NASA

VOYAGER 2 NEPTUNE ENCOUNTER PRESS KIT

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CONTENTS

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VOYAGER 2 ENCOUNTER OF NEPTUNE

Voyager 2, one of a pair of twin spacecraft launched by NASA in 1977, will complete its 12-year tour of the four giant outer planets of the solar system when it flies closely past Neptune at 12 midnight EDT, on Aug. 24, 1989.

Voyager's flyby will be the first time a spacecraft has visited Neptune, which orbits the sun at an average distance of 2.793 billion miles. Although Neptune is the fourth largest planet, it is invisible to the naked eye from Earth. Even the biggest and best telescopes on Earth have been able to discern only meager details about the planet.

Neptune is pale blue, about four times as big as Earth, and probably has a center consisting of a slurry-like mixture of ice and rock surrounded by gases of hydrogen, helium and methane. It holds in its orbit what appear to be fragmented rings and one of the largest and most interesting moons in the solar system, Triton. Striking latitudinal bands, a giant dark spot and smaller light spots have become apparent in Neptune's colorful atmosphere as Voyager has approached the planet. The early observations show that Neptune possesses a much more visibly, lively atmosphere than its supposed twin, Uranus, and that Neptune shares broad atmospheric characteristics with its larger planetary cousins Jupiter and Saturn.

Voyager 2 will pass within 3,000 miles of Neptune's cloud tops, which is closer than the flyby distance of any of Voyager 2's previous encounters. The spacecraft flew past Jupiter on July 9, 1979, Saturn on Aug. 25, 1981 and Uranus on Jan. 24, 1986.

The aging spacecraft's last close look at any body in the solar system will occur at 5:14 a.m. EDT, on Aug. 25, 5 hours after the closest approach to Neptune, when Voyager 2 will pass within 24,000 miles of the surface of the Neptunian moon Triton. The exact flyby distance to Triton won't be known until after it happens, because the moon's diameter cannot be measured precisely until the spacecraft gets there. Estimates based on observations from Earth put Triton's diameter at less than 2,240 miles.

Triton is expected to be one of the most interesting objects of the dozens Voyager 1 and 2 have studied in their long missions. The moon is thought to possess an atmosphere of methane and possibly nitrogen. In recent years, scientists have debated whether Triton might have frozen or liquid pools of nitrogen on its surface. In any case, studies from Earth suggest that whatever exists on Triton's surface should be visible through the atmosphere.

From Neptune, it will take 4 hours, 6 minutes for Voyager's radio transmissions -- traveling at the speed of light (186,000 miles per second) -- to reach Earth. The data will be received at NASA's Jet Propulsion Laboratory (JPL), Pasadena, Calif., where the Voyager mission was conceived, the spacecraft designed and constructed and the mission controlled.

The Neptune encounter takes place the week of the 12th anniversary of Voyager 2's Aug. 20, 1977 launch. An identical spacecraft, Voyager 1, was launched Sept. 5, 1977, and flew past Jupiter on March 5, 1979 and Saturn on Nov. 12, 1980.

The two Voyager spacecraft are the most intelligent machines to leave Earth's gravity, and they have accomplished the most productive mission of scientific exploration ever conducted by NASA. Together, the Voyagers have returned more new information about the outer planets and the interplanetary medium than had previously existed.

When launched, the spacecraft were designed to operate for about 5 years and encounter only two planets, Jupiter and Saturn. The destinations of Uranus and Neptune were authorized long after launch and Voyager 2 has gone the extra distance.

Two key spacecraft characteristics made the extra planetary encounters possible: reprogrammable onboard computers' receptive creative software engineering and three radioisotope thermoelectric generators -- devices that convert the heat from the radioactive decay of plutonium 238 into electricity to power the spacecraft components and instruments. The radioisotope thermoelectric generators allow the Voyager spacecraft to operate in regions of the solar system where solar panels cannot be used.

Voyager 2 already has begun returning a wealth of new information about Neptune. The imaging system alone -- just one of 11 scientific experiments on the spacecraft -- will return nearly 8,000 photographs of the remote, blue planet, its truncated system of rings, the Neptunian moons known to exist, as well as others that likely await discovery.

The Neptune encounter promises as many surprises as the Voyager spacecraft found at Jupiter, Saturn and Uranus. Remarkable phenomena and many new celestial bodies have been found wherever the Voyagers have traveled. Given past experience, Voyager scientists believe that, at the very least, the spacecraft will find more moons, a unique ring system and powerful storms in Neptune's blue atmosphere.

Among the major discoveries the Voyagers made at Jupiter were active volcanoes on the satellite Io, thin rings of dust encircling the planet and three new moons orbiting our solar system's largest planet.

At Saturn, Voyager 1 found that the large Saturnian moon Titan has an atmosphere composed primarily of nitrogen containing simple organic compounds that might have evolved into living organisms if Titan was not so cold. Several moons were discovered. Saturn's rings were found to be dynamic, with thousands of tiny wave-like features caused by the gravitational effects of small moons found in and around the rings. These radial spoke-like features may be electrically charged dust particles levitated above the ring plane.

At Uranus, Voyager 2 found a strange magnetic field with a corkscrew-shaped tail extending millions of miles into space. From the information Voyager returned about the magnetic field, Voyager scientists inferred that electrically conductive atmospheric layers must exist deep beneath the deceptively bland, visible atmosphere. Voyager's close-ups of the Uranian moon, Miranda, showed the small satellite to be dramatically fractured by geophysical forces. Miranda was found to have one of the most geologically diverse landscapes seen in the solar system.

More than 100,000 photos were taken during the Voyager 1 and 2 encounters of Jupiter and Saturn, and another 7,000 images were returned by Voyager 2 during the Uranus encounter.

Since the Uranus encounter, improvements have been made to the huge antennas at the NASA/JPL Deep Space Network (DSN) stations in Spain, Australia and California through which communications with the Voyagers are conducted. The three largest DSN antennas have been enlarged from 210 feet to 230 feet in diameter to maximize the amount of data that can be received from the spacecraft. The increased antenna aperture is extremely valuable, given that the strength of the signal received from Voyager amounts to only one ten-quadrillionth (1/10,000,000,000,000,000th) of a watt. For comparison, consider that a digital wristwatch operates at a power level 20 billion times greater. In addition to the enlarged antennas, the hearing of their super-sensitive receivers has been made even more acute with state-of-the-art supercooled, low-noise amplifiers.

Because of Neptune and Voyager's location in the sky, the Australian tracking site has the best radio "view" of the spacecraft and will receive most of the data returned during closest approach. The spacecraft will be almost directly above the Australian complex during the encounter. This is beneficial because Voyager's signal has a more direct, and thus less disruptive, path through the Earth's atmosphere there than it does when received at the stations in Spain or California. As during the Uranus encounter, the DSN antennas will be electronically linked to other large antennas that will simultaneously receive Voyager's faint signal, allowing more signal to be captured from the spacecraft. This technique, called arraying, greatly increases the data return from Voyager.

The Australian government's 210-foot Parkes Radio Telescope again will support the DSN when Voyager returns data during its closest approaches to Neptune and Triton.

The 200-mile distance between the DSN tracking station at Tidbinbilla and the Parkes Radio Telescope reduces the risk that data at both stations might be jeopardized due to simultaneous rain showers or thunderstorms.

