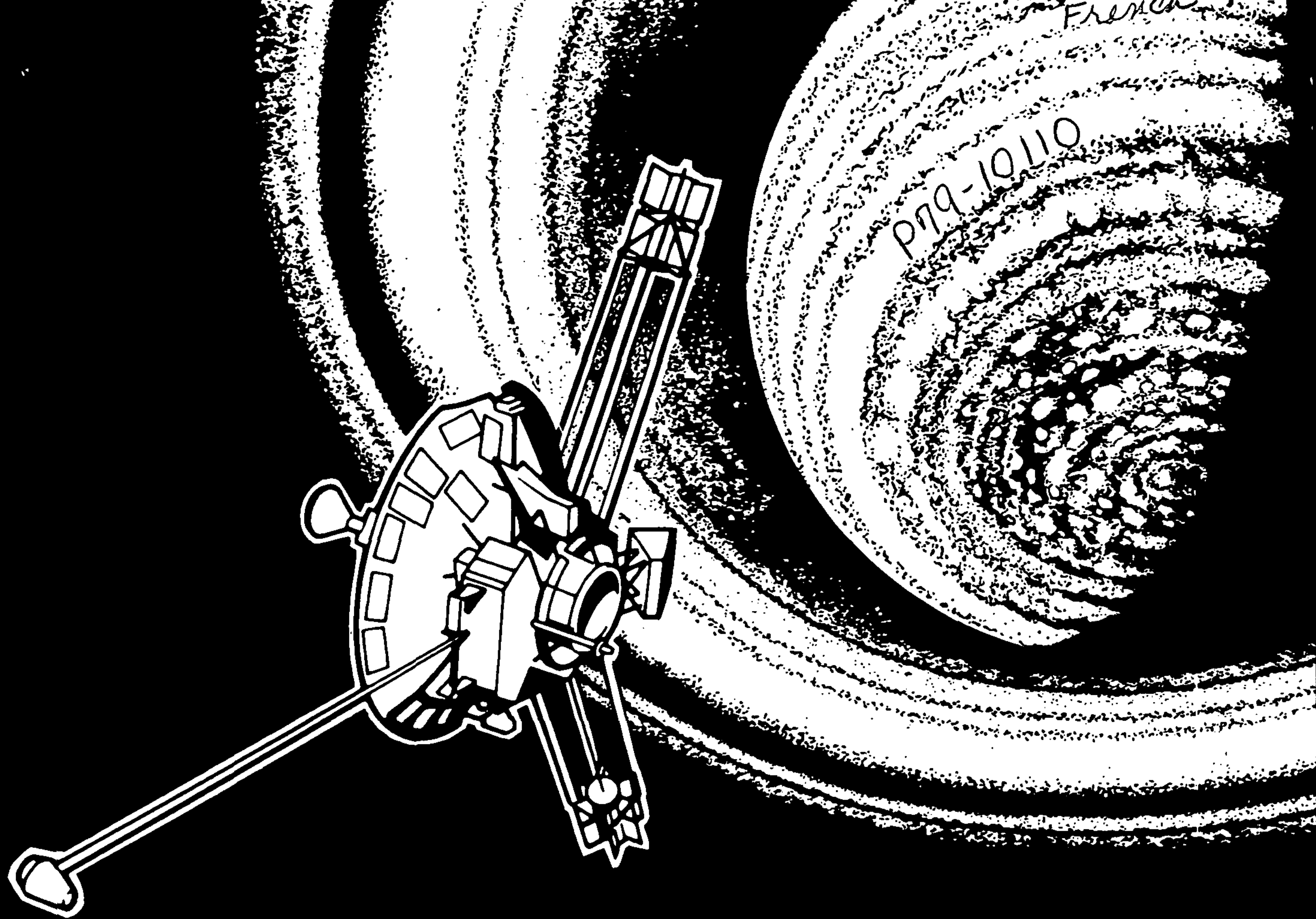

(NASA-News-Release-79-108) PIONEER TO ENCOUNTER SATURN ON SEPTEMBER 1 (National Aeronautics and Space Administration) 80 p N79-29210
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Pioneer Saturn Encounter

Press Kit

NASA
National Aeronautics and
Space Administration

Washington D. C 20546

RELEASE NO: 79-108

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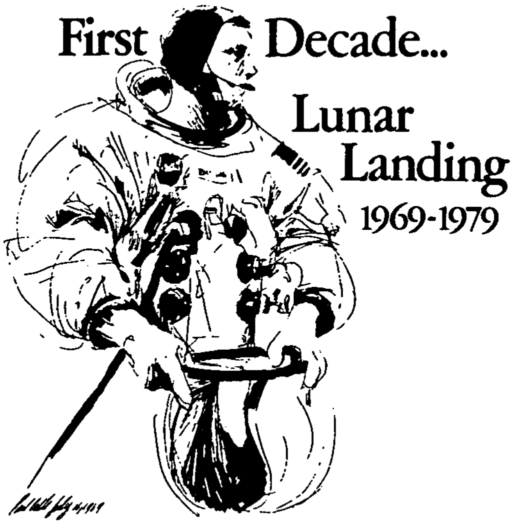

NASA News
National Aeronautics and
Space Administration
Washington, D.C. 20546
AC 202 755-8370

For Release:

WEDNESDAY,
August 22, 1979

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RELEASE NO: 79-108

PIONEER TO ENCOUNTER SATURN ON SEPT. 1

NASA's Pioneer 11 spacecraft will reach the giant ringed planet Saturn on Sept. 1, after a six-year, three-billion-kilometer (two-billion-mile) journey across the solar system.

Pioneer 11 will take the first closeup pictures and make the first close measurements of Saturn, its mysterious rings and several of its 10 satellites, including the planet-sized Titan.

-more-

August 15, 1979

Sweeping through the most intense part of Saturn's massive radiation belts, Pioneer will come within 21,400 km (13,300 mi.) of the planet and as close as 1,900 km (1,200 mi.) to the Saturnian rings.

Closest approach will be at 2 p.m. EDT, Sept. 1.

The images returned by Pioneer 11 (also called Pioneer Saturn) are expected to provide five to six times more detail of the planet than the best pictures taken from Earth.

Information returned by the spacecraft is expected to contribute to a better understanding of the origin and evolution of the Sun and planets. This, in turn, should provide scientists with a greater knowledge of our own Earth.

Data obtained by Pioneer 11 will also be useful in planning the encounters of Voyager 1 and 2 with the ringed planet in 1980 and 1981. The Voyagers are now Saturn-bound after encounters with Jupiter in March and July respectively.

Saturn is the second largest planet in the solar system, only slightly smaller than Jupiter. It is an immense diffuse body whose volume is 815 times that of Earth, but whose mass is only 95 times greater.

This makes Saturn the least dense planet in the solar system, lighter on the average than water. Like Jupiter, Saturn appears to be composed mainly of hydrogen and helium and to behave in many ways like a liquid planet.

Appearing to the Earth observer as a bright yellowish star of the first magnitude, Saturn is the sixth planet from the Sun, around which it revolves at an average distance of 1.4 billion km (886 million mi.). It completes one orbit around the Sun every 29 1/2 years. If the years are long, the days are short -- it rotates on its axis every 10 hours, 14 minutes.

Difficult to observe in detail from Earth because of its great distance, Saturn is known to have a banded structure which is probably due to cloud systems similar to those of Jupiter.

Saturn's most distinctive trademark is its elaborate ring system -- believed to consist of ice, ice-covered rocks or ice imbedded with rocks. The planet's rings are one of the great spectacles of the solar system. Discovered by Galileo in 1610, the rings range outward about 77,000 km (48,000 mi.) from Saturn's cloud tops. Total width of the three visible rings is 64,800 km (40,300 mi.).

The rings are very thin, with estimates of thickness ranging from several meters to as much as three kilometers (two miles). The rings are so thin that they are nearly invisible when viewed edge-on from Earth. Astronomers have determined from Earth that the orbiting ring particles are in part, and probably mostly, water ice. They may also contain metals, perhaps from the core of a broken-up moon. There is little rock. Most authorities think the particles range from snowball-sized to automobile-sized pieces with a few having a diameter of a mile or more.

The rings are believed to have originated either from the capture of a "wandering moon", which was then torn apart by Saturn's gravity, or -- more likely -- as a result of gravitational forces that prevented formation of a close-in satellite from the original planetary nebula.

Until the recent discovery of thin rings around Jupiter and Uranus -- the two giant planets that flank Saturn -- the Saturnian ring system was believed to be unique.

The Saturn encounter is the second planetary surveillance task for Pioneer 11. On Dec. 2, 1974, it skimmed within 42,760 km (26,725 mi.) of Jupiter's cloud tops.

This close passage permitted the gravity and motion of Jupiter to act as a slingshot, increasing the spacecraft's velocity and placing it on the trajectory which is now carrying it toward its close encounter with Saturn.

The trajectory from Jupiter to Saturn is about three times as long as the first leg of Pioneer's outbound journey from Earth to Jupiter. Pioneer's trajectory carried it high above the plane of the ecliptic in which solar system planets revolve around the Sun, reaching a maximum height of about 160 million km (100 million mi.) in 1976.

As Pioneer approaches Saturn, its trajectory lies above the ring plane and, since the ring plane is tipped up relative to the direction of the Sun, the plane is lighted from below. The view from Pioneer will therefore be of a ring plane lighted from the other side and this should permit optical measurements of ring structure never before possible.

Picture resolution of Saturn will begin to exceed that from Earth on Aug. 26 as the spacecraft approaches the planet at a distance of five million km (three million mi.). After Aug. 30, Pioneer will be too close to Saturn to image the full planet with its rings.

At about noon on Aug. 31, the last picture of Saturn's full disc, without the rings, will be made. Two hours before closest approach to Saturn itself, Pioneer will make its most detailed picture, resolving cloud features 80-100 km (50-60 mi.) in size.

A critical event will occur on the morning of Sept. 1, when Pioneer -- traveling at a speed of 85,000 km/hr (53,000 mph) -- passes through the plane of Saturn's rings at a very shallow angle (4.7 degrees) on its descent toward the planet. Planetary debris could be in the area. Even impact with a small fragment could disable the spacecraft. Ring plane passage will take about 0.8 seconds.

As it rushes in toward the planet, Pioneer Saturn will approach from the north and cross outside the edge of Saturn's outer ring at a distance of 34,600 km (21,500 mi.). It will then skim in under the rings, from 2,000 to 10,000 km (1,200 to 6,200 mi.) below them. At the point of closest approach, on the planet's night side, Pioneer will come within 21,400 km (13,300 mi.) of Saturn's banded cloud tops.

For an hour and 20 minutes, Pioneer will make the historic first passage under Saturn's rings, making closeup optical measurements to determine their structure and other first-time observations.

The spacecraft will be moving too fast for good ring pictures while beneath the rings.

When Pioneer makes its closest approach to Saturn's cloud tops, just before it passes behind the planet, it will be traveling 114,100 km/hr (71,900 mph). Closest approach will occur at 12:34 p.m. EDT spacecraft time. Earth-received time of spacecraft signals at NASA's Ames Research Center, Mountain View, Calif., which manages the Pioneers, will be 2 p.m. EDT. Almost 1 1/2 hours are required for radio signals to cover the Earth-Saturn distance of 1.4 billion km (960 million mi.). The spacecraft will make another shallow-angle crossing of Saturn's ring plane on its ascent away from the planet.

On Sept. 2, Pioneer will make its closest approach to Titan, Saturn's largest moon, taking pictures and making measurements of the satellite from 356,000 km (220,700 mi.) away.

Titan is the largest known planetary satellite in the solar system, larger than Mercury. It appears to be wrapped in opaque orange smog and has a methane-containing atmosphere which may be as dense as Earth's at the surface, and is far denser than Mars'. Titan's hydrocarbon atmosphere is thought to be very similar to the primordial atmosphere of Earth and may well have produced organic molecules, the building blocks of life.

Like Jupiter, Saturn has white, yellow and yellow-brown banded cloud belts which appear to be the tops of planet-circling atmospheric streams, driven by the ringed planet's fast, 10-hour spin and by an internal heat source.

Pioneer 11 is expected to return approximately 150 pictures of Saturn, with the first transmission scheduled for Aug. 20 at a distance of about one million km (634,000 mi.) from the planet.

About two-thirds of the 150 images expected by project scientists at the Ames Center will show more detail than is possible through observations made from Earth. These high resolution photographs will be received at Ames from Aug. 26 until Sept. 8. The smallest object visible will be about 95 km (50 mi.) in diameter.

Travel time for spacecraft data being transmitted back to Earth at the speed of light will be 86 minutes, as compared with 52 minutes required for Voyager 2 data to reach Earth from Jupiter in July 1979.

After passing the planet, Pioneer Saturn will head out of the solar system, traveling in roughly the same direction that the solar system does with respect to the local stars in our galaxy.

A sister spacecraft, Pioneer 10, flew past Jupiter for the first time in history in December 1973, and is now on its way out of the solar system, the first manmade object to do so. Pioneer 10's solar system exit path is almost opposite to Pioneer Saturn's, and it has already reached the orbit of Uranus.

On the outside chance that the Pioneers may be captured by an intelligent species during their nearly endless travels among the stars, each carries a plaque with a message about Earth.

Spacecraft operations during encounter will be complicated by the two-hour, 52-minute roundtrip communications time and the need to send roughly 10,000 commands to the spacecraft in the two weeks centered on closest approach, most commands going to the spacecraft imaging system. Operations strategy is to set most systems in one standard mode throughout the encounter.

Pioneer Saturn weighs 260 kilograms (570 pounds) and is spin-stabilized, giving its instruments a full circle scan 7.8 times a minute. It uses nuclear sources for electric power because sunlight at Jupiter and beyond is too weak for an efficient solar-powered system.

Pioneer's 2.75-meter (9-foot) dish antenna looks back at Earth throughout the mission -- adjusting its view by changes in spacecraft attitude as the spacecraft and home planet move in their orbits around the Sun.

Pioneer carries a 30-kg (65-lb.) scientific payload of 11 operating instruments. Two other experiments use the spacecraft and its radio signal as their instruments.

At Saturn, Pioneer's instruments are expected to:

- Determine whether the planet has a magnetic field and belts of high-energy charged particles, and the effects of the rings on such belts.

- Provide a temperature and density profile from the planet's cloud tops to its core.

- Determine the presence of an internal heat source; how much heat Saturn is radiating; and effects of this heat on internal and atmospheric circulation.

- Determine the masses of Saturn's two outer rings. Are the rings made mostly of ice, or perhaps metals?

- Determine the existence and character of the hypothesized outer "E-ring," which could double total ring width, and pose a hazard to Pioneer, the two Voyagers and other future spacecraft.

• Measure light intensity and polarization from the mysterious ninth moon, Iapetus, which is six times as bright on its leading hemisphere as its trailing one; first findings of mass and density of the moon, Rhea; and confirm and improve these measurements for Titan.

• Characterize Titan's atmospheric aerosols (smog), its atmosphere structure and temperature, and take its picture.

• Measure Saturn's hydrogen/helium ratio (its two main constituents) and determine atmospheric structure, layering and heat distribution, both horizontally and vertically.

• Study structure, temperature and flow of the atmosphere's belt and zone system, and obtain data related to atmosphere composition.

• Make at least 50 closeup color pictures of Saturn, its rings and cloud tops.

The Pioneer 10 and 11 projects are managed by Ames. The two spacecraft were built by TRW Systems, Redondo Beach, Calif.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

(Note: All times in the Background Information section of the press kit are Pacific Daylight Time -- PDT.)

ENCOUNTER PROFILE

Encounter Sequence

The two-month Pioneer 11 encounter period, Aug. 2 to Oct. 1, will proceed as follows:

- Beginning Aug. 2, the spacecraft, 1.5 billion km (932 million mi.) from Earth, will be tracked via 64-m (210-ft.) dish antennas in Spain and Australia for about 10 hours a day. Pioneer will be 25 million km (15 million mi.) from Saturn, traveling toward it at 30,600 km/hr (19,000 mph) relative to the planet.

- On Aug. 6, when tracking time increases to 18 hours a day and the station at Goldstone, Calif., joins the team of tracking stations, Pioneer will be 1.5 million km (939 million mi.) from Earth. With 20 million km (12 million mi.) left to reach Saturn, all science instruments will be undergoing checks in preparation for the encounter. As the spacecraft moves toward Saturn at 31,000 km/hr (19,200 mph), the imaging photopolarimeter begins taking polarimetry measurements of Saturn.

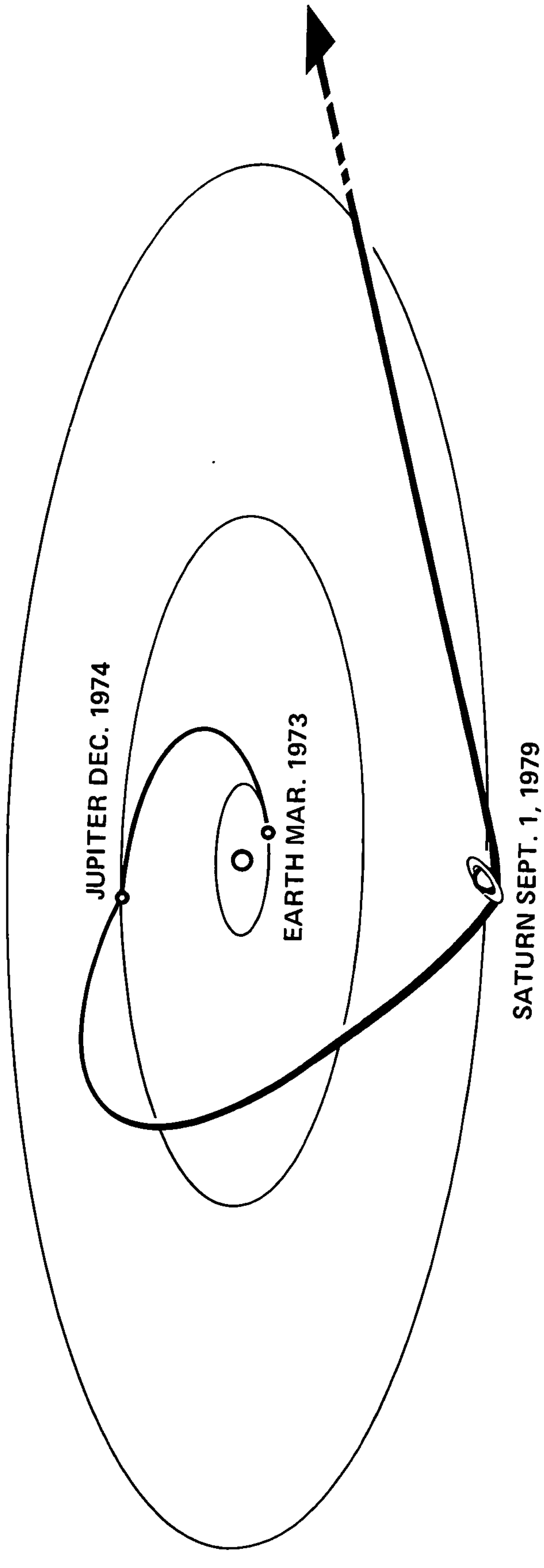
- The ultraviolet photometry instrument will begin four days of Saturn observations on Aug. 16. On the 17th, with Pioneer 1.53 billion km (949 million mi.) from Earth, tracking stations begin 24-hour tracking of the spacecraft, as it travels toward Saturn at 31,300 km/hr (19,400 mph). At this point, Pioneer will be 12.7 million km (8 million mi.) from Saturn.

- Encounter activity intensifies on Aug. 20, when the imaging photopolarimeter begins taking images of Saturn. These first pictures are not expected to show much detail since the spacecraft will still be 10.2 million km (6.3 million mi.) from the planet. During the encounter, Pioneer will transmit more than 100 images of Saturn, its rings and the planet-sized moon Titan.

- On Aug. 24, photopolarimetry measurements will be made of the Saturnian moon Iapetus.

- On Aug. 25, with Pioneer 1.55 billion km (959 million mi.) from Earth, two-station tracking will begin, doubling the rate of data transmission and substantially improving image quality. At this point, 5 million km (3 million mi.) from Saturn, picture resolution will begin to be better than anything obtained from Earth-based telescopes.

PIONEER SATURN VOYAGE



Most of the images of the rings obtained during the mission will show the rings lighted from the other side, thus providing optical measurements not obtainable from Earth.

