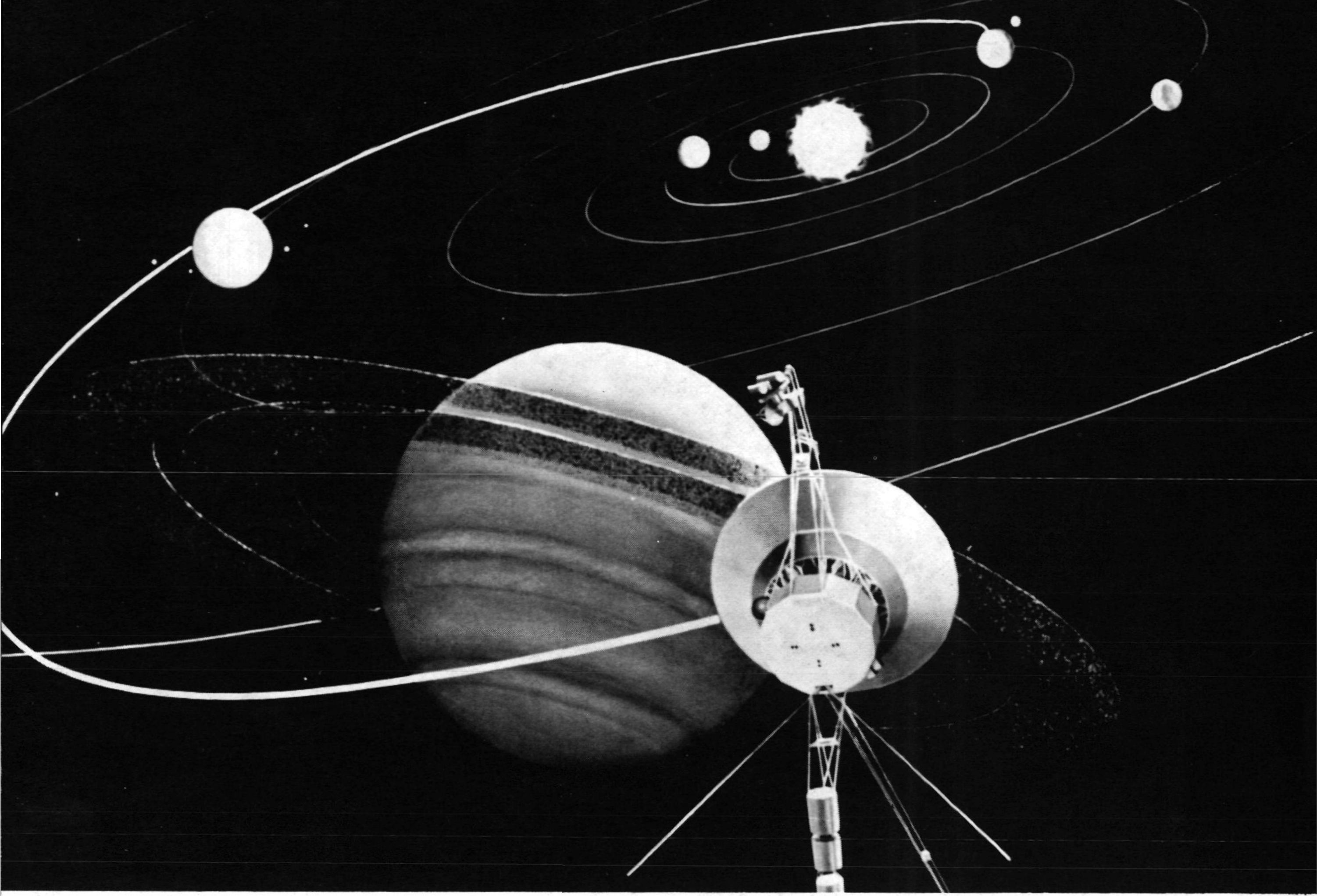


P80-10167
Mr. French

Voyager 1

Encounter With Saturn

(NASA-News-Release-80-159) VOYAGER 1: ENCOUNTER WITH SATURN (National Aeronautics and Space Administration) 48 p CSCL 03B
N80-34324
Unclas
H2/91 35221

NASA
National Aeronautics and
Space Administration

Press Kit

RELEASE NO: 80-159

CONTENTS

NASA News

National Aeronautics and
Space Administration

Washington, D.C. 20546
AC 202 755-8370

For Release:

10 A.M. EST, TUESDAY
October 28, 1980

Nicholas Panagakos
Headquarters, Washington, D.C.
(Phone: 202/755-3680)

Frank Bristow
NASA Jet Propulsion Laboratory, Pasadena, Calif.
(Phone: 213/354-5011)

RELEASE NO: 80-159

VOYAGER TO TAKE A CLOSE LOOK AT SATURN ON NOV. 12

America's Voyager 1 will arrive at Saturn early next month, marking the third episode in a decade-long, multibillion-mile space odyssey to the outer planets and beyond.

Voyager 1 will encounter the ringed planet on Nov. 12, making its closest approach at approximately 6:45 p.m. EST at a distance of 124,200 kilometers (77,174 miles) from the visible cloud tops.

The flyby of Saturn comes more than 20 months after Voyager's close approach to Jupiter in March 1979, and 16 months after a sister craft, Voyager 2, made its Jovian encounter in July 1979.

October 23, 1980

-more-

Voyager 1's detailed scientific examination of Saturn, its rings and moons, is the NASA spacecraft's final planetary encounter before it leaves the solar system about 1990. Voyager 2 will encounter Saturn later next year, followed by possible Uranus and Neptune encounters in 1986 and 1989 respectively.

The closeup looks at the outer planets are the most current steps in the United States program of systematic planetary exploration, in which the solar system is used as a natural laboratory. By being able to compare the similarities and differences of the various planets, scientists hope to learn more about the history and future of the solar system and particularly our own planet Earth. The outer planets, evolving at a different rate and under different conditions than the inner planets -- Mercury, Venus and Mars -- play a particularly important role in this effort.

A prime target for study by Voyager 1 will be Saturn's satellite Titan, the largest moon in the solar system and the only moon known to have retained a substantial atmosphere. The spacecraft will approach Titan at a distance of 4,000 km (2,500 mi.) from the surface, the closest approach to any body in the Voyager mission, on Nov. 12 at 12:41 a.m. EST (spacecraft time).*

*If one were able to watch the event from Earth, the eye would see the close encounter one hour, 25 minutes later -- the time it takes light to travel the 1.5 billion km (930 million mi.) back to Earth. The same velocity is true using the Voyager radio to observe the event. Scientists call this the "Earth-received time." Times listed in this press kit are spacecraft times

The same day, Voyager also will make its closest approach to Saturn and the satellites Tethys (415,320 km or 258,067 mi.) at 5:16 p.m. EST; Mimas (88,820 km or 55,190 mi.) at 8:42 p.m.; Enceladus (202,521 km or 125,840 mi.) at 8:50 p.m.; and Dione (161,131 km or 100,122 mi.) at 10:39 p.m. Closest approach to Rhea (72,000 km or 44,739 mi.) will be at 1:21 a.m. EST on Nov. 13.

When the two Voyager spacecraft have completed their television experiments they will have sent more than 70,000 pictures of Jupiter, Saturn and its rings, 13 satellites and black space near the two planets. Black-space imaging at Jupiter resulted in discovery of one its three newly found moons.

At Saturn, as at Jupiter, Voyager's radio signals will be used extensively to measure the atmospheres of the planet and satellites and assess the size and density of the ring particles.

The Voyager 1 trajectory includes occultations of the Earth and Sun by Titan, Saturn and the rings. During these three occultations, Earth will be eclipsed by Titan, Saturn and the rings from the spacecraft's point of view. As Voyager passes behind each body, its radio signals will pass through the atmospheres of Saturn and Titan and through the rings toward Earth; resultant changes in the radio signals will provide information on characteristics of the planet's and satellite's atmospheres, ionospheres and the size and density of ring particles.

-more-

Each Voyager uses 10 instruments and the spacecraft radio system to study the planets, their principal satellites, Saturn's rings, the magnetic and radiation regions surrounding the planets, and the interplanetary medium. (The photopolarimeter on Voyager 1 has failed and will not be used at Saturn; the one on Voyager 2 is still operating.)

The Voyagers are carrying telescope-equipped television cameras, cosmic ray detectors, infrared spectrometers and radiometers, low-energy charged-particle detectors, magnetometers, photopolarimeters, planetary radio astronomy receivers, plasma detectors, plasma wave instruments and ultraviolet spectrometers.

The spacecraft began the observatory phase of its encounter on Aug. 22 and will conclude the 117-day surveillance of the Saturnian system on Dec. 15.

Voyager 2 will follow its sister spacecraft to Saturn in August 1981. Its possible four-planet itinerary includes encounters with Uranus in January 1986 and Neptune in August 1989.

Saturn is the sixth planet from the Sun, second largest in the solar system. Like Jupiter, it is a giant sphere of gas -- mostly hydrogen and helium with a small core of rocky material.

The planet takes 29.46 years to complete one orbit around the Sun, which is approximately 1.42 billion km (886 million mi.) away. A day on Saturn lasts 10 hours, 39 minutes, 24 seconds.

Until recently, Saturn was believed to be the only planet encircled by rings. But both Jupiter and Uranus were discovered to have thin, barely visible rings. (The Jovian ring was discovered by Voyager.) Saturn's rings, however, are much richer in material, probably chunks of ice and dirt, and are bright and highly visible from Earth-based telescopes.

At least six rings surround Saturn. From the planet outward, they are designated D, C, B, A, F and E. Divisions between the rings are believed to be caused by the three innermost satellites, Mimas, Enceladus and Tethys. The Cassini Division, a space between the B and the A ring, is the only division clearly visible with a small telescope from Earth.

The Encke Division is a small gap in the rings. The Pioneer spacecraft, which flew past Saturn in September 1979, detected a gap between the A and F rings. Pioneer also reported a third division between the C and B rings.

Saturn's face, in comparison to Jupiter's, is bland and tranquil in appearance. This may be due to thick, high-altitude haze that gives Saturn its opaque appearance, hiding weather activity in the planet's atmosphere.

Saturn has at least 13 satellites, though many more not yet discovered may orbit the planet. The existence of 10 has been known for some time and these objects have been named; of the three recently discovered satellites, two appear to share the orbit of Dione and one of Enceladus.

-more-

From the planet outward, the 10 named satellites are Janus (whose existence is now doubtful), Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus and Phobe.

In its excursion though the Jovian system, Voyager 1 discovered a wispy ring of particles around Jupiter and towering volcanoes on Io. Superbolts of lightning and immense auroras were found in the planet's violently churning atmosphere.

More than 18,000 pictures of Jupiter, the four Galilean satellites -- Io, Europa, Ganymede and Callisto -- and tiny Amalthea were obtained with Voyager 1's two-camera imaging system during the 98-day encounter.

Voyager 2's visit to the Jovian system yielded an additional 15,000 pictures of the giant planet and its satellites.

Using Jupiter's enormous gravity, the two spacecraft were hurled onto trajectories toward Saturn.

When Pioneer 10 and 11 passed through Jupiter's intense radiation in their 1973 and 1974 encounters, the two Voyagers were still being assembled. Based on data from the Pioneers, some Voyager parts were exchanged for more radiation-resistant components, electronic circuits were modified, and additional radiation shielding was added to each spacecraft. As a result, the Voyagers suffered little damage in their flybys of Jupiter.

