Pioneer 10

On 4 December 1973, after 21 months in flight, Pioneer 10 passed by Jupiter at a distance within 130,000 km of its cloud tops. During the month before and after, instrumentation on the spacecraft made a number of scientific measurements of the Jupiter environment, thus completing one of three scientific objectives of the mission. Previously, Pioneer 10 had explored the asteroid belt and had completed the second scientific objective by determining that the belt did not present a hazard to spacecraft passing through it. The third objective, the exploration of interplanetary phenomena, started with the launch of Pioneer 10 and will not be completed until 1977 when the spacecraft nears the orbit of Uranus and the signal from the spacecraft becomes too weak to be heard at ground receivers. To accomplish these scientific objectives, Pioneer 10 carries a payload of 11 instruments weighing 33 kg and using about 24 watts of electric power. The instruments, together with the institution providing them and the names of the principal investigators, are listed in Table 1.

In addition, the S-band telecommunication signal of the spacecraft is being used by A. J. Kliore of the Jet Propulsion Laboratory to study the ionospheres of Jupiter and Io when they occult the spacecraft, and by J. D. Anderson of the Jet Propulsion Laboratory to measure the masses of Jupiter and its satellites by means of precision tracking of the spacecraft.

A sketch of Pioneer 10 is shown in Fig. 1. The spacecraft weighs 258 kg, and the diameter of the high-gain antenna reflector is 2.74 m. The spacecraft spins about an axis parallel to the axis of the reflector at 4.8 rev/min. Small thrusters using hydrazine and located at the edge of the reflector are used for making in-flight velocity adjustments, altering the spin rate, and changing the direction of the reflector so that it points toward Earth and maintains high communication data rates. Eight data rates (from 8 to 2048 bits per second) are selectable by ground command so as to optimize the data

