Voyager Bulletin

MISSION STATUS REPORT NO. 61 JANUARY 14, 1981

The dust has settled. All the visiting scientists have gathered their reams of computer printouts and reels of magnetic tapes and gone home to sift through them. The hordes of press people and guests have left. Initial findings have been reported. Planning for Voyager 2's Saturn event next August is moving forward, with many changes in the nuts and bolts details caused by Voyager 1's insights into this fascinating realm.

What have we learned? That there is still much more to learn. That Saturn is not just a colder version of Jupiter, nor are its satellites just miniature Galileans. Its magnetic field is pretty weird. And its rings . . . well, that's a pretty long story by itself.

Voyager 1 has completed its planetary exploration. No other planets lie in its path, nor can its course be redirected now to any other planet. It is exiting the solar system, climbing up out of the ecliptic bound towards the constellation Ophiuchus, which it may chase for aeons and never catch.

But this remarkable spacecraft is not being shut down or turned off. There are those who are interested in what lies beyond the planets, and between them. Voyager 1 will continue to test the interplanetary waters, telling us about the solar wind that blows over and around all the planets – our inhabited earth as well as the cold, silent worlds that share our sun. Some day, Voyager 1 and other interplanetary spacecraft will reach the heliopause – the outer edge of the sun's magnetic influence. In other words, the edge of the solar system. We don't know where this is, or when we will reach it. Like a planet's magnetosphere, the heliosphere probably increases and decreases in size according to the sun's activity. That's why the Deep Space Network is tracking these spacecraft, each headed in slightly different directions, to get even a rough idea of how big this invisible portion of our solar system really is. The best guess right now is that Voyager 1 will cross the heliopause around 1990, at forty times earth's distance from the sun. Right now it is slightly more than ten times earth's distance from the sun.

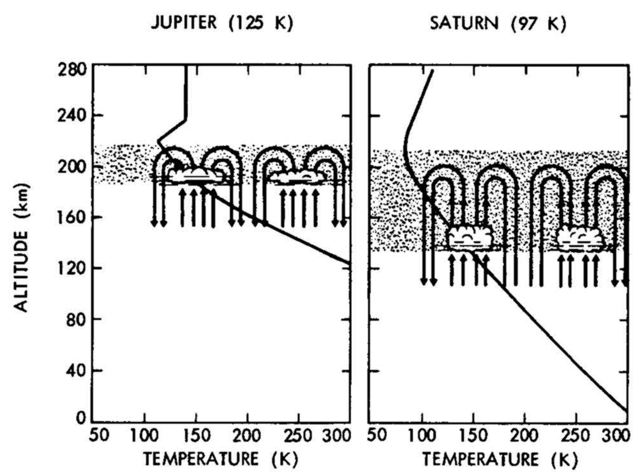
This is the last scheduled Voyager bulletin before Voyager 2 begins its Saturn observations in June. A short summary of Voyager 1's findings on Saturn, the rings, and the satellites is given below.

Saturn Science Results

The Planet

The body of Saturn has a strange, delicate beauty all its own. After seeing the wild, colorful turbulence of Jupiter, many looked forward to seeing more of the same on Saturn. But Saturn's markings are muted by a thick haze layer above the cloud tops, perhaps three times thicker than a similar haze on Jupiter. And Saturn is colder – perhaps 25 to 30 K colder at the cloudtops than Jupiter. One might expect it to be even colder since it is nearly twice as far from the sun as Jupiter. But Saturn probably has some sort of heat-producing mechanism deep in its interior. Saturn also rotates very fast (once each 10 hours 40 minutes) for its size (75,000 miles in diameter). Near Saturn's equator, the wind speeds are four times as great as on Jupiter, and cloud features tend to be short-lived in this gusty environment. These equatorial winds blow more than 1600 kilometers (1000 miles) per hour.

Below this blanket of haze, Saturn's atmosphere, like Jupiter's, forms relatively long-lived alternating dark belts and light zones, circulating storm regions, and other unique dark and light cloud markings. The light and dark bands on both planets are not static, but vary over periods of one to



At Saturn, clouds form lower in the atmosphere than at Jupiter. Saturn also has a thicker haze layer. Upwelling currents diverge at higher altitudes above the cloud decks. Also, the atmospheric temperatures rise more sharply at Jupiter, as shown in the curves.

