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Volume III

Tracking and Data System Support for the Pioneer Project

Pioneer 10 – From April 1, 1972, Through the Jupiter Encounter Period, January 1974

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PREFACE

This volume is one of a series of documents describing and evaluating support of the Pioneer 10 and 11 Jupiter missions with Project Management at the Ames Research Center of the National Aeronautics and Space Administration. The work described in this volume was performed by the Tracking and Data Acquisition organization of the Jet Propulsion Laboratory, with Dr. N. A. Renzetti as Tracking and Data Systems Manager for the Pioneer Project. In the time frame of this report, the principal Tracking and Data Acquisition involvement was the Deep Space Network of the Jet Propulsion Laboratory and the NASA Communications Network of the Goddard Space Flight Center.

ACKNOWLEDGMENT

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ABSTRACT

This report describes the Tracking and Data Systems support of the Pioneer 10 mission from April 1, 1972, through the Jupiter encounter period which ended January 5, 1974. The period covered involves operations in the interplanetary environment from the time of completion of the second trajectory correction to the start of Jupiter encounter, the implementation, planning, and testing that lead to the Jupiter encounter, and the operations during the 60-day encounter period.

I. INTRODUCTION

A. MISSION DESIGN AND OBJECTIVES

The Pioneer Program, authorized under the Project Approval Document 844-840-811, dated February 8, 1969, is identified as a Planetary Exploration Program and assigned to NASA Headquarters, Office of Space Science. The project is managed by NASA's Ames Research Center (ARC), with Tracking and Data System (TDS) responsibility assigned to the Jet Propulsion Laboratory (JPL).

The primary objectives of the Pioneer 10 and 11 missions are to conduct exploratory investigations of the nature of the asteroid belt, the environmental and atmospheric characteristics of the planet Jupiter, and the interplanetary medium beyond the orbit of Mars to the extreme of the spacecraft communications. A secondary mission objective is to advance the technology and operational capability for long-duration flights to the outer planets.

Pioneer 10 was launched on March 3, 1972, (GMT) and Pioneer 11 was launched April 6, 1973 (GMT). At the time of writing, both spacecraft have completed the first of the primary objectives, investigation of the nature of the asteroid belt, and Pioneer 10 has completed the second objective in a successful Jupiter encounter. The Jupiter encounter is the major subject of this document. Meeting of the third of the primary objectives will require continued support of the Pioneer 10 and 11 operations by the TDS through the end of this decade. The Pioneer 10 trajectory received a sufficient velocity change during its closest approach to the planet Jupiter so that the spacecraft will eventually become the first man-made object to escape the solar system. Every day that data are received from the Pioneer 10 spacecraft is a further penetration into new regions of space never before explored by man.

The earlier history of the Pioneer Projects is outlined in Volume I of this series.

B. PIONEER PROJECT MANAGEMENT AND JPL SUPPORT ORGANIZATIONS

The NASA Headquarters Office of Space Science was responsible for the planetary programs. The Pioneer Program Manager headed all activities of the Pioneer Project. NASA's ARC, located at Moffett Field, California, was in charge of all management coordination and control aspects for the Pioneer missions. The Pioneer Project Office was headed by the Pioneer Project Manager, who was supported by a project staff. In addition, several government-sponsored organizations supported the Pioneer 10 mission with specific services. The Space Nuclear Systems Division of the Atomic Energy Commission controlled the development and production of the radio-isotope thermal electric generators (RTG's). Teledyne Isotopes was the prime contractor for these generators. The Experiment System, Spacecraft System, and Mission Operations System were supported by individual teams of the ARC. The spacecraft contractor was TRW Systems Group, TRW, Inc.

Several organizations of JPL were involved in supporting the Pioneer 10 mission. These organizations are shown in Fig. 1. Responsibilities of the respective JPL organizations are briefly as follows:

(1) Tracking and Data Acquisition (TDA). Responsible for TDA planning, Deep Space Network (DSN) Systems and Subsystem Engineering, and operation of the DSN.

(2) Office of Computing and Information Systems (OCIS). Responsible for the Mission Control and Computing Center (MCCC), associated supporting research, engineering, and operations.

(3) Flight Projects: Operation Support Coordination Office. Responsible for the Ground Data System (GDS) coordination and interface with the project. This involves assuring that the interface between the TDA and OCIS will result in a GDS that meets project requirements.

(4) Telecommunications Division. Responsible for DSN research and subsystem implementation.

(5) Mission Analysis Division. Responsible for the navigation support of the Pioneer Project.

This document is a report on only that portion of JPL support provided as a part of the TDS which encompasses only the organizational elements Number 1 and 4, above. Support by the other JPL organizations involved in Pioneer 10 is described only insofar as they interacted with the support provided by the TDS.