• On Aug. 27, hurtling toward Saturn at 33,100 km/hr (20,500 mph), Pioneer will pass Phoebe, the moon farthest from Saturn, at a distance of 9,453,000 km (5,860,860 mi.). Scientists estimate Pioneer could cross the bow shock of Saturn on Aug. 27. (The location of the bow shock at Jupiter was found to be very variable and dependent on solar wind intensity.)

• On the 28th, Pioneer will make the first ultraviolet photometer measurements of Saturn's large moon Titan, as well as added photopolarimetry measurements of Iapetus, Saturn's mysterious ninth moon, which is six times brighter on one side than the other. Iapetus will be encountered at a distance of 1,039,000 km (644,180 mi.) as Pioneer flies by at 33,500 km/hr (20,800 mph). At that time, Pioneer will be 3.3 million km (2 million mi.) from Saturn. More light measurements (photopolarimetry) will be made of the satellite on Aug. 29. Also on that day, ultraviolet photometry measurements will be made of the three moons, Hyperion, Tethys and Dione.

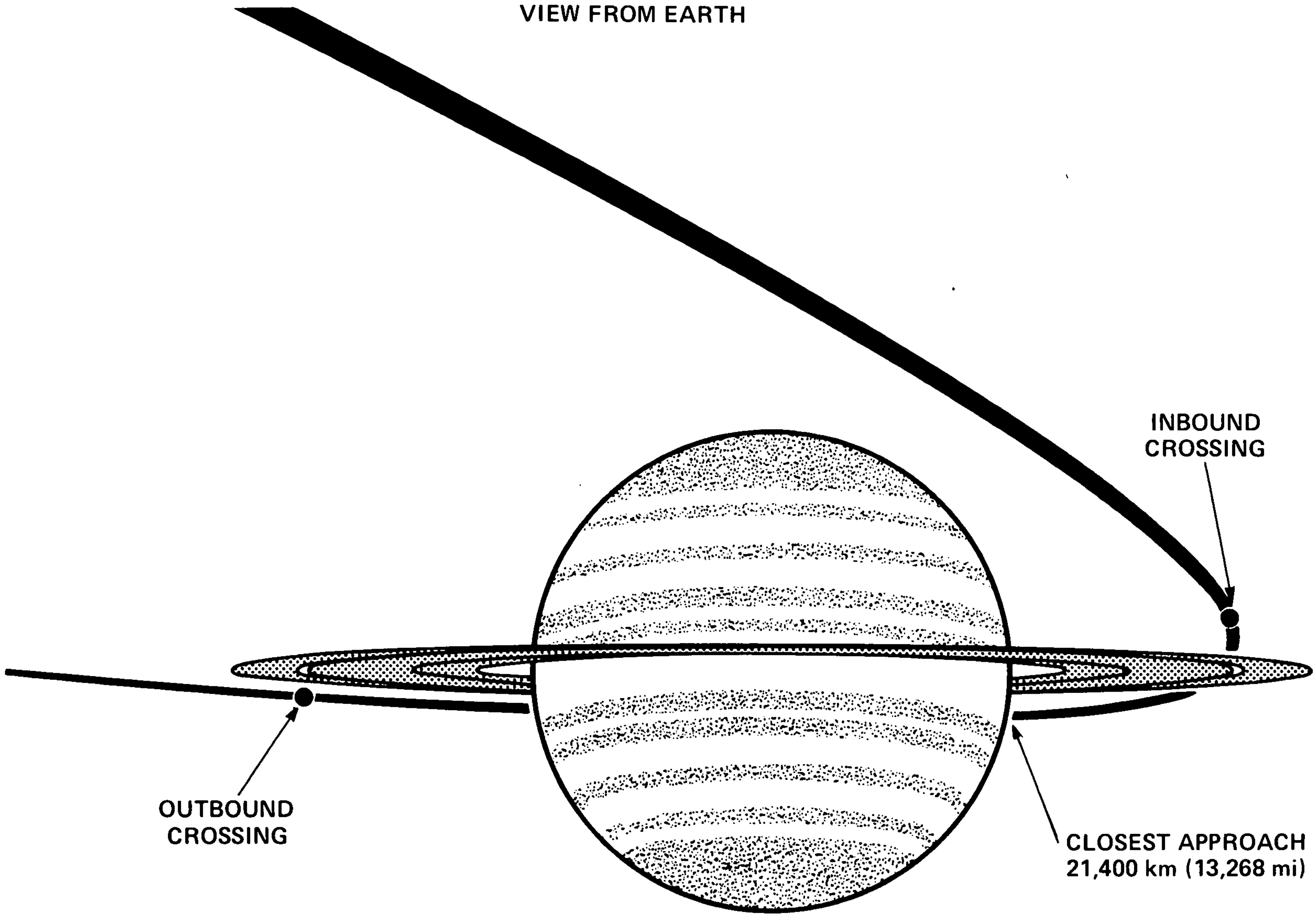
• Pioneer will continue moving closer to Saturn, sending back full-disc pictures of the planet and its rings until Aug. 30, when the spacecraft will be 2 million km (1.3 million mi.) from Saturn, too close to take images of the planet and rings together. The last full-planet picture of the inbound journey will be taken from 1 million km (700,000 mi.) away on Aug. 31 at about 1:55 a.m. PDT and probably will be the best full-planet view.

• In the early morning hours of Aug. 31, Pioneer 11 will pass the eighth Saturnian satellite, Hyperion (diameter 224 km or 140 mi.) at a distance of 674,000 km (417,880 mi.), as the spacecraft speeds toward Saturn at 37,800 km/hr (23,400 mph). At this point, Pioneer will be too close to the planet to get full-disc views. Photopolarimetry measurements will be made of Hyperion on Aug. 30 and 31 and of Rhea on the 31st. Ultraviolet photometer measurements of Rhea will be made on Aug. 30. On the 31st, the instrument will measure light from five satellites: Titan, Rhea, Dione, Tethys and Enceladus. Ultraviolet measurements of Saturn's rings also will be made on Aug. 31. Ten hours before closest approach on Sept. 1, the photometer will begin 14 hours of measurements of Saturn's ultraviolet light.

• Two hours before closest approach, the imaging photopolarimeter will take its most detailed pictures, showing cloud features as small as 80-100 km (50-60 mi.) in size.

PIONEER SATURN RING PLANE CROSSINGS
112,000 km (69,440 mi)

VIEW FROM EARTH



● The most critical and dangerous event of the mission will occur at 9:05 a.m. PDT Sept. 1, when Pioneer flies through the plane of Saturn's rings at a very shallow angle (4.7 degrees) on its descent toward the planet. Some planetary debris is almost certainly present in Saturn's ring plane, outside the visible rings. An impact with a fragment could destroy the spacecraft. For an hour and 20 minutes, 1.55 billion km (963 million mi.) away from Earth, Pioneer 11 will make the historic first flight under Saturn's rings, making closeup optical measurements to determine their structure. (Pictures during the ring flight will be of Saturn, not of the rings.)

● At 10:30 a.m. PDT, Sept. 1, Pioneer also will make its closest approach to Saturn's fifth moon, Dione, inside Dione's orbit, 291,000 km (180,500 mi.) away. About 20 minutes later, it will pass the second moon, Mimas, at 103,400 km (64,100 mi.).

● At 11:05 a.m. PDT, Pioneer will reach its closest approach to Saturn's cloud tops at 21,400 km (13,300 mi.) just before it passes behind the planet. The spacecraft will be traveling at 114,100 km/hr (70,900 mph).

● One-and-a-half minutes after closest approach, Pioneer will pass behind Saturn and be out of radio contact with Earth for 78 minutes. After Pioneer emerges, it will continue to fly under the sunlit side of Saturn's rings for about 10 minutes. At 12:50 a.m. PDT, Pioneer will make its closest approach to the fourth moon, Tethys, at 331,700 km (205,700 mi.). Five minutes later, the spacecraft will make another shallow-angle crossing of Saturn's ring plane on its ascent away from the planet. As it recrosses the ring plane, it will come closest to the third moon Enceladus at 225,200 km (139,600 mi.). An hour after the ascent crossing of the ring plane, Pioneer again will have a view of the rings lighted from below.

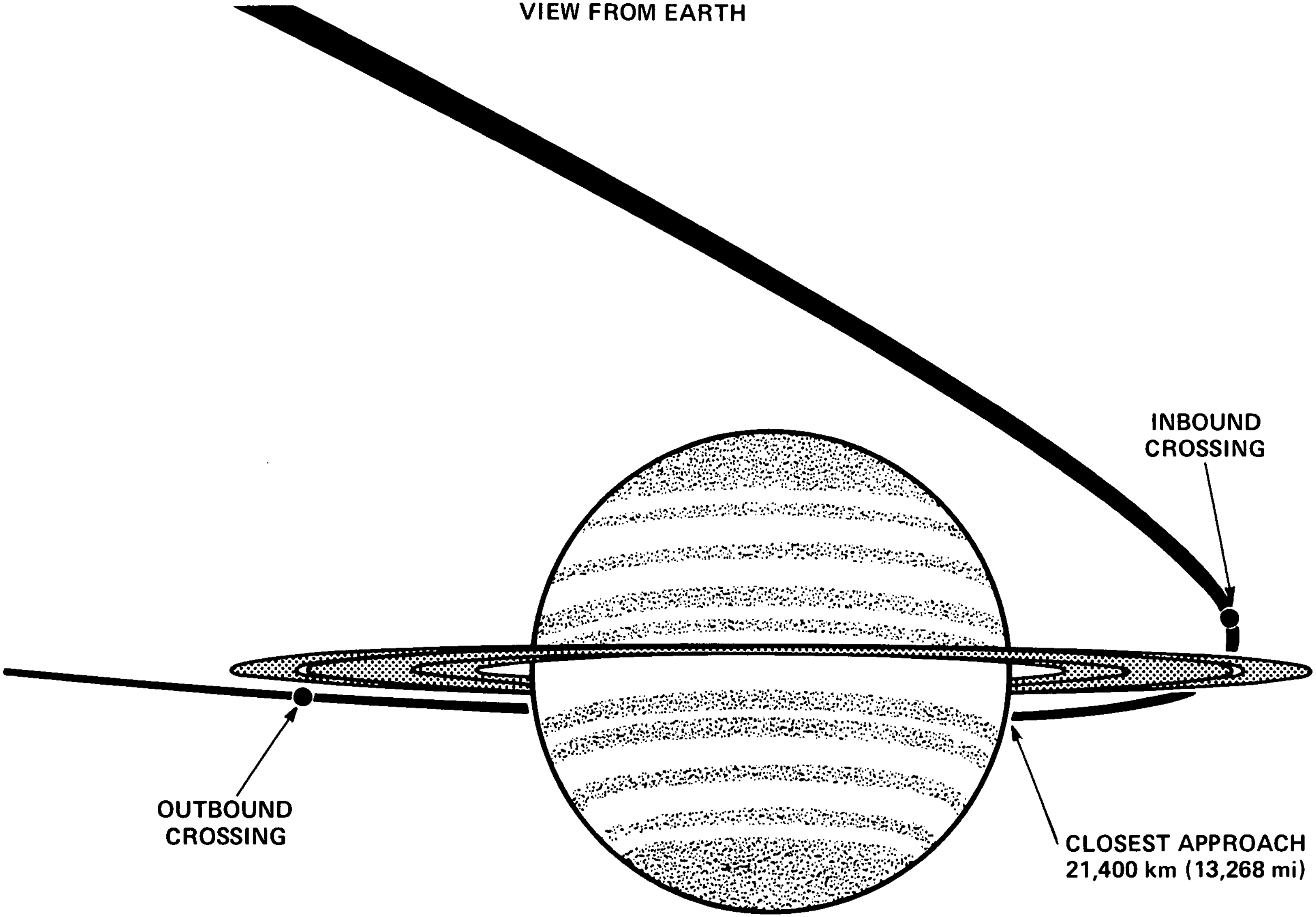
● At 5:00 p.m. PDT, Pioneer will make its closest approach to the sixth moon, Rhea, at a distance of 341,900 km (212,000 mi.). Three hours later, from about 420,000 km (260,000 mi.) away, Pioneer will again get a full view of the planet plus its rings. Pioneer will be moving away from the planet at about 54,000 km/hr (33,700 mph).

● On Sept. 2, at 12:30 p.m. PDT, Pioneer will make its closest approach to planet-sized Titan, Saturn's seventh moon, at a distance of 356,000 km (220,700 mi.). Pioneer will photograph and make other measurements of the 5,800-km (3,600-mi.)-diameter moon, the largest known satellite in the solar system. This moon dominates Saturn's satellite family both in diameter and mass, exerting a measurable gravitational force on the bodies in that system.

PIONEER SATURN RING PLANE CROSSINGS

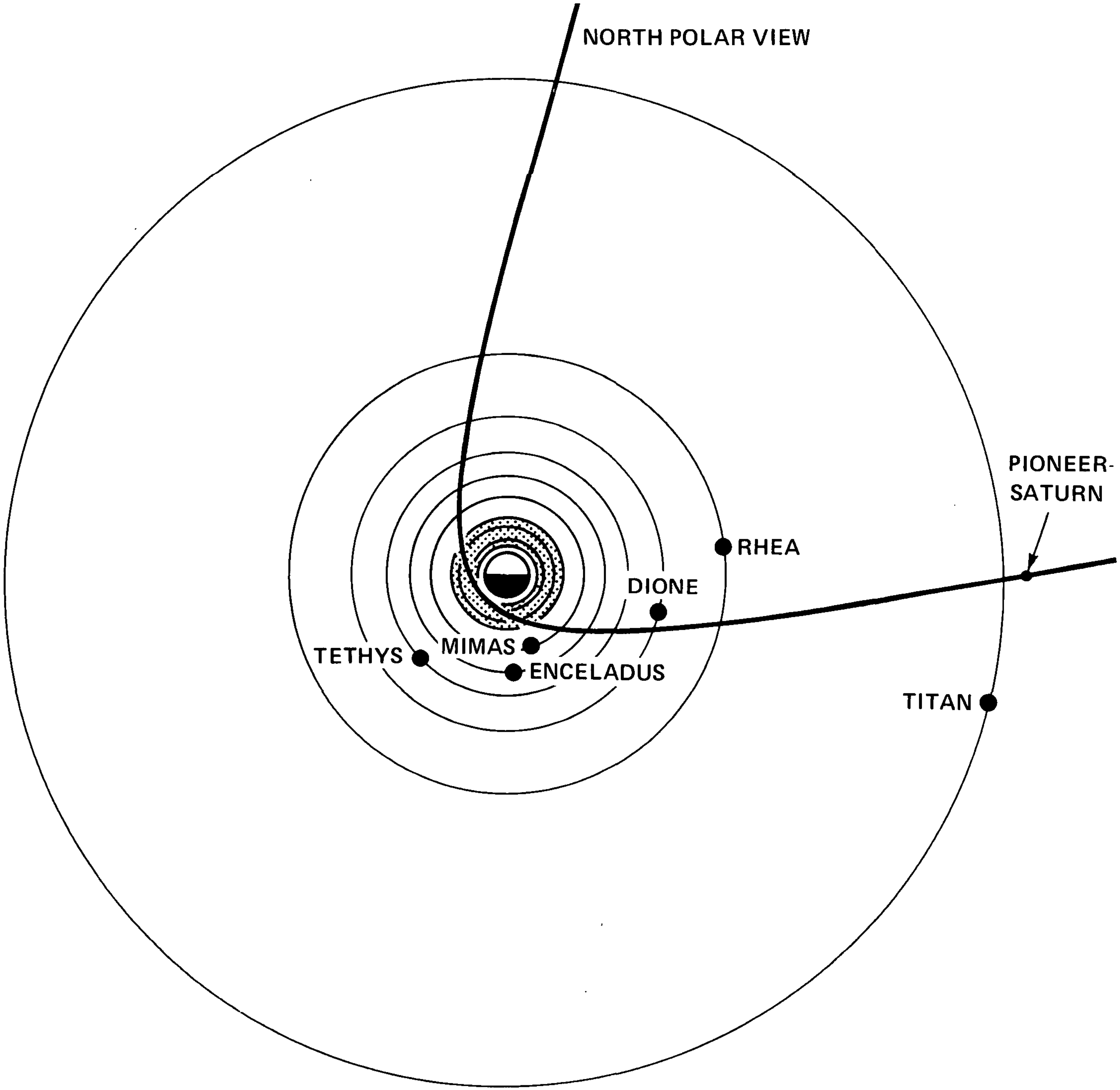
112,000 km (69,440 mi)

VIEW FROM EARTH



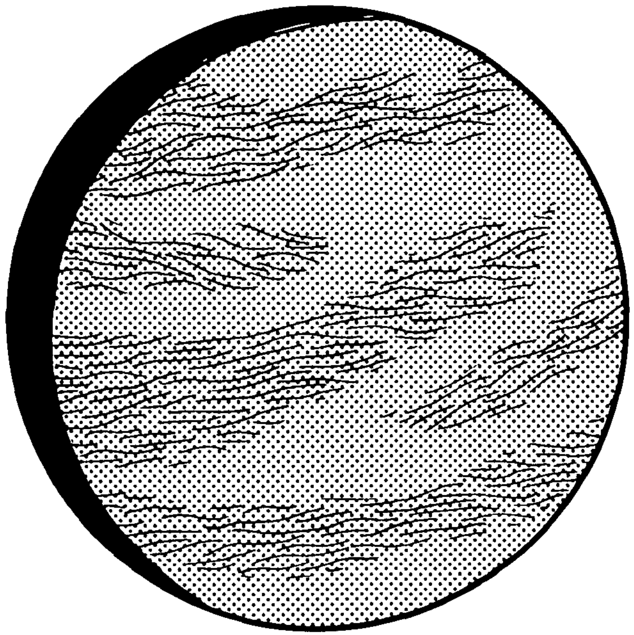
PIONEER SATURN TRAJECTORY

SATELLITE POSITIONS AT TITAN CLOSEST APPROACH

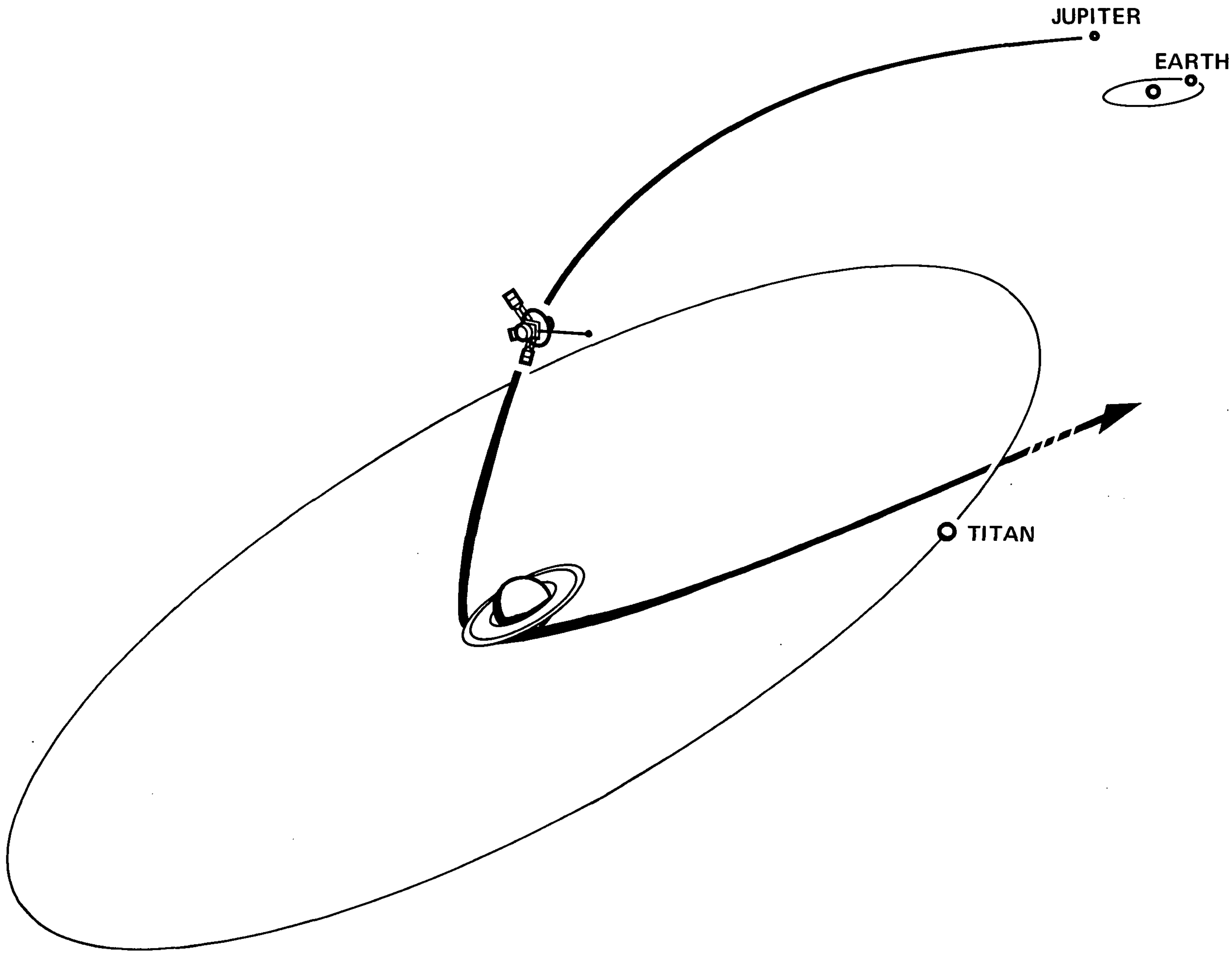


SPACECRAFT VIEW OF TITAN

SEPTEMBER 2, 1979; 11:34 a.m. PDT
DISTANCE — 360,000 km (223,200 mi)



TITAN ENCOUNTER



By Sept. 3, when Pioneer has moved 1.4 million km (900,000 mi.) away from Saturn, tentative infrared and ultraviolet measurements are expected to become available. By Sept. 6, an infrared map of Saturn may be available, as well as early calculations of the masses of the rings and of Rhea and Titan. Picture resolution will be better than Earth-based imaging through midnight, Sept. 7.