National Aeronautics and Space Administration

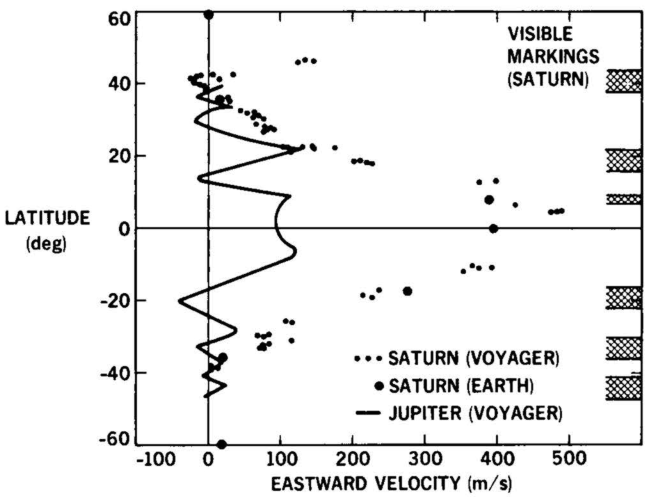
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

Recorded Mission Status (213) 354-7237
Status Bulletin Editor (213) 354-4438
Public Information Office (213) 354-5011

ten years. Saturn's bands seem to be about twice as wide as Jupiter's, and extend into the polar regions. While Jovian winds appear to be closely linked to the belt-zone structure, this does not appear to be true at Saturn. Oval spots have been identified in Saturn's atmosphere and will be tracked by Voyager 2 to learn more about the planet's atmospheric circulation patterns.

Auroras seen near Saturn's poles are comparable in intensity to earth's polar auroras (the "northern and southern lights"). Saturn's auroras are probably caused by molecular hydrogen high in the atmosphere. The ultraviolet spectrometer also detected auroral-type emissions near the illuminated limbs of the planet, and Voyager 2 will continue to study these phenomena.

Radio signals typical of lightning discharges have been detected, but lightning has not been photographed on Saturn since the rings reflect so much light onto the dark side of the planet that it is too bright to see the lightning. The lightning-like discharges are believed to originate in the rings rather than in the atmosphere.



Wind speeds at Saturn range up to 1600 kilometers per hour, four to five times faster than any winds at Jupiter. This plot compares zonal wind velocities on the two planets.

The Rings

The revelation of hundreds of rings encircling Saturn blew the cork off any theories of a few, well-behaved classically-observed rings. Even more shattering was the discovery that some of these ringlets are elliptical. One is even braided. Said one scientist, "The rings are doing exactly what the laws of physics tell them to do – we are just not understanding those laws!"

Labelling the ring structure is going to be a monumental task. The nomenclature presently in use labels them as (moving outward from the planet) D, C, B, A, F, and E, named in order of their discovery. Besides the obvious gaggle of rings in the A, B, and C rings, Voyager 1 confirmed the existence of the D-ring closest to the cloudtops, and found two more rings which lie between the F and E rings. The F-ring was also found to be comprised of three interwoven ringlets. Not even the empty spaces are really empty, it seems. At least twenty ringlets fill this 3500-kilometer wide space between the A and B-rings. The A-ring's Encke Division may truly be empty, however.

Analysis of the spacecraft's radio signals as they passed through ring material on the way to earth (a ring occultation experiment) shows that the particles, mostly ice or frosted rock, may range in size anywhere from dust to boulders. The C-ring has chunks that average about two meters across, while the E-ring has mostly very fine particles. There certainly is a lot of bumping and grinding going on between ring particles as they orbit. The optical densities of the rings, as indicated by the amount of light they allow to pass through, also vary, with the optical thickness of the B-ring being the greatest.

Voyager 1 also provided clues to the puzzle of the rings' stability – why have they existed for so long? Why do the particles continue to orbit the planet rather than drifting off into space? A theory that large chunks, or small satellites, rotating within the rings may control their orbits gained stature when several small satellites were discovered near the outer edge of the A-ring and on either side of the F-ring. Satellites 13 and 14 flank the F-ring, herding it much like sheepdogs moving an unruly flock down a country lane. Satellite 15 is thought to control the outer edge of the A-ring.

The rings probably do not possess a dense atmosphere, but they almost certainly have electric fields, dielectric particles, and collisions between particles – all part of the essential conditions for earth-like lightning.

Saturn's magnetic field appears to interact with the B-ring particles to cause the spoke-like phenomena seen in many pictures. Electrostatic charging may temporarily levitate very fine particles above the ring surface. These fine particles scatter light differently than the larger particles in the denser body of the ring, and thus appear dark from some viewing angles and bright from others.