Saturn's radiation is much gentler than Jupiter's. When Pioneer 11 flew beneath Saturn's rings, radiation intensity dropped dramatically, showing that charged particles are interrupted and absorbed by particles in the rings.

Voyager 2 was launched Aug. 20, 1977, from Cape Canaveral, Fla., aboard a Titan Centaur rocket. Two weeks later, on Sept. 5, Voyager 1 was launched on a faster, shorter trajectory and sped past its twin before the end of the year. By the time Voyager 1 reaches Saturn, Voyager 2 will be nine months behind.

When Voyager 1 encounters Saturn it will have traveled more than 2 billion km (1.24 billion mi.) since launch.

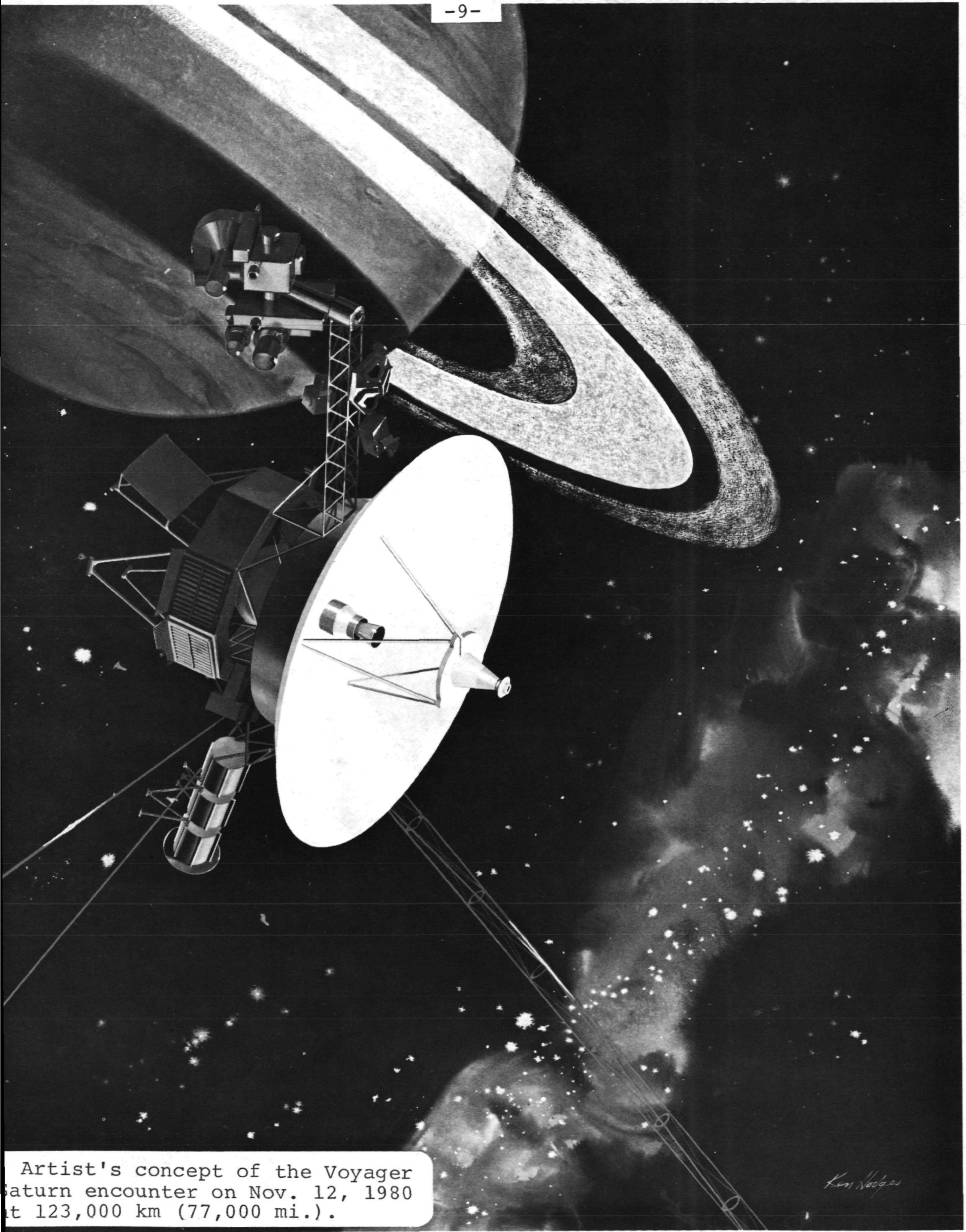
After completing their planetary missions, each spacecraft will search for the outer limit of the solar wind -- that presumed boundary somewhere in our part of the Milky Way where the influence of the Sun gives way to that of other stars of the galaxy.

The Voyager Project is managed for NASA by the Jet Propulsion Laboratory, Pasadena, Calif., a government-owned facility, operated for the space agency by the California Institute of Technology.

NASA program manager is Frank A. Carr, and Dr. Milton A. Mitz is NASA program scientist. Voyager project manager is Raymond L. Heacock, JPL, and Dr. Edward C. Stone of Caltech is project scientist.

Estimated cost of the Voyager Project, exclusive of launch vehicles, tracking and data acquisition and flight-support activities is $338 million.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)



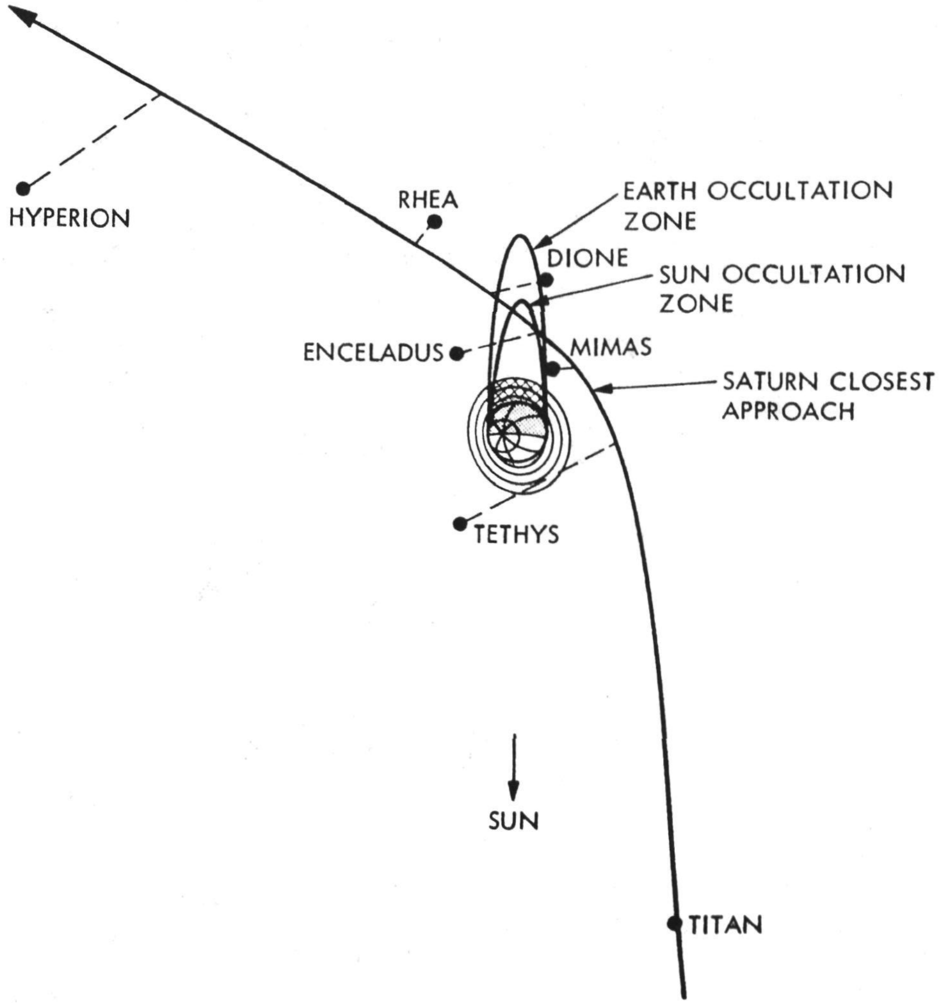
Artist's concept of the Voyager aturn encounter on Nov. 12, 1980 t 123,000 km (77,000 mi.).

VOYAGER 1 SATURN ENCOUNTER EVENTS

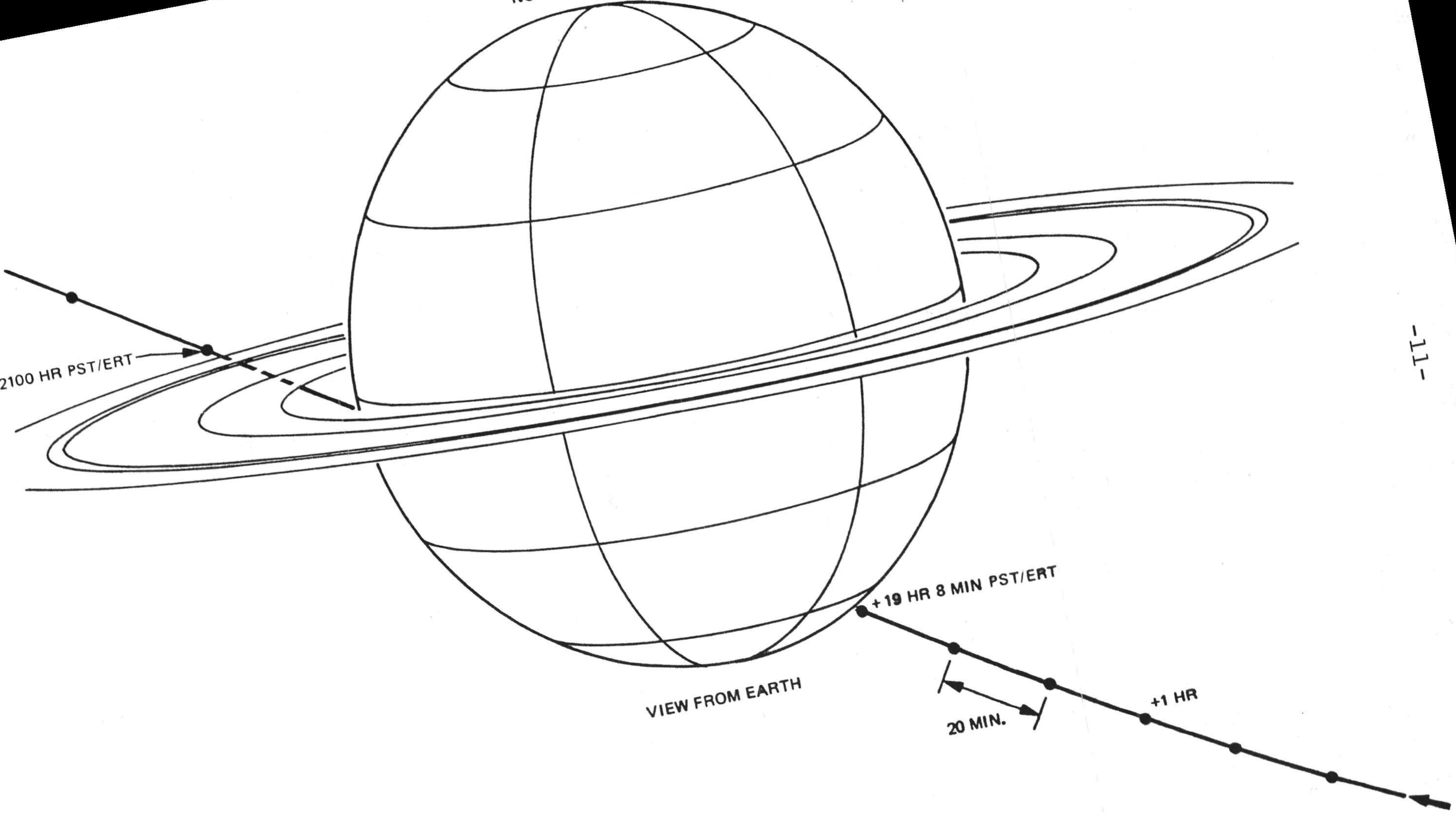
	PST*	EVENT	DISTANCE TO SURFACE kilometers	DISTANCE TO SURFACE miles
Nov. 11	11:05 p.m.	Titan closest approach	4,520	2,800
	11:11	Enter Titan-Sun occultation		
	11:12	Enter Titan-Earth occultation		
	11:22	Exit Titan-Sun occultation		
	11:23	Ring plane crossing (north-south)		
	11:25	Exit Titan-Earth occultation		
Nov. 12	10:10 a.m.	Phoebe closest approach	13,500,000	8,390,000
	3:40 p.m.	Tethys closest approach	415,600	258,250
	5:10	Saturn closest approach	124,100	77,120
	6:02	Mimas closest approach in light**	108,330	67,320
	7:08	Enter Saturn-Earth occultation		
	7:15	Enceladus closest approach	202,620	125,910
	7:21	Enter Saturn-Sun occultation		
	8:02	Exit Saturn-Sun occultation		
	8:35	Exit Saturn-Earth occultation		
	8:44	Enter ring-Earth occultation		
	8:53	Dione closest approach in light**	161,290	100,230
	9:00	Exit ring-Earth occultation		
	9:45	Ring plane crossing (south-north)		
	11:46	Rhea closest approach	72,400	44,990
Nov. 13	10:09 a.m.	Hyperion closest approach	879,180	546,320
Nov. 14	12:10 p.m.	Iapetus closest approach	2,460,000	1,530,000