Picture Sequences

Plans call for the imaging photopolarimeter to make about 155 images between Aug. 20 and Sept. 8. However, the instrument has been in space for six years, and it is possible that the total number of images could be fewer than predicted.

All of the images will not be available for distribution. Scientists hope to process for immediate distribution up to three or four images each day during the encounter period.

Between Aug. 20 and midnight Aug. 25, plans call for the imaging photopolarimeter to take 49 images of Saturn. The distance from the spacecraft to the planet will decrease from 10.2 million km (6.3 million mi.) to 6.1 million km (3.8 million mi.).

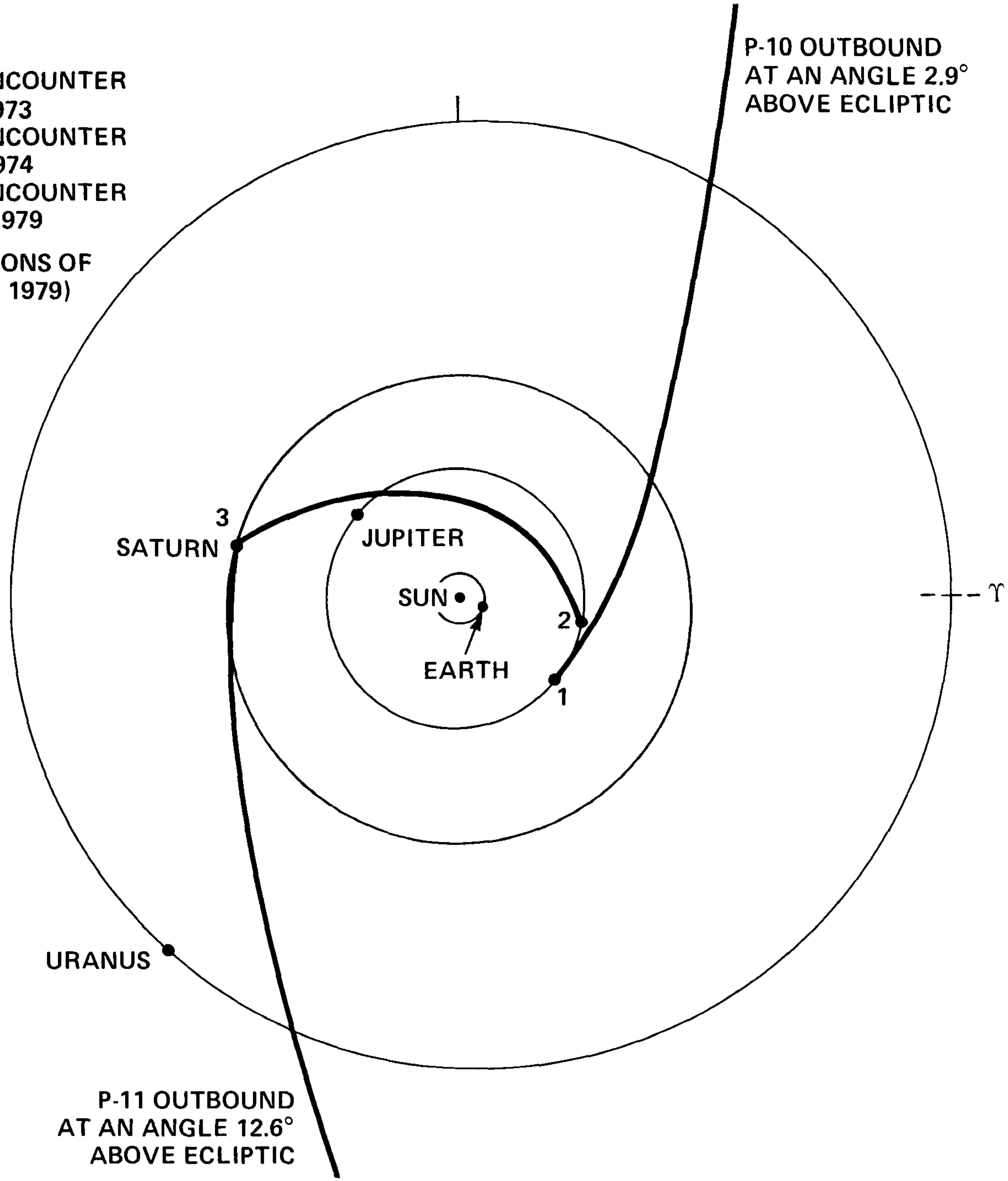
Between Aug. 26 and Sept. 8, 106 images are planned, these having better resolution than Earth-based photographs. Processing of the best images for distribution purposes will begin Aug. 27. A maximum of seven images are planned on Aug. 26 and another seven for Aug. 27. By Aug. 28, some images should be available for distribution.

-more-

PIONEER 10 AND PIONEER SATURN OUTBOUND TRAJECTORIES

1. P-10 JUPITER ENCOUNTER DECEMBER 4, 1973
2. P-11 JUPITER ENCOUNTER DECEMBER 3, 1974
3. P-11 SATURN ENCOUNTER SEPTEMBER 1, 1979

(PLANET POSITIONS OF SEPTEMBER 1, 1979)



SATURN PICTURE TIME SCHEDULE

Date	Time Received On Earth (PDT)	Image	Distance From Spacecraft Km	Distance From Spacecraft Mi.	Planned No. of Images	Pixel Size (Resolution) Km	Pixel Size (Resolution) Mi.
Aug. 20	3 p.m. - 8 p.m.	Saturn	10,200,000	6,300,000	2	5,100	3,200
Aug. 21	Mdnt. - Mdnt.	Saturn	9,400,000	5,800,000	10	4,700	2,900
Aug. 22	Mdnt. - Mdnt.	Saturn	8,600,000	5,300,000	10	4,300	2,700
Aug. 23	Mdnt. - Mdnt.	Saturn	7,900,000	5,000,000	10	3,900	2,400
Aug. 24	Mdnt. - 8 p.m.	Saturn	7,000,000	4,300,000	8	3,500	2,200
Aug. 25	Mdnt. - 2 a.m.	Saturn	6,550,000	4,100,000	1	3,300	2,000
	6 a.m. - Mdnt.	Saturn	6,100,000	3,800,000	8	3,000	1,900
Aug. 26	Mdnt. - Mdnt.	Saturn	5,400,000	3,350,000	7	2,700	1,700
Aug. 27	Mdnt. - Noon	Saturn	4,800,000	3,000,000	4	2,400	1,500
	3 p.m. - Mdnt.	Saturn	4,400,000	2,700,000	3	2,200	1,350
Aug. 28	Mdnt. - 4 a.m.	Saturn	4,100,000	2,500,000	1	2,100	1,300
	Noon - Mdnt.	Saturn	3,600,000	2,200,000	4	1,800	1,100
Aug. 29	Mdnt. - 6 a.m.	Saturn	3,300,000	2,050,000	2	1,600	1,000
	8 a.m. - Mdnt.	Saturn	2,800,000	1,700,000	8	1,400	870
Aug. 30	Mdnt. - 4 a.m.	Saturn	2,450,000	1,500,000	1	1,200	760
	6 a.m. - 8 p.m.	Saturn	2,050,000	1,300,000	6	1,000	640
Aug. 31	Mdnt. - 3 a.m.	Saturn	1,600,000	1,000,000	1	800	500
	5 a.m. - Mdnt.	Saturn	1,100,000	700,000	9	540	330
Sept. 1	Mdnt. - 4 a.m.	Saturn	535,800	332,200	2	270	170
	4 a.m. - 8 a.m.	Saturn	325,800	202,000	3	160	100
	8 a.m. - 9 a.m.	Saturn	94,200	58,400	1	50	30
	1 p.m. - 4 p.m.	Saturn	258,000	160,000	2	130	80
	4 p.m. - 8 p.m.	Saturn	477,600	296,100	1	240	150
	8 p.m. - Mdnt.	Saturn	672,600	417,000	1	340	210
Sept. 2	Mdnt. - 4 a.m.	Saturn	854,400	529,700	2	430	265
	4 a.m. - 8 a.m.	Titan	423,000	262,300	1	210	130
	4 a.m. - 8 a.m.	Saturn	1,000,000	620,000	2	510	320
	8 a.m. - Noon	Titan	365,400	226,500	1	180	110
	8 a.m. - Noon	Saturn	1,200,000	740,000	2	600	370
	Noon - 4 p.m.	Titan	363,600	225,400	1	180	110
Sept. 3	1 a.m. - 9 a.m.	Saturn	1,900,000	1,200,000	4	970	600
	10 a.m. - 1 p.m.	Saturn	2,150,000	1,300,000	1	1,080	670
	2 p.m. - 6 p.m.	Saturn	2,300,000	1,400,000	2	1,170	720
	7 p.m. - Mdnt.	Saturn	2,500,000	1,550,000	2	1,260	780
Sept. 4	Mdnt. - 3 a.m.	Saturn	2,700,000	1,700,000	1	1,330	830
	9 a.m. - Mdnt.	Saturn	3,400,000	2,100,000	1	1,680	1,030
Sept. 5	Mdnt. - Mdnt.	Saturn	3,900,000	2,400,000	10	1,900	1,200
Sept. 6	Mdnt. - Mdnt.	Saturn	4,700,000	2,900,000	10	2,300	1,400
Sept. 7	Mdnt. - Mdnt.	Saturn	5,500,000	3,400,000	10	2,700	1,700

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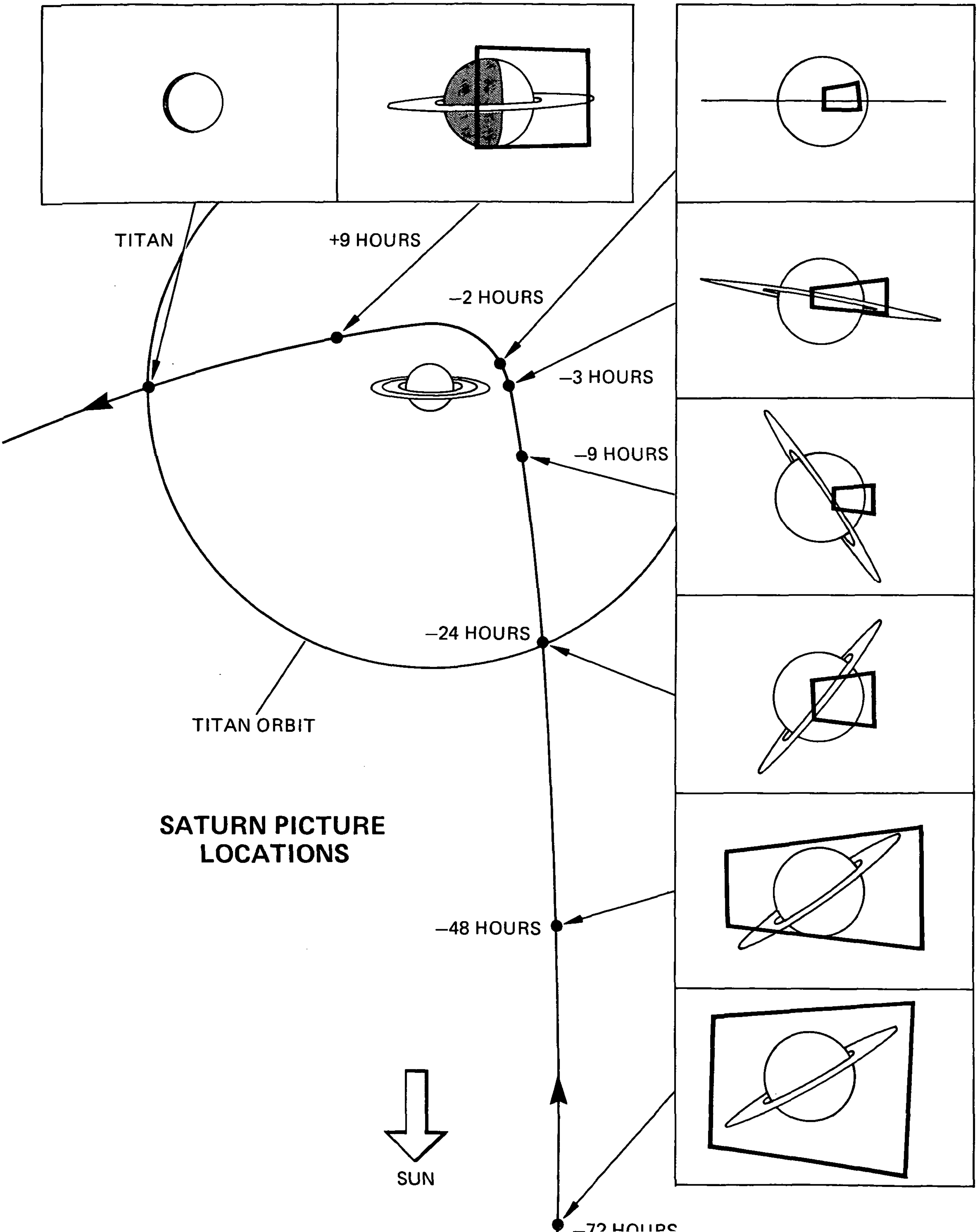

TITAN
+9 HOURS
-2 HOURS
-3 HOURS
-9 HOURS
-24 HOURS
TITAN ORBIT
SATURN PICTURE LOCATIONS
-48 HOURS
SUN
-72 HOURS

Trajectory Selection

Pioneer Saturn began its journey to Jupiter and Saturn on April 5, 1973. It followed Pioneer 10, the first spacecraft to Jupiter, launched in March 1972.

When Pioneer 10 successfully completed the first flyby of Jupiter in December 1973, Pioneer 11 was retargeted to a trajectory that would provide both data that best complemented that from Pioneer 10 and included a subsequent transfer orbit to Saturn. Pioneer 11 reached Jupiter on Dec. 3, 1974, and returned new data about the Jovian environment. It then began its 2.4 billion km (1.5 billion mi.) trek across the solar system toward Saturn. Preliminary maneuvers were executed in 1975 and 1976 to put the spacecraft on an interim trajectory.

From the many original targeting options, two semi-final aim points were selected. The principal difference between the two aim points, known as the "inside" and "outside" options, was their relationship to Saturn's unique ring system.

A trajectory to the inside area on Pioneer's inbound descending approach would have come very close to the planet -- 3,600 km (2,232 mi.) inside the visible C ring. The advantage of the inside target area was hard to firmly establish, however, because of the apparent discovery of an inner D ring by Pierre Guerin in 1969. Guerin's photographs appear to show ring material within the C ring, extending close to the planet, and a new division (the Guerin division) between the C and D rings. Although the density profile for the D ring could not be measured, most assessments showed considerable risk for survival of Pioneer Saturn on the inside trajectory, even if targeted through the Guerin division at 14,400 km (8,928 mi.).

For an outside trajectory the inbound descending and outbound ascending flight paths can be located at any distance beyond the A ring, which extends to 77,400 km (48,100 mi.) from Saturn's cloud tops. However, outside targeting is again complicated by evidence of ring material in an E ring extending beyond the visible rings.

Since the existence of the E ring is critical to Voyager, NASA officials determined that the maximum return from all missions would be achieved by targeting Pioneer Saturn outside the rings.

A very crucial moment of the Pioneer Saturn mission will occur on the morning of Sept. 1, when Pioneer passes through the ring plane at an angle of nearly 5 degrees, 112,000 km (70,000 mi.) from Saturn on its descent toward the planet. An impact with a fragment of the E ring could destroy the spacecraft.

Ring-plane passage takes only about 0.8 second, and is repeated four hours later when the spacecraft recrosses the ring plane on its ascent from the planet, again at 112,000 km (70,000 mi.) from Saturn's cloud tops.

The outside ring plane crossing at 112,000 km (70,000 mi.) provides a "balanced" flyby where the inbound descending and outbound ascending courses are both at that distance, with full visibility from Earth. Closest approach is 21,400 km (13,300 mi.). Inclination of the trajectory is 4.7 degrees to Saturn's ring plane with periapsis in the southern hemisphere. Earth and solar occultations occur shortly after periapsis.

Post-Saturn

Like Pioneer 10, Pioneer Saturn will escape the solar system on its post-encounter trajectory. Pioneer Saturn will be traveling in the opposite direction from its sister spacecraft. The escape is in the general direction of the nose of the heliosphere, which marks the boundary between the solar wind and the interstellar medium. Communications with both spacecraft should be possible through the mid-1980s. Both Pioneers carry a message plaque for any intelligent species that may capture the spacecraft during their years of wandering among the stars.

ENCOUNTER TIMELINE

Notes:

(All times are spacecraft times, PDT, except as noted.)
ERT = Earth Received Time PDT
One-way light time: Aug. 20-22, 85 min.; Aug. 23 - Sept. 7, 86 min.
Two-way light time: Aug. 20-22, 2 hrs. 50 min.; Aug. 23 - Sept. 7, 2 hrs. 52 min.
E = Cloest approach to Saturn (9/1/79, 9:34 a.m.)

8/2/79	Start encounter activities. Spacecraft now tracked via 64-meter (210 foot) dishes in Spain and Australia for about 10 hours a day.
8/6/79	Tracking increases to 18 hours a day--Goldstone Station is added. Routine science data-gathering taking place. All science instruments on and being checked for encounter readiness. Pioneer instrument begins to make polarimentry measurements of Saturn.
8/12/79	Spacecraft is precessed to keep the high-gain antenna pointed within .5 degree of Earth, to maintain highest possible data rates.
8/16/79	Begin 4-day ultraviolet imaging of planet. Spacecraft turned 1.3 degrees away from Earth for ultraviolet imaging.
8/17/79	Spacecraft now tracked 24 hours a day on the 64 m (210 ft.) stations.
8/20/79	Critical encounter period begins. Photopolarimeter now begins to take images of Saturn. Distance is too great to see detail. Second precession performed to keep antenna pointing within .5 degree of Earth.
8/25/79	Spacecraft now covered by two stations simultaneously to increase data return. Commands sent via 26-m (86-ft.) station and data is received via 64-m (210-ft.) station. This will increase the data rate from 512 bps to 1024 bps and substantially improve image quality.