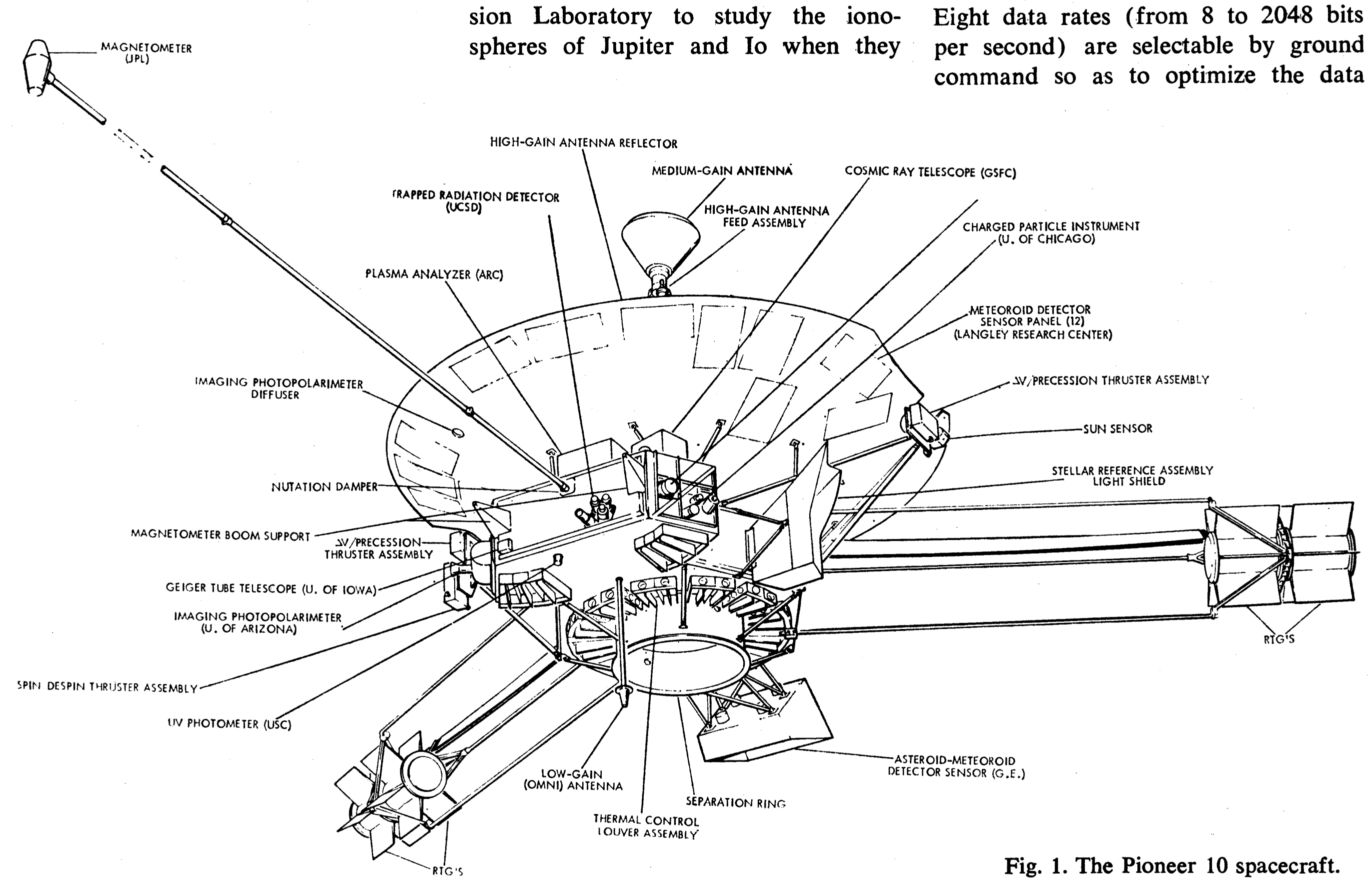


Fig. 1. The Pioneer 10 spacecraft.

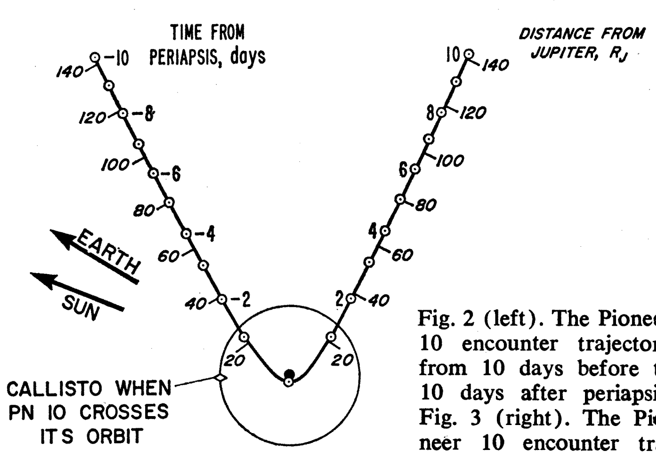
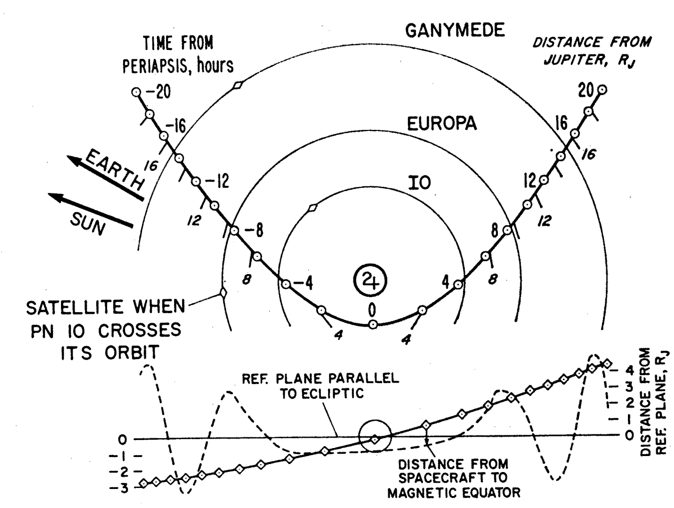


Fig. 2 (left). The Pioneer 10 encounter trajectory from 10 days before to 10 days after periapsis. Fig. 3 (right). The Pioneer 10 encounter trajectory from 20 hours before to 20 hours after periapsis.



indicative of their primarily silicon and iron composition. The outer planets have typical densities of about 1 g/cm^3, from which one concludes that they are composed primarily of the light elements. A major unknown has been the exact composition of the outer planets. Helium had been postulated on Jupiter, but the observations from Pioneer 10 were the first to verify its existence. A value for the abundance ratio of hydrogen to helium is now emerging from the data.

Another major unknown on Jupiter has been the total amount of energy radiated by the giant planet. Earth-based observations indicated that the infrared radiation emitted by the planet was much in excess of the energy it receives from the sun, implying an internal source of heat (*4*). However, these estimates were based only on measurements made on the day side of the planet, as the night side is inaccessible from the earth. The Pioneer 10 infrared radiometer has established that the excess radiation is 2 to 2.5 times the solar input and that there is no temperature change at the cloud top levels across the evening terminator of the planet. This value of the total heat released from Jupiter can now be used as a boundary value for future models of the atmosphere and the interior.