*Earth received time. One-way light time to Saturn is 1 hour 25 minutes.

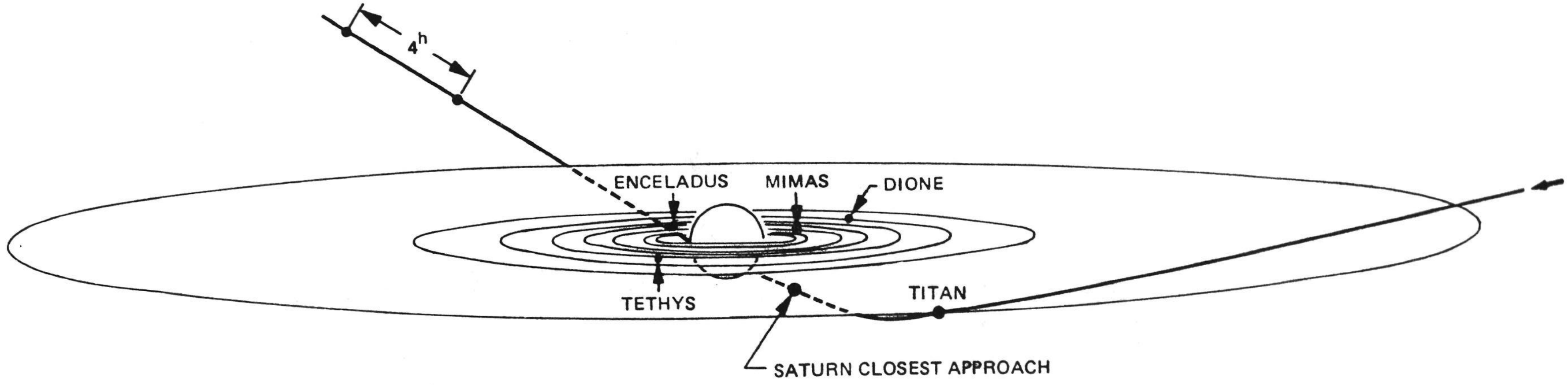
**Mimas and Dione are in darkness at closest approach.

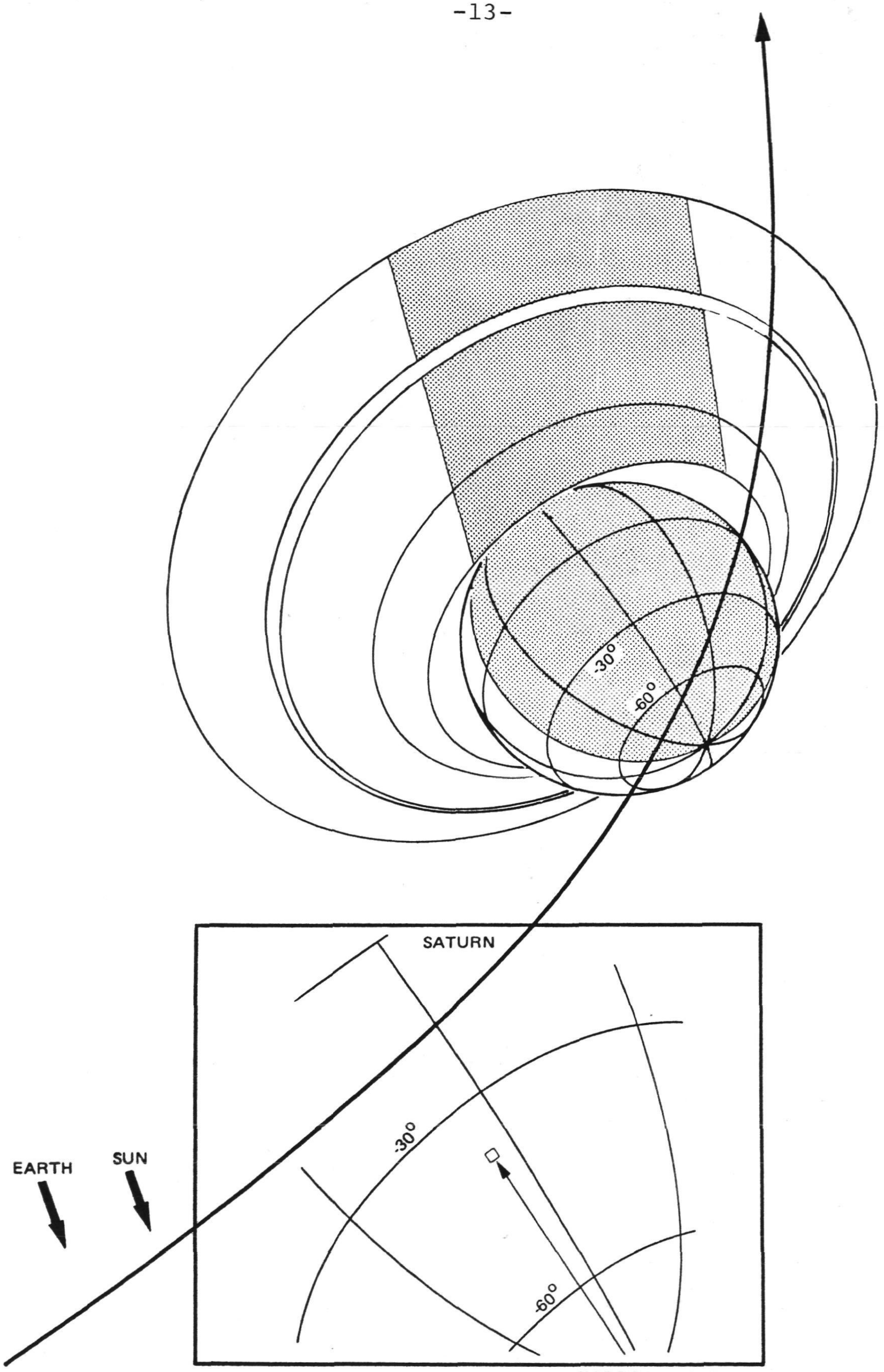


VOYAGER 1 SATURN ENCOUNTER
NOVEMBER 12, 1980



VIEW FROM EARTH

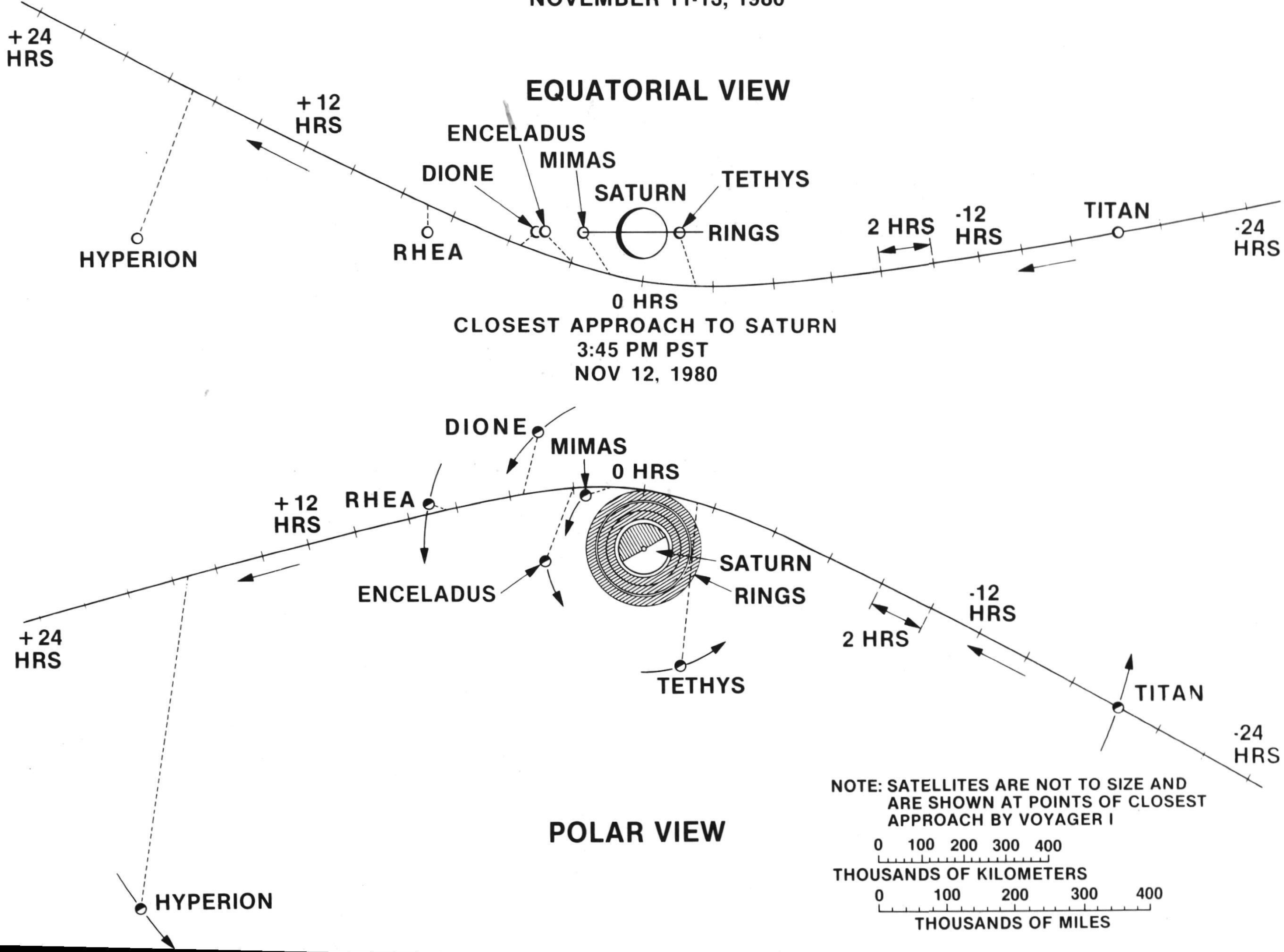




SATURN CLOSEST APPROACH

TWO VIEWS OF VOYAGER I FLYBY OF SATURN

NOVEMBER 11-13, 1980



NOTE: SATELLITES ARE NOT TO SIZE AND ARE SHOWN AT POINTS OF CLOSEST APPROACH BY VOYAGER I

THE PLANET SATURN

The ancients believed Saturn to be the most distant planet from the Sun. Not until Sir William Herschel discovered Uranus in 1781 did anyone know of the existence of planets beyond Saturn.

