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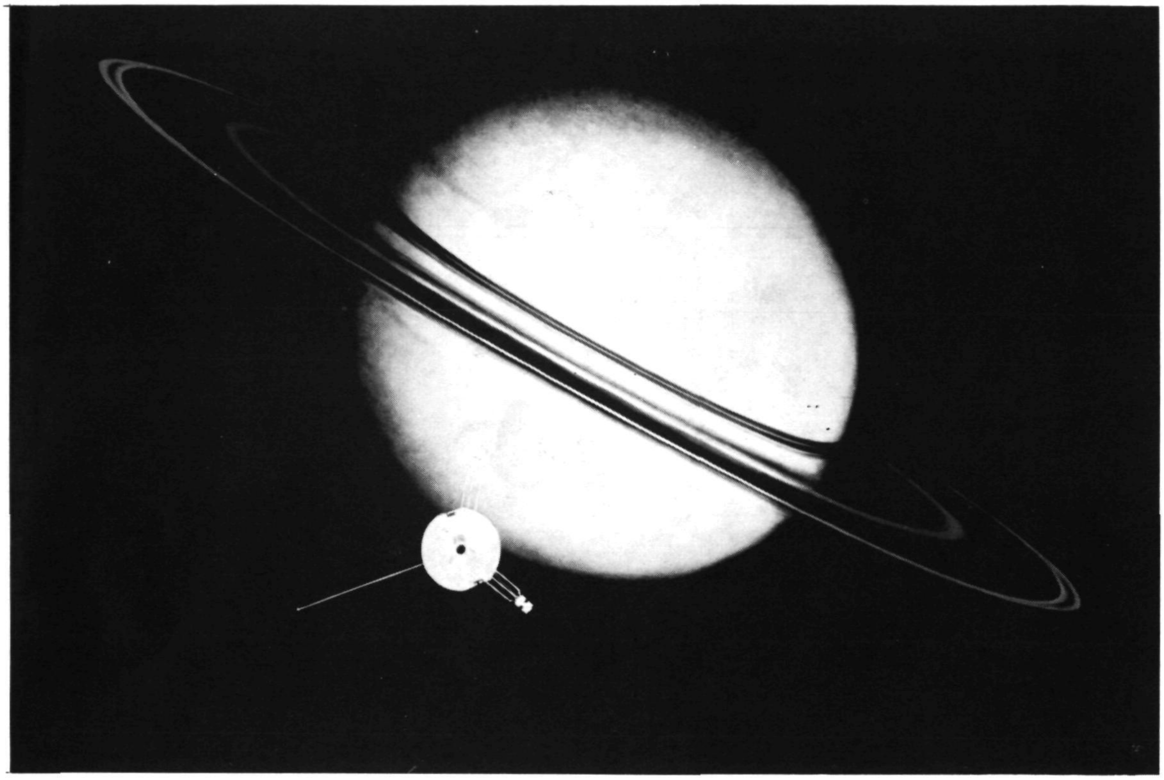
VOYAGER 1



SATURN ENCOUNTER

SUMMARY OF EVENTS

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Further Information

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

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

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SUMMARY OF EVENTS

The following is a summary of Voyager 1 encounter events at Saturn. (All times are Pacific times -- Daylight or Standard -- and represent the times when data are received on Earth.)

Voyager Encounter Phases

Observatory phase began at 7:30 a.m. PDT, Aug. 22, 1980, and runs until 6:25 a.m. PDT, Oct. 24. The Observatory phase ends when controllers cannot be sure of capturing the full Saturn disk in a single narrow-angle frame because of pointing uncertainties. It includes inbound movie sequences.

Far-Encounter 1 phase begins at 6:25 a.m. PDT, Oct. 24, and runs until 5:14 p.m. PST, Nov. 2. The start corresponds to the beginning of four-frame narrow-angle mosaics of the full Saturn disk. The phase ends when the full disk cannot be assured in those narrow-angle mosaics.

