Pioneer 10 and 11 Mission Support

R. B. Miller
Mission Support Office

Pioneers 10 and 11 continue to function normally and return new information on the interplanetary medium beyond the orbit of Mars. This article describes the current state of the Pioneer 10 and 11 missions, including discussions on significant events since Pioneer 10 Jupiter encounter, possible upgrading of communications capabilities for future Pioneer 10 and 11 operations, and the nature of the Pioneer 11 Saturn trajectory.

I. Significant Events Since Pioneer 10 Jupiter Encounter

Both Pioneers 10 and 11 are continuing to function normally and are continuing to return new information on the interplanetary medium beyond the orbit of Mars. Every day that Pioneer 10 is tracked and data returned represents further penetration into new regions of space never before explored by man. This continued study of the propagation of energetic solar events to large distances from the Sun has already produced some scientific surprises. The Pioneer 10 magnetic field, solar wind, plasma, and energetic charged-particle measurements obtained thus far indicate a much higher degree of interplanetary turbulence and a surprisingly smaller gradient in the galactic cosmic rays than had been expected. Already the Pioneer 10 and 11 results require reformulation of present coronal expansion and cosmic ray modulation theory.

In February 1974, both Pioneers 10 and 11 went through a solar conjunction. Simultaneous with the solar conjunction was the extensive post-Venus closest approach Mariner Venus/Mercury data taking. Since Mariner Venus/Mercury 1973 (MVM'73) approached Venus from the dark side, it was during this post-encounter time period when the majority of the good Venus imaging took place. Mariner Venus/Mercury 1973 required 64-meter coverage in this time period in order to achieve the maximum return of imaging data. Pioneers 10 and 11 also required 64-meter coverage in order to safeguard the spacecraft during the solar conjunction. Closest approach of MVM'73 to Venus occurred on February 5, 1974; the Pioneer 10 center of solar conjunction occurred on about February 19, 1974; and the Pioneer 11 center of solar conjunction occurred on about February 21, 1974.

There are two important factors affecting Pioneers 10 and 11 during a solar conjunction. The first is the desire to maintain the high-gain antenna pointed as near to the Earth direction as possible in order to maintain the uplink and downlink margin to the spacecraft. When the

Sun, during solar conjunction, gets within a few degrees of the spacecraft–Earth line, the solar sensor on the spacecraft is unable to operate. The solar sensor is utilized to produce a roll pulse which serves as the pointing reference for all of the on-board instruments. It is, therefore, necessary to point the spacecraft slightly off the Earth–spacecraft line in order to avoid loss of roll reference. This requires a successive precessing of the spacecraft during a solar conjunction to step around the Sun position and avoid loss of roll reference while still maintaining good communications with Earth. The second factor during solar conjunction is the fact that the spacecraft design on both Pioneers 10 and 11 has incorporated protection against receiver failure by automatically causing the spacecraft to switch to the redundant receiver in the event that an uplink has not been detected within 36 hours. This requirement necessitates the daily establishment of an uplink to the Pioneer spacecraft right through the solar conjunction period in order to prevent the switching of the radio subsystem. This automatic switching can be inhibited by ground command, so it was decided, since Pioneer 10 had achieved Jupiter encounter, that the risk of inhibiting this function on Pioneer 10 would be acceptable for this solar conjunction. It was held, however, that the risk would be too high for Pioneer 11, so a daily uplink would have to be established. This daily uplink requires, during the height of solar conjunction, a 64-meter antenna in order to break through the solar corona into the spacecraft receiver. On about February 2, 1974, Pioneer 10, with the automatic receiver switching inhibited, was maneuvered off to a position that would cause Earth to come back into the beam of the high-gain antenna after solar conjunction. Communication was then lost during this blind maneuver, as planned, until some time after the solar conjunction. This decision by the Pioneer Project Office greatly relieved the excessive demand on 64-meter coverage in this time period. Pioneer 11-required 64-meter coverage was achieved principally using partial passes shared with MVM'73.

Based on the experience with Pioneer 10 at Jupiter encounter, the decision was made by the Pioneer Project Office to re-target Pioneer 11 to enable a gravity-assist at Jupiter encounter to carry the Pioneer 11 spacecraft on to the vicinity of Saturn.