Saturn is the sixth planet from the Sun. It is unique in the solar system in that it is the only planet lighter than water, with a density of 0.7 grams per cubic centimeter. (The density of water is one gram per cubic centimeter.)

Saturn's rings are the planet's most distinctive feature. It was thought to be the only planet encircled by rings until the discoveries of Uranus' rings in 1977 and Jupiter's in 1979.

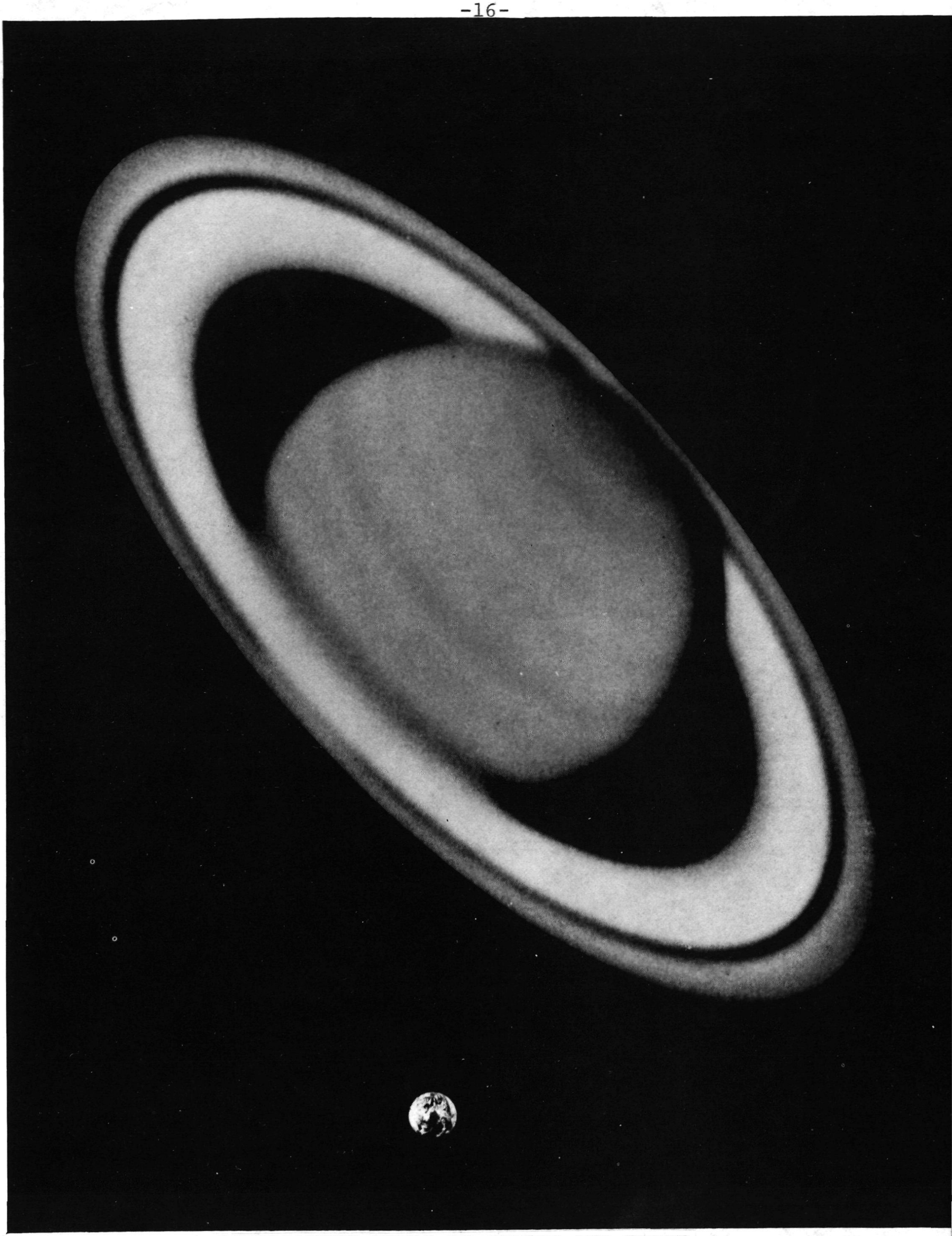
The first telescopic observations of the planet were made by Galileo Galilei in 1610. His telescope, which gave a magnification of only eight power, led the early astronomers to believe he had seen not one but three planets because of the confusing image of Saturn's encompassing rings. Using a better telescope, Dutch astronomer Christian Huygens correctly identified the rings in 1655.

Saturn is the second largest planet in our solar system. It has a volume 815 times that of Earth, but a mass only 95.2 times greater. Like its giant neighbor, Jupiter, Saturn's extremely rapid rotation has caused the planet to be flattened at its poles. Saturn's equatorial radius is 60,330 km (37,490 mi.), while the polar radius is considerably smaller -- 54,000 km (33,554 mi.). Its surface gravity is 1.15 (Earth's gravity is 1.0).

Saturn takes 29.46 Earth years to complete one orbit around the Sun. Though a Saturnian year is long, its days are short, lasting only 10 hours, 39 minutes, 24 seconds (as determined by Voyager).

In its slow orbit around the Sun, Saturn is perturbed by the other planets -- especially Jupiter -- so its orbital path is not strictly elliptical. The planet wavers in its distance from the Sun in a region of between 9.0 AU and 10.1 AU. (An astronomical unit, or AU, is the mean distance from the Sun to Earth -- 149,597,870 km or 92,955,806.8 mi.). Saturn receives only about one-one hundredth as much sunlight as that which reaches Earth.

Like the three other gas giants -- Jupiter, Neptune and Uranus -- Saturn has no solid surface, but is a huge, multi-layered globe of gas with a small core of iron and rocky material.



COMPARATIVE SIZES OF SATURN AND EARTH

Because Saturn is farther from the Sun, it is colder than Jupiter. Material in its atmosphere freezes at greater depths than on Jupiter. Ammonia, for example, freezes and forms clouds on Saturn at a depth of two or three Earth atmospheres (two to three times the surface pressure of Earth, which is 1,000 millibars), compared to six tenths of an atmosphere on Jupiter.

Gravity-field analysis and temperature-profile measurements made by Pioneer 11 suggest that Saturn's core, extending out about 13,800 km (8,575 mi.) from the center, is twice the size of Earth, but is so compressed that its iron and rocky core contains 15 to 20 times the mass of Earth.

Surrounding the core is a layer of electrically conductive metallic hydrogen. This form of hydrogen has not been observed on Earth, since immense pressure is required for its production.

The outermost layer of the planet is an envelope of hydrogen and helium. The interaction between these two elements may explain Saturn's emission of heat. Both Jupiter and Saturn release about twice the amount of energy they receive from the Sun. But scientists believe the two planets produce their energy in entirely different ways.

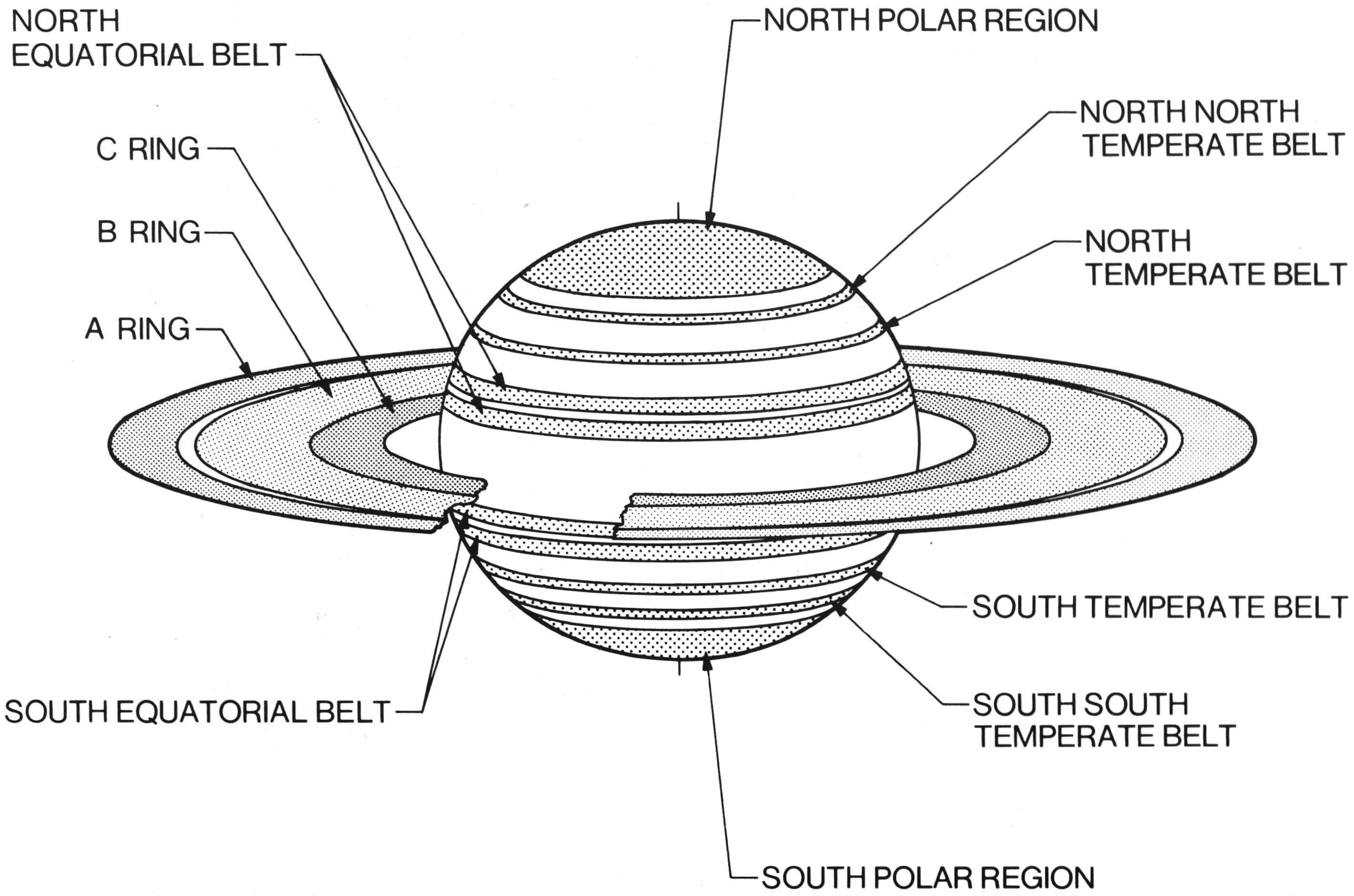
Jupiter emits energy left over from the gravitational contraction that occurred when the planet was formed 4.6 billion years ago. But because Saturn is smaller, scientists conclude that it cannot emit energy in the same manner: Any heat left over from Saturn's gravitational contraction would have dissipated long ago. Instead, Saturn's heat production may be the result of the separation of hydrogen and helium in the outer layer, with heavier helium sinking through the planet's liquid hydrogen interior.

