NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
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PRESS KIT

PROJECT: PIONEER 11 JUPITER ENCOUNTER

contents

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Washington, D. C. 20546
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FOR RELEASE:

10 a.m. Tuesday, November 19

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PIONEER ENCOUNTERS JUPITER DEC. 3

Man's second spacecraft to Jupiter will reach the giant planet early on December 3, after a billion-kilometer (620-million-mile) journey that has taken nearly two years.

Hurtling through intense radiation never before encountered, Pioneer 11 will skim Jupiter at a distance of 41,000 kilometers (26,600 miles)--three times closer than its predecessor, Pioneer 10.

Closest approach will be at 12:22 a.m. EST.

- more -

November 4, 1974

The 260-kilogram (570-pound) robot from Earth will sweep over the face of Jupiter at more than 171,000 kilometers (107,000 miles) an hour--the highest speed ever achieved by a manmade object.

Then, if Pioneer survives the radiation, it will boomerang across the solar system and head for a rendezvous with Saturn and its mysterious rings in 1979.

Pioneer 11 will be the first to use the gravity of one outer planet (Jupiter) to fly on to the next outer planet (Saturn), an essential maneuver for continued exploration of the outer solar system.

Because Pioneer will zoom in toward Jupiter from below, color photographs of the planet will show never-before-seen polar regions--providing an entirely different look at the colossus of the planets.

The close polar pass also will permit the first scientific measurements in high polar latitudes of both the planet and its outer environment. And it will allow the first deep probe of the inner radiation belt which girdles the planet like a doughnut.

Since radiation increases rapidly with nearness to the planet, Pioneer's close trajectory will hurl it through the most intense sector of Jupiter's inner belt. Radiation levels may be ten times those encountered by Pioneer 10, and 40,000 times greater than Earth's belts--easily enough to destroy a spacecraft.

However, Pioneer 11 will be moving so rapidly that no serious damage is anticipated. The sister craft, Pioneer 10, experienced minor malfunctions on its longer pass through the weaker outer part of the belt last December.

Controllers have aimed in Pioneer 11 far below Jupiter's south pole. There the planet's immense gravity will suck the spacecraft almost straight up, passing it quickly through the thin disc of maximum radiation in about half an hour at a very high angle and at record speed. Pioneer then will loop around behind the planet and depart--still heading upward--above Jupiter's north pole.

The "corkscrew" maneuver is required to send the spacecraft to Saturn, and also to help cut down exposure in the equatorial region, the deadliest part of Jupiter's radiation zone.

The trajectory will also take the spacecraft around the planet against Jupiter's direction of rotation--permitting for the first time a look at a complete revolution of the planet's magnetic field, radiation belt and surface.

Discussing the radiation hazard, Dr. John Wolfe, Pioneer project scientist at Ames Research Center, points out:

"On this trajectory, we expect that the total radiation dose will be no more than that received by Pioneer 10. What we don't know is how the spacecraft will stand the short-time peak radiation as it crosses the center plane of the inner belt. At Pioneer 10's closest approach, radiation striking the spacecraft was already a billion electrons per square centimeter per second and rising. Three times closer will make the peak level perhaps ten times higher for a few minutes.

"Of course, scientifically, we want to measure the intense, inner region of the belts and we need the information for future Jupiter orbiter and atmosphere probe missions."

If Pioneer 11 survives, it has a reasonable chance of functioning long enough to reach Saturn six-and-one-half years after launch. Pioneer 6 still performs well after ten years in space. Pioneer 10, well beyond Jupiter now, is operating after almost three years in space.

In the 48 hours centered on closest approach to Jupiter, Pioneer 11 will take 22 color pictures of the brightly-banded planet, all having three to five times the resolution of pictures from Earth. All will be from angles unavailable from Earth or Pioneer 10, with six of them looking down on south or north polar regions. These color pictures will show a "gibbous" Jupiter (between a half and full moon) with the large semi-circle of the polar regions bordered by concentric orange and blue-grey semi-circular bands.

During the same 48 hours, Pioneer will take pictures of the planet-sized moons Callisto and Ganymede, and of Io, the most reflective object in the solar system. It will make the first spacecraft measurements of Amalthea, tiniest and innermost of Jupiter's 13 moons, which orbits Jupiter at a distance of 115,000 kilometers (69,000 miles).

After encounter, Pioneer 11 will fly into an uncharted region of space about 160 million kilometers (100 million miles) above the orbit planes of most of the planets. There it can provide information on a new portion of the heliosphere. This is the region surrounding the Sun dominated by the solar wind--the gas blowing out from the Sun--and the weak magnetic fields imbedded in that wind.

Because Pioneer 11's path will be through uncharted territory, scientists hope that it will flesh out the information on the giant planet returned by Pioneer 10. That spacecraft provided the first firm ideas of what Jupiter is really like.

The structure of the planet, from the highest levels of the atmosphere down through its center, is much more accurately known now. According to the findings, recently released, Jupiter is a whirling ball of liquid hydrogen without any detectable solid surface. In many respects, it is more like a star than a planet. It is much hotter than previously believed, with an interior that is hotter than the surface of the Sun. At the same time, at some distance below the top of the clouds, temperatures are moderate enough to conceivably support life.

Like its predecessor, Pioneer 11 carries a plaque telling any intelligent species which might find it several million years from now, who sent it and where it came from.

Pioneer 11's radio signals, traveling at the speed of light (186,000 miles per second), will take 46 minutes to reach Earth from Jupiter.

Spacecraft operations during the encounter will be complicated by the 92-minute round-trip communications time, and the need to send 10,000 commands to the spacecraft in the two weeks centered on the closest approach--the most commands ever handled by the Deep Space Network. Operations strategy is to set most systems in one standard mode throughout the encounter, with most commands going to the spacecraft imaging system.

Pioneer 11 weighs 260 kilograms (570 pounds) and is spin-stabilized, giving its instruments a full circle scan five times a minute. It uses nuclear sources for electric power because sunlight is too weak at Jupiter and beyond 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 home planet moves in its orbit around the Sun.

Pioneer carries a 30-kilogram (65-pound) scientific payload of 12 instruments. Two other experiments use the spacecraft and its radio signal as their instruments.

Partners with the spacecraft are the three incredibly sensitive "big dish" antennas of NASA's Deep Space Network, which retrieve Pioneer data. Pioneer's 8-watt radio signal reaches these antennas from Jupiter with a power of 1/100,000,000,000,000,000 watts. Collected for 19 million years, this energy would light a 7.5-watt Christmas tree bulb for one-thousandth of a second.

Cost of the two Pioneer Jupiter spacecraft, scientific instruments, and data processing and analysis is about $100 million.

NASA's Office of Space Science has assigned management of the Pioneer Jupiter project to Ames Research Center, Mountain View, Calif. The spacecraft were built by TRW Systems, Redondo Beach, Calif. The scientific instruments were provided by NASA centers, universities, and private industry.

Tracking and data acquisition is the responsibility of NASA's Deep Space Network, operated by the Jet Propulsion Laboratory, Pasadena, Calif.

(END OF GENERAL RELEASE. BACKGROUND INFORMATION FOLLOWS.)

ENCOUNTER PROFILE

Pioneer 11 began its journey to Jupiter and Saturn on April 5, 1973.

On its 607-day trip to Jupiter, it has followed a curving path about one billion kilometers (620 million miles) long, covering about a million miles a day.

On its flyby trajectory, Pioneer 11 will pass through the narrow "window" (which lies in front of Jupiter as it moves on its orbit) that will allow Jupiter to throw it almost completely across the solar system to Saturn.

The spacecraft will fly a sort of corkscrew loop around the planet. As seen from above, it will cross its incoming trajectory on the way out.

Radiation Danger

Pioneer 11 will encounter its principal hazard when it flies through Jupiter's radiation belt. Most intense radiation will be encountered in a 12-hour period centered on periapsis. The belt has a total energy many millions of times that of Earth's belt.

At its 131,220 kilometers (81,000 miles) closest approach to Jupiter, Pioneer 10 found that peak electron intensity was 10,000 times that of the Earth's belt and was increasing ten times for every three Jupiter radii clcser to the planet. Proton radiation also was at very high levels. These radiation intensities were near the maximum that spacecraft systems could stand.

Since Pioneer 11 will come three times closer to Jupiter than Pioneer 10--more than one Jupiter radius (55,000 miles) closer--the radiation hazard is severe.

However, peak radiation intensities were found at the equatorial plane of Jupiter's magnetic field. The field contains the radiation belt. Calculations indicate that intensity of the belt drops three times at a distance of 20 degrees above the magnetic equator, and ten times at 40 degrees above it.

To pass safely through the belt, Pioneer 11 will fly through at a very high angle to the magnetic equatorial plane (55 degrees). Controllers will bring in the spacecraft far below Jupiter's south pole and then fly almost straight up through the plane of the magnetic equator and its intense radiation zone at a record speed of 173,340 kilometers per hour (107,000 mph).

Project officials calculate that on this course, at this speed, total radiation experienced by Pioneer 11 will be similar to that encountered by Pioneer 10, although peak radiation levels will be far higher. (See section Jupiter's Radiation Belts)

If the spacecraft should be lost, so would the Saturn mission. However, substantial findings would still be available. Since Pioneer 11 will approach Jupiter against the direction of planet rotation, large parts of the magnetic field and radiation belts would be mapped at very high latitudes, measurements of the most intense parts of the radiation belts will have been made, and incoming polar pictures of the planet will have been achieved.

The scientific instruments are susceptible to damage from Jupiter's radiation belts in the following order: The Asteroid-Meteoroid Detector is especially sensitive to radiation. Three of the four high-energy radiation counters are considered to be next most vulnerable. The solar wind, ultraviolet, and photopolarimeter counters are third most likely to be damaged. The magnetometer, the fourth high-energy radiation counter, the infrared and meteoroid instruments are least likely to suffer radiation damage.

Among spacecraft subsystems, all are equally susceptible to radiation damage.

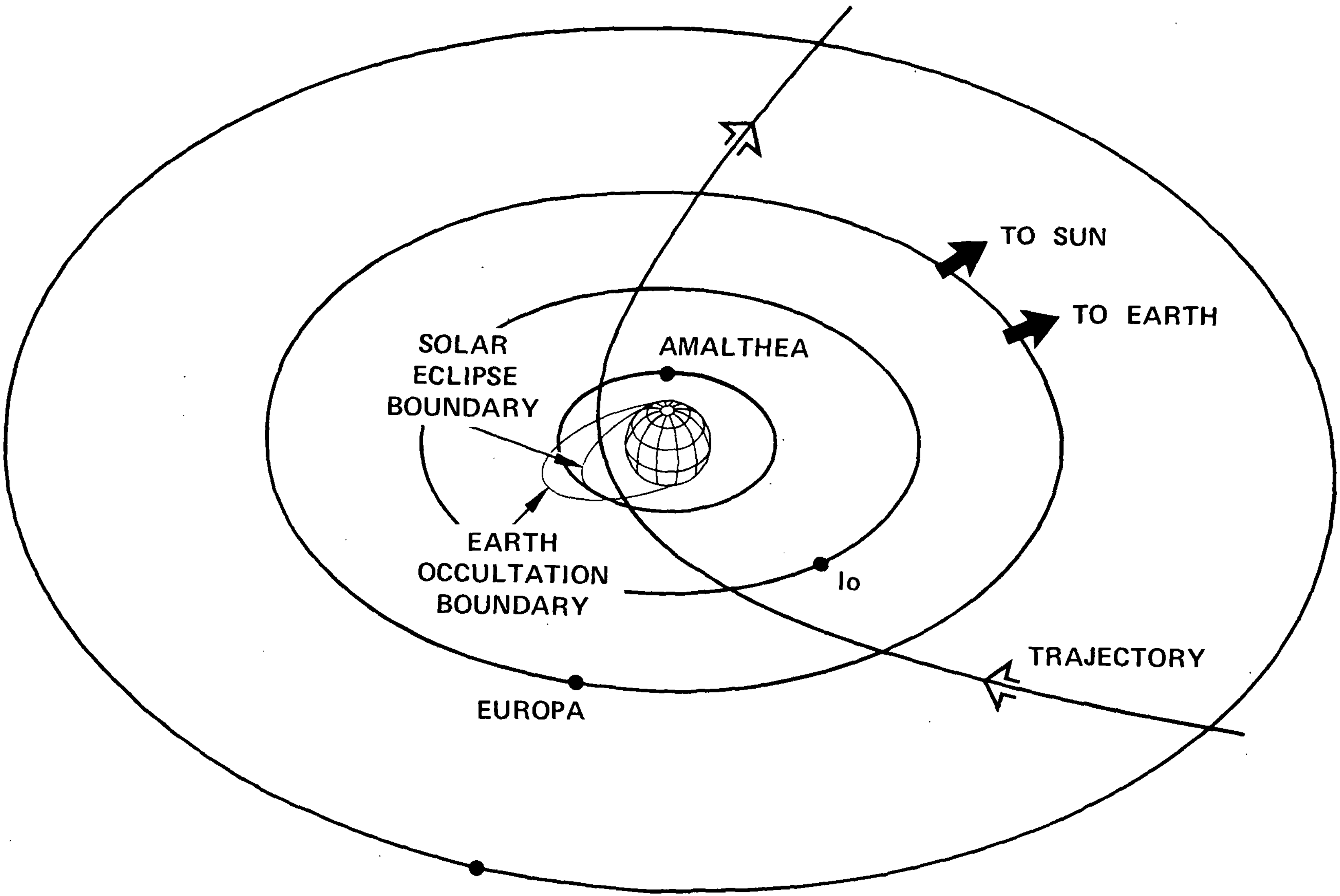
Encounter Sequence

The two-month Pioneer encounter period, Nov. 2, 1974 to Jan. 3, 1975, breaks down as follows:

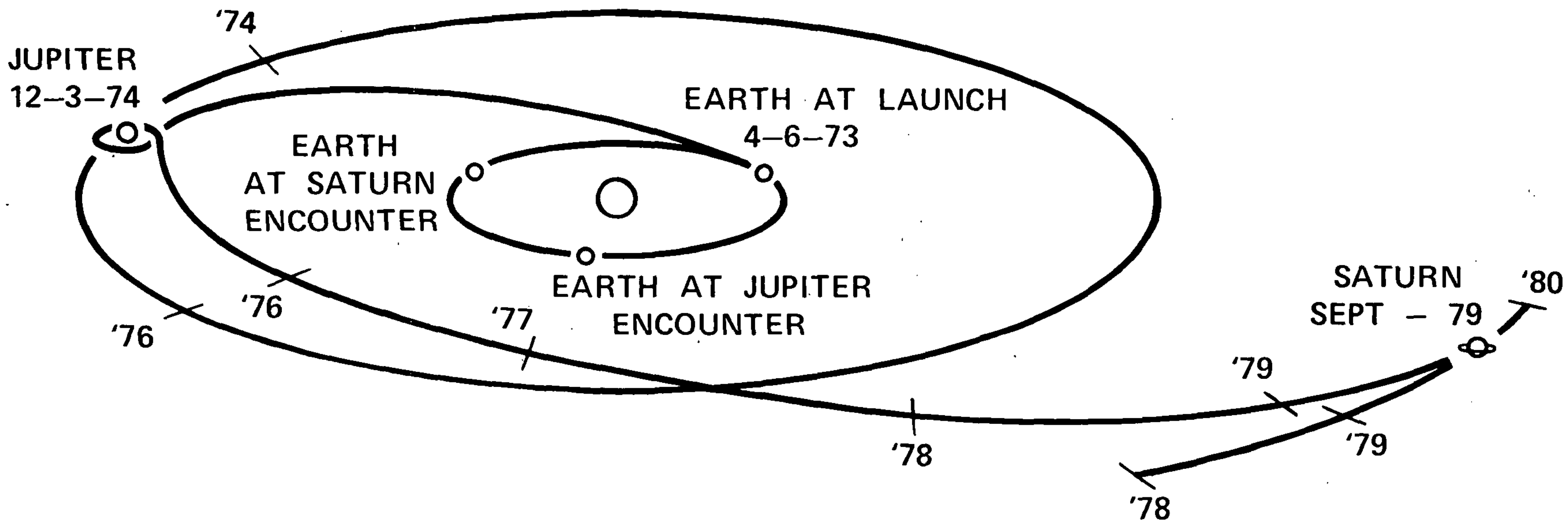
- During the three weeks, Nov. 3 to 24, the spacecraft (still in interplanetary space) will move in from about 27 million km (17 million miles) from the planet to about 10 million km (6.2 million miles).

