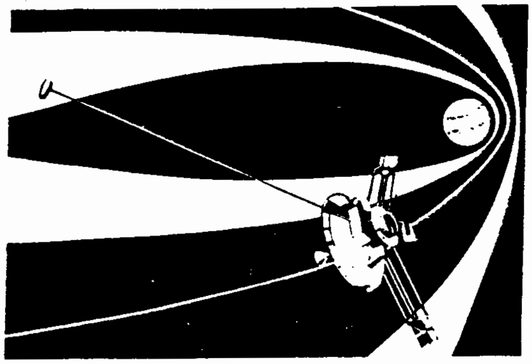
PROJECT MANAGEMENT: NASA AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA



A. J. Siegmeth

pioneer / jupiter

PIONEER 10 launched 3 MARCH 1972
PIONEER 11 launched 6 APRIL 1973

STATUS BULLETIN

No. 1 *Published by: Pioneer Project Support Office, Jet Propulsion Laboratory* 27 November 1973

PIONEER 10 APPROACHES JUPITER

The culmination of the dramatic voyage of the first of the two Jupiter-bound Pioneers will be Pioneer 10's arrival at the largest planet of the solar system. The far encounter phase of this mission started on 4 November 1973; the support operation began the near encounter phase on 26 November 1973. The near encounter activities will end on 10 December and the far encounter exit activity will end on 4 January 1974. The spacecraft's closest range toward Jupiter, the periapsis of approximately 140,000 km, will be reached on 4 December 1973 at 02:26 GMT (in Pacific Standard Time: 3 December, 6:24 pm). It is expected that, during the near encounter phase of the Pioneer 10 mission, the on-board observations will surpass the resolution of Earth-based sightings and measurements. Until now the only source of our knowledge of Jupiter's mysteries was based on pictures and data collected by astronomical observatories.

LATEST EVENTS SUMMARY – PIONEER 10

On 25 November 1973 at 4:00 pm Pacific Standard Time:

Range		802.1 million km
	vs Earth	
Velocity		39.3 km/sec
Range		749.5 million km
	vs Sun	
Velocity		9.9 km/sec
Range		8.5 million km
	vs Jupiter	
Velocity		10.12 km/sec

Data returned to active experiments: As planned

Jupiter Images: Approximately 35 colored far encounter images have been obtained. After picture data processing, the scientific investigators were pleased with the improved resolution of belt images.

Trajectory: During October, Jupiter took over from the Sun the role of the gravitational center body for Pioneer 10. This spacecraft cruised for 18 months in an elliptical solar orbit, which was changed by Jupiter into a hyperbolic trajectory. Before Jupiter's influence was observed, the Pioneer 10 cruising velocity vs the Sun was 9.5 km/sec. At the periapsis, the velocity vs the planet will be 36.4 km/sec. This will be the fastest speed ever achieved by a manmade object. Jupiter's orbit velocity relative to the Sun is 13.8 km/sec. Pioneer 10 passed the trajectories of the 7 Jovian outer moons.

Expected Events: Bowshock Passage: Earliest – 25 November '73
Latest – 1 December '73

SPACECRAFT DESCRIPTION

The main features of the spacecraft and the locations of the on-board instruments are shown on Figure 1. Measured from its farthest ends, from the horn of its medium-gain antenna to the tip of its omnidirectional antenna, Pioneer 10 is 2.9 meters (9½ feet) long. Its widest cross-wise dimension, exclusive of booms, is the 2.7-meter (9-foot) diameter high-gain antenna. Pioneer weighs 270 kilograms (570 pounds).

The spacecraft carries 11 instruments that gather data on atomic particle and other radiation, magnetic fields, temperatures, and meteoroids, and on chemical elements. In addition, two experiments will be carried out using the spacecraft and its communications system. One will help to refine estimates of Jupiter's, and perhaps Io's, atmospheric densities. The other will add to knowledge about Jupiter's mass, distance from Earth, and orbit around the Sun. Pioneer's electronic imaging system will telecast to Earth the first close-ups of Jupiter.

Pioneer 10 is the first NASA spacecraft to draw its power entirely from nuclear-fueled generators. It has four radioisotope thermoelectric generators that turn heat from decaying plutonium 238 into electricity. The nuclear fuel is adequate to continue to supply more than 100 watts of power five years after launch.

Pioneer carries at least one item that no previous unmanned spacecraft has had. Considering that Pioneer will leave the solar system and the possibility, however remote, that it might be captured by intelligent beings of another planetary system, scientists attached a special plaque to Pioneer 10. Diagrams, sketches, and binary numbers etched into a gold-anodized aluminum plaque indicate when, where, and by what kind of creatures Pioneer 10 was launched.

TRACKING DATA ACQUISITION AND COMPUTING SUPPORT

During the near encounter phase, the three 64-meter diameter antennas augmented when necessary with 26-meter antenna stations of Deep Space Network, will maintain a continuous two-way radio link.

The Pioneer 10 radio signals, traveling at the speed of light, will take 45 minutes to span the distance from Jupiter. This time span means that commands to Pioneer must have a lead time of 45 minutes and that any information requested from Pioneer takes 1½ hours to obtain.

The digital telemetry data acquired by the Deep Space Stations and the digital command data controlling the uplink transmitters are processed by the facilities of JPL's Mission Control and Computing Center (MCCC). This center is also processing the precision two-way doppler data necessary for the navigation function. The MCCC interfaces with and supports the Pioneer Mission Operations Center and Mission Control Center located at Ames Research Center (ARC) Moffett Field, California. The Pioneer Project controls all Pioneer Missions from ARC. The MCCC maintains and operates a Pioneer Mission Support Area (PMSA) at JPL. This PMSA is used as a backup facility of the Operations and Control Center of ARC, and provides additional real-time visibility of spacecraft operations.

During the near encounter phase, the three DSN 64-meter antenna stations plan to maintain continuous 1024 bps telemetry, along with the two newly completed 64-meter stations: DSS 43 Canberra in Australia and DSS 63 in Madrid, Spain. These stations will share joint operations with DSS 14 at Goldstone, which has been in operation since 1966, thus DSN has now an advanced capability to maintain a continuous telemetry with bit rates increased by a factor of ten.

During the 60-day long Jupiter encounter period by Pioneer 10, starting on 4 November 1973 and ending on 4 January 1974, the Project Mission Operations Team plans to transmit 15,000 timed commands to the spacecraft to operate all on-board instruments and to maintain the spacecraft housekeeping functions. One group of these commands is used to verify the operational characteristics of all spacecraft subsystem to aid in ensuring a reliable operation during the flyby. Special command sequences will also be sent to ensure uninterrupted telemetry during contingency conditions.

A large part of the timed commands is transmitted to the Imaging Photo-Polarimeter (IDP) instrument. This device will acquire the first Jupiter images ever made from a spacecraft. The IPP instrument includes an optical telescope that is positioned by a stepping motor coordinated with movement about the spacecraft's free-space spin axis. The spacecraft's rotational movement of the telescope generates the horizontal picture lines, and the stepping capability achieves vertical scanning. The imaging aperture is 0.5 x 0.5 milliradian. The project plan is to acquire approximately 300 Jupiter images during the near encounter phase. During the same period, 125 photo polarimetry observations will be made.

To make the ground based, coherent tracking equipment compatible with the high doppler rates to be experienced during the flyby of the largest planet, DSN has equipped DSS 14 at Goldstone and DSS 43 at Canberra with digitally controlled oscillators (DCO). These devices can be manually preprogrammed to frequency-ramp the S-band uplink during large doppler frequency variations. This technique minimizes the loop stress and thus improves lock reliability of the spacecraft's and DSN's phase-locked loop tracking receivers. In addition, triangular frequency ramps of the coherent uplink make possible direct spacecraft versus Deep Space Station range measurements. Three-way precision doppler methods will be also used to compensate for tracking uncertainties caused by ephemeris errors of Jupiter's moons.

For the past twelve months, JPL management has improved the overall reliability of its Ground Data System facilities. Most of the existing subsystems have backup units available in case of an operational subsystem failure.

During the first ten months of the Pioneer 10 mission, the Pioneer Project's Mission Operations and Control Team was responsible for operation of the spacecraft's on-board instruments in all required modes and configurations. The team noted that, if the Pioneer 10 was to function effectively during the Jovian encounter, the reliability of the command function had to be improved. From a study of the mission sequence of events, the team estimated that, during the 4 November '73 to 4 January '74 encounter period, the Project would have to transmit at least 15,000 timed commands to the spacecraft. Most of these commands would be necessary to operate the imaging photo polarimeter instrument regularly to acquire several hundred Jupiter and satellite images and to obtain polarimetry measurements.

During the Spring of 1973, under the guidance of E. Pounder, a special study team was established with the objective of making a detailed reliability analysis of the Ground Data System's Command System. Based on this team's recommendations, DSN and MCCC made hardware, software, and procedural improvements. In addition JPL's Pioneer Support Team was instrumental in analyzing the end-to-end performance characteristics of the command function. Because the Pioneer 10 mission is controlled from the Pioneer PMOC/PMCCC located at Ames Research Center and all commands are transmitted from this facility, an extensive systems engineering effort was expanded to ensure the highest command reliability achievable between the command operator's input typewriter and the spacecraft. After all improvements were implemented, all facilities of the Ground Data System participated in an intensive testing and training program. After completion of 46 systems tests encompassing 510 test hours, all elements of the Ground Data System demonstrated that they were ready to support the 60-day long Pioneer 10 encounter event.

During the far encounter entrance phase, DSN and MCCC together with the Project's Control Center at ARC successfully conducted, between 5 November and 20 November, the highly sensitive time command sequences to Pioneer 10 (over a 123-hour period). Only one interruption occurred in the scheduled command time blocks (on 9 November '73) when an equipment failure at DSS 43 interrupted the command sequence. At this time, the command capability was restored in 20 minutes. It should be mentioned that, during the first half of 1973 (before the command reliability improvements were implemented), the command system had a mean time to failure of 25 hours and a mean time to restore operations of 16 minutes.

