Table 1. Instrumentation on Pioneer 10.

Instrument	Institution	Principal investigator
Helium vector magnetometer	Jet Propulsion Laboratory (JPL)	E. J. Smith
Plasma analyzer	Ames Research Center (ARC)	J. H. Wolfe
Charged-particle detector	University of Chicago	J. A. Simpson
Geiger-tube telescope	University of Iowa	J. A. Van Allen
Cosmic-ray telescope	Goddard Research Center (GSFC)	F. B. McDonald
Trapped radiation detector	University of California, San Diego (UCSD)	R. W. Fillius
Ultraviolet photometer	University of Southern California (USC)	D. L. Judge
Imaging photopolarimeter	University of Arizona	T. Gehrels
Infrared radiometer	California Institute of Technology	G. Münch
Asteroid-meteoroid detector	General Electric Company (G.E.)	R. K. Soberman
Meteoroid detector	Langley Research Center	W. H. Kinard

rate with respect to distance from Earth. During the Jupiter encounter the bit rate was 1024 bits per second. Electrical power is supplied by four radioisotope thermoelectric generators (RTG) located at the end of two truss works extending from the body of the spacecraft. A long boom extending from the scientific-instrument compartment supports the magnetometer sensor.

The projection of the Pioneer 10 trajectory into a plane parallel to the ecliptic and passing through the center of Jupiter is shown in Figs. 2 and 3. Figure 3 also shows the distance of the spacecraft above or below this plane.

Measurements by the Pioneer 10 magnetometer indicate that the magnetic equator is at an angle of 15° to the geometric equator. Since Jupiter rotates about once every 10 hours, the magnetic equator wobbles up and down relative to the spacecraft with a 10-hour period. The distance of the spacecraft from the magnetic axis is also shown in Fig. 3. During the passage through the Jovian radiation belts, spacecraft equipment was subjected to a severe radiation environment. However, none of the equipment suffered any damage; minor changes in performance believed to result from the radiation were a 2 percent change in bus voltage and current, a 3 to 10 percent change in currents for the communication power amplifier, and a change of 3 parts in 10^6 in the frequency of the on-board crystal oscillators. In general, the performance of this equipment is returning to normal since the passage through the radiation belts.

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Pioneer 10 Mission: Summary of Scientific Results from the Encounter with Jupiter

Pioneer 10 has made the first direct exploration of space beyond the orbit of Mars. The mission had three objectives: to investigate the interplanetary medium, to study the asteroid belt, and to make the first in situ measurements of the near environment of Jupiter. The third objective is critical to the future exploration of the outer planets. Spacecraft are planned which will use Jupiter's gravitational field for acceleration to the outer planets. Thus, it is essential to know the trapped radiation environment of Jupiter through which the spacecraft must pass. The encounter trajectory of Pioneer 10 was selected to carry the spacecraft through the heart of the trapped radiation zone. The following paragraphs provide a summary of the results of the Pioneer 10 encounter. The interplanetary results have been reported elsewhere (*1*). Most of this information was drawn from the accompanying 14 reports by the investigators.

Magnetosphere and radiation environment. The presence of a strong magnetic field at Jupiter has been deduced from earth-based observations of intense radio emissions from the planet dating back to 1955. The observed decimetric radio emissions from Jupiter were attributed to synchrotron radiation from relativistic electrons trapped in Jupiter's magnetic field. Synchrotron radiation provides information only on the combined effect of the electron energy flux and the planetary magnetic field. It does not provide separable data on either, nor does it provide information on protons or nonrelativistic particles of either species. The experiments on board Pioneer 10 (*2*) were therefore specifically chosen to measure each of these important parameters individually.

Pioneer 10 did, in fact, measure a strong magnetic field of approximately 4 gauss, and found that there is a magnetosphere populated by extremely high energy electrons and protons and a thermal plasma. The Jovian bow shock was encountered first near 108 to 109 Jupiter radii (R_J). The magnetosheath was observed at 96 R_J and then again at 50 R_J. On the outbound pass beyond Jupiter the magnetosheath and bow shock passed back and forth over the spacecraft. The spacecraft entered the magnetosphere at a sun-planet-spacecraft angle of 35° and exited near 100°. The responsiveness of the magnetosphere to pressure changes in the solar wind has led several investigators to postulate that it is highly inflated with thermal plasma.

The high energy trapped radiation detectors observed energetic electron precursors of the magnetosphere at 360 R_J from the planet. Inside the magnetosphere a flat, disklike particle distribution was observed. The disk appeared to be modulated by the tilted magnetic field with a 10-hour period, which corresponds to the rotational period of the planet. Stable particle trapping, similar to that observed at the earth, was detected inside approximately 20 R_J. Within this boundary, the peak fluxes were 5×10^8 cm^{-2} sec^{-1} for electrons with energies greater than 3 Mev and 10^7 cm^{-2} sec^{-1} for electrons with energies greater than 50 Mev. The flux of protons with energies greater than 30 Mev was approximately 4×10^6 cm^{-2} sec^{-1}.

The magnetic field measurements imply that the dipole is inclined at approximately 15° to Jupiter's axis of rotation. It is offset about 0.1 R_J north of the equatorial plane and approximately 0.2 R_J toward longtitude 170°. This moment represents a surface field between 2.3 and 11.7 gauss, compared to a field of 0.3 to 0.6 gauss on the earth. The moment is approximately half that determined by radio astronomical observations (*3*).