The 210-foot Usuda Radio Observatory, owned by the Institute of Space and Astronautical Science of Japan, will join the Australian complex in collecting critical radio science observations during Voyager's closest approach to Neptune. In addition to the antenna array in Australia, the 27 90-foot antennas of the National Radio Astronomy Observatory's Very Large Array near Socorro, N.M., will be arrayed with the DSN station in California.

An unprecedented number of radio antennas on Earth are involved in the upcoming encounter. Altogether, 38 antennas on four continents will be used to receive data from Voyager during the Neptune flyby.

Mission controllers have taken full advantage of their ability to reprogram the 12-year-old spacecraft over the past several years and have taught it new methods for acquiring, processing and sending data. Routines executed by Voyager's onboard computers have been customized to allow the spacecraft to gather, compress and return as much information as it can while at Neptune. These new capabilities will help Voyager overcome problems caused by the dim lighting conditions at Neptune and the distance over which the spacecraft must communicate with Earth.

Voyager's flight path will be fine-tuned within days of the spacecraft's nearest encounter with Neptune. The point at which Voyager makes its closest approach to the planet was chosen to send the spacecraft on to its flyby of Triton. The trajectory will allow Voyager to avoid colliding with the vestigial rings that probably exist around the planet, while sending the spacecraft as close to the top of the planet's atmosphere as safety permits. Flying too close to Neptune could cause enough atmospheric drag on Voyager to damage the spacecraft or change its course. Last-minute changes in Voyager's instructions also will allow controllers to update the spacecraft on the precise locations of its targets and permit study of any new features or new moons that may become apparent as the spacecraft approaches Neptune.

Picture-taking at Neptune presents a multifaceted hurdle. Because of the faint sunlight at Neptune, which gets about a thousand times less sunlight than Earth, Voyager's camera shutters must be open longer to gather more light. Lengthy exposures in combination with the relative motion of the spacecraft and its target would normally result in badly smeared images. Innovative methods have been devised, however, to overcome these difficulties.

The encounter formally ends on Oct. 2, 1989, when Voyager 2 will be well past Neptune. From then on, Voyager 2 will join Voyager 1 in examinations of ultraviolet stars and in studies of fields, particles and waves in interplanetary space. It will begin its search for the heliopause -- the boundary between the solar wind and interstellar space. The heliopause has never been reached by any spacecraft, and the Voyagers may be the first to pass through this region. It is thought to exist somewhere between 50 and 150 astronomical units (5 billion to 14 billion miles) from the sun. Scientists expect that sometime in the next 10 years the two spacecraft will cross an area known as the termination shock. This is where the million mile-per-hour solar wind slows to about 250,000 miles-per-hour as the pressure of interstellar space impinges on the sun's influence. Ten to 20 years after reaching the termination shock, the Voyagers will cross the heliopause -- the end of the sun's influence.

Communications with the two spacecraft may continue until about 2020. At about that time, the electrical power provided to the spacecraft by their plutonium-based electrical generators will be below the level required to keep the Voyagers operating.

Eventually, the Voyagers will remotely pass by other stars. In about 40,000 years, Voyager 1 will fly within 1.6 light-years (9.3 trillion miles) of AC+79 3888, a star in the constellation of Camelopardalis. At about the same time, Voyager 2 will come within about 1.7 light-years of the star Ross 248. In 296,000 years, Voyager 2 will pass the star Sirius at a distance of about 4.3 light-years (25 trillion miles). The Voyagers are destined to continually wander through the Milky Way.

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EDITOR'S NOTE: Encounter times used in this document denote the time the event occurs at the spacecraft; the data from the spacecraft will not be received on Earth until 4 hours, 6 minutes later.

THE VOYAGER MISSION

The Voyager mission was conceived and the spacecraft developed and constructed by the NASA Jet Propulsion Laboratory (JPL), Pasadena, Calif. The mission was born of a concept known as "The Grand Tour" to take advantage of a geometric arrangement of the outer planets in the late 1970s. This layout of Jupiter, Saturn, Uranus and Neptune, which occurs about every 176 years, would allow a properly pointed spacecraft to swing from one planet to the next without using large spacecraft propulsion systems. The gravity of each planet would bend the flight path and increase the velocity of the spacecraft enough to deliver it to its next destination.

Because they would be traveling too far from the sun to use solar panels, the Voyagers would use radioisotope thermoelectric generators. These devices, used on other deep space missions, convert the heat, produced from the natural radioactive decay of plutonium, into electricity to power the spacecraft instruments, computers and radio.

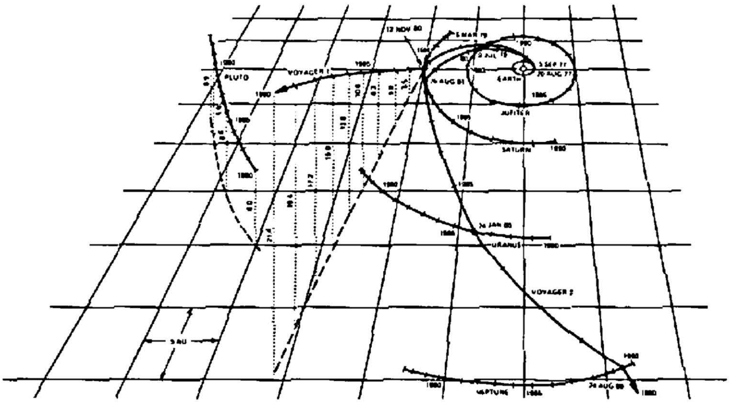
The Voyager mission was originally funded to conduct intensive flyby studies of only Jupiter and Saturn. From NASA's Kennedy Space Center, Fla., Voyager 2 was launched first, on Aug. 20, 1977. Voyager 1 was launched on a faster, shorter trajectory on Sept. 5, 1977. Both were launched atop Titan-Centaur launch vehicles.

Voyager 1 encountered Jupiter on March 5, 1979 and Saturn on Nov. 12, 1980. Voyager 2 encountered Jupiter on July 9, 1979 and Saturn on Aug. 25, 1981.

Mission planners might have sent one of the Voyagers directly from Saturn to Pluto, but geometric constraints would prevent the same spacecraft from making close flybys of Saturn's moon Titan, Uranus or Neptune. Titan was a critical target of the mission, so Voyager 1 would focus on that large moon and the Saturnian rings. In conducting its close studies of Saturn's rings and Titan, Voyager 1's flight path was thus bent inexorably northward out of the ecliptic plane -- the plane in which most of the planets orbit the sun. Voyager 2 meanwhile, was targeted to a point at Saturn that would automatically take it to Uranus and Neptune. Pluto had to be left for exploration by future generations.

After the successful completion of Voyager 2's Saturn encounter, NASA provided additional funding to continue operating the two spacecraft and authorized JPL to explore Uranus and Neptune with Voyager 2. The spacecraft encountered Uranus on Jan. 24, 1986, returning detailed photos and other data on the planet, its moons, rings and magnetic field.

Voyager 1 is still in operation and continues to press outward, conducting studies of interplanetary space. Its instruments may be the first to sense the boundary of this solar system and the beginning of interstellar space.



