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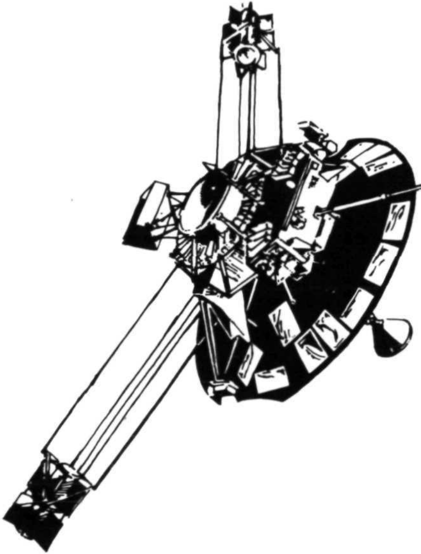


PIONEER F & G

MISSION TO JUPITER

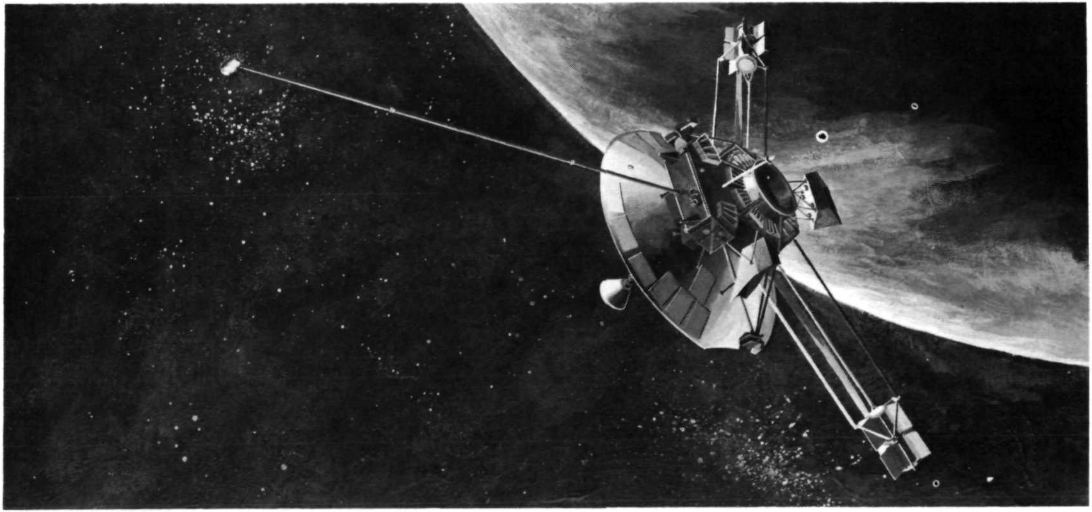
Pioneer F and G Missions

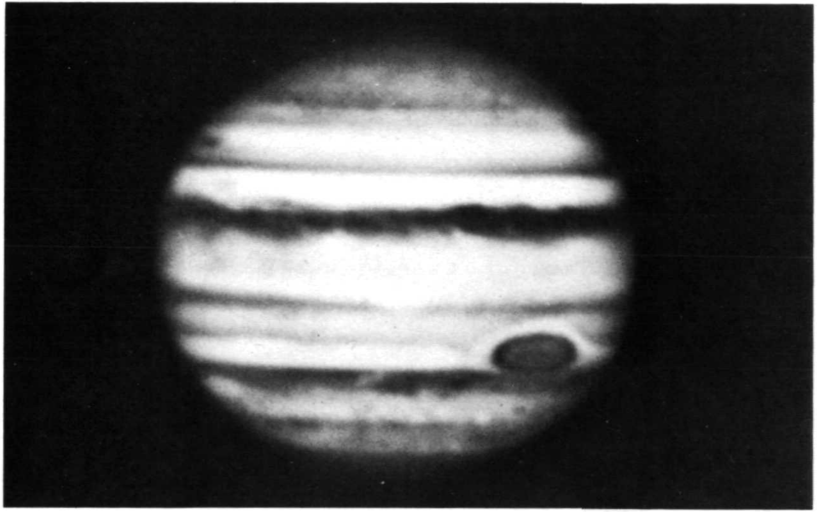
Man's first reconnaissance of the giant planet Jupiter will begin with the launch of two spacecraft, Pioneers F and G, in 1972 and 1973 on missions which are planned to last for several years.

These spacecraft are expected to be the first to go beyond the orbit of Mars, to pass through the Asteroid Belt and to use Jupiter's gravity to escape the solar system. After a trip of more than a billion miles, each craft will spend about a week swinging around Jupiter, with maximum scientific return during closest approach, to within about 90,000 miles.

The bizarre and spectacular planet Jupiter is potentially the most interesting in the solar system. Striped in yellow-orange and blue-gray like an enormous rubber ball, it has a huge red "eye" in its southern hemisphere. Its mass is more than twice that of all the other planets combined. Scientists recently have raised the possibility of life on the planet. It has 12 moons and, like a small star, appears to have its own internal heat source. Jupiter rotates at fantastic speed. A spot on its equator travels at 22,000 mph, compared to 1,000 mph for a similar spot on Earth. Because of the planet's apparent semi-liquid character, this rotation produces a large equatorial bulge.

One goal of the Pioneer F and G missions is to develop technology and experience for other missions to the outer planets, planned for the late 1970s, and also to assess hazards of deep

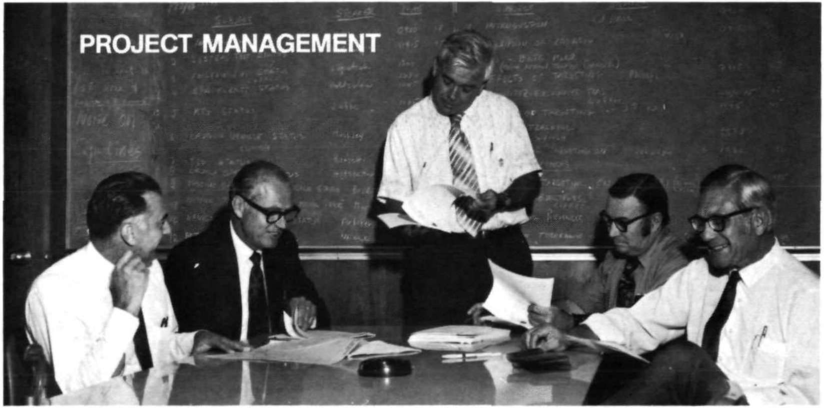




space, primarily penetration by a high-velocity rock fragment in the Asteroid Belt, and possibly crippling effects of Jupiter's radiation belts.