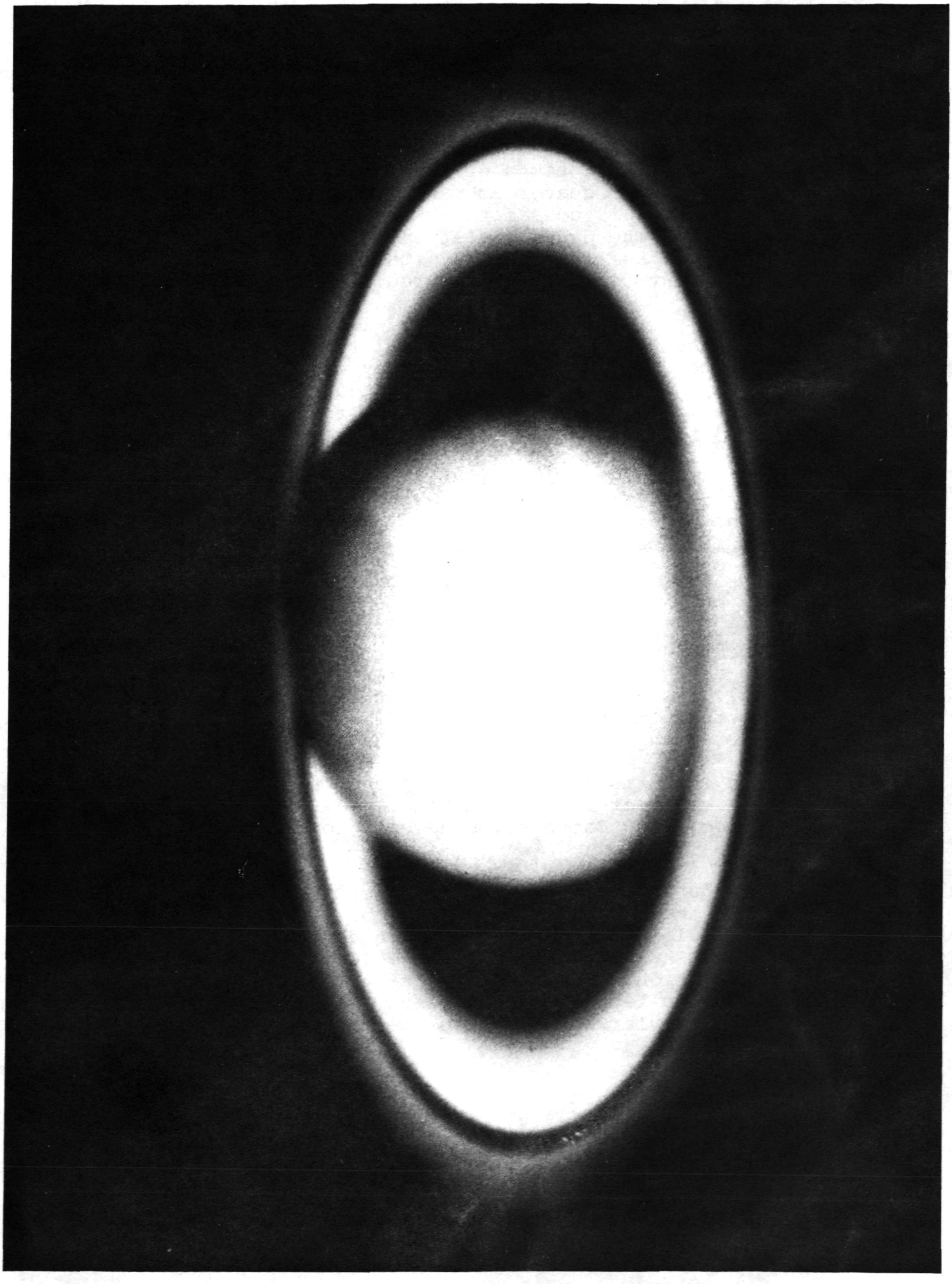
	Begin picture resolution better than Earth-based. Expect at least 50 such pictures through 9/8/79. (Most will show rings, lighted from below.)
8/27/79 (E -5 days)	
1:02 a.m.	Closest approach to Saturn's 10th moon, Phoebe, at 9,453,000 km (5,860,860 mi.).
	Possible bow shock crossing. Time or times depend on local solar wind intensity.
8/28/79 (E -4 days)	
11:05 p.m.	Closest approach to Saturn's ninth moon, Iapetus, (diameter 1400 km, or 900 mi.) at 1,039,000 km (644,180 mi.). (Photometry measurements.)
8/29/79	Third precession performed to correct antenna pointing.
8/30/79	
6:34 p.m. (E -39 hours)	Pioneer completes last image of full planet with rings, twice the best Earth resolution.
8/31/79	
12:34 a.m. (E -33 hrs.)	Last full planet picture (perhaps best full planet view); five times best Earth resolution.
5:31 a.m. (E -28 hrs.)	Closest approach to Saturn's eigth satellite, Hyperion, (diameter 225 km, or 140 mi.) at 674,000 km (417,880 mi.). (Ultraviolet measurements.)
10:10 a.m.	Series of 21 commands, designed to keep spacecraft subsystems in proper encounter mode, are transmitted every hour for the next two days.
11:34 a.m.	Begin 14 hours of ultraviolet observations of Saturn.
9/1/79	
8:00 a.m.	Begin 1½ hours of infrared imaging of Saturn.

7:34 a.m. (E -2 hrs.)	Best picture resolution (objects 80-100 km, or 50-60 mi. in size), 20 times best Earth resolution.
7:35 a.m. (9:01 a.m. ERT)	Pioneer crosses Saturn's ring plane on its descent toward the planet. (Critical event.) (112,000 km, or 70,000 mi., above clouds.)
8:09 - 11:05 a.m.	Flight under Saturn's rings (lit side), 3,500 km (2,200 mi.) away. 1 hr. 20 min. before occulation to 10 min. after occulation.
9:04 a.m. (E -½ hr.)	Closest approach to Saturn's fifth satellite, Dione, (diameter 1000 km, or 620 mi.) at 291,100 km (180,482 mi.). (Photometry measurements.)
9:14 a.m.	Begin 20 minutes of radio occultation measurements of Saturn's ionosphere and atmosphere.
9:27 a.m.	Closest approach to Saturn's second moon, Mimas, (diameter 940 km, or 585 mi.) at 103,400 km (65,108 mi.).
**9:34 a.m. (11:00 a.m. ERT)	Closest approach to cloud tops of Saturn, at 21,400 km (13,300 mi.). Speed is 114,100 km/hr (70,900 mph). (Distance from Earth is 1.4 billion km, or 963 million mi.)
9:35 a.m.	Enter 78-minutes of Earth occulation.
9/1/79	
9:35:57 a.m.	Enter 79-minutes of Sun occultation -- Penumbra
9:36: a.m.	-- Umbra
10:53:32 a.m.	Leave Earth occultation, end radio blackout and data storage. Begin 20 minutes of radio occultation measurements of Saturn's atmosphere and ionosphere.
10:54:42 a.m.	Leave Sun occultation -- Umbra
10:54:47 a.m.	-- Penumbra
11:28 a.m.	Closest approach to Saturn's fourth satellite, Tethys, (diameter 1000 km, or 650 mi.) at 331,700 km (205,654 mi.). (Photometry and ultraviolet measurements.)

11:33 a.m. (E +2 hrs.) (12:59 p.m. ERT)	Pioneer crosses Saturn's ring plane on its ascent away from the planet. (Critical event.) (112,000 km, 70,000 mi.)
11:33	Closest approach to Saturn's third satellite, Enceladus, (diameter 1100 km, or 680 mi.) at 225,200 km (139,624 mi.). (Ultraviolet measurements.)
12:34 p.m. (E +3 hrs.)	Resume close-up views of rings (unlit side).
3:34 p.m. (E +6 hrs.)	Closest approach to Saturn's sixth satellite, Rhea, (diameter 1600 km, or 1000 mi.) at 341,900 km (211,978 mi.). (Photometry and ultraviolet measurements.)
6:34 p.m. (E +9 hrs.)	Resume half-ring plus planet view (1/3 disc).
9/2/79	
4:00 a.m.	Start Titan imaging
6:40 a.m. (E +19 hrs.)	First ultraviolet imaging of Titan.
8:41 a.m. (E +24 hrs.)	Second ultraviolet imaging of Titan.
11:05 a.m. (E +25 ½ hrs.)	Closest approach to Saturn's seventh moon, Titan, (diameter 5800 km, or 3600 mi.) at 356,000 km (220,720 mi.).
12 Midnight	Titan infrared imaging.
9/3/79 (E +2 days)	Tentative infrared and ultraviolet findings.
9/6/79 (E +5 days)	Infrared map of Saturn; first mass calculations of Saturn's moons.
9/8/79	Start of superior conjunction (when the Sun is between the Earth and Saturn). Spacecraft passes close to Sun as viewed from Earth. Data rates will be low (16-32 bps) for the next seven days. No images will be taken during that period. From this point on, resolution ceases to surpass Earth-based resolution.
9/15/79	Superior conjunction ends. Resume normal data-gathering activity.
10/1/79	End of encounter activities.

NASA
National Aeronautics and
Space Administration

Headquarters
Washington, D.C.



SATURN

Saturn is the only planet in the solar system less dense than water. It has a volume 815 times greater than Earth's but a mass only 95.2 times greater. It is the second largest planet. Saturn's equatorial radius is 60,000 km (37,300 mi.). The polar radius is considerably smaller -- 53,500 km (33,430 mi.). The dynamic flattening, caused by Saturn's rapid rotation and increased by its low density, is the greatest of any planet yet measured.

Saturn's rings were discovered in 1610 when Galileo Galilei aimed the first astronomical telescope at Saturn. Even Galileo didn't realize what they were. He reported seeing "cup handles" in his less-than-adequate telescope. Forty-five years later, in 1655, Christian Huygens described the rings' true form.

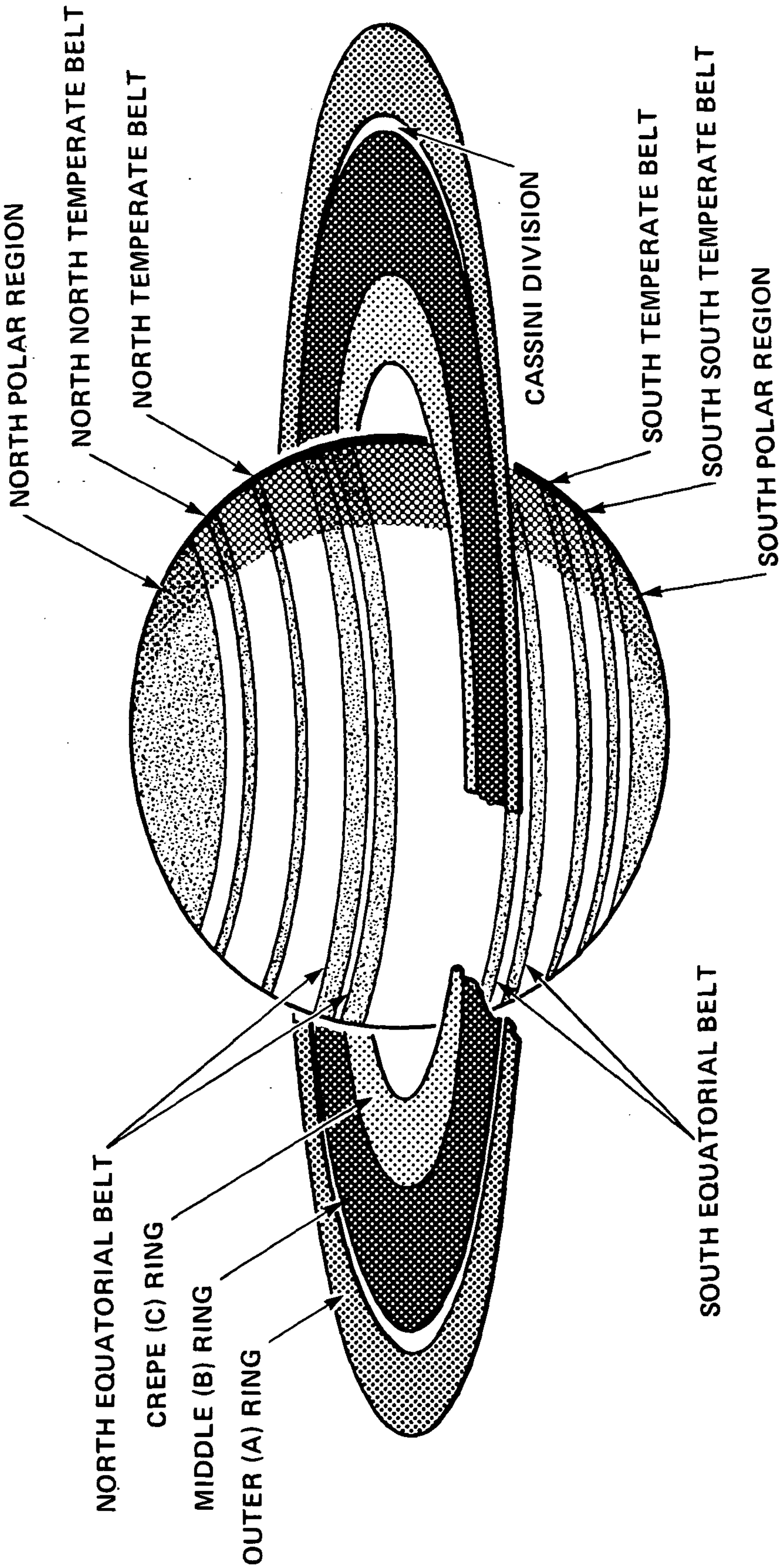
A day on Saturn's equator is only 10 hours, 14 minutes -- 18.5 minutes longer than a day on Jupiter. Saturn completes one orbit of the Sun in 29.46 Earth years. The average distance of Saturn from the Sun is 9.5 A.U.* Saturn receives only about 1/100th of the Sun's intensity that strikes Earth.

Saturn, like the other outer giants, bears some resemblance to Jupiter -- enough that they are often coupled together as the Jovian planets. Like Jupiter, Saturn apparently has no solid surface, but changes gradually from a thin outer atmosphere through progressively denser layers to the core, which may be a small chunk of iron and rock.

When scientists discuss the planet's atmosphere, they generally restrict their attention to a region where pressure varies from 1,000 Earth atmospheres to one 10-billionth atmosphere (10^{-10}).

Like Jupiter, the principal constituents of the Saturnian atmosphere are thought to be hydrogen and helium. Three molecules have definitely been detected in Saturn's atmosphere: hydrogen (H_2), methane (CH_4) and ethane (C_2H_6). Radioobservations provide indirect evidence for ammonia (NH_3) at atmospheric levels inaccessible to optical measurements. No other molecular or atomic speices has been detected.

*An astronomical unit (A.U.) is the mean distance from the Sun to the Earth -- 149,600,000 km (92,960,000 mi.).


NORTH POLAR REGION
NORTH NORTH TEMPERATE BELT
NORTH TEMPERATE BELT
CASSINI DIVISION
SOUTH TEMPERATE BELT
SOUTH SOUTH TEMPERATE BELT
SOUTH POLAR REGION
NORTH EQUATORIAL BELT
CREPE (C) RING
MIDDLE (B) RING
OUTER (A) RING
SOUTH EQUATORIAL BELT

Also, like Jupiter, Saturn is believed to be composed of materials in about the same ratio as the Sun, formed into the simplest molecules expected in a hydrogen-rich atmosphere.

Saturn appears to radiate nearly twice as much energy as it receives from the Sun. In the case of Jupiter, that radiation has been explained as primordial heat left over from the time, about 4.6 billion years ago, when the planet coalesced out of the solar nebula. The same may be true for Saturn. Convection is the most likely transport mechanism to carry heat from the interior of the planet to the surface.

Saturn has cloud bands similar to Jupiter's, although they are harder to see and contrast less with the planetary disc. Photographs confirm that Saturn's bland appearance is real. The blandness may be a result of lower temperatures and reduced chemical and meteorological activity compared with Jupiter or a relatively permanent and uniform high altitude haze.

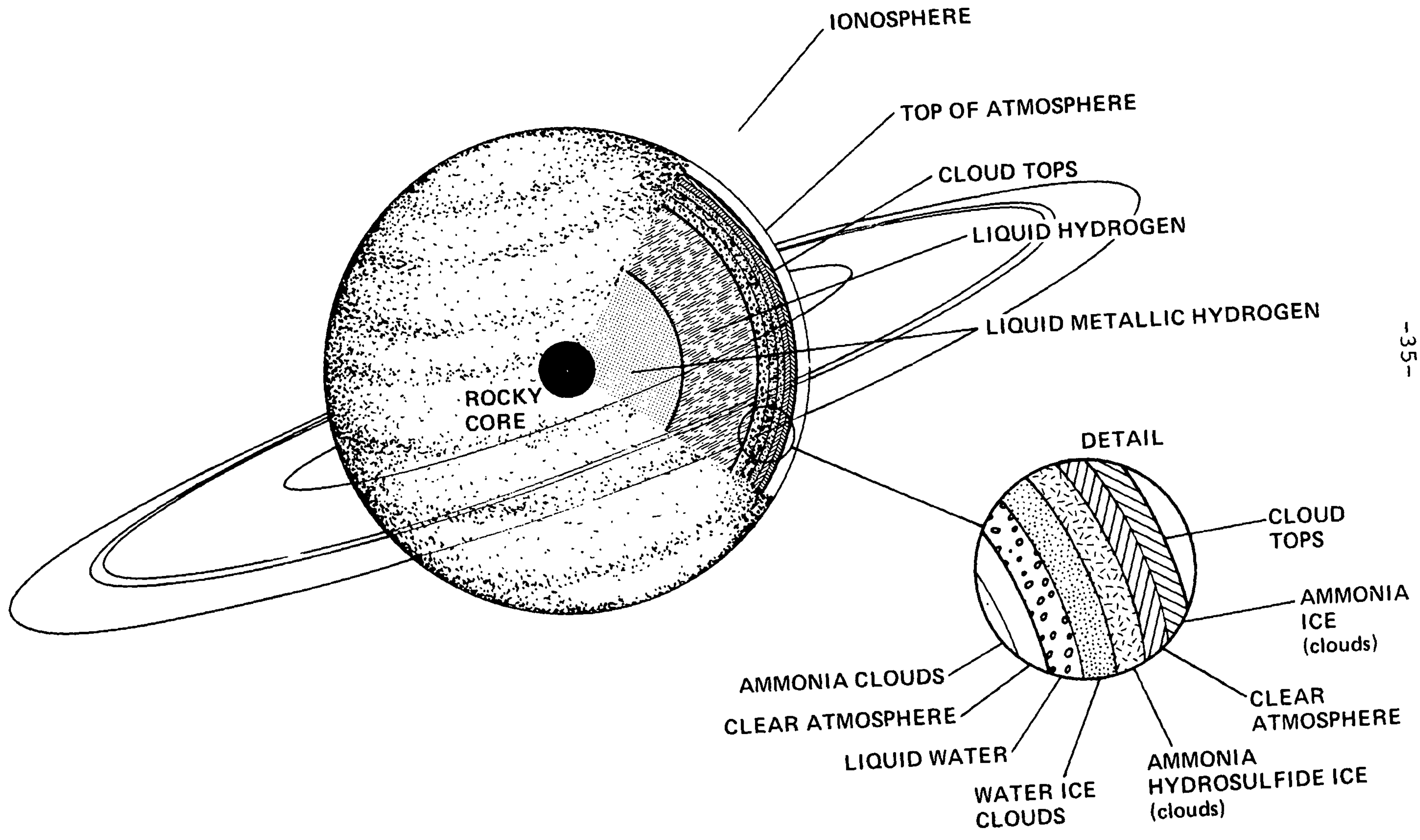
The prinicpal features of Saturn's visible surface are stripes that parallel the equator. Six dark belts and three light zones have been seen continuously over 200 years of observations.

Spots have been observed in the upper atmosphere of Saturn. Unlike the Great Red Spot of Jupiter they are not permanent nor are they easily identifiable. The spots that have been observed have lifetimes up to a few months. Sometimes they are light, sometimes dark. They are confined to a region within 60 degrees of the equator and typically are a few thousand kilometers across. They may be comparable to hurricanes on Earth.