Trajectories of Voyagers 1 & 2

VOYAGER QUICK LOOK FACTS

CLOSEST APPROACHES

Location	Date	Time (at the spacecraft)	Distance
Nereid	8/24/89	8:12 p.m. EDT	2,890,000 mi
Ring-plane crossing (inbound)	8/24/89	11:03 p.m. EDT	
Neptune	8/24/89	12:00 midnight EDT	3,000 mi
Ring-plane crossing (outbound)	8/25/89	1:29 a.m. EDT	
Triton	8/25/89	5:14 a.m. EDT	23,600 mi

GENERAL FACTS

Voyager 1 Launch Date	September 5, 1977
Voyager 2 Launch Date	August 20, 1977
One-way light time, Voyager at Neptune to Earth	4 hours, 6 minutes
Distance of Voyager 2 from Earth on August 24, 1989	2,748,802,418 mi
Velocity of Voyager 2 (on 8/24/89)	Geocentric 90,381 mph Heliocentric 43,236 mph
Total (arc length) distance Voyager 2 has traveled since launch at closest approach	4.4 billion mi.
Total number of images taken at Neptune	8,000
Cost of Voyager missions as of Neptune Encounter (for both spacecraft not including launch, tracking or data acquisition)	$556 million

General directions of Voyagers after leaving solar system

.....Voyager 1 northward to the star AC+79 in Camelopardolis

.....Voyager 2 southward to the star Ross 248 in Andromeda

NEPTUNE

Neptune is the only planet to have been located through mathematical predictions rather than by systematic observations of the sky.

In the years following William Herschel's discovery of Uranus in 1781, astronomers noted that Uranus was not faithfully following its predicted path. Uranus seemed to accelerate in its orbit prior to 1822 and then slow down. Amateur astronomer T.J. Hussey in England suggested that Uranus's behavior might be attributed to the gravitational pull of an unknown planet.

Two mathematicians, each working without knowledge of the other, set out in search of the cause of Uranus's erratic behavior. In 1845, Englishman John Couch Adams took his calculations to Astronomer Royal Sir George Airy at the Greenwich Observatory. But Airy did nothing with the information. Then in 1846, Frenchman Jean Joseph Urbain Le Verrier, unable to interest astronomers in his own country, sent similar calculations to Johann Gottfried Galle at the Berlin Observatory. Galle began a search immediately. His assistant, Heinrich Louis d'Arrest, provided him with the latest star maps of the area in question. After about an hour's telescopic search on the first night, they found an unidentified disc in the sky. On the second night, after the object had moved, their discovery of an eighth planet could be claimed.

Currently, Neptune is the farthest planet from the sun. Pluto moved closer to the sun than Neptune in early 1979 and will move farther away in early 1999.

Neptune's equatorial diameter is about 30,700 miles making it only slightly smaller than Uranus, which has a diameter of 31,760 miles. But Neptune is denser than Uranus, which means that Neptune contains heavier material.

Neptune is believed to be composed primarily of hydrogen and helium. Atmospheric methane, which absorbs red light, gives Neptune its bluish hue. Clouds of methane are expected to condense at a pressure level of about 2 bars (twice the atmospheric pressure at sea level on Earth), at a temperature level of about -307 degrees Fahrenheit. Other cloud layers, including water ice clouds, probably exist deeper in the atmosphere.

At a distance of nearly 3 billion miles from the sun, Neptune receives about 1,000 times less sunlight than does Earth, and about two-and-a-half-times less than Uranus. But strangely, Neptune's overall temperature is about the same as that of Uranus's. Scientists believe that to account for this discrepancy, Neptune must have some internal heat of its own, as do Jupiter and Saturn.

Neptune's rotation rate is between 17 and 18 hours. The planet's rotational axis is tilted about 29 degrees to the plane of its orbit around the sun. (For comparison, the Earth's axis tilts 23.5 degrees.) Neptune's south pole is experiencing summer and "midnight sun" while its north pole is cloaked in darkness. Each season on Neptune lasts more than 40 years.

Scientists expect Neptune to have a magnetic field as do Mercury, Earth, Jupiter, Saturn and Uranus. It should be detected about 1 day before the spacecraft's closest approach to the planet.

Neptune's Rings

In recent years, astronomers have used a classic technique to search for rings around Neptune. On the rare occasions when Neptune moves in front of a bright star, observers on Earth look for flickers in the starlight. Rings may be deduced if the star's light dims or blinks on and off at regular intervals on both sides of the planet. In Neptune's case, the data has hinted of some ring material, but nothing has been observed to indicate that complete rings encircle the planet. The results of these searches lead scientists to believe that Neptune must be orbited by partial rings, or ring arcs, that are most likely composed of dust or pebble-sized material. There may be three narrow 5- to 12-mile nearly circular sets of arcs in or near Neptune's equatorial plane at distances that range from 11,000 to 26,000 miles from the planet's cloud tops.

Voyager 2's flight path carries the spacecraft close to the outermost set of possible ring arcs. As at Uranus, there is likely to be diffuse material that could fill much of the space within the ring arc region. Although such a diffuse sheet of material is not expected outside the ring arc area, the flight path can be adjusted as late as 10 days before the closest approach to Neptune in the event more distant ring arcs are discovered.

Several observations will be retargeted when individual ring arcs are located in images taken as the spacecraft approaches the planet. Pointing instructions for Voyager may be uplinked only a day or two before the spacecraft's closest approach to the planet.

As Voyager passes behind the rings, changes in Voyager's radio signal will be analyzed to determine the sizes of the particles in the rings as well as the structure of the rings or ring arcs.

Neptune's Moons

Neptune had two known satellites -- Triton and Nereid -- before Voyager began its approach. Voyager 2 found a third, designated 1989 N1, in early July. The new moon travels in a nearly circular, equatorial orbit, while neither Triton nor Nereid travels in the plane of the planet's equator. The plane of Triton's retrograde orbit (a direction opposite the planet's rotation) is at an angle inclined at about 20 degrees to Neptune's equator, while the plane of Nereid's prograde orbit (a direction with the planet's rotation) is at an inclined angle of 30 degrees.

In early August, Voyager 2 found three additional moons orbiting Neptune, bringing the total known moons to six. The three newest Neptunian moons, temporarily designated 1989 N2, 1989 N3 and 1989 N4, occupy nearly circular and equatorial orbits around the blue planet. All move in prograde orbits, making the large moon Triton, which occupies a retrograde orbit, even more of an oddity. All three new moons exist in the region where partial Neptunian rings or "ring arcs" are thought to exist. If the arcs exist, the new moons might play an important role in "sheperding" and maintaining them.

Triton is roughly the size of Earth's moon. Based on early observations by Voyager 2, Triton appears to be fewer than 2,500 miles in diameter. Earth's moon is 2,159 miles in diameter.

Until recent Voyager data suggested otherwise, scientists believed that because of Triton's peculiar retrograde orbit and the exaggerated tilt of its orbital plane, Triton must have been a planetesimal wandering the solar system alone when it was captured by Neptune. Since Voyager's discovery of 1989 N1, however, scientists are more uncertain about Triton's origin. If Triton were a relative newcomer to the Neptune system, it would have passed near enough to the low orbit of any preexisting moon such as 1989 N1 to collide with it or sweep it up through gravitational attraction. The existence of 1989 N1 in the orbit it occupies suggests that Triton may not be a captured object, but instead a native to Neptune.

Triton was discovered by William Lassell of England in 1846, less than a month after the discovery of Neptune.