Far-Encounter 2 phase begins at 5:14 p.m. PST, Nov. 2, and continues until 3:14 p.m. PST, Nov. 11. Start corresponds to the end of narrow-angle imaging of Saturn. The phase ends about eight hours before closest approach to Titan.

Near-Encounter phase begins at 3:14 p.m. PST, Nov. 11, and ends at 2:40 p.m. PST, Nov. 13. It includes Saturn and Titan closest approaches.

Post-Encounter phase begins at 2:40 p.m. PST, Nov. 13, and ends at 7:32 p.m. PST, Dec. 15. The start will occur after the first opportunity for post-encounter uplink. The phase includes a post-encounter movie sequence. The phase ends after fields-and-particles measurements of the Saturnian magnetosphere are complete.

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Science Rationale

Saturn is one of the solar system's four giants; the others are Jupiter, Uranus and Neptune. While all are similar on a gross scale -- huge accumulations of hydrogen and helium surrounding small, rocky cores -- each exhibits its own unique properties.

One key difference between Jupiter and Saturn to which Voyager 1 will pay special attention is their mechanisms for generating internal heat. Both Jupiter and Saturn radiate about twice the energy they receive from the Sun. That heat, theoreticians believe, was generated 4.6 billion years ago, as the solar system formed. Jupiter is so large that its primordial heat has been escaping ever since. However, theoreticians say that Saturn should have cooled off to equilibrium long ago. Therefore, Saturn's current surplus heat must be caused by some other mechanism, perhaps through the separation of hydrogen and helium deep within Saturn. The heavier helium sinks toward the center, according to the theory.

The subjects of Voyager 1's research at Saturn are:

- the planet;
- the rings;
- the satellites, with emphasis on Mercury-sized Titan;
- the magnetosphere.

The Saturnian system is too distant from Earth to be studied as thoroughly as Jupiter; Saturn is twice as far away from Earth, and the satellites appear as pinpoints of light in an Earth-based telescope.

● <u>Saturn</u>: Since Saturn is so far from the Sun -- 106 billion kilometers (66 billion miles) -- 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 to three Earth atmospheres, instead of one atmosphere as on Jupiter. (One Earth atmosphere is 1,000 millibars, the pressure at Earth's surface.)

Saturn displays fewer and more subtle features than Jupiter. That is probably because a high-altitude atmospheric haze obscures Saturn's clouds.

Astronomers have determined that the wind at Saturn's cloud tops has twice the velocity of the wind on Jupiter. Calculations show Saturn's wind speed is about 1,400 km (900 mi.) an hour.

The calculations are based on Earth-bound observations of spots in Saturn's clouds, combined with Voyager's radio measurements of the rotation of the interior of Saturn.

Voyager scientists want to understand the atmosphere in terms of:

- Its overall structure and composition -- what gases and other chemicals are present, in what ratios, and fine-scale (or very small) differences;

- Differences of temperature and composition between bright zones and dark belts;

- How material changes with depth in the atmosphere;

- Size, density and composition of the core. The core is thought to be about the size of Earth, but to contain 15 or 20 times Earth's mass.

• Rings: The rings' designations were assigned chronologically, and have nothing to do with relative positions. This summary will list them beginning with the outermost ring:

E-ring; extending to about eight Saturn radii (480,000 km or 298,000 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, distant and separate from both the E-ring and the A-ring.

A-ring; outermost ring visible with small telescopes.

B-ring; the brightest ring lies inside the A-ring, separated from it by Cassini's Division. The division is not clear of material, but contains a minute amount of ice or dust. From Earth the B-ring appears completely filled; a Pioneer 11 image, however, shows light leaking through, leading to speculation there may be holes in the ring.

C- or crepe ring; barely visible in small telescopes, it lies inside the B-ring.

A D-ring has been reported between the C-ring and the cloud tops. Some scientists doubt its existence.