From observations, the velocity of winds at Saturn's cloud tops appears to be about 1,400 km (900 mi.) an hour -- twice that on Jupiter. The calculations are based on observations from Earth of spots in Saturn's clouds, combined with Voyager's radio measurements of the rotation of the planet's interior.

Saturn has at least 13 satellites, though the family may finally number many more. Titan is the largest satellite in the solar system: With a diameter of 4,345 to 5,632 km (2,700 to 3,500 mi.) its size approximates that of Mercury. It is the only satellite in the solar system known to have retained a substantial atmosphere. Titan's atmospheric density is now calculated to be between 20 millibars and 2,000 millibars at the surface. (Earth's atmospheric density is about 1,000 millibars; Mars atmospheric density is about 10 millibars.) Its prevailing temperature is low -- about -198 degrees Celsius (-324 degrees Fahrenheit).

-more-

MAJOR FEATURES OF SATURN



Saturn's other satellites are like no others we have ever seen. Most of them are larger than Mars' tiny satellites, Phobos and Deimos, but they are not as large as the four Galilean satellites of Jupiter. They are midsized bodies, expected to consist of mixtures of rock and ice, with rocky material averaging 30 to 36 percent, or they could be all ice. It now appears that Voyager may discover a number of new, small satellites outside the A ring.

The rings' designations were assigned in the order of discovery; the letters have nothing to do with their relative positions. Beginning with the outermost ring, the rings are:

- E ring; extending to about eight Saturn radii (480,000 km or 298,260 mi. from the planet. It has been photographed from Earth.

- F ring; identified in images taken by Pioneer 11. It is a very narrow ring just outside the A ring, but distinct and separate from the E ring.

- A ring; outermost ring visible with small telescopes.

- B ring; the brightest ring, lies inside the A ring, and is separated from it by Cassini's Division. (The division is not completely clear of material.) From Earth the B ring appears completely filled with material. However, a few Pioneer 11 images show light leaking through, leading to speculation there may be holes in the ring.

- C ring (or "crepe ring"); barely visible in small telescopes; lies inside the B ring; 17,000 km (11,000 mi.) from cloud tops.

In addition, a D ring has been claimed between the C ring and the cloud tops. Some scientists doubt its existence.

The Cassini Division between the B and A ring is the most prominent gap between the rings and easily visible with Earth-based telescopes. A thin space within the outermost edge of the A ring is the Encke Division. Pioneer identified a new, 3,600-km (2,200-mi.) division within the A ring.

The composition of the rings is unknown. The rings appear to be entirely ice or ice-covered material about 1 to 30 centimeters (0.3 to 12 inches) in diameter. Scientists want to determine the particle sizes and densities and discover if other material is present. How and why the rings formed is also a major question.

Jupiter's thin ring is made up of dust particles 0.05 cm (0.0002 in.) in diameter, as perceived by Voyager from forward scattering of sunlight.

But Saturn's rings contain much larger particles, so Voyager will use radio signals aimed at the rings and toward Earth at occultation to determine the presence of particles the size of 30 to 90 cm (1 to 3 ft.) in diameter.

The B ring contains the greatest amount of material and is so dense that little light can penetrate.

Scientists want to determine why density apparently differs from ring to ring, and if there are waves within the rings. Large objects in the rings themselves may also cause local variations in density.

Saturn's magnetic field is 1,000 times stronger than Earth's and 20 times weaker than Jupiter's. Saturn's magnetosphere is unique in that its north-south axis is within one degree or less of the planet's rotation axis, unlike the 10-degree tilt to the rotation axis of Earth, Jupiter and the Sun.

The magnetosphere, a magnetic bubble in the solar wind that surrounds the planet, is larger than Earth's but smaller than Jupiter's. It is a teardrop-shaped magnetic envelope about 8 million km (5 million mi.) wide, that extends about 2.5 million km (1.5 million mi.) from the planet.

Saturn possesses radiation belts of high-energy electrons and protons comparable in intensity to Earth's, though the region they occupy is about 10 times larger. The intensity of Saturn's radiation was unknown until Pioneer 11 flew past the planet and determined that the radiation belts are several hundred times weaker than Jupiter's. When the spacecraft passed below the rings, the radiation intensity dropped dramatically, indicating that ring material interrupts and absorbs the charged particles that bounce back and forth between the planet's poles.

The absorption of charged particles makes the area around the rings the most radiation-free sector of space yet found in the solar system. The innermost satellites also absorb radiation particles.

Pioneer's infrared instrumentation showed the equatorial zone is cooler than adjoining higher-latitude regions. The difference in temperature indicates varying heights of belts and zones.

Ultraviolet radiation detected at Saturn's poles is possibly the result of auroral activity like that which Voyager discovered at Jupiter.

Each of the Voyager experiments -- 10 instruments and the spacecraft radio -- gather specific data individually, but it is through the synergistic combination of data from several instruments that the science teams will assemble a coherent picture of the entire Saturn system.

SATURN SCIENCE EXPERIMENTS

Voyager 1's science investigations at Saturn fall into four broad classifications:

1. Saturn's atmosphere, studied by:

- Imaging
- Infrared Interferometer Spectrometer and Radiometer
- Ultraviolet Spectrometer
- Radio Science.

2. Seven of the satellites of Saturn -- Titan, Rhea, Dione, Mimas, Iapetus, Hyperion and Enceladus. A study will be conducted of recently discovered small satellites, and a search for undiscovered bodies. The studies will be conducted by:

- Imaging
- Infrared Interferometer Spectrometer and Radiometer
- Ultraviolet Spectrometer
- Radio Science.

3. Saturn's magnetic field and its interaction with the solar wind and the satellites, studied by:

- Plasma
- Low-energy charged particles
- Cosmic ray
- Magnetometers
- Planetary radio astronomy
- Plasma wave
- Radio science.

4. Saturn's rings, studied by:

- Imaging
- Infrared Interferometer Spectrometer and Radiometer
- Ultraviolet Spectrometer
- Radio Science.

Magnetic Fields Investigation

The magnetic field of a planet is an externally measurable indication of conditions deep within its interior. Four magnetometers aboard Voyager 1 gather data on the planetary magnetic fields at Saturn, the satellites, solar wind and satellite interactions with the planetary field, and the interplanetary (solar) magnetic field.

The magnetometers effectively probe the interplanetary medium -- the tenuous, ionized and magnetized gas called the solar wind.

To form the solar wind, the Sun constantly emits electrically charged particles -- protons and electrons -- from the ionization of hydrogen. Those particles are in the fourth state of matter, called plasma (the other three states are solid, liquid and neutral gas). The plasma is of extremely low density and it fills all interplanetary space. Because it is ionized the solar wind is an electrically conducting medium.

The solar wind is deflected by planetary magnetic fields (such as Earth's, Jupiter's and Saturn's) and streams around and past the obstacles, confining the planetary magnetic fields to regions called the magnetosphere.

The shape of Saturn's magnetic field is not clearly understood. But because Voyager 1 and Voyager 2 arrive nine months apart, scientists can link long-term measurements of the solar wind to the magnetosphere as the latter changes size and shape in response to variations in the solar wind.

The outer regions of Jupiter's, and probably Saturn's magnetic fields are shaped much differently from Earth's. The rapid rotation of Jupiter and Saturn may be one explanation as their magnetic fields corotate with the planets. At great distances, the planets' magnetic-field lines appear to form a spiral structure, which could be explained by outward-flowing plasma. A striking difference between the magnetic fields of the three planets is that Earth's and Jupiter's north magnetic poles are offset at least 10 degrees from their geographic poles, while Saturn's is offset 1 degree or less, according to data from Pioneer 11, which studied Saturn in September 1979.

Cosmic Ray Investigation

Cosmic rays are the most energetic particles in nature and are atomic nuclei, primarily protons and electrons. They comprise all known natural elements. Over certain energy ranges and at certain periods of time, the content of cosmic rays is similar in proportion to that of all the matter in the solar system.

-more-

Generally, however, their composition varies significantly with energy, indicating to scientists that a variety of astrophysical sources and processes contributes to their numbers.

Cosmic rays may, as we search for their origins, tell much about the solar system's origins and processes. Cosmic rays are material samples of the galaxy, and can tell us much about how stars synthesize the various elements in their interiors.

Voyager's cosmic ray instrument will study the energy content, origin and acceleration process, and life history of cosmic rays.

Planetary Radio Astronomy

The planetary radio astronomy will measure radio emissions from Saturn in the low-frequency range from 20 kilohertz to 40.5 megahertz. (AM radio stations broadcast at frequencies between 550 kilohertz and 1.6 megahertz.) Scientists say emissions ranging in wavelength from less than 10 m (33 ft.) to thousands of meters can result from wave-particle-plasma interactions in the magnetosphere and ionosphere of Saturn.

Saturn's weak, kilometer wavelength radio bursts have been used by the scientists to determine the planet's rotation rate with high precision. That rotation rate, determined with data from this instrument, is 10 hours, 39 minutes, 24 seconds.

Another goal of the planetary radio astronomy experiment is to search for lightning in Saturn's atmosphere, since lightning was discovered in the atmosphere of Jupiter, and it has been postulated as a catalyst for the formation of life. Together with the plasma wave experiment and several optical instruments, planetary radio astronomy may be able to demonstrate the existence of lightning on Saturn.

One current theory says that lightning in an atmosphere of hydrogen, methane, ammonia and water could set off reactions that eventually form complex organic molecules.

Infrared Interferometer Spectrometer and Radiometer

Saturn presents a more subtle appearance to Earth-based observers than Jupiter, with its well-defined and colorful light zones, dark belts and large storm systems.

Voyager's infrared interferometer spectrometer and radiometer -- called, simply, IRIS -- will try to determine why the differences are so marked between the two apparently similar planets.

Each chemical compound has a unique spectrum. Measuring the infrared radiation emitted and reflected by an object provides data on atmospheric gas composition, abundance, clouds, haze, temperatures, circulation and heat balance.

Hydrogen, deuterium (heavy hydrogen), methane, ammonia, ethane and phosphine have been identified in Saturn's atmosphere. There is also evidence for the presence of helium, although the amount is uncertain.

Knowledge of the absorption properties of the atmosphere's major constituents can be used to measure the temperature at various depths as it changes with pressure. The presence of a considerable quantity of dust in the atmosphere is deduced from the sharp drop in overall reflectivity from 5,000 Angstroms to 3,000 Angstroms.

Satellite temperature maps will be constructed using the distinctive spectral signatures of ices and minerals found on the surfaces. Maps and pictures of the satellites can be used to study the geology and evolution of the bodies, and how they differ with distance from Saturn.

Radio Science

The radio that provides tracking and communication with Voyager also explores the planets and space.