Orbiting at an average distance of 220,300 miles from Neptune, Triton is nearly as far from its parent planet as the moon is from Earth. Triton is the only large moon in the solar system with a retrograde orbit. The moon completes one rotation on its axis every 5.88 days. That is the same amount of time it takes Triton to circle Neptune, so the satellite always shows the same face to Neptune, just as Earth's moon shows Earth.

Current evidence suggests that methane exists as frost or ice on the satellite's surface, giving rise to methane in the atmosphere. Triton is cold enough for nitrogen to exist as a solid on its surface and possibly as a liquid as well (liquid nitrogen's melting/freezing point is -346 degrees Fahrenheit.) Thus, Triton may harbor shallow puddles or iced pools of liquid nitrogen containing small amounts of methane and have nitrogen in its atmosphere at a pressure equivalent to about a tenth of Earth's atmosphere. Voyager should be able to see Triton's surface through the atmosphere.

Triton's reddish color is believed to be due to photochemistry -- the action of sunlight on hydrocarbons in the atmosphere -- like that which occurs in the much denser atmosphere of Saturn's moon Titan.

Voyager's instruments will probe Triton's surface in search of a rich, hydrocarbon sludge of organic molecules that might exist there.

Triton's highly inclined orbit may contribute to dramatic seasonal variations. Each pole spends 82 years facing the sun, while the other pole is in darkness. At the sunlit pole, ices of nitrogen, methane and argon may vaporize, adding to Triton's atmosphere. Meanwhile, vaporous substances at the dark pole would condense into an ice cap. This alternating shrinkage and growth of polar caps could mean that Triton's atmosphere varies dramatically, growing thicker and thinner with its 41-year-long seasons as it orbits the sun with Neptune every 165 years.

Nereid is between 190 to 680 miles in diameter and travels around Neptune in a highly elliptical orbit ranging from 862,000 to 5,987,000 miles. Nereid was discovered in 1949 by Gerard Kuiper of the United States.

Voyager 2's closest flyby distance to this little moon will be about 2,890,000 miles. Even at that range, Voyager may discern bright and dark areas on Nereid's surface.

The innermost of the new moons is 1989 N3, which orbits at a distance of 32,300 miles from the center of the planet or about 17,000 miles from Neptune's cloud tops. The moon 1989 N4 orbits about 38,000 miles from the planet's center or about 23,300 miles from the cloud tops. Next is 1989 N2, orbiting at about 45,400 miles from Neptune's center or about 30,000 miles from the cloud tops. The moon 1989 N1, which could range in diameter from 126 to 400 miles, orbits about 57,500 miles from Neptune's cloud tops. Voyager 2 will continue to study the new moons, and search for others, throughout the encounter.

The Radiation Environment at Neptune

The radiation environment near the planet is not expected to be as intense as that observed at Jupiter, where the radiation was fatal to Voyager 1's photopolarimeter instrument and temporarily desensitized the spacecraft's ultraviolet spectrometer. In addition, Voyager 1 sustained enough temporary radiation damage to confuse the spacecraft's internal clock, throwing off the synchronization between two of the computers onboard the spacecraft by 8 seconds. This timing problem resulted in, among other things, some smeared or blurred images of Jupiter and its moons.

Although the Voyager team believes such risks are minimal at Neptune, computer command sequences for the Neptune flyby have been carefully written to minimize adverse radiation effects on the observations.

SCIENCE OBJECTIVES

Voyager 2's complement of 11 investigations will be dedicated to more than two dozen major scientific objectives during the Neptune encounter.

The spacecraft is equipped to observe a broad range of planetary phenomena. At Neptune, it will find a banded, storm-ridden atmosphere, a ring system unlike any other in the solar system, a large and peculiar moon with an atmosphere of its own and probably several small icy or rocky moons that cannot be seen from Earth.

Ten instruments are mounted on various locations throughout the spacecraft and the radio through which Voyager communicates with Earth doubles as a scientific instrument that probes planetary and satellite atmospheres.

The instruments can be divided into two general classes: those that require pointing (remote sensors) and those that do not (in situ sensors).

There are five pointable instruments: the imaging science subsystem (consisting of wide-angle and narrow-angle television cameras), infrared interferometer spectrometer and radiometer, photopolarimeter, radio science subsystem and ultraviolet spectrometer. All but the radio ride on the spacecraft's steerable scan platform.

The other six instruments measure energetic particles, radio emissions and magnetic fields in space and near planets. They are the magnetic fields experiment (consisting of four magnetometers), plasma subsystem, low-energy charged-particle detector, cosmic-ray subsystem, plasma-wave subsystem and the planetary radio astronomy experiment.

Voyager 2's observations with these instruments can be divided into four groups at Neptune: atmosphere, rings, satellites and magnetosphere.

Atmosphere

Light emitted and reflected from Neptune's atmosphere will be measured by the photopolarimeter, the imaging and the infrared instruments to determine the atmospheric chemistry and composition.

As the spacecraft passes behind Neptune, the spacecraft's radio signals will pass through the upper layers of the atmosphere. As the signals are received on Earth, scientists will analyze how the received transmissions were affected as they passed through Neptune's atmosphere. This will determine such characteristics as the amount of atmospheric methane and helium. This 50-minute experiment also will determine the vertical structure of Neptune's ionosphere and study turbulence in the atmosphere and ionosphere.

Ultraviolet emissions from Neptune may form a corona above the atmosphere. Auroras may be seen in ultraviolet light on the dark northern face of Neptune near the north pole. As the spacecraft passes behind Neptune, the ultraviolet spectrometer will study the way sunlight is changed by the atmosphere. From this, scientists may derive the composition and thermal structure of the atmosphere.

While the ultraviolet spectrometer examines the upper atmosphere, the infrared and radio science experiments will provide information on the composition, pressures and temperatures deeper in the atmosphere.

Voyager scientists hope to observe and define the global circulation and meteorology of the upper, visible clouds of Neptune, as well as the horizontal and vertical distribution of clouds and hazes.

Various instruments, notably the infrared spectrometer, will be used to determine the heat balance at Neptune -- the ratio of internal energy emitted to solar energy absorbed. It is known that like Jupiter and Saturn, but unlike Uranus, Neptune emits more heat than it receives from the sun. Measures of the excess energy emitted will have important implications for theories on Neptune's formation and weather mechanisms. Imaging will help characterize wind speeds at different latitudes.

Voyager 2 will pass behind Triton, where both the sun and Earth will be hidden from view for about 3 minutes. The ultraviolet spectrometer will be able to view the atmosphere as the sun shines through it, and the spacecraft's radio beams will probe the atmosphere to determine temperature and pressure levels.

The masses of Triton and Neptune will be determined with Voyager's radio. As the spacecraft accelerates through the Neptunian system, the frequency changes in its radio signal -- the Doppler shift -- will be precisely measured to study the magnitude of the planet's and Triton's gravity. From this information, scientists can determine each body's mass.

Magnetic Field

The interplanetary medium through which Voyager flies is dominated by the solar wind -- charged particles blowing out from the sun. As the solar wind nears a planet, it is deflected by and flows around the planet's magnetic field.