After the flight past Jupiter, scientific data from Pioneer F will be retrieved out to the limit of the spacecraft's communication system, 1.5 billion or more miles from the Sun.

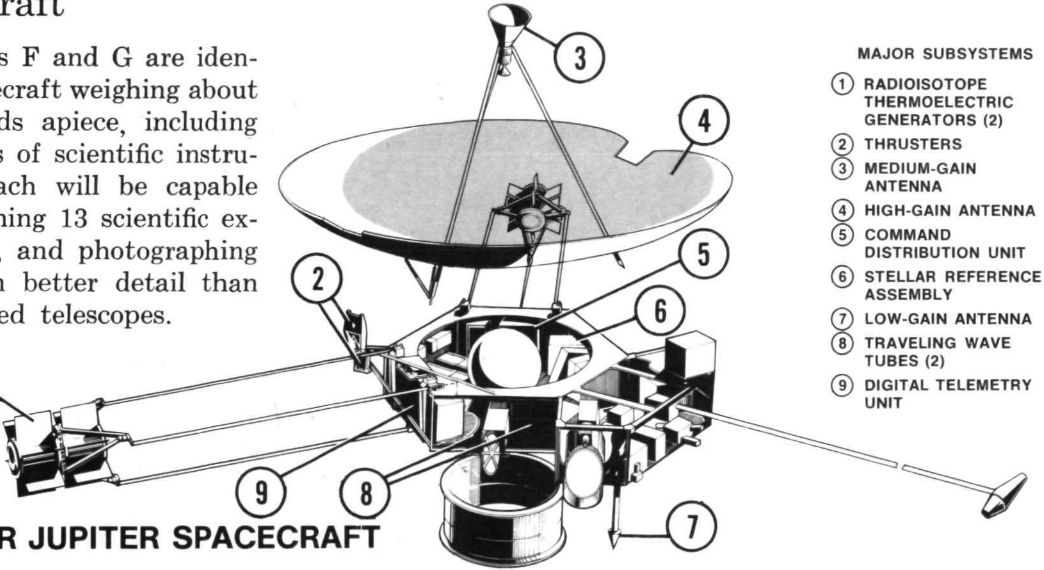
Pioneer F will be launched between February 27 and March 13, 1972, Pioneer G between April 3 and 20, 1973.



The Pioneer Project is managed by the National Aeronautics and Space Administration's Ames Research Center, Mountain View, California, for the Office of Space Science and Applications, NASA Headquarters, Washington, D.C.

Spacecraft

Pioneers F and G are identical spacecraft weighing about 570 pounds apiece, including 65 pounds of scientific instruments. Each will be capable of performing 13 scientific experiments, and photographing Jupiter in better detail than Earth-based telescopes.



MAJOR SUBSYSTEMS

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

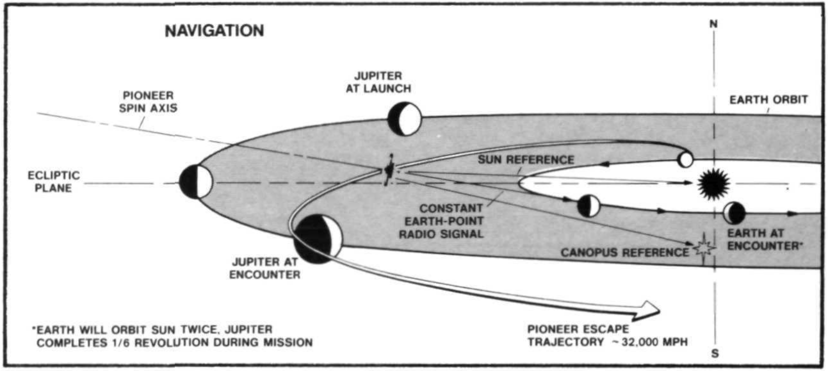
PIONEER JUPITER SPACECRAFT

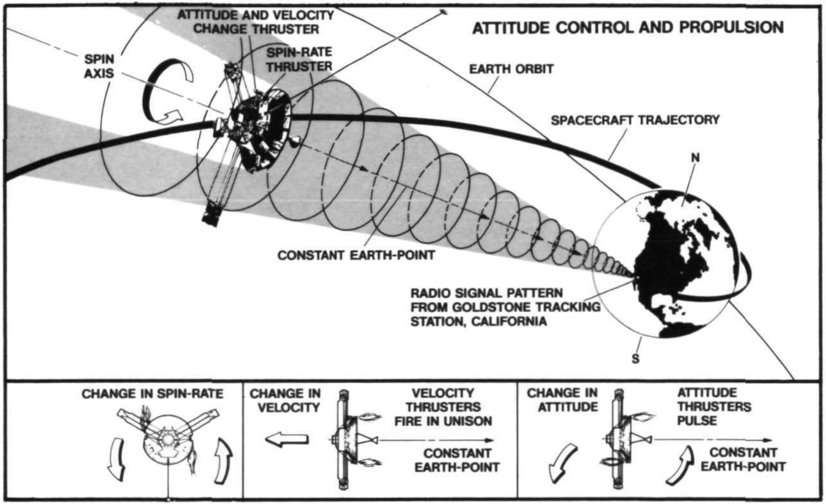
Navigation, Attitude Control, and Propulsion

For navigation, the Doppler shift in frequency of the Pioneer radio signals will be used to calculate continuously the speed, distance, and position of the spacecraft. The Doppler shift is caused by motion of the spacecraft and is measured by ground tracking.

Because the planes of the orbits of the Earth and of Jupiter almost coincide, the most efficient trajectories to Jupiter lie in the Earth's orbital plane (the ecliptic).

