Photographs from the distant Voyager

By Simson L. Garfinkel

Technology

The eight-year journey away from the sun, involving slingshot turns and visits to the colored rings of Saturn and the moons of Jupiter, has brought the traveler three-billion miles from home.

The traveler will visit another world in two days.

The Voyager 2 spacecraft is about to make its closest approach to Uranus, the seventh planet from the sun. On Friday, Jan. 24, at 1 pm EST, the spacecraft will pass within 51,600 miles of the planet's blue-green cloud tops as it travels to the fringe of the solar system.

The MIT community will be able to witness the visit by watching unedited transmissions from the camera-toting Voyager 2 over a slow-scan television link between MIT and the Jet Propulsion Laboratory (JPL) in Pasadena, CA, said John W. Belcher, professor of physics at the MIT Center for Space Research (CSR).

The planet: Uranus is the third largest planet in the solar system, ringed by dark particles and tiny moons. It orbits the sun once every 84 years at a distance 19 times that separating the Earth from the sun. The planet's axis of rotation is tilted 95 degrees from the planet's plane of rotation. During the Voyager 2 encounter, Uranus' south pole will be pointing toward the sun.

The visitor: The Voyager 2 spacecraft carries a 10 kilogram instrument to measure plasma in space, the high-temperature, ionized gas composed of electrons and positive ions that can be found in lightning bolts and cosmic rays, in addition to television cameras and nine other experiments. The instruments will measure the planet's magnetosphere and the solar wind. Herbert S. Bridge PhD '50 heads the team running the experiment.

The $600 million Grand Tour

The National Aeronautics and Space Administration launched the Voyager 2 on August 29, 1977. The craft flew past Jupiter on July 9, 1979, Saturn on August 25, 1981, and will encounter Neptune on August 25, 1989. The JPL estimated the cost of the Voyager Project, excluding the cost of the launches and tracking, at $600 million.

Since the 1950s, scientists had been considering the possibility of a "Grand Tour" spacemission to probe the outer planets, according to Belcher. But the outer planets are positioned on the same side of the sun only once every 176 years, making such a mission possible only very rarely.

"It was fortunate that the technology was there in 1977," Belcher said at a lecture on the Uranus flyby. There will not be an opportunity for a similar mission until 2153.

Voyager used the "slingshot" effect to reach the outer planets so quickly. "Everytime you go by a planet, you pick up energy," explained Belcher. Voyager 2 has been traveling on "planet energy" ever since it approached Jupiter, he continued.

The primary purpose of the two Voyager missions was to study Jupiter and Saturn. "Originally, it was called the Mariner Jupiter-Saturn mission," said CSR Assistant Professor Ralph L. McNutt Jr. PhD '80. One of the high-priority science items at Saturn was to examine the atmosphere of Titan, a moon which scientists thought might hold life. A study of Titan would have "kicked [Voyager 2] out of the solar system," as it did Voyager 1, McNutt continued.

Voyager 1 found Titan's atmosphere to be composed of nitrogen and simple organic compounds at one and one-half times the pressure of Earth's atmosphere, according to the JPL. "If Voyager 1 had failed, they would have retargeted Voyager 2, and there would have been no Uranus and Neptune [Voyager 2 missions]," McNutt told the audience.