II. The Future of Pioneers 10 and 11

Pioneer 10 will continue to move out from the Sun and eventually escape our solar system. Pioneer 11 will encounter Jupiter on December 3, 1974, where it will swing around onto a Saturn trajectory with an expected Saturn arrival of September 5, 1979. Plots of the Earth-to-spacecraft range for both Pioneers 10 and 11 are shown in Fig. 1. This figure, designed by A. J. Siegmeth of the Pioneer Project Support Office, also shows the expected communications performance for both spacecraft. The received carrier power on this chart, at which each bit rate thresholds, is pessimistic by about 1 dB. It is anticipated that, with the existing 64-meter antenna configuration with a 12-Hz loop in the receiver, we should be able to continue to receive useful telemetry from Pioneer 10 out to about 19 AU, which corresponds to about a -164.5-dBmW received carrier power. This range will be reached at about the end of March 1979. Means of extending the range to which we can track Pioneer 10 are being investigated. They include the planned upgrade of the 64-meter network to 68 meters, possible use of the 3-Hz loop in the Block IV receiver, and the ganging of a fourth 64-meter antenna planned for Goldstone, California, with the existing DSS 14 antenna. Allowing for the 1 dB of pessimism, it is seen from the chart that Pioneer 11 at Saturn encounter will have marginal performance at 512 bits per second. The Pioneer Project Office is extremely interested in trying to achieve 1024 bits per second at Saturn encounter. This would be the same bit rate as was achieved at Jupiter encounter. The principal hope for achieving 1024 bits at Saturn encounter is the completion of the fourth 64-meter antenna at Goldstone, which would enable the ganging of two 64-meter antennas with a performance improvement of nearly 3 dB. As can be seen from the chart, the 3 dB should make the 1024-bit rate possible. A 512-bit rate, instead of 1024 bits per second, would mean either loss of color information during the ± 2 days of closest approach to Saturn, or else color imaging with pictures only one-half the height that would be possible at 1024 bits per second. Reference 1 should be consulted for a description of the imaging instrument on board Pioneers 10 and 11.

The imaging photopolarimeter (IPP) instrument takes a full color image over 14 deg of spacecraft roll. As described in the referenced article, a 1024-bit rate is required in order to play back a 14-deg color image. At 512 bits per second, the spacecraft can either play back a 7-deg full color picture or a 14-deg black-and-white image. At closer than approximately ± 2 days to encounter, the uncertainty in spacecraft pointing plus the size of the planet disk exceeds 7 deg. It is hoped that, with two 64-meter antennas ganged in phase, coupled with low-noise listen-only receiving subsystems, full imaging return can be achieved during the September 1979 Saturn encounter.

III. The Pioneer 11 Saturn Trajectory

Figure 2 shows the Pioneer 10 and 11 targeting points at Jupiter encounter. Speaking in terms of the direction that Jupiter moves in its orbit around the Sun, Pioneer 10 was targeted to follow the planet Jupiter in nearly the equatorial plane of the planet. Pioneer 11 has now been targeted to lead the planet Jupiter in a more nearly polar trajectory. The closest approach for Pioneer 10 was at 2.86 Jupiter radii (203,250 kilometers) from the center of the planet. Pioneer 11 will have a closest approach of only 1.6 Jupiter radii (113,000 kilometers) from the center of the planet. That is only 6/10th of a Jupiter radius from the visible surface of the planet. (Note that Fig. 2 does not directly show the radius of closest approach to the planet, but rather where the spacecraft trajectory intersects a plane perpendicular to the hyberbolic approach velocity of the spacecraft.)

There was considerable concern prior to Pioneer 10 Jupiter encounter as to whether the spacecraft could survive the high level of radiation that might be present around the planet Jupiter. It appeared that Pioneer 10 had received about the maximum dosage of radiation possible without sustaining severe damage to the spacecraft. The minor damage that was experienced by Pioneer 10 was mostly of a temporary nature. A natural question to ask is how can Pioneer 11 be sent 1.2 Jupiter radii closer than Pioneer 10 and be expected to survive. There are two principal factors which should make the Pioneer 11 trajectory such that the total dosage of radiation experienced by Pioneer 11 will be the same as Pioneer 10. First, Pioneer 11, because of its closer flight, will be flying by the planet much faster. A more important factor is that the radiation around the planet Jupiter is latitude-dependent and peaks in a disk about the equator of the planet. Because Pioneer 11 is going to a lower latitude than Pioneer 10, it will actually be crossing the region of peak radiation at a farther distance from the planet.

