Pioneer 10 and 11 Mission Support

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Possible improvements in the Deep Space Network and their potential effect on the telecommunications limit of Pioneer 10 and on Pioneer 11 Saturn encounter are discussed.

I. Introduction

The Pioneer 10 spacecraft is continuing to return data on new regions of the solar system never before explored by a man-made object. Project estimates are predicting a spacecraft useful life out to 1983. With existing DSN configuration at a 64-m station, the telecommunications limit at minimum bit rate will be reached in mid-1980 at a range of about 22 Astronomical Units (AU) which is 2 AU beyond the orbit of Uranus. It is therefore interesting to explore how potential improvements in performance at DSN 64-m stations might enable extending the telecommunications limit closer to the projected end of useful spacecraft life.

Performance improvements are also of vital interest to Pioneer 11 Saturn encounter where the highest data rate possible is desired to return full imaging, but with a telecommunications link designed for Jovian distances. The problem is compounded by the nearness of the Saturn encounter to solar superior conjunction.

Performance improvement at 26-m stations is of interest for Pioneer 11 coverage improvement between now and the Saturn encounter.

Figure 1 shows the predicted telecommunications performance for both 26- and 64-m Deep Space Stations. Solar conjunction, elevation, and spacecraft antenna-pointing can cause reduction in performance from the values on the chart.

As Pioneer 10 approaches the limit of telecommunications, the two Helios spacecraft may still be alive and Pioneer Venus still orbiting Venus while both Mariner Jupiter Saturn (MJS) 1977 spacecraft are between Jupiter and Saturn. The fact that the Deep Space Network will most likely still be oversubscribed in 1979 through 1981 is important to keep in mind when considering some of the possible ways of extending the telecommunications limit.

II. Projected Spacecraft Life

Pioneer 10 is projected to have sufficient attitude-control propellant (used for antenna-pointing) out to 1989. The 1983 useful end of life is determined from the projected Radio-Isotope Thermoelectric Generator (RTG) degradation to the minimum point for the operation of the science instruments.

There are also some practical problems to be solved in maintaining control of the spacecraft with the large round-trip light times in the latter part of the mission.

Pioneer 11 RTG prediction is to reach the minimum power for science operation in 1984.

III. Potential Performance Improvements at the 64-m Deep Space Stations

The practical (existing technology) prospects for improving the 64-m performance are listed in Table 1.

The potential improvement is the difference the listed item would make in the telecommunications limit compared to the existing 64-m configuration (12-Hz loop, 22 K diplex cone) expressed in dB. The range ratio is the performance improvement translated to a factor which can be used to multiply the geocentric range. It is convenient to express the improvement in range as a ratio because some of the items are multiplicative. For example, if we used items (a) and (c), the range ratio would be $1.12 \times 1.09 = 1.22$, which would extend the range to 1.22×22 AU $= 26.8$ AU. Items (b), (c), and (d) are all different possible improvements in system temperature and do not add, while items (a), (e), and (f) are multiplicative along with any one of the items from (b) through (d).

Item (a) is available now in the operational configuration, and it is planned to use it. The 1.0 dB improvement extending the range to 24.6 AU is only an estimate which it is planned to refine by some testing on Pioneer 10 in the near future.

Item (b) is a special "listen-only" (no uplink transmission to the spacecraft) configuration currently available, but adds serious operational constraints when the total DSN loading is taken into account. First, a second station (26-m) would have to simultaneously view the spacecraft in order to provide commanding. Second, getting into this configuration requires extra station time before and after each pass.

Items (c) and (d) involve implementing known possible improvements to the operational receiver front ends, where (c) would be the usual operation configuration of transmitting to the spacecraft while receiving (diplex mode) which would have no operational constraints, where (d) would be the new equivalent of item (b) with the same operational constraints as item (b).

The improved cone is currently in the DSN program for completion prior to 1979; however, it is subject to being dropped from DSN plans because of tightening resource constraints and the need to give priority to implementations required for prime mission events.

Items (e) and (f) are possible structural improvements to the 64-m antennas which might be reasonable from an engineering standpoint for a 1980 implementation if they could be accommodated within the total NASA program; however, mission support requirements of MJS might preclude allowing the extended station downtime required for the first station until late 1981-early 1982. These improvements are, however, not in the current DSN plans until post-1985.

IV. Summary of Potential 64-m Performance Improvement Benefit to Pioneer 10

With the current 64-m operational configuration, Pioneer 10 should reach its telecommunications limit at about 22 AU (geocentric) some time in the first half of 1980. Use of the available 3 Hz loop in the Block IV receiver should extend this to about 24.6 AU reached in early 1981. Use of a planned improved receiver front end in the usual diplex mode would extend the potential range to 26.8 AU reached at the end of 1981 or early 1982. Shaped hyperbola and extension to 70 meters (not currently in the DSN plan early enough to benefit Pioneer 10) would further increase the potential range to 31.3 AU, which (extrapolating the attached curve a bit too far) would probably be early 1983, coincident with the projected useful spacecraft life. The listen-only modes, items (b) and (d), would not be recommended because of operational impact.

V. Effect on Pioneer 11 Saturn Encounter of 64-m Performance Improvement

Pioneer 11 will be 8 degrees from the Sun at Saturn encounter, and the desired bit rate is 1024 bits/s. It can be seen from the attached curve that even with the planned improvement of item (c)—an 18.5K diplex cone—it will probably not be possible to achieve 1024 bits/s. With the listen-only (14.5K) mode of item (d), the 1024 bit rate might become marginally useful. The operational constraints of requiring a 26-m simultaneously for uplink would probably be practical for on the order of one week of the 60-day Saturn encounter period.