Observations in 1966 -- when the rings were last seen edgewise from Earth -- yielded ring thicknesses of 1 to 3 km (0.62 to 2 mi.), although recent analysis suggests that the rings, particularly the E-ring, may be thicker.

The rings appear to be entirely ice or ice-covered material a few centimeters to a few meters in diameter. Scientists want to measure particle sizes and densities, and find out if material other than ice is present. How and why the rings formed is also a major question. The manner in which sunlight is scattered depends on the area and size of particles and their numbers. Jupiter's ring forward scatters because it contains particles about 0.0005 centimeters (0.0002 inches) in diameter. Saturn's rings backscatter strongly. Forward scattering by Saturn's rings cannot be observed from Earth.

Radio signals sent by the spacecraft through the rings to Earth (as the spacecraft goes behind them) will help answer the size question. (Photos will not show individual particles unless they prove to be hundreds of meters across.) Based on the same principle of strong forward scattering as light, the radio signals, can be used to identify particles 30 to 100 cm (1 to 3 ft.) in diameter. Measurements of the signals attentuation by the rings will give information on smaller particles that are larger than a few centimeters, however.

Scientists want to determine why density apparently differs from ring to ring, and if there are waves or clumps of particles within the rings. Waves may form in the ring material by gravitational forces from satellites outside the rings. Large objects in the rings may also cause local variations in density.

• Satellites: The moons of Saturn thus far explored by spacecraft are different from any observed circling the other planets.

Titan is the largest satellite in the solar system, and is the only one known to have a substantial atmosphere. Uncertainties in determination of its size are great enough that Titan could be anywhere from 5 to 20 percent larger than Mercury. It could be either all ice, or ice mixed with as much as 15 percent rock. Scientists hope to photograph Titan's surface, if the atmosphere is clear enough; available evidence indicates it will not be. Titan's atmospheric pressure is estimated between 20 millibars and 2,000 millibars at the surface. (Earth's surface atmospheric pressure is about 1,000 millibars; Mars' atmospheric pressure is about 10 millibars.) Two opposing theories on Titan's atmosphere presently exist. One predicts a thin atmosphere with low surface pressure and the other a high surface pressure and opaque atmosphere.

The other satellites to be observed differ from those already observed by a spacecraft. Jupiter's Galilean satellites are larger; Amalthea and the tiny Martian satellites Phobos and Deimos are smaller. Uncertainties about densities of all the Saturnian satellites are great enough that they could range from ice bodies to mixtures of ice and rock.

Voyager is expected to discover new, small satellites outside the A-ring.

• Magnetosphere: Scientists want to know why Saturn's magnetosphere behaves differently from the magnetospheres of Earth and Jupiter. Pioneer data show that Saturn's magnetosphere is weaker than Jupiter's. Saturn's magnetic pole is offset less than one degree from the rotational pole; the magnetic poles of Earth, Jupiter and the Sun are offset substantially.

• Rotation Period: Voyager has determined with high precision the length of a day on Saturn: 10 hours, 39.4 minutes. That rotation period refers to the interior of Saturn and was measured with Voyager radio-astronomy data obtained since January 1980. Earth observations had shown similar periods for temperate and polar regions of Saturn, but a much shorter (10 hours, 14 minutes) period near the equator, indicating the presence of a high-velocity equatorial jet stream.

Data from all experiments combine synergistically. While single instruments determine specific quantities -- for example, the IRIS measures temperature and composition -- it is by combining data from several instruments that the science teams will assemble a coherent picture of the entire Saturnian system.

Encounter Events - November 6-18

The remainder of this summary deals with the days when NASA's Voyager Saturn News Center at the Jet Propulsion Laboratory in Pasadena, Calif., will be in operation: Nov. 6 through Nov. 18.

NOVEMBER 6: Voyager 1 makes a variety of observations; distance to Saturn ranges from 9,300,000 km (5,779,000 mi.) to 7,900,000 km (4,909,000 mi.). Saturn, Titan, Rhea, Dione, Mimas, Iapetus and the rings are subjects for Voyager's cameras.