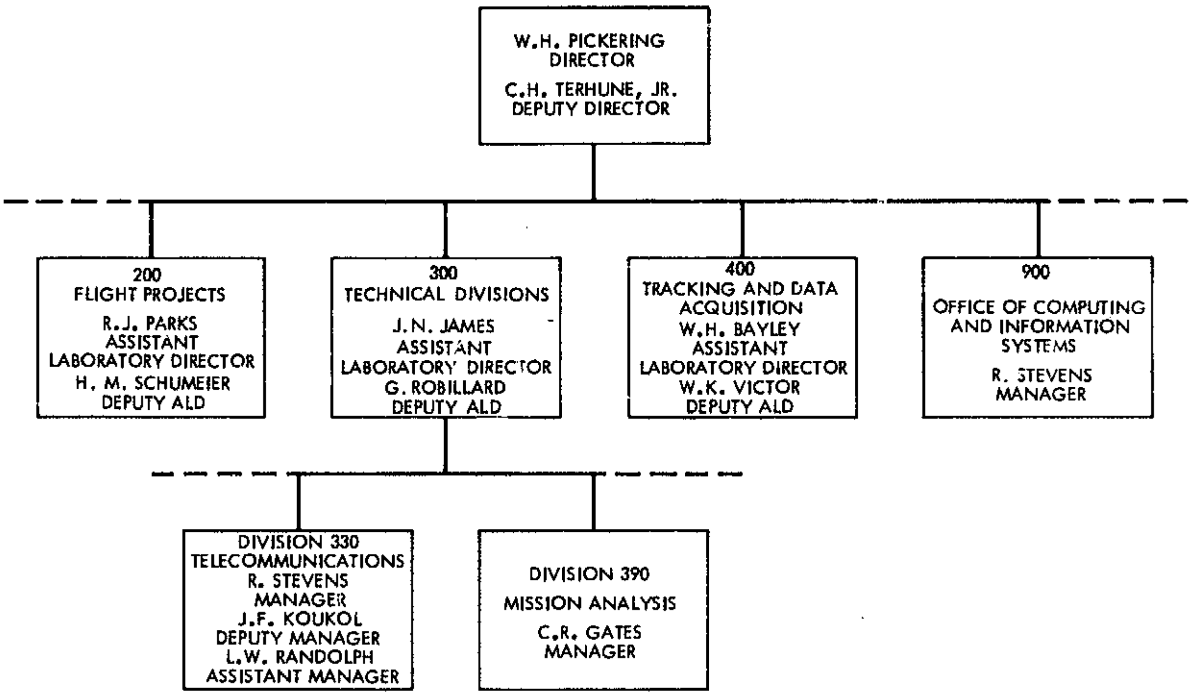


Fig. 1. JPL organizations supporting Pioneers 10 and 11 as of January 1974

C. MAJOR MISSION EVENTS AND CURSORY SCIENTIFIC RESULTS

Two major cruise events occurred since the publication of Volume I of this document: (1) the successful exit of the spacecraft from the asteroid belt and (2) a solar occultation.

One of the primary objectives of the Pioneer 10 and 11 missions was to investigate the nature of the asteroid belt and, in particular, to ascertain what risk is posed to future mission success in spacecraft passage through the asteroid belt. Pioneer 10 entered the asteroid belt in the middle of July of 1972 and safely exited from the region of the asteroid belt in January of 1973. The spacecraft sustained no measurable damage during this time period.

The Pioneer 10 and 11 spacecraft carried two meteoroid related instruments. The first was an asteroid meteoroid detector constructed by General Electric. This instrument was designed to detect particles greater than 10^{-6} g in mass. Its detection method was by reflected solar light. The instrument consisted of four independent telescopic subsystems providing four overlapping fields of view; the light signatures were detected by photomultiplier tubes. The telescope arrangement allowed the determination of trajectories of detected particles. The second instrument was a meteoroid detector from Langley Research Center. This experiment detection method consisted of pressurized cells mounted on the back side of the spacecraft high-gain antenna. When particles penetrated the cells, the rate at which pressure was lost from the cell indicated the size of the hole made, and thus the mass and energy of the particle responsible for the impact.

Significantly, there was no noticeable change in the number of events determined by the two meteoroid instruments upon entering or exiting the asteroid belt. Instead a nearly continuous decrease in the event rate was observed after the spacecraft was launched on March 3, 1972 (GMT).

The solar occultation period extended from essentially January 11 through January 21 of 1973. The two major spacecraft concerns during this time period were: (1) trying to avoid the automatic switching of elements in the spacecraft radio subsystem that would take place if there was no uplink for longer than 36 hours, and (2) the loss of roll reference that would occur if the spacecraft spin axis was oriented too close to the Sun.

The technique that was used to avoid these problems was to step the spacecraft around the Sun prior to solar occultation and leave the spacecraft in an orientation ahead of the Sun so that the Earth-spacecraft angle would slowly converge on realigning the spacecraft high-gain antenna. This reorientation was accomplished on the 11th of January. The result was that the spacecraft high-gain antenna was not directed at Earth and, therefore, the effective gain of the spacecraft antenna was decreased. However, the result was actually an increase in the effective uplink margin during the solar occultation because the off-pointing decreased the noise input from the solar corona into the spacecraft antenna. The off-pointing with respect to the Sun enabled the Sun sensor roll pulse to be operative during the solar occultation. Use of DSS 14 400-kW transmitter during the solar occultation enabled the daily establishment of an uplink to prevent the automatic switching within the spacecraft receiver subsystem. To aid in the determination that an uplink had been established during the height of the solar blackout, an experimental open-loop receiver was used to detect the change from the noncoherent to the coherent frequency on the downlink. Telemetry blackout extended from January 13 to January 17. Although there were extensive problems with the DSS 14 R&D high-power transmitter, excellent support by station and DSN operations personnel enabled the uplink requirement to be met each day of the blackout.

The Pioneer 10 magnetic fields, solar wind, plasma, and energy charged particle measurements obtained between the orbit of Mars and Jupiter indicated a much higher degree of interplanetary turbulence and a surprisingly smaller gradient in the galactic cosmic rays than had been expected. Even these early results of Pioneer 10 require reformulation of existing coronal expansion and cosmic ray modulation theory.

Closest approach to Jupiter was reached at 02:25:19 (GMT) on December 4, 1973, at a range of 2.86 Jupiter radii, 203,250 km from the center of the planet (the radius of the visible disk is about 71,000 km), or 132,250 km from the visible surface.

The Jupiter environment was found to be much more complex and interesting than had been anticipated. The field and particle environment is not simply a field with trapped particles interacting with the solar wind in a semistatic fashion. Tremendous fluctuations in the extent of the bow shock were observed, apparently related to the changes in intensity of the solar wind.

Complex structure was observed inside of the bow shock, and a radiation 1000 times higher than is considered lethal to a human being, although the actual magnetic field strength measured was at the lower end of the preflight range of estimates.

The spacecraft appeared to have experienced nearly the maximum radiation dose it could take without catastrophic damage to equipment and instruments. Temporary (reversible) damage was experienced in some areas such as in the ultraviolet spectrometry, and mild effects on the radio subsystem were apparent as shifts in the on-board oscillator frequency and receiver rest frequency. The asteroid/meteoroid detector suffered permanent damage in its optics; however, its primary mission had been completed on passing through the asteroid belt. There was no loss of primary science data as a result of radiation effects, although the very closest pictures planned in the few hours near closest approach were lost because of saturation of the gain control in the imaging system. This will not be a problem for Pioneer 11 because the automatic gain control can be overridden on that spacecraft.

