, low-energy charged particles, plasmas, and cosmic rays. These teams receive real-time data in 160 bits per second (bps) using the 34-meter Deep Space Network of antennas and facilities.[7] The Voyager missions are equipped with several instruments and sensors to relay data collected from flybys back to Earth. They contain cameras, spectrometers, polarimeters, radio receivers, and a variety of sensors to detect particles and perform visual scans of atmospheres. They use their communications systems to then transmit the data back to Earth.[8] Several key instruments, including a magnetometer, an ultraviolet spectrometer, and the plasma wave subsystems, are critical for the five ongoing science investigations, such as magnetic field and plasma wave investigations. These systems are powered by three radioisotope thermoelectric generators that use decaying plutonium-238, generating about 249 watts of power per spacecraft.[9]

The magnetometer measures the changes in the sun's magnetic field as well as the effects of solar winds on the outer planets and their moons. This instrument was also critical in analyzing the transition region between interstellar space and the solar system in addition to transmitting critical information about the galactic magnetic field.[10] The ultraviolet spectrometer measures UV light in space, which helps detect certain atoms or ions and infer reactions via atomic absorption and emission spectroscopy. This system determines a planet's atmospheric composition and the composition of planetary rings based on the emission lines by measuring between 40 and 180 nm.[11] The plasma wave subsystem helps characterize plasma conditions in solar winds and interstellar space. The subsystems consist of 2 large antennae at right angles and measure frequencies between 10 Hz to 56 kHz. By looking at plasma as functions of energy and charge, scientists can determine plasma density, temperature, and velocity.[12]

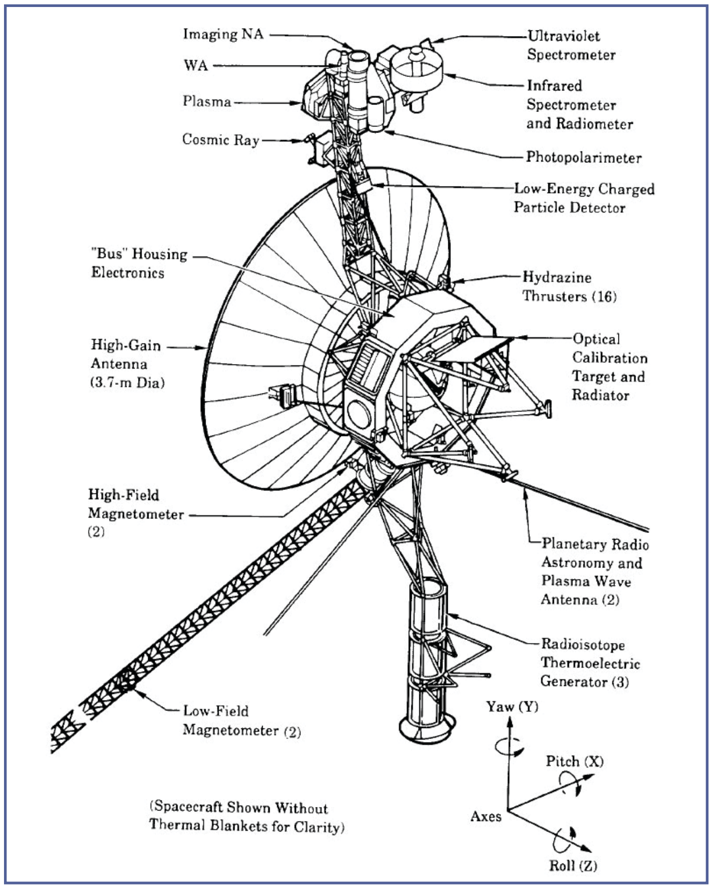

Figure 3: Schematic representation of the Voyager probes.

There are several other critical instruments onboard, such as the Imaging Science Subsystems, which take important measurements of interstellar space and other deep space objects. However, these instruments are only expected to operate until 2025 and are estimated to be in the Deep Space Network range until roughly 2036 before perpetually traveling into the vastness of space.[13]

THE GOLDEN RECORDS

As scientists were designing Voyager 1 and 2, they knew that these probes would be in the depths of space for an indefinite period and that there was a small chance that alien species might see these probes. They wanted to provide a way for extraterrestrial intelligent life to learn about humans and life on Earth, and thus, they created the Golden Records. Astronomer Carl Sagan was tasked with curating a representation of Earth and its diversity. The physical record contains various audio recordings, including the sounds of nature, spoken greetings, and music, and images converted into analog form, including photos of Earth in space, human anatomy, and nature. On the cover of the record, scientists created an assemblage of instructions that tells aliens how to play the record and decode the information alongside an interstellar map that shows where Earth is located in relation to other stars and celestial landmarks.[14] The Voyager missions are not expected to reach any other planetary system for another 40,000 years, but scientists hope that when the probes reach any nearby planetary systems, alien civilizations will find the probes and know that there is more intelligent life in the universe.[14]

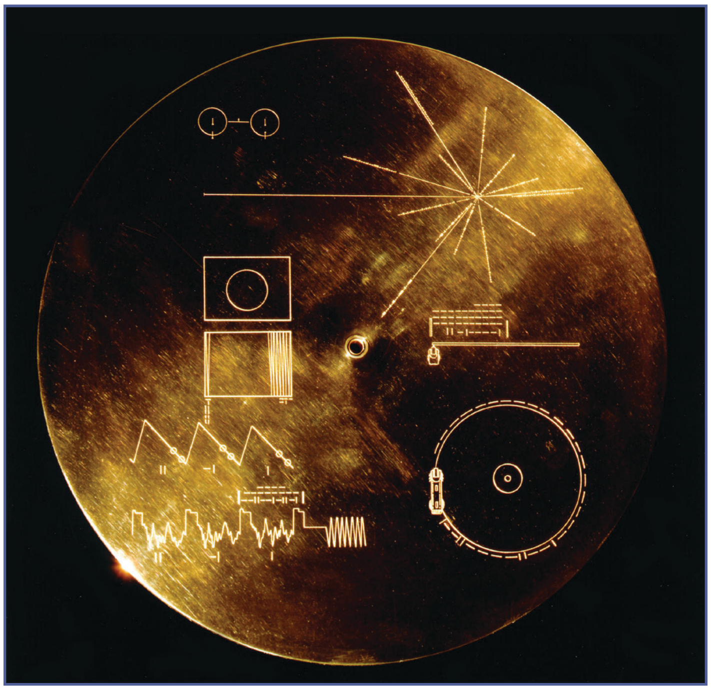

Figure 4: The cover of the Golden Records that contain information about decoding the record and an interstellar map of Earth.

WHAT IS NEXT?

Though Voyager missions are expected to be operational only until 2025, they will continue to drift through space and toward other planets and solar systems for the rest of eternity. Voyager 1 is currently traveling toward the star Gliese 445, and Voyager 2 continues to drift towards Ross 248, a small star on its way to Sirius.[4] As the Voyager missions travel deeper and deeper into interstellar space and farther away from us, we are reminded that they are a way for us to leave our mark in the universe long after we are gone.

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