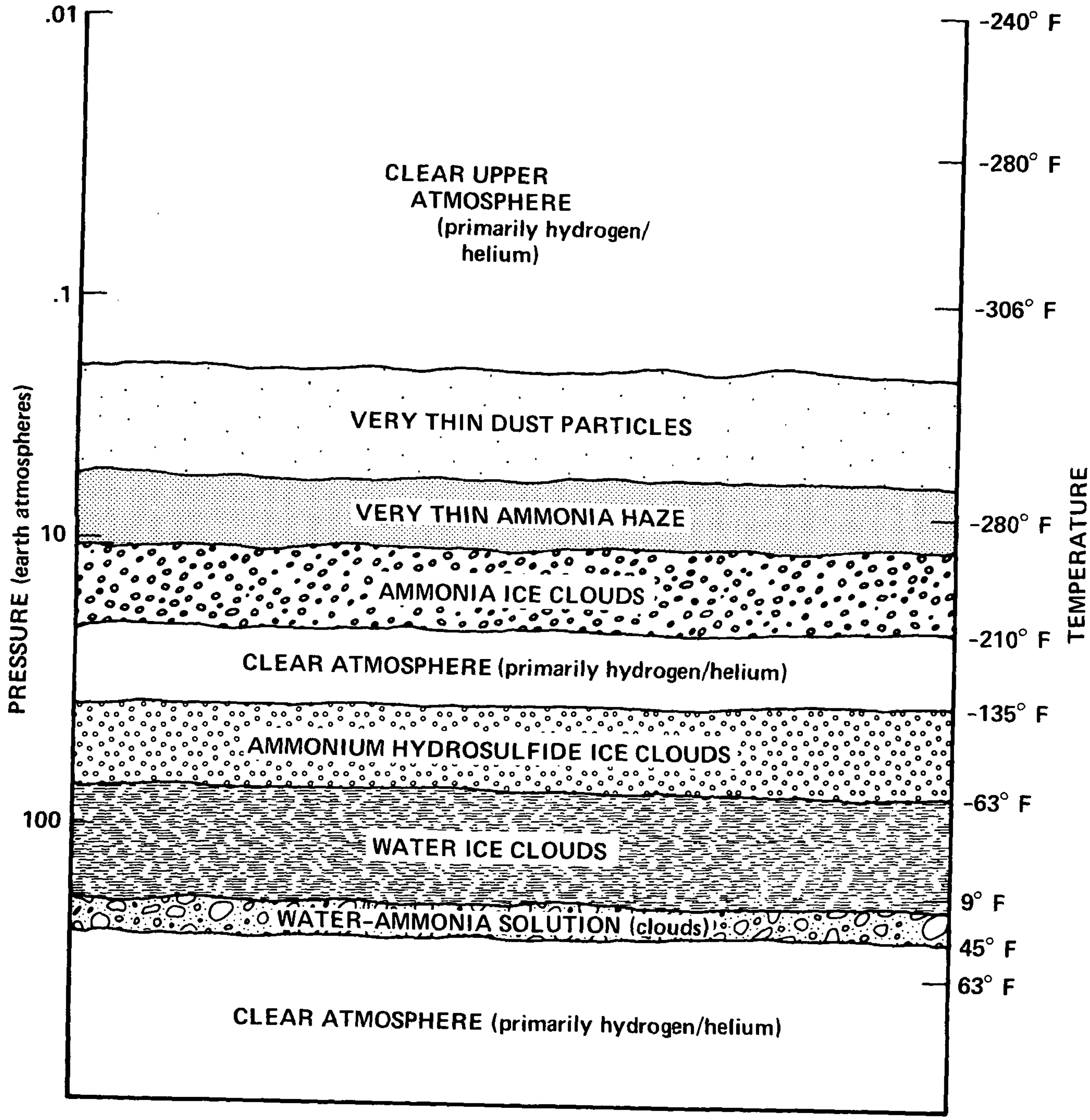
Saturn has 10 known satellites. The most recent discovery was Janus, found in 1966 by Audouin Dollfus. Janus has been seen in only a few photographs. It appears to travel in the plane of Saturn's rings and near them. Its low albedo and proximity to the rings make Janus difficult to observe except when the rings are edge-on to Earth and recent studies indicate that at least two separate satellites may be masquerading under the name of Janus.

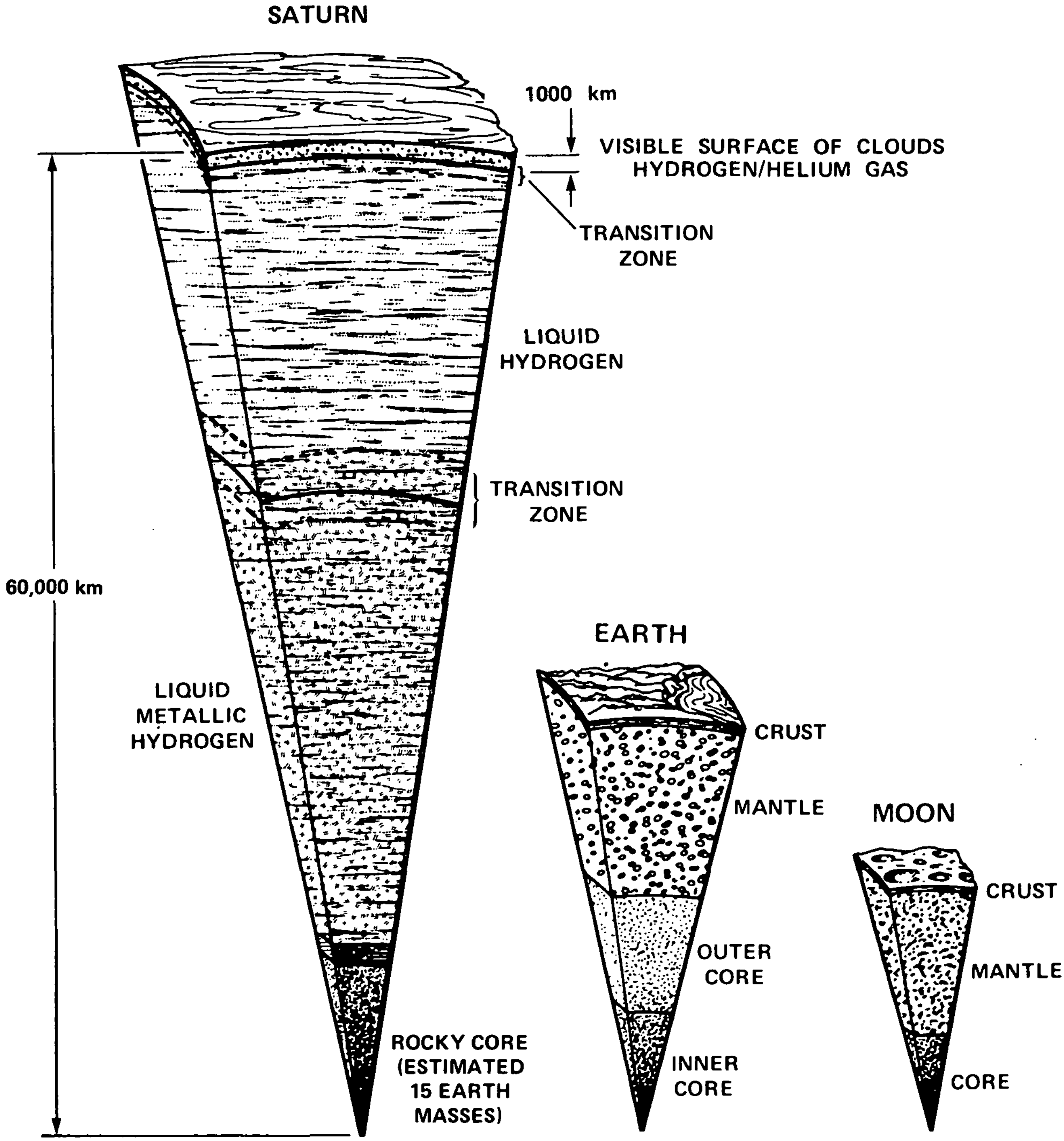
The largest known satellite in the solar system is Saturn's satellite Titan. Titan has a diameter of 5,800 km (3,600 mi.), greater than the planet Mercury, and is known to have an atmosphere. In 1944, the late Dr. Gerard Kuiper detected a methane atmosphere on Titan. Titan's atmospheric pressure may be comparable to Earth's. Other molecules identified include ethane and probably acetylene and many scientists believe there is also a major undetected gas present. The most likely candidate is nitrogen.

SATURN ATMOSPHERE MODEL*



NOMINAL SATURN ATMOSPHERE




SATURN
1000 km
VISIBLE SURFACE OF CLOUDS
HYDROGEN/HELIUM GAS
TRANSITION
ZONE
LIQUID
HYDROGEN
TRANSITION
ZONE
60,000 km
LIQUID
METALLIC
HYDROGEN
ROCKY CORE
(ESTIMATED
15 EARTH
MASSES)
EARTH
CRUST
MANTLE
OUTER
CORE
INNER
CORE
MOON
CRUST
MANTLE
CORE

Some scientists believe organic compounds may be present on the surface of Titan, leading some to suggest it as a possible abode of some primitive life forms.

Iapetus is another Saturnian satellite that draws scientific interest. Its brightness varies by a factor of about five as it rotates on its axes, indicating that one face is bright and the other dark. The light face appears to be covered with ice but the composition of the dark face is unknown.

Saturn's rings have been a curiosity to astronomers since their discovery. Their origin is unknown but a number of hypotheses have been put forward. They might be the remains of some early satellite broken up by gravitation or remnants of the primordial material that somehow became trapped in orbit. The age of the rings is not known.

The rings lie in Saturn's equatorial plane, which is tipped 27 degrees to the orbital plane of Saturn. Although it is certain the rings are not a solid sheet, little else is known about their composition and structure. Spectroscopy shows that they are made primarily of water ice or ice-covered silicates.

The individual particles probably vary from less than a millimeter (0.04 m) to more than a 10 m (32.8 ft.), but most are a few centimeters in size -- about as big as a snowball.

Three distinct rings can be seen. The inner or "crepe" ring begins about 17,000 km (11,000 mi.) from the planet's visible cloud surface and extends for 15,000 km (9,000 mi.) to 32,000 km (20,000 mi.). The second ring begins at that point and extends for 26,000 km (16,000 mi.) to a distance of 58,000 km (36,000 mi.) from the planet. There, a phenomenon known as Cassini's Division breaks the rings' continuity. Cassini's Division is 2,600 km (1,600 mi.) wide.

The outer ring begins 60,000 km (38,000 mi.) from the equator of Saturn and appears to end 16,000 km (10,000 mi.) farther away at a distance of 76,000 km (47,000 mi.).

Cassini's Division is real. It is explained by a phenomenon in celestial mechanics. Any particle at that distance would have an orbital period of 11 hours 17 ½ minutes, just half the period of the satellite Mimas. The particle would be nearest Mimas at the same place in its orbit every second time around. This repeated gravitational perturbation would eventually move the particle to a different distance, Accurate measurements of the ring thickness are not possible, but limits have been placed. They appear to be somewhere between 1 and 4 km (0.6 to 2.5 mi.).

Until recently there was no evidence that Saturn has a magnetic field. Neither decimeter nor decametric radio emissions had been observed -- the kind of "radio noise" from Jupiter that was evidence for its magnetic field. But radiometric observations from the Earth-orbiting satellite IMP-6 have provided indirect evidence for a magnetic field. If a magnetic field is present, it is probably distorted by the rings.

EARTH, JUPITER, SATURN COMPARISON TABLE

PARAMETER	EARTH	JUPITER	SATURN
Radius (Equatorial)	6,378 km (3,963 mi.)	71,400 km (44,366 mi.)	60,000 km (37,300 mi.)
Satellites	1	13	10
Year	1	11.86	29.46
Day	23h 56m 04s	9h 55m 30s	10h 14m
Mass	1	317.9	95.2
Density (water = 1)	5.5	1.3	0.7
Mean distance from Sun	1 A.U.	5.2 A.U.	9.5 A.U.

-more-

THE SATELLITES OF SATURN

NAME	DIAMETER (km-mi)			SEMIMAJOR AXIS (km-mi)		PERIOD (Days)
	km		mi	km	mi	
Janus	300	(est.)	187	168,700	105,000	0.815
Mimas	400		300	185,800	120,000	0.942
Enceladus	550		390	238,300	148,000	1.370
Tethys	1,200		745	294,900	183,200	1.888
Dione	1,150		715	377,900	235,000	2.737
Rhea	1,450		900	527,600	328,000	4.518
Titan	5,800		3,600	1,222,600	760,000	15.945
Hyperion	300	(est.)	187	1,484,100	922,000	21.276
Iapetus	1,800		1,120	3,562,900	2,214,000	79.33
Phoebe	200	(est.)	125	12,960,000	8,093,000	550.45
(Phoebe's motion is retrograde)						

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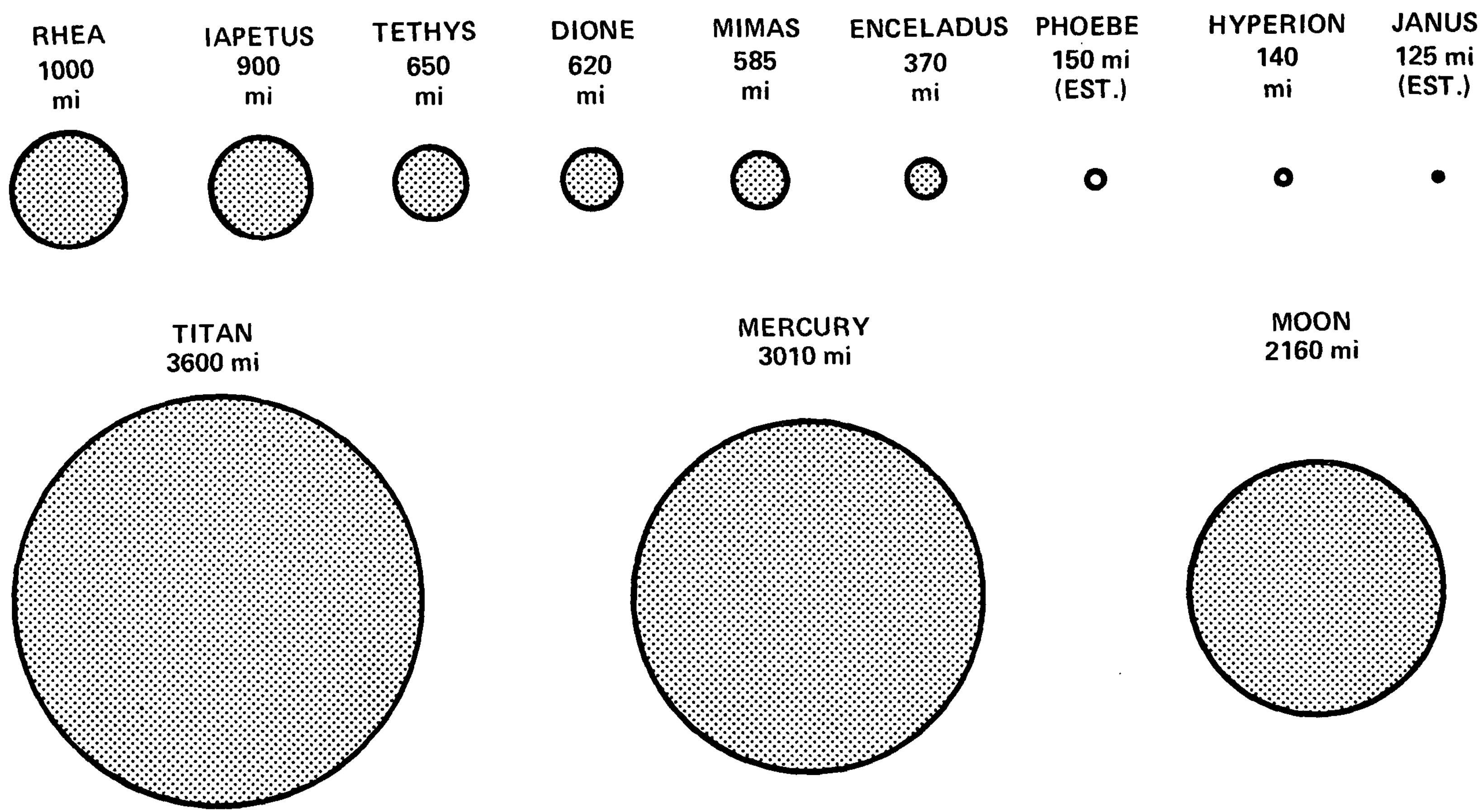
SATURN SATELLITE DIAMETERS



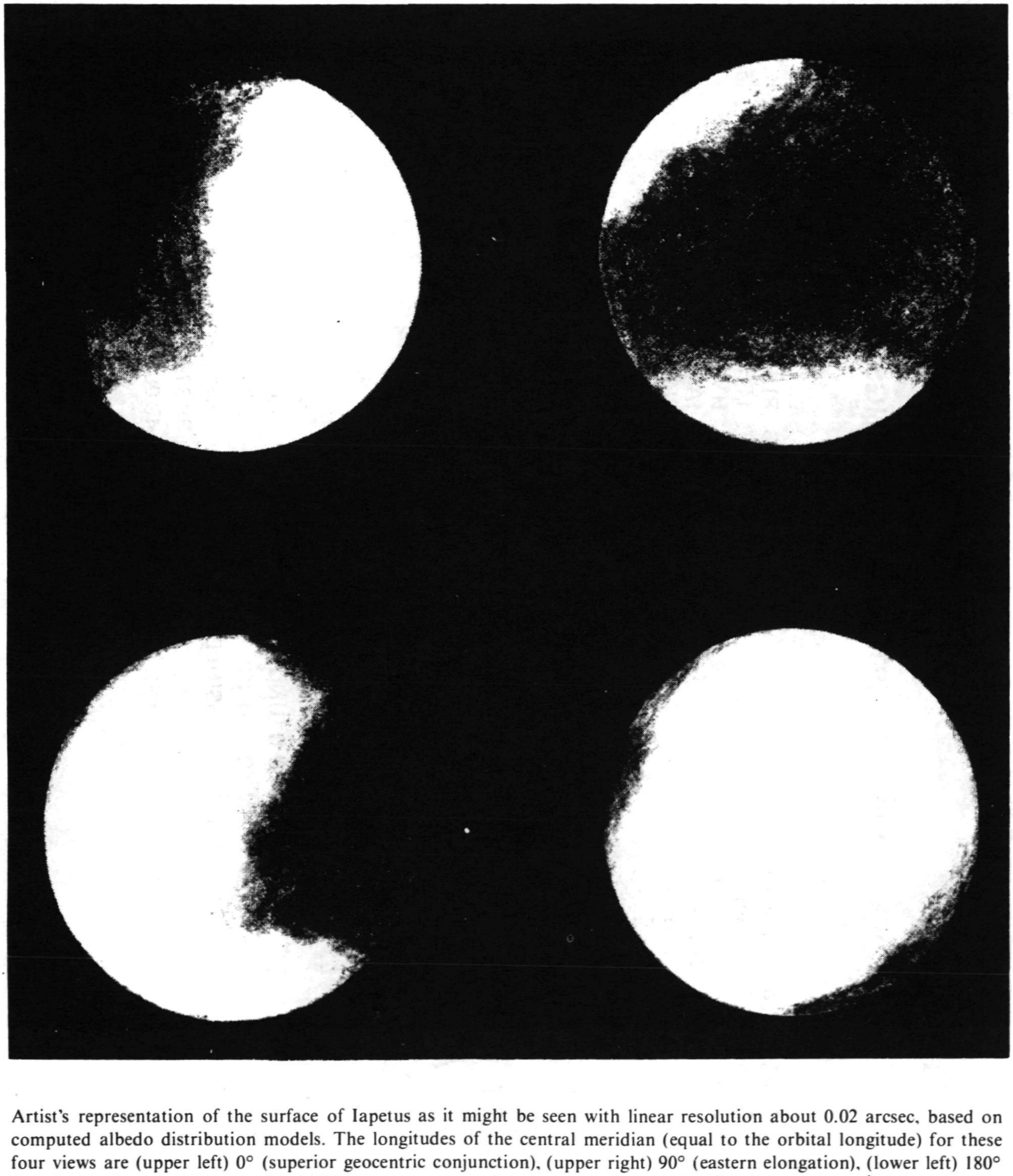
1/2 in. = 750 mi

ORBITAL DISTANCES AND RINGS

1. JANUS, 62,000 mi FROM SATURN
2. MIMAS, 78,000 mi
3. ENCELADUS, 110,000 mi
4. TETHYS 146,000 mi
5. DIONE, 200,000 mi
6. RHEA, 300,000 mi
7. TITAN, 720,000 mi
8. HYPERION, 880,000 mi
9. IAPETUS, 2.2 MILLION mi
10. PHOEBE, 8 MILLION mi

1/2 in. = 62,500 mi

SATURN DIAMETER	74,000 mi
SATURN TO C RING	7,812 mi
SATURN TO B RING	19,716 mi
SATURN TO CASSINI DIVISION	35,340 mi
SATURN TO A RING	38,316 mi
SATURN TO OUTER EDGE OF RINGS	48,000 mi



Artist's representation of the surface of Iapetus as it might be seen with linear resolution about 0.02 arcsec, based on computed albedo distribution models. The longitudes of the central meridian (equal to the orbital longitude) for these four views are (upper left) 0° (superior geocentric conjunction), (upper right) 90° (eastern elongation), (lower left) 180° (inferior conjunction), (lower right) 270° (western elongation). Note that these drawings illustrate only one of a range of similar albedo distributions that are consistent with the available data. From David Morrison et al. (1975).