The world-wide facilities of the Ground Data System are engineered, maintained, and operated by more than 2,000 JPL and contractor employees. All personnel engaged in the preparations and operation of the first close exploration of Jupiter have demonstrated excellent cooperation and team spirit necessary to ensure the best Jupiter flyby support.

During the past two weeks, the Pioneer Project completed acquisition of numerous far encounter Jupiter and satellite images, tested the spacecraft subsystems thoroughly, and made contingency preparations.

Figure 2 displays the Pioneers 6,7,8,9,10, and 11 locations including the Mariner 10 location at the Pioneer 10 Jupiter encounter. Pioneers 6,7,8, and 9 are still active, and their total lifetime is now 22 years. They are orbiting the Sun in the vicinity of Earth's orbit.

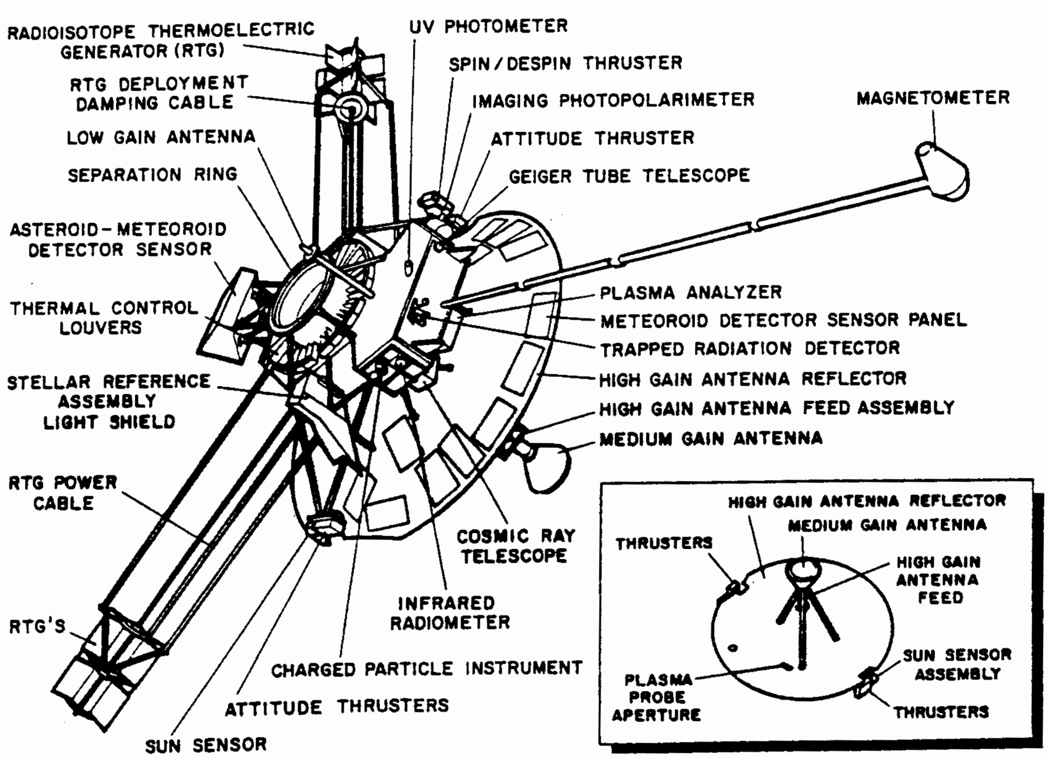


Figure 1. Pioneer/Jupiter Spacecraft

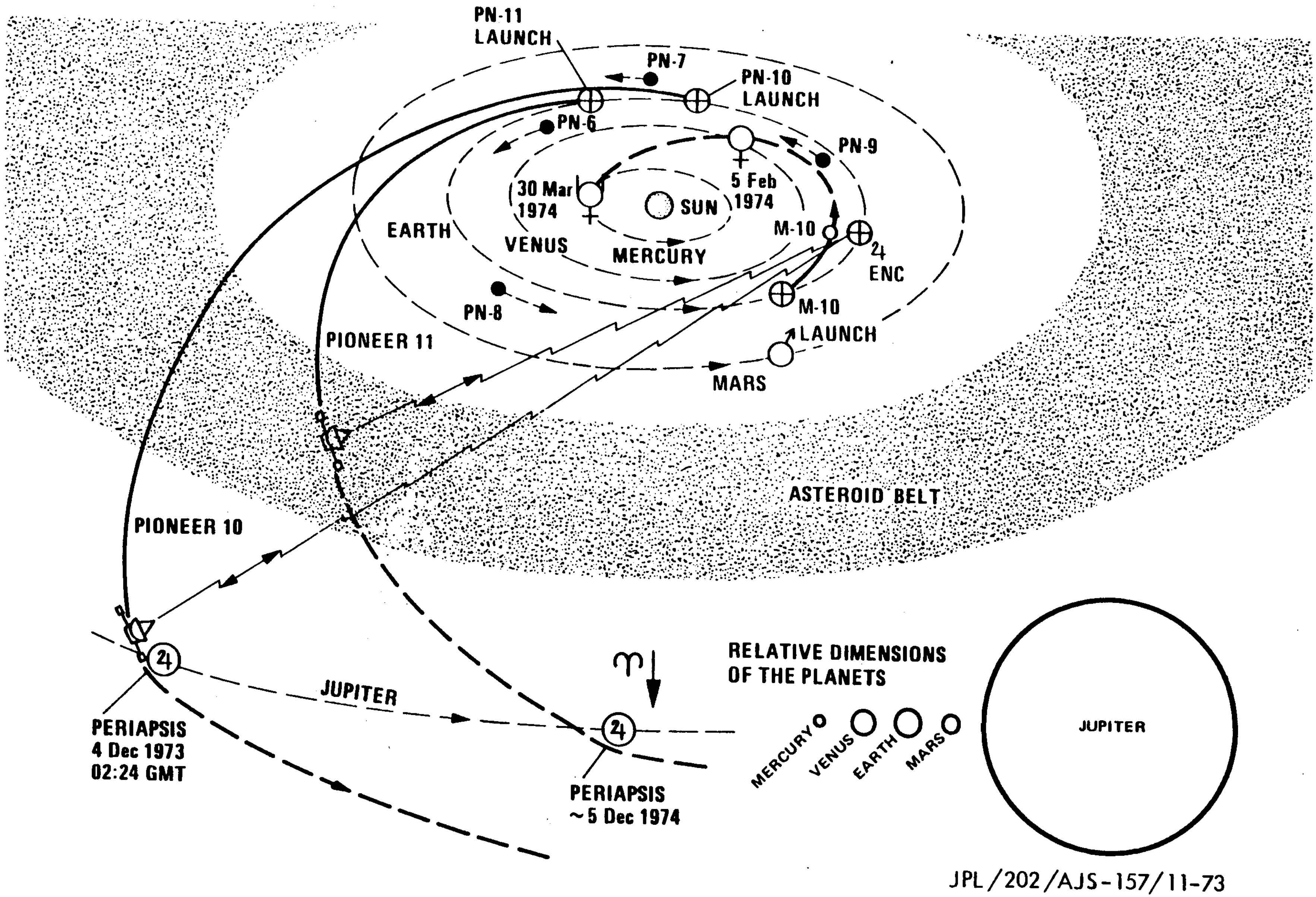


Figure 2. Pioneers 6,7,8,9,10, and 11 Locations Including Mariner 10 Location at Pioneer 10 Jupiter Encounter

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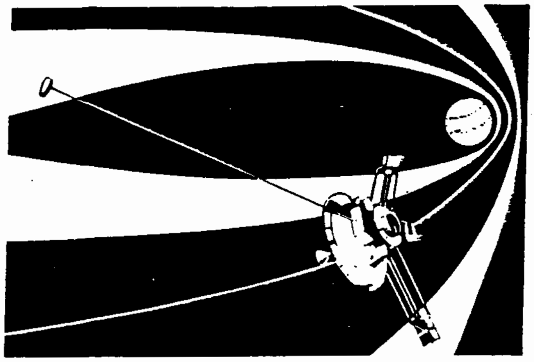