The Satellites

As Titan loomed larger and larger on November 10 and 11, it still looked like a fuzzy yellow tennis ball, and spectators thought at last they were going to find some boring satellites. Not so. Saturn's satellites present a new class of icy, intermediate-sized objects unlike any planetary moons thus far explored, and unlike the asteroids as well. These satellites are generally divided into three discussion areas: the new small moons, giant Titan, and the intermediate-sized objects.

To date, Voyager 1 has confirmed six new satellites at Saturn. This includes confirmation of one satellite spotted three times by Pioneer 11 in September 1979. All of these satellites were photographed, but only two, satellites 10 and 11, from close enough to determine their shapes. Both of these are irregularly-shaped with their long axes pointed toward Saturn, and are apparently composed of water ice. They share an orbit about 91,000 kilometers (57,000 miles) above Saturn's cloud tops and thus are referred to as the "co-orbitals".

Little is known about satellites 12 through 15 other than their orbits. Satellite 12 occupies the orbit of Dione, slowly oscillating about a point 60° ahead of Dione. Satellites 13, 14, and 15 orbit just outside the F-ring, just inside the F-ring, and just outside the A-ring, respectively.

Rivers of methane may cut through glaciers of methane under a nitrogen sky on Titan. Voyager data confirm that the main constituent of Titan's atmosphere is nitrogen rather than methane as previously thought, and this means that Titan is the only other place besides earth known to have a nitrogen-based atmosphere.

Near the surface, Titan's atmospheric temperature and pressure are near the triple point of methane, which means that it can probably exist as a solid, liquid, and a gas. (The triple point for water, for example, is 32°F and 6 millibars pressure, at which point it can be liquid water, ice, or water vapor.) Methane probably plays the same role on Titan that water plays on earth as rain, snow, ice, and gas. The clouds may drop liquid methane rain on the surface.

Voyager 1 measured Titan's surface temperature at about 92 Kelvin (about −293°F). The minimum atmospheric temperature of about 70 Kelvin (−333°F) is reached at the 100 millibar pressure level, about 50 to 70 kilometers above Titan's surface. The atmospheric pressure at the surface is fifty percent greater than at earth, and the atmosphere is five times as deep as earth's.

The spacecraft's radio signals reached the surface of Titan — something the cameras could not do because of the thick atmosphere. Titan appears to have a dark north polar hood and a three-tiered haze layer above the atmosphere.

Once thought to be the largest satellite in the solar system, Titan has been dethroned. Its diameter has been measured to be about 5120 kilometers (3200 miles). The new king is Jupiter's Ganymede, 5276 kilometers (3278 miles) in diameter. Both satellites are larger than the planet Mercury.

One of the mysteries remaining is why Titan is the only satellite with a substantial atmosphere, while Ganymede, slightly larger, has at best a very tenuous atmosphere.

Titan exerts considerable gravitational forces on other bodies, and may be a factor in tidal heating of Enceladus. Titan's interaction with Saturn's magnetosphere is of keen interest, for as the magnetosphere ebbs and flows with the varying pressure of the solar wind, the magnetopause (the outer edge) sometimes sweeps across Titan, leaving Titan temporarily completely outside the magnetic influence of Saturn. When Titan is within the magnetopause, the magnetosphere also leaves a wake as it flows past the satellite.

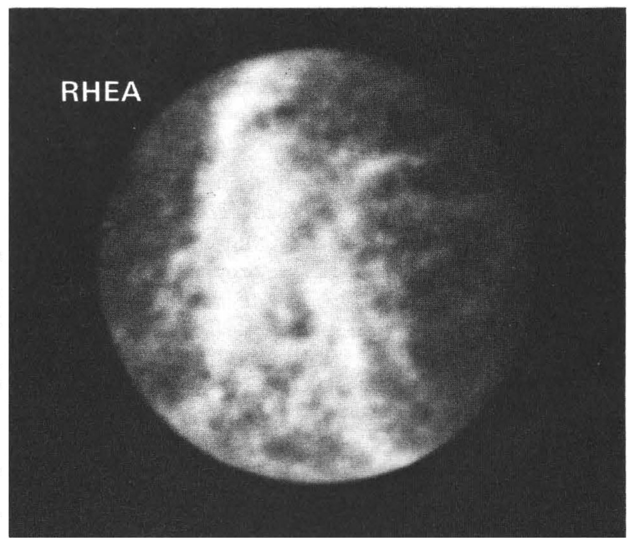
The inner moons — Mimas, Enceladus, Tethys, Dione, and Rhea — seem to be composed mainly of water ice. Work is continuing to unravel the chemical composition of these bodies, which may also contain ammonia compounds. The thermal histories of small satellites — their heating or cooling — depends on their composition because of the different melting temperatures of various ices.