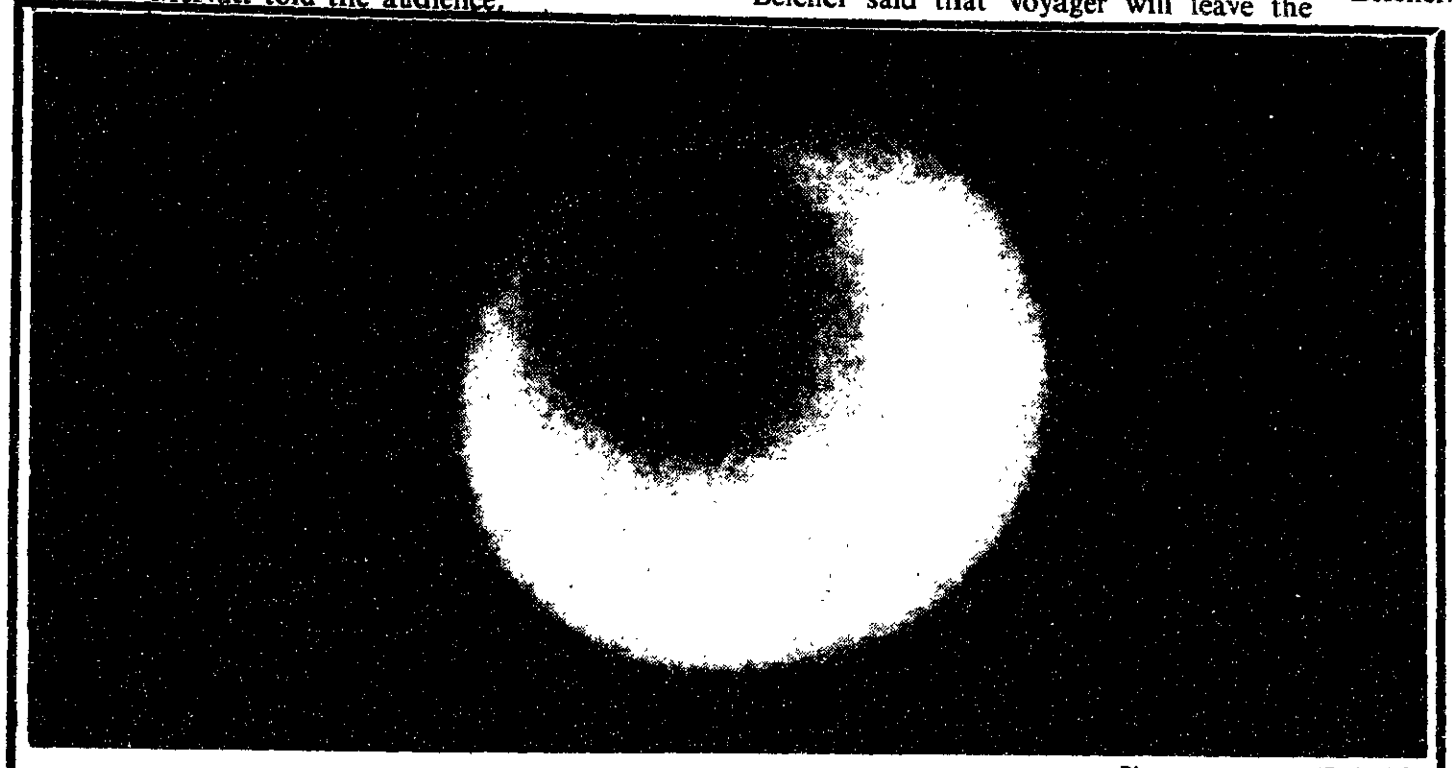


Photo courtesy JPL/NASA

This Voyager 2 photograph of Uranus is the first picture to show clear evidence of latitudinal banding in the planet's atmosphere, and one of the first indicating atmospheric structure of any sort. The computer-enchanced picture is a summation of five images returned Dec. 27, 1985, by Voyager's narrow-angle camera. The spacecraft was 36 million kilometers (22 million miles) from Uranus. At this distance, Voyager's cameras could have detected individual features as small as 660 kilometers (410 miles) across.

The concentric pattern emanates like a bull's-eye from the planet's pole of rotation, which in this view lies left of the center. Clouds in the Uranian atmosphere give rise to the pattern. In the original, unprocessed images, the contrast of the features producing the banding is low.

As Voyager speeds toward its Jan. 24 closest approach, it will return several thousand images of the planet, its moons and thin rings.

"99.9 percent of everything we will know about Uranus will come from this encounter," McNutt explained. "I just want to emphasize how unique this is. If you are very, very lucky, you might get to see Halley's Comet again, but there are currently no plans to go out to this part of the solar system again," he elaborated.

Communicating with an 8-year-old

The Voyager 2 spacecraft was designed for a five-year lifespan. Although the craft has survived in good shape, additional funding was required to receive and process the data the spacecraft is now sending. "Until recently, it wasn't clear" whether JPL would be able to run the mission, said McNutt. "We just got Uranus and Neptune by the skin of our teeth."

Communicating with an eight-year-old spacecraft 3 billion miles away is one of the continuing challenges of the Voyager program. Failures in both the primary and backup radio receivers prevented Voyager 2 from locking on to the transmission frequency of Earth commands. Voyager's engineers must therefore transmit commands at an exact frequency for the spacecraft to receive the signal, according to the JPL. This frequency depends on the spacecraft's temperature and the radio signal's Doppler shift, a phenomenon caused by relative motion between the Earth and the spacecraft.