A. J. Siegmeth

pioneer / jupiter

PIONEER 10 launched 3 MARCH 1972
PIONEER 11 launched 6 APRIL 1973

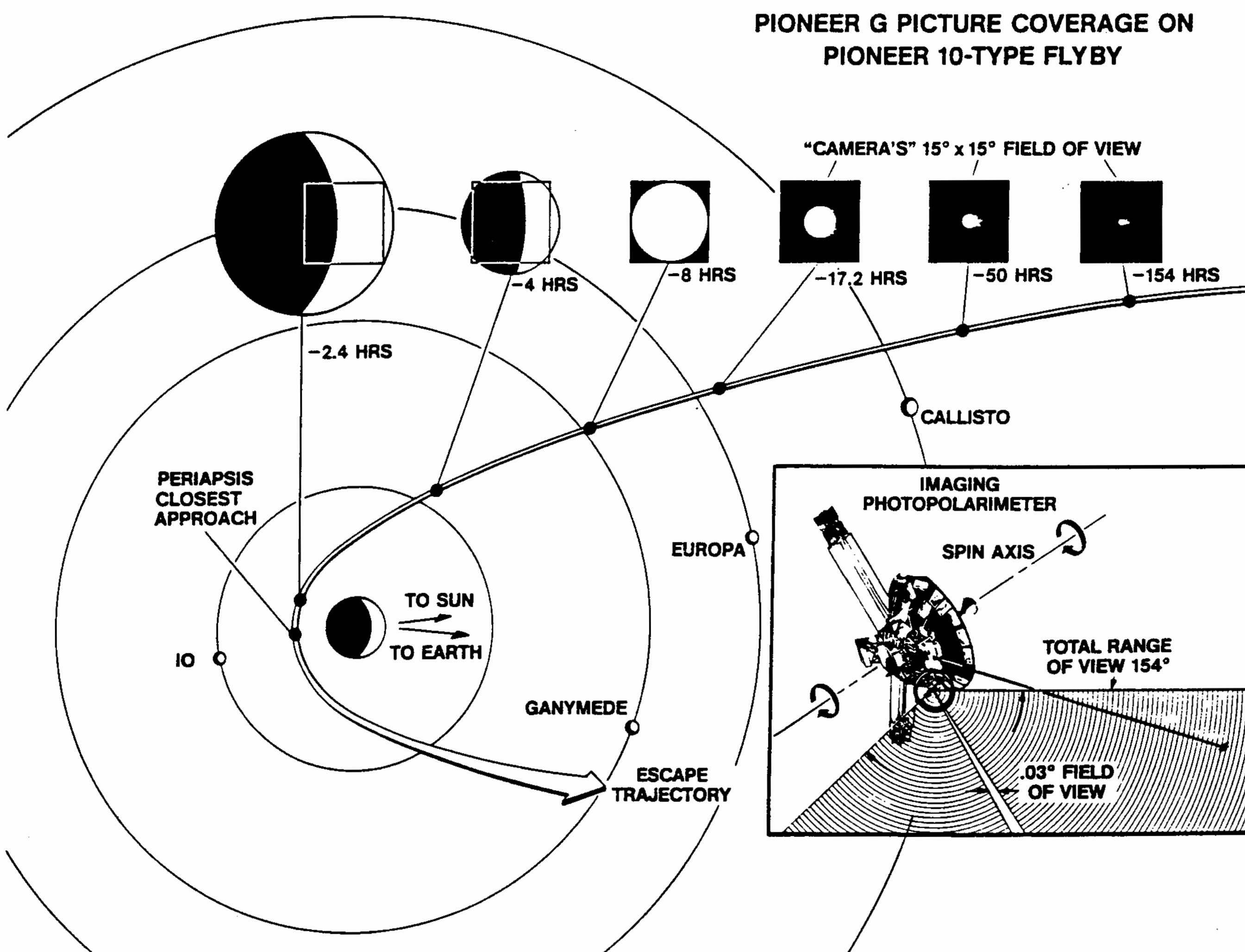
STATUS BULLETIN

No. 2 *Published by: Pioneer Project Support Office, Jet Propulsion Laboratory* 28 November 1973

The Pioneer 10 mission status as of 13:00 PST, 27 November '73 (Day 331) is nominal and all spacecraft events were supported continuously by DSN and MCCC. The spacecraft is 6 days away from the closest approach. The project expects that the Jovian periapsis target point will be reached nominally on 3 December '73, 6:24 pm.

During the past two days, more than 30 colored images were acquired and polarimetry measurements made on Jupiter, Io, and Ganymede. During the past 7 days, the view angle of Jupiter has more than doubled and the resolution of the pictures taken are defined by 40 scan lines across the planet disk. Some of the latest images show Jupiter's red spot, and one shows the shadow of Io projected on the Jovian surface.

As the spacecraft accelerates toward Jupiter, the image resolution will increase rapidly. By 1 December, the pictures will have 100 lines and during the close encounter, the resolution will increase to approximately 1000 lines referenced to the diameter of Jupiter. Some of the closeup images will cover only one tenth of Jupiter's surface. Figure 1 depicts the increase in the size of the planet relative to the closest approach.

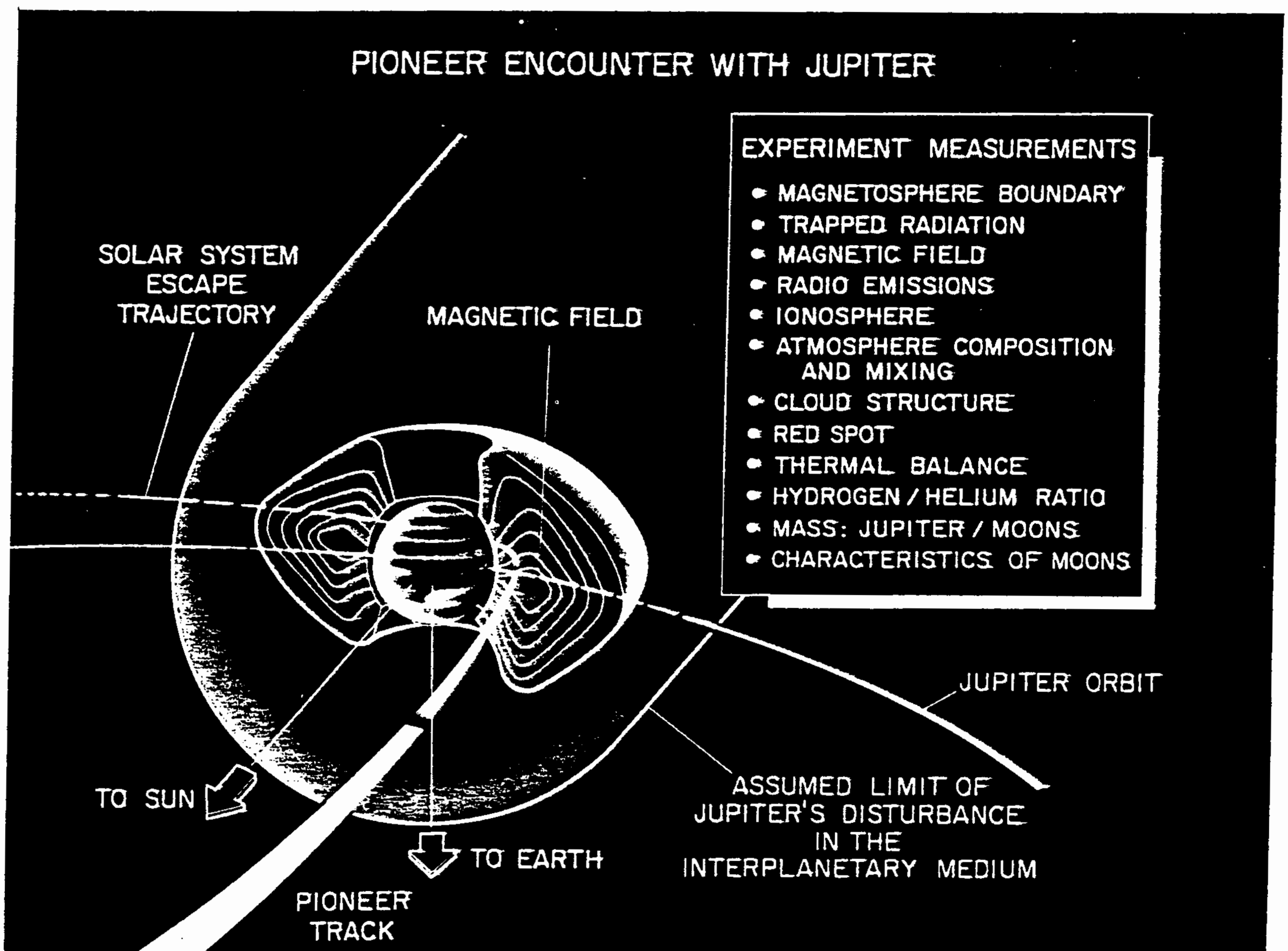


Around noontime (PST) of the 26 November, Pioneer 10 crossed the bowshock wavefront. In Figure 2, this area is identified as the assumed limit of Jupiter's disturbance in the interplanetary medium. This observation was made by almost all of the on-board instruments, which have continuously monitored the interplanetary behavior of the solar wind and the intensity and direction of the magnetic field. The detected bowshock wavefront is the boundary between the essentially stable interplanetary magnetic field coupled with the solar wind and Jupiter's magnetospheric activity. Up to the magnetopause, which is the outer shell of the magnetosphere, the highly disturbed transition region is characterized by erratic magnetic field behavior combined with a slowdown of the solar wind velocity. The bowshock wave was detected at a distance of 108 Jupiter radii, which is equivalent to 7.6 million kilometers. The Earth's bowshock wave has a range of 13 Earth radii, equivalent to 900,000 km. This comparison shows that Jupiter's magnetosphere is huge and dramatic. The relatively early encounter with the shockwave indicates that, apparently, the Jovian magnetic field is around 20 gauss. The models made by earth observations were estimating this field being in the vicinity of 5 gauss. If the increased magnetic field prediction is reality and the proton density of the magnetosphere is larger than originally predicted, the spacecraft electronic components can be damaged during the closest approach (Monday, 3 December). It is estimated that Pioneer 10 will cross the outer shell of the magnetosphere (called magnetopause) during 28 or 29 November.

On 26 November, the project reoriented the spacecraft spin axis in the direction of Earth, thus assuring an optimized two-way radio link between the spacecraft and the Deep Space Stations. Since 4 November '73, the project transmitted via the ground stations more than 3600 timed commands to Pioneer 10. The DSN and MCCC personnel operated all ground based facilities very well and demonstrated a very good system reliability.