About 188,220 kilometers from Saturn*, Mimas (mī-mus) is about 390 kilometers (240 miles) in diameter — about half the size of the largest asteroids. At some point in its history, Mimas was rocked by an impact which left a gaping center nearly one-fourth the diameter of the satellite itself. Such a blow must have nearly shattered the satellite. The crater walls are about 9 kilometers (5.6 miles) high, with a central peak 4 to 5 kilometers (2.5-3 miles) tall. Voyager 1 photographed parts of Mimas with a resolution of 2 kilometers.

Of the five inner moons, only Enceladus (en sel a dus) shows no evidence of any impact craters (at a scale of 12 kilometers or 7 miles). Voyager 2 will get a much closer look at Enceladus in August. Since Enceladus is locked in a 2:1 orbital resonance with Dione (one orbit for every two by Dione), there is speculation that this causes the same type of tidal stresses suffered by Io in the tug-of-war between Jupiter and Europa. There is also speculation that Enceladus may be a source of E-ring particles since the maximum intensity of the E-ring occurs near the orbit of Enceladus, about 240,190 kilometers from Saturn. Its diameter is about 490 kilometers (300 miles).

A wide (60-kilometer or 40-mile) valley stretches 750 kilometers (470 miles) across the surface of Tethys (tē this). The trench may be a crustal fracture caused by a blow which formed an 180-kilometer (110-mile) impact crater on the other side of the satellite. Tethys may be pure ice. Slightly larger than the largest asteroids, it has a diameter of about 1050 kilometers (650 miles) and orbits about 296,560 kilometers from Saturn's center.

Several sinuous valleys, some of which appear to branch, are visible on Dione's surface. Bright wispy streaks stand out against an already highly-reflective surface, and are probably the result of relatively fresh ice ejecta thrown out of more recent (geologically-speaking) impact craters. Dione (dī ō nē) is slightly more dense than the other five inner moons, breaking a pattern of progressively less dense satellites moving out from the planet. Dione may be 30 to 70 percent rock. Its diameter is about 1110 kilometers (690 miles) and its orbital distance is 379,070 kilometers.



1,700,000 km (1,000,000 mi)

Voyager 1 11/6/80

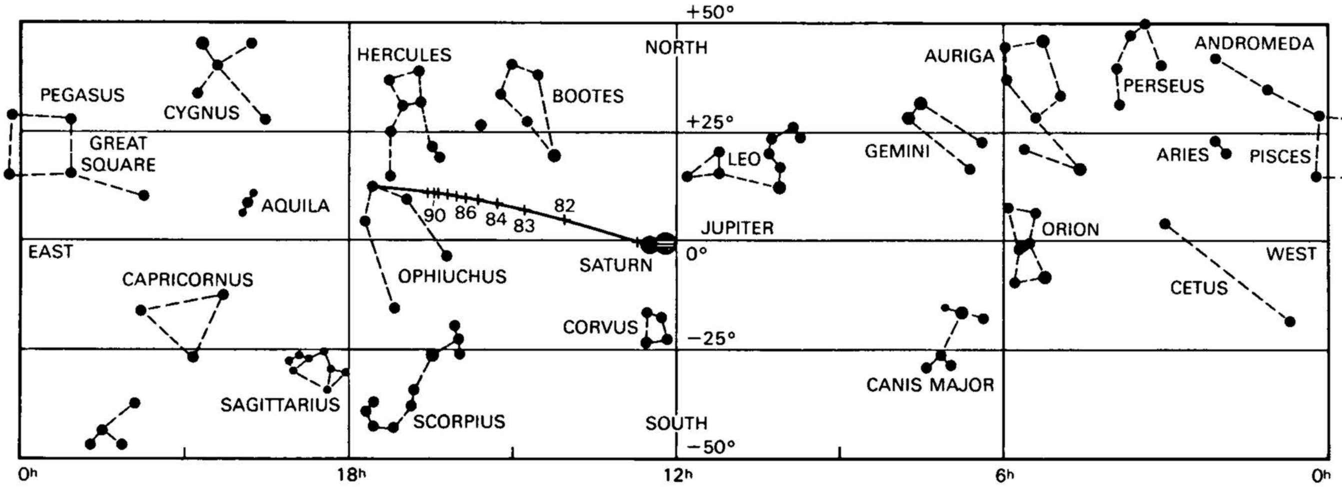
Rhea's (rē a) surface is also highly reflective and shows bright wispy breaks which may be fresh ice thrown out of impact craters during a later bombardment period. Its diameter is 1520 kilometers (940 miles), and its orbital radius 527,830 kilometers.