On Nov. 25 or 26, Pioneer is expected to pass through the bow shock wave in the solar wind created by Jupiter's magnetic field and enter Jupiter's magnetosphere, approaching to about 7.5 million km (4.7 million miles).

PIONEER 11 JUPITER FLYBY



PIONEER 11
SATURN TRANSFER TRAJECTORY



Between Nov. 27 and Dec. 1, Pioneer 10 will fly to within 1.6 million km (1.1 million miles) of Jupiter and will pass through the outer magnetosphere, while viewing the planet from a distance.

During the last day and a half (38 hours), before closest approach on Dec. 3, Pioneer will move in to its closest distance of 42,800 km (26,600 miles) above the planet's cloud tops (pericenter). During this last 38 hours, it will make its most important planet measurements and pictures, and will pass through the most intense parts of the radiation belts (between six hours before and six after pericenter). It also will traverse regions of dust concentrations near the planet.

The spacecraft will repeat this sequence as it exits the planet environment.

Passage of Jupiter's Moons

Early in the encounter, on Nov. 7, about 23 million km (14 million miles) out, Pioneer crossed the orbits of Hades and Poseidon, first two of Jupiter's four outer moons; the following day, it crossed the orbit of Pan.

On Nov. 10, it crossed Andrastea's orbit.

On Nov. 22, eleven days later, Pioneer will reach and cross the orbits of the three middle moons, Demeter, Hera, and Hestia, located 11.3 million km (7 million miles) from Jupiter.

On Dec. 2, the spacecraft will make its closest approach to all five of Jupiter's inner moons. It will come within 786,500 km (488,730 miles) of Callisto, which is as large as the planet Mercury, 21 hours before pericenter. It will sweep by Ganymede at a distance of 692,300 km (430,000 miles), seven hours from pericenter. Ganymede, Jupiter's largest moon, is larger than Mercury, although not nearly as dense. At 2 hours out, Pioneer will come within 314,000 km (195,000 miles) of Io, which is larger than the Earth's moon. It will most closely approach Europa, which is about the size of our moon, at about one hour from pericenter.

The spacecraft will come within 128,000 km (80,000 miles) of Amalthea, Jupiter's tiny inner moon at an hour and a quarter after pericenter. Pioneer's closest approach to Jupiter will be 67,600 km (42,000 miles) inside Amalthea's orbit.

Pictures

Imaging of Jupiter and its four large moons began on Nov. 2, 29 days from pericenter. Early images were largely for calibration. On Nov. 25, imaging activity will go on a 23-hour-a-day basis.

At pericenter minus 48 hours, on Dec. 1, imaging results should become equal to, or better, than those of Earth telescopes.

At pericenter minus about 12 hours, on Dec. 2, the planet will overlap the spacecraft camera's view field.

Numbers of pictures:

- Dec. 1. Pioneer 11 is expected to take 14 images of Jupiter, and two images of Callisto.

- Dec. 2. Plans call for 8 pictures of Jupiter, about half looking up at the South pole and one each of Callisto and Ganymede.

- Dec. 3. After closest approach, 11 images of the planet are scheduled, many looking down at Jupiter's north pole. One picture of Io will be taken.

- Dec. 4. There will be 22 pictures.

- Dec. 9. Imaging will return to a schedule of 3 to 8 hours a day.

The Imaging Photopolarimeter (IPP), which takes the pictures, will use half the spacecraft's data return capacity of 1024 bits per second during encounter, largely for picture transmission. About 60 percent of the IPP observation time will be used for pictures.

Picture Quantity and Quality

Pioneer 11's imaging system (see Experiments--Imaging Photopolarimeter) will take pictures in red and blue light. During the 96 hours centered on pericenter (beginning at 2,867,400 km (1,770,000 miles) out, quantities will be: about 40 pictures of the full planet, many of portions of the planet's surface, three of the moon Callisto, and one each of Ganymede and Io. As Pioneer 11 swings around Jupiter, Sun angles not possible from Earth (and not obtained from Pioneer 10) will be seen with almost every picture.

Incoming color and black and white pictures will be displayed on TV monitors as they arrive from Pioneer. They will then be photographed from the monitors and distributed.

Computer rectification will improve all pictures. Total time after picture receipt on Earth required for rectification (at Ames and the University of Arizona) will average 72 hours (3 days) for black and white pictures, and 96 hours (4 days) for color pictures.

In the closest pictures, looking down on either pole, general appearance of Jupiter will be dramatically different from Pioneer 10 or Earth views. The planet will appear gibbous (between a half and full moon), showing concentric semicircular zones instead of the parallel bands.

Resolution of all pictures in the 96-hour period centered on closest approach should be better than the best views from Earth. The best pictures will be in the 24 hours before and after closest approach, when the spacecraft is within a million miles of Jupiter. These pictures should be much better than any ever made from Earth, the best ever taken of Jupiter, except those made by Pioneer 10. They will show cloud eddies and features invisible from Earth, and may provide deep views into the transparent atmosphere which may exist at the poles. The several closeup pictures taken near closest approach will be somewhat distorted but comprehensible.

Average resolution of all the pictures during the close-in 96 hours may be two to three times better than that from Earth. Resolution of the last picture before pericenter (a portion of Jupiter's surface including the Red Spot) may be about five times that of the best Earth pictures.

Encounter Science Sequence

The first evidence at the spacecraft of Jupiter's presence may come on Nov. 25 or 26. This is the earliest date for passage through the bow shock wave created as the solar wind strikes Jupiter's magnetic field.

On Oct. 9, Pioneer 11 made its final attitude change to assure precise pointing of the spacecraft at Earth for optimum communications. Controllers will make no further attitude changes until four days after pericenter to provide an impertubed trajectory for the gravity-sensing experiment, which measures mass concentrations of Jupiter and orbits and masses of its moons.

Most likely dates for entering Jupiter's magnetic field are Nov. 26 or 27.

The first ultraviolet measurements will be of Callisto and Ganymede on Nov. 30. Because of spacecraft attitude required by the Saturn-bound flyby trajectory, there will be no ultraviolet measurements of Jupiter itself. However, there will also be ultraviolet measurements of Ganymede on Dec. 1 and 2, and of Europa, on Dec. 2. These studies will look for hydrogen and helium and other ultraviolet glow phenomena on the three moons.

Infrared viewing to determine temperature begins the day before pericenter with measurements of Callisto. Pioneer will "take the temperature" of Callisto again on Dec. 4; of Ganymede, Dec. 2 and 3; of tiny Amalthea twice on Dec. 2; and of Io on Dec. 2 and 3. These will be the first temperature measurements of Amalthea, since Pioneer 10 made none.

The most important infrared measuremnts will be of the planet itself, during inbound and outbound viewing periods. Inbound is a two-hour-and-45-minute period starting four hours and 21 minutes before pericenter; outbound is 2 1/2 hours, starting one hour, 39 minutes after pericenter.

Since Nov. 2, the imaging photopolarimeter (IPP) has been studying the nature of atmospheric gas above Jupiter's cloud--the amount of aerosols it contains, and the structure and composition of Jupiter's upper cloud layers. The IPP will provide similar information on Jupiter's moons. Nearly all of these measurements will be from view angles not available to Pioneer 10, making the data especially valuable.

Pericenter will occur at 9:22 p.m. PST, and some minutes later, Pioneer will pass from the southern hemisphere through Jupiter's equatorial plane.

Twenty minutes before pericenter, the spacecraft will pass behind Jupiter itself for 42 minutes. Experimenters on Earth will make refraction studies as Pioneer's radio signal passes through the atmosphere. These should tell more about electron density of Jupiter's ionosphere, and density and composition of its atmosphere--especially in the higher latitudes reached by Pioneer 11 on its near-polar pass. Measurements will be made both going in and coming out from behind Jupiter.

Just seconds before radio blackout, the spacecraft will have entered the Jovian night for 33 and a half minutes. Returning into sunlight, Pioneer will begin its exit from Jupiter's environment, continuing to make measurements as it goes out.

Post Encounter

After encounter, solar wind, particle, land magnetometer experiments will continue to look for the answers also sought by Pioneer 10.

The most interesting experimental questions over the next five years in the region near Jupiter's orbit and in the unexplored regions 160 million km (100 million miles) above the ecliptic (plane of Earth's orbit) to be reached by Pioneer 11 will be: What will be the solar wind and solar magnetic field expansion processes as seen over five years at various distances from the Sun and the ecliptic? What will be the flux of galactic cosmic rays and the distribution of neutral hydrogen, non-solar-wind plasmas and interstellar hydrogen and helium? What do these tell about the interstellar space beyond the boundary of the heliosphere (the Sun's atmosphere)?

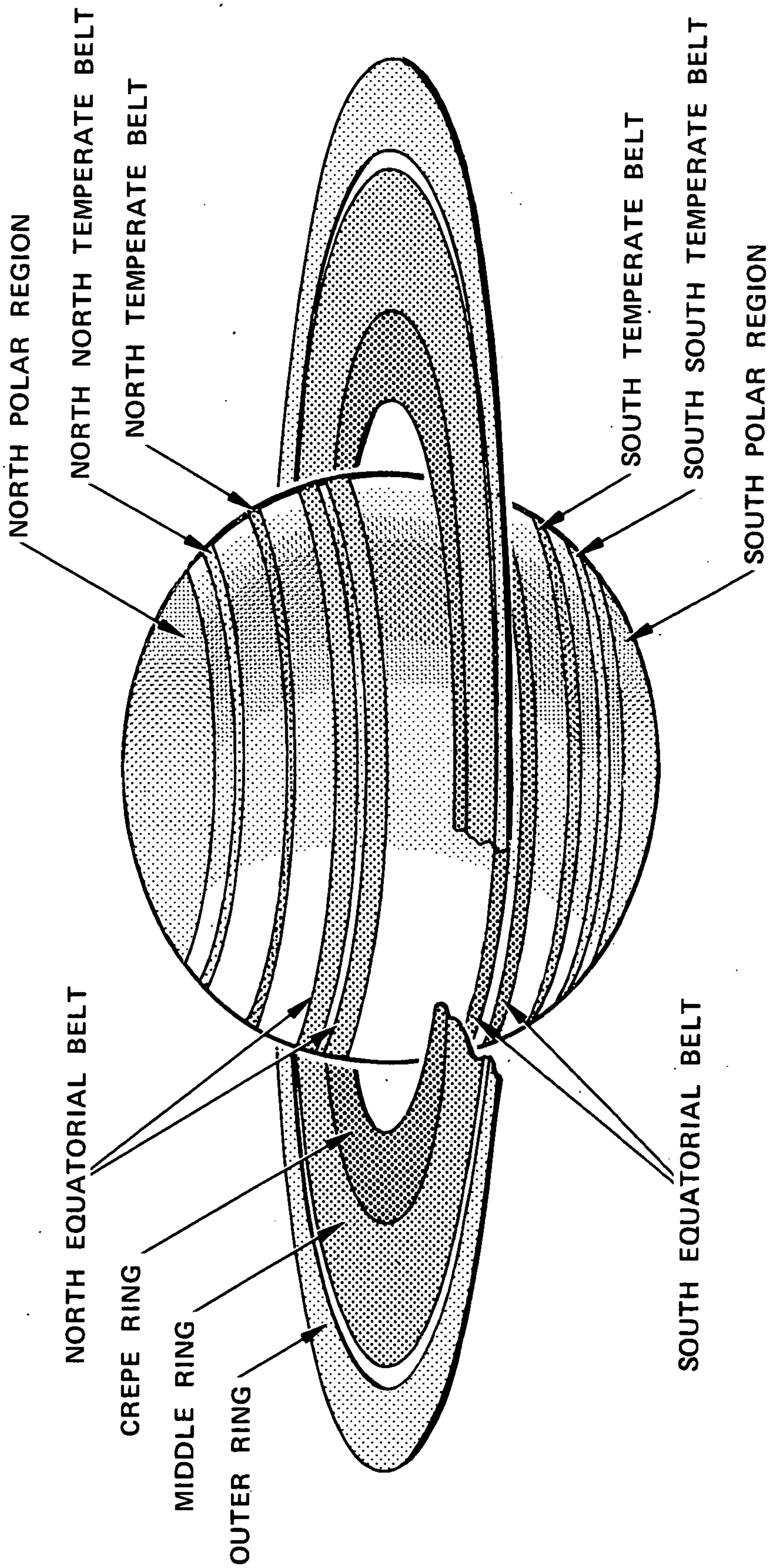
Journey to Saturn

After leaving Jupiter, Pioneer 11 will head for Saturn. Because of its high-angle encounter trajectory, taking it far up over Jupiter's north pole, Pioneer's course to Saturn will attain an over all angle to the plane of the Earth's orbit of 15.6 degrees. This will take it 161,835,000 km (100,564,000 miles) above the Earth's orbit plane, by far the highest above the plane of most of the planets that any spacecraft has ever gone.

The Saturn flight will last six years. Pioneer will almost cross the inner solar system on the way--first passing inside Jupiter's orbit almost back into the outer fringes of the Asteroid Belt at 3.75 Astronomical Units (about 557,400, 000 km. (348,400,000 miles) from the Sun. Then it will recross Jupiter's orbit around April 20, 1977, and fly on to Saturn, reaching the ringed planet in September 1979.

Several Saturn flyby trajectories are possible. One of these options sends the spacecraft between Saturn's rings and the planet.