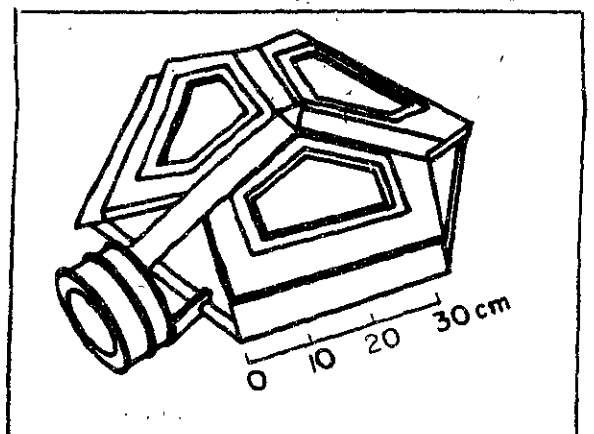
Receiving data from the Voyager 2 is also difficult. Voyager's 20 watt X-band transmitter's signal has diminished in power to 10^{-21} watts. Only three receiving stations in the world can detect this signal. These stations, which make up the Deep Space Network, were specially upgraded to receive Voyager 2's Uranus pictures, according to McNutt.

Despite the improvements to the space network, JPL engineers have been forced to slow the data transmission rate of Voyager 2 from 44,800 bits per second at Saturn to 21,600 bits per second to improve the quality of the received signal. The engineers have also programmed Voyager 2's computers to compensate by sending data in a compressed format which takes less time to transmit.

Plasma: the MIT experiment

"We look at plasma," Belcher said in his Voyager lecture. Between the planets, "you don't see a vacuum — you see solar wind." Belcher said that Voyager will leave the Sun's "extended atmosphere" in the year 2010.

The MIT Plasma Science Experiment consists of a 30 centimeter box mounted on Voyager 2's scientific arm, explained Frances Bagenal PhD '81, a visiting scientist at the CSR. The experiment is designed to detect low energy charged particles, in the energy range of 10 electron-volts to 6 kilo-electron-volts. As Voyager 2 approaches a planet, the device measures the interactions of the solar wind with the planet, Bagenal continued.



Plasma Science instrument on Voyager 2 spacecraft courtesy MIT CSR.

These interactions depend on whether or not the planet possesses a magnetic field. Scientists do not know whether Uranus has a magnetic field.

If Uranus has no magnetic field, the MIT experiment will detect "perturbations [in the solar wind] from Uranus. It would be similar to interactions with Venus and Mars, which don't have magnetic fields," Bagenal said, "but with important differences because [Uranus] is much more distant from the sun."

In the past, scientists have found the presence of radio-emissions to be indicative of planetary magnetic fields. Begenal said she would have expected Voyager 2 to detect radio emissions from Uranus by now if it possessed a magnetic field. Jupiter and Saturn both possess magnetic fields. Like these two planets, Uranus is a gas giant planet.

Pictures from a distant traveler

Uranus has been a faceless stranger to scientists, because Earth-based telescopes cannot see any detail in the distant planet. At this time, scientists have little idea what the final Voyager 2 photographs will look like.

"A lot of people didn't want [the direct transmission] to happen," McNutt said. "All the video images might show is a big silver ball and everybody will think, 'We paid all that money for this? Whether you are going to see five hours of silver balls or one by four by nine monoliths is anybody's guess,' " he said.

Two hours and 45 minutes after Voyager 2 makes its closest approach to the planet Uranus — the time it takes the radio signal to travel from the craft to Earth — its pictures will be displayed, unedited, at JPL and MIT in 34-101, as well as at several other universities around the country. This is the first time that JPL has broadcast unedited, live pictures, according to Belcher. The viewing has been two years in the planning. "It's a complicated thing to plan and it's amazing it works. You don't make a mistake with a spacecraft three billion miles away," Belcher said.

The photographs will be transmitted from an electronic antenna array consisting of the Australian government's Parkes Radio Observatory 64-meter antenna and the Canberra Deep Space Network complex to JPL in Pasadena, according to the JPL press release. From JPL, the images will be transmitted over telephone lines by slow-scan television to MIT, explained Belcher.