PIONEER SATURN SCIENCE

The Voyager and Pioneer missions to Jupiter and Saturn are addressing fundamental questions about the origin and nature of the solar system. Understanding interplanetary space and the other planets should give scientists a greater knowledge of Earth.

According to current theoretical models of the origin and evolution of the solar system, a gaseous nebula composed of solar material -- gases and dust of various elements -- collapsed to form the Sun. Some of the material remained behind and began to coalesce to form the planets, their satellites, the asteroids, comets and meteors. Temperature, pressure and density of the gas decreased with distance from the Sun.

Formation of the planets is believed to have resulted from accretion of the nebular material. Observed differences in the planets are accounted for in these theories by variations in material and conditions at the places where they formed. Thus, knowledge gained at each planet can be related to others and should contribute to an overall understanding of the solar system as well as our own planet Earth.

Missions to Mars, Venus, Mercury and the Moon have contributed greatly to the body of knowledge. Each planet has its own personality, significantly different from others because of its unique composition and relationship to the Sun. Individual as they are, the inner planets are related as bodies that originated near the Sun and that are composed mainly of heavier elements. They are classified as "terrestrial planets," since the Earth is approximately representative.

Scientists have known for a long time that Jupiter, Saturn and the other outer planets differ significantly from terrestrial planets. They have low average densities; only hydrogen and helium among all the elements are light enough to match observations to date. Jupiter and Saturn are sufficiently massive (318 and 95 times Earth's mass, respectively) to insure that they have retained almost all their original material. They are, however, only relatively pristine examples of the material from which the solar system formed. While almost no material has been lost, the planets have evolved over their 4.6-billion-year lifetimes and the nature and ratio of the materials may have changed. If that 4.6-billion-year evolution can be traced, scientists will obtain a clearer picture of the early state of their region of the solar system.

SCIENTIFIC OBJECTIVES

Magnetic Field, Magnetosphere and Solar Wind -- Determine the presence of a Saturn magnetic field. Map the field and determine its intensity, direction and structure. Find if the field's center and magnetic equator coincide with Saturn's geographical center and equator. Find if the field is dipole or multipole. Find the rotation rate of the deep interior of this gas planet (compared with the surface rate) by measuring the field's rotation. Measure changes in the field due to Saturn's rings. Find the shape and character of Saturn's proposed magnetosphere. Chart the magnetosphere boundary and its bow shock wave in the solar wind, and study a variety of planet interactions with electrons and protons of the solar wind. Look for energetic particles, accelerated in the magnetosphere, far out in the interplanetary medium, before Pioneer reaches Saturn.

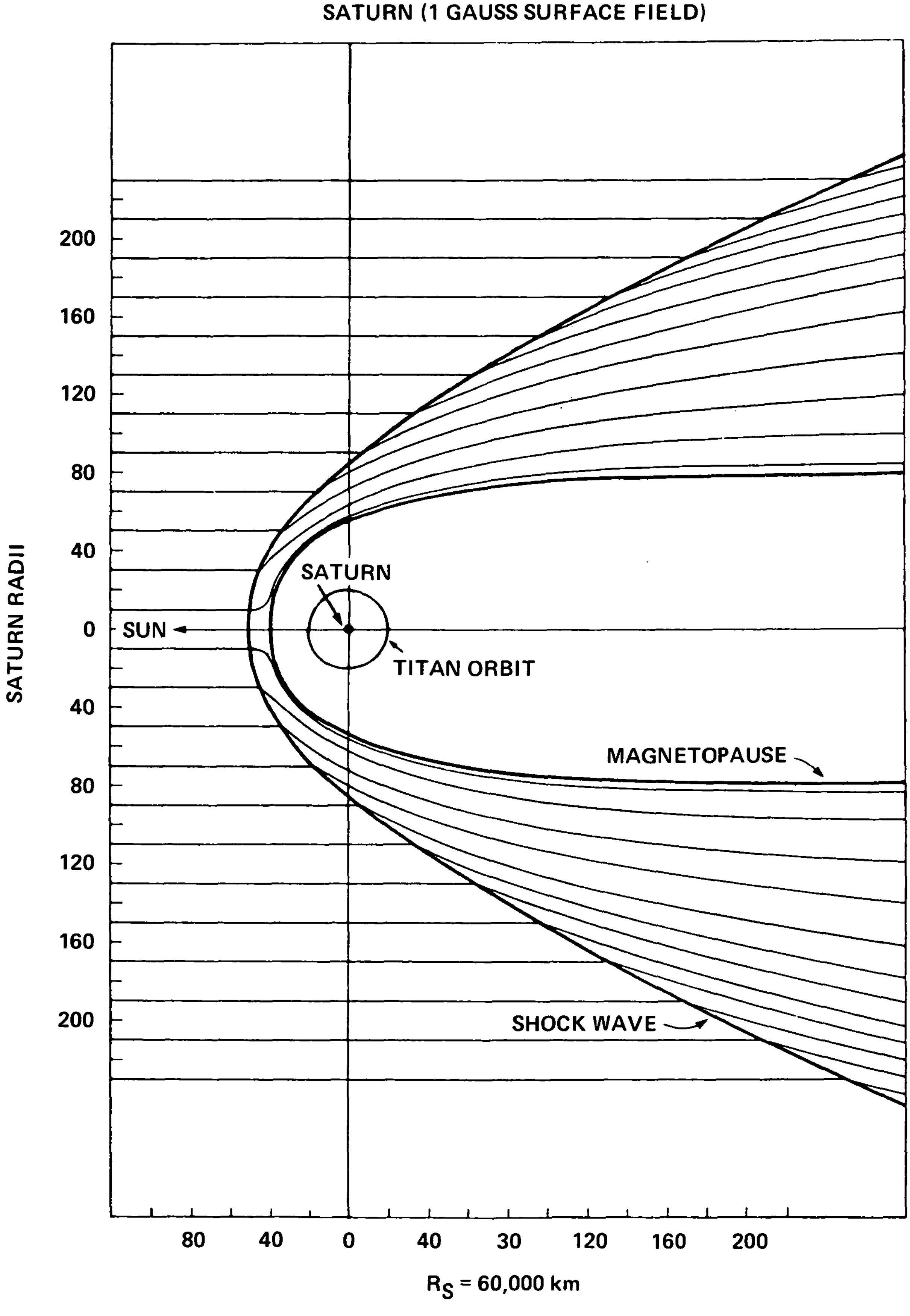
Radiation Belts -- Find the densities and energies of electrons and protons and other ions along the trajectory of the spacecraft through the Saturn system. Find any radiation belts in Saturn's magnetosphere. Find mini-belts between Saturn's rings and use them to determine belt-origin and particle acceleration processes. Study the character of the rings, as shown by passages of high-energy particles through them.

Upper Atmosphere and Ionosphere -- Determine structure, pressure, temperature, density, altitudes and some composition information on the upper atmosphere and ionosphere. Detect clouds, hazes and mixing rate in the upper atmosphere.

Saturn's Interior -- Map Saturn's gravity field to an accuracy of 70 parts per million and hence find its global shape. This will allow estimates of the size of Saturn's rocky core and determination of the presence of liquid metallic hydrogen in the deep interior. Finding of a magnetic field would further confirm the presence of metallic hydrogen. Gravity measurements combined with heat data also will allow calculation of the planet's temperature and density profile from surface to core.

Planetary Heat Balance -- Measure the effective temperature of Saturn's total disc, and from it determine the strength of Saturn's internal heat source by subtracting reflected solar heat from total heat radiated by the planet.

PROPOSED SATURN MAGNETOSPHERE



Rings -- Determine individual masses of both the A ring and B ring (the outer two rings) to find whether ring material is primarily water ice or metals. (Other compositions appear to have been largely eliminated.) Study distribution, structure and character of material in all of the rings by photometry, polarimetry, two-channel ultraviolet and observation of energetic particle paths. Determine existence of the proposed E ring and density of material it contains, to find safe trajectories for Voyager and other spacecraft through this region. Use above observations and the ring-plane passage of Pioneer itself for this finding. Measure temperatures of the rings.

Satellites -- Make photopolarimetry measurements of Iapetus, Dione, Tethys, Rhea and Titan and make two-channel ultraviolet observations of Titan, Hyperion, Rhea, Dione, Tethys and Enceladus to determine their surface characteristics. Make first determination of mass and density of Rhea and Titan. Improve data on satellite orbits.

Titan -- Characterize Titan's atmosphere. Determine opacity and nature and layering of aerosols in its atmosphere. Look for greenhouse effect in atmosphere. Determine Titan's temperature and heat balance. Look for doughnut-shaped hydrogen region around Titan's orbit and for its magnetic wake. Improve measurements of Titan's mass to an accuracy of .3 per cent and confirm current estimates of its density. Refine Titan orbit measurements. Make two-color images and two-channel ultraviolet observations of Titan.

Saturn System -- Improve precision and confidence in determination of the total mass of the Saturn system and of Saturn's orbit. Use this to determine dynamics of the solar system and for checks on relativity theory.

Saturn's Atmosphere -- Make a rough measurement of Saturn's hydrogen-helium ratio by infrared and ultraviolet observations. Make atmosphere composition calculations from radio occultation and photopolarimetry measurements. Determine atmosphere structure and layering and make observations of flow characteristics, rates of flow, vertical structure of belts and zones and polar regions by imaging and photopolarimetry.

Atmospheric Heat -- Map the temperature structure of Saturn's atmosphere by infrared and radio occultation measurements providing a vertical profile. Horizontally, look for hot and cold spots and belt and zone temperature differences.

Imaging -- Make 50 two-color close-up pictures of Saturn, its rings and cloud features, as well as two such pictures of Titan.

THE EXPERIMENTS

Instruments aboard Pioneer Saturn return data in the following broad categories:

Magnetic Fields

Magnetometer (Jet Propulsion Laboratory): This instrument will measure Saturn's magnetic field and magnetosphere, as well as the interplanetary magnetic field in three axes out to the limits of spacecraft communication.

The instrument is a helium vector magnetometer. Its sensor is mounted on the lightweight mast extending 6.5 m (21.5 ft.) from the center of the spacecraft to minimize interference from spacecraft magnetic fields.

The instrument operates in any one of eight different ranges, the lowest covering magnetic fields up to +4 gamma; the highest, fields up to 140,000 gamma. Earth's surface field is 50,000 gamma. These ranges are selected by ground command or automatically by the instrument itself. The magnetometer can measure fields as weak as 0.01 gamma.

Its sensor is a cell filled with helium, excited by radio frequencies and infrared optical pumping. Changes in the helium caused by fields the spacecraft passes through are measured. It weighs 2.6 kg (5.7 lb.) and uses up to 5 watts of power.

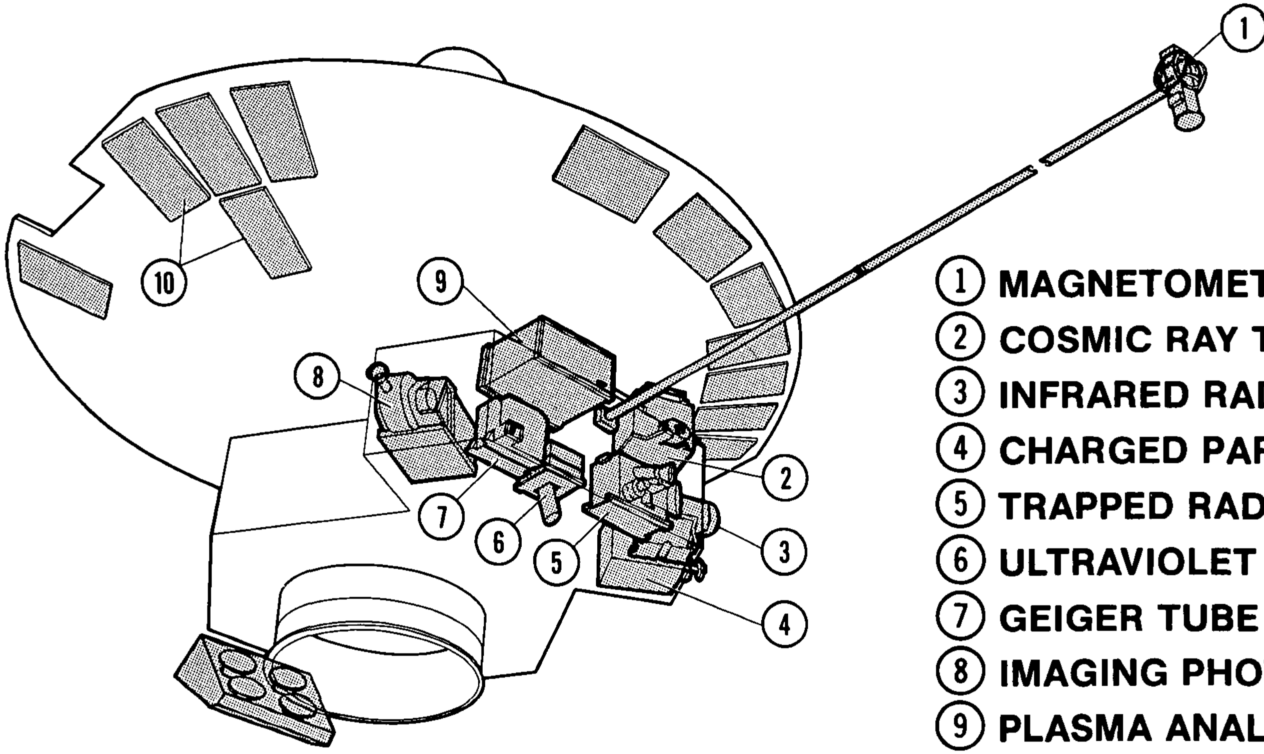
Fluxgate Magnetometer (Goddard Space Flight Center): This instrument is designed to measure the strength of intense planetary fields up to one million gamma in each of three perpendicular directions.

The instrument consists of two dual-axis sensors and their electronics. Each sensor is composed of a ring core, magnetic multivibrator, a frequency doubler and two phase-sensitive detectors. The instrument weighs .27 kg (.6 lb.) and uses approximately .36 watts of power.

Interplanetary Solar Wind, Bow Shock Wave and Magnetosphere

Plasma Analyzer (Ames Research Center): The plasma instrument maps the density and energy of the solar wind (ions and electrons flowing out from the Sun) and will look for their interactions with Saturn's magnetosphere.

PIONEER SATURN EXPERIMENTS



1. MAGNETOMETER SENSOR
2. COSMIC RAY TELESCOPE
3. INFRARED RADIOMETER
4. CHARGED PARTICLE INSTRUMENT
5. TRAPPED RADIATION DETECTOR
6. ULTRAVIOLET PHOTOMETER
7. GEIGER TUBE TELESCOPE
8. IMAGING PHOTOPOLARIMETER
9. PLASMA ANALYZER
10. METEOROID DETECTOR SENSOR PANELS

The instrument consists of a high resolution and medium resolution analyzer. It looks toward the Sun through an opening in the spacecraft dish antenna, and the solar wind enters like the electron beam in a TV tube. The instrument measures direction of travel, energy (speed) and numbers of ions and electrons.

The particles enter between curved metal plates and strike detectors, which count their numbers. Their energy is found by the fact that when a voltage is applied across the plates in one of 64 steps, only particles in that energy range can enter. Direction of particle travel is found from orientation of the instrument and which detector the particle struck.

In the high resolution analyzer, the detectors are 26 continuous-channel multipliers, which measure the ion flux in energy ranges from 100 to 8,000 electron volts. Detectors in the medium resolution detector are five electrometers, which measure ions in ranges from 100 to 18,000 electron volts and electrons from one to 500 electron volts.

The plasma analyzer weighs 5.5 kg (12.1 lb.) and uses 4 watts of power.

Radiation Belts and Cosmic Rays

Charged Particle Composition Instrument (University of Chicago): This instrument has a family of four measuring systems. Two are particle telescopes primarily for interplanetary space. The other two measure trapped electrons and protons in planetary radiation belts, such as those proposed for Saturn.

During interplanetary flight two telescopes identify the nuclei of all eight chemical elements from hydrogen to oxygen and separate the isotopes deuterium, helium-3 and helium-4. Because of their differences in isotopic and chemical composition and spectra, galactic particles can be separated from solar particles. The instrument also measures the manner in which streams of high energy particles travel through interplanetary space. There is a main telescope of seven solid-state detectors which measure from 1 to 500 million electron volt particles and a three-element telescope which measures 0.4 to 10 million electron volt protons and helium nuclei. If a key detector element is destroyed in space, diagnostic procedures and commands from Earth can bypass it.

For magnetospheres such as that proposed for Saturn, two new types of sensors were developed to cope with extremely high intensities of trapped radiation.

A solid-state electron current detector operating below -40 degrees Celsius (-40 degrees Fahrenheit) measures electrons. The trapped proton detector contains a foil of thorium which undergoes nuclear fission from protons above 30 million electron volts, but is not sensitive to electron radiation. The instrument weighs 3 kg (7.3 lb.) and uses 2.2 watts of power.

Cosmic Ray Telescope (Goddard Space Flight Center): The Cosmic Ray Telescope monitors solar and galactic cosmic ray particles. It tracks the twisting paths of high energy particles from the Sun and measures bending effects of the solar magnetic field on particles from the galaxy. The instrument distinguishes which of the 10 lightest elements make up these particles. It will look for such particles in Saturn's proposed radiation belts.

The instrument consists of three three-element, solid-state telescopes. A high energy telescope measures the flux or protons between 56 and 800 million electron volts. A medium energy telescope measures protons with energies between 3 to 22 million electron volts, and identifies the eight elements from helium to oxygen. The low energy telescope studies the flux of electrons between 50,000 electron volts and 1 million electron volts and protons between 50,000 electron volts and 20 million electron volts.

The instrument weighs 3.2 kg (7 lb.) and uses 2.2 watts of power.

Geiger Tube Telescopes (University of Iowa): This instrument will measure Saturn's proposed radiation belts. The instrument employs seven Geiger-Muller tubes to survey the intensities, energy spectra and angular distributions of electrons and protons along Pioneer's flight path by Saturn.

The tubes are small cylinders containing gas that generates electrical signals from charged particles.

Three tubes (considered a telescope) are parallel. Three others are in a triangular array to measure the number of multiparticle events (showers) which occur. The combination of a telescope and shower detector will enable experimenters to compare primary with secondary events in Saturn's proposed radiation belts.

Another telescope detects low energy electrons (those above 40,000 electron volts). The instrument can count protons with energies above 5 million electron volts and electrons with energies greater than 50,000 electron volts.

The instrument weighs 1.6 kg (3.6 lb.) and uses 0.7 watts of power.

-more-

Trapped Radiation Detector (University of California at San Diego): The nature of particles believed trapped by Saturn, particle species, angular distributions and intensities is determined by this instrument. It measures a very broad range of energies from 0.01 to 100 million electron volts for electrons and from 0.15 to 350 million electron volts for protons (Hydrogen nuclei).

The instrument has five detectors to cover the planned energy range. An unfocused Cerenkov counter, which measures direction of particle travel by light emitted in a particular direction, detects electrons of energy above 1 million electron volts and protons above 450 million electron volts. A second detector measures electrons at 100,000 electron volts, 200,000 electron volts and 400,000 electron volts.

An onmi-directional counter is a solid-state diode, which discriminates between minimum ionizing particles at 400,000 electron volts and high energy protons at 1.8 million electron volts.

Twin direct current scintillation detectors for low energy particles distinguish roughly between protons and electrons because of different scintillation material in each. Their energy thresholds are about 10,000 electron volts for electrons and 150,000 electron volts for protons.