VI. 26-m Performance Improvements and Their Effect on Pioneer 11

An experimental lower noise cone has been implemented on one of the Goldstone 26-m antennas which has provided an 0.7-dB improvement as well as a 3-Hz loop in the receiver which provided an additional 1.5 dB improvement. Using the left side of the attached figure, you can see this should extend the coverage from the single 26-m station for Pioneer 10 at 16 b/s for one year to the end of this year. However, Pioneer 10 drops off rather quickly and no further 26-m improvement appears practical in a time scale to benefit Pioneer 10. A very small performance improvement would enable 26-m coverage of Pioneer 11 at 16 b/s out to Saturn encounter in September 1979. For this reason, an activity has been initiated to install two other 3-Hz loops that were available at an Australian and a Spanish 26-m station for a 1.5-dB improvement. There are no additional 26-m experimental lower noise cones available, and it is doubtful the DSN program will be able to accommodate building any more in the Pioneer 11 time scale.

Table 1. 64-m Improvements

Item	Potential improvement	Range ratio
(a) 3 Hz loop in receiver	1.0 dB	1.12
(b) Current listen-only (18 K)	0.8 dB	1.11
(c) Improved cone: Diplex (18.5 K)	0.7 dB	1.09
(d) Improved cone: Listen-only (14.5 K)	1.8 dB	1.23
(e) Shaping hyperbola	0.5 dB	1.06
(f) Enlarge to 70-meter	0.8 dB	1.10

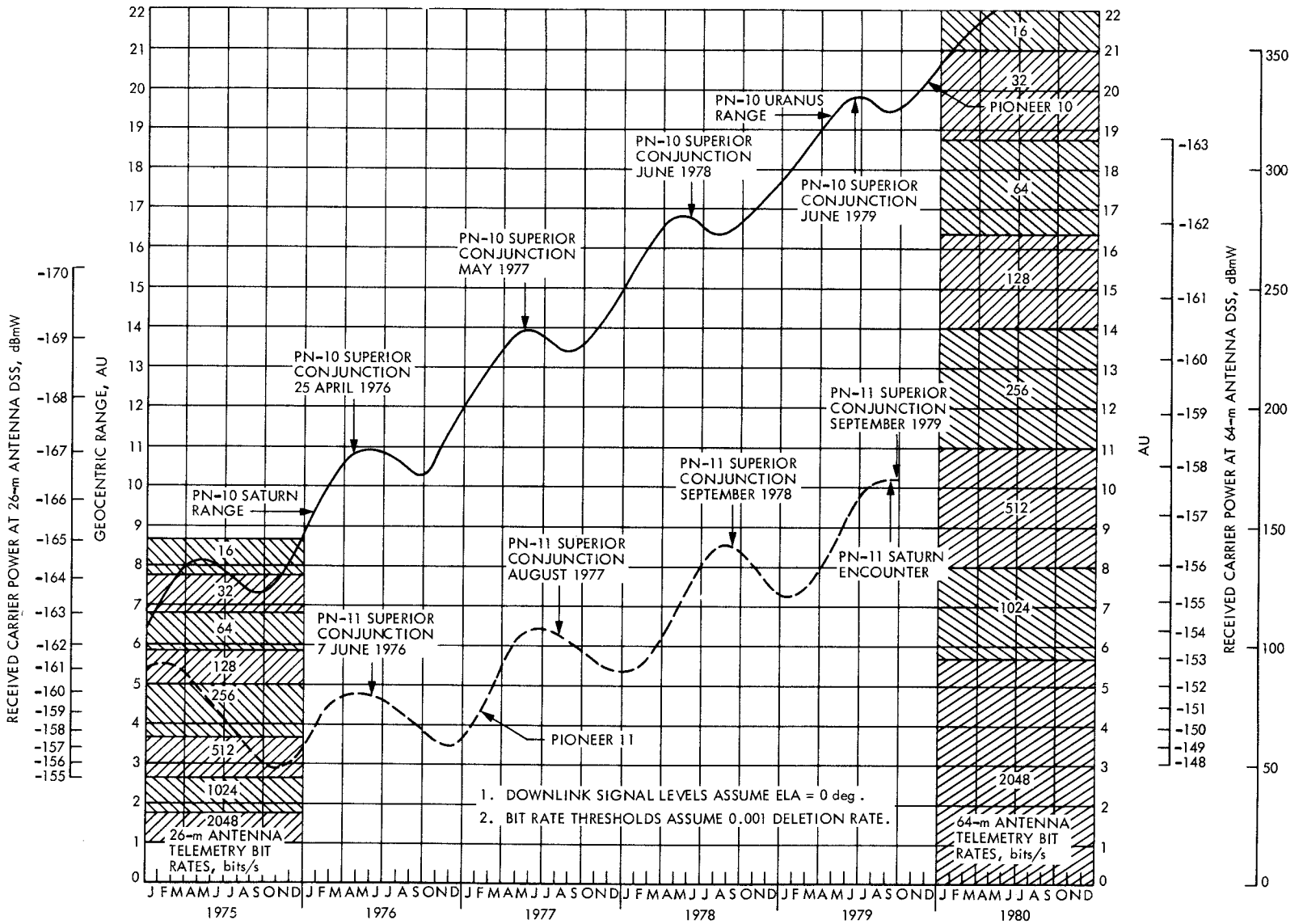

Fig. 1. Downlink performance estimates for Pioneers 10 and 11