On 27 November '73 at 00:00:00 GMT, the Pioneer 10 location and velocity can be described as follows:

vs Earth	Range	804	Mkm
	Velocity	39.43	km/sec
vs Sun	Range	750	Mkm
	Velocity	9.97	km/sec
vs Jupiter	Range	7.615	Mkm
	Velocity	10.29	km/sec



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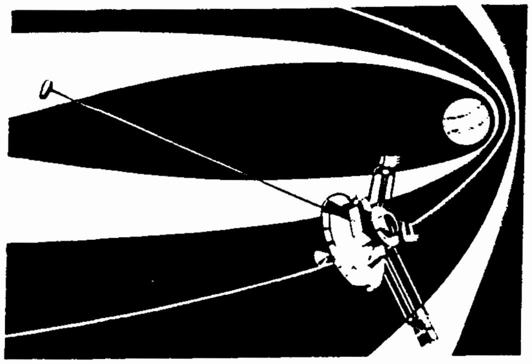


pioneer / jupiter

PIONEER 10 launched 3 MARCH 1972
PIONEER 11 launched 6 APRIL 1973

STATUS BULLETIN

No. 3 *Published by: Pioneer Project Support Office, Jet Propulsion Laboratory* 30 November 1973

PIONEER 10 TO HIT THE BULL'S-EYE ON MONDAY (AT 6:24 pm PST)

SUMMARY

The Pioneer 10 Mission status as of 08:00 PST 30 November 1973 (day 334) is nominal. The Pioneer Project's Management and Mission Operations Control are extremely pleased with the progress of the first Jupiter-bound mission.

All instruments and engineering subsystems of the spacecraft are working well and the Jovian environment has not affected the reliability of the on-board electronics. All elements of the Ground Data System continue to maintain a very good support performance record, and the excellent reliability of the commanding function has made possible the uninterrupted and errorless transmission of 5500 timed commands since 4 November 1973.

The spacecraft will reach the closest Jovian distance of 131,000 km in 3½ days on 3 December at 18:24 Pacific Standard Time.

SCIENCE

Figure 1 displays the range between Jupiter and Pioneer 10 during November and December '73 and the spacecraft's Sun relative velocity during the same time. Pioneer 10's exit velocity will more than double it's entrance velocity, thus the energy coupled into the spacecraft from Jupiter results in a hyperbolic swing around trajectory with an asymptote pointing toward the Taurus constellation. It is estimated that the spacecraft will arrive in 85,000 years near the vicinity of one of the neighboring solar systems. It can be speculated that the skeleton of Pioneer 10 will be captured by some beings of a high-level civilization and will get a glimpse of a spaceship made by the inhabitants of the "Spaceship Earth." It can happen that Pioneer 10 will be one of the few remnants of our civilization preserved in the vacuum of deepspace traveling 85,000 years between our solar system and the Taurus constellation.

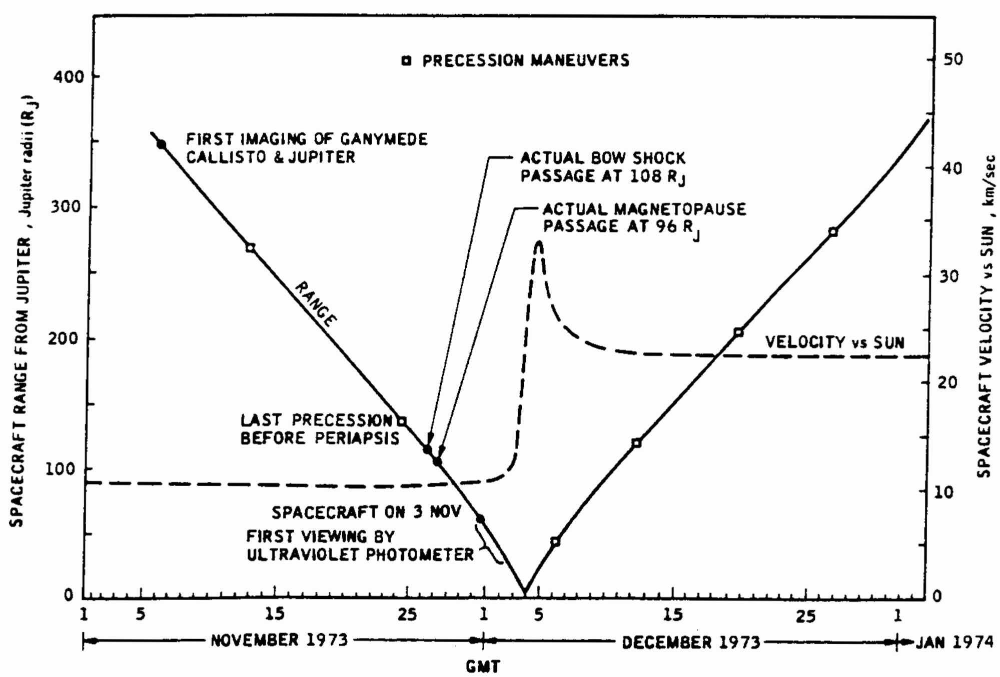


Figure 1. Spacecraft's Jupiter Related Range and Spacecraft's Sun Relative Velocity with Timeline Events of Encounter ± 30 Days

We reported in Bulletin No. 2 that Pioneer 10 crossed the bowshock wave front on 26 November at 108 Jupiter radii (Rj). One day later on the 27 November in the afternoon, the spacecraft traversed the magnetopause at 96 Rj, and it already travels inside Jupiter's magnetic cavity, almost two days ahead of previous predictions. The first indication of the crossing of the shockwave was the measured drop of the solar wind from 450 km/sec to 200–250 km/sec. The plasma temperature rose from 10,000 degrees to over a million degrees.

Between the shockwave and the magnetopause the solar winds flow direction has changed and its vector has shown a somewhat turbulent type behavior. Since the detected shockwave at 108 Rj is further out than previously predicted, a new surface magnetic field strength of 20 gauss was estimated. This value, however, is still uncertain until the spacecraft vs planet distance has decreased and a better visibility of the magnetosphere is achieved. If the 20-gauss surface field prediction holds up, it is estimated that the magnetic field at the periapsis (spacecraft at ~ 131,000 km from the visible surface of Jupiter) will be around 1 gauss. At the magnetopause crossing, the solar wind stopped at Jupiter. This sighting correlates with the behavior of the Earth's magnetosphere.

After encountering the magnetopause and entering the magnetosphere, the typical thermoplasma was detected, electrons with energy levels of only a few electron volts. After analyzing data from Pioneer 10 flying inside the Jovian magnetosphere, it was determined that Jupiter's and Earth's magnetosphere are basically similar, but in detail quite different. Jupiter's magnetic field at the outside regions of the magnetosphere is not showing a magnetic dipolar character because of a heavy thermoplasma and it's magnetic effects in this area. The spacecraft is rushing now into the deeper zones of the Jovian magnetosphere and is being exposed to an increase in energetic particle density.

The on-board instruments that are engaged in the exploration of the Jovian magnetosphere are:

- Magnetometer (JPL)
- Plasma Analyzer (ARC)
- Charged Particule Instrument (UC)
- Cosmic Ray TElescope (GSFC)
- Geiger Tube Telescope (UI)
- Trapped Radiation Detector (UCSC)
- Meteoroid Detector (LaRC)

The images made of Jupiter by the Imaging Photo Polarimeter are revealing day by day more details of the planet, it's red spot, and sometimes the Gallilean moons captured directly or as a shadow on the planet's surface. The quick-look colored images displayed at ARC on the monitor of the Pioneer Image Conversion System have excellent quality without geometric rectification and the planet's colored bands are showing an excellent contrast. (Polaroid copies of some of these images will be displayed starting 3 December in the lobby of JPL Building 230.) From 26 November more than 70 Jupiter images were acquired.

SPACECRAFT

Pioneer 10's performance is nominal and all redundant subsystems are operative. Detailed contingency plans were developed and mission operations will institute work-arounds in case some subsystems are affected by the dense radiation environment of Jupiter as the spacecraft crosses through the GR_j-3R, - 6 R_j zone (between 1 pm to 11 pm on 3 December '73). DSN and MCCC will support the contingency type workarounds with all available resources.

NAVIGATION

Pioneer 10 needs 641 days to make the trip from Earth to Jupiter. Based on the estimates available now, the arrival time uncertainty of the Jupiter periapsis target point is ± 1 minute. This can be the deviation from the predicted arrival time of 6:24 pm PST on 3 December '73. This highly accurate arrival time was calculated from the trajectory solution generated from precision two-way doppler data, which was acquired by DSN during Pioneer 10's flight since its launch.

The availability of solar systems precision navigational technology made it possible to plan for an Io occulation, which will have a duration of 1 to 2 minutes and will take place 20 minutes after the periapsis passage. Io is about as big as Earth's Moon, is orange colored, and may have an atmosphere. Its shadow on Jupiter seems hotter than the surrounding sunlit areas, and its passage around Jupiter is marked by massive electric discharges (lightning) in Jupiter's atmosphere. As Pioneer 10 goes behind Io, its radio waves will be affected by the satellite's ionosphere, if any. Analses of the changes in the radio waves will tell whether and perhaps what kind of atmosphere Io has. A similar technique will be used to analyze Jupiter's atmosphere.

UPCOMING EVENTS

Figure 2 displays the spacecraft's Jupiter related range and velocity during 3 and 4 December. This timeline shows also the major events during the culmination of the near-encounter phase. Figure 3 details the geometry between Jupiter and Pioneer 10's trajectory during 12 hours of the flight centered around the periapsis.

On 3 December '73, Monday, the major events are (all times are Pacific Standard Time):

All day	18 close encounter images of Jupiter, 1 image of Io, 1 image of Europa. Polarimetry of Jupiter.
2:26 a.m.	P – 16 hours Cross orbit of Ganymede at 14 R_j, 999,208 km (622,700 miles) from Jupiter. Ganymede is Jupiter's largest moon.
3:17 a.m.	P – 15 hours, 9 minutes Infrared view of Ganymede.

4:26 a.m. P – 14 hours
Closest approach to Callisto 1,
410,000 km (876,000 miles).

5:56 a.m. P – 12 hours, 30 minutes
Closest approach to Ganymede,
446,250 km (277,300 miles).