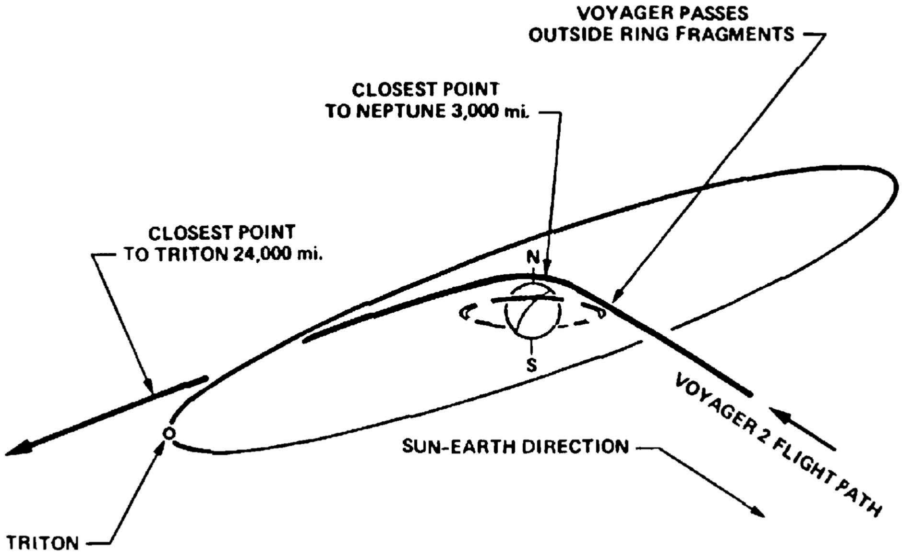
The magnetic fields of Earth, Jupiter, Saturn and Uranus are all shaped like windsocks, with the bulbous end facing the sun and a long tail sweeping behind the planet away from the sun. Where the solar wind meets the planet's magnetic field, there is a shock wave whose edge ebbs and flows according to the solar wind's varying strength.

Fields and particles instruments on Voyager 2 are continuously sampling the interplanetary medium, searching for signs of Neptune's magnetosphere. Voyager may fly through an auroral region over Neptune's north pole. About 1 hour before closest approach, the spacecraft will rotate to measure charged particles that probably spiral into Neptune's atmosphere in this region. On the dark side of Neptune, the ultraviolet instrument will look for auroral activity. About 2 hours after closest approach, the spacecraft will roll again to study plasmas that rotate with the planet.

Fields and particles investigations also will search for evidence of a torus from Triton -- a vaporous cloud composed of material carried off from the satellite's atmosphere that could surround Neptune. The instruments will look for "shadows" in the Neptune radiation environment -- gaps that would indicate the presence of unseen moons or ring arcs absorbing some of the trapped high-energy particles flowing along magnetic field lines.

Sometime before closest approach, Voyager 2's planetary radio astronomy antennas will pick up radio emissions generated in the planet's magnetosphere. These emissions are generated around other planets by energetic particles as they spiral along magnetic field lines into the atmosphere. As at Jupiter, Saturn and Uranus, such an emission from Neptune will give an accurate measurement of the planet's length of day.

The plasma wave instrument will search for signals produced in and around the magnetic field by plasmas, which are concentrations of charged particles. It also will detect lightning in the atmosphere and the presence of tiny ring particles that might strike the spacecraft as it moves through the Neptune system.



VOYAGER 2 FLYBY OF NEPTUNE
AUGUST 25, 1989

Rings

The partial rings or "ring arcs" of Neptune are probably made of dark material like the rings of Uranus. Searches for ring arcs will be conducted throughout the spacecraft's approach and during several retargetable observations planned for the near encounter-period. When in the shadow of Neptune, Voyager may see a broad sheet of ring particles backlit by the sun.

Voyager's instruments will be used to determine the size, distribution and reflective properties of ring particles. Toward this end, Voyager will conduct stellar occultation studies, measuring the amount of starlight from the star Sigma Sagitarii passing through the ring plane area. In addition, radio occultation studies will measure changes in a radio signal sent through the ring plane to Earth.

The photopolarimeter and radio experiment may pinpoint the locations of at least some of the ring arcs while helping to define their structures. Voyager will search for tiny satellites that could be affecting the organization of the distorted and broken ring system.

Moons

Triton's atmosphere will be measured by the photopolarimeter, ultraviolet and infrared instruments, TV cameras and radio.

The ultraviolet instrument and photopolarimeter will gather information on the extent and structure of the moon's atmosphere as Triton eclipses the star Beta Canis Majoris from the spacecraft's point-of-view.

Infrared mapping of the moon's dark and sunlit sides will reveal temperatures and some surface properties. Variations in the surface temperature may indicate the existence of frozen or liquid nitrogen on the ground.

Radio science investigations will reveal the density of Triton's atmosphere and help determine its composition. Methane is known to exist in Triton's atmosphere and there is a suggestion that some nitrogen is present. A dense atmosphere is expected if it is mostly nitrogen-based; a less dense atmosphere if it is mostly methane (carbon-based). In either case, hydrocarbons, at least in the form of methane, are known to exist there, so Triton is certain to be home to more complex chemistry than exists on most other moons in the solar system.

A mosaic of high-resolution images of Triton will be used to map the surface and study geological processes, and photos of the atmosphere will provide clues to its composition.

Measurements of Triton's mass will be combined with the radius determined by radio occultation and imaging to estimate Triton's density. The density estimate will indicate how much rock and ice comprise the overall composition of the moon.

Science Plans Beyond Neptune

The Voyager Interstellar Mission will start after the completion of the Neptune encounter on Oct. 2, 1989. During this phase of the mission, Voyager 1 and Voyager 2 will be tracked as they move out of the sun's influence. But the beginning of the interstellar leg of Voyager 2's trek will mean the end of the working lives of some of the instruments on the spacecraft that will no longer be needed.

By about mid-1990, the cameras, infrared instrument and photopolarimeter will be turned off. The electrical energy savings from their shutdown will contribute to the operational lives of the other instruments -- planetary radio astronomy, plasma wave, low-energy charged-particle, plasma, cosmic ray and magnetic field -- that will measure the fields and particles these instruments observe during Voyager's passage into interstellar space. The ultraviolet spectrometer will be devoted to observations of ultraviolet stars. No regular radio science experiments are planned.

THE SCIENCE INSTRUMENTS

Imaging Science Subsystem

The imaging science subsystem consists of two television (vidicon) cameras mounted on the scan platform. The cameras photograph visible characteristics of the Neptunian system and are used to conduct searches for new satellites and ring material.

The wide-angle camera has a focal length of 200mm and is sensitive in the range of 4,000 to 6,200 angstroms. The narrow-angle camera has a focal length of 1,500mm and can image in the range from 3,200 to 6,200 angstroms. The imaging science subsystem weighs 84.2 pounds and uses 41.9 watts of power.

Each camera is equipped with a filter wheel whose individual filters have a wide variety of uses. These filters permit specific types or wavelengths of light to pass through and block all other types from reaching the camera detectors.

The wide-angle camera carries one clear filter; one filter each in blue, green and orange wavelengths; a sodium-D filter, and two filters for study of the distribution of atmospheric methane. The narrow-angle camera carries two clear filters, two green filters and one filter each of violet, blue, orange and ultraviolet.

The design of the Voyager imaging system was based on those of previous Mariner spacecraft with advances and changes dictated by the specific requirements of the Jupiter and Saturn encounters. Since the Saturn encounter, the cameras have been operating beyond the environment and lifetime for which they were designed, but no serious problems have occurred.

The very low light levels, relative velocities between spacecraft and target and the resulting long exposures required at Neptune necessitate the image-motion compensation techniques used during the Uranus encounter, in addition to new ones developed in the last 3 years.