The occultation experiment was successful. An ionosphere was detected on the moon Io, and all data were obtained during the entry and exit phases of the Jupiter occultation. The occultation experiment sought to determine atmospheric characteristics by ground-based measurement of the effects on the S-band radio link as it transmitted through the atmosphere. The complex Jupiter atmosphere required extensive analysis by the experimenter to model the observed effects.

The imaging photo polarimeter returned many intriguing pictures of the planet. The radiation measurements by other instruments peaked at something like 400 million 30-MeV electrons and 4 million 3-MeV protons per square centimeter per second. The temperature measurements showed that the planet radiates about 2-1/2 times the thermal energy it receives from the Sun and that there is no significant difference between daytime and nighttime temperatures. Jupiter's center was estimated to be at 30,000°C (54,000° F), which is six times as hot as the surface of the Sun itself.

The combination of the imaging and infrared data indicated that the alternating light and dark bands of the planet are indications of rising and sinking gases where the gray-white zones are rising currents and the rust-colored belts are troughs of descending atmosphere. The most enigmatic Jovian feature, the giant red spot, was described as the vortex of a giant storm likened to a terrestrial hurricane which has raged for at least several hundred year. Smaller similar features were discovered in the returned color images.

II. TRACKING AND DATA SYSTEM

A. TRACKING AND DATA SYSTEM ORGANIZATION

Section II of Volume II of this series describes organizational changes which took place at JPL during the time scale of the Pioneer 11 launch. This involved the separation of the Central Computing Facility from the DSN. At the same time, the TDA functions at the Laboratory were reorganized. A further change, which took place between the time of Pioneer 11 launch and Pioneer 10 Jupiter encounter, was the introduction of Section 295 to assist in the GDS coordination function for the Pioneer Project. The GDS Project Engineer, who was temporarily assigned to the Tracking and Data System Manager for Pioneer 11 launch, transferred to this section and the Network Operations Representative for Pioneer, who had temporarily expanded duties to cover the entire GDS for the Pioneer 11 launch, also transferred to this section. The principal function of these positions, coupled with the Pioneer Project Support Coordination Office under the Flight Projects Division, was to ensure that the MCCC and DSN interface was properly coordinated to provide a total GDS that would meet project requirements.

The TDA organization involved in support of the Pioneer Project is shown in Fig. 2. The Manager of the DSN Systems Engineering Office also serves as the TDS Manager for the Pioneer Project. The TDS Manager acts as the interface between the project and the TDS support agencies to match requirements with the capabilities of the support agencies to establish a compatible integrated system of tracking and data acquisition resources which are then called the "Tracking and Data System." The DSN Manager acts as the Assistant TDS Manager for Pioneer and is responsible for all DSN support for the Pioneer Project. The DSN Manager is responsible for negotiating the requirements and commitments with the Pioneer Project for the DSN and is responsible for assuring that all capabilities required are planned and implemented on schedule to meet Project requirements.

Under the Network Operations section, Fig. 3, there is a Network Operations Project Engineer (NOPE) assigned for Pioneer. The NOPE is responsible for all 420 support of the Pioneer Project. This involves achieving operational readiness, producing operational procedures, scheduling the DSN activity, and conducting operations. Under the Network Operations Control Group, a Network Operations representative is assigned to Pioneer. The Network Operations representative is responsible for coordinating the day-to-day operational activities in support of the Pioneer Project.

B. DSN FACILITIES AND THE GROUND DATA SYSTEM

An additional unique aspect of the Pioneer 10 Jupiter encounter was that for the first time the mission operations control for a major unmanned mission event supported by JPL was in a remote control center and did not reside within JPL facilities at Pasadena, California. Major elements involved in the total GDS which supported the Pioneer 10 and 11 missions as it existed during the Pioneer 10 Jupiter encounter time frame are pictured in Fig. 4.

The next three section headings correspond to the three major sections in the GDS which are geographically separated. Paragraph headings within the three sections correspond to the elements portrayed in Fig. 4 within the three geographic locations. The following discussion concentrates on the data flow through the GDS. Note that Fig. 4 is not necessarily a logical breakdown to a uniform level of detail in all elements of the GDS, but rather a convenient construction for this discussion.

1. Deep Space Station

The station configuration was essentially identical for the encounter phase as for Pioneer 10 and 11 cruise support, except that a higher level of redundancy was provided for critical mission periods. There are four major elements within the DSS and within the DSN: the Telemetry, Command, Tracking, and Monitor Systems.

a. Monitor. The Monitor System collects status and performance information in real time for transmission by high-speed data line (HSDL) and further processing for use by DSN Operations Control. The monitor data are not used by the Project.

The ground communications form an additional DSN system and are comprised of voice, high-speed data (HSD), and teletype transmission equipment.

b. Telemetry. The DSS Telemetry Subsystem detects the telemetry subcarrier, acquires bit (or symbol in coded mode) synchronization, decodes coded data, and produces a Digital Original Data Record (DODR) for recovery of data lost during real-time transmission. The Telemetry Subsystem formats the telemetry data for HSD transmission and provides an off-line capability for performing data recalls.

c. Command. The Command Subsystem receives command instructions via HSD, stores a number of commands for later transmission either when enabled or at preselected times, sends the commands to the modulator in the exciter, and performs various self-checking functions to assure that commands are transmitted without error.

d. Tracking. The Tracking Subsystem receives predictions via HSD for controlling the transmitter and ground reference frequency, and for pointing the antenna. The Tracking Subsystem also generates and samples doppler and angle information, and formats this information, called radio metric data (RMD), for HSD transmission.

