DSN System Testing: A Report on the DSN Pioneer G Compatibility Program

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The Pioneer G compatibility test program was nonstandard as no DSN/Pioneer G spacecraft testing was conducted prior to tests performed at Cape Kennedy on March 6, 1973. This report describes these compatibility tests and the test results for establishment of DSN/spacecraft compatibility.

I. Introduction

This report covers the DSN/Pioneer G spacecraft compatibility testing that extended over approximately 25 hours on March 6, 7, and 28, 1973. The compatibility tests performed on these three days were divided as follows:

(1) DSN/spacecraft RF tests at both strong and weak signal levels on March 6, 1973.

(2) Project end-to-end system tests for telemetry and command on March 7, 1973.

(3) Verification of RF compatibility performed on March 28, 1973 with the Pioneer G spacecraft on Pad 36B mated to the launch vehicle.

A Pioneer project decision was made not to perform any compatibility testing between the Pioneer G spacecraft and the DSN prior to delivery at Cape Kennedy. This decision made the establishment of telecommunications compatibility between the DSN and the Pioneer G spacecraft dependent upon the tests performed at Cape Kennedy. This approach to DSN/spacecraft is nonstandard as, in general, DSN/spacecraft compatibility can be divided into two broad phases:

(1) *Phase 1, Design Compatibility.* Phase 1 tests are design compatibility tests between an engineering model and/or flight spacecraft with CTA 21. For example, DSN/Pioneer 10 system design compatibility was established between CTA 21 and the spacecraft through an RF link from CTA 21 in Pasadena to TRW, Redondo Beach, California.

(2) *Phase 2, Design Compatibility Verification.* Phase 2 tests are conducted between DSS 71 and the spacecraft to verify that compatibility established during Phase 1 tests is maintained for each flight spacecraft. Additionally, DSN/spacecraft design changes and uncompleted design tests from Phase 1 are accomplished at Cape Kennedy.

II. Test Report

The DSN/Pioneer 11 spacecraft telecommunications compatibility testing, performed by DSS 71, utilized a test system that was operationally representative of a standard DSN tracking station. The test system was under control of a computer to provide appropriate test conditions in an automatic mode of operation. This capability is described in DSN Document 801-1, Addendums 1 and 2.

The spacecraft configurations during all of the following tests were agreed upon by the Flight Project and the DSN. Spacecraft modes were selected to exercise a representative subset of all possible configurations, and to minimize the time required for completion of an adequate test program. Details concerning spacecraft modes and measured test results are contained in DSN test procedures prepared for this subject test and in Division 420 reports.

A. RF Compatibility Tests

The following tests were performed on March 6, 1973, with the spacecraft located in Building AO:

(1) *Downlink Modulation Index and Spectrum Analysis.* This test verified the proper telemetry modulation index of 1.15 ± 0.1 radians, and confirmed that no spurious signal components were present within 30 dB of the carrier. The test was performed with the spacecraft configured for three different telemetry and RF modes.

(2) *Downlink Threshold.* This test verified that no degradation of the DSS receiver threshold is caused by the spacecraft RF spectrum. Threshold was measured with the spacecraft configured for four different telemetry and RF modes.

(3) *Residual Carrier Phase Jitter.* This test verified that the spacecraft transmitter phase jitter is within specified criteria for the noncoherent mode of operation. Phase jitter in the coherent mode was measured for information purposes only. The carrier phase jitter test was performed with the spacecraft configured for three different telemetry and RF modes.

(4) *Subcarrier Frequency and Phase Jitter.* This test verified the proper telemetry subcarrier frequency of 32768 Hz ± 0.1%. Subcarrier phase jitter was not measured because of hardware problems in the test system interface. This test was rescheduled for performance during the RF verification test.

(5) *Telemetry Processing With Doppler.* This test verified proper telemetry operation with signal levels and doppler conditions expected during the mission. With doppler offsets of ±2 Hz at subcarrier frequency, the degradation in SNR at the SSA was no greater than 0.15 dB. Degradation of SNR due to doppler offset was measured at the downlink signal level expected at Jupiter encounter and in one spacecraft mode.