Depending on which Saturn flyby course is selected, Pioneer 11 will either escape the solar system or go into a very large oval orbit around the Sun.


NORTH POLAR REGION
NORTH NORTH TEMPERATE BELT
NORTH TEMPERATE BELT
SOUTH TEMPERATE BELT
SOUTH SOUTH TEMPERATE BELT
SOUTH POLAR REGION
NORTH EQUATORIAL BELT
CREPE RING
MIDDLE RING
OUTER RING
SOUTH EQUATORIAL BELT

PIONEER 10 AND 11 EVENTS

1972		
	3/2	PIONEER 10 LAUNCH
	5/25	PIONEER 10 CROSSES MARS' ORBIT
	7/15	PIONEER 10 ENTERS ASTEROID BELT
1973		
	2/15	PIONEER 10 EXITS ASERIOD BELT
	4/5	PIONEER 11 LAUNCH
	8/18	PIONEER 11 ENTERS ASTEROID BELT
	12/3	PIONEER 10 OCCULATION BY Io
		PIONEER 10 JUPITER ENCOUNTER
1974		
	3/18	PIONEER 11 EXITS ASTEROID BELT
	4/19	PIONEER 11 COURSE CHANGED FOR JUPITER SWING-BY AND FLIGHT TO SATURN
	12/2	PIONEER 11 JUPITER ENCOUNTER
1975		PIONEER 11 SWINGS INSIDE JUPITER ORBIT TO CROSS SOLAR SYSTEM TO SATURN BY 1979
1976		
	3/1	PIONEER 10 CROSSES SATURN ORBIT
	8/7	PIONEER 11 REACHES HIGHEST POINT ABOVE ECLIPTIC (15.6° 162 MILLION km)
1977		
	4/20	PIONEER 11 RECROSSES JUPITER ORBIT AND HEADS OUT TO SATURN
1978		
1979		
	9/5	PIONEER 11 REACHES SATURN
		PIONEER 10 CROSSES ORBIT OF URANUS AND REACHES COMMUNICATION LIMIT
1980		

ENCOUNTER TIME LINE

NOTES:

1. All times PST

2. One Jupiter diameter = 142,744 km

11-2-74 8:00 a.m.	Begin imaging (picture-taking) and polarimetry 4 to 8 hours per day through 11-24-74. Imagery primarily to support photopolarimetry measurements. Ames operations personnel will run the University of Arizona Imaging Photopolarimeter until 11-18-74 when Arizona team will join them.
9:00 a.m.	Conscan measurements are made every other day throughout the Jupiter encounter to verify pointing accuracy of spacecraft antenna at the Earth. Last change in antenna pointing direction before pericenter was October 9; next change December 6, 4 days after closest approach (pericenter).
11-7-74 4:30 a.m.	Cross orbit of Jupiter's outermost moon, Hades 23,632,000 kilometers (14,683,000 miles) from Jupiter - 165 Jupiter diameters from planet.
4:49	Cross orbit of Poseidon, second of the 4 outer moons at 23,204,000 km (14,417,000 miles) - 162 Jupiter diameters from planet.
11-8-74 7:50 p.m.	Cross orbit of Pan, third of the 4 outer moons, at 22,276,000 km (13,841,000 miles) - 156 Jupiter diameters from planet.
11-10-74 7:29 p.m.	Cross orbit of Andrastea, closest of 4 outer moons, at 20,634,000 km (12,820,000 miles) - 145 Jupiter diameters from planet.
11-18-74 8:00 a.m.	University of Arizona team arrives to begin intensive imaging and photopolarimetry activity. Imaging and polarimetry operations will continue up to 8 hours per day through 11-24-74.
11-21-74 10:03 a.m.	Cross orbit of Hera, outermost of Jupiter's middle group of moons, at 11,667,000 km (7,248,000 miles) - 82 Jupiter diameters from planet.
10:50 a.m.	Cross orbit of Demeter, second of Jupiter's 3 middle moons at 11,639,000 km (7,231,000 miles) - 81.5 Jupiter diameters from planet.

5:21 p.m.	Cross orbit of Hestia, closest of Jupiter's 3 middle moons, at 11,403,000 km (7,084,000 miles) - 80 Jupiter diameters from planet.
11-25-74 All day	Eleven images of Jupiter, polarimetry of Jupiter, Callisto, Ganymede and Europa.
4:00 p.m.	Begin 23 hours-a-day imaging and polarimetry for 14 days through December 9. Both imaging and polarimetry of Jupiter will occur every day through this period; imaging a little more than half the time.
11-25-74 8:00 a.m.	Earliest time for bow-shock wave crossing, inbound
11-26-74 All day	Twenty-five images of Jupiter. Polarimetry of Jupiter and Io.
8:00 a.m.	Earliest time for magnetopause crossing, inbound.
12:00 noon	Resolution of pictures sent back by Pioneer equals that of typical Earth telescope pictures.
9:00 p.m.	Earliest time for magnetopause crossing, inbound. (Time period when crossing likely is 19 hours, from 11-26-74, 9:00 p.m. to 11-27-74, 4:00 p.m.)
11-27-74 All day	Seventeen images of Jupiter. Polarimetry of Jupiter, Io, and Europa.
9:21 p.m.	Pioneer 5 days from pericenter,5,905,000 km (3,669,000 miles) - 41.5 Jupiter diameters away.
9:21 p.m.	Planet occupies 1/10th (1.4 degrees) of Pioneer's 14 degrees field of view. Would have a 2-inch diameter on a 21-inch TV screen.
11-28-74 All day	Twenty-two images of Jupiter. Polarimetry of Jupiter and Io.
9:21 p.m.	Pioneer 4 days from pericenter, 4,919,000 km (3,050,000 miles) - 34.5 Jupiter diameters from the cloudtops.
9:21 p.m.	Planet occupies 1.6 degrees of Pioneer's 14 degrees view field - 2-1/2-inch diameter on a 21-inch TV screen.
11-29-74 All day	Fifteen images of Jupiter. Polarimetry of Io, Europa, Jupiter.

9:21 p.m.	Pioneer three days from closest approach, 3,895,000 km (2,420,000 miles) - 27 Jupiter diameters from cloudtops.
9:21 p.m.	Planet occupies 1/7th (2.1 degrees) of Pioneer's 14 degrees view field - 3-inch diameter on a 21-inch TV screen.
11-30-74 All day	Twenty-four images of Jupiter. Polarimetry of Ganymede, Callisto, and Jupiter.
9:21 p.m.	All pictures from now until 48 hours after pericenter better than typical Earth telescope pictures. Average resolution in this 96-hour period two to three times better than telescope Pictures. During these 96 hours Pioneer will return 40 pictures of the full planet, many pictures of portions of Jupiter's surface, three of Callisto, one each of Ganymede and Io.
11-30-74 9:21 p.m.	Two days from pericenter. Pioneer 2,813,000 km (1,748,000 miles) - 20 Jupiter diameter from the cloudtops.
9:21 p.m.	Planet occupies 2.8 degrees of Pioneer's 14 degrees view field - 4-1/4-inch diameter on a 21-inch TV screen.
11:28 p.m.	Ultraviolet photometer measurement of Callisto.
12-1-74 All day	Fourteen images of Jupiter, two images of Callisto. Polarimetry of Callisto, Io and Jupiter.
11:26 a.m.	Ultraviolet photometer measurement of Ganymede.
5:27 p.m.	Cross orbit of Callisto, outermost Galilean moon, at 1,812,800 km (1,125,295 miles).
9:21 p.m.	Pioneer one day from pericenter, 1,617,000 km (1,005,000 miles) - 11.5 Jupiter diameters from the cloudtops.
9:21 p.m.	Planet occupies one third (4.8 degrees) of Pioneer's 14 degrees view field - 7-1/4-inch diameter on a 21-inch TV screen.
9:21 p.m.	Begin best pictures of Jupiter. During the 24 hours before and after pericenter when Pioneer is within one million miles of the planet, pictures are much better than any from Earth, the best ever made of Jupiter except those taken by Pioneer 10.

10:18 p.m.	Infrared measurements of Callisto, inbound.
12-2-74 All day	Eight images of Jupiter, one image of Callisto, one image of Ganymede. Polarimetry of Jupiter.
12:21 a.m.	Closest approach to Callisto, 786,500 km (488, 730 miles) at 21 hours from pericenter.
1:50 a.m.	Ultraviolet measurements of Ganymede, 19 hours 31 minutes from pericenter.
8:01 a.m.	Cross orbit of Ganymede, second outermost Galilean moon, at 1,001,140 km (624,953 miles) - seven Jupiter diameters from cloudtops, 13 hours 33 minutes from pericenter.
8:21 a.m.	Last full disc picture of Jupiter. Subsequent pictures will more than fill spacecraft 14 degrees view field.
1:56 p.m.	Infrared measurement Ganymede, inbound - 7 hours 25 minutes before pericenter.
2:06 p.m.	Cross orbit of Europa, second closest Galilean moon, at 601,780 km (372,803 miles) - 4.2 Jupiter diameters from the cloudtops, 7.25 hours from pericenter.
12-2-74 2:09 p.m.	Closest approach to Ganymede, 692,300 km (430,195 miles) - 7.2 hours from pericenter.
2:45 p.m.	Ultraviolet measurement of Europa - 6 hours 36 minutes before pericenter.
3:21 p.m.	Enter radiation belt at 3.5 Jupiter diameters from clouds, six hours from closest approach.
4:00 p.m.	Begin two-hour scan for last picture on incoming trajectory thus showing Red Spot, portion of Jupiter's surface. During picture, taken from 4:00 p.m. - 6:00 p.m., Pioneer well inside radiation belt. Range 424,000 km resolution five times Earth telescope resolution.
5:00 p.m. to 7:45 p.m.	Infrared measurements of Jupiter - 2 hours 45 minutes of measurements starting at 4 hours 21 minutes from pericenter.
5:13 p.m.	Infrared measurement of Amalthea - 4 hours 8 minutes from pericenter.

5:23 p.m.	Cross orbit of Io, innermost Galilean moon, at 352,560 km (217,945 miles) - 2.45 Jupiter diameters from cloudtops, four hours from pericenter
7:02 p.m.	Infrared measurements of Io at 2 hours and 19 minutes before pericenter.
7:09 p.m.	Closest approach to Io, 314.000 km (195,120 miles), 2 hours ten minutes pericenter.
7:58 p.m.	Crossing of Pioneer 10's previous closest approach distance.
8:10 p.m.	Cross orbit of Amalthea, closest Jovian moon, at 137,260 km (68,630 miles) - 0.77 Jupiter diameters from cloudtops, 1 hour nine minutes before pericenter
8:15 p.m.	Closest approach to Europa, 586,700 km (364,575 miles), 1 hour six minutes before pericenter
9:00:21 p.m.	Enter 33 minutes 31 seconds solar occultation - starts at 20 minutes, 58 seconds before pericenter.
9:00:42 p.m.	Enter Jupiter radio occultation (blackout) - duration 42 minutes 2 seconds. Starts 20 minutes 18 seconds before pericenter.
9:22 p.m.	Pericenter - Pioneer is 42,828 km (26,613 miles) - 0.31 Jupiter diameters from cloudtops.
9:33:52 p.m.	Exit solar occultation, 12 minutes, 23 seconds after pericenter.
9:43:03 p.m.	Exit Jupiter radio occultation, 21 minutes 44 seconds after pericenter.
12-2-74 10:30 p.m.	Closest approach to Amalthea, 127,500 km (79,229 miles), 1 hour 8 minutes after pericenter.
10:52 p.m.	Infrared measurement of Amalthea outbound-1 hour 31 minutes after pericenter.
11:00 p.m.	Start 4-1/2-hours Jupiter viewing period, outbound, for infrared instrument. Begins 1 hour 39 minutes after pericenter.
12-3-74 All day	Eleven images of Jupiter, one image of Io, polarimetry of Jupiter, Ganymede, and Callisto.
1:30 a.m.	End 4-1/2-hours Jupiter view period for infrared instrument outbound. Ends 4 hours 9 minutes after pericenter.

3:21 a.m.	Exit radiation belt at 3.5 Jupiter diameters from cloudtops, six hours after pericenter.
7:58 a.m.	Infrared measurement of Io, outbound, 10 hours 37 minutes after pericenter.
9:21 p.m.	One day after pericenter. Pioneer is 1,617,000 km (1,005,000 miles) - 11.3 planet diameters from Jupiter.
11:43 p.m.	Infrared measurement of Ganymede, outbound, 26 hours 22 minutes after pericenter.
12-4-74 All day	Fifteen images of Jupiter. Polarimetry of Jupiter, Io, Ganymede, and Europa.
9:21 p.m.	Two days after pericenter, Pioneer is 2,813,000 km (1,748,000 miles) from Jupiter.
9:45 p.m.	Infrared measurement of Callisto, outbound, 48 hours 24 minutes after pericenter.
12:00 midnight	Jupiter occupies 1/5 of 14 degrees view field.
12-5-74 All day	Eighteen images of Jupiter. Polarimetry of Europa, Ganymede, Callisto, Jupiter.
9:21 p.m.	Three days after pericenter. Pioneer is 3,895, 000 km (2,420,000 miles) from Jupiter.
12-6-74 All day	Ten images of Jupiter. Polarimetry of Jupiter and Ganymede.

12-6-74 5:30 a.m. to 1:30 p.m.	First precession maneuver after pericenter to change pointing angle at the Earth of Pioneer radio antenna. Maneuver lasts 6 to 8 hours and will change pointing direction about two degrees.
9:21 p.m.	Four days after pericenter. Pioneer is 4,919,000 km (3,050,000 miles) from Jupiter.
12-7-74 All day	Twenty-two images of Jupiter. Polarimetry of Jupiter, Ganymede, Io, Callisto.
12:00 noon	Jupiter occupies 1/10 of Pioneer view field.
9:21 p.m.	Five days after pericenter Pioneer is 5,906,000 km (3,669,000 miles) from Jupiter.
12-8-74 All day	Twenty-eight images of Jupiter. Polarimetry of Jupiter, Ganymede, and Callisto.
12:00 noon	Earliest time for magnetopause crossing, outbound - 20-hour period when crossing expected is 12:00 noon, 12-8-74 to 4:00 a.m., 12-9-74.
12-9-74 All day	Nineteen images of Jupiter. Polarimetry of Jupiter.
3:00 p.m.	End of 23-hour-per-day imaging and photopolarimetry. Return to four to eight-hours-per-day operation through 1-3-75. Arizona imaging photopolarimetry team goes home, but will return for full day of operations on 12-17-74, after today (12-9-74) imaging photopolarimeter will be run by Ames operations personnel, and will be used primarily for photopolarimetry not imaging.
8:00 p.m.	Latest possible time for magnetopause crossing, outbound.
12-10-74 12:00 midnight	Lastest time for bow shocking crossing, outbound.
12-17-74 All day	Fifteen images of Jupiter by Arizona-Ames team. Arizona then returns instrument to Ames operation. Imaging and polarimetry four to eight-hours-per-day through 1-3-75.