2. Mission Control and Computing Center

The MCCC provided real-time engineering processing for the Project, navigation processing, and the processing for DSN Operations Control functions. Telemetry data could also be processed directly by the ARC, which was used as a backup mode of operations.

a. 360/75 Real-Time System. The real-time system provides real-time engineering data processing including production of Project telemetry formats for local display and transmission to ARC, radio metric data processing including pseudoresiduals, and a Master Data Record (MDR) for processing by the Navigation Team. DSN Operations Control processing, including the generation of predicts and Monitor System data displays, resided in the 360/75. The telemetry and command Master Data Records were produced in this system and shipped to ARC. Extensive command processing, including command file creation and manipulation, was also provided.

b. DSN Operations Control. The DSN Operations Control area resided in the MCCC and was the location where all DSN real-time activities were monitored and controlled.

c. MCCC Operations Control. MCCC self-monitoring and control functions are carried out in the MCCC.

d. Pioneer Mission Support Area. A limited Pioneer Project staff manned the Pioneer Mission Support Area (PMSA), which was an area provided in the MCCC. Most of the 360/75 displays are available only to the few Project operators located in this area. This area supplemented the Pioneer Project real-time operations and served as a backup mission operations center in the event of a failure in ARC equipment or the communications between JPL and ARC.

e. Navigation. The Navigation Team was a JPL-supported function for the Pioneer Project which utilized the 1108 computer system for orbit determination and maneuver analysis by processing the radio metric data.

f. 360/75 Off-Line. An off-line 360/75 (not shown in Fig. 4) was used for limited time periods to support special tracking predict generation necessary for the special use of digitally controlled oscillators during the Pioneer 10 encounter.

3. Pioneer Mission Control Center

The Prioneer Mission Control Center (PMCC) was located at the ARC and the principal real-time processing was performed on a Sigma 5. There are three Sigma 5s at ARC with one ordinarily processing Pioneer 10 data, one processing Pioneer 11 data, and the third serving as a backup and performing off-line processing. During the critical encounter periods, Pioneer 11 data were processed in the direct mode to relieve 360/75 loading.

a. Sigma 5 Real-Time System. This system does some limited engineering telemetry processing, plus all of the science telemetry processing, and it produces listings for use by the experimenters. In addition, it accepts command instructions and interfaces with the 360/75 command software via high-speed data in standard NASA Communications (NASCOM) blocks.

b. Sigma 5 Off-line System. The off-line system serves as a backup to the on-line and processes the received MDRs to produce the Experimenters' Data Record (EDR).

4. Ground Data System Complexity

The complexity of the GDS for the support of Pioneers 10 and 11 was particularly evident in command operations. During Pioneer 10 and 11 operations, including encounter, all commands were entered by operators at ARC into the Sigma 5 for high-speed transmission to the 360/75 at JPL, extensive processing in the 360/75, then high-speed transmission to the Telemetry and Command Processor (TCP) in the DSS, and finally through the transmission link and radiated to the spacecraft. Therefore, there were a large number of individual elements in the command path which had to be all working properly to assure command flow. Fortunately, backup plans existed to continue command operations in the event of failures in specific areas of the total ground data system. For example, commanding could be performed from the PMSA in the event of a failure in the PMCC, and a small number of commands could be entered directly by station personnel at the DSS when necessary.

Recognizing the complexity of the GDS for Pioneer 10 and 11, ARC and the DSN have planned implementation of a direct interface between the PMCC and the DSS after Pioneer 11 encounter sometime in early 1975.

5. Deep Space Network

The DSN portion of the Pioneer GDS consisted of the Deep Space Station (DSS), the ground communications network, and the functions required for Network Operations Control (NOC).

A more detailed block diagram of the Pioneer configuration at each DSS is shown in Fig. 5. The DSS which supported Pioneer 10 and 11 in the time period covered by this document and their location are shown in Fig. 6. The ground communications network provided during the Pioneer 10 Jupiter encounter is shown in Fig. 7.

6. 64-meter Antenna Support

Noteworthy is the fact that one of the early Pioneers was the first spacecraft tracked by DSS 14 at Goldstone, California — the first 64-meter antenna.