(6) *Spacecraft Receiver Rest Frequency.* The rest frequency versus temperature of both spacecraft receivers was measured. The measured values were within the specified criteria of ±2 kHz from nominal center frequency of the individual channels. This test was performed at weak and strong uplink signal levels on both spacecraft receivers.

(7) *Spacecraft Receiver Tracking.* This test verified the rate at which the DSS exciter may be tuned while maintaining spacecraft transponder phase lock. The spacecraft receivers will track a frequency change rate of 100 Hz/s, with a strong uplink level (−125 dBm), to at least ±30 kHz from the rest frequency. With a weak uplink level (−140 dBm), the receivers will track a change rate of 20 Hz/s to at least ±12 kHz from rest frequency.

(8) *Uplink Theshold.* The threshold of one spacecraft receiver was measured to insure that no degradation in the design specification is caused by the DSS/spacecraft RF link interface. The measured threshold of −156.5 dBm, for spacecraft receiver 2, is within specified criteria.

B. End-to-End System Tests

The following tests verified the compatibility of the integrated telecommunications system required for support of the Pioneer 11 mission. In addition to DSS 71 and the spacecraft, participating elements were: the Mission Control and Computing Center (MCCC), Pioneer Mission Support Area (PMSA), and Ames Research Center (ARC). These tests were performed on March 7, 1973, with the spacecraft located in Building AO.

(1) *Command Response.* This test verified compatibility and proper performance of the total command system from ARC to the spacecraft. Commands were transmitted to the spacecraft by DSS 71 under remote control from ARC. Spacecraft receipt and proper execution of commands was verified by PMSA and ARC. Command response tests were performed with both spacecraft receivers and decoders.

(2) *Telemetry and Command.* This test verified compatibility of the total data system from the spacecraft to the user (ARC). The spacecraft was commanded to all telemetry modes by remote control of DSS 71, and proper telemetry operation was verified in each mode by PMSA and ARC.

(3) *Conical Scan System Prime Mode.* Proper spacecraft response to a simulated Conical Scan System (Conscan) signal and DSN capability to support a Conscan maneuver were verified by this test. A 2-dB peak-to-peak Conscan signal was generated by DSS 71 and transmitted to the spacecraft. Proper identification and display of the telemetered Conscan data and DSS 71 automatic gain control (AGC) information via high-speed data (HSD) were verified at PMSA and ARC.

C. RF and Data Verification Tests

The following tests were performed on March 28, 1973, with the spacecraft mated to the launch vehicle at Complex 36B:

(1) *Spacecraft Receiver Rest Frequency.* The rest frequency versus temperature of both spacecraft receivers was measured. The measurements were performed with a weak uplink signal level, and verified to be within the specified criteria of channel center frequency ± 2 kHz.

(2) *Downlink Modulation Index and Spectrum Analysis.* This test verified no degradation of the spectrum from the previous test on March 6, 1973. No spurious components within 30 dB of the carrier were detected and the modulation index remained 1.15 $\pm$ 0.1 radians. The spectrum was examined with the spacecraft in four different RF and telemetry modes.

(3) *Subcarrier Phase Jitter.* This test had been rescheduled for performance during the RF Verification Tests due to hardware problems in the test system interface.

Although the test system was known to function properly, the measured subcarrier phase jitter was excessive. Post-test simulation of the RF link variations caused by the spacecraft shroud, personnel in the vicinity of the spacecraft, and the vehicle support structure verified that RF link amplitude and phase variations contributed to the measured phase jitter.

The test was aborted after three attempts with no conclusive results. However, the telemetry doppler tests imply acceptable stability of the telemetry subcarrier.

(4) *Command Response.* Compatibility of the total command system was again verified. Commands were generated at PMSA for transmission to the spacecraft by DSS 71. Spacecraft response was verified from telemetry at the PMSA.

III. Conclusions

The successful conclusion of the Cape Kennedy compatibility tests enabled the formal establishment of DSN/Pioneer 11 spacecraft compatibility at the Pioneer 11 Project Launch Readiness review on April 3, 1973. This establishment of compatibility was documented by the DSN Tracking and Data System Manager and the Pioneer 10/11 Spacecraft Manager.

It should be recognized that this nonstandard program to establish DSN/spacecraft compatibility was successful only because design compatibility had been established with the Pioneer 10 spacecraft.