12-20-74 4:45 a.m. to 12:45 p.m.	Second precession maneuver after pericenter to change pointing angle at the Earth of Pioneer radio antenna. Maneuver lasts six to eight hours, changes pointing direction about two degrees.
12-30-74 6:00 a.m. to 2:00 p.m.	Third precession maneuver after pericenter to change pointing angle at the Earth of Pioneer radio antenna. Maneuver lasts six to eight hours, changes pointing direction about two degrees.
1-3-75 8:00 a.m.	End of four-to-eight-hour-per-day imaging and photopolarimetry.
4:00 p.m.	End encounter period.

PICTURE TIME SCHEDULE

During the 52 hours centered on periapsis, Pioneer will take 25 pictures of Jupiter, one each of Callisto, Ganymede, and Io.

	Earth Receipt Times (PST)	Picture
Dec. 1	7:57 – 8:47 p.m.	Jupiter
	8:47 – 9:28 p.m.	Jupiter
	9:28 – 10:14 p.m.	Jupiter
	10:56 – 11:45 p.m.	Jupiter
Dec. 2	11:45 p.m. – 12:22 a.m.	Jupiter
	1:20 – 1:51 a.m.	Callisto (moon)
	2:36 – 3:35 a.m.	Jupiter
	5:25 – 6:21 a.m.	Jupiter
	6:56 – 7:55 a.m.	Jupiter
	8:30 – 9:42 a.m.	Jupiter
	10:11 – 11:19 a.m.	Jupiter (small part N cut off)
	11:27 – 11:55 a.m.	Ganymede (moon)
	12:54 – 2:03 p.m.	Jupiter (small part S cut off)
	2:14 – 4:05 p.m.	Jupiter (small part N cut off)
	5:02 – 6:06 p.m.	Jupiter (10% N&S cut off)
	6:10 – 7:03 p.m.	Jupiter (10% N&S cut off)
Dec. 3	12:54 – 1:51 a.m.	Jupiter (1/3 S cut off)
	1:55 – 2:57 a.m.	Jupiter (1/3 S cut off)
	3:54 – 5:00 a.m.	Jupiter (5% N&S clipped)
	5:34 – 7:21 a.m.	Jupiter
	7:50 – 9:11 a.m.	Jupiter
	9:20 – 9:51 a.m.	Io
	10:57 a.m. – 12:11 p.m.	Jupiter
	1:03 – 2:27 p.m.	Jupiter

PICTURE TIME SCHEDULE (CONT.)

PST	Image of
3:02 - 3:51 p.m.	Jupiter
7:00 - 8:00 p.m.	Jupiter
8:00 - 8:25 p.m.	Jupiter
11:00 - 11:20 p.m.	Jupiter

JUPITER-BASIC CHARACTERISTICS

Size, Orbit, Rotation. Galileo made the first tele-scopic observations of Jupiter and discovered the four large moons in 1610.

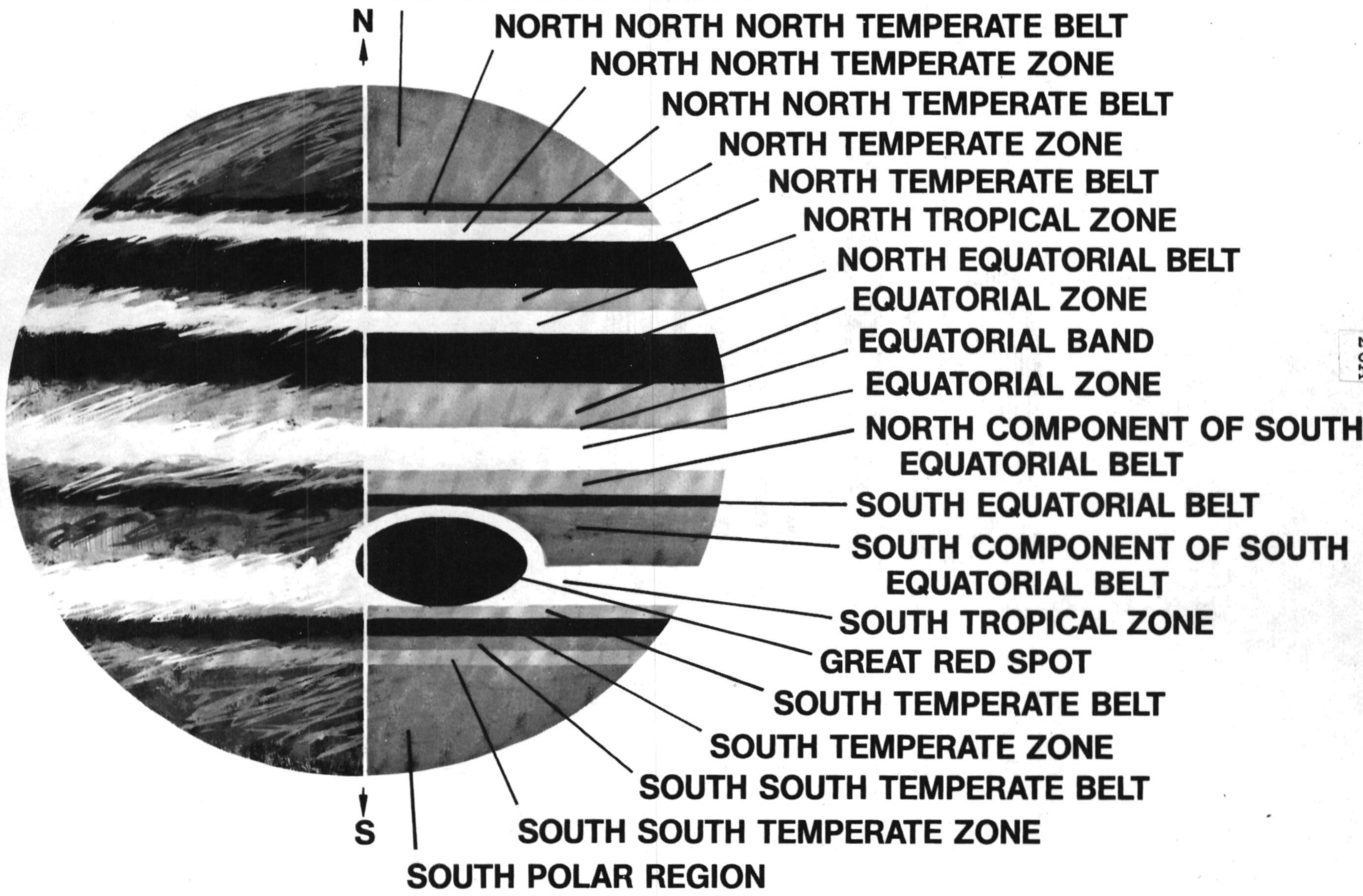
From Earth, Jupiter is the second brightest planet, and the fourth brightest object, in the sky. It is 773 million kilometers (480 million miles) from the Sun, and circles it once in just under 12 years. The planet has 13 moons, including the one discovered in September; the four outer ones are in "backward orbit" compared to other known moons. The largest, Ganymede has a ten per cent greater diameter than the planet Mercury; Callisto, the next largest, is equal in size to Mercury. Two other, Io and Europa, are similar in size to the Earth's moon.

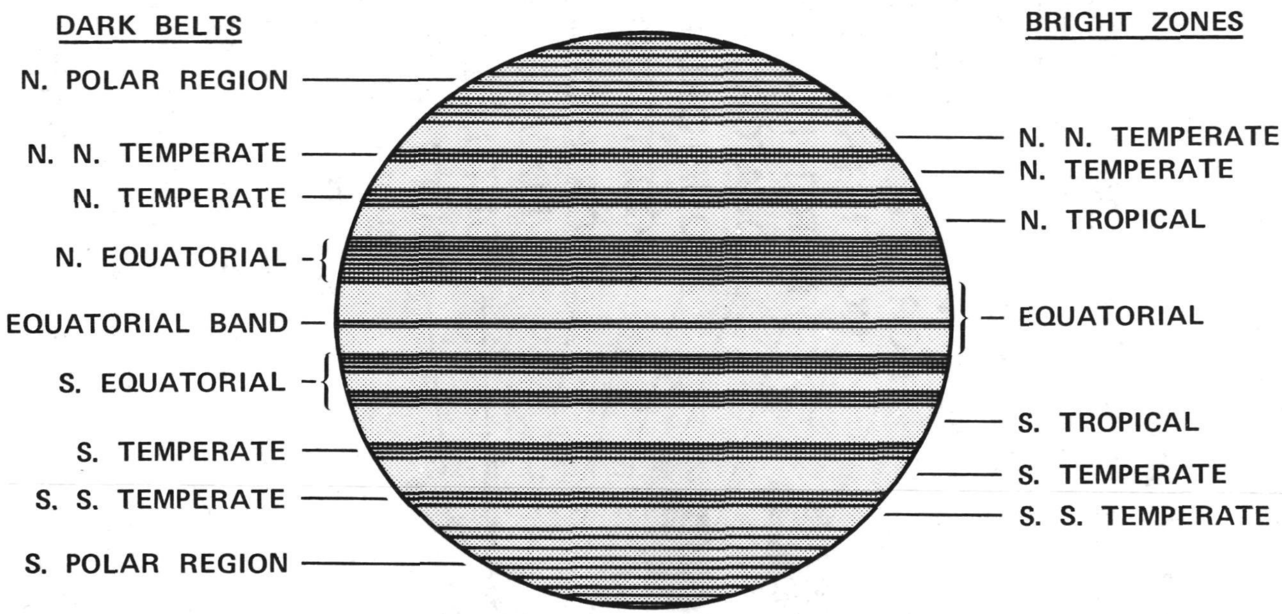
Jupiter spins once every 10 hours, the shortest day of any of the nine planets. Because of Jupiter's size, this means that a point at the equator on its visible surface (cloud tops) races along at 35,400 km/hr (22,000 m.p.h.), compared to a speed of 1,600 km/hr (1,000 m.p.h.) for a similar point on Earth.

Jupiter's visible surface (its cloud tops) cover 62 billion square kilometers (about 24 billion square miles). The planet's gravity at cloud top is 2.36 times that of Earth.

The mass of the planet is 318 times the mass of Earth. Its volume is 1,000 times Earth's. The planet is made up of a mixture of elements similar to that in the Sun or the primordial gas cloud which formed the Sun and planets. This means at least three quarters of it is the lightest gases, hydrogen and helium. Scientists have identified hydrogen, deuterium (the heavy isotope of hydrogen), helium, methane (carbon and hydrogen), and ammonia (nitrogen and hydrogen) in Jupiter's clouds.

JUPITER'S VISIBLE SURFACE




DARK BELTS
N. POLAR REGION
N. N. TEMPERATE
N. TEMPERATE
N. EQUATORIAL
EQUATORIAL BAND
S. EQUATORIAL
S. TEMPERATE
S. S. TEMPERATE
S. POLAR REGION
BRIGHT ZONES
N. N. TEMPERATE
N. TEMPERATE
N. TROPICAL
EQUATORIAL
S. TROPICAL
S. TEMPERATE
S. S. TEMPERATE

Appearance. Jupiter has large dusky, gray regions at both poles. Between the two polar regions are five, bright salmon-colored stripes, known as zones, and four darker, slate-gray stripes, known as belts.

The Great Red Spot in the southern hemisphere is frequently bright red, and since 1665 has disappeared completely several times.

The gray polar regions may be condensed methane. The bright cloud zones have a complete range of colors from yellow and delicate gold to red and bronze. Clouds in the belts range from gray to blue-gray.

In addition to the belts and zones Pioneer 10 found many smaller features--streaks, wisps, arches, loops, patches, lumps, and spots. Many of these are hundreds of thousands of kilometers in size.

Circulation of these features is vigorous. The entire Equatorial Zone, 20 degrees wide, sweeps around the planet 410 km/hr (225 m.p.h.) faster than the cloud regions on either side. The South Tropical current and a cloud current sweeping completely around the Great Red Spot are well-known.

Radio Signals and Heat. Earth receives more radio noise from Jupiter than from any other source except the Sun. Jupiter broadcasts three kinds of radio noise: (1) thermal--from the temperature-induced motions of the molecules in its atmosphere (wavelength, 3 centimeters); (2) decimetric (centimeter range)--from the gyrations of electrons around the lines of force of the planet's magnetic field (wavelength 3-70 centimeters); and (3) decametric (up to 10s of meters)--believed to be from huge discharges of electricity (like lightning flashes) in Jupiter's ionosphere (wavelength 70 centimeters to 60 meters).

The powerful decametric radio waves have been shown to be modulated by passeges of Jupiter's close moon, Io, whose orbit is 2.5 planet diameters, 350,000 kilometers (about 217, 000 miles), above Jupiter's cloud tops. Some scientists believe that Io links up magnetic lines of force in the planet's ionosphere, allowing huge discharges of built-up electrical potential.

The power of these decametric radio bursts is equal to the power of several hydrogen bombs. Their average peak value is 10,000 times greater than the power of Jupiter's decimetric signals.

Only about 1/27th as much heat from the Sun arrives at Jupiter as reaches Earth.

Moons. Jupiter's 13 natural satellites have some odd characteristics. The second moon, Io, is the most reflective known object in the solar system. Infrared measurements show Europa and Ganymede to have water ice on their surfaces.

The inner moons are: tiny Amalthea, diameter 160 kilometers (100 miles), which orbits Jupiter twice a day at only 1.5 planet diameters, 106,000 km (66,000 miles), above the cloud tops; the four large moons Io, Europa, Ganymede, and Callisto, whose orbits ie between 422,000 km (262,000 miles) and 1,882,000 km (1,169,000 miles) from Jupiter.

Beyond these are the seven tiny outer moons. The inner three of these, Hestia, Hera, and Demeter, have orbits which lie between 11.5 and 11.7 million kilometers (7.2 and 7.3 million miles) from Jupiter. An eighth small moon was discovered last September.

Orbits of the four outermost, Andrastea, Pan, Poseidon, and Hades, lie between 20.7 million and 23.7 million km (12.9 and 14.7 million miles) from Jupiter. All are in "backward" orbits, counter to the direction of planet rotation. This suggests that they may be captured asteroids. Diameters of six of the outer moons range from 15 to 40 km (9 to 24 miles), with Hestia, the seventh, having a diameter of about 130 km (81 miles).

Orbital periods of the four larger inner moons range from 1.7 days (for Io) to 16.7 days. Orbital periods of the inner three of the outer seven moons are around 250 days. While the four farthest-out moons complete their retrograde orbits in around 700 days.

THE VIEW FROM PIONEER 10

Pioneer's target planet, Jupiter, is unique in the solar system. With more than two-thirds of all the planetary material in the solar system, it has more than 1000 times the volume of the Earth. It has 13 moons, four around the size of the planet Mercury. By itself, the Jovian system is more than a planet. It constitutes a vast new region in space.

Scientists want to add to the spectacular discoveries made by Pioneer 10, just released. The findings indicate that:

- Jupiter is entirely liquid--a big, fast-spinning ball of liquid hydrogen without any detectable solid surface.