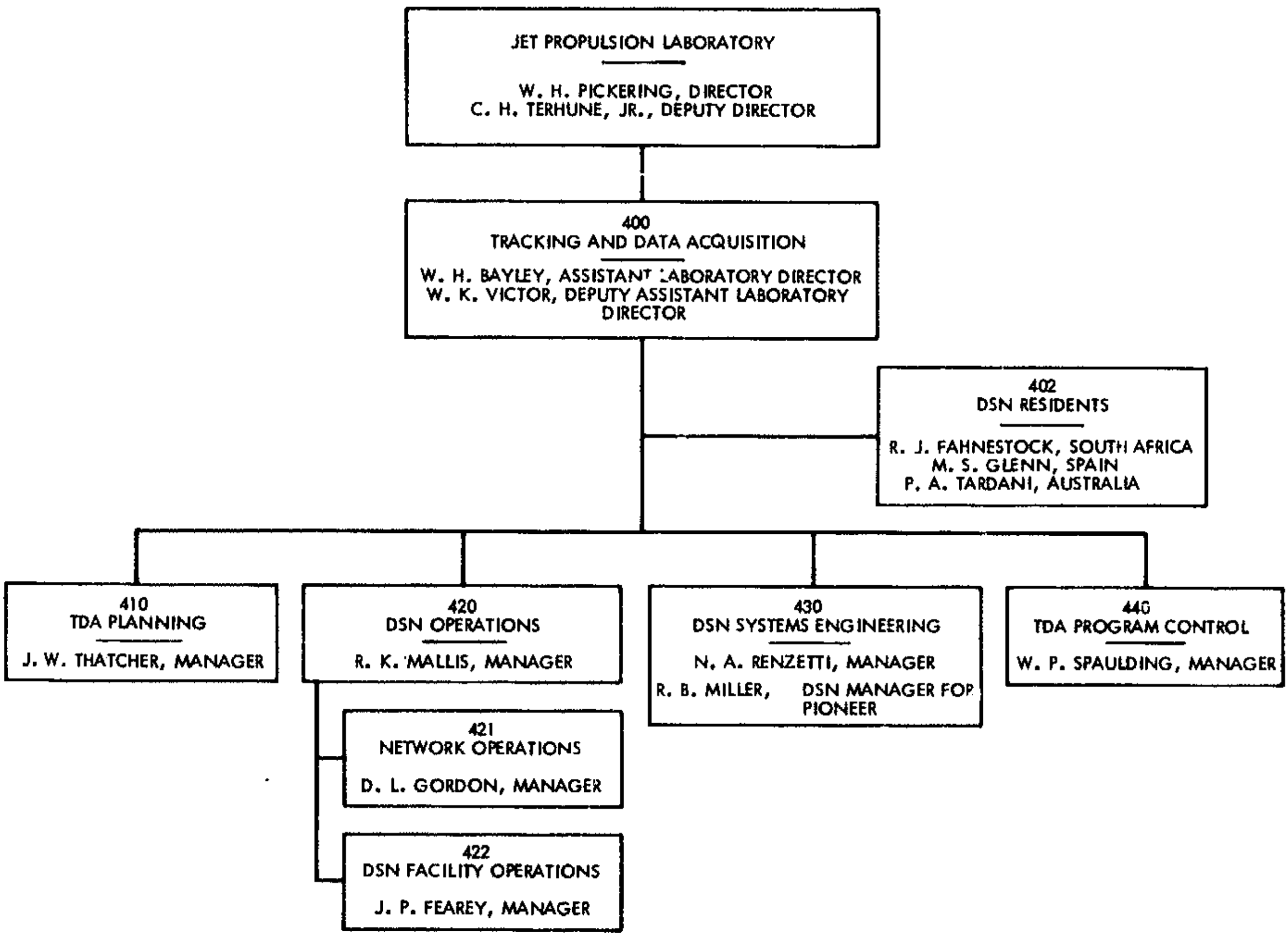


Fig. 2. Tracking and data acquisition organization in support of Pioneer 10 and 11 as of December 1973