8:40 a.m. Start second ultraviolet view of Jupiter. View period 4 hours, 48 minutes from 8:40 a.m. to 1:28 p.m., P – 9 hours, 46 minutes to P – 4 hours, 58 minutes.

Radiation may saturate instrument during this second view period.

10:26 a.m. P – 8 hours
Cross Europa's orbit at 8.4 R_j, 599,400 km (372,500 miles) from Jupiter.

11:08 a.m. P – 7 hours, 18 minutes
Infrared view of Europa.

11:26 a.m. P – 7 hours
Closest approach to Europa at 321,000 km (199,470 miles).

12.38 p.m. P – 5 hours, 48 minutes
Infrared view of Io, Jupiter's closest large moon, and most reflective known object in the solar system.

12:26 p.m. P – 6 hours
Enter region of intense radiation. Hard radiation continues for 12 hours until 12:26 a.m., 12-4-73 – from P – 6 hours to P + 6 hours.

Critical region for the spacecraft and future missions with regard to radiation hazards. Hard radiation belts begin at 5 R_j from planet. They will be measured by high energy particle detectors from Universities of California-San Diego, Iowa, and Chicago; and NASA-Goddard Space Flight Center.

2:26 p.m. Crossing of Io's orbit at P – 4 hours – 4.9 R_j, 349,720 km (217,300 miles) from Jupiter.

2:26 p.m. P – 4 hours
Jupiter overlaps the 8 X 8 inch (14° X 14°) view-frame of the imaging system. Has about a 12-inch diameter relative to frame.

2:56 p.m. P – 3 hours, 30 minutes
Closest approach to Io at 357,000 km (221,840 miles).

3:45 p.m. Begin imaging of Red Spot for about 1 hour, 2:45 a.m. to 4:45 a.m. This takes place between 142,830 km (88,740 miles) and 196,380 km (122,000 miles) from Jupiter, 2 R_j to 2.75 R_j.

4:02 p.m. P – 2 hours, 24 minutes
The 8 X 8 inch (14° X 14°) view-field of the imaging system covers about a quarter of the full disc of Jupiter.

4:15 p.m. Begin 82-minute viewing period of Jupiter in infrared light, continues until 5:37 p.m. (P – 2 hours, 11 minutes to P – 49 minutes).

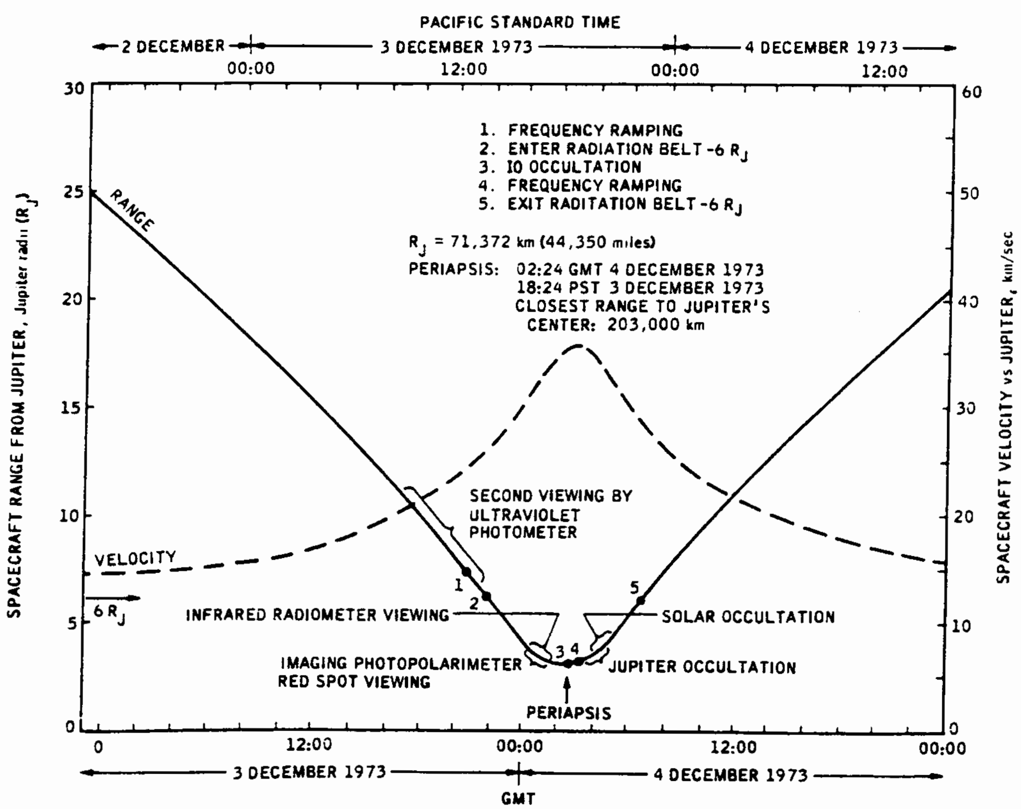


Figure 2. Spacecraft's Jupiter Related Range and Velocity
with Timeline Events of Near Encounter

Investigate Jupiter's atmospheric composition, temperature structure, and thermal balance. This is the only opportunity to determine these through IR throughout the whole mission. View period is 3 R_j to 2 R_j from Jupiter.

6:15 p.m. P – 11 minutes
IR view of Amalthea.

6:24 p.m. P – 0 days
Periapsis – 131,000 km (81,000 miles) from Jupiter's cloud tops.

6:26 p.m. P – 0 days
Closest approach to Amalthea's orbit, 18,500 km (11,470 miles)

Amalthea is Jupiter's smallest and closest moon.

6:36 p.m. P + 10 minutes
Crossing Jupiter's equatorial plane – Location of a potentially hazardous dust ring. NASA-Langley Research Center meteoroid detector will count dust particles. General Electric Co. Asteroid-Meteoroid Telescope will make dust observations during encounter, if not saturated by radiation.

6:41:45 p.m.
Begin 1 minute, 31 second occultation by Io, 6:41:45 to 6:43:16 p.m., P + 15 minutes, 45 seconds to P + 17 minutes, 16 seconds. Jet Propulsion Laboratory experimenter will determine whether Io has an atmosphere and an ionosphere by studying effects on spacecraft radio signal of its passage by the moon. Io's atmosphere is not measurable from the Earth.

7:42 p.m. Begin 65 minute occultation by Jupiter, from 7:42 to 8:47 p.m. (P + 1 hour, 16 minutes to 2 hours, 21 minutes).

Determine planet's ionospheric structure and investigate nature of neutral atmosphere via studies on Earth of spacecraft radio signal effects. (See Io occultation just above.) During this time, Pioneer is out of contact with Earth.

8:16 p.m. Begin solar eclipse of spacecraft – Flight through Jovian night (shadow).

Duration is 51 minutes, 8:16 p.m. to 9:07 p.m. (P + 1 hour, 50 minutes to P + 2 hours, 41 minutes).

12-4-73
All day 23 images of planet looking back at thin crescent Jupiter. Polarimetry of Jupiter, Io.

12:26 a.m. Exit hard radiation region.

6:26 p.m. P + 1 day
Pioneer is 1,526,200 km (948,256 miles) from Jupiter.

Errata to Pioneer Status Bulletin No. 2, dated 28 November 1973:

1. **Delete erroneous heading of the figure on the first page.**
2. **The 13 Earth radii should be ≈90,000 km instead of 900,000 km on the second page.**

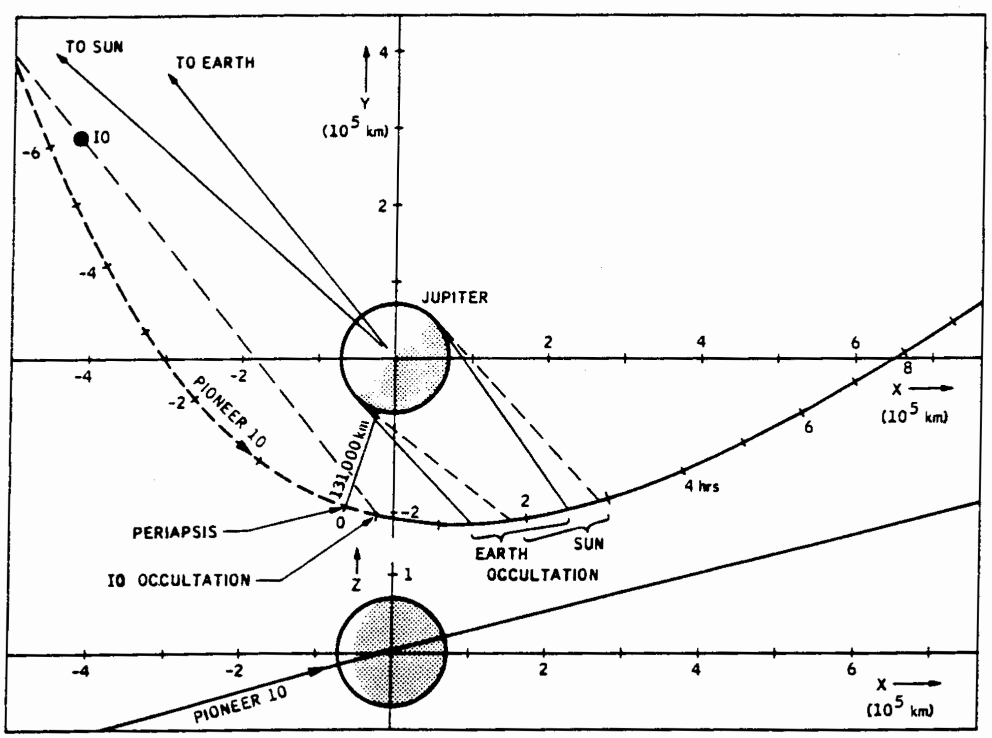
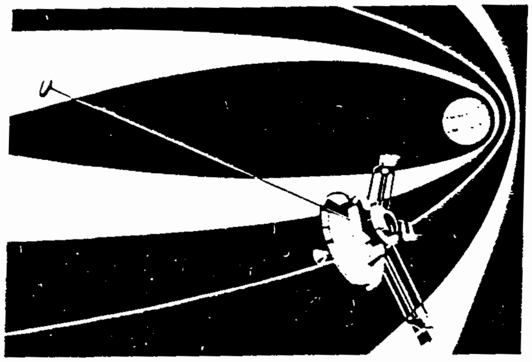