A potential concern for the DSN in the closer approach to Jupiter of Pioneer 11 is the peak doppler offset and rates that will be experienced. Fortunately, the Saturn trajectory is such that the peak doppler amplitude and rates occur during the Jupiter–Earth occultation. Therefore, the rates that will be experienced during the Pioneer 11 encounter will be equal to or less than those of Pioneer 10.

Figure 3 depicts the Pioneer 11 trajectory from launch to Saturn encounter. Notice that the spacecraft actually gets closer to Earth again after Jupiter encounter on its way to Saturn. This can also be seen in Fig. 1. The spacecraft actually gets closer than 3 AU to Earth on its way to Saturn. Notice also that the spacecraft goes between 1 and 1½ AU, or nearly 15 deg, out of the ecliptic plane in transit to Saturn. Also notice that Saturn is very near solar conjunction at the time of Saturn encounter of Pioneer 11. At the time of closest approach of Pioneer 11 to Saturn, the spacecraft will be only 6 deg from the Earth–Sun line. This means that very little post-Saturn encounter data will be returned. The details of the Saturn flyby have not yet been determined; however, there has been discussion of trying to target Pioneer 11 to thread one of the gaps in the Saturn rings.

Reference

1. Miller, R. B., "Pioneer 10 and 11 Mission Support," in *The Deep Space Network Progress Report,* Technical Report 32-1526, Vol. XVI, pp. 15–21, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1973.