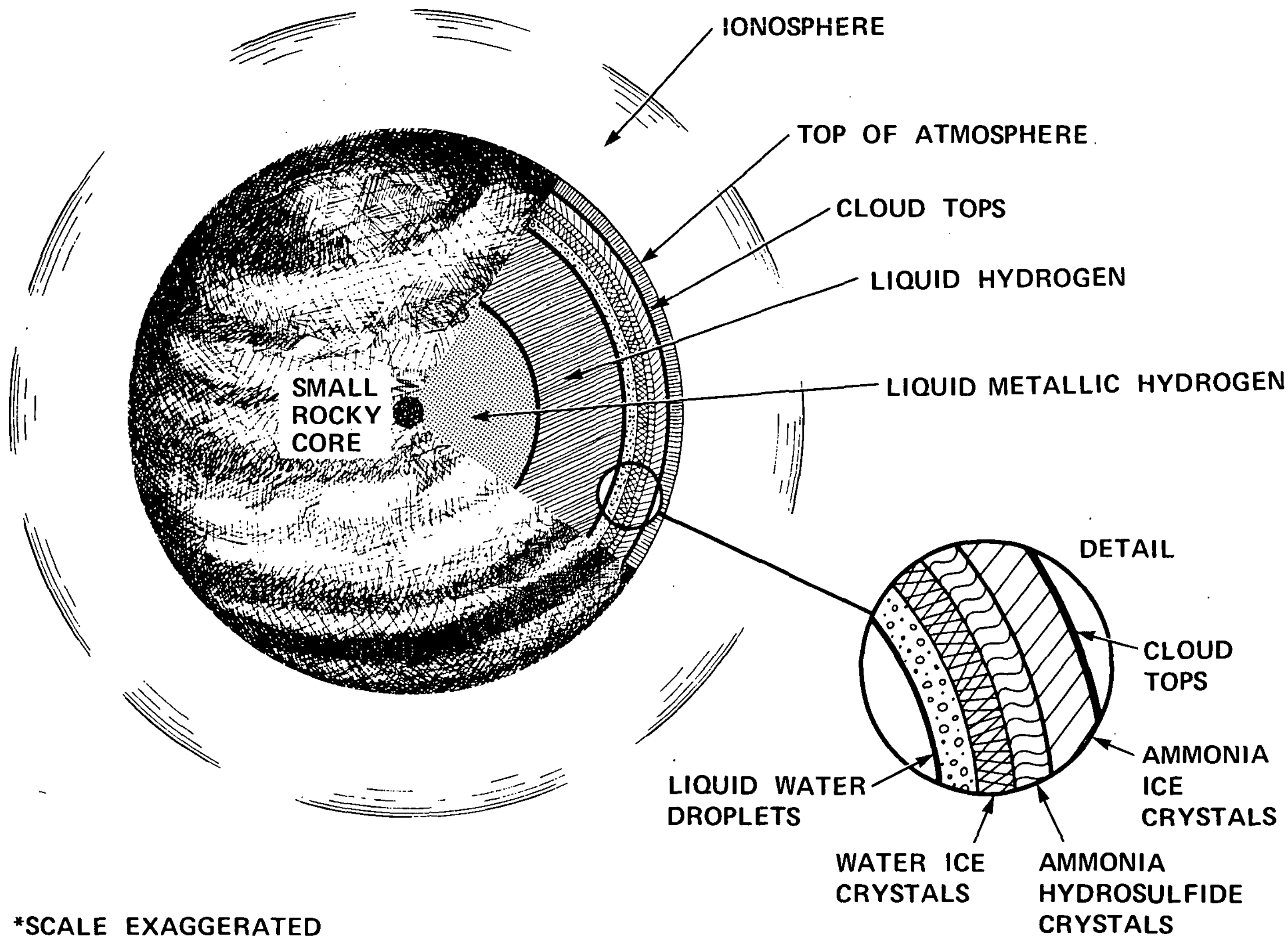
- Jupiter is very hot inside (at its core, six times hotter than the Sun's surface). This heat dates back to the formation of the planet, 4.5 billion years ago. Down-ranging densities of the four large inner moons (directly proportional to distance from the planet) seem to prove this early intense heat. The inner two, Io and Europa, seem to be rocky, with the outer two, Ganymede and Callisto, the density of water-ice and rock.

- The enormous Great Red Spot is a "permanent" 20,000-mile-wide hurricane which has been raging for at least 400 years.

- The place for a manned landing in the Jovian system (if one ever occurs) is the big moon Callisto which is outside the worst radiation and pops in and out of the radiation belts as they wobble 20 degrees up and down each ten-hour planet rotation.

JUPITER ATMOSPHERE MODEL*

ATMOSPHERE DEPTH TO LIQUID ZONE IS 1000 km (600 mi)



*SCALE EXAGGERATED

- Jupiter could contain life. Its atmosphere contains ammonia, methane, hydrogen, and probably water, believed to have produced life on Earth about four billion years ago. Many scientists believe that vast regions below the clouds are at room temperature. Combined with Jupiter's abundant energy, these conditions could produce living organisms. However, rapid circulation of both atmosphere and interior of a hot, liquid planet means organisms would have to be fastmoving or short lived.

- Jupiter's weather is fantastically different from Earth's, but has familiar "highs and lows" like Earth's. Instead of constantly moving and rotating like Earth cyclones, these features are permanent and stretch completely around the planet. They account for Jupiter's colorful bands.

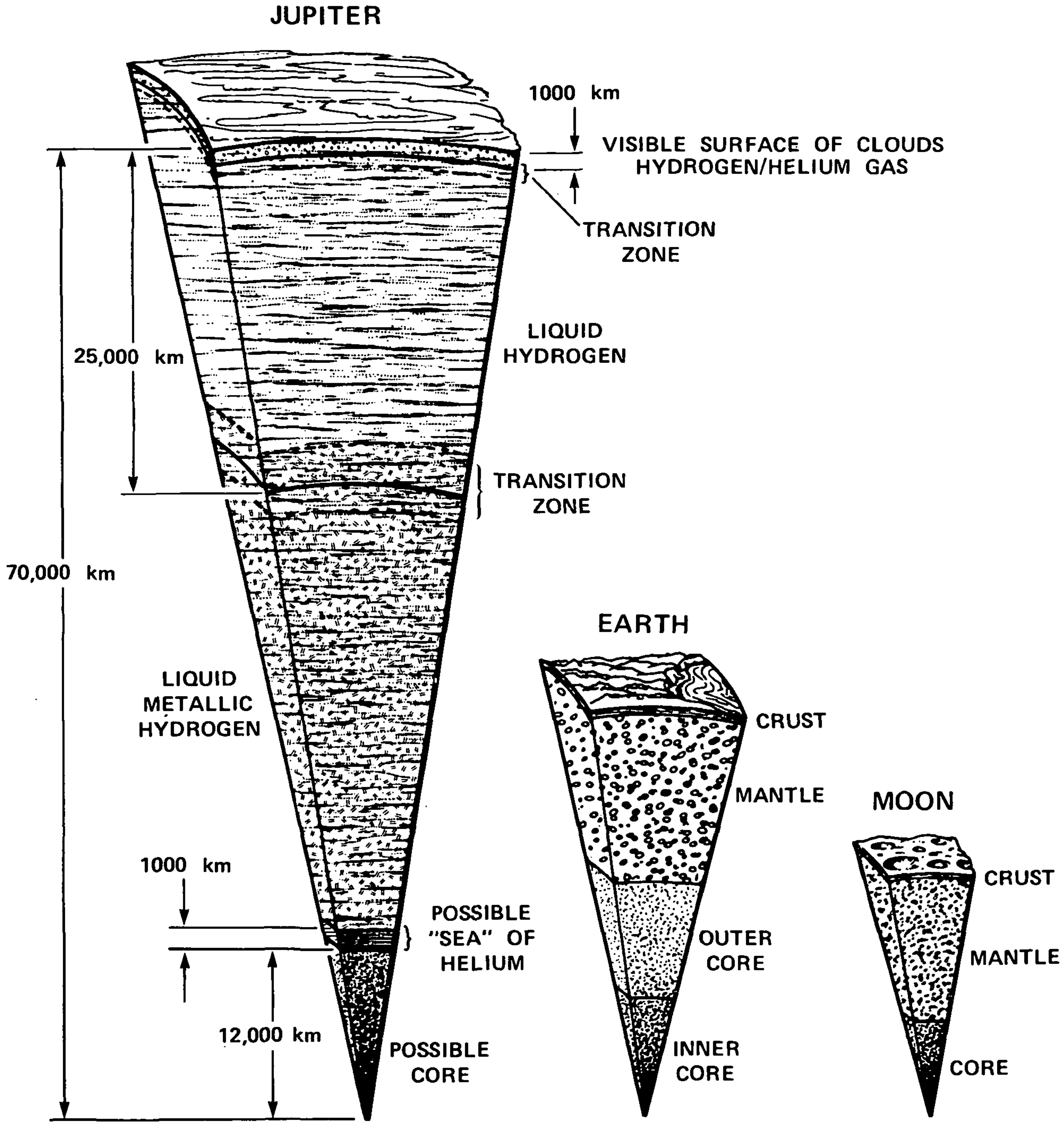
- The bright zones are planet-girdling, rising columns of atmosphere, and the dark belts, descending atmosphere regions, stretched completely around the planet.

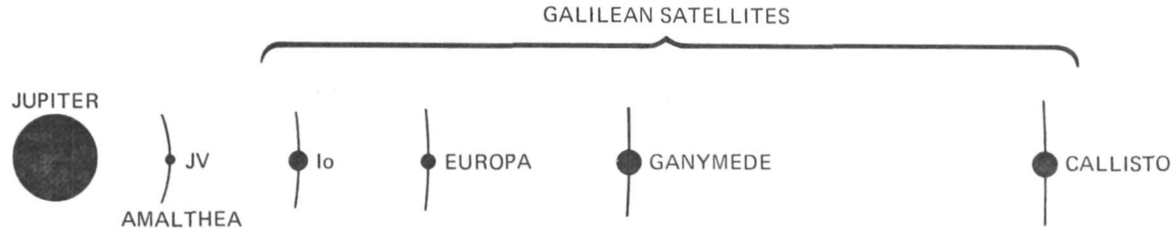
- The permanence of Jupiter weather features seems to result from its liquid character and internal heat source, which spreads heat evenly throughout the planet, not just at the equator as with solar heat on Earth.

- The big moons, Io, Ganymede, Europa, and Callisto all seem to have atmospheres. Pictures of Ganymede appear to show maria and highlands similar to the moons' and Mars'.

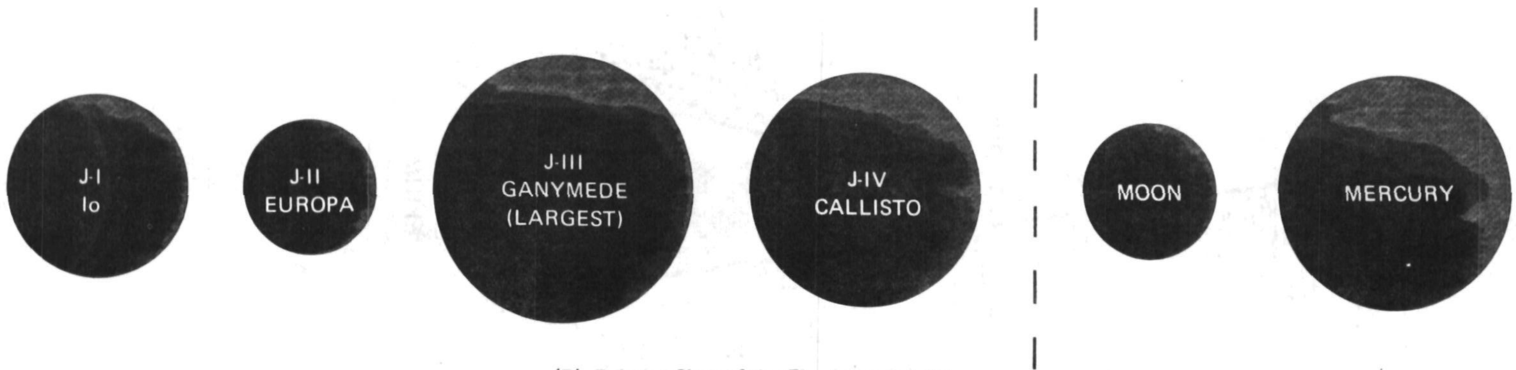
- Jupiter's magnetic field is much larger than predicted. Its radiation belts are far more intense than many expected.

- Jupiter is a source of high-energy particle radiation, the only one in the solar system except the Sun.


JUPITER
1000 km
VISIBLE SURFACE OF CLOUDS
HYDROGEN/HELIUM GAS
TRANSITION ZONE
LIQUID HYDROGEN
25,000 km
TRANSITION ZONE
70,000 km
LIQUID METALLIC HYDROGEN
1000 km
POSSIBLE "SEA" OF HELIUM
12,000 km
POSSIBLE CORE
EARTH
CRUST
MANTLE
OUTER CORE
INNER CORE
MOON
CRUST
MANTLE
CORE



(A) The Inner Moons



(B) Relative Sizes of the Five Inner Satellites

The satellites of Jupiter: distances and sizes.

- Jupiter apparently retains a mixture of elements similar to that in the Sun, predominantly hydrogen and helium.

Pioneer 11 hopefully will make major additions to these discoveries. Because of the polar pass, it can measure the thickness of both the radiation belts and of Jupiter's magnetosphere (space filled by the planet's magnetic field). Different interpretations of Pioneer 10 data have protons (the heavy particles in the radiation belts) either declining inside 182,000 km (114,000 miles), or else continuing to increase. This is a key question for determining the radiation hazard. Infrared and ultraviolet measurements of the big moons Callisto, Ganymede, Europa, and Io should produce valuable new data.