Jupiter and satellites. The properties of the outer planets differ in several aspects from those of the terrestrial planets. One of the major differences is in density. Typically, the terrestrial planets have densities of about 5 g/cm^3,

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

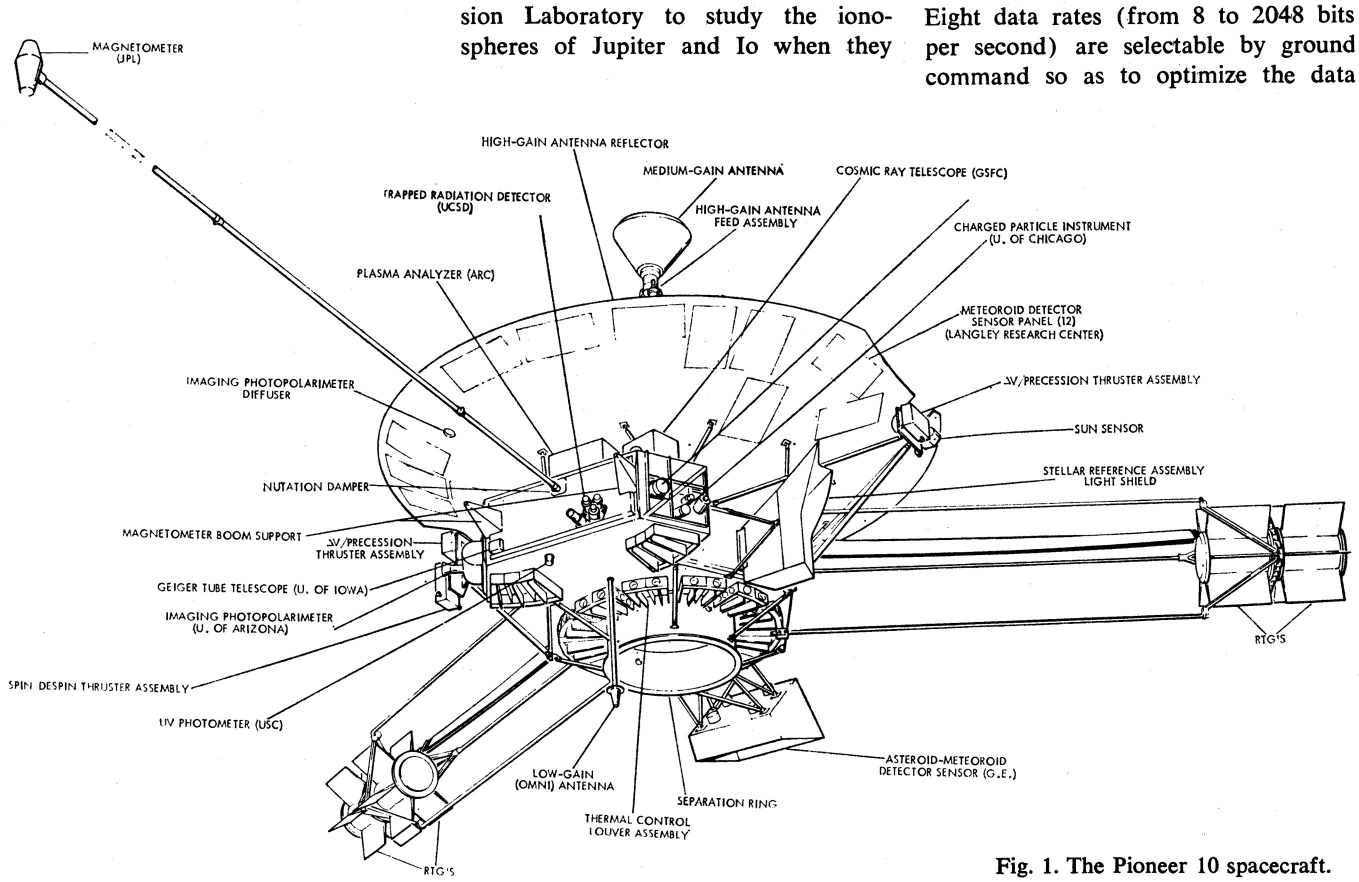

Fig. 1. The Pioneer 10 spacecraft.

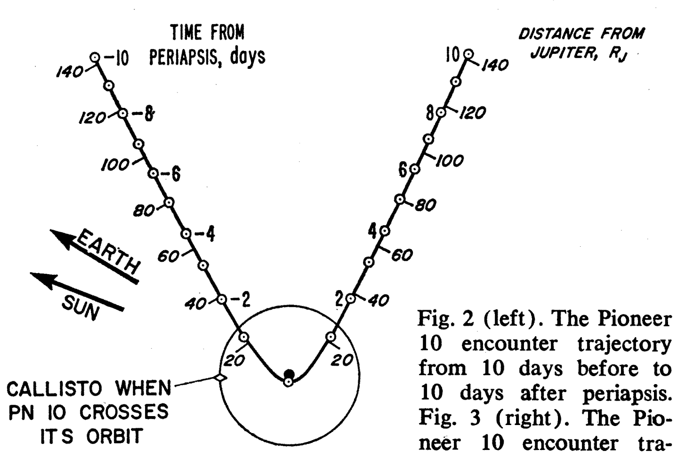

Fig. 2 (left). The Pioneer 10 encounter trajectory from 10 days before to 10 days after periapsis. Fig. 3 (right). The Pioneer 10 encounter trajectory from 20 hours before to 20 hours after periapsis.