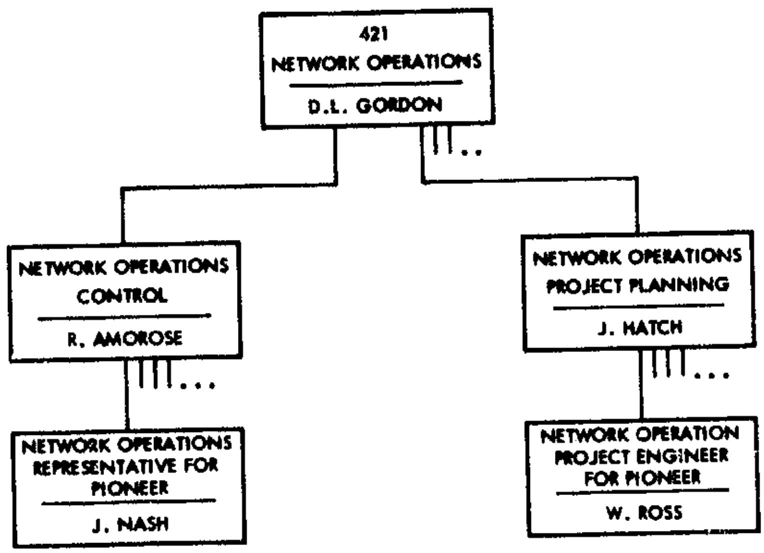


Fig. 3. Network Operations Pioneer interface as of December 1973

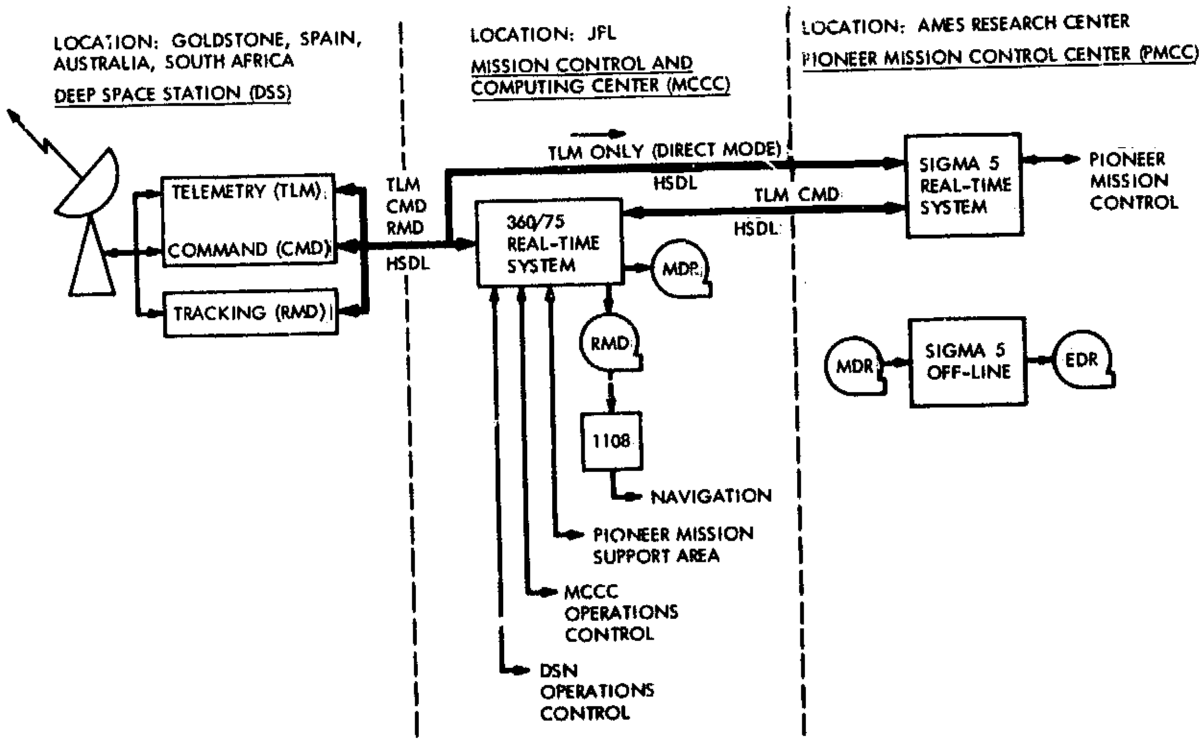


Fig. 4. Pioneer 10 Ground Data System during Jupiter encounter

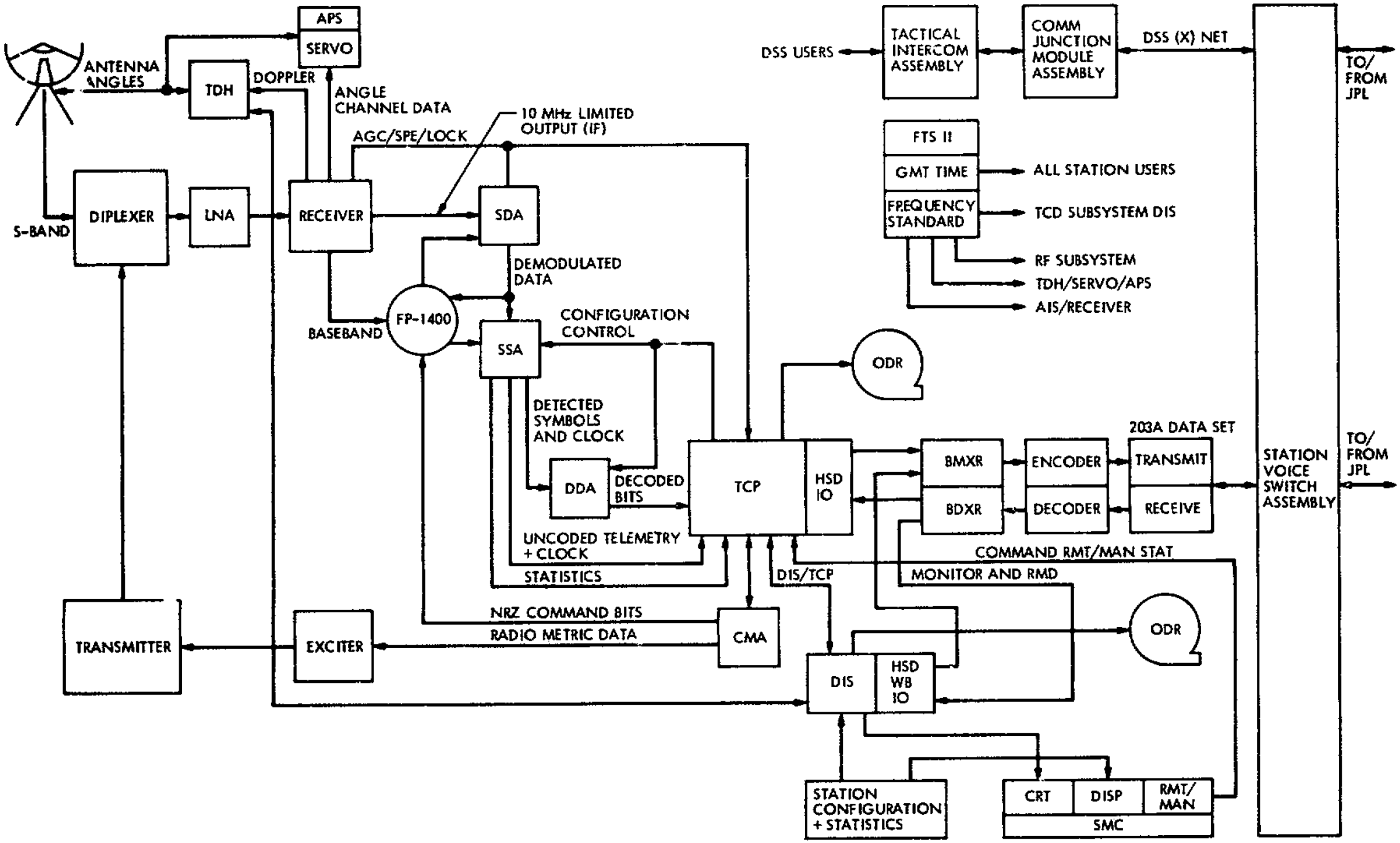