The instrument weighs 1.7 kg (3.9 lb.) and uses 2.9 watts of power.

Dust, Meteoroids and Interplanetary Dust

Asteroid-Meteoroid Detector (General Electric Co.): This instrument was disabled in Jupiter's intense radiation belts.

Meteoroid Detector (Langley Research Center): To detect the distribution of particles (with masses of about 100 millionth of a gram or greater), scientists use a system of 234 pressure cells mounted on the back of the spacecraft dish antenna. The pressure cells come in 30 x 30 cm (12 x 12 in.) panels, 18 to a panel, with six panels. They have a total area of about one-quarter of a square meter, or one square yard.

Each pressure cell is filled with a gas mixture of argon and nitrogen. When a particle penetrates a cell it empties of gas. A transducer notes this, counting one particle impact per cell. Cell walls are 0.001-inch stainless-steel sheet, thin enough to allow penetration of particles with a mass of about 100-millionth of a gram or more.

The total weight of the instrument (panels and electronics) is 1.7 kg (3.7 lb.) and it uses 0.7 watts of power.

CELESTIAL MECHANICS

Celestial Mechanics (Jet Propulsion Laboratory): This experiment uses the spacecraft as an instrument to determine the mass of Saturn and its satellites by measuring their effects on its trajectory.

Doppler tracking determines spacecraft velocity along the Earth-spacecraft line down to a fraction of a millimeter per second, once per minute. These data are further augmented by optical and radar position measurements of the planets. Computer calculations using the spacecraft trajectory and known planet and satellite orbital characteristics will provide findings on: Saturn's mass, the masses of two of its moons, the rings, the planet's polar flattening and mass of its surface layers and deep interior.

Atmosphere, Temperature, Moon, Interplanetary Hydrogen, Helium and Dust

Ultraviolet Photometer (University of Southern California): During flyby, the ultraviolet photometer will measure scattering of ultraviolet light from the Sun by Saturn, Titan, other moons and the rings in two wavelengths, one for hydrogen and one for helium. It will look for other properties.

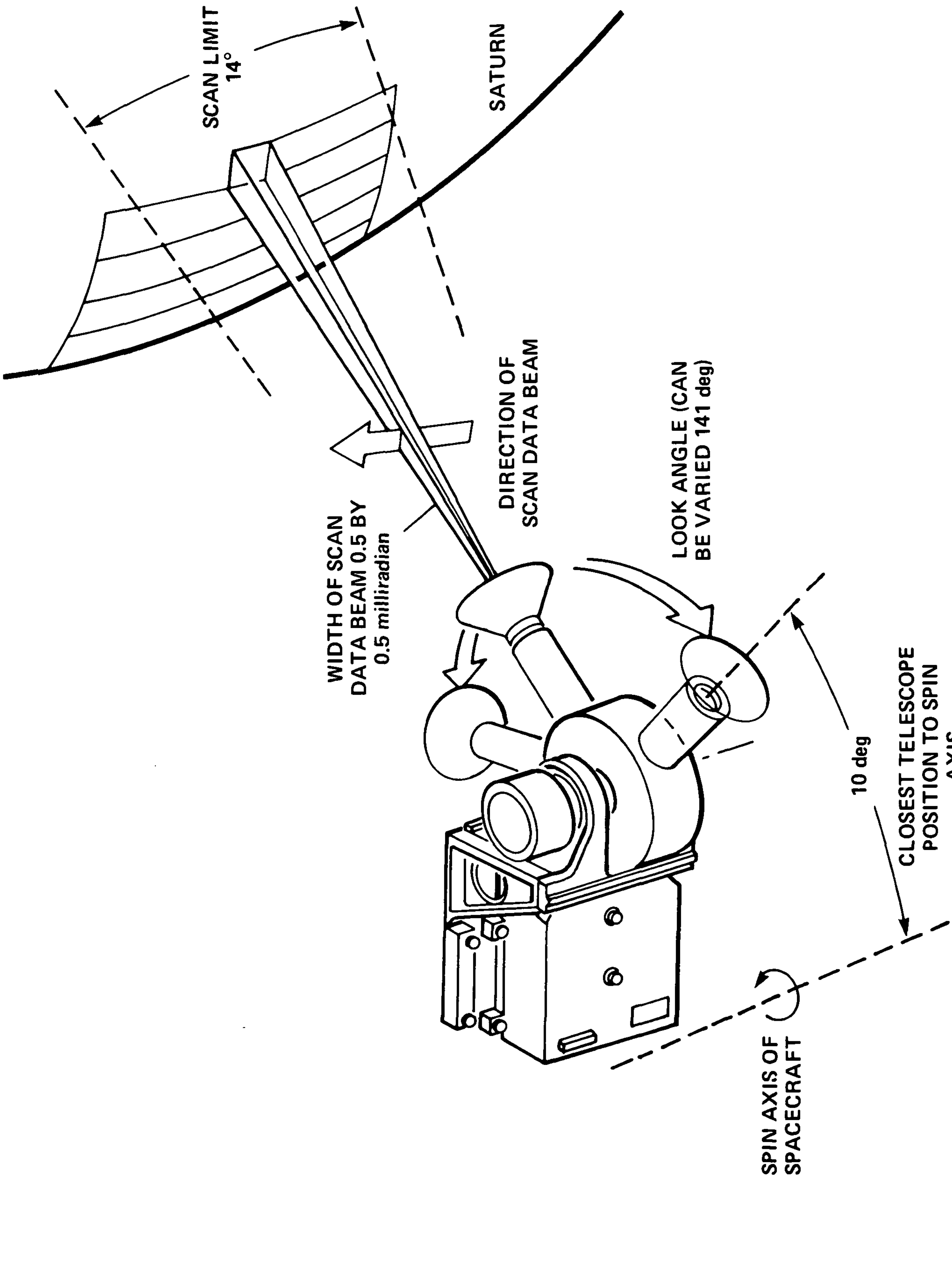
Radiotelescope measurements show that the solar system is immersed in an interstellar gas of cold neutral hydrogen. By measuring the scattering of the Sun's ultraviolet light the instrument can measure amounts of this neutral hydrogen within the heliosphere.

The instrument has two detectors, one which measures ultraviolet radiation at 1216 angstroms, the other at 584 angstroms -- the wavelengths at which hydrogen and helium scatter solar ultraviolet.

The instrument has a fixed viewing angle and will use the spacecraft spin to scan the planet. It weighs 0.7 kg (1.5 lb.) and uses 0.7 watts of power.

Pictures, Atmospheres and Moon Surfaces

Imaging Photopolarimeter (University of Arizona): This instrument provides data in a number of areas using photometry (measurement of light intensity) and polarimetry (photometry measurements of the linear polarization of light) and imaging.


SCAN LIMIT
14°
SATURN
DIRECTION OF
SCAN DATA BEAM
LOOK ANGLE (CAN
BE VARIED 141 deg)
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DATA BEAM 0.5 BY
0.5 milliradian
10 deg
CLOSEST TELESCOPE
POSITION TO SPIN
AXIS
SPIN AXIS OF
SPACECRAFT

The instrument will take pictures of Saturn, its rings and Titan, as the spacecraft passes the planet.

Images will be made in both red and blue light, and these will be superimposed, providing "color pictures" using red and blue data plus amounts of green based on Earth telescope pictures.

The instrument uses a photoelectric sensor which measures changes in light intensity, something like the light sensor for a television camera. But unlike a TV camera it will employ the 5 rpm spin of the spacecraft to scan the planet, in narrow strips 0.03 degrees wide.

This electronic imaging system will complete the scans for a picture in from 25 to 110 minutes, depending on distance from the planet. Scan data are converted to digital form on the spacecraft and radioed to Earth by telemetry. Engineers then will build up the images, using various computer techniques.

Controllers can vary the viewing angle of the instrument's 8.64-cm (3.4-in.) focal length telescope by about 160 degrees relative to the spacecraft's spin axis, which is fixed on the Earth-spacecraft line. The telescope can see to within 10 degrees of the spin axis, looking away from the Earth.

Picture reconstruction is complicated by the fact that picture scans will be curved as the telescope rotates with the spacecraft, while looking out at various angles to the spin axis. The only straight-line scans will be those looking straight out from the spin axis.

This factor means that computers will have to sort out scan paths whose curvature changes steadily with spacecraft movement. They will also have to compensate for smear caused by rotation of the planet and motion of the spacecraft.

During flight under the rings, the spacecraft will take no pictures due to a 20 to one "underlap" of picture scans.

During Saturn flyby, experimenters also will use the instrument to study Saturn's clouds, and to determine the nature of atmospheric gas above the clouds, and of aerosols in this gas as well as various other atmosphere properties. The instrument will measure light scattering of the Saturn satellites, to find their surface properties and atmospheres. It will make similar measurements of the rings.

The instrument includes a 2.5-cm (1-in.) aperture, 8.6-cm (3.4-in.) focal length telescope which can be moved 160 degrees in the plane of the spacecraft spin axis by ground command or automatically. Incoming light is split by a prism according to polarization into two separate beams. Each beam is further split by going through a red filter (5,940-7,200 angstroms), and through a blue filter (3,900-5,000 angstroms). Channeltron detectors turn the light into electrical impulses, which are telemetered to Earth.

The instrument uses three viewing apertures: one 40 x 40 milliradians for zodiacal light measurements, a second 8 x 8 milliradians for non-imaging light measurements and a third 0.5 x 0.5 milliradians for scans of the planet from which pictures will be reconstructed.

The instrument weighs 4.3 kg (9.5 lb.) and uses 2.2 watts of power.

Atmosphere, Ionosphere, Temperature

Infrared Radiometer (California Institute of Technology): Experimenters will measure the net heat energy emitted by Saturn and Titan, as well as vertical and horizontal temperature measurements in Saturn's atmosphere and a rough measurement of the atmosphere's hydrogen-helium ratio.

The two-channel radiometer will make measurements in the 14-25 and 29-56 micron wavelength regions to study the net heat energy flux, its distribution and the thermal structure and chemical composition of Saturn's atmosphere.

The radiometer uses a fixed telescope, so that its scans of the planet are made by rotation of the spacecraft. The instrument will view the planet during the two and a half hours just before closest approach.

The instrument has a 7.2-cm (3-in.) diameter Cassegrain telescope, and the detectors in its two channels are 88-element: thin film, bimetallic thermopiles.

The instrument weighs 2 kg (4.4 lb.) and uses 1.3 watts of power.

Occultation Experiment (Jet Propulsion Laboratory): The passage of spacecraft radio signals through Saturn's atmosphere and ionosphere as Pioneer swings behind the planet will be used to measure temperature, density and other characteristics of Saturn's ionosphere and Saturn's atmosphere down to a pressure level of about one Earth atmosphere.

Experimenters will use computer analysis of the incoming radio signals recorded on tape to determine the refractive index profile of Saturn's atmosphere.

ENCOUNTER OPERATIONS

During encounter operations, the many functions on the spacecraft will be monitored in several ways. Pioneer returns complete engineering data on its subsystems every 48 seconds. This is scanned by computer. With uncommanded changes, or functions beyond normal limits, the computer presents alarm signals on controllers' data displays. In addition, analysts will review spacecraft data every 10 minutes.

Pioneer control and spacecraft operations are at the Pioneer Mission Operations Center, NASA Ames Research Center, Mountain View, Calif. The operations center has computing capability both for commanding the spacecraft and to interpret the data stream as it comes in from the Deep Space Network stations.

Several Ames organizations direct and support the encounter.

The Pioneer Mission Operations Team consists of personnel from many government and contractor organizations and operates under control of the flight director. In addition to several assistant flight directors, the operations team includes the following groups:

- The spacecraft Performance Analysis Team analyzes and evaluates spacecraft performance and predicts spacecraft responses to commands.

- The Navigation and Maneuvers Team handles spacecraft navigation and attitude control.

- The Science Analysis Team determines the status of the on-board scientific instruments and formulates command sequences for the instruments.

TRACKING AND DATA RETRIEVAL

With facilities located at 120 degree intervals around the Earth, NASA's Deep Space Network will support Pioneer continuously during encounter. As the spacecraft "sets" at one station, due to the Earth's rotation, it will "rise" at the next one.

The network maintains three highly sensitive 64-m (210-ft.) dish antennas at Goldstone, Calif.; Madrid, Spain; and Canberra, Australia. As a backup, it has six 26-m (85-ft.) dish antenna stations at Madrid (Robledo de Chavela and Cebreros), Canberra and two stations at Goldstone.

The 26-m (85-ft.) stations have enough power to command Pioneer at Saturn. Where necessary they can receive data, but at the extremely low rate of 128 bits per second, compared with the 1,024 bits-per-second rate of the 64-m (210-ft.) antennas.

At periapsis, there will be a four-hour overlap between the Goldstone and Canberra 64-m (210-ft.) stations, with both receiving this vital data. However, Goldstone loses the spacecraft about one hour after closest approach. Canberra will handle the last part of periapsis operations. This will mean long-distance communications from Australia to Pioneer Control at Ames.

As Pioneer is drawn in by Saturn's gravity, increases in speed will cause the Doppler shift to grow very large. This will require "ramping" operations at tracking stations, complicated by communications cut-off when Pioneer passes behind the planet. Also, at Saturn, round-trip communications time will be almost three hours.

All stations have general-purpose telemetry equipment capable of receiving, data-synchronizing, decoding and processing data at high transmission rates.

The tracking and data acquisition network is tied to the Jet Propulsion Laboratory's Mission Control and Computing Center at Pasadena, Calif., by NASA's Communications Network.

The Deep Space Network provides tracking information on course and direction of the flight, velocity and range from Earth. It also receives engineering and science telemetry, including planetary television coverage, and sends commands for spacecraft operations. All communications links are in the S-band frequency.

The stations relay spacecraft Doppler tracking information to the control center, where computers calculate orbits in support of navigation and planetary target planning. High-speed data links from all stations are capable of 7,200 bits per second, permitting real-time transmission of all data from spacecraft to Pioneer control centers at Ames or JPL.

All networks are under the direction of the Office of Space Tracking and Data Systems, NASA Headquarters, Washington, D.C. The Jet Propulsion Laboratory manages the Deep Space Network, while the Goddard Space Flight Center, Greenbelt, Md., manages all the others.

The Goldstone stations are operated and maintained by the Jet Propulsion Laboratory with the assistance of Bendix Field Engineering. The Canberra station is operated by the Australian Department of Supply. The two facilities near Madrid are operated by the Spanish government's Instituto Nacional de Tecnica Aerospacial.

THE SPACECRAFT

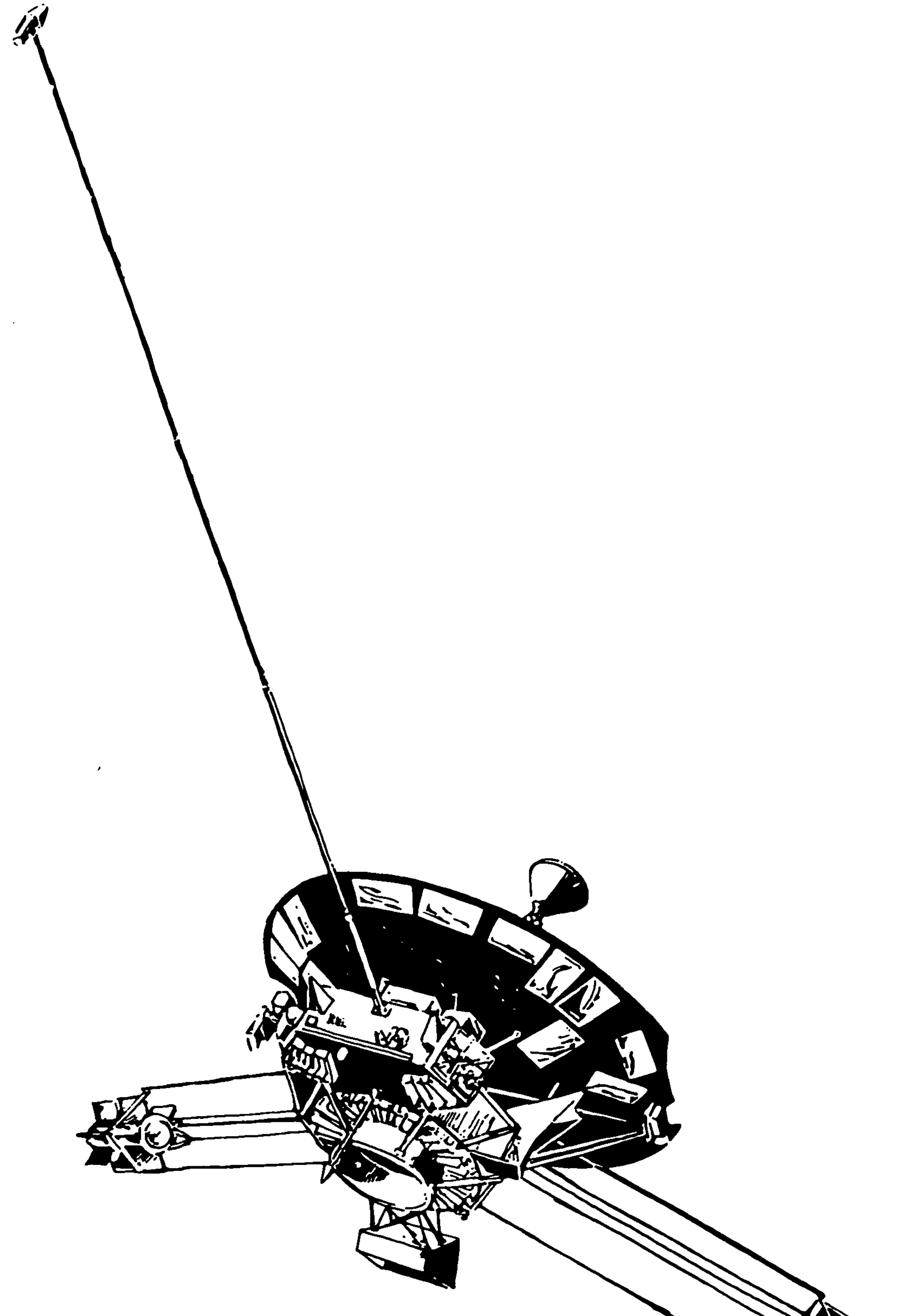
Pioneer 11 and Pioneer 10 are the first spacecraft designed to travel into the outer solar system and operate there for many years. They must have extreme reliability, have communications systems for distances of billions of miles, and employ non-solar power sources. Designers chose spin stabilization for its simplicity and effectiveness.

Launch energy requirements to the outer planets are far greater than for short missions, so the spacecraft is very light. Pioneer Saturn weighed only 270 kg (570 lb.) at launch. This included 30 kg (65 lb.) of scientific instruments.

For reliability, spacecraft builders have employed an intensive screening and testing program for parts and materials. They have selected components designed to withstand radiation from the spacecraft's nuclear power source and from planetary radiation belts. In addition, key systems are redundant. (That is, two of the same components or subsystems are provided in case one fails.) Communications, command and data return systems, propulsion electronics, thrusters and attitude sensors are largely redundant.

The Earth-facing dish antenna is in effect the forward end of the spacecraft. Pioneer Saturn is 2.9-m (9.5 ft.) long, measuring from its farthest forward component, the medium-gain antenna horn, to its farthest rearward point, the tip of the aft-facing omnidirectional antenna. Exclusive of booms, its widest crosswise dimension is the 2.7-m (9-ft.) diameter of the dish antenna.

The axis of spacecraft rotation and the centerline of the dish antenna are parallel, and Pioneer spins constantly for stability.



PIONEER SATURN

The spacecraft equipment compartment is a hexagonal box, roughly 35.5 cm (14 in.) deep. Each of its six sides is 71 cm (28 in.) long. One side joins to a smaller box also 35.5 cm (14 in.) deep, whose top and bottom are irregular hexagons.

This smaller compartment contains most the 12 onboard scientific experiments. However, 12.7 kg (28 lb.) of the 30 kg (65 lb.) of scientific instruments (the plasma analyzer, cosmic ray telescope, four asteroid-meteoroid telescopes, meteoroid sensors and the magnetometer sensors) are mounted outside the instrument compartment. The other experiments have openings for their sensors. Together both compartments provide 1.4 square m (16 square ft.) of platform area.

Attached to the hexagonal front face of the equipment compartment is the 2.7-m (9-ft.) diameter 46-cm (18-in.) deep dish antenna.