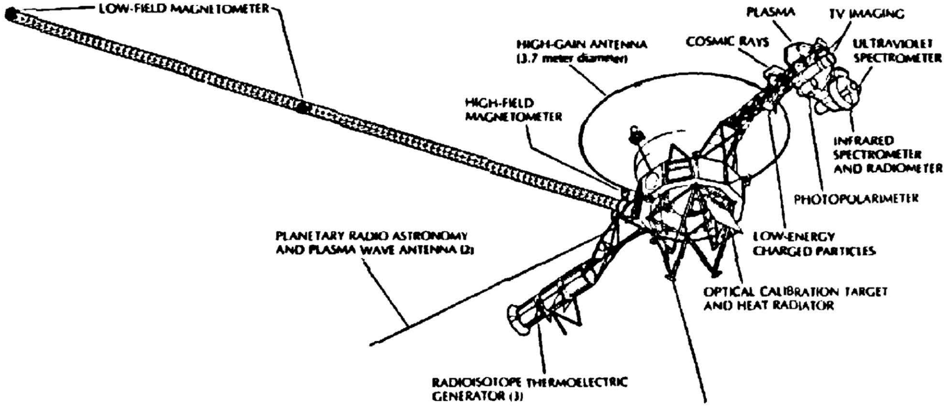
Three techniques will be used to compensate for the motion of the spacecraft and its targets during an exposure:

o "Classical image-motion compensation" was used extensively during the Uranus encounter and involves rotating the entire spacecraft to track the target during an exposure. This method necessarily moves the spacecraft out of contact with Earth, so images acquired this way must be tape-recorded on the spacecraft for later transmission.

o "Nodding image-motion compensation" is similar in effect to the "classical" technique, but rotates the spacecraft only to a point within the boundary where it would lose contact with Earth. Images acquired this way may be transmitted as they are taken. The spacecraft then rolls back, or "nods," to its original position, never losing communication with Earth.

o The third technique is called "maneuverless image-motion compensation" and uses only the movable scan platform, on which the cameras are mounted, to track the target while the spacecraft's attitude remains static. Communications with Earth are maintained using this technique.

As it flies through space, Voyager wobbles slightly in response to various activities on the spacecraft itself. Even the onboard tape recorder imparts motion to the spacecraft when the recorder stops, starts or changes direction at the end of the tape. To reduce this wobbling during flight, the spacecraft is steadied by automatic 10-millisecond jets of hydrazine propellant from its attitude control thrusters. The spacecraft motion, resulting from the 10-millisecond firings, would badly blur images during picture-taking, so flight engineers have shortened the jet firings to just 4 milliseconds during the encounter. The shorter jet firings will keep the spacecraft wobble under control while significantly reducing the image smearing that would otherwise occur.

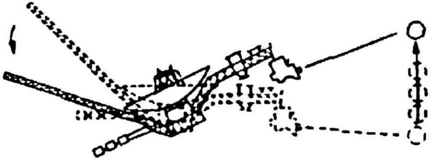


VOYAGER SPACECRAFT

Voyager

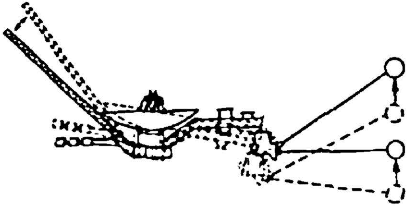
NEPTUNE NEAR ENCOUNTER HIGHLIGHTS

IMAGE MOTION COMPENSATION



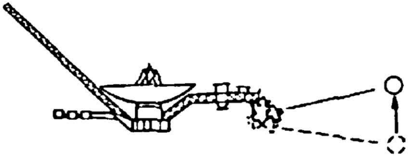
CLASSICAL IMC

ENTIRE SPACECRAFT TURNS TO TRACK TARGET - BREAKS COMMUNICATIONS LINK WITH EARTH



NODDING (NIMC)

SPACECRAFT "NODS" TO TRACK TARGET - STAYS ON EARTHLINE - CAMERAS REPOINTED BETWEEN IMAGES



MANEUVERLESS (MIMC)

MOVE SCAN PLATFORM ONLY - ELEVATION ONLY

Onboard spacecraft data compression and encoding techniques like those used at Uranus, in combination with the upgraded receiving capability of the DSN, have ensured that Voyager 2 will be transmitting high-quality data at a rate of 21.6 kilobits-per-second -- the same data rate used from Uranus -- despite being 1 billion miles farther from the Earth.

Despite Voyager's increased distance from Earth, it will send images back at the same rate at which images were transmitted from Uranus. Improvements in telecommunications capabilities on the ground will allow receipt of a maximum of about 12 to 17 images-per-hour and an average of about 200 a day. But this rate of return can be accomplished only through special techniques of data compression and encoding in which the 5 million bits-per-picture will be compressed to 2 million bits and fed into the telemetry stream at a lower rate than was used at Jupiter or Saturn.

Dr. Bradford A. Smith of the University of Arizona, Tuscon, is the imaging team leader.

Infrared Interferometer Spectrometer and Radiometer

The infrared interferometer spectrometer and radiometer is a telescope-based system that measures the spectrum of thermal energy radiated by Neptune and Triton at infrared wavelengths from 2.5 to 50 microns and the reflected light at wavelengths from 0.3 to 2 microns. The instrument weights 40.6 pounds and uses 14 watts of power.

Dr. Barney Conrath of NASA's Goddard Space Flight Center, Greenbelt, Md., is principal investigator.

Photopolarimeter Subsystem

The photopolarimeter subsystem (PPS) consists of a telescope fitted with filters and polarization analyzers. It measures the way its targets reflect light; it determines their properties as the reflected light is polarized by chemicals and aerosols in the case of Neptune's and Triton's atmospheres or by small particles in the ring arcs and on satellite surfaces.

The PPS will conduct studies of Neptune and Triton's atmospheres and the ring arcs. The instrument will measure changes in the starlight from Sigma Sagitarii and Beta Canis Majoris when Neptune, Triton and the ring plane pass in front of the stars from the spacecraft's point of view. The instrument weighs 9.72 pounds and uses 2.4 watts average power.

Dr. Arthur L. Lane of NASA's Jet Propulsion Laboratory, Pasadena, Calif., is principal investigator.

Radio Science Subsystem

Voyager's two-way radio communications link with Earth also is used to conduct scientific investigations. Precise measurements of the phase and amplitude of the radio signal can be analyzed to detect minute variations caused by its passage near or through Neptune's and Triton's atmospheres and through the ring plane.

Dr. G. Len Tyler of the Center for Radar Astronomy at Stanford University, Calif., is team leader.

Ultraviolet Spectrometer

The ultraviolet spectrometer will gather data on the composition of the atmospheres of Neptune and Triton through atomic emission and absorption techniques.

The ultraviolet spectrometer uses a grating spectrometer sensitive to ultraviolet radiation in the range from 500 to 1,700 angstroms. The experiment weighs 9.90 pounds and uses 2 watts of power.

Dr. A. Lyle Broadfoot of the University of Arizona, Tucson, is principal investigator.

Cosmic-Ray Subsystem

The primary function of the cosmic-ray subsystem is to measure the energy spectra of trapped, energetic electrons.

The cosmic-ray subsystem uses seven independent solid-state-detector telescopes. Working together, they cover the energy range from 0.5 million to 500 million electron volts. The cosmic-ray subsystem weighs 16.6 pounds and uses 5.2 watts of power.