Pioneers F and G will be positioned in the ecliptic plane by pointing their high-gain, narrow-beam dish antennas continuously at the Earth. The gyroscopic effect of a spin of five revolutions per minute will stabilize them in this attitude. The axes of spacecraft

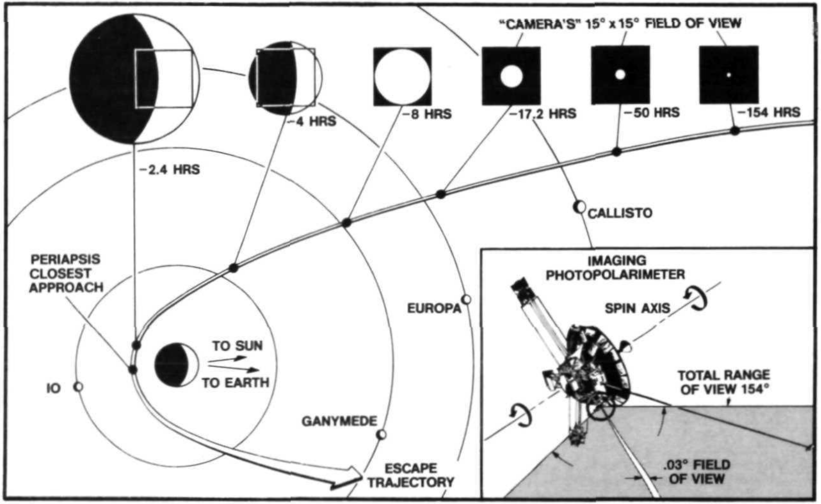




spin coincide with the axes of the radio beams of the spacecraft high-gain antennas.

Earth-point of the spacecraft high-gain antennas is maintained by a conical scan system on the spacecraft. It uses the intensity pattern of the incoming radio signals to measure amount and direction of drift of the spin axes from exact Earth-point. Drift is then automatically corrected.

Since the spacecraft rotate continuously, thrusts to change their attitudes can occur at only photopolarimeter will show the entire planet, while at closest approach (to within one planet diameter, 86,900 miles) the image will cover about 25 per cent of the planet's surface. This picture will show the terminator (the line between sunlit and dark hemispheres), which is never seen from the Earth. Scanning in strips 0.03° wide, the camera will complete a picture in from 25 to 110 minutes.

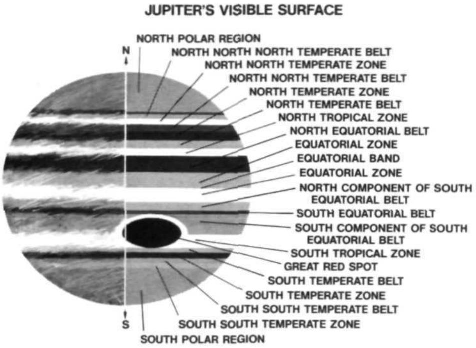


Jupiter

Jupiter has a mass some 318 times that of the Earth. Two of its 12 moons, Ganymede and Callisto, are larger than the Earth's moon.

The atmosphere is made up of hydrogen with minor amounts of methane and ammonia, probably helium, and some water. Temperatures in the upper atmosphere may be near room temperature. These conditions could produce the building blocks of life, or even life itself.

The surface is hidden by a dense layer of clouds which form bright yellow-orange and slate blue bands (atmosphere currents) around the planet. Jupiter has a huge "eye" or Red Spot, 30,000 miles long and 8,000 miles wide, which drifts very slowly about the same latitude, but floats more rapidly in longitude.



one point on the circle of rotation. Sensors will fix upon either the Sun or the star, Canopus, to provide the reference for these thrusts.

Mid-course trajectory corrections will be made by small changes in velocity of the spacecraft. Thrusters will turn the Pioneers, aligning the spin axes in the direction of the velocity change. They will then fire continuously to make the course change, and afterwards will return spin axes and antennas to Earth-point.

Communications and Data Handling

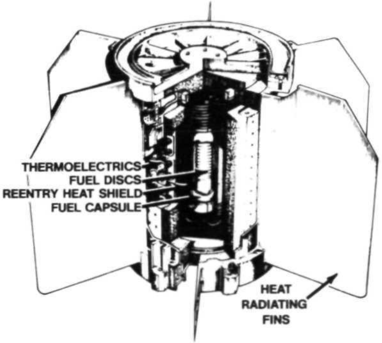
Communication equipment includes the nine-foot aluminum-honeycomb, high-gain, narrow-beam (3°) dish antenna for long distance communication, plus a wider beam (32°) medium-gain antenna. Other components are an omni-directional antenna, two receivers, and two transmitters powered by redundant traveling wave tubes.

At Jupiter, the spacecraft will return to Earth 1024 data bits per second (BPS). The spacecraft can provide a coded data stream for scientific and engineering data, at rates from 16 to 2048 BPS. While transmitting, the spacecraft can, at the same time, store up to 49,152 data bits for later transmission.

Commands from Earth are routed by the Command Distribution Unit to any one of 255 destinations on the spacecraft. Up to five commands can be stored for later execution.

Electric Power

At Jupiter and beyond, solar radiation is too weak to efficiently provide power from solar cells, so four radioisotope thermoelectric generators (RTG's) will be used. Two pairs of RTG's are mounted at the ends of two booms, 120° apart. The RTG's, devices which convert nuclear energy to electricity, provide 160 watts of power at launch with power output expected to be at least 120 watts five years later. The RTG's are fueled with Plutonium 238 dioxide, and their nuclear energy (heat) is turned into electricity by 90 thermoelectric couples.



RADIOISOTOPE THERMOELECTRIC GENERATOR

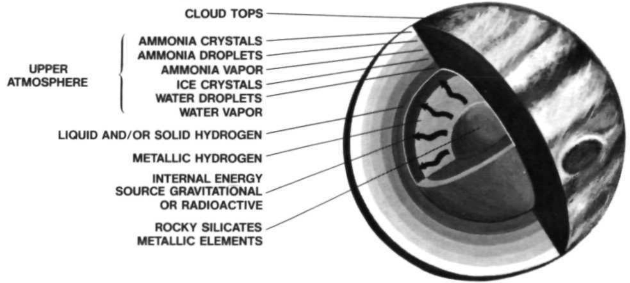
The Pictures

The photo polarimeter experiment will provide images of Jupiter.