THE EXPERIMENTS AND PROJECTED FINDINGS

The 14 Pioneer 11 experiments are designed to produce findings about Jupiter and the heliosphere. Their objectives are:

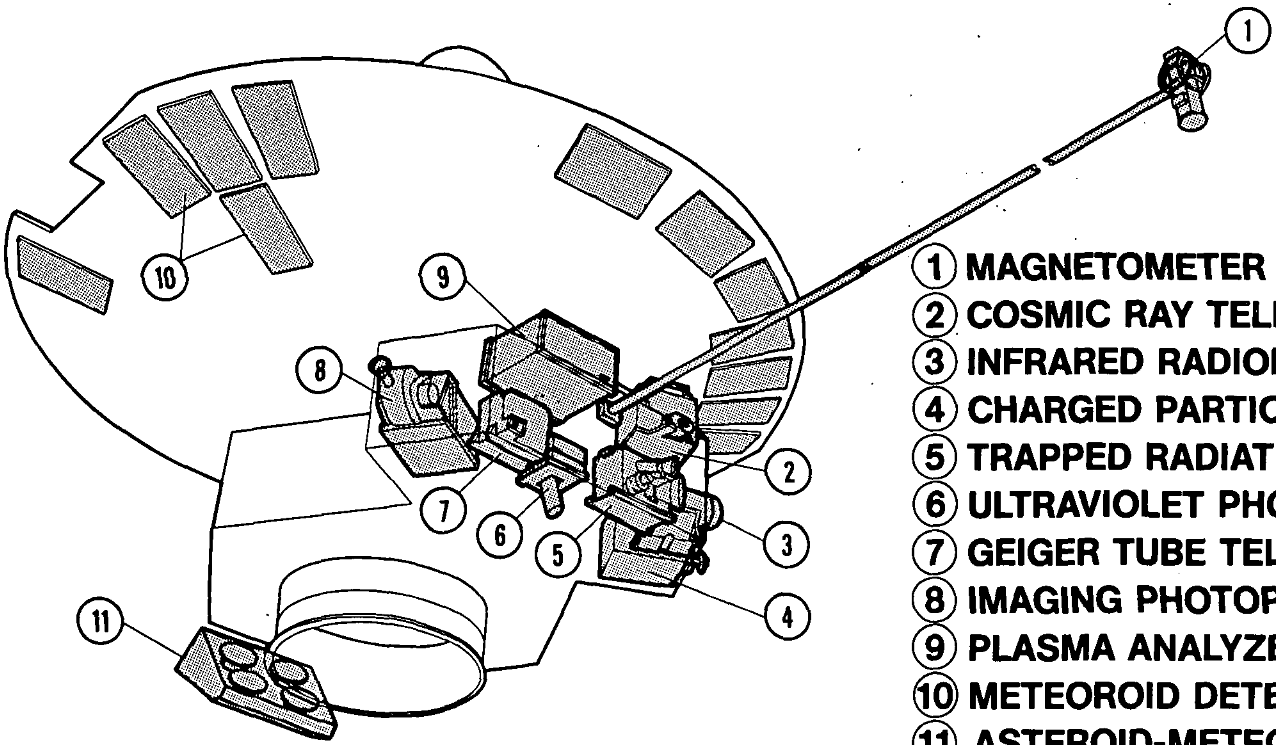
For Jupiter

- To map the magnetic field.
- To measure distributions of high energy electrons and protons in the radiation belts, and look for auroras.
- To find a basis for interpreting the decimetric and decametric radio emissions from Jupiter.
- To detect and measure the bow shock and magnetospheric boundary and their interactions with the solar wind.
- To verify the thermal balance and to determine temperature distribution of the outer atmosphere.
- To measure the hydrogen/helium ratio in the atmosphere.
- To measure the structure of the ionosphere and atmosphere.
- To measure the brightness, color and polarization of Jupiter's reflected light.
- To perform two-color visible light imaging.
- To increase the accuracy of orbit predictions and masses of Jupiter and its moons.

For Interplanetary Space

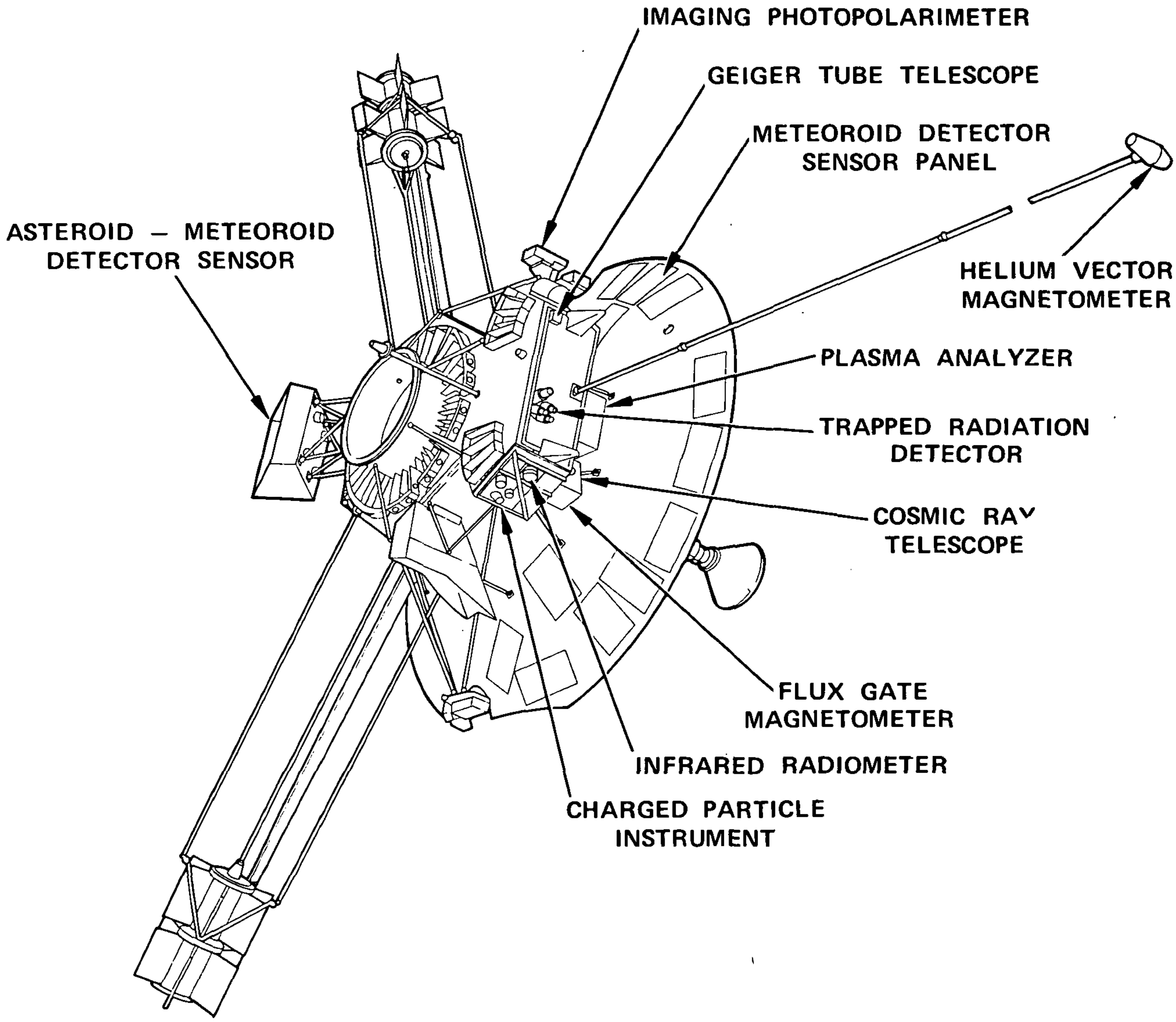
- To map the interplanetary magnetic field.
- To study the radial gradient of the solar wind and its fluctuations and structure.
- To study the radial and transverse gradients and arrival directions of high energy charged particles (solar and galactic cosmic rays).
- To investigate the relationships between the solar wind, magnetic field and cosmic rays.

PIONEER/JUPITER EXPERIMENTS



1. MAGNETOMETER
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
11. ASTEROID-METEOROID DETECTOR SENSOR

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
AMES RESEARCH CENTER, MOFFETT FIELD, CALIFORNIA


IMAGING PHOTOPOLARIMETER
GEIGER TUBE TELESCOPE
METEOROID DETECTOR SENSOR PANEL
ASTEROID – METEOROID DETECTOR SENSOR
HELIUM VECTOR MAGNETOMETER
PLASMA ANALYZER
TRAPPED RADIATION DETECTOR
COSMIC RAY TELESCOPE
FLUX GATE MAGNETOMETER
INFRARED RADIOMETER
CHARGED PARTICLE INSTRUMENT

- To search for the boundary and extent of the heliosphere (solar atmosphere).

- To determine the density of neutral hydrogen.

- To determine the properties of interplanetary dust.

The instruments aboard Pioneer 11 return data in roughly the following categories:

Magnetic Fields

Magnetometer (Jet Propulsion Laboratory). This sensitive instrument measures the interplanetary magnetic field in three axes from the orbit of Earth out to the limits of spacecraft communication. It will study solar wind interaction with Jupiter and map Jupiter's strong magnetic fields at all longitudes and many latitudes.

The instrument is a helium vector magnetometer. Its sensor is mounted on the lightweight mast extending 6.5 meters (21.5 feet) 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 gammas; 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 lbs.) and uses up to 5 watts of power.

Fluxgate Magnetometer (Goddard Space Flight Center). This instrument is designed to sense strength and direction of Jupiter's magnetic field very close to the planet and up to very high values. It can measure field strength up to one million gamma in each of three perpendicular directions.

The instrument will be able to continuously measure the magnetic field along the spacecraft trajectory from about 12.6 Jupiter radii to the point of closest approach. It consists of two dual-axis sensors and their electronics. Each sensor is composed of a ring core, a magnetic multivibrator, a frequency doubler and two phase-sensitive detectors. The instrument weighs .6 pounds and uses approximately .36 watts of power.

-more-

Interplanetary Solar Wind and Heliosphere

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). It determines solar wind interactions with Jupiter, including the planet's bow shock wave.

The instrument consists of a high resolution and medium resolution analyzer. It will look toward the Sun through an opening in the spacecraft dish antenna, and the solar wind will enter 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 lbs.) and uses 4 watts of power.

Jupiter's Radiation Belts, Radio Emissions 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 inside the Jovian magnetic field.

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 (MEV) particles and a three-element telescope which measures 0.4 to 10 MEV protons, and helium nuclei. If a key detector element is destroyed in space, diagnostic procedures and commands from Earth can bypass it.

-more-

For the magnetosphere of Jupiter, two new types of sensors were developed to cope with the extremely high intensities of trapped radiation. A solid-state electron current detector operating below -40°C (-40°F) measures only those electrons that generate the radio waves which reach Earth. The trapped proton detector contains a foil of thorium which undergoes nuclear fission from protons above 30 MEV, but is not sensitive to the presence of the intense electron radiation. The instrument weighs three (7.3 lbs.) 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 also will measure particles in Jupiter's 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 MEV. A medium energy telescope measures protons with energies between 3 to 22 MEV, and identifies the eight elements from helium to oxygen. The low energy telescope studies the flux of electrons between 50,000 electron volts and one MEV and protons between 50,000 electron volts and 20 MEV.

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

Jupiter's Charged Particles

Geiger Tube Telescopes (University of Iowa). This experiment measures Jupiter's 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 path.

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 enables experimenters to compare primary with secondary events in the Jovian radiation belts.

Another telescope detects low energy electrons (those above 40,000 electron volts).

The instrument can count protons with energies above 5 MEV and electrons with energies greater than 50 KEV.

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

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

Experimenters will attempt to correlate particle data with Jupiter's little understood radio signals.

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 one MEV and protons above 450 MEV. A second detector measures electrons at 100 KEV, 200 KEV and 400 KEV.

An omni-directional counter is a solid-state diode, which discriminates between minimum ionizing particles at 400 KEV and high energy protons at 1.8 MEV.

Twin dc 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 EV for electrons and 150,000 EV for protons.

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

Jovian Dust, Meteoroids and Interplanetary Dust

Asteroid-Meteoroid Detector (General Electric Company). This instrument measures the orbits of the material in the vicinity of the spacecraft.

Four non-imaging telescopes can characterize objects, ranging from asteroids down to particles with a mass of one millionth of a gram, by measuring sunlight reflected from them, the telescopes measure particle numbers, sizes, velocity and direction.

Each of its four telescopes consists of a 20-cm (8-in.) mirror, an 8.4-cm (3.3-in.) secondary mirror, coupling optics, and a photomultiplier tube. Each telescope has an 8° view cone. The four cones overlap in part, and particle distance and speed are measured by timing entry into and exit from the cones.

The instrument is highly sensitive to hard radiation of the type expected at Jupiter, and may be damaged during encounter. It weighs 3.3 kg (7.2 lbs.) and uses 2.2 watts of power.

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. In construction, the panels are something like a stainless-steel air mattress.

Each of the pressure cells 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 penetrates 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 lbs.) 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 Jupiter 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 should verify Pioneer 10 findings on: Jupiter's mass, the masses of its four large moons, the planet's polar flattening and mass of its surface layers.

Jupiter's Atmosphere, Temperature, Moons, Interplanetary Hydrogen, Helium and Dust

Ultraviolet Photometer (University of Southern California). During flyby the ultraviolet photometer will measure scattering of ultraviolet (UV) light from the Sun by Jupiter's moons in two wavelengths, one for hydrogen and one for helium.

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 lbs.) and uses 0.7 watts of power.

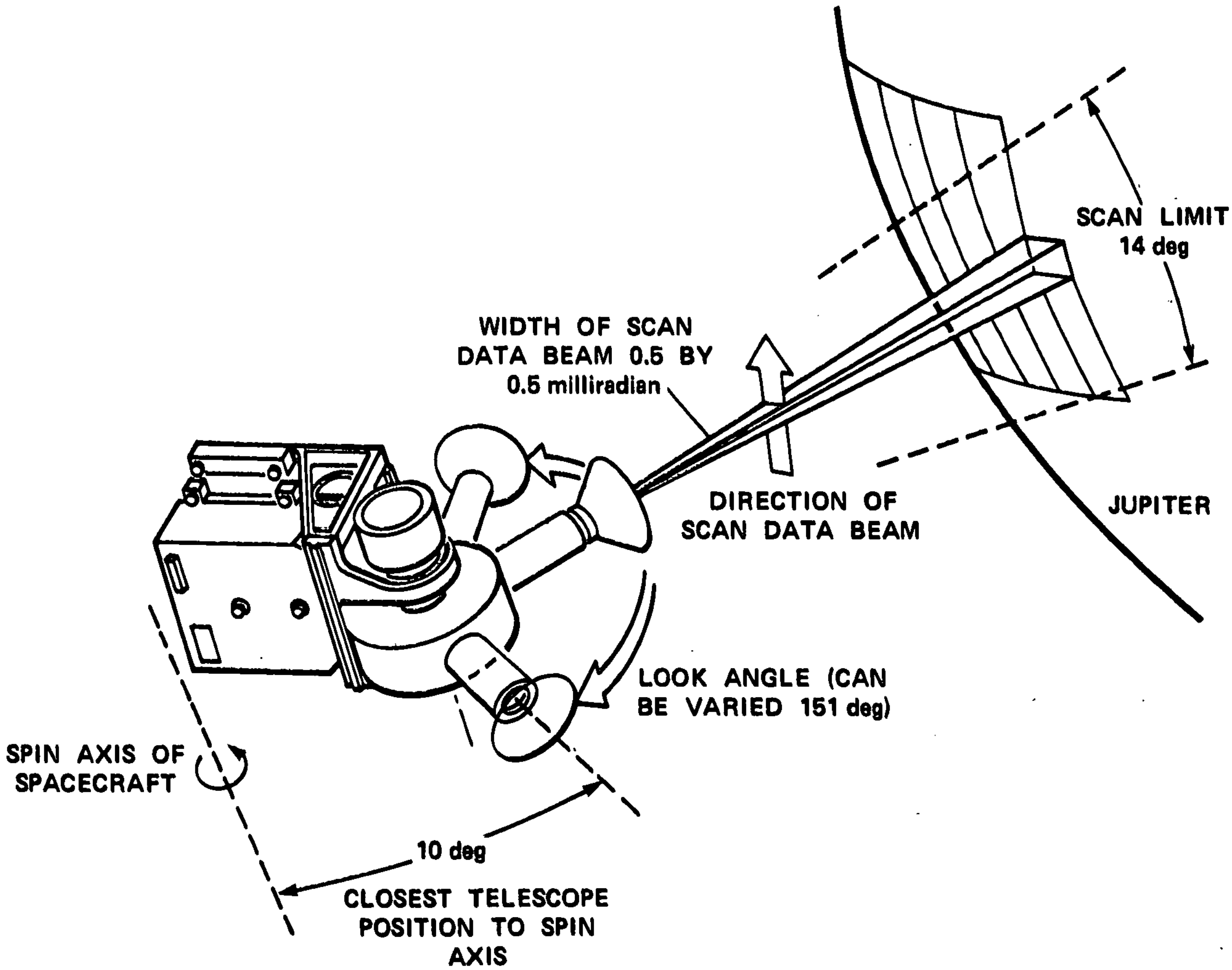
Pictures of Jupiter and Moons, the Planet's Atmosphere

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.