Dr. Edward C. Stone of the California Institute of Technology, Pasadena, is principal investigator.

Low-Energy Charged-Particle Detector

The low-energy charged-particle detector (LECP) is designed to characterize the composition, energies and angular distributions of charged particles in interplanetary space and within planetary systems.

Two solid-state particle detector systems are mounted on a rotating platform. The detector's sensitivity to charged particles ranges from 15,000 to more than 160 million electron volts. The LECP weighs 16.5 pounds and draws 4.2 watts of power during encounter operations.

Dr. S. M. (Tom) Krimigis of the Applied Physics Laboratory at Johns Hopkins University, Laurel, Md., is principal investigator.

Magnetic Fields Experiment

The magnetic fields experiment consists of four magnetometers that detect and measure magnetic fields. At Neptune, they will study the interaction of the magnetic field with moons orbiting within it and observe the interplanetary-interstellar magnetic fields in the vicinity of the planet.

Two low-field magnetometers are mounted on a 43-foot boom away from the magnetic field of the spacecraft itself. Two high-field magnetometers are mounted on the spacecraft body to measure fields more than 30 times stronger than that at Earth's surface. The total weight of experiment components is 12 pounds. The experiment uses 3.2 watts of power.

Dr. Norman F. Ness of the Bartol Research Institute at the University of Delaware, Newark, is principal investigator.

Planetary Radio Astronomy Experiment

Voyager 2's planetary radio astronomy experiment (PRA) will search for and characterize a variety of radio signals emitted by Neptune. The PRA will determine the relationship of these emissions to the moons, the magnetic field, atmospheric lightning and plasma environment. The detector also will measure planetary and solar radio bursts from different directions in space and relate them to measurements made from Earth.

The PRA uses two 33-foot electric antennas as detectors, which PRA shares with the plasma-wave subsystem. PRA covers the range from 20 kilohertz to 40.5 megahertz in the radio-frequency band. The instrument weighs 16.9 pounds and uses 6.8 watts of power.

Dr. James W. Warwick of Radiophysics Inc., Boulder, Colo., is principal investigator.

Plasma Subsystem

The plasma subsystem (PLS) studies the very hot ionized gases, or plasmas, that exist in interplanetary regions and within planetary magnetospheres.

At Neptune, the PLS will study the extent and configuration of the magnetic field and the nature and sources of internal plasma. In addition, it will observe the solar wind and its interaction with the Neptune system.

Later in the Voyager Interstellar Mission, the PLS will determine the extent of the solar wind and the nature of the boundary between the solar wind and the interstellar medium.

The PLS consists of two plasma detectors sensitive to solar and planetary plasmas -- both positive ions and electrons -- with energies between 10 and 6,000 electron volts. The experiment weighs 21.8 pounds and draws 8.3 watts of power.

Dr. John Belcher of the Massachusetts Institute of Technology, Cambridge, is principal investigator.

Plasma-Wave Subsystem

Voyager's plasma-wave subsystem (PWS) is designed to measure the electric-field components of local plasma waves. At Neptune, it will measure the density and distribution of plasma, interactions of plasma waves with energetic particles and the interactions of moons and ring arcs with the planet's magnetosphere.

The PWS will provide key information on the phenomena related to the interaction of plasma waves and particles that control the dynamics of the magnetosphere.

Two extendable electric antennas, shared with the planetary radio astronomy experiment, serve as plasma-wave detectors. The system covers the range from 10 hertz to 56 kilohertz. In the normal mode, the PWS acts as a scanner, stepping from one frequency to another. In a second mode at selected times during the encounter, the system can record electric-field waveforms across all frequencies in a broad band (50 hertz to 10 kilohertz).

The experiment weighs 3.02 pounds and uses 1.4 watts of power in the normal step-frequency mode and 1.6 watts in the step frequency-plus-waveform-analyzer mode.

Dr. Donald Gurnett of the University of Iowa, Iowa City, is principal investigator.

VOYAGER 2's HEALTH

The Voyager spacecraft engineering team has learned to cope creatively with several problems the geriatric machine has experienced in its long lifetime. Still, the spacecraft and all of its instruments are in good operating condition.

Malfunctioning Radio

On April 5, 1978, the spacecraft's computer-command subsystem automatically switched to the back-up receiver. The back-up at that point had concealed a problem of its own -- a faulty tracking loop capacitor -- meaning that the receiver could not hold onto the changing frequency of the transmitted signal. This required the ground transmitter to send the precise frequency, taking into account the Doppler shift caused by the relative motion between the spacecraft and Earth, so that it would match the frequency that the receiver on the spacecraft was expecting. That frequency depends on a number of factors, including the receiver's temperature which fluctuates with spacecraft activity. When the prime receiver was turned back on, it failed almost immediately, requiring that the rest of the mission be flown on the tone-deaf back-up receiver.

Voyager engineers have determined how the tuning depends on temperature and how the operation of different subsystems onboard affects the temperature of the receiver. Even so, there is a period after any change in the spacecraft's configuration when it is impossible to know the receiver's temperature with adequate precision. As a result, commands are not routinely transmitted to Voyager after a change in the spacecraft configuration until the receiver's temperature has had time to stabilize.

If need be, controllers can send commands to the spacecraft at different frequencies in rapid succession to ensure that one will be picked up by the receiver. This and other techniques, that work around the crippled receiver, were successfully employed at Jupiter and have been refined further in ensuing years.

There is always a chance that the backup receiver could fail or lose contact with Earth permanently. The Voyager team has planned against this possibility by programming a backup spacecraft computer with simplified encounter routines for execution at Neptune. The spacecraft has been instructed to send data back to Earth even in the event that it loses uplink contact.

The Stuck Scan Platform

In 1981, Voyager 2's scan platform jammed in one axis just after its Saturn encounter. The problem limited pointing of the instruments for the duration of the encounter.

After 2 days, the platform was again movable. Three years of analysis and testing showed that the problem was due to a loss of lubricant from overuse at high speeds, which resulted in damage to a bearing in the high-speed gear train of the platform. The lubricant apparently migrated back into the gear train after a short period of rest and the platform was successfully operated at lower speeds during the Uranus encounter.

The scan platform continues to be fully operable at lower speeds and has operated successfully during the cruise to Neptune. It is expected to operate without problems through the end of the Neptune encounter.

MISSION OPERATIONS

Commands for controlling Voyager 2's systems and operations are sent to the spacecraft in a single beam of radio signals from an antenna at one of NASA's Deep Space Network complexes. The DSN is comprised of large antennas at communications complexes in Spain, Australia and California. One command load of up to 2,500 18-bit words can provide the spacecraft with enough instructions to carry out a sequence of tasks over a period ranging from 2 days to 6 months.

The Voyager science teams determine the observations to satisfy mission objectives. In turn, the Voyager sequence team designs time blocks in which the spacecraft will make the science observations as it concurrently performs engineering and navigation tasks. These sequences are tested in computer-based simulations of the spacecraft to ensure their consistency with the spacecraft's hardware, software and operational constraints.

The Voyager project has maintained nearly the same operating procedures employed during the Jupiter and Saturn encounters, but with about one-third the staff. This has resulted in fewer but longer-running command loads to the spacecraft during interplanetary cruise phases since the Saturn encounter and has limited the number of calibrations performed.