The camera-like device will use the spin of the Pioneers to scan the planet in narrow strips in both red and blue light. Investigators will then combine these elements to make composite pictures. Superimposition of the red and blue elements will provide two-color pictures of Jupiter.

At 350,000 miles from Jupiter, a complete scan by the

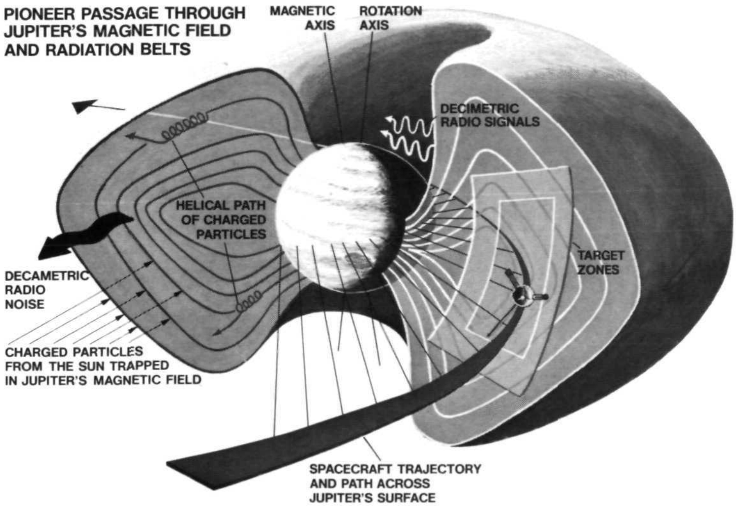
MODEL OF JUPITER INTERIOR



The planet periodically emits huge surges of radio noise. It has a magnetic field estimated to be 20 times as strong as the Earth's, and radiation belts estimated to be a million times more intense than Earth's.

Jupiter appears to radiate three times as much energy as it absorbs from the Sun, suggesting that it may have interior processes similar to those of the Sun.

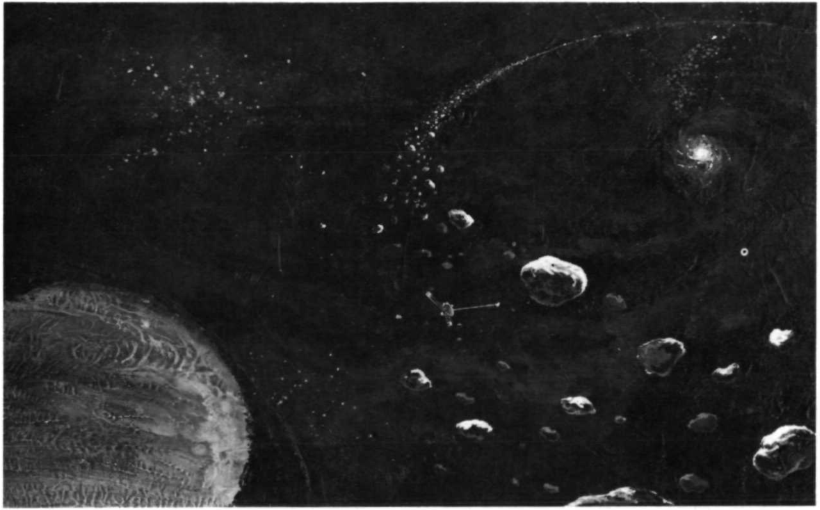
Composition of the giant planet is believed to be at least three quarters hydrogen. Earth based studies have not yet shown whether the "surface" is solid hydrogen, or slush, or liquid hydrogen. Pioneers F and G will examine the sunlit side as they approach, and the dark side as they pass behind the planet. The dark side cannot be seen from the Earth.



Asteroids

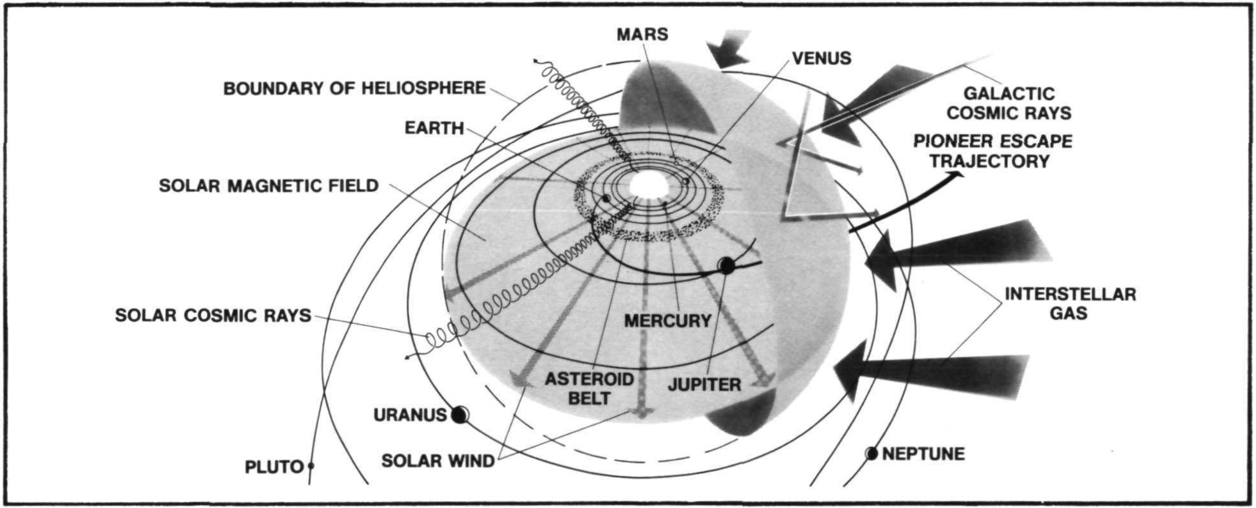
Both Pioneer spacecraft will spend from six months to a year passing through the asteroid belt which circles the Sun between the orbits of Mars and Jupiter.

There may be as many as 50,000 asteroids ranging in size from one mile in diameter to the 480-mile-diameter Ceres. In addition, there are many hundreds of thousands of still smaller asteroids and probably millions of fragments. In total, there is estimated to be enough asteroidal material to form a



small planet.