Fig. 5. Deep Space Station block diagram

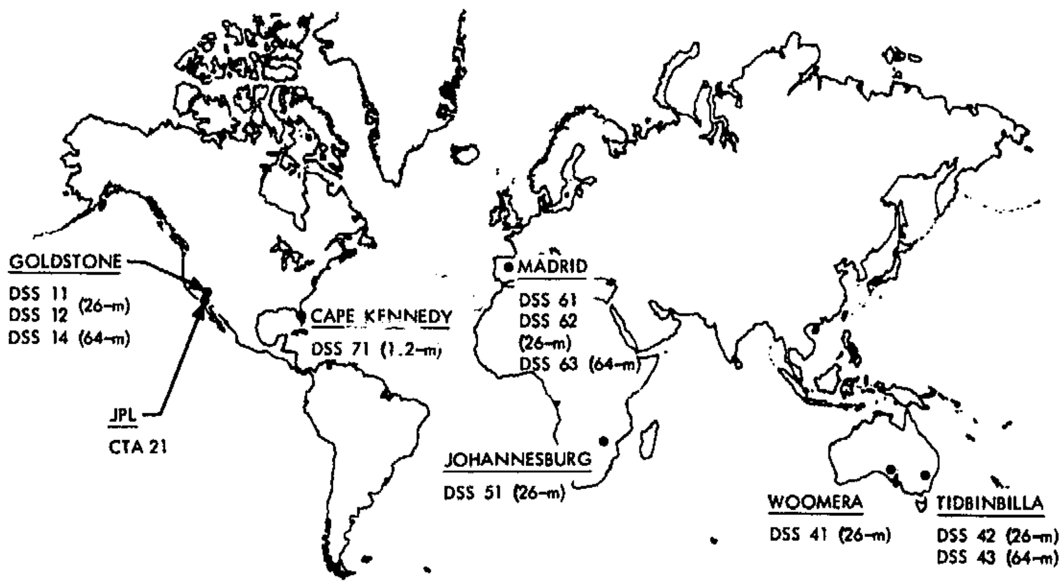


Fig. 6. DSS support for Pioneer 10 and 11 during period of this document

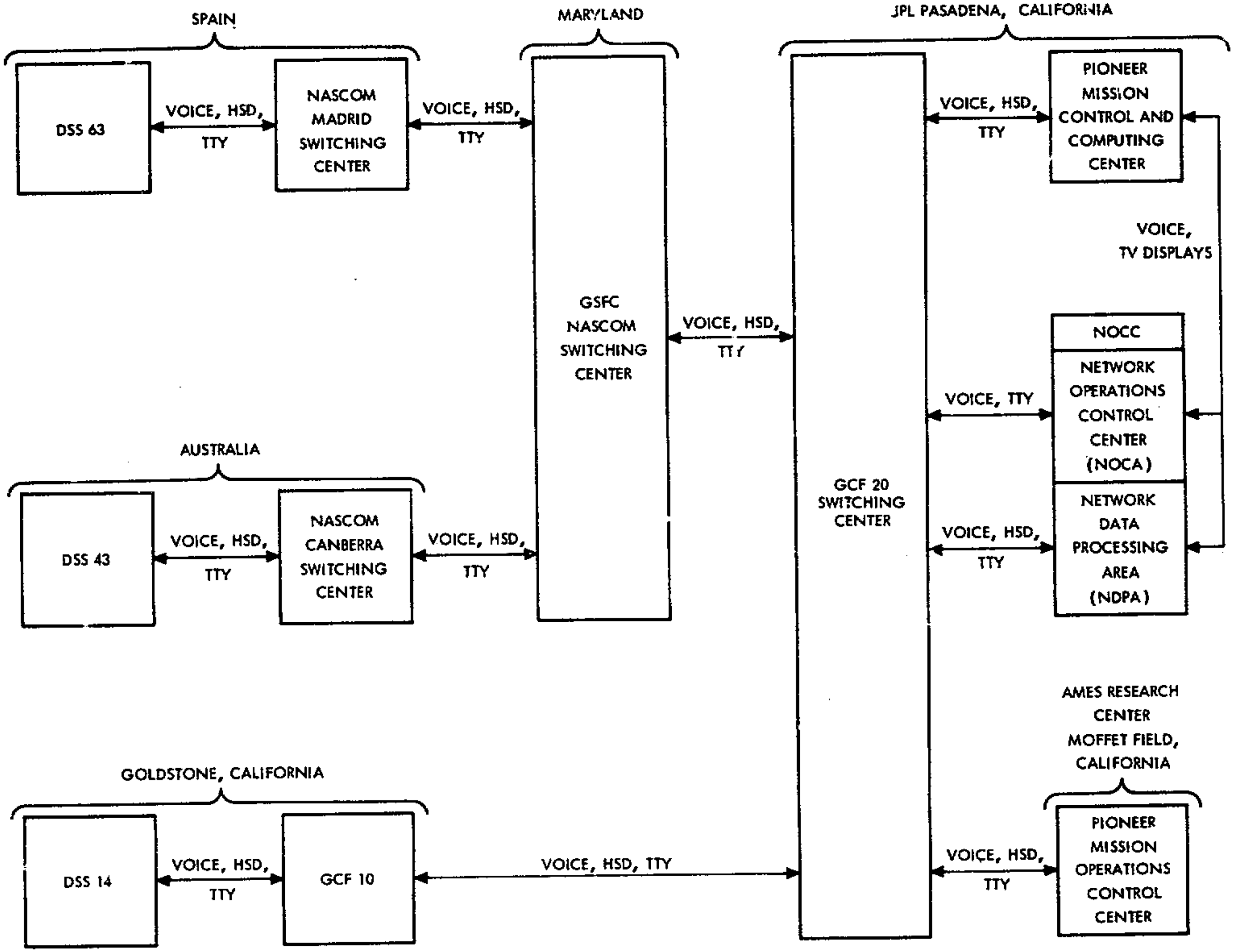


Fig. 7. Ground communications system configuration during Pioneer 10 Jupiter encounter