Saturn's atmospheric features will be studied. Titan is the only satellite with an appreciable atmosphere; its surface (if visible) is a prime target; close approach imaging of Rhea on Nov. 12 will provide finer surface detail than the other icy satellites.

NOVEMBER 7: First images of Saturn are from 7,877,000 km (4,895,000 mi.). By the end of the day, Voyager 1 is 6,694,000 km (4,159,000 mi.) from Saturn. Four photos near Saturn will be used to search for new satellites. Titan is a prime imaging subject. Rhea and Iapetus will also be photographed; Iapetus is of interest because one side is bright, while the other is dark -- the difference in brightness is a factor of six. Ultraviolet and other instruments will measure Saturn, the rings and the satellites. 201 photos.

NOVEMBER 8: The opening range to Saturn is 6,514,000 km (4,048,000 mi.). By day's end, the distance closes to 5,300,000 km (3,293,000 mi.). Satellites are prime imaging targets: Tethys, Enceladus, Rhea and Dione. Saturn pictures and photographic searches for new satellites continue. 173 photos.

NOVEMBER 9: Voyager is 5,215,000 km (3,240,000 mi.) from Saturn as the day begins. An east-to-west infrared map will be started. Photographic searches for new satellites will continue. 299 photos.

NOVEMBER 10: Pictures of Saturn begin when the spacecraft is 3,879,000 km (2,410,000 mi.) from Saturn; final Saturn pictures will be taken from 2,598,000 km (1,614,000 mi.).

The infrared east-west map of Saturn is complete early in the morning; the day ends as work on an infrared north-south map begins. Purpose of the east-west infrared maps: To measure global atmospheric temperature, composition and heat balance on the sunlit side of the planet. North-south infrared map will measure latitude and longitude variations in temperature and composition.

Satellite photos will be made -- one every 22 1/2 degrees for surface mapping -- of Rhea, Tethys, Dione; Titan pictures will be for atmospheric studies, and mapping (only if the surface is visible). The imaging scientists now believe that Titan's atmosphere will be so opaque that even the extreme closeup pictures may not reveal the satellite's surface. The best opportunity appears to be a slim chance that a few holes in the clouds may provide occasional glimpses of the surface. 427 photos.

NOVEMBER 11: Saturn photos will start when Voyager 1 is more than 2,500,000 km (1,553,000 mi.) distant (part of the continuing infrared north-south map carried over from Nov. 10).

Some fields-and-particles experimenters will be looking for signs of Saturn's magnetic field -- the bow shock.

In mid-morning the spacecraft will perform a fields-and-particles maneuver: a 384-degree roll to lock on the star Beta Carinae (Miaplacidus), to sample the region around Saturn. The spacecraft may be out of communication with Earth from 9:52 a.m. to 10:37 a.m. PST.

First event after the fields-and-particles maneuver is a 16-photo sequence of Titan to study atmospheric dynamics and map the surface, if visible.

A plasma-wave observation in the evening (6:00 p.m. to 6:05 p.m.) is one of a long series of measurements inside Saturn's magnetosphere. Plasma-wave structure affects interpretation of other fields-and-particles experiments.

Closest approach to Titan (followed by Titan-Earth and Titan-Sun occultations) occurs at 11:06 p.m. PST (ERT - Earth Received Time). Important Titan photo sequences occur as follows: 3:19 p.m. to 5:16 p.m. (36 photos); 6:09 p.m. to 7:06 p.m. (13 photos); 7:11 p.m. to 8:00 p.m. (10 photos); 8:03 p.m. to 8:34 p.m. (23 photos recorded for later transmission); 8:41 p.m. to 9:09 p.m. (six photos); 9:13 p.m. to 10:24 p.m. (16 photos); 10:33 p.m. to 10:45 p.m. (four photos). A large share of the Titan data around closest approach will be recorded for playback to Earth later (see timeline for details). Titan-Earth occultation runs from 11:12 p.m. to 11:25 p.m.