In the center of the Belt, projectile-like asteroidal material has an estimated average speed of about 30,000 mph. While size distribution of asteroidal material is not known, a collision between the spacecraft and even very small asteroids is probably unlikely. Analyses suggest that Pioneer F will approach no closer than three million miles to any known asteroid.

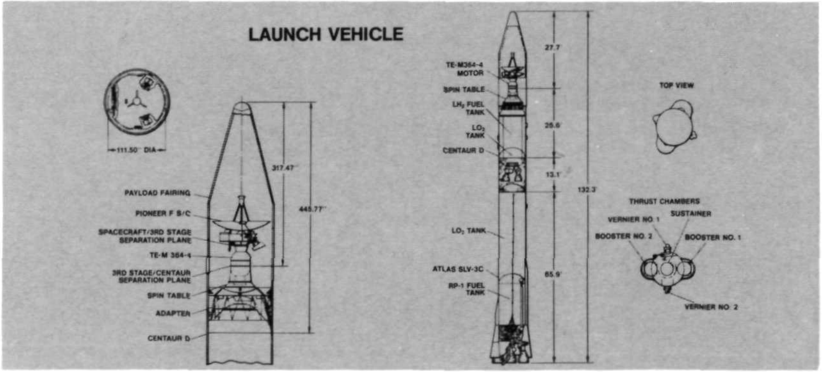

MARS
VENUS
BOUNDARY OF HELIOSPHERE
GALACTIC COSMIC RAYS
EARTH
PIONEER ESCAPE TRAJECTORY
SOLAR MAGNETIC FIELD
INTERSTELLAR GAS
SOLAR COSMIC RAYS
MERCURY
ASTEROID BELT
JUPITER
URANUS
PLUTO
SOLAR WIND
NEPTUNE

Launch

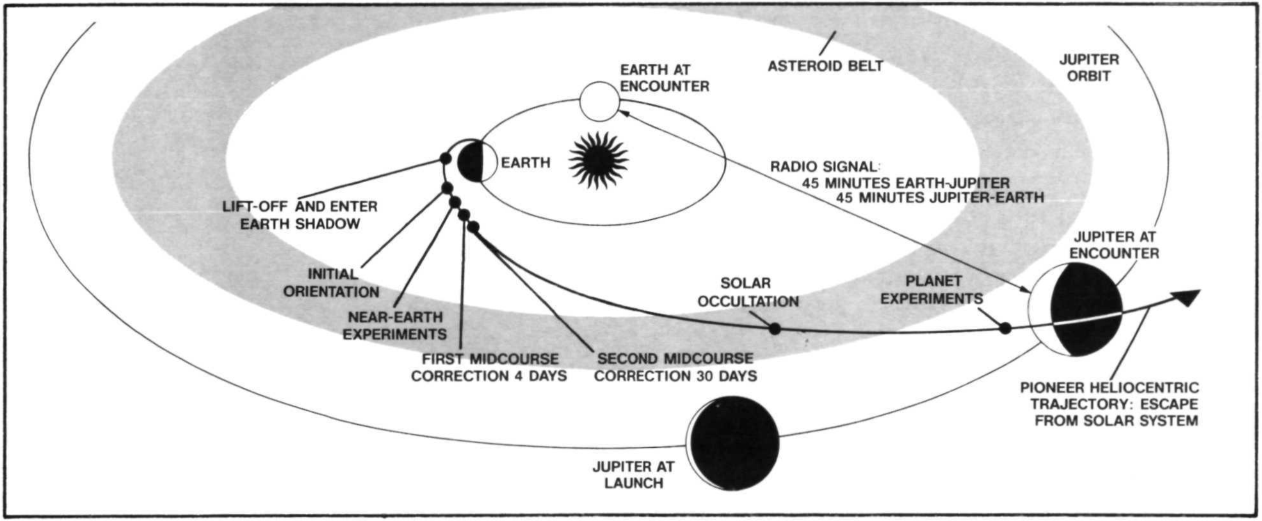
The Pioneers will be launched by Atlas-Centaur launch vehicles mounted with TE-M-364-4 solid-fuel third stages. The TE-M-364-4 has a thrust of 14,800 pounds.

An Atlas-Centaur vehicle for a Pioneer mission is about 130 feet high and 10 feet in diameter. The booster is the Atlas SLV-3C which has an overall thrust of 413,400 pounds. The upper stage is the 30-foot, Centaur vehicle with a thrust of 30,000 pounds.

Launch will be from Cape Kennedy, on a direct ascent trajectory. At third stage cut-off, the Pioneers will have a velocity of about 32,400 miles-per-hour, believed the fastest a man-made object has ever traveled in space.



Mission Events and Operations



The flights to Jupiter will take from 630 to 795 days, with the shorter trip times resulting from launches during the earlier days of the 15-day launch windows.

Mission events include: lift-off, passage through the Earth's shadow, acquisition of the spacecraft by the Deep Space Network (DSN) and first orientation to point the spacecraft antenna toward the Earth.

Experiments will be turned on one at a time, starting an hour after launch. After four hours, the spacecraft, traveling at half-a-million miles per day, will have passed out of the Earth's magnetosphere into interplanetary space.

Ground computers will constantly refine calculations of the spacecraft trajectory. Controllers will correct the trajectory at four days and again at 30 days, to precisely target the spacecraft for its encounter with Jupiter hundreds of days later.

Attitude changes to sharpen Earth-pointing of the spacecraft will be made every two or three days early in the mission and every week thereafter.

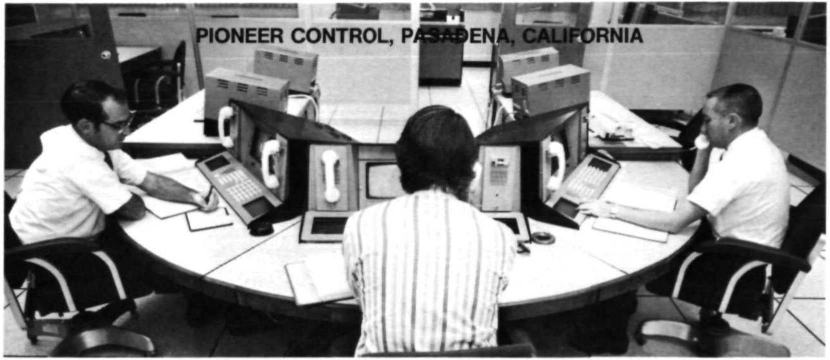
After 180 days or more, the Pioneers will begin passage through the asteroid belt. Controllers will prepare emergency procedures for possible impact by asteroid fragments.