Commands are sent at a rate of 16 bits-per-second through the 230-foot antenna at any one of the three DSN complexes. Traveling at the speed of light, the commands will reach the spacecraft at Neptune in 4 hours, 6 minutes. With the long delay in round-trip communication time, engineers are unable to respond quickly if a spacecraft problem develops. For this reason, the spacecraft's master computer, called the computer command subsystem, has been programmed with a set of stored responses to anticipated problems.

The computer allows the spacecraft to act autonomously, quickly protecting itself from situations that could jeopardize communications or spacecraft operations. The computer command subsystem also contains the back-up mission load, the basic commands that would allow Voyager 2 to conduct rudimentary investigations of Neptune if the spacecraft's radio receiver were to fail.

Occasionally the need arises to change the state of the spacecraft or one of its instruments beyond the scope of the commands already in the spacecraft computer. Commands of this type are called real-time commands and are usually sent for immediate execution by the spacecraft.

The telemetry received at the DSN complexes is transmitted to JPL via wide-band and high-speed data lines. The wide-band lines are used primarily for high-bit-rate science telemetry, while the high-speed lines are used for engineering telemetry and low-bit-rate science collected during the cruise phase.

Overseas lines are routed through NASA's Goddard Space Flight Center, Greenbelt, Md., via satellite links. The Goldstone, Calif., transmissions are sent directly to JPL through ground microwave stations.

Both wide-band and high-speed transmissions are received at JPL by the Network Operations Center, where they are logged on tape and routed in real time to the Mission Control and Computing Center (MCCC). The MCCC is responsible for display, control, decoding and routing of real-time telemetry to the Test and Telemetry System (TTS) and JPL's Multimission Image Processing Laboratory. The TTS displays engineering telemetry in real time for the spacecraft team and the mission control team and processes and displays science data for each of the science teams other than imaging.

Imaging data are transferred to the Multimission Image Processing Laboratory for processing and analysis. Here, the imaging data are decompressed. During this process, the images can be enhanced to bring out subtle features and, in some cases, corrected for errors.

All data from the spacecraft experiments are collected and processed into Experiment Data Records, which contain all available science and engineering data from a given instrument. The records are the final data product forwarded to investigators for analysis. A companion record called the Supplementary Experiment Data Record accompanies the Experiment Data Records and contains the best estimate of the conditions under which the observations were made.

Reducing the Volume of Data

As Voyager travels farther away, the rate decreases, at which the DSN antennas can reliably receive the data. For example, at Jupiter about a half-billion miles from Earth, the highest data rate was 115,200 bits-per-second (bps); at Neptune, 2.5 billion miles away, the data rates will be 21,600 and 14,400 bps.

To increase the amount of data that reliably can be returned, flight engineers have devised ways to reduce the number of bits required to transmit images. These include changing the way the spacecraft encodes the data before sending it, editing and compressing the data.

At Jupiter and Saturn, all science data except imaging was encoded with an error-correcting code that required as many bits of data for the code as there were bits of data. For Uranus, all science data, including imaging, was coded with a more efficient technique to reduce the overhead to about 15 percent. The same coding will be used at Neptune.

Imaging data also may be edited or compressed to reduce the number of bits-per-image. A Voyager imaging frame comprises 800 lines by 800 picture elements (pixels) per line – a total of 640,000 pixels-per-image. Eight bits express the gray level of each pixel, ranging from 0 (black) to 255 (white). Thus, each image requires 5.12 million bits.

Data compression reduces the bit volume by 60 to 70 percent. The total number of bits needed to transmit an image is reduced, but images still can be returned at full size and full resolution. The edges of "busy" scenes may be jagged.

To compress the data, each line is divided into blocks of five pixels. The absolute brightness of the first pixel in each line is sent, and then the brightness of each of the following pixels is expressed as its difference from the brightness of the preceding pixel.

TELECOMMUNICATIONS

The Deep Space Network, operated by the NASA JPL, has carried out all tracking and communication with the Voyagers since they left the Earth.

DSN stations are located around the world, in multi-antenna complexes at Goldstone, in California's Mojave Desert; in Robledo, near Madrid, Spain; and on the Tidbinbilla Nature Preserve near Canberra, Australia. The three complexes are spaced at widely separated longitudes so that spacecraft can be in continuous view as the Earth rotates.

Each location is equipped with 230-foot antenna (enlarged from 210 feet); one standard and one high-efficiency 112-foot antennas; and a 85-foot antenna.

In addition to the antennas, each of the network's signal processing centers houses equipment for transmission, receiving, data-handling and interstation communication. The downlink radio frequency system includes cryogenically-cooled, low-noise amplifiers.

Uplink

The uplink operates at S-band radio frequency (2,113 megahertz), carrying commands and ranging signals from ground stations to the spacecraft. The 230-foot antenna stations have 400-kilowatt transmitters. Transmitting power for the standard 112-foot stations is 20 kilowatts.

Downlink

The downlink is transmitted from the spacecraft at S-band (approximately 2,295 MHz) and X-band (approximately 8,415 MHz) frequencies. The standard 112-foot antennas and the 230-foot antennas can receive the S- and X-band signals simultaneously. The high-efficiency, 112-foot antennas receive only X-band transmissions.

The signal from Voyager's 20-watt transmitter (about the same wattage as the light bulb in a refrigerator) gets progressively fainter as the spacecraft moves farther away. By the time it reaches Earth, the signal is about 20 billion times weaker than the battery power that runs an ordinary digital wristwatch. To track this faint signal, either larger antennas or more sensitive receivers are needed. In addition, more power (up to 100 kilowatts for Voyager) is needed to transmit to the spacecraft across the vast distance.

Shortly after the Voyager 2 Uranus flyby, the three largest (210 feet in diameter) and most sensitive antennas of the Deep Space Network were systematically stripped of their surfaces and rebuilt to create an even larger (230-foot) receiving area for the incoming signal.

During the Neptune encounter, the 230-foot and 112-foot antennas at each complex will be arrayed so that their combined collecting areas will increase the amount of signal captured. This will improve the potential for high-rate, low-error data return.

At Canberra, the three DSN antennas will be arrayed with the 210-foot Parkes Radio Astronomy Observatory. The Parkes facility, operated by the Congress of Scientific and Industrial Research Organization, is once again critical to spacecraft support during the Neptune encounter. As during the Uranus encounter, the high southern (-23 degree) declination of Voyager 2 will result in long, 12-hour periods during which the spacecraft will be over the Canberra complex and 9 hours over the Parkes antenna. (The shorter viewing time at Parkes is due to antenna pointing constraints.) The quality of data received at the Australian facility also is likely to be higher than that received in California and Spain because of the large distance between antennas, which decreases the risk of data loss due to local weather conditions.

Innovative uses of other, existing equipment, along with the larger antennas, will significantly increase the potential data return from Voyager during its last planetary encounter.

In Japan, the 210-foot Usuda Radio Observatory tracking antenna, owned by the Institute of Space and Astronautical Science of Japan, will join the Canberra station in collecting radio science data during the Neptune and Triton radio occultation experiments.

In the U.S., radio astronomy antennas never before used to track spacecraft have been accepted into service to track Voyager at Neptune. The 27 90-foot antennas of the Very Large Array in Socorro, N.M., operated by Associated Universities, Inc., for the National Science Foundation, will be arrayed with the Goldstone, Calif., tracking station.

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