Measurements of Voyager's radio signals provide information on gravity fields and atmospheres of Saturn and its satellites, the solar corona and general relativity.

Changes in frequency, phase, delay, intensity and polarization of radio signals between spacecraft and Earth provide information about the space between the two, and about gravitational forces that affect the spacecraft and alter its path.

When the spacecraft moves behind a body as viewed from Earth (called occultation), radio waves coming from the spacecraft pass through the ionosphere and atmosphere on their way Earthward. Changes in signal characteristics during those events give information about the vertical structure of the ionosphere, atmosphere, clouds and turbulence.

Imaging

Voyager 1's two television cameras will take about 18,000 pictures during the Saturn encounter. By themselves and coupled with data from other instruments, the cameras can provide vast amounts of scientific data about the objects to be studied -- Saturn and at least seven of its satellites.

On a gross scale, one would expect Saturn to be very much like Jupiter -- a vast accumulation of hydrogen and helium surrounding a small, dense, rocky core.

But there are also a variety of differences between the two: while both have a layer of high-altitude atmospheric haze, Saturn's appears from Earth to be much thicker than Jupiter's. That, plus Saturn's greater distance from Earth, makes motions within the planet's atmosphere difficult to study from Earth. As a result, imaging scientists expect to make the first extensive study of global wind systems in the atmosphere of Saturn.

Though the gross cloud structure in Saturn's atmosphere is dominated by the familiar belt-zone pattern as seen on Jupiter, there is a marked absence of any long-lived features analogous to Jupiter's Great Red Spot. The few spots or features that have been seen from Earth indicate that tropical latitudes on Saturn rotate more rapidly than do the temperate and polar regions (recall that this is analogous to Jupiter). One explanation for the sparsity of spots in Saturn's atmosphere may be the presence of a thick haze layer that diminishes atmospheric contrast. Scientists hope that high-resolution, high-contrast Voyager images will reveal the elusive features.

Most scientists believe Saturn's atmosphere must be as active as Jupiter's. The bland appearance of the cloud tops, they feel, is most likely due to obscuration by the high-altitude haze.

Atmospheric features will be affected by such phenomena as high wind speeds on Saturn, atmospheric convection and a rotation rate similar to Jupiter, radiation of internal heat that is more than 2.5 times greater than the radiation received from the Sun, the Coriolis force created by such rapid rotation, and the effects of the ring shadow on portions of the cloud tops.

Determining the structure of the atmosphere of Saturn is considered one of the classic problems to be solved by Voyager photography. Constant monitoring of the planet and motion picture sequences will help provide data to satisfy that requirement.

Since particles in Saturn's rings are thought to be extremely small (from a few centimeters to a few meters in size), Voyager's cameras will not resolve the individual ring particles. But waves or clumps of particles, as well as large, satellite-sized objects orbiting within or near the rings should be identifiable. (The radio science experiments are intended to resolve many of the scientific questions about particle size.)

The satellites of Saturn (along with the rings) are expected by imaging scientists to provide the most surprises. Little is known about these satellites besides rough estimates of the sizes and densities.

Their densities indicate they could be solid ice or some combination of ice and rock up to about 30 to 40 percent rock. Infrared reflection spectra from Earth telescopes have also identified water ice or frost on many of the satellite surfaces.

It is known that Titan's clouds are reddish-colored; through a telescope Titan looks as red as Mars. But even the surface pressure of Titan's atmosphere is unknown -- current estimates range from 2 bars, twice the surface atmospheric pressure of Earth, to about 20 millibars, about twice the surface pressure at Mars, or 2 percent of Earth's surface pressure. But sizes, surface characteristics, densities and composition of the other satellites are not known.

Low-Energy Charged Particles

The low-energy charged particle instrument is a strong coupling factor in Voyager's complement of fields and particles investigations, contributing to many areas of interest, including the solar wind, solar flares, particle accelerations, magnetic fields and cosmic rays.

Two detectors allow measurements during the long interplanetary cruise and the encounters. The wide dynamic range, combined with wide coverage in energy and species, allow characterization of a wide range of energetic-particle environments, including the intense trapped-radiation environment around the planets. The low-energy charged particle measures particles traveling 2,400 to more than 150,000 km (1,500 to more than 93,000 mi.) a second. (High-energy particles travel at or near the speed of light -- 299,792 km or 186,282 mi. a second.)

Observations of particle acceleration provide data for understanding solar flare processes, cosmic ray acceleration and processes in Earth's magnetosphere.

Plasma

Voyager's plasma instrument measures plasma properties including velocity, density and temperature for a wide range of flow directions in the solar wind and planetary magnetospheres.

Traveling at supersonic speed (averaging 400 km or 250 mi. a second), plasma streams in all directions radially from the Sun, forming the solar wind. Solar wind interaction with Earth's magnetic field results in the northern lights and geomagnetic storms. Similar events have been observed at other planets.

At Saturn, the plasma team will study the interaction of the solar wind with Saturn; the sources, properties, forms and structure of Saturn's magnetospheric plasma; and the interaction of the magnetospheric plasma with the satellites and rings.

Although the plasma instrument cannot directly observe the neutral atoms in the magnetosphere, neutral gas is eventually ionized and becomes part of the Saturnian magnetosphere plasma.

It is possible that Titan, largest satellite in the solar system and the only one known to have a substantial atmosphere, has a torus, or donut-shaped cloud of ionized material associated with it. If that is the case, the plasma instrument should detect some of those ions when Voyager nears the orbit of Titan.

Saturn's magnetosphere probably extends into space about 40 times the radius of Saturn (2.4 million km or 1.49 million mi.). That distance appears typical for a quiet magnetosphere and quiet solar wind. (When Pioneer 11 arrived at Saturn late in August 1979, the Saturnian magnetosphere was strongly affected by violent solar wind activity.)

During Voyager 1's encounter with Saturn, the pressure of the solar wind at Saturn and the size of Saturn's magnetosphere can be predicted using data from Voyager 2 -- farther from Saturn and closer to the Sun. Comparing data from both spacecraft during the Voyager 1 encounter will reveal the reaction of the Saturnian magnetosphere to changes in the incoming solar wind. The leading edge of the magnetosphere will pulse in and out depending on changes in solar wind pressure.

Voyager's first encounter with Saturn's magnetosphere will be detected when the spacecraft crosses the bow shock wave, a region of demarcation between the solar wind and the Saturn environment. Voyager 1 is expected to cross the bow shock about Nov. 10, two days before closest approach.

Immediately behind the bow shock is a transition region called the magnetosheath that separates the solar wind from the magnetosphere. The inner boundary of the magnetosheath, the magnetopause, separates the modified solar wind plasma in the magnetosheath from the plasma in the magnetosphere proper. Plasma in the magnetosphere comes from several sources -- Saturn's ionosphere, ions from satellites and atmospheres, and the solar wind.

In the inner magnetosphere, plasma trapped by the magnetic field is forced to rotate with the planet. This region of corotation may extend as far as the magnetopause; the farther from the planet, the more the centrifugal force causes stretching of the magnetic field lines, more or less parallel to Saturn's equator.

Plasma Wave

Voyager 1 is surrounded by a low-density, ionized gas called a plasma. That plasma, composed entirely of atoms that are broken apart into electrons and positively charged ions, is a good electrical conductor with properties that are strongly affected by magnetic fields.

Plasma sources include the Sun, the planets and some of their satellites. Low-density plasmas are unusual; ordinary collisions between ions are unimportant, and individual ions and electrons interact with the rest of the plasma by means of emission and absorption of waves.

Localized interactions between waves and particles strongly control the dynamics of the entire plasma medium, and Voyager's plasma-wave instruments are providing the first measurements of those phenomena at the outer planets.

Plasma waves are low-frequency oscillations that have their origins in instabilities within the plasma. They are of two types -- electrostatic oscillations (similar to sound waves) or electromagnetic waves of very low frequency.

The plasma wave instrument measures the electric field component between 10 and 56,000 hertz. By way of comparison, Voyager's magnetometers measure the magnetic components of electromagnetic plasma waves below 10 hertz, while the planetary radio astronomy instrument measures waves with frequencies above 20 kilohertz.

Plasma ions and electrons collectively emit and absorb plasma waves. While the resulting particle-wave interactions affect the magnetospheric dynamics of the outer planets and the properties of the distant interplanetary medium, they have never been directly observed in those regions, since plasma waves cannot be observed far from their source and since there have been no previous wave studies at the outer planets.

Some effects to be studied include heating of solar wind particles at the outer planet bow shocks, acceleration of solar wind particles that produce high-energy trapped radiation, and the maintenance of boundaries between the rotating inner magnetospheres and the solar wind streaming around the planets.

Another objective of the plasma wave experiment is to study the influence of wave-particle effects on interactions between inner satellites and the planet's rapidly rotating magnetosphere.

Detection of lightning bolts in the atmosphere of Saturn, as discussed earlier, would also be significant in searches for energy sources that contribute to the planet's structure. The plasma wave instrument searches for whistler signals that escape into the magnetosphere from lightning discharges.

The descending-scale whistle that is characteristic of lightning is caused by different velocities for plasma waves traveling along the magnetic field; higher frequencies arrive at the receiver sooner than lower frequencies.

-more-

Using the high-rate telemetry usually reserved for transmission of imaging data, the plasma wave instrument will play to Earth the entire audible signal of space -- plasma waves, spacecraft power, thruster firing and other instruments.

Ultraviolet Spectrometer

Voyager's ultraviolet spectrometer will study the composition and structure of Saturn's atmosphere and the material surrounding the satellites. Two techniques, airglow measurements and occultation, have been developed to probe a planet's atmosphere without entering that atmosphere:

- Airglow observations require coverage of a large area for maximum sensitivity to the weak emissions high in the atmosphere -- where collisions between atoms and molecules are rare.

- Occultation measurements require an instrument that reads ultraviolet radiation from the Sun as it is absorbed and scattered by a planet's atmosphere as the spacecraft moves into the shadow with the planet between it and the Sun.

Airglow observations measure atomic hydrogen and helium in the upper atmosphere by recording the resonance scattering of sunlight. Resonance scattering occurs when atoms and molecules absorb solar ultraviolet at specific wavelengths and reradiate at the same wavelengths. That differs from fluorescence, in which the activating wavelength is absorbed and energy is reemitted at different wavelengths. It is also possible that auroral emissions will be observed at Saturn, since they were observed at Jupiter.

As the spacecraft disappears behind Saturn, the planet's atmosphere passes between the Sun and the ultraviolet spectrometer. Since the gases that make up an atmosphere have identifiable absorption characteristics at short wavelengths (they absorb various wavelengths differently), the ultraviolet spectrometer can measure how much of each gas is present at what temperature.

The important point is not how much sunlight enters the atmosphere, but what happens to it as it enters -- how it is absorbed and scattered.