The instrument will take pictures of Jupiter as the spacecraft approaches 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.

-more-



SCAN LIMIT
14 deg
WIDTH OF SCAN
DATA BEAM 0.5 BY
0.5 milliradian
DIRECTION OF
SCAN DATA BEAM
JUPITER
LOOK ANGLE (CAN
BE VARIED 151 deg)
SPIN AXIS OF
SPACECRAFT
10 deg
CLOSEST TELESCOPE
POSITION TO SPIN
AXIS

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° 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.

Pictures also will be taken of Jupiter's four large moons.

Controllers can vary the viewing angle of the instrument's 8.64-cm (3.4-in.) focal length telescope by about 160° 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.

For the first pictures, the telescope will be looking almost down the spacecraft spin axis toward Jupiter. For the last pictures, close to the planet, it will be looking almost at right angles to the spin axis.

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.

These two factors mean 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 high-speed rotation of the planet and motion of the spacecraft.

Pioneer 11's record speed of nearly 110,000 mph is so fast that no pictures will be taken for the six hours of closest approach due to a severe "underlap" of spin scans.

During Jupiter flyby, experimenters also will use the instrument to study Jupiter's clouds, and to determine the nature of atmospheric gas above the clouds, and of aerosols in this gas. The instrument will measure light scattering of the Jovian satellites, to find their surface properties and atmospheres.

-more-

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 (MR) for zodiacal light measurements, a second 8 x 8 MR for non-imaging light measurements of Jupiter, and a third 0.5 x 0.5 MR for scans of the planet from which pictures will be reconstructed.

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

Jupiter's Atmosphere, Ionosphere, Temperature

Infrared Radiometer (California Institute of Technology). Experimenters will measure Jupiter's net heat energy output.

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 over the Jovian disc, and the thermal structure and chemical composition of Jupiter'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 inbound and outbound periods of about two and a half hours each. It also will measure Callisto, Ganymede and Io -- and make the first measurements of tiny Amalthea.

The instrument has a 7.2-cm (3-in.) diameter Cassegrain telescope, and the detectors in its two channels are 88-element, thin film, bi-metallic thermopiles. Its field of view is about 2,400 by 700 km (1,500 by 420 mi.) on Jupiter's cloud surface at closest approach of one Jupiter diameter. At this distance, it has a resolution of about 2,400 km (1,500 mi.)

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

Occultation Experiment (Jet Propulsion Laboratory). Passage of the spacecraft radio signal through Jupiter's atmosphere as Pioneer swings behind the planet will measure Jupiter's ionosphere, and density of the 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 Jupiter's atmosphere.

ENCOUNTER OPERATIONS

During the two weeks of Pioneer 11's near encounter with Jupiter, the team of spacecraft controllers, analysis, and scientists at Ames Research Center, and personnel of NASA's Deep Space Network (DSN) will run a three-shift, 24-hour-a-day operation.

They will send about 10,000 commands to the spacecraft -- along with the Pioneer 10 encounter, the most intensive command activity the DSN has ever handled. They will be constantly alert to analyze and recover from expected but unpredictable problems with spacecraft systems or with scientific instruments.

Their job will be complicated by the 82 minutes of round-trip communications time to Jupiter. They will wait an hour and a half between the sending of a command and verification of its execution.

The Pioneers are controlled primarily by instruction from Earth -- not by operations sequences stored in on-board computers, though five commands can be stored on board. The spacecraft also can store up to 49,152 bits of science data.

Mission planners have simplified the encounter operation.

Operations strategy is to turn on, well in advance, most spacecraft subsystems and scientific instruments in a standard operating mode, and leave them this way throughout the encounter.

If all goes well, only a few routine spacecraft operations will need to be commanded. These are: daily checks of pointing direction of the spin axis (spacecraft attitude), changes in telemetry data formats either twice or three times a day, and readjustments of spacecraft attitude on the third day after periapsis.

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Only 8 of the 12 scientific instruments will require commands. Six of the eight will need only a few commands per day. Of the other two, the infrared radiometer will require several hundred commands near periapsis to scan Jupiter's five close moons. The bulk of the 10,000-plus commands will direct the imaging photopolarimeter in scanning the planet or its moons, for pictures of polarimetry.

Many types of problems have had to be anticipated. Six major rehearsals and training tests have been held since September, involving the entire worldwide operations team.

Controllers have tested all redundant backup systems on the spacecraft. With the large amount of DSN equipment, some failures are almost certain. Rehearsals have involved: Swaps of computers in case of failure, loss of high-speed data links, and coping with the 10-minute loss of command during switch-over between DSN stations.

At Jupiter, potential problems include:

o Damage to subsystems and scientific instruments by the radiation belts.

o Passage of Pioneer through Jupiter's strong magnetic field will set up eddy currents in the spinning spacecraft, creating magnetic torques and slowing spacecraft spin somewhat.

o Dust concentrations near Jupiter may mean high-velocity particle penetrations of Pioneer and damage to subsystems.

o The four scientific instruments which do not require commands are: the ultraviolet photometer, which is "on" throughout the encounter. (Its viewing periods result from the combination of the instrument's look angle and changes in spacecraft attitude as it moves around Jupiter.)

Other noncommand instruments are: two of the four high-energy particle instruments and the meteoroid detector.

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During encounter operations, the many other uncommanded functions on the spacecraft will be monitored in several ways. Pioneer returns complete 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 (PMOC) Ames Research Center, Mountain View, Calif.

The PMOC has computing capability both for commanding the spacecraft and to interpret the data stream as it comes in from the DSN stations.

Several Ames organizations direct and support the encounter.

The Pioneer Mission Operations Team (PMOT) 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 PMOT includes the following groups:

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

o The Navigation and Maneuvers Team handles spacecraft navigation, and attitude control in space.

o 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 degrees intervals around the Earth, NASA's Deep Space Network (DSN) will support Pioneer continuously during encounter. As one spacecraft "sets" at one station, due to the Earth's rotation, it will "rise" at the next one.

The DSN maintains three highly sensitive 64-meter (210-foot) dish antennas at Goldstone, Calif.; Madrid, Spain; and Canberra, Australia. As a backup, DSN 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 stations have enough power to command Pioneer at Jupiter. Where necessary they can receive data, but at the extremely low rate of 128 bits per second (bps), compared with the 1,024 bps reception rate of the 64-m antennas.

At periapsis, there will be a 4-hour overlap between the Goldstone and Canberra 64-m stations, with both receiving this vital data. However, Goldstone loses the spacecraft about 1 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 Jupiter'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.

DSN stations will track the spacecraft on its 5-year flight to Saturn if the mission continues that long. At Saturn, round-trip communications time will be almost 3 hours.

All DSN 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 Mission Control and Computing Center (MCCC), JPL's central data processing facility at Pasadena, by NASA's Communications Network (NASCOM).

During encounter, some Ames controllers will be at the MCCC to provide a backup command capability in case of failure of high-speed data links between DSN stations and Ames.

For all of NASA's unmanned missions in deep space, Pioneers and Mariners, the DSN 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.

DSN stations relay spacecraft Doppler tracking information to the MCCC, where computers calculate orbits in support of navigation and planetary target planning. High-speed data links from all stations are capable of 4,800 bps, permitting real time transmission of all data from spacecraft to Pioneer control centers at Ames or JPL. Throughout the mission, scientific data recorded on magnetic tape will be sent from DSN stations to Ames where it will be divided into individual magnetic tapes for each experimenter.

All of NASA's networks are under the direction of the Office of Tracking and Data Acquisition, NASA Headquarters, Washington, D.C. The Jet Propulsion Laboratory manages the DSN, while the STDN facilities and NASCOM are managed by NASA's Goddard Space Flight Center, Greenbelt, Md.

The Goldstone DSN stations are operated and maintained by JPL with the assistance of the Philco-Ford Corporation.

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 (INTA).

THE SPACECRAFT

Pioneers 10 and 11 are the first spacecraft designed to travel into the outer solar system and operate there, possibly for as long as 7 years and as far from the Sun as 3.2 billion km (2 billion miles).

For these missions, the spacecraft must have extreme reliability, be of very light weight, have communications systems for extreme distances, and employ non-solar power sources.

Pioneer 11 is identical to Pioneer 10 except that a 12th onboard experiment has been added, a fluxgate magnetometer, to measure high fields very close to Jupiter. Pioneer 11 is stabilized in space like a gyroscope by its rotation, so that its scientific instruments scan a full circle 5 times a minute. Designers chose spin stabilization for its simplicity and effectiveness.

Since the orbit planes of Earth and Jupiter coincide to about one degree, the spacecraft will be in or near Earth's orbit plane (the ecliptic) throughout its flight. To maintain a known orientation in this plane, controllers regularly adjust spacecraft position so that the spin axis points constantly at Earth. The spin axis coincides with the center line of the radio beam, which also points constantly at Earth.

Spacecraft navigation is handled on Earth using two-way Doppler tracking and by angle-tracking.

For course corrections, the Pioneer propulsion system can make changes in velocity.

The spacecraft can return a maximum of 1024 data bits per second (bps) from Jupiter to the 64-m (210-ft) antennas of the Deep Space Network.

Pioneer 11 is controlled largely from the Earth rather than by sequences of commands stored in onboard computers.

Launch energy requirements to reach Jupiter are far higher than for shorter missions, so the spacecraft is very light. Pioneer 11 weighed only 270 kg (570 lbs) at launch. This included 30 kg (65 lbs) 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 Jupiter's radiation belts. In addition, key systems are redundant. (That is, two of the same components or subsystemsare provided in case one fails.) Communications, command and data return systems, propulsion electronics, thrusters and attitude sensors are largely redundant.

Virtually all spacecraft systems reflect the need to survive and return data for many years a long way from the Sun and the Earth.

Pioneer 11 Description

Pioneer's Earth-facing dish antenna is in effect the forward end of the spacecraft. Pioneer 11 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.

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 of the 12 onboard scientific experiments. However, 12.7 kg (28 lbs) of the 30 kg (65 lbs) of scientific instruments (the plasma analyzer, cosmic ray telescope, four asteroid-meteroid 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, omni-directional 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, deploying the spacecraft's nuclear electric power generator 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.

Orientation and Navigation

The spacecraft communications system also is used to orient the Pioneer in space.

Heart of the communications system is the spacecraft's fixed dish antenna. This antenna is as large as the diameter of the launch vehicle permits. It focuses the radio signal on Earth in a narrow beam.

The spacecraft spin axis is aligned with the center lines of its dish antenna and of the spacecraft radio beam. Except during the early part of the mission and course changes, all three are pointed toward Earth throughout the mission. Pioneer maintains a known attitude in space as a result of this continuous Earth point.

For navigation, analysts will use the Doppler shift in frequency of the Pioneer radio signal and angle-tracking by DSN antennas to calculate continuously the speed, distance and direction of the spacecraft from Earth. (Motion of the spacecraft away from Earth causes the frequency of the spacecraft radio signals to drop and wavelength to increase. This is known as the Doppler shift.)

Propulsion and Attitude Control

The propulsion and attitude control system provides three types of maneuvers.

- It can change velocity, thus altering course to adjust the place and time of arrival at Jupiter.

- It can change the attitude of the spacecraft in space, either to point thrusters in the right direction for velocity-change thrusts or to keep the spacecraft narrow-beam antenna pointed precisely at the Earth. Controllers will command about 150 of these Earth-point adjustments as Pioneer11 and Earth constantly change positions in space.

- The system also maintains spacecraft spin at 4.8 rpm.

Over the entire mission, the propulsion and attitude control system can make changes in spacecraft velocity totaling 720 km per hour (420 miles per hour), attitude changes totaling 1,200 degrees (almost four full rotations of the spin axis), and total spin-rate adjustments of 50 rpm. These capacities should be substantially more than needed.

The system employs six thruster nozzles which can be fired steadily or pulsed and have 0.4 to 1.4 pounds of thrust each. Electronics and attitude sensors are fully redundant.

For both attitude and velocity changes, two thruster pairs have been placed on opposite sides of the dish antenna rim. One thruster of each pair points forward, the other aft.

To change attitude, the spacecraft spin axis can be rotated in any desired direction. This is done using two nozzles, one on each side of the dish antenna. One nozzle is fired forward, one aft, in momentary thrust pulses once per spacecraft rotation. Thrusts are made at two fixed points on the circle of spacecraft rotation.

Pulses are timed by a signal which originates either from the star sensor which sees the star Canopus once per rotation, or from one of the two Sun-sensors which see the Sun once per rotation. Each pair of thrust pulses turns the spacecraft and its spin axis a few tenths of a degree, until the desired attitude is reached.

For velocity changes, the spin axis is first rotated until it points in the direction of the desired velocity change. Then two thruster nozzles, one on each side of the dish, but both facing forward or both facing aft, are fired continuously.

Flight directors command these velocity change maneuvers directly in real time. Or they can put commands for the maneuvers into the system's attitude-control storage register. Positioning of the spin axis, velocity change thrust and rotation back to Earth-point can then all take place automatically. This automatic sequence may be important at very long distances where, if Earth-point were lost, recovery of communication with the spacecraft might be difficult.

Operations to point the spacecraft high-gain antenna toward the Earth make use of the fact that the movable feed for the antenna dish can be offset one degree from the spin axis. This means that when the spin axis is slightly off exact Earth-point, signals received by the spacecraft from Earth vary up and down in strength.