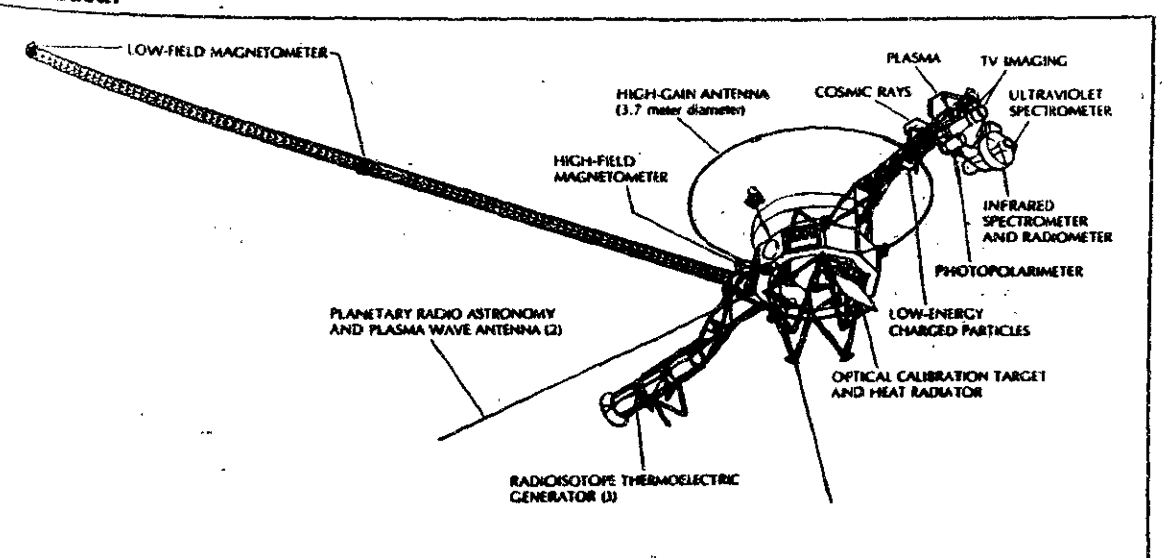
"These will be the raw pictures, not a lot of contrast," Belcher said. "The planet is bland, not like Saturn and Jupiter. . . . [The pictures] may be dull, but you are seeing them at the same time as people at the JPL," he continued.

Even if the photographs appear featureless on the slow-scan television, McNutt said, scientists in the field of imaging processing at JPL will be able to extract hidden detail. "Rest assured that the people in image processing will work around the clock to send pictures to the White House," he said.

MIT Cable TV will broadcast four press conferences from JPL. The lab's staff will explain the significance of the Voyager 2 Uranus expedition and show their best computer-enchanced photographs of the planet. McNutt expects the press conferences on Wednesday, Saturday and Tuesday to be the most interesting.

The CSR has made available a computer simulation of the Uranus encounter on Project Athena. The program is called "/usr/potluck/uranus" and may be run on any Athena graphics terminal in the Student Center cluster.

Voyager 2's Plutonium power supply will have lost enough energy in the year 2010 to render the spacecraft useless, although Belcher believes that it will be possible to track the probe until it is an ancient traveler, 300 AU (47 billion miles) from its creators.



Drawing of Voyager 2 spacecraft courtesy JPL/NASA

Uranus

Schedule of Events

Wednesday, Jan. 22:

1-3 pm, MIT Cable TV and 37-252. Kick-off JPL press conference live via satellite.

8pm, 26-100 Illustrated lecture on the science and technology of the Pioneer and Voyager missions to the outer planets.

Thursday, Jan. 23: *1-3pm*

Friday, Jan 24: *12-4pm*

Real time slow-scan images direct from Voyager 2, unedited. Videos and films from past encounters. Also, Friday only, the daily JPL press conference.

Saturday, Jan. 25:

1-3pm, MIT Cable TV and 37-252

Monday, Jan. 27:

1-3pm, MIT Cable TV and 37-252

Tuesday, Jan. 28:

1-4pm, MIT Cable TV and 37-252

JPL press conferences. The press conference Saturday is the first press conference after closest approach. Final wrap-up conference and summary on Tuesday.