Figure 3. Geometry Between Jupiter and Pioneer 10's Trajectory with Io, Earth, and Sun Occultation

PROJECT MANAGEMENT: NASA AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA



A. J. Siegmeth

pioneer / jupiter

PIONEER 10 launched 3 MARCH 1972
PIONEER 11 launched 6 APRIL 1973

STATUS BULLETIN

No. 4 *Published by: Pioneer Project Support Office, Jet Propulsion Laboratory* 12 December 1973

FIRST JUPITER ENCOUNTER A GREAT SUCCESS

During a historical press conference after Pioneer 10's successful encounter with Jupiter, Robert S. Kraemer, Director for Planetary Programs for NASA headquarters, hailed this remarkable milestone by stating:

> "We sent Pioneer out to tickle the dragon's tail and the spacecraft gave it a good yank . . . but I was amazed to see it survive. We could hardly play the game any tighter and come through. Some sensors were 99 percent saturated with radiation before the danger eased off.
>
> The fact that the probe did survive, however, paves the way for the sophisticated Mariner-Jupiter-Saturn Mission in 1977, because the Mariner will fly past Jupiter at twice the distance as Pioneer."

STATUS SUMMARY

The Pioneer 10 Mission status as of 11 December 1973, 12:00 PST is normal and the spacecraft is now moving out from the influence of Jupiter and maintains a two-way communications link with the Ground Data System. After the successful encounter, Pioneer 10 has crossed the Jovian magnetosheet, around 10:00 GMT on 10 December '73 (PST: 2:00 am, 10 December). It is expected that Pioneer 10 will fly through the bowshock wave on 12 December 1973. After this event, Pioneer 10 will continue the exploration of the interplanetary environment beyond Jupiter.

Pioneer 10 receiving additional energy and velocity from Jupiter will leave the solar system in the direction of the constellation Taurus. Since most stars in this area are hundreds of light years away, it is now believed that Pioneer 10 has to travel possibly 10 to 20 million years until some high-level civilization can capture it's skeleton and the engraved metal plate with the message from earth. Pioneer 10 will cross Saturn's orbit in January 1976 and Uranus' range in mid-1979. If the spacecraft's electrical power continues to keep the degradation rate trend observed during the past two years, it can be assumed that DSN can maintain two-way contact with Pioneer 10 up to 1980.

NAVIGATION TO JUPITER

Pioneer 10 reached the periapsis, the closest point to Jupiter, at 02:25:19 Greenwich Mean Time on 4 December 1973 (PST: 6:25:19 pm on 3 December 1973).

The actual Periapsis was at a range of 203,252.6 km measured from the center of the planet; this range is equivalent to 2.86 Jupiter radii (R_J). Assuming that this radius of Jupiter's visible surface is 71,000 km, Pioneer 10's closest approach range relative to the atmosphere of the planet was 132,252 km, or 82,000 miles. The estimated measurement uncertainty of the periapsis range is 10 km.

Pioneer 10's voyage to Jupiter was 641 days long, the difference between the predicted and actual target range was 660 km. During the 15 years of unmanned exploration of the solar system, significant improvements were made in the field of deep space navigation. The accurate navigation of the Pioneer 10 flight added new vistas toward the exploration of the outer planets.

After the periapsis passage, the S-band radio signals were occulted by the Jovian satellite Io. The actual entrance and exit times of the signal interruption were within ten seconds of the predictions. The timing residuals were caused by the measurement uncertainties of earth based observations. Pioneer 10's flyby has already significantly improved man's knowledge of the celestial mechanics constants of the Jovian system; therefore, future Jupiter and outer planet missions can be navigated with much higher accuracies.

One hour after the Io occultation, the radio communication link with the spacecraft was interrupted by Jupiter for more than one hour. During the 8-hour period around the periapsis, the doppler shift of the S-band signals moved more than 150 kHz. This shift was caused by the spacecraft's acceleration toward Jupiter. To assure, during this time, an uninterrupted coherent radiolink with the spacecraft, the pre-programmed and digitally controlled frequency ramping oscillators at the Goldstone and Canberra 64-meter antenna stations were controlling the S-band uplink beams. These oscillators were compensating for the large doppler shifts, thus lowering the risk of losing the signals between the spacecraft and ground receivers. During the entrance and exit phases of the Io and Jupiter occultations, the spacecraft/earth radiobeam penetrated their ionospheres and atmospheres. The frequency phase and amplitude signatures of the carrier are used by the S-band occultation experimenter to determine pertinent characteristics of the probed media.

MISSION CONTROL AND GROUND DATA SYSTEM SUPPORT

During the Jupiter encounter the one-way light propagation time was 46 minutes and the two-way light trip time, 92 minutes. This corresponds to a communications range of 5½ astronomical units. All spacecraft commands originated by Mission Control and transmitted by the Deep Space Network travelled 46 minutes from the earth to Pioneer 10 and the command verification messages together with science and engineering telemetry data travelled in deep space an additional 46 minutes until they arrived at the DSN stations and at Mission Control. It would be almost impossible to fly a Pioneer 10 type mission and utilize the adaptive capabilities of the flight equipment with the necessity to verify every command after a time delay of 96 minutes. Therefore, since the launch of Pioneer 10, the Pioneer Project, DSN, and MCCC have been engaged in an intensive joint planning activity to improve the reliability of the commanding functions. By having continuous radio contact with the spacecraft since it's launch, the project was able to analyze in great detail the operational performance characteristics of the spacecraft. DSN and MCCC were also engaged in a well planned activity in improving the operational reliability of all ground facilities. Parallel with these efforts, a firm objective was set to generate and iterate all frequency, event time, and radio link performance predictions at a high accuracy so that all uplink frequencies and spacecraft commands could be transmitted "blind," without waiting for verification. It should be emphasized that 12,500 timed commands were transmitted to Pioneer 10 since 4 November '73, all arrived on time at the spacecraft to make all required adjustments of flight instruments and spacecraft subsystems. A great number of these timed commands controlled the Imaging Photo Polarimeter, which made more than 300 Jupiter images during this history making flight. Only a half dozen commands were aborted by the DSN; fortunately, the omission of these commands did not affect time sensitive command sequences.

SPACECRAFT AND MISSION PERFORMANCE

The spectacular results of the first Jupiter flyby mission has demonstrated that: a present state of the art spacecraft can encounter Jupiter successfully at a closest approach range of 2.86 R_J without any significant deterioration of the on-board electronic components. The spacecraft power subsystem and S-band amplifier subsystem have shown some slight deteriorations as the spacecraft was flying within the 6 R_J range. Most of the performance variations have been insignificant and most of them not permanent. One day after the closest approach almost all flight equipment have shown normal operational characteristics. The on-board crystal oscillators have displayed a slight change in frequency, approximately 3,000 Hertz of the S-band carrier. At the present time, the permanency of this frequency drift is not known; it is still under observation. Some flight instruments, which have reached their saturation levels, have been disconnected during the closest range to avoid any permanent damage. The transparency of the optical elements of the Asteroid/Meteroid Detector has degraded.

In its passage through the radiation belt the spacecraft received a radiation dosage 1,000 times heavier than a dosage required to kill a man.

During the flight from earth to Jupiter the S-band telecommunications link operated within the predicted vs actual performance residuals of ±1 dB and this performance was also maintained during the encounter. The spacecraft's radio link operated at the Jupiter range as well as at the Mars range; the link's efficiency did not degrade. It is expected that the same condition will exist up to Neptune's range.

The spin axis torquing technique to achieve continuous earth pointing of the spin-stabilized spacecraft's high-gain antenna, was very successful. Almost 100 torquing maneuvers were necessary since launch to maintain a reliable radio link with the earth based tracking stations. Numerous measurements of the critical spinaxis earth-pointing angle were made successfully and unambiguously by the on-board Conscan System.

The four radioisotope thermoelectric generators (RTGs) have supplied the required electrical power for the spacecraft without any malfunction. Their first successful use demonstrated that NASA can now explore the outer planets with reliable power sources.

Pioneer 10's wide range of telemetry bit rates from 64 bps to 2048 bps in steps of a factor of 2 made possible the timely adaptation to changing link conditions, thus assuring near-optimum data return.

The spacecraft transmitted almost all telemetry data in convolutional coded form; after on-site decoding, errorless telemetry data was obtained near to the radiolink threshold level.

PRELIMINARY SCIENTIFIC RESULTS

The quick-look evaluation of the scientific information acquired during the first Jupiter flyby has already surpassed all expectations. It has revealed many unknown facts about the planet and opened new specultation about it. Jupiter's moon Io is very unlike the other satellites; Io has a mass like our earth and possesses a tenuous ionosphere and atmosphere. An ultra-violet glow detected around Io remains unexplained. It can be assumed that Io is covered with highly reflective methane snowfields.

Jupiter radiates 2½ times as much heat energy as it absorbs from the sun, and no significant difference occurs in the surface temperature between the sunlit side and the dark side. The temperature varies within 15 degrees between the different cloud bands surrounding Jupiter and the Red Spot is slightly warmer. The presence of helium (not identified before) has been detected in the Jovian atmosphere and measurements indicate that the ionosphere of Jupiter is hundreds of miles deep. The magnetic field of Jupiter extends out many million miles from the planet and is tilted to the planet's spinaxis by 12 degrees.