For the week-long Jupiter fly-by, they will develop a detailed sequence of events. Commands must be precisely timed with the spacecraft's position relative to the planet. Operations will be complicated by the round trip communication time of 90 minutes due to limitations of light speed.

Hazards at planet encounter include possible crippling damage from Jupiter's radiation belts.

The Pioneers are unique among U.S. interplanetary spacecraft in being controlled almost entirely from the ground rather than by automatic, onboard systems. Controllers will be on duty 24 hours a day. During cruise, they will send around 20 commands per day, and, at encounter with Jupiter, hundreds of commands. Responses to malfunctions must be immediate.

These direct-control features of the Pioneers make them relatively low cost and adaptable for many missions.

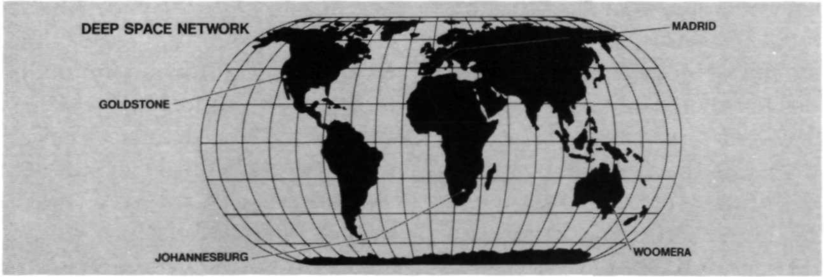

PIONEER CONTROL, PASADENA, CALIFORNIA

Data Return, Command, and Tracking

NASA's Deep Space Network (DSN), operated by the Jet Propulsion Laboratory, will track and receive data from the Pioneers. For early parts of the mission, tracking will be by the DSN's 85-foot (26-meter) antennas. Where high rates of data return are required, the powerful global net of 210-foot (64-meter) antennas of the DSN will take over. At Jupiter distance, the 85's can receive 128 bits per second (BPS), while the larger 210-foot dishes can hear 1024 BPS. The 210's will be able to retrieve spacecraft data out to about 1.5 billion miles from the Sun.

Mission Control will be at Cape Kennedy for the launch, and at the DSN's Space Flight Operations Facility (SFOF), Pasadena, California, immediately after launch and during Jupiter fly-by. During cruise, both before and after planet encounter, control will move to the Pioneer Mission Analysis Area, Ames Research Center, Mountain View, California.

Incoming telemetry data from the spacecraft will be received at the DSN stations, and immediately formatted for high-speed transmission to the SFOF computers. These computers will check for critical changes and provide data for analysis by specialists on the spacecraft, on the experiments, and on ground systems. Their analyses will be used immediately for spacecraft control. All data will also be transmitted to the Ames Research Center for detailed operational and engineering analysis and distribution to individual experimenters. Outgoing commands will be verified by the Mission Control computers and then sent to individual DSN stations for transmission to the spacecraft. The same computers will confirm spacecraft response to commands as they process incoming telemetry data.



The Experiments—What They Tell

Magnetic Fields

Magnetometer — will map the interplanetary magnetic field beyond the orbit of Mars, Jupiter's magnetic fields, and the modulation of Jupiter's magnetic fields by its inner moons.

The Interplanetary Solar Wind and the Heliosphere

Plasma Analyzer—will map the density and mechanisms of the solar wind (ions and electrons flowing out from the Sun) beyond the orbit of Mars; will determine solar wind interactions with Jupiter, including the planet's bow shock wave; and will look for the boundary at which the solar wind and solar atmosphere (the heliosphere) end and interstellar space begins.

Cosmic Rays, Jupiter's Radiation Belts and Radio Signals

Charged Particle Instrument, Cosmic Ray Telescope — These two experiments will map beyond the orbit of Mars the density, speed, direction, and mechanisms of cosmic rays (atomic nuclei) coming from the Sun and Galaxy. These instruments can distinguish whether the particles are nuclei of one or more of the ten lightest elements (helium, carbon, oxygen, etc.) and which one. They also will observe the interaction of charged particles (protons and electrons) with Jupiter and within Jupiter's radiation belts.

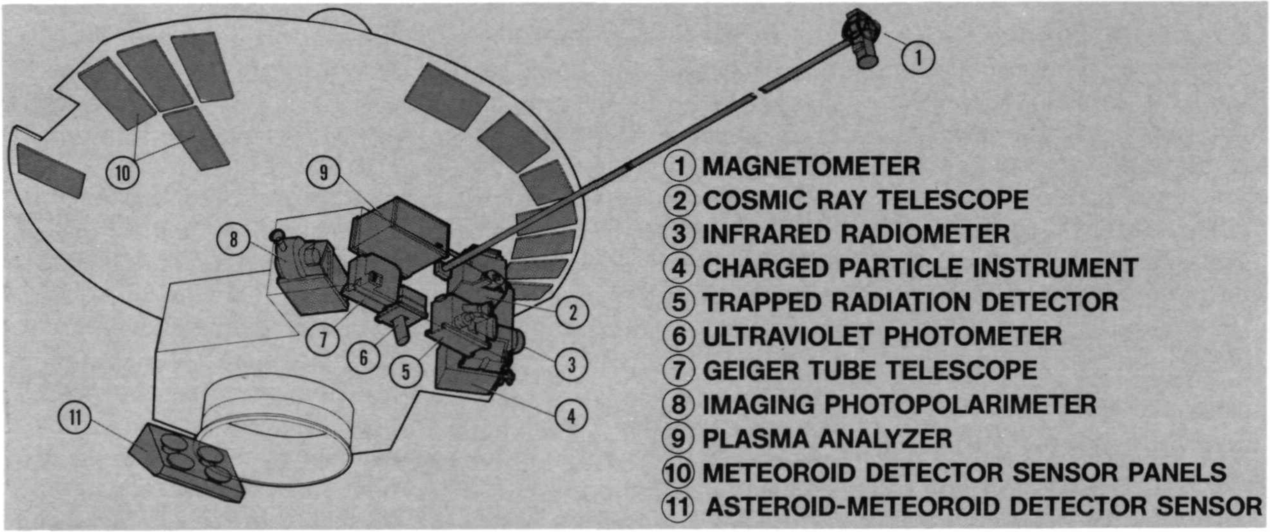
Jupiter's Charged Particles

Geiger Tube Telescope, Trapped Radiation Detector — These two experiments will attempt to learn the contents and mechanisms of Jupiter's radiation belts by measuring the intensities, energies, and distribution of energetic electrons and protons in the belts, and will study Jupiter's huge, periodic radio signals.