Hyperion (hī pēr ē an) is apparently non-icy and has a gravitational relationship with Titan. Its diameter is about 310 kilometers (190 miles) and its orbital radius is 1.5 million kilometers.

Iapetus (ī ap i tas), about 1450 kilometers (900 miles) in diameter, orbits about 3.56 million kilometers from Saturn and has light and dark hemispheres. The leading face (that which faces forward as Iapetus orbits Saturn) reflects only about one-fifth as much light as the bright trailing side. Its orbit is inclined significantly to the plane in which the rings and other inner satellites orbit.

Tiny Phoebe (fē bē), in a retrograde (clockwise as seen from above) orbit highly inclined to the ring plane, will have to wait to be photographed until Voyager 2 arrives at Saturn next summer. Daily observations will begin in June, with closest approach to Saturn on August 25, 1981 at 8:24 pm PDT (spacecraft event time).

*Unless otherwise stated, the orbital distances are from the center of Saturn.



Voyager 1, having completed its tours of the Jupiter and Saturn systems, is heading out of the solar system toward the constellation Ophiuchus. As the years pass, a stargazer might imagine seeing it at the above points. Ophiuchus is moving away faster than Voyager 1 is approaching.

Update

NASA Headquarters has officially approved the Voyager Project's recommendation for Voyager 2's continuation on to Uranus.

Space Achievement Award

On November 10, in ceremonies at the Caltech campus, the Voyager Program Team received the American Astronautical Society's Space Achievement Award *"for outstanding performance in the successful Voyager Program and in recognition of their major contribution to the advancement of mankind's understanding of the Solar System."*

Plasma Instrument III

Voyager 1's plasma instrument stopped transmitting useable science data on November 23, 1980, and has returned no useful science data since then. The instrument remains on, however, while engineers and scientists continue to look for ways to correct the problem or work around it.

Soon after the problem was detected, several calibrations were made. Data from these tests appeared normal except for the high-voltage calibrations of the modulator, that part of the instrument that electrically switches between active and reference sensors. There may be some similarity between this problem and one that existed between February and May 1978, which was corrected.

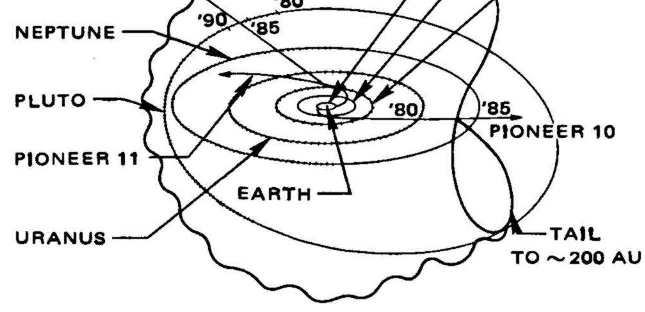
The problem occurred after the instrument had completed all of its measurements of the Saturn system, and after a spacecraft maneuver in which the sun illuminated portions of the instrument for about 19 hours.

The plasma experiment measures the velocity, density, and temperature of interplanetary plasma for a wide range of flow directions in both the solar wind and magnetospheres. Plasma refers to the clouds of low density, high-speed, ionized gases which originate from the sun and other stars. The plasma experiment is one of several aboard the spacecraft which will continue to sample the solar wind as Voyager 1 heads out of the solar system.

Saturn Satellites Characteristics Summary

	Radius (km)	Density	Albedo
Leading Co-Orbital	~80	?	~0.4
Trailing Co-Orbital	~40-45*	?	~0.4
Mimas	195 ± 5	1.21 ± 0.10	0.6 ± 0.1
Enceladus	245 ± 15	1.12 ± 0.52	1.0 ± 0.1
Tethys	525 ± 10	1.03 ± 0.06	0.8 ± 0.1
Dione	555 ± 10	1.43 ± 0.09	0.6 ± 0.1
Rhea	760 ± 10	1.33 ± 0.10	0.7 ± 0.1
Titan	2560 ± 30	1.94 ± 0.02	-
Hyperion	155 ± 20	?	0.3 ± 0.1
Iapetus	725 ± 20	1.24 ± 0.48	±0.5 ±0.1 (bright side)

*Not circular



Although their planetary explorations are over, spacecraft such as Pioneers 10 and 11 and the Voyagers will be tracked for many years as they head for the outer reaches of the solar system.