The high-gain antenna feed and the medium-gain antenna horn are mounted at the focal point of the antenna dish on three struts projecting about 1.2 m (4 ft.) forward of the rim of the dish. The low-gain, omnidirectional spiral antenna extends about .76 m (2.5 ft.) behind the equipment compartment.

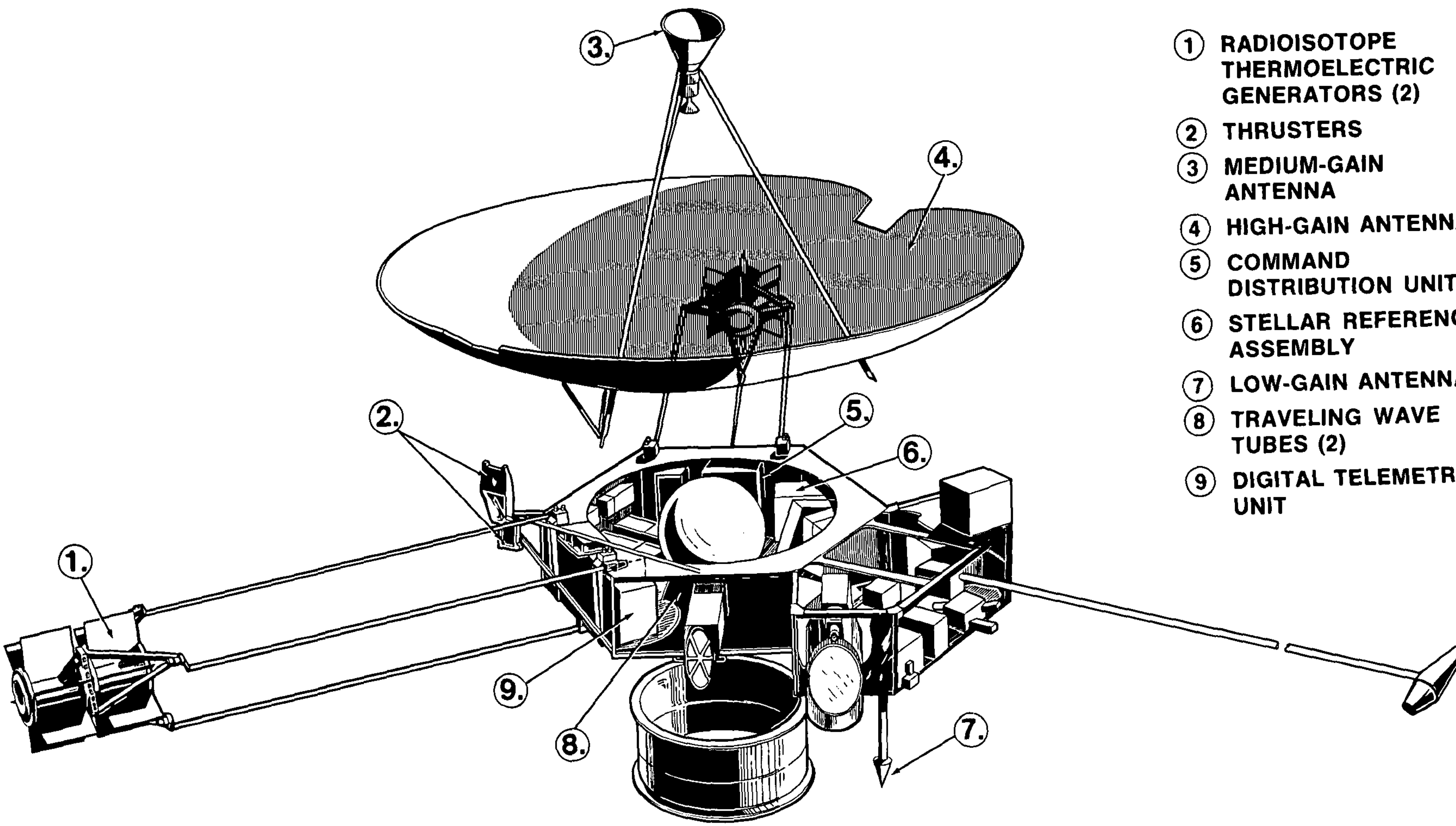
Two three-rod trusses, 120 degrees apart, project from two sides of the equipment compartment, supporting the spacecraft's nuclear electric power generators about 3 m (10 ft.) from the center of the spacecraft. A boom, 120 degrees from each of the two trusses, projects from the experiment compartment and positions the helium vector magnetometer sensor 6.6 m (21.5 ft.) from the spacecraft center. The booms are extended after launch.

At the rim of the antenna dish, two Sun sensors are mounted. A star sensor looks through an opening in the equipment compartment and is protected from sunlight by a hood.

Both compartments have aluminum frames with bottoms and side walls of aluminum honeycomb. The dish antenna is made of aluminum honeycomb.

Rigid external tubular trusswork supports the dish antenna, three pairs of thrusters located near the rim of the dish, radioisotope thermoelectric generator trusses and launch vehicle attachment ring. The message plaque also is attached to this trusswork.

PIONEER SATURN MAJOR SUBSYSTEMS



1. RADIOISOTOPE THERMOELECTRIC GENERATORS (2)
2. THRUSTERS
3. MEDIUM-GAIN ANTENNA
4. HIGH-GAIN ANTENNA
5. COMMAND DISTRIBUTION UNIT
6. STELLAR REFERENCE ASSEMBLY
7. LOW-GAIN ANTENNA
8. TRAVELING WAVE TUBES (2)
9. DIGITAL TELEMETRY UNIT

THE HELIOSPHERE

On its trip to Saturn from Jupiter, Pioneer 11 explored intensively a new segment of the heliosphere (the atmosphere of the Sun). The spacecraft has surveyed a region of space 870 million km (540 million mi.) wide between the outer edge of the Asteroid Belt and the orbit of Saturn.

Pioneer also studied this region at points up to 15.6 degrees (160 million km) above the ecliptic (Earth's orbit plane), far higher than measurements previously have been made. Major result of this flight was discovery of the basic dipole structure of the Sun's magnetic field.

After leaving Saturn, Pioneer will study the outer heliosphere until spacecraft communication ceases perhaps around 1990, near the orbit of Neptune.

The thinly diffused solar atmosphere is hundreds of times less dense than the best vacuums on Earth. Yet it is important because it contains:

- The ionized gas known as the solar wind, roughly a 50-50 mixture of protons (hydrogen nuclei) and electrons. It flows out from the 3,600,000 degrees F (2,000,000 degrees C) corona of the Sun in all directions at average speeds of 1.6 million km/hr (one million mph).

- Complex magnetic and electric fields, carried out from the Sun by the solar wind.

- Solar cosmic rays, high energy particles thrown out by the huge explosions on the Sun's surface at up to 480 million km/hr (300 million mph).

The heliosphere also encompasses comets and dust. It is traversed by electro-magnetic radiation from the Sun: radio waves, infrared, ultraviolet, and visible light.

The heliosphere further contains cosmic ray particles from within and beyond our galaxy, traveling at nearly the speed of light. This means enormous particle energies, up to 10^{14} million electron volts. (10^{14} is 1 followed by 14 zeros.) There are also neutral hydrogen atoms from the interstellar gas which formed the Sun and planets.

Study of these phenomena has many applications. Storms of solar particles striking Earth interrupt radio communications and sometimes electric power transmission.

There is evidence that solar storm particles travel through the heliosphere and trigger the Earth's long-term weather cycles.

The heliosphere can be thought of as a huge laboratory where phenomena occur that cannot be simulated on Earth. For example, man cannot accelerate particles in Earth laboratories to the near-light speeds reached by galactic cosmic ray particles. These particles are observed by Pioneer instruments.

Solar Wind, Magnetic Field, and Solar Cosmic Rays

Near the Earth, the speed of the solar wind varies from one to three million km/hr (600,000 to 2,000,000 mph), depending on activity of the Sun. Its temperature varies from 10,000 to 1,000,000 degrees C (18,000 to 1,800,000 degrees F). The wind also fluctuates due to features of the rotating solar corona, where it originates, and because of various wave phenomena.

The fastest solar cosmic ray particles jet out from the Sun in streams which can cover the 150 million km (93 million mi.) to Earth in as little as 20 minutes. Slower particle streams take one or more hours to reach Earth.

The positive ions from the Sun are 90 per cent protons and 10 per cent helium nuclei, with occasional nuclei of heavier elements.

There are from none to hundreds of flare events on the Sun each year which produce high energy solar particles, with the largest number of flares at the peak of the 11-year cycle.

The best resolution yet seen of elements making up the solar high energy particles has been obtained by Pioneer 10 from the August 1972 solar flare. It identified sodium and aluminum for the first time, determined relative abundances of helium, carbon, nitrogen, oxygen, fluorine, neon, sodium, magnesium, aluminum, and silicon nuclei coming from the Sun.

The solar wind, as viewed near the Earth's orbit, is most dramatically seen as containing high speed, up to 2,520,000 km/hr (1,566,000 mph) streams embedded in slower speed, 1,000,000 km/hr (624,000 mph) streams. These high-speed streams are presumably caused by high temperature regions in the solar corona.

Between the Earth and Jupiter these high-speed streams speed up the gas ahead of them and they in turn are slowed down, This accounts for the large amount of turbulence in the solar wind and magnetic field still observed as far out as 510 million km (420 million mi.). In addition, this stream interaction also produces thermal energy so that the solar wind does not cool as expected for a simple expansion model. Solar wind streams become much more regular beyond the orbit of Saturn.

The Interstellar Gas

Pioneer Saturn measures neutral helium and hydorgen. Both hydrogen and helium atoms are believed to be part of the interstellar gas which has forced its way into the heliosphere as the solar system moves through interstellar space at 72,000 km/hr (45,000 mph).

The Pioneer ultraviolet instruments have been able to locate concentrations of neutral hydrogen and helium and to make separations between gas originating in the Sun and that penetrating the solar system from interstellar space.

The experimenters have measured the ultraviolet light glow emitted by interplanetary neutral hydrogen and helium atoms. The interstellar neutral hydrogen appears to enter the heliosphere in the plane of the Earth's orbit at around 100,000 km/hr (62,000 mph). Surprisingly, this entry point is about 60 degrees away from the direction of travel of the solar system through interstellar space, and hence the direction from which these particles ought to come.

Galactic Cosmic Rays

Galactic cosmic ray particles usually have far higher energies (velocities) than solar cosmic rays. These particles may get their tremendous energies from the explosion of stars (supernovas), the collapse of stars (pulsars), or acceleration in the colliding magnetic fields of two stars. Pioneer studies of these particles may settle questions of their origin in our galaxy and important features of the origin and evolution of the galaxy itself. These studies should answer such questions as the chemical composition of stellar sources of cosmic ray particles in the galaxy.

Galactic cosmic rays consist of protons (hydrogen nuclei), 85 per cent; helium nuclei, 23 per cent; nuclei of other elements, 2 per cent; and high energy electrons, 1 per cent.

Because of the expected decrease in shielding by the solar wind and magnetic field, numbers of low energy cosmic ray particles (0 to 100 million electron volts) were expected to increase by Saturn distance. This did not occur, apparently because despite the decline of solar wind density and magnetic field strength, turbulence remained as high as near Earth. This turbulence shuts out a large part of the low energy galactic particles from the inner solar system, as far out as Saturn and beyond.

PIONEER EXPERIMENTERS

Magnetic Fields

Instrument:	Magnetometer
Principal Investigator:	Edward J. Smith Jet Propulsion Laboratory, Pasadena, Calif.
Co-Investigators:	Palmer Dyal David S. Colburn Ames Research Center, Mountain View, Calif. Charles Sonett University of Arizona, Tucson Douglas E. Jones Brigham Young University, Provo, Utah Paul J. Coleman, Jr. University of California at Los Angeles Leverett Davis, Jr. California Institute of Technology, Pasadena
Instrument:	Flux-Gate Magnetometer
Prinicpal Investigator:	Mario Acuna Goddard Space Flight Center Greenbelt, Md.
Co-Investigator:	Norman F. Ness Goddard Space Flight Center

Plasma Analyzer

Instrument:	Plasma Analyzer
Principal Investigator:	John H. Wolfe Ames Research Center

Co-Investigators: Louis A. Frank
University of Iowa, Iowa City

Reimer Lust
Max Planck Institute fur Physik
und Astrophysik
Institute fur Extraterrestrische Physik
Munchen, Germany

Devrie Intriligator
University of Southern California, L.A.

William C. Feldman
Los Alamos Scientific Laboratory, N.M.

Harold R. Collard
Ames Research Center

John D. Mihalov
Ames Research Center

Darrell D. McKibben
Ames Research Center

Charged Particle Composition

Instrument: Charged Particle Instrument

Principal Investigator: John A. Simpson
University of Chicago

Co-Investigators: Joseph J. O'Gallagher
University of Maryland, College Park

Anthony J. Tuzzolino
University of Chicago

Cosmic Ray Energy Spectra

Instrument: Cosmic Ray Telescope

Principal Investigator: Frank B. McDonald
Goddard Space Flight Center.

Co-Investigators: James H. Trainor
Bonnard J. Teegarden
Goddard Space Flight Center

William R. Webber
Edmond C. Roelof
University of New Hampshire, Durham

Charged Particles

Instrument:	Geiger Tube Telescope
Principal Investigator:	James A. Van Allen University of Iowa, Iowa City

Trapped Radiation

Instrument:	Trapped Radiation Detector
Principal Investigator:	R. Walker Fillius University of California at San Diego
Co-Investigator:	Carl E. McIlwain University of California at San Diego

Meteoroid Detection

Instrument:	Meteoroid Detector
Principal Investigator:	William H. Kinard Langley Research Center, Hampton, Va.
Co-Investigators:	Robert L. O'Neal Jose M. Alvarez Donald H. Humes Langley Research Center

Celestial Mechanics

Instrument:	Pioneer 11 and the Deep Space Network
Principal Investigator:	John D. Anderson Jet Propulsion Laboratory
Co-Investigators:	George W. Null Jet Propulsion Laboratory

Ultraviolet Photometry

Instrument:	Ultraviolet Photometer
Principal Investigator:	Darrell L. Judge University of Southern California, Los Angeles
Co-Investigator:	Robert W. Carlson University of Southern California

Imaging Photopolarimetry

Instrument:	Imaging Photopolarimeter
Principal Investigator:	Tom Gehrels University of Arizona, Tucson
Co-Investigators:	Martin Tomasko David L. Coffeen Charles Blenman, Jr. Charles E. KenKnight University of Arizona
	Robert F. Hummer Santa Barbara Research Center

Infrared Thermal Structure

Instrument:	Infrared Radiometer
Principal Investigator:	Andrew Ingersoll California Institute of Technology
Co-Investigators:	Gerry Neugebauer California Institute of Technology
	Stillman C. Chase Santa Barbara Research Center
	Laurence M. Trafton University of Texas, Austin

S-Band Occultation

Instrument:	Space Craft Radio Transmitter and the Deep Space Network

S-Band Occultation

Instrument:	Spacecraft Radio Transmitter and the Deep Space Network
Principal Investigator:	Arvydas J. Kliore Jet Propulsion Laboratory
Co-Investigators:	Gunnar Lindal Dan L. Cain Boris L. Seidel Jet Propulsion Laboratory
	S. Ichtiaque Rasool NASA Headquarters Washington, D.C.

THE ENCOUNTER TEAM

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Dr. Adrienne F. Timothy	Assistant Associate Administrator for Space Science
Angelo Guastaferro	Director, Planetary Programs
Fred D. Kochendorfer	Pioneer Program Manager
Dr. Albert G. Opp	Pioneer Program Scientist

Office of Space Tracking and Data Systems

Dr. William C. Schneider	Associate Administrator for Space Tracking and Data Systems
Charles A. Taylor	Director, Network Operations

Ames Research Center

Clarence A. Syvertson	Director
A. Thomas Young	Deputy Director
Dr. Dean Chapman	Director of Astronautics
Charles F. Hall	Pioneer Project Manager
Dr. John H. Wolfe	Pioneer Project Scientist
Robert P. Hogan	Chief, Flight Operations
Henry Asch	Reliability and Quality Assurance
John W. Dyer	Chief, Mission Analysis

NASA Jet Propulsion Laboratory

Dr. Bruce C. Murray	Director
W. P. Spaulding	Tracking and Data Systems Manager
Richard Miller	Pioneer Tracking and Data Systems Manager
Robert Ryan	Pioneer Project Support Team Manager
William E. Kirhofer	Navigation

Department of Energy

Advanced Nuclear Systems and Projects Division

David S. Gabriel	Director
Glenn A. Newby	Associate Director, Space Nuclear Systems Division
Harold Jaffe	Manager, Isotope Flight Systems Office

TRW Systems Group

Bernard J. O'Brien	Pioneer Project Manager

Bendix Field Engineering Corp.

Thomas F. Groves	Pioneer Program Manager
Pat Barclay	Deputy Pioneer Program Manager

PIONEER SATURN CONTRACTORS

EMR Telemetry Division Weston Instruments, Inc. Sarasota, Fla.	Telemetry Decommutation Display Equipment
Edcliff Instrument Division Systron Donner Monrovia, Calif.	Despin Sensor Assembly
Electronic Memories Division Electronic Memories and Magnetics Corp. Hawthorne, Calif.	Memory Storage Units
Jet Propulsion Laboratory Pasadena, Calif.	Helium Vector Magnetometer
Time Zero Corp. Torrance, Calif.	Plasma Analyzer and Magneto- meter Electronics
University of Chicago Chicago, Ill.	Charged Particle Instrument
University of Iowa Iowa City, Iowa	Geiger Tube Telescope
University of California at San Diego San Diego, Calif.	Trapped Radiation Detector
Analog Technology Corp. Pasadena, Calif.	Ultraviolet Photometry
Santa Barbara Research Center Santa Barbara, Calif.	Imaging Photopolarimeter and Infrared Radiometer
General Electric Co. Philadelphia, Pa.	Asteroid/Meteoroid Detector
Teledyne Isotopes Germantown, Md.	Radioisotope Thermoelectric Generators
Mound Laboratories Miamisburg, Ohio	Radioisotope Heater Unit Capsule, Fuel and Capsules
Los Alamos Scientific Laboratory Los Alamos, N.M.	Radioisotope Thermoelectric Generator Fuel Discs

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Bendix Field Engineering Corp. Columbia, Md.	Software
General Dynamics Convair Division San Diego, Calif.	Launch Vehicle - First and Second Stages
Thiokol Chemical Co. Elkton, Md.	Launch Vehicle - Third Stage Motor
McDonnell Douglas Corp. Astronautics Co. Huntington Beach, Calif.	Launch Vehicle - First Stage Motor
Rockwell International Rocketdyne Division Canoga Park, Calif.	Launch Vehicle - First Stage Motor
Pratt and Whitney Aircraft Co. East Hartford, Conn.	Launch Vehicle - Second Stage Motor
TRW Systems Group TRW, Inc. Redondo Beach, Calif.	Spacecraft
Frequency Electronics, Inc. New Hyde Park, N.Y.	Oscillator
United Detector Technology, Inc. Santa Monica, Calif.	Silicon Photo Detectors
Holex, Inc. Hollister, Calif.	Explosive Cartridge
Allen Design Burbank, Calif.	Propellant Valves
Electra Midland Corp. Cermatrik Division San Diego, Calif.	Current Limiters
Bendix Mosaic Fabrication Division Sturbridge, Mass.	Fiber Optics
Pressure Systems, Inc. Los Angeles, Calif.	Propellant Tanks
Xerox Data Systems El Segundo, Calif.	Computer Systems

Wavecom, Inc. Chatsworth, Calif.	Diplexer Assemblies
Teledyne Microwave Sunnyvale, Calif.	Radio Frequency Transfer Switch
Yardney Electric Corp. Pawcatuck, Conn.	Silver-Cadmium Battery Cells
Siliconix, Inc. Santa Clara, Calif.	Integrated Circuits
Amelco Semiconductor Mountain View, Calif.	Integrated Circuits
Wakins-Johnson Co. Palo Alto, Calif.	Traveling Wave Tube Amplifier
Texas Instruments Dallas, Texas	Integrated Circuits
Data Products Corp. Woodland Hills, Calif.	Automatic Data Processing Line Printer
Computer Communications, Inc. Inglewood, Calif.	Communication Stations
Honeywell, Inc. Radiation Center Lexington, Mass.	Sun Sensor Assemblies

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