Voyager 1 will cross Saturn's ring plane inbound at 11:23 p.m. 257 photos.

<u>NOVEMBER 12</u>: This is closest-approach-to-Saturn day.

First photos of Saturn are taken from a range of 955,900 km (593,000 mi.); final pictures are from a distance -- beyond the planet -- of 330,000 km (205,000 mi.).

Closest approach to Tethys (415,320 km or 258,067 mi.) occurs at 3:41 p.m. PST (ERT). Closest approach to Saturn (124,200 km or 77,174 mi.) occurs at 5:11 p.m. PST (ERT).

Closest approach to Mimas (108,400 km or 67,356 mi.) takes place at 6:02 p.m. PST. (NOTE: This is closest approach when the satellite is sunlit; actual closest approach doesn't occur until 7:07 p.m. -- when Mimas is in the shadow of Saturn.)

Earth occultation begins at 7:07 p.m.; Sun occultation begins a few minutes later -- at 7:20 p.m.

Closest approach to Enceladus occurs at 7:15 p.m., at a distance of 202,521 km (125,840 mi.).

No telemetry will be received from Voyager 1 for five hours, beginning at 6:34 p.m.

Sun occultation ends at 8:03 p.m.; Earth occultation ends at 8:36 p.m. Ring occultation begins soon afterward.

Closest approach to Dione, while it is sunlit, occurs at 8:53 p.m., and closest approach to Rhea takes place at 11:46 p.m. at a range of 72,100 km (44,800 mi.). 315 photos.

<u>NOVEMBER 13</u>: A primary target for the instruments will be the rings of Saturn: mostly infrared measurements and photographs. Some special observations of Saturn will be made: the ring shadow; north and south poles, although scientists don't expect Voyager will be able to see both poles on the same day; for composition differences there; searches for auroras and lightning in the atmosphere; and opacity measurements to find compositional differences between belts and zones.

Satellites to be photographed include Iapetus, Titan, Dione and Rhea.

The day ends with another north-south infrared map to determine temperature, composition and heat balance on the dark side. 201 photos.

<u>NOVEMBER 14</u>: Infrared north-south map continues.

From 9:48 a.m. to 5:59 p.m. the spacecraft will take 154 photos of the rings.

Closest approach to Iapetus (more than 2,000,000 km or 1,243,000 mi.) occurs at 12:50 p.m. 176 photos.

<u>NOVEMBER 15</u>: Between 3:58 a.m. and 4:43 a.m., Voyager 1 will take a series of long-exposure (15 seconds each) pictures of Saturn to search for auroras and lightning in the atmospshere on the dark side; range, 3,570,000 km (2,218,000 mi.).

An east-west infrared mapping, with supporting visible light photos, begins at 5:23 a.m.

Photos of Saturn, [illegible]n, Rhea and Iapetus are taken throughout the day. 157 photos.

<u>NOVEMBER 16</u>: A search will be made for new satellites outside the Roche Limit -- the minimum distance a moon must keep from its planet in order to avoid being torn apart by the gravitational force exerted by the planet.

A series of photos for the post-encounter motion picture begins at 2:53 a.m.

Beginning at 8:41 p.m., and continuing until 6:46 p.m. Nov. 17, Voyager 1 will take a series of 276 photos of Saturn for the post-encounter rotation movie sequence. This series, with simultaneous infrared observations, will constitute most of the science data received for the next 22 hours. 424 photos.

<u>NOVEMBER 17, 18</u>: As noted above, most of Nov. 17 is taken with photographing the planet for the post-encounter rotation film. A similar exercise begins at 8:38 p.m., Nov. 17, and runs until 6:44 p.m., Nov. 18. 276 photos Nov. 17; 276 photos Nov. 18.

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