The hard region of Jupiter's trapped radiation belt extends out approximately 15 Jovian radii (more than 1000,000 km), the less powerful region up to 35 radii, and the third area (probably not trapped) extends to 100 radii. The visible surfaces magnetic field is four gauss. The planet if flattened out much more than predicted. Received data also indicates that the space around Jupiter appears dusty, at least ten micrometeorite hits were detected by Pioneer 10. The flux density of these particules is considerable higher than in the interplanetary space.

The almost continuous and errorless data received from Pioneer 10 is considerable. During November and December 1973, the spacecraft operated at the telemetry rate of 1024 bps. If one would convert the binary bit stream acquired during the 14-day near encounter phase of this mission into alpha-numeric characters, this data would fill up sixty regular textbooks each containing 1,000 printed pages.

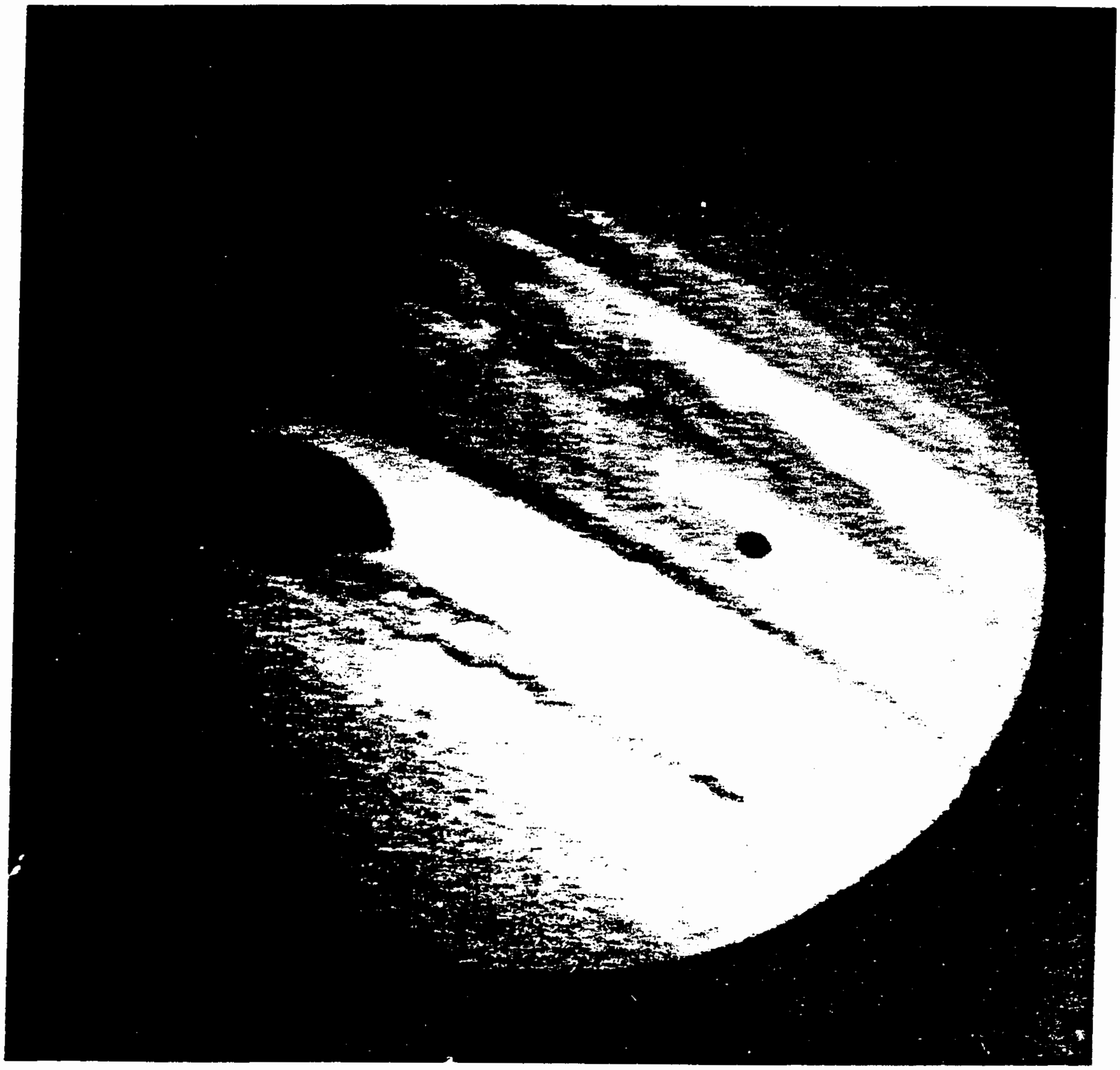
It will take several months until the detailed scientific results are obtained from the data collected. It is expected that hundreds of processed Jupiter pictures acquired by the IPP instrument will display better resolution than photographs made by earth based equipment.

PIONEER 11

Meanwhile, Pioneer 11, launched on 6 April 1973, is continuing its flight to Jupiter and has already passed through the middle of the asteroid belt. The Pioneer Project Office together with the Scientific Investigators are studying, at the present time, the retargeting strategy for this second Jupiter-bound spacecraft.

The project is planning to trim the transfer trajectory of this spacecraft to a different Jovian target point. This correction would result in a flyby trajectory with modified aspect angles and ranges, thus augmenting the flyby measurements made by Pioneer 10. The project is also analyzing the feasibility to accelerate Pioneer 11's velocity at the Jovian flyby to a level that will bring this spacecraft to the close vicinity of Saturn.

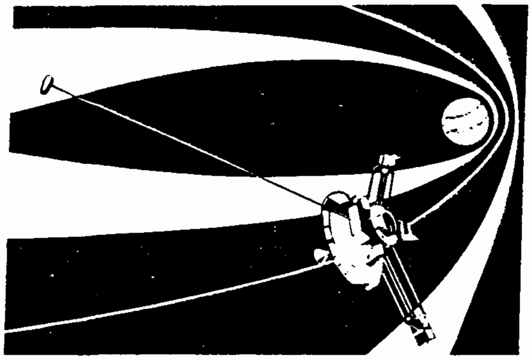
The expected arrival time of Pioneer 11 at Jupiter is around 5 December 1974.



JUPITER

As seen by Pioneer 10's IPP instrument from a distance of 2,500,000 km. Jupiter's Red Spot, and a shadow of the moon Io, plus Jupiter's cloud structure are shown in this photograph, which was taken at 11:02 pm PST on 1 December 1973. It is a blue image processed in black and white by the Optical Sciences Center at the University of Arizona.

PROJECT MANAGEMENT: NASA AMES RESEARCH CENTER MOFFETT FIELD, CALIFORNIA



pioneer / jupiter

PIONEER 10 launched 3 MARCH 1972
PIONEER 11 launched 6 APRIL 1973

STATUS BULLETIN

No. 5 *Alfred J. Siegmeth, Editor* *Published by: Pioneer Project Support Office, Jet Propulsion Laboratory* 3 January 1974

STATUS

The Pioneer 10 mission status as of 3 January 1974, 13:00 PST, was normal. The spacecraft left the Jovian magnetosphere on 17 December '73 at 08:15 PST. The MCCC has continued the generation of merged real-time telemetry system data records up to the end of the transmission day of 19 December '73. This support by the MCCC has made possible the immediate generation of telemetry data records at ARC for the Principal Investigators.

During the next several months, a detailed analysis of the measurements obtained during this historic flyby will unravel some of the mysteries of our solar system's largest planet.

Pioneer 10's on-board instruments are continuing the successful exploration of the unknown void beyond Jupiter. The project's mission control team is continuing to gather images and polarimetric measurements of Jupiter, with the rapidly decreasing view angle of the planet.

CONGRATULATIONS!

The fifth Pioneer Spacecraft managed and operated by the Ames Research Center has successfully encountered Jupiter. JPL and contractor people in the Deep Space Network, the Mission Control and Computing Center, and the Flight Project Organization have demonstrated an outstanding dedication and team spirit during the planning, testing, training and operations of the Pioneer 10 encounter.

It is an exciting and rewarding experience to have an active role in this world-wide endeavor, creating records and focusing international interest on this initial exploration of the largest planet of the solar system. Each of you has made a significant contribution, in making possible the near-optimum utilization of spacecraft capabilities. Each of us wishes to convey his congratulations on your great competence, dedication and perserverance. Please accept our gratitude for a magnificent performance.

Charles F. Hall
Manager
Pioneer Project

William H. Bayley
Assistant Laboratory Director
Tracking and Data Acquisition

Robert J. Parks
Assistant Laboratory Director
Flights Projects

Robertson Stevens
Manager
Office of Computing and Information Systems

Alfred J. Siegmeth
Manager
Pioneer Project Support Office

All on-board equipment is functioning normally. A few of the subsystems that exhibited performance degradation as a result of exposure to large doses of radiation during the flyby have recovered. The on-board oscillators of the communications subsystem have undergone slight frequency changes, but this condition is not causing any problems in the maintenance of the two-way earth/spacecraft S-band radio link. Although some workaround procedures were required, it can be assumed that the oscillators will slowly recover from the radiation effects.

THE PIONEER 10 OBJECTIVES BEYOND JUPITER

The trajectories of Pioneers 10 and 11 are depicted on the back page. Pioneer 10, as shown, will eventually leave our solar system and will continue its exploration of the outer interplanetary environment. It is assumed that radio contact with this spacecraft can be maintained until 1980.

Some of the significant areas that the spacecraft will permit Pioneer scientists to explore are:

- The model of the solar wind and the solar magnetic field around Jupiter.
- The distribution of matter and particles originating from within and beyond our solar system. Special interest will be given to determine the flux of galactic cosmic rays and the distribution of neutral hydrogen, plasmas of external origin, and interstellar hydrogen and helium.
- Determination of the solar wind vis-a-vis the interstellar space boundary.