Asteroids, Meteoroids, Interplanetary Dust, and Celestial Mechanics

Asteroid-Meteoroid Detector — consists of four optical telescopes which can detect asteroids and meteoroids as small as 1/100,000th gram by measuring sunlight reflected from them. The instrument can measure particle concentrations, size, velocities, and direction. This will begin the first survey of meteoroid and cometary matter, and its source, beyond the orbit of Mars.

Meteoroid Detector — consists of 216 penetration cells attached to the spacecraft exterior. The cells measure impacts of particles from 1/100 millionth to 1/trillionth of a gram to gain information on concentrations of interplanetary particles.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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

Celestial Mechanics — Experimenters will use precision Doppler tracking of the Pioneer radio signals to improve calculations on: the mass of Jupiter, character of the Jovian gravity field, mass of Jupiter's 12 moons, Earth's orbit, and other solar system data.

Interplanetary Hydrogen, Helium, and Dust; The Heliosphere; Jupiter's Atmosphere, Temperatures, Auroras, and Moons

Ultraviolet Photometer — will determine the density of neutral hydrogen in interplanetary space, will attempt to find the limits of the heliosphere by measurements of hydrogen distribution, will measure the hydrogen-helium ratio in Jupiter's upper and lower atmospheres, will look for Jovian auroral activity near both poles, and for phenomena resulting from passages of the moon, Io. Measurements of light in the far ultraviolet given off by hydrogen and helium will provide data to study these phenomena.

Infrared Radiometer — will measure infrared radiation to find Jupiter's emissions of thermal energy, and its temperature distribution. These data will help tell how much internal energy Jupiter radiates, temperature of the dark hemisphere, location of hot or cold spots in the outer atmosphere, whether there is a polar ice cap of frozen methane, and the hydrogen-helium ratio in the atmosphere.

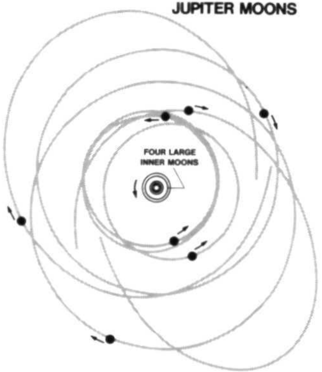
Occultation Experiment —

will measure effects of Jupiter's atmosphere on the Pioneer radio signals as the spacecraft disappears behind the planet and reappears again. These changes will show the refractive index of the planet's atmosphere, add to knowledge of its hydrogen-helium ratio, and show electron density in the ionosphere.

Imaging Photopolarimeter

—will measure intensities and polarization of visible light. Its measurements of reflected light (zodiacal light) will be used to calculate the amount, distribution, and origin (from asteroids and comets) of interplanetary dust. At Jupiter, experimenters will use the data to attempt to find the structure and composition of the Jovian clouds and atmosphere, data on the planet's thermal balance, and to retrieve close-up pictures. The instrument also will attempt to collect data on Jupiter's little-known moons.

JUPITER MOONS



Project Team

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Planetary Programs — R. S. Kraemer
Pioneer Programs Manager — F. D. Kochendorfer

NASA-AMES RESEARCH CENTER (ARC) PROJECT MANAGEMENT

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Director of Development — J. V. Foster

Pioneer Project Office
Project Manager — C. F. Hall

Project Staff
Management Control — J. R. Spahr
Mission Analysis & Launch Coordination — R. U. Hofstetter
Nuclear Power — A. C. Wilbur

Project Support
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Contracts — E. W. Kaser
Reliability & Quality Assurance — J. R. Mulkern
R. O. Convertino
Magnetics — E. J. Iufer

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D. S. Gabriel
Space Nuclear Systems Office
G. A. Newby
Isotope Power Systems Project
Branch — H. Jaffe
SNAP-19/Pioneer Project
Engineer — B. Rock

Teledyne Isotopes

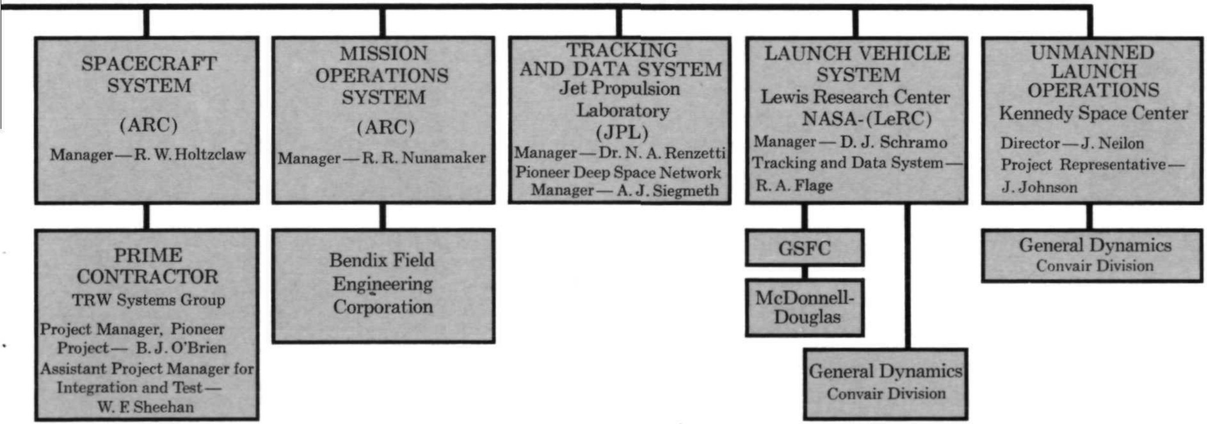
EXPERIMENTS SYSTEM

(ARC)