EXPERIMENT	PRINCIPAL INVESTIGATOR	INSTRUMENT AND FUNCTIONS
Imaging Science	Bradford A. Smith University of Arizona	Two TV cameras with 1,500 mm. f/8.5 and 200 mm, f/3 optics; multiple filters, variable shutter speeds and scan rates. Wide-angle field of view = 56 x 55 milliradian (about 3 degrees square). On scan platform.
Infrared Interferometer Spectrometer	Rudolf H. Hanel Goddard Space Flight Center	Spectrometer-radiometer measuring temperature and molecular gas composition, with narrow, 1/4-degree field of view, producing measurements every 48 seconds; on scan platform.
Ultraviolet Spectrometer	A. Lyle Broadfoot University of Southern California	Grating spectrometer measuring ion, atomic and small-molecular gas abundances; spectral range 500-1, 700 Angstroms; on scan platform.
Photopolarimeter	Arthur L. Lane Jet Propulsion Laboratory	(Instrument not operating on Voyager 1.)
Plasma	Herbert S. Bridge Massachusetts Institute of Technology	Dual plasma detectors, one aligned toward Earth and Sun and one perpendicular, with detection ranges from 10 ev to more than 6 kev/nucleon.
Low-Energy Charged Particles	S. M. Krimigis Johns Hopkins Applied Physics Laboratory	Dual rotating solid-state detector sets, covering various ranges from 10 kev to more than 30 mev/nulceon.

Cosmic Ray	Rochus E. Vogt California Institute of Technology	High-energy, low-energy and electron telescope systems using arrays of solid-state detectors, several ranges from 0.5 to 500 mev/nucleon.
Magnetometer	Norman F. Ness Goddard Space Flight Center	Two low-field triaxial fluxgate magnetometers located on a 13-m (43-ft.) boom; two high-field (about 20 gauss) instruments on spacecraft body.
Planetary Radio Astronomy	James W. Warwick Radiophysics, Inc.	Two 10-m (33-ft.) whip antennas and two-band receiver 1.2 Khz to 40.5 Mhz detecting planetary radio emissions and bursts and solar-stellar bursts.
Plasma Wave	Frederick L. Scarf TRW Defense and Space Systems	Uses 10-m (33-ft.) planetary radio astronomy antennas with step-frequency detector and waveform analyzer to measure plasma waves, thermal plasma density profiles at Jupiter and Saturn, satellite/magnetosphere interactions and wave-particle interactions.
Radio Science	G. Len Tyler Stanford University	Uses spacecraft S-band/X-band links in occultations of planets, satellites and rings to perceive changes in refractivity and absorption; celestial mechanics information calculated from tracking data.

VOYAGER JUPITER SCIENCE RESULTS

Voyager 1 began its encounter with Jupiter in January 1979, completing it in early April. Voyager 2 began its encounter with Jupiter a few weeks later, in April 1979, and continued into August. The two spacecraft took more than 33,000 pictures of Jupiter and its five major satellites.

Although astronomers had studied Jupiter from Earth for more than three centuries, scientists were astonished by the findings from Voyager 1 and 2. They found new physical, geological and atmospheric processes in the planet, its satellites and magnetosphere.

Discovery of active volcanism on the satellite Io was probably the greatest surprise -- and may turn out to have the most far-reaching effects. It is likely that activity on Io may be affecting the entire Jovian system. Io appears to be the source of matter that pervades the Jovian magnetosphere -- the region of space surrounding the planet that is primarily influenced by the planet's strong magnetic field. Sulfur, oxygen and sodium, apparently erupted by Io's many volcanoes, were detected as far as the outer edge of the magnetosphere. Particles of the same material were detected inside Io's orbit, where they are accelerated to more than 10 percent of the speed of light.

The following is a summary of the more important science results from the Voyager encounters with Jupiter:

Jupiter's Atmosphere

- Atmospheric features of broadly different sizes appear to move with uniform velocities. That suggests that mass motion (movement of material) and not wave motion (movement of energy through a relatively stationary mass) is being observed.

- Rapid brightening of features in the atmosphere was observed, followed by spreading of cloud material. That is probably the result of disturbances that trigger convective (upwelling and downwelling) activity.

- A belt-zone pattern of east-to-west winds was seen in the polar regions, roughly similar to the pattern seen in the more temperate areas. Previous investigations led scientists to believe the polar regions are dominated by convective upwelling and downwelling. Information from the two Voyagers shows that this was not the case.

- Material associated with the Great Red Spot, the planet's most prominent atmospheric feature, moves in a counterclockwise (anticyclonic) direction. The material appears to have a rotation period of about six days.

- Smaller spots appear to interact with the Great Red Spot and with each other.

- Auroral emissions (similar to Earth's northern lights) were observed in Jupiter's polar regions. They have been seen in both ultraviolet and visible light. The ultraviolet auroral emissions were not present during the Pioneer 10 encounter in 1973. They appear to be associated with material from Io that spirals along magnetic field lines to fall into Jupiter's atmosphere.

- Cloud-top lightning bolts, similar to superbolts in Earth's high atmosphere, were detected.

- The atmospheric temperature at 5 to 10 millibars is about 160 degrees Kelvin (-171 degrees Fahrenheit), part of an inversion layer -- a warm region above a cold layer, similar to the phenomenon that traps smog in the Los Angeles Basin. (Earth's surface pressure is about 1,000 millibars.)

- The Voyagers observed an ionospheric temperature that changed with altitude, reaching about 1,100 Kelvin (1,520 degrees Fahrenheit). That was also not observed by Pioneer 10, and Voyager scientists believe they are witnessing large temporal or spatial changes in the ionosphere of Jupiter.

- Atmospheric helium was measured; its percentage compared to hydrogen is important to understand the composition and history of the atmosphere -- and indirectly, the primordial cloud out of which the Sun and planets formed. The relative abundance of helium is about 11 percent that of hydrogen.

- The atmospheric temperature above the Great Red Spot is somewhat colder (3 degrees Celsius or 5.4 degrees Fahrenheit) than in surrounding regions.

Satellites and Ring

- Eight currently active (erupting) volcanoes, probably driven by tidal heating, were positively identified on Io by Voyager 1. Many more are suspected. Voyager 2 saw six more still active, but the largest had shut down. An eighth was out of range of Voyager 2's instruments. Plumes from the volcanoes extend up to 250 km (155 mi.) above the surface. The material is being ejected at rates up to 1 km per second (2,200 mph). By comparison, ejection velocities have been measured at Mount Etna, one of Earth's most explosive volcanoes, at 50 m per second (112 mph). The volcanism on Io is apparently associated with heating of the satellite by tidal pumping. Io's orbit is perturbed by Europa and Ganymede, two other large satellites nearby, and Io is drawn back again by Jupiter. That action causes tidal bulging as great as 100 m (330 ft.).

- Voyager 1 measured the temperature of two hot spots on Io. Both are associated with volcanic features. While the surrounding terrain has a temperature of -138 C (-216 F), the hot spot's temperature is about 20 C (68 F). That hot spot may, scientists believe, be a lava lake, although the temperature indicates that the surface of the spot is not molten; it is, at least, reminiscent of lava lakes on Earth. The other hot spot is associated with Plume No. 1, called Pele. That hot spot, though smaller, registered temperatures as high as 300 C (572 F).

- Europa displayed a large number of intersecting linear features in the distant, low-resolution photos from Voyager 1. Scientists at first believed the features might be deep cracks, caused by crustal rifting or tectonic processes. The closer, high-resolution photos from Voyager 2, however, left scientists puzzled: the features were so lacking in topographic relief that they "might have been painted on with a felt marker," one scientist commented. There is a possibility that Europa may be internally heated due to tidal forces, although at a much lower level than Io.

- Ganymede showed two distinct types of terrain -- cratered and grooved. That suggests to scientists that Ganymede's entire, ice-rich crust has been under tension from global tectonic processes.

- Callisto has an ancient, heavily cratered crust, with remnant rings of enormous impact basins. The basins themselves have been erased by the flow of the ice-laden crust -- to the degree that little topographic relief is apparent in the high-resolution pictures taken by the Voyagers.

- Amalthea has an elliptical shape: It is 265 km (164 mi.) by 140 km (87 mi.). Amalthea is about 10 times bigger than Mars' larger satellite, Phobos.

- A ring of material was discovered around Jupiter. The outer edge is 128,000 km (79,500 mi.) from the center of the planet, and is no more than 30 km (18.6 mi.) thick. There appears to be more than one ring, and the material appears to gradually fall inward to the planet itself. Studies of the scattering of light by the ring should yield a good indication of the size of the particles.

Magnetosphere

- An electric current of about 2.5 million amperes was detected in the flux tube connecting Jupiter and Io. That was two-and-a-half times stronger than the current predicted before Voyager 1's arrival. The spacecraft did not fly through the flux tube, as has been planned, since the flux tube had been displaced 7,000 km (4,300 mi.) from the expected location.

- The Voyagers detected ultraviolet emissions from doubly and triply ionized sulfur and from doubly ionized oxygen. Since Pioneer 10 and 11 did not detect those emissions, that indicates a hot plasma was not present in 1973 and 1974 when the Pioneer encounters took place. The sulfur apparently originates in Io's volcanoes.

- Plasma electron densities in some regions of the Io torus (a tube-shaped ring of matter in the region of Io's orbit) exceeded 4,500 per cubic centimeter.

- A cold plasma, rotating with Jupiter, was discovered inside six Jupiter radii (428,000 km or 266,000 mi.) from the planet. Ions of sulfur and oxygen were detected.

- High-energy trapped particles were also detected in the same region near Jupiter. They had significantly enhanced abundances of oxygen, sodium and sulfur.

- A hot plasma was measured near the Jovian magnetopause (the outer edge of the magnetosphere), composed mostly of protons, oxygen and sulfur.

- Kilometric radio emissions were detected coming from Jupiter. The emissions, in the frequency range from 10 kilohertz to 1 megahertz, might be associated with the Jovian auroral processes.

- Plasma flows were detected in the dayside middle magnetosphere; they rotate with the planet at a 10-hour period.

- Voyager 1 saw evidence of a transition from closed magnetic field lines to a magnetotail on the antisolar side of Jupiter. Although such a magnetotail was never in serious question, its existence had not been detected before.

- Voyager also measured radio spectral arcs (from about 1 megahertz to more than 30 megahertz) in patterns that correlate with Jovian longitude.

VOYAGER SCIENCE TEAMS

Cosmic Ray

Rochus E. Vogt, California Institute of Technology, Principal Investigator

J. Randy Jokipii, University of Arizona

Frank B. McDonald, Goddard Space Flight Center

A. W. Schardt, Goddard Space Flight Center

Edward C. Stone, California Institute of Technology

James H. Trainor, Goddard Space Flight Center

William R. Webber, University of New Hampshire

Infrared Radiometry and Spectrometry

Rudolf A. Hanel, Goddard Space Flight Center, Principal Investigator

Barney Conrath, Goddard Space Flight Cneter

Dale Cruikshank, University of Hawaii

F. Michael Flasar, Goddard Space Flight Center

Daniel Gautier, Observatoire de Paris, France

Peter Gierasch, Cornell University

Shailendra Kumar, University of Southern California

Virgil Kunde, Goddard Space Flight Center

William Maguire, Goddard Space Flight Center

John Pearl, Goddard Space Flight Center

Joseph Pirraglia, Goddard Space Flight Center

Cyril Ponnamperuma, University of Maryland

Robert Samuelson, Goddard Space Flight Center

Imaging Science

Bradford A. Smith, University of Arizona, Team Leader

Geoffrey Briggs, NASA Headquarters

Allan F. Cook II, Center for Astrophysics

G. Edward Danielson, California Institute of Technology

Merton E. Davies, Rand Corp.