The magnetic field measurements at Jupiter will also enable us to investigate more exactly the core of the planet. Several models of the core have been proposed which include either frozen or liquid metallic hydrogen as well as a rocky core containing several tens of earth masses (*5*). Planetary dynamos are generally postulated to explain large magnetic fields such as Jupiter's and the earth's. The magnetic field observed by Pioneer 10 is essentially a dipole in nature but is considerably offset from the center of the planet. The vector moment is 4 gauss $R_J{}^3$. To be acceptable, models of the interior of Jupiter must now be able to explain the offset as well as the inclination.

The satellite Io represents a particularly interesting case in the Jupiter system. An ionosphere has been observed on Io. From the radio occultation experiment a peak electron density of about 6×10^4 cm^{-3} has been determined at an altitude of 60 to 140 km, with the ionosphere extending from near the surface to about 1000 km. The presence of an ionosphere at this altitude suggests the existence of a neutral atmosphere of about 10^{10} to 10^{12} molecules per cubic centimeter at the surface. In addition, data from the celestial mechanics experiments were used to establish a new value for the density of Io, namely 3.5 g/cm^3, close to the density of the moon and Mars. This experiment also determined that the densities of the other satellites are progressively lower in proportion to their distance from Jupiter, a situation which matches closely the distribution of planetary densities from Mercury to Jupiter.

Postencounter. All scientific instruments have survived the passage through Jupiter's radiation environment and continue to supply data on the solar wind plasma, dust particles, and cosmic rays in the unexplored region beyond Jupiter.

During its brief encounter with Jupiter, Pioneer 10 answered a number of basic questions, but at the same time exposed a variety of other puzzles—a perfectly normal situation in the process of scientific inquiry. These new questions and a more detailed description of the magnetosphere of Jupiter will be tackled by Pioneer 11 when it passes through another portion of the magnetosphere of Jupiter on 5 December 1974. Following that, a Mariner mission to Jupiter and Saturn scheduled for launch in 1977 will further extend and amplify our knowledge of Jupiter, its environment, and its satellites.

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References

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Preliminary Pioneer 10 Encounter Results from the Ames Research Center Plasma Analyzer Experiment

Abstract. *Preliminary results from the Ames Research Center plasma analyzer experiment for the Pioneer 10 Jupiter encounter indicate that Jupiter has a detached bow shock and magnetopause similar to the case at Earth but much larger in spatial extent. In contrast to Earth, Jupiter's outer magnetosphere appears to be highly inflated by thermal plasma and therefore highly responsive in size to changes in solar wind dynamic pressure.*

The Pioneer 10 Ames Research Center plasma analyzer experiment consists of a medium-resolution and a high-resolution quadrispherical electrostatic analyzer system. The medium-resolution analyzer has a 12-cm mean radius of curvature and a 1-cm plate separation. This analyzer utilizes five secondary-electron, suppressed-current collectors and attendant electrometer amplifiers. The high-resolution analyzer has a 9-cm mean radius of curvature and a 0.5-cm plate separation. The high-resolution analyzer employs 26 detectors (Bendix type CEM 4012 Channeltron) utilized in the pulse counting mode. The combined system covers the charged particle plasma regime for protons from 100 to 18,000 ev and for electrons from approximately 1 to 500 ev. The dynamic range of the experiment includes charged particle fluxes from approximately 1×10^2 to 3×10^9 cm^{-2} sec^{-1}. This experiment has not only operated flawlessly since launch on 3 March 1972 but has exceeded expectations with respect to sensitivity, resolution, dynamic range, and stability. The preliminary Jupiter results presented here are based on the real time data obtained during the Pioneer 10 Jupiter encounter. These data consisted of approximately one complete sample of the solar wind parameters taken at approximately 45-minute intervals so that the times [ground-received times (GRT)] and distances reported here are only approximate.

The first indication of the interaction of the solar wind with Jupiter occurred at approximately 2030 U.T., 26 November 1973, when the Pioneer 10 spacecraft was inbound at a planet center distance of 109 Jovian radii (R_J). At this time the solar wind bulk speed discontinuously decreased from 420 to approximately 250 km sec^{-1}, the temperature increased from 1×10^4 °K to over 10^6 °K, the density increased by a factor of 3 from approximately 0.03 to 0.1 proton per cubic centimeter, and the flow direction shifted from a direction roughly from the sun to a very large angle (by at least 40°) with respect to the Jupiter-sun line. This rather well-defined tran-