The on-board instruments that are used to gather and record data include the plasma analyser, the magnetometer, the high-energy particle detector, and the ultraviolet photometer.

PIONEER 10 – THE KEY TO NEW NAVIGATIONAL VISTAS

The two-way precision doppler method resulted in unprecedented trajectory accuracies. New navigational methods were also introduced to further decrease the measurement uncertainties.

During the Jovian exit phase, attempts were made to tie Pioneer 10's trajectory, and indirectly Jupiter's ephemeris, into the location of a very-distant radiostar. This star can then serve as a benchmark of the universe.

On 10 December, the 64-meter antenna station at Goldstone and the 26-meter antenna station at Canberra simultaneously tracked the Pioneer 10 carrier signal. Then both antennas were pointed to an adjacent and known radiostar. In both cases, radio interferometric measurements were made relative to the very long Goldstone/Canberra baseline.

After repeating the spacecraft and the radiostar angle measurements several times, the difference between the spacecraft vs radiostar angle of signal arrival was established. Using a very long baseline the signal-arrival angle can be measured to a resolution of 1/1000 of an arc-second. It is further speculated that this method of measurement, known as differential very long baseline interferometry, can be used to solve timing uncertainties within the solar system.

Since existing methods for measuring time are affected by the aberrations of the earth's movement around the sun, it is hoped that by referencing the solar system to fixed radiostars, the planetary ephmerides can be determined more accurately.

If the spacecraft's performance keeps up its excellent records demonstrated during its flight in 1972 and 1973, it can be assumed that the Pioneer 10 signals beyond Jupiter will be tracked up to a range of 20 Astronomical Units (AU) from earth, at which range the spacecraft will be almost 3 light hours from us. This great distance provides an unparalleled opportunity to gain a greater understanding of our solar system.

The earth's revolution around the sun can also provide us with an ultra-long measurement baseline with a length of two AUs (299 million kilometers). If this baseline is perpendicular to the Pioneer 10/sun line, every 6 months the Pioneer 10 vs fixed radiostar angles as seen from earth will go through extreme conditions, thus providing a parallax method to improve the precision of angle of arrival measurements. Such measurements can be combined with spacecraft vs tracking station range measurements, using for the first time with Pioneer 10 a frequency-ramped turnaround signal. It was already demonstrated that Pioneer 10 vs earth range was determined with an uncertainty better than 10 km. Using advanced data-reduction techniques, it can be assumed that the precision of these measurements can be improved to 1 km. It can be envisioned that the Pioneer 10 vs earth range can be measured up to distances of 20 AU which is equivalent to 3 billion kilometers or 1.9 billion miles. This means that it will be possible to measure these vast distances of our solar system to uncertainties of 10^{-9}.

The navigational methods described above are only a few of the examples which can be applied to this first exploratory mission with a spacecraft penetrating the outer fringes of our solar system beyond the orbit of Uranus.

PIONEER 11 RETARGETING

The Pioneer 11 spacecraft is currently exploring the outer part of the asteroid belt, and based on the data obtained of the Jovian environment during first encounter, Pioneer Principal Investigators and Pioneer Project Office have proposed that Pioneer 11 spacecraft could be utilized fuller if it were retargeted after February 1974 toward a Jovian aiming point of 1.6 Jupiter radii, and placed in a south/north flyby trajectory. This flight path would provide a good spacecraft view of both hemispheres as well as the equatorial region.

The flyby at the 1.6 Jovian radii could accelerate the spacecraft into a Saturn-bound trajectory, with an estimated time of arrival at Saturn of about August 1979. The Jupiter-Saturn voyage would require 4.5 earth years. The Pioneer 11 trajectory shown on the back page is displaying the sharp turnaround at Jupiter.

The Pioneer Navigation Team is developing a plan for the Pioneer 11 retargeting maneuver. When approved, the second Jupiter bound spacecraft will be the first man-made instrument investigating the mysteries of Saturn and will give us a close look of the second largest planet of the solar system.

TRACKING AND DATA ACQUISITION SUPPORT

The DSN will provide almost continuous support for the Pioneer 10 mission up to 1 July 1974, at which time the nominal mission will end. Negotiations for an extended mission plan will start in January of 1974.

Pioneer 11 will obtain continuous DSN support during 1974, and will prepare for the second Jupiter encounter in November and December of this year.

Both Pioneer 10 and 11 spacecrafts will have a superior conjunction with the sun around 18 February 1974. A spacecraft high-gain antenna re-pointing plan has been developed for both missions to ensure the resumption of two-way communication with both spacecraft after the radio signal path moves away from the close vicinity of the sun to a point where solar noise effects are not degrading the telemetry reception.

To ensure a similar or improved Ground Data System support performance during the Pioneer 11 encounter, the Pioneer Project Team will operate this mission with the same ground configuration as used for Pioneer 10. The MCCC will provide a mission support area in Building 230, which will not only serve as a backup for the Pioneer Mission Control and Operation Center, but also will provide additional real-time visibility on specific engineering or science information.

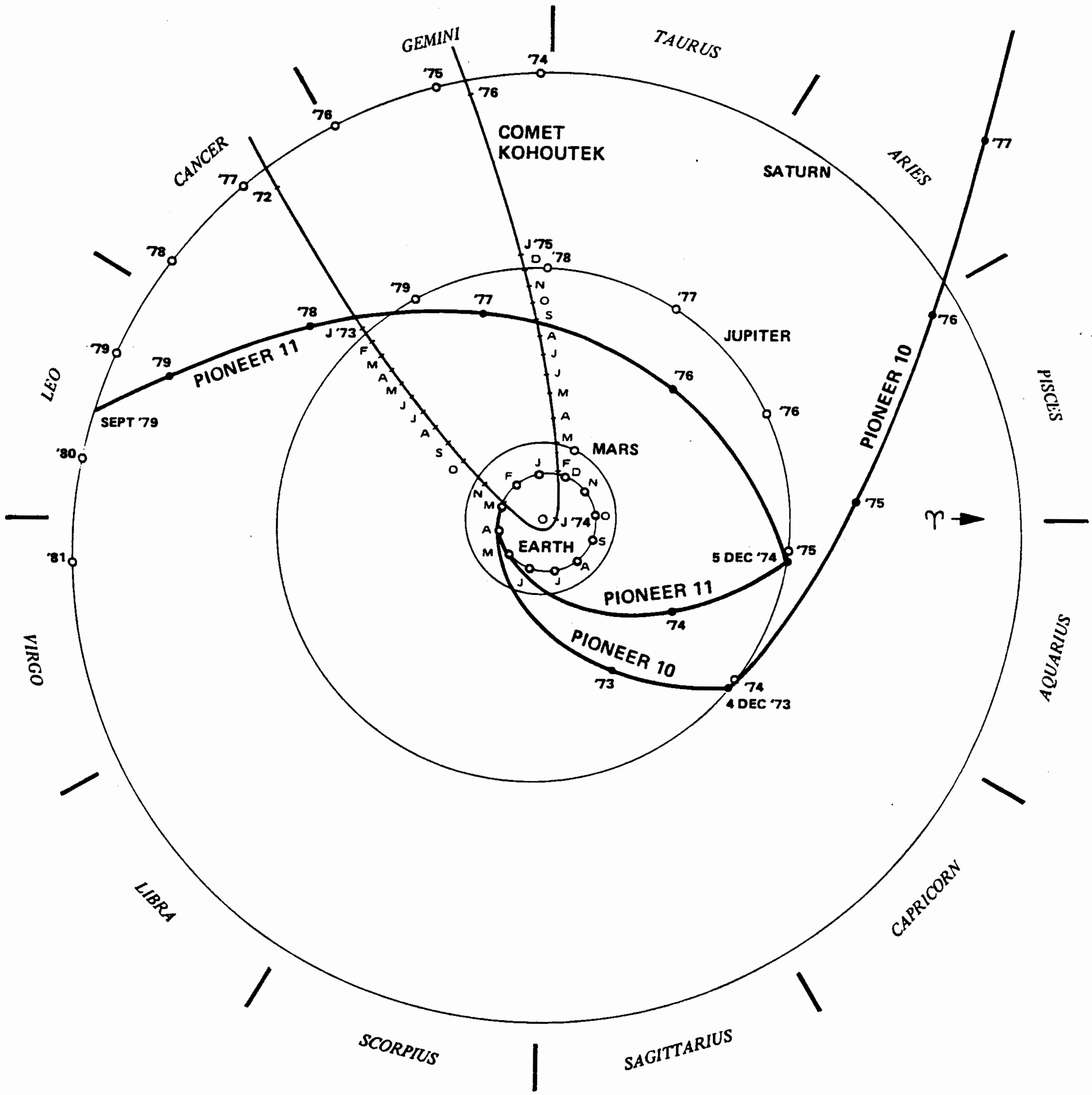
The December 17, 1973, edition of Time magazine (page 93) showed a colored version of the photo made by Pioneer 10. This photo was published in black and white on the back page of Pioneer/Jupiter Status Bulletin No. 4.

Pictorial and polarimetry data of Jupiter obtained by Pioneer 10 is undergoing intensive enhancement and rectification processing at the University of Arizona to recover all the very valuable information collected during the first Jupiter flyby.

Jet Propulsion Laboratory
California Institute of Technology
National Aeronautics and Space Administration
4800 Oak Grove Drive, Pasadena, California 91103

PIONEER 10 AND 11 TRAJECTORIES PROJECTED INTO THE ECLIPTIC PLANE

THE ORBITS OF EARTH, MARS, JUPITER, SATURN, AND COMET KOHOUTEK ARE DISPLAYED FOR REFERENCE



PLANET OR SPACECRAFT LOCATIONS DURING THE FIRST DAY OF MONTH OR YEAR