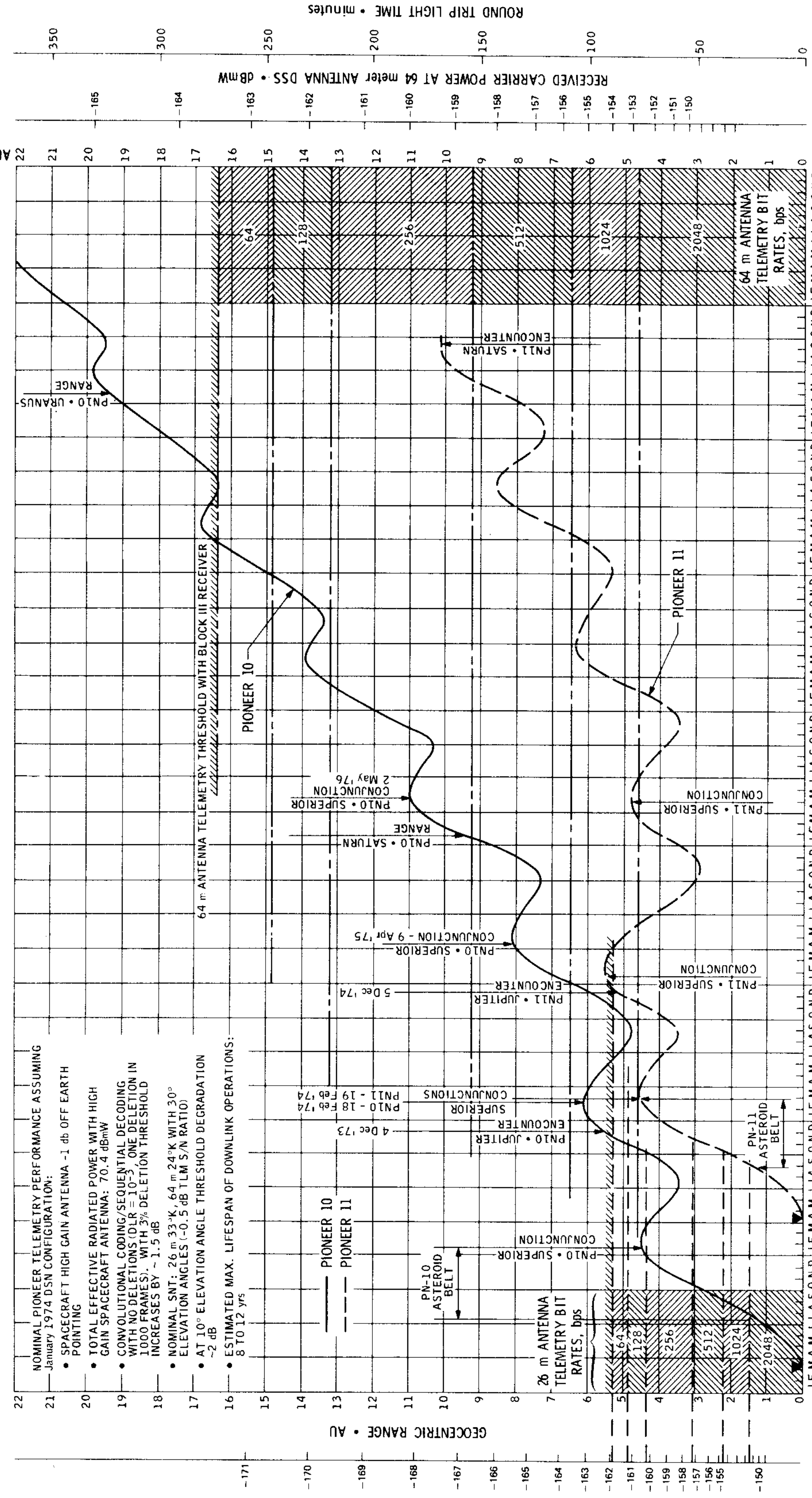

Fig. 1. Pioneer 10 and 11 telemetry downlink performance estimates

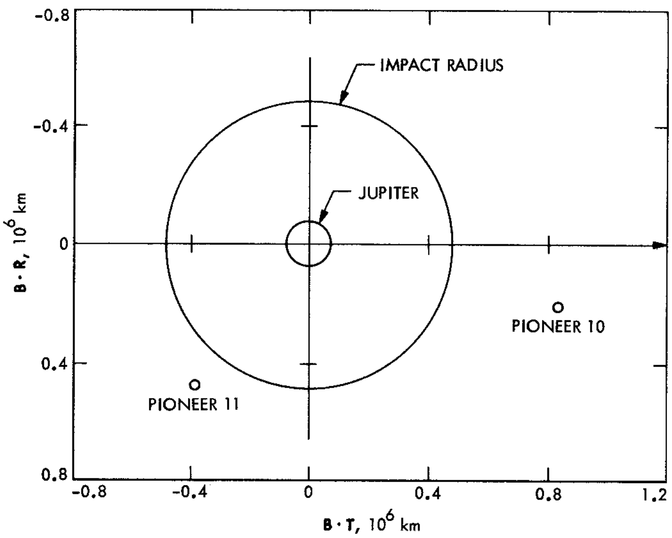

Fig. 2. Pioneer 10 and 11 targeting at Jupiter

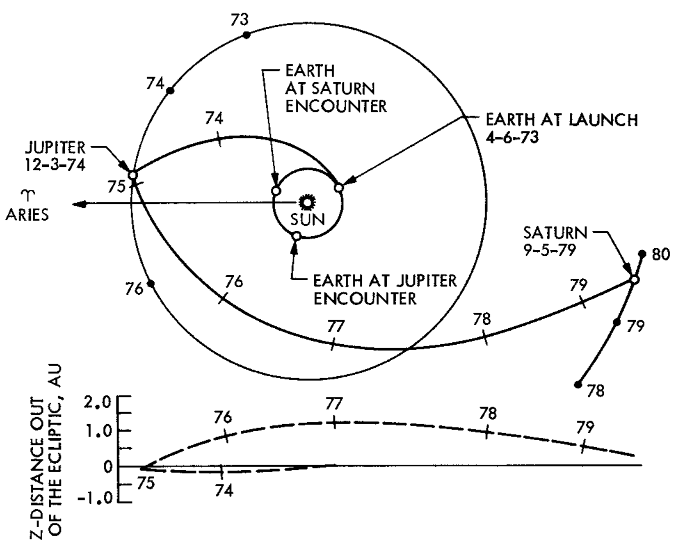

Fig. 3. Pioneer 11 Saturn transfer trajectory