An automatic system on the spacecraft is known as Conscan, changes attitude in a direction to reduce this variation in signal strength, returning the spin axis again to precise Earth-point. An onboard signal processor uses the varying radio signal to time attitude-change thrusts. Spatial reference for these maneuvers is provided by either Sun or star sights.

Earth-point can be trimmed by ground command if necessary, using variations in strength of the spacecraft radio signal as received by ground stations. This variation also is due to offset of the spacecraft antenna feed.

The spacecraft medium-gain horn is permanently offset 9 degrees to the spin axis and can also be used for Earth-point maneuvers.

To change spin rate, a third pair of thrusters, also set along the rim of the dish antenna, will be used. These thrusters are on a line tangent to the rim of the antenna (the circle of spacecraft rotation). One thruster points against the spin direction and is fired to increase spin rate; the other points with the direction of spin and is fired to reduce spin.

Thrust is provided by liquid hydrazine, which is decomposed into gas by a catalyst in the chamber of each thruster and then ejected from thruster nozzles. The hydrazine is stored in a single 42-cm (16.5-in.) diameter pressurized spherical tank. Tank and connecting lines are kept from freezing by electric heaters.

Nuclear-Electric Power

Nuclear-fueled electric power for Pioneer comes from four SNAP-19 radioisotope thermoelectric generators (RTGs), developed by the Atomic Energy Commission. These units turn heat from their nuclear power source into electricity.

Two each of these power units are located at the ends of each of the two 2.7-m (9 ft) spacecraft RTG trusses. The RTGs are located on the opposite side of the spacecraft from the experiment compartment to minimize effects of their neutron and gamma radiation on the scientific instruments. Design of experiments and spacecraft equipment has been such as to counter effects of RTG radiation.

The four RTGs provide about 140 watts at Jupiter and should provide more than 100 watts 5 years after launch. Spacecraft power requirements at Jupiter will be around 106 watts, of which 26 watts are for the scientific instruments.

The RTGs are fueled with plutonium-238. Thermoelectric converters consist of banks of thermoelectric couples surrounding the cylindrical fuel compartment, 90 for each of the four RTGs. The couples are made of lead telluride for negative elements and an alloy of tellurium, silver, germanium, and antimony for the positive elements.

Each RTG consists of a 28-cm (11-in.) cylinder with six radial fins and weighs about 14 kg (30 lbs.).

Electric power is distributed throughout the spacecraft. It goes from each RTG through one of four inverters to form a main alternating current (ac) bus. Most of this ac power is rectified to supply the main 28-volt dc bus, with excess dumped through an external heat radiator. A battery automatically carries overloads, and is recharged when power is available. The scientific instruments and the radio transmitter's traveling wave tube amplifiers receive power from the main dc bus. Most other spacecraft systems are supplied from the central transformer, which receives power from the ac bus and provides various dc output voltages.

Communications

The communications system provides for two-way communication between Earth and the spacecraft. The system is fully redundant.

The system depends on the sensitivity of the DSN's 64-m (210 ft) antennas and their receivers which can hear the very low amounts of energy sent from Pioneer at Jupiter. When used in reverse as transmitters, the 64-m antennas have such precision and radiated power (up to 400 kilowatts) that outgoing commands are still strong enough to be received when they reach the spacecraft.

The spacecraft system consists of high-gain, medium-gain, and low-gain antennas, used for both sending and receiving. The high-gain antenna uses the spacecraft's parabolic reflector dish; the medium-gain antenna is on struts at the focus of the dish. The low-gain antenna is a spiral, pointed to the rear, designed to provide communication at the few times when the aft end of the spacecraft is toward Earth.

Each antenna is always connected to one of the two spacecraft radio receivers, and the two receivers are interchangeable by command, or automatically after a certain period of inactivity, so that if one receiver fails the other can take over.

For transmitting, the high-gain antenna produces a maximum gain of 33 decibels and has a 3.3 degree beam width; the medium-gain antenna, a gain of 12 decibels and beam width of 32 degrees. Other components for transmitting are two radio transmitters and two traveling-wave-tube power amplifiers (TWTs). The TWTs weigh only 1.75 kg (3.85 lbs.) but produce 8 watts of power in S-band.

In addition to commands and data return, the communications system provides data for Doppler tracking and maintaining spacecraft Earth-point.

Communication is on S-band frequencies, uplink to the spacecraft at 2,110 and downlink at 2,292 Mhz. The system can return 1,024 data bits per second to the DSN-s 64-m dish antennas at Jupiter range.

Command System

Controllers use 222 different commands to operate the spacecraft. The command system consists of two command decoders and a command distribution unit. For reliability, two redundant command decoders are provided, and redundant circuits are provided throughout the logic of the command distribution unit.

Commands are transmitted to the spacecraft at a rate of one data bit per second. A single command message has 22 bits.

The command distribution unit routes commands to any one of 222 functions on the spacecraft. Seventy-three of these operate the experiments, the remaining 149, spacecraft systems. The science commands include moving the photometer telescope for pictures of the planet, calibrating instruments, and changing data types. Up to five commands can be stored for later execution.

If a command is not properly verified by the decoder, the command distribution unit does not act on the order, thus reducing the possibility of executing wrong commands. Commands also are verified by computer on the ground before transmission.

Data Handling

The spacecraft data system turns science and engineering information into an organized stream of data bits for radio transmission back to Earth.

The system also can store up to 49,152 data bits for later transmission to Earth. This allows for taking data faster than the spacecraft can transmit it.

System components include the digital telemetry unit, which prepares the data for transmission in one of nine data formats at one of eight bit rates of from 16 to 2,048 bits per second; the data storage unit; and the convolutional coder, which rearranges the data in sequential form that allows identification and correction of errors by computers on the ground. This coding allows higher bit rates to be retained for greater spacecraft distances without loss of accuracy.

The nine data formats are divided into science and engineering groups. The science group includes two basic science formats and three special-purpose science formats. The basic science formats each contain 192 bits, 144 of which are assigned to the scientific instruments; the remainder are for operating instructions of various kinds. One of the basic science formats is primarily for interplanetary flight, the other for Jupiter encounter.

The three special-purpose science formats transmit all 192 bits of data from only one or two instruments. This allows high data rates from one instrument such as the photopolarimeter during Jupiter picture taking, or the infrared radiometer whose principal purpose is to take a careful look at Jupiter's heat radiation just before closest approach.

There are four engineering formats, each of 192 bits. Each of the engineering formats specializes in one of the following areas: data handling, electrical, communications and orientation, and propulsion. These specialized data formats provide high bit rates during critical spacecraft events.

Short samples of science data can be inserted into engineering formats and vice versa.

The digital telemetry unit, which puts all data together, has redundant circuits for critical functions.

Timing

The digital telemetry unit contains a stable crystal-controlled clock for all spacecraft timing signals, including those for various orientation maneuvers and experiments.

Temperature Control

Temperature on the spacecraft is controlled at between -25 degrees and 40 degrees C (-10 degrees and 100 degrees F) inside the scientific instrument compartment, and at various other levels elsewhere for satisfactory operation of the spacecraft equipment.

The temperature control system must cope with gradually decreasing heating as the spacecraft moves away from the Sun. It will have a frigid period when Pioneer 11 passes through Jupiter's shadow during flyby. The system also handles heat from spacecraft nuclear electric power generators and other equipment.

The equipment compartments are insulated by multi-layered blankets of aluminized Mylar or Kapton. Temperature-responsive louvers at the bottom of the equipment compartment, opened by bi-metallic springs, allow controlled escape of excess heat. Other equipment has individual thermal insulation and is warmed by electric heaters and 12 one-watt radioisotope heaters, fueled with plutonium-238, developed by the Atomic Energy Commission.

POST ENCOUNTER SCIENCE--THE HELIOSPHERE

If its scientific instruments survive Jupiter's radiation belts, Pioneer 11 will explore intensively a new segment of the heliosphere (the atmosphere of the Sun) after encounter. The spacecraft will survey a region of space 870 million km (540 million miles) wide between the outer edge of the Asteroid Belt and the orbit of Saturn.

Pioneer also will study this region at points up to 15.6 degrees (160 million kilometers) above the ecliptic (Earth's orbit plane), far higher than measurements previously have been made.

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} millionelectron volts (MEV). (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 1,8000,000 degrees F). Near the Earth, collisions between streams of the solar wind use up about 25 percent of its energy. 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 miles) to Earth in as little as 20 minutes. Slower particle streams take one or more hours to reach Earth. Both types tend to follow the curving interplanetary magnetic field.

The positive ions from the Sun are 90 percent protons and ten percent 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. It identified sodium and aluminum for the first time, determined relative abundances or 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 miles). In addition, this stream-stream interaction also produces thermal energy so that the solar wind does not coll as expected for a simple expansion model. Present estimates indicate that the solar wind will ultimately become steady (constant speed) somewhere beyond the orbit of Jupiter, perhaps as far out as the orbit of Saturn.

The Interstellar Gas

Pioneer 11 will measure neutral helium and hydrogen. 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 percent; helium nuclei, 13 percent; nuclei of other elements, 2 percent; and high energy electrons, 1 percent.

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 out to Jupiter. 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 apparently can shut out a large part of the low energy galactic particles from the inner solar system, perhaps as far out as beyond Jupiter.

THE EXPERIMENTERS

Magnetic Fields Experiment

Instrument:	Magnetometer
Principal Investigator:	Edward J. Smith Jet Propulsion Laboratory, Pasadena, Calif.
Co-Investigators:	Palmer Dyal David S. Colburn Charles P. Sonett NASA-Ames Research Center, Mountain View, Calif. 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

Jovian Magnetic Fields Experiment

Instrument:	Flux-Gate Magnetometer
Principal Investigator:	Norman Ness NASA-Goddard Space Flight Center Greenbelt, Md.
Co-Investigator:	Mario Acuna Goddard Space Flight Center

Plasma Analyzer Experiment

Instrument:	Plasma Analyzer
Principal Investigator:	John H. Wolfe NASA-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
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Devrie Intriligator
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William C. Feldman
Los Alamos Scientific Laboratory, N.M.

Harold R. Collard
NASA-Ames Research Center

John D. Mihalov
NASA-Ames Research Center

Darrell D. McKibben
NASA-Ames Research Center

Charged Particle Composition Experiment

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 Experiment

Instrument:	Cosmic Ray Telescope
Principal Investigator:	Frank B. McDonald NASA-Goddard Space Flight Center, Greenbelt, Maryland
Co-Investigators:	William R. Webber Edmond C. Roelof University of New Hampshire, Durham
	Bonnard J. Teegarden James H. Trainor NASA-Goddard Space Flight Center

Jovian Charged Particles Experiment

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

Jovian Trapped Radiation Experiment

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

Asteroid-Meteoroid Astronomy Experiment

Instrument: Asteroid-Meteoroid Detector

Principal Investigator: Robert K. Soberman
General Electric Company,
Philadelphia Drexel University,
Philadelphia

Co-Investigators: Herbert A. Zook
NASA-Manned Spacecraft Center,
Houston, Texas

Meteoroid Detection Experiment

Instrument: Meteoroid Detector

Principal Investigator: William H. Kinard
NASA-Langley Research Center,
Hampton, Virginia

Co-Investigators: Robert L. O'Neal
Jose M. Alvarez
Donald H. Humes
NASA-Langley Research Center

Celestial Mechanics Experiment

Instrument: Pioneer 11 and the DSN

Principal Investigator: John D. Anderson
Jet Propulsion Laboratory

Co-Investigators: George W. Null
Jet Propulsion Laboratory

Ultraviolet Photometry Experiment

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 Experiment

Instrument:	Imaging Photopolarimeter
Principal Investigator:	Tom Gehrels University of Arizona, Tucson
Co-Investigators:	David L. Coffeen William Swindell Martin Tomasko Charles Belnman, Jr. Charles E. KenKnight University of Arizona
	Robert F. Hummer Santa Barbara Research Center
	Jerry Weinberg Martha Hanner Space Astronomy Laboratory, State University of New York

Jovian Infrared Thermal Structure Experiment

Instrument:	Infrared Radiometer
Principal Investigator:	Guido Munch 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, Texas

S-Band Occultation Experiment

Instrument:	The Spacecraft Radio Transmitter and the DSN
Principal Investigator:	Arvydas J. Kliore Jet Propulsion Laboratory
Co-Investigators:	Gunnar Fjeldbo Dan L. Cain Boris L. Seidel Jet Propulsion Laboratory
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Joel Sperans	Pioneer Experiment System Manager
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Harold Jaffe	Manager, Isotope Flight Systems Office

TRW Systems Group

Bernard J. O'Brien	Pioneer Project Manager

The Bendix Corp.

Walter L. Natzic	Pioneer Program Manager

PIONEER 11 CONTRACTORS

Contractor	Location	Item
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 of Electronic Memories and Magnetics Corp.	Hawthorne, Calif.	Memory Storage Units
Jet Propulsion Laboratory	Pasadena, Calif.	Helium Vector Magnetometer
Time Zero Corporation	Torrance, Calif.	Plasma Analyzer and Magnetometer Electronics
University of Chicago	Chicago, Ill.	Charged Particle Instrument
University of Iowa	Iowa City, Ia.	Geiger Tube Telescope
University of California at San Diego	San Diego, Calif.	Trapped Radiation Detector
Analog Technology Corporation	Pasadena, Calif.	Ultraviolet Photometry
Santa Barbara Research Center	Santa Barbara, Calif.	Imaging Photopolarimeter and Infrared Radiometer
General Electric Company	Philadelphia, Pa.	Asteroid/Meteoroid Detector
Teledyne Isotopes	Germantown, Md.	Radioisotope Thermoelectric Generators (RTGs)
Mound Laboratories	Miamisburg, Ohio	Radioisotope Heater Unit Capsules, RTG Fuel and Capsules

Contractor	Location	Item
Los Alamos Scientific Laboratory	Los Alamos, N.M.	RTG Fuel Discs
Bendix Corporation	Columbia, Md.	Software
General Dynamics Convair Division	San Diego, Calif.	Launch Vehicle - First and Second Stages
Thiokol Chemical Company	Elkton, Md.	Launch Vehicle - Third Stage Motor
McDonnell-Douglas Corp. Astronautics Company	Huntington Beach, Calif.	Launch Vehicle - First Stage Motor
Rockwell International Rocketdyne Division	Canoga Park, Calif.	Launch Vehicle - First Stage Motor
Pratt and Whitney Aircrfft 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 (TCXO)
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
Zerox Data Systems	El Segundo, Calif.	Computer Systems

Contractor	Location	Item
Wavecom Inc.	Chatsworth, Calif.	Diplexer Assemblies
Teledyne Microwave	Sunnyvale, Calif.	RF 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
Watkins-Johnson Co.	Palo Alto, Calif.	Traveling Wave Tube Amplifier
Texas Instruments	Dallas, Texas	Integrated Circuits
Data Products Corp.	Woodland Hills, Calif.	ADP Line Printer
Computer Communications Rnc.	Inglewood, Calif.	Communication Stations
Honeywell, Inc. Radiation Center	Lexington, Mass.	Sun Sensor Assemblies