Garry E. Hunt, University College London

Torrence V. Johnson, Jet Propulsion Laboratory

Harold Masursky, U.S. Geological Survey

Tobias Owen, State University of New York

Carl Sagan, Cornell University

Laurence Soderblom, U.S. Geological Survey

Verner E. Suomi, University of Wisconsin

Low-Energy Charged Particles

S.M. (Tom) Krimigis, Johns Hopkins University, Principal Investigator

Thomas P. Armstrong, University of Kansas

W. Ian Axford, Max Planck Institut fur Aeronomie

Carl O. Bostrom, Johns Hopkins University

Chang-Yun Fan, University of Arizona

George Gloeckler, University of Maryland

Ed Keath, Johns Hopkins University

Louis J. Lanzerotti, Bell Laboratories

Magnetic Fields

Norman F. Ness, Goddard Space Flight Center, Principal Investigator

Mario F. Acuna, Goddard Space Flight Center

Ken W. Behannon, Goddard Space Flight Center

Len F. Burlaga, Goddard Space Flight Center

Ron P. Lepping, Goddard Space Flight Center

Fritz M. Neubauer, Der Technischen Universat Braunschweig

Plasma Science

Herbert S. Bridge, Massachusetts Institute of Technology, Principal Investigator

John W. Belcher, Massachusetts Institute of Technology

Len F. Burlaga, Goddard Space Flight Center

Christoph K. Goertz, Max Planck Institut fur Aeronomie

Richard E. Hartle, Goddard Space Flight Center

Art J. Hundausen, High Altitude Observatory

Alan J. Lazarus, Massachusetts Institute of Technology

Keith Ogilvie, Goddard Space Flight Center

Stanislaw Olbert, Massachusetts Institute of Technology

Jack D. Scudder, Goddard Space Flight Center

George L. Siscoe, University of California, Los Angeles

James D. Sullivan, Massachusetts Institute of Technoloy

Vytenis M. Vasyliunas, Max Planck Institut fur Aeronomie

Photopolarimetry

(This instrument, on Voyager 1, is not operating correctly and has been turned off. The photopolarimeter on Voyager 2 is operating and will be used at Saturn.)

Arthur L. Lane, Jet Propulsion Laboratory,
Principal Investigator

David Coffeen, Goddard Institute for Space Studies

Larry Esposito, University of Colorado

James E. Hansen, Goddard Institute for Space Studies

Charles W. Hord, University of Colorado

Kevin Pang, Science Applications, Inc.

Makiko Sato, Goddard Institute for Space Studies

Robert West, University of Colorado

Planetary Radio Astronomy

James W. Warwick, Radiophysics, Inc., Principal Investigator

Joseph K. Alexander, Goddard Space Flight Center

Andre Boischot, Observatoire de Paris, France

Walter E. Brown, Jr., Jet Propulsion Laboratory

Thomas D. Carr, University of Florida

Samuel Gulkis, Jet Propulsion Laboratory

Fred T. Haddock, University of Michigan

Christopher C. Harvey, Observatoire de Paris, France

Michael L. Kaiser, Goddard Space Flight Center

Yolande LeBlanc, Observatoire de Paris

Jeffrey B. Pearce, Radiophysics, Inc.

Robert G. Peltzer, Martin Marietta Corp.

Roger Phillips, Jet Propulsion Laboratory

Anthony C. Riddle, University of Colorado

David H. Staelin, Massachusetts Institute of Technology

Plasma Wave

Frederick L. Scarf, TRW Defense and Space Systems, Principal Investigator

Donald A. Gurnett, State University of Iowa

Radio Science

G. Len Tyler, Stanford University, Team Leader

John D. Anderson, Jet Propulsion Laboratory

Thomas L. Croft, SRI International

Von R. Eshelman, Stanford University

Gerald S. Levy, Jet Propulsion Laboratory

Gunnar F. Lindal, Jet Propulsion Laboratory

G. E. Wood, Jet Propulsion Laboratory

Ultraviolet Spectroscopy

A. Lyle Broadfoot, University of Southern California, Principal Investigator

Sushil K. Atreya, University of Michigan

Michael J. S. Belton, Kitt Peak National Observatory

Jean L. Bertaux, Service d'Aeronomie du CNRS

Jacques E. Blamont, Jet Propulsion Laboratory

Alexander Dalgarno, Harvard College Observatory

Thomas M. Donahue, University of Michigan

Richard Goody, Harvard University

John C. McConnell, York University

Michael B. McElroy, Harvard University

H. Warren Moos, Johns Hopkins University

William R. Sandel, University of Southern California

Donald E. Shemansky, University of Southern California

Darrell F. Strobel, Naval Research Laboratory

VOYAGER MISSION SUMMARY

August 1977 to September 1980

Voyager 2, first of the two spacecraft to begin the journey to the outer planets, was launched from Cape Canaveral, Fla., aboard a Titan-Centaur launch vehicle at 10:29 a.m. EDT, Aug. 20, 1977.

Voyager 1 was launched 16 days later, at 8:46 a.m. EDT, Sept. 5.

On Dec. 10, 1977, both spacecraft entered the asteroid belt, a band of rock and dust 360 million km (223 million mi.) wide that circles the Sun between the orbits of Mars and Jupiter. Voyager 1 flew out of the asteroid belt Sept. 8, 1978. Voyager 2 left the belt behind on Oct. 21.

Earlier -- on Dec. 15, 1977 -- Voyager 1, flying a shorter and faster course to Jupiter, had overtaken Voyager 2. At the time, they were 170 million km (105 million mi.) from Earth.

In the early months of 1978, two major problems occurred, one on each spacecraft.

During a calibration of Voyager 1's scan platform, the movable housing for the cameras and some other instruments became jammed. Engineers determined that a tiny piece of soft debris had found its way into the gears. By maneuvering the platform, engineers were able to free the platform.

Voyager 2's primary radio receiver failed on April 5, 1978, and the spacecraft's computer-command subsystem automatically switched to the backup receiver. The backup receiver, however, developed a faulty tracking loop capacitor. But engineers have provided a work-around solution to the tracking loop capacitor. The spacecraft now cannot lock on a signal from Earth and track it as the frequency varies because of the spacecraft's velocity and the Earth's rotation (Doppler shift). But ground-based computers have been programmed to precisely control the frequency transmitted so they can arrive at the spacecraft at the frequency at which Voyager 2 can receive them.

And an automated sequence for Saturn has been stored aboard Voyager 2's computer. In the event that the second receiver should fail, and the spacecraft can no longer be commanded, Voyager 2 will perform its Saturn encounter experiments and return useful data to Earth.

Both Voyagers conducted fields and particles experiments during the long cruise to Jupiter, and the period between Jupiter and Saturn and Saturn encounters.

-more-

Voyager 1 began the observatory phase of its Jupiter encounter Jan. 4, 1979, while it was 61 million km (38 million mi.) from the planet. Immediately obvious to the scientists on Voyager's imaging team was the change in Jupiter's cloud features in the four years since Pioneer 11 had flown past Jupiter (in December 1974).

Voyager 1 made its closest approach to Jupiter at 4:05 a.m. PST, spacecraft time, on March 5, 1979, at an altitude of 278,000 km (173,000 mi.). (See Jupiter science results section of press kit.) It passed the Galilean satellites after passing Jupiter, then began its 20-month journey to Saturn, boosted on its way by Jupiter's orbital motion and immense gravity.

Despite the intense radiation dose dealt Voyager 1 by particles in Jupiter's magnetopshere, the spacecraft experienced only one failure: circuitry in the photopolarimeter failed about six hours before closest approach. It has not recovered and will not be used during the Saturn encounter.

Voyager 2's encounter with Jupiter began April 25, just 19 days after Voyager 1's encounter ended. The same general sequence was followed with the Voyager 2 encounter, with some important differences:

- Voyager 2 passed farther from Jupiter than Voyager 1 -- 650,000 km (404,000 mi.) above the cloud tops.

- Voyager 2's science sequences were designed from knowledge gained by Voyager 1.

- Voyager 2 observed the Galilean satellites at close range on the inbound leg of the trajectory. Those satellites always present the same face to Jupiter, so between the two spacecraft, photos of both faces of the satellites were obtained.

The closest approach point at Jupiter was chosen to provide a trajectory to Saturn (for Voyager 2) that in turn would yield a trajectory to Uranus. At Jupiter and Saturn, the flight path and velocity of the spacecraft are changed by gravitational attraction of the planets and their orbital motion.

Voyager 1's encounter with Saturn began Aug. 22, 1980. It will make its closest approach to Saturn on Nov. 12. Voyager 2's encounter will begin in May 1981; closest approach occurs Aug. 26. Then Voyager 2 begins the cruise toward Uranus.

THE SATELLITES OF SATURN

Name	Radius		Distance		Orbital Time
	(km)	(mi.)	(km)	(mi.)	(Earth Days)
Janus*	150	93	168,700	104,825	0.815
Mimas	175	109	185,500	115,264	0.942
Enceladus	260	162	238,000	147,886	1.370
Tethys	510	317	294,700	183,118	1.888
Dione	550	342	377,400	234,506	2.737
Rhea	750	466	527,000	327,463	4.518
Titan	2,915	1,811	1,222,000	759,316	15.945
Hyperion	150	93	1,484,000	922,115	21.276
Iapetus	800	497	3,562,000	2,213,324	79.33
Phoebe	40	25	12,960,000	8,052,971	550.45

* Janus' existence is in doubt.

(A number of other satellites have been discovered during the past 14 months, both by the Pioneer spacecraft and from Earth; Voyager 1 will conduct several sequences to verify those new satellites and their orbits and to search for others as yet undiscovered.)

VOYAGER TEAM

NASA Office of Space Science

Dr. Thomas A. Mutch	Associate Administrator for Space Science
Andrew J. Stofan	Deputy Associate Administrator
Dr. Adrienne F. Timothy	Assistant Associate Administrator for Science
Angelo Guastaferro	Director, Planetary Division
Dr. Geoffrey A. Briggs	Deputy Director, Planetary Division
Dr. C. Howard Robins	Manager, Operations
Frank A. Carr	Program Manager, Acting
Dr. Milton A. Mitz	Program Scientist

NASA Office of Tracking and Data Systems

Robert E. Smylie	Associate Administrator for Tracking and Data Systems
Charles A. Taylor	Director, Network Systems Division
Dr. Richard Green	Manager, Deep Space Network Operations
Harold G. Kimball	Director, Communications and Data Systems Division

Jet Propulsion Laboratory

Dr. Bruce C. Murray	Director
Gen. Charles H. Terhune, Jr.	Deputy Director
Robert J. Parks	Assistant Director for Flight Projects
Raymond L. Heacock	Project Manager

CONVERSION TABLE

Multiply	By	To Get
Inches	2.54	Centimeters
Centimeters	0.3937	Inches
Feet	30.48	Centimeters
Centimeters	4.7244	Feet
Feet	0.3048	Meters
Meters	3.2808	Feet
Yards	0.9144	Meters
Meters	1.0936	Yards
Statute Miles	1.6093	Kilometers
Kilometers	0.6214	Miles
Feet Per Second	0.3048	Meters Per Second
Meters/Second	3.281	Feet/Second
Meters/Second	2.237	Statute Miles/Hour
Feet/Second	0.6818	Miles/Hour
Miles/Hour	1.6093	Kilometers/Hour
Kilometers/Hour	0.6214	Miles/Hour
Pounds	0.4563	Kilograms
Kilograms	2.2046	Pounds

To convert Fahrenheit to Celsius (Centigrade), subtract 32 and multiply by 5/9.

To convert Celsius to Fahrenheit, multiply by 9/5 and add 32.

To convert Celsius to Kelvin, add 273.

To convert Kelvin to Celsius, subtract 273.

-end-

(Index: 23, 36, 44)