Manager — J. E. Lepetich

Time Zero Corporation

Santa Barbara Research Center


SPACECRAFT SYSTEM
(ARC)
Manager—R. W. Holtzclaw
MISSION OPERATIONS SYSTEM
(ARC)
Manager—R. R. Nunamaker
TRACKING AND DATA SYSTEM
Jet Propulsion Laboratory
(JPL)
Manager—Dr. N. A. Renzetti
Pioneer Deep Space Network Manager—A. J. Siegmeth
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Lewis Research Center
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Manager—D. J. Schramo
Tracking and Data System—R. A. Flage
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Kennedy Space Center
Director—J. Neilon
Project Representative—J. Johnson
PRIME CONTRACTOR
TRW Systems Group
Project Manager, Pioneer Project— B. J. O'Brien
Assistant Project Manager for Integration and Test—W. F. Sheehan
Bendix Field Engineering Corporation
GSFC
McDonnell-Douglas
General Dynamics
Convair Division
General Dynamics
Convair Division

Experiments and Experimenters

Instrument	Principal Investigator
1. Imaging Photo Polarimeter	Dr. Thomas Gehrels University of Arizona
2. Helium Vector Magnetometer	Dr. Edward J. Smith Jet Propulsion Laboratory
3. Plasma Analyzer	Dr. John H. Wolfe NASA-Ames Research Center
4. Charged Particle Instrument	Dr. John A. Simpson University of Chicago
5. Geiger-Tube Telescope	Dr. James A. Van Allen University of Iowa
6. Cosmic Ray Telescope	Dr. Frank B. McDonald NASA-Goddard Space Flight Center
7. Trapped Radiation Detector	Dr. R. Walker Fillius University of California at San Diego
8. Ultraviolet Photometer	Dr. Darrell L. Judge University of Southern California

Instrument	Principal Investigator
9. Infrared Radiometer	Dr. Guido Munch California Institute of Technology
10. Asteroid-Meteoroid Detector	Dr. Robert K. Soberman General Electric Company
11. Meteoroid Detector	William H. Kinard NASA-Langley Research Center
12. The spacecraft radio transmitter used for S-Band occultation experiment	Dr. Arvydas J. Kliore Jet Propulsion Laboratory
13. The spacecraft and the Deep Space Network Doppler radar used for celestial mechanics experiment	Dr. John D. Anderson Jet Propulsion Laboratory

Pioneer Accomplishments

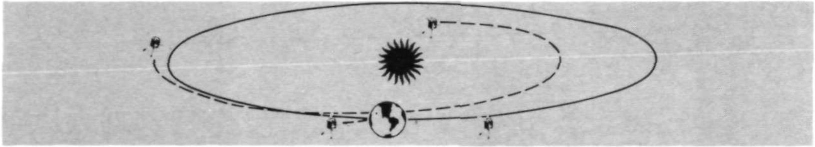
Pioneers 6 to 9 continue to operate in solar orbit, and some of their accomplishments are:

1. The most precise determination so far of characteristics of the solar atmosphere (the heliosphere).

2. Determination of solar cosmic ray and solar wind flow patterns, and magnetic and electric field mechanisms in the solar atmosphere.

3. Longest-lived operational interplanetary spacecraft (Pioneer 6, launched December 16, 1965).

4. Pioneers 6 to 9, by the end of 1971, had achieved 230 months of day-to-day tracking and data acquisition. Almost 20 billion data bits had been received, processed, analyzed, and reported to the scientific community. A total of 26,000 commands had been transmitted to these four spacecraft.



5. First use of telecommunications characteristics for spacecraft orientation.

6. First gathering of space weather data for operational use.

7. First spacecraft to use convolutional coding/sequential decoding (Pioneer 9).

8. First occultations by solar disc of man-made signal source (Pioneers 6 to 9).
9. First lunar occultation using an interplanetary spacecraft (Pioneer 7).

10. First simultaneous receipt of two spacecraft signals using a single ground antenna (Pioneers 6 and 7).

11. First particles and fields investigations of radial and spiral characteristics of solar wind and solar cosmic rays (Pioneers 6 and 7).

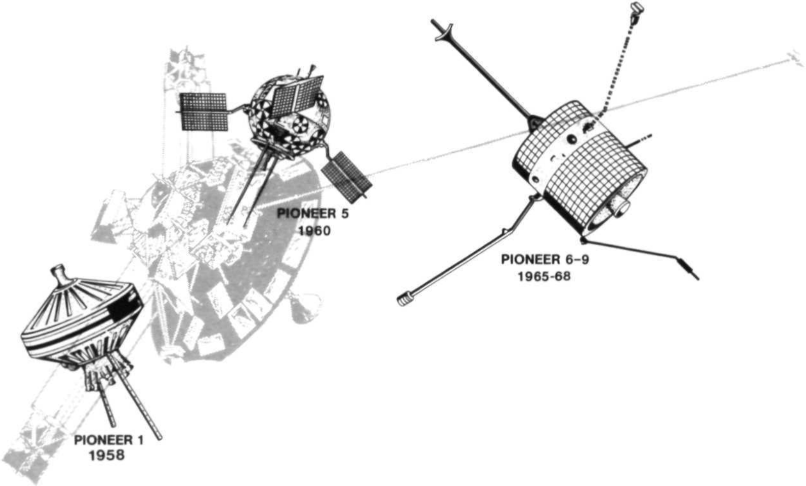
12. Most distant intelligible telemetry data from Earth, and most distant use of command functions, 170 million miles (Pioneer 6).

13. First spacecraft to define character of Earth's magnetic tail (Pioneers 6 and 7).

14. First spacecraft to use linearly polarized S-band antenna and therefore only spacecraft able to conduct Faraday rotation experiments during solar occultation (Pioneers 6 and 9).

15. First spacecraft equipped with a telecommunications range-adaptive telemetry system.

16. First major spacecraft system designed, developed, and delivered on a fixed-price incentive-fee contract.



The Pioneer spacecraft have a record of reliability and performance which makes them candidates for future deep space missions.

National Aeronautics and Space Administration
Ames Research Center
Moffett Field, California 94035

☆ GPO 791-263