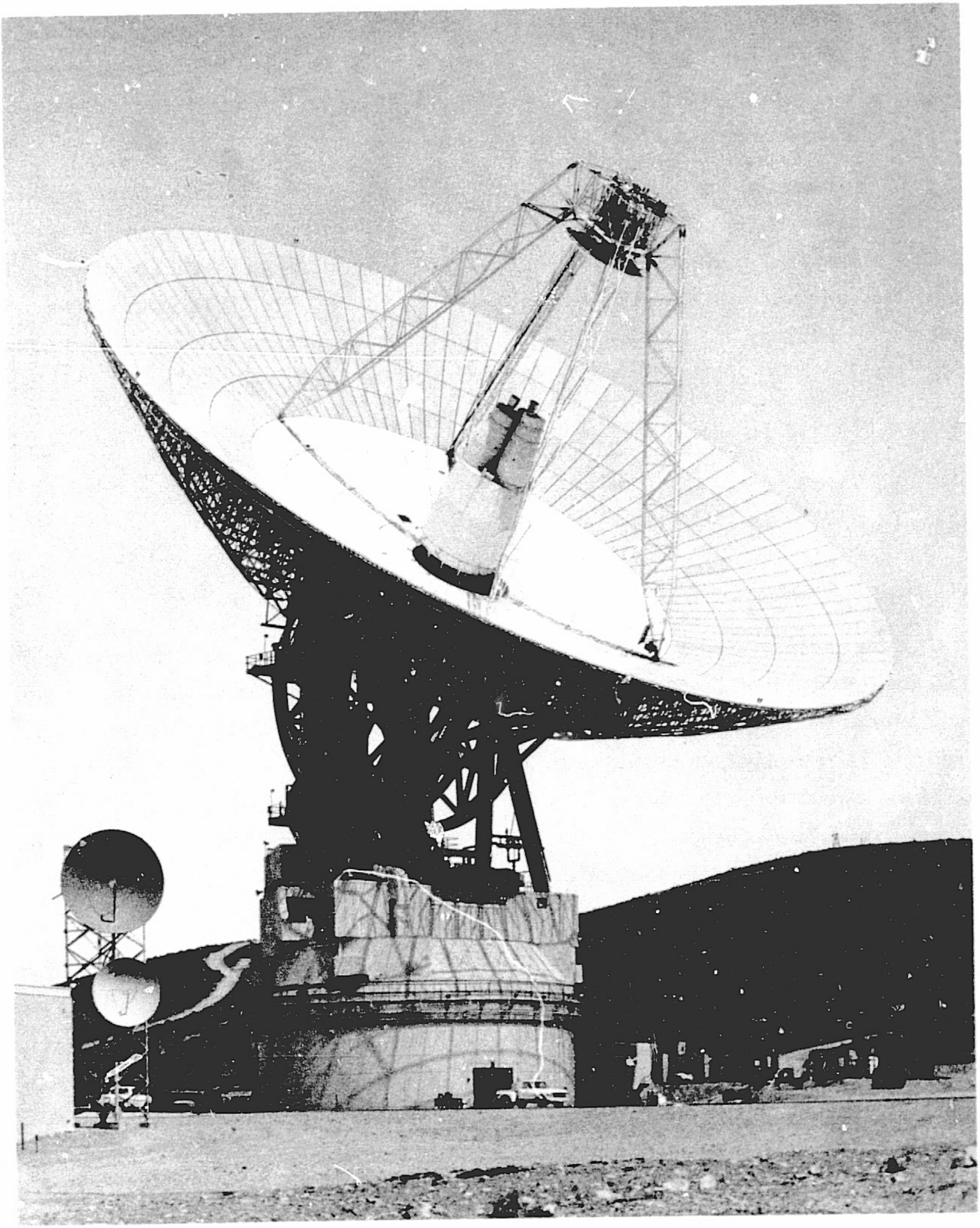


Fig. 8. 64-meter antenna of the Deep Space Network

Pioneer 10 and 11 were the first spacecraft to be tracked by the new 64-meter antennas, DSS 43 and DSS 63, in Australia and Spain. DSS 43 started tracking support in April 1973 on a research and development basis, and became operational in July 1973. DSS 63 became operational in September of 1973. Figure 8 is a photograph of a 64-meter antenna.

Communications to the spacecraft using 64-meter antennas were critical to the success of the mission in achieving significant science return at the Jovian distance. Instead of receiving data at 1024 bits per second, a data rate of 64 bits per second would have been barely achievable. This would have meant no imaging data and less than 1/8 of the nonimaging science would have been returned.

III. MISSION PROFILE

A. PIONEER 10 SPACECRAFT

1. Introduction

The basic mission objective of Pioneer 10 and 11 Project, when authorized in February of 1969, was to design a low-cost mission to the planet Jupiter as a precursor for later, more sophisticated flights. It was understood that in order to have missions to the outer planets in the 1970s and 1980s utilizing existing launch vehicle energy capabilities, use of gravity-assist type trajectories would be necessary. These trajectories would most likely utilize the planet Jupiter for a slingshot effect to shorten the time of flight to the more distant planets of Saturn, Uranus, and Neptune.

It was anticipated, based on Earth observations, that the planet Jupiter had a sizable magnetic field, indicating that the planet was surrounded by trapped radiation. The magnitude of this radiation hazard and its effect on a spacecraft flying close to Jupiter needed to be clearly understood in order to design missions to the outer planets. The Pioneer Jupiter mission was to then be the trailblazing mission to assess the radiation hazard of the planet Jupiter and determine how close to the planet future slingshot missions could safely go.

A second concern for future outer planet missions was the hazard of the asteroid belt that exists between the orbit of the planet Mars and the orbit of the planet Jupiter. There was conjecture before the Pioneer Jupiter missions flew that there would be particles of sufficient size in the region of the asteroid belt to destroy a spacecraft and prevent its safe passage through this region of space. Pioneer 10 and 11 have shown, however, that a spacecraft can safely pass through the asteroid belt with no significant increase in micro-meteorite hits compared to the rest of free space that man has explored.

2. Spacecraft Features

The Atlas-Centaur launch vehicle was selected for the Pioneer Jupiter mission. The spacecraft (Fig. 9) was, therefore, designed to fit within the 3-meter (10-ft) diameter shroud of the Centaur vehicle. The Pioneer 10 spacecraft would have to communicate over the greatest distance from the Earth of any mission to date. For this reason, the dominant feature of the spacecraft is a 2.75-meter (9.02-ft) parabolic high-gain antenna. The unique feature of the Pioneer 10 spacecraft, as compared to features in the previous deep space missions, is the source of electric power. Since this spacecraft was to go farther from the Sun than any previous flight, converting solar power to electrical energy was not practical for a small low-cost spacecraft. At the distance of the planet Jupiter, sunlight carries only 1/27th the energy it does at Earth. For this reason, the Pioneer 10 spacecraft carried four radioisotope thermoelectric generators (RTGs) deployed on two booms, each of which extends 2.75 meters (9 ft) from the center of the spacecraft.

Since the spacecraft would have to survive nearly two years in space before reaching the Jupiter encounter, simplicity of design for reliability's sake was an important design factor. The spacecraft is, therefore, spin-stabilized with six hydrazine thrusters used in various combinations to control spin rate and antenna pointing, and to execute trajectory correction maneuvers.

At launch, the RTGs generated approximately 155 W of electrical power, which decayed to approximately 140 W by the time of Jupiter encounter. The depletion of power is not caused by the half life of the nuclear source itself, but from the deterioration of the junctions of the thermocouples converting the heat into electricity. The spacecraft requires only 100 W to operate all systems, 26 W of which are for the science instruments.

Another dominant feature of the spacecraft is the magnetometer boom, which extends 6.5 meters (21.5 ft) from the center of the spacecraft. This boom was folded for launch and is mounted against the spacecraft with a spring-loaded arrangement so that the boom functions as a nutation damper whenever the spacecraft orientation is precessed.

B. SCIENTIFIC OBJECTIVES AND EXPERIMENTS

The scientific objectives encompassed investigating both the interplanetary medium beyond the orbit of Mars and the Jovian system. Objectives of the interplanetary experiments are (Ref. 1):

(1) Map the magnetic field in interplanetary space.

(2) Determine how the solar wind changes with the distance from the Sun.

(3) Measure cosmic rays originating both from within and from outside the solar system.

(4) Study interaction among the interplanetary magnetic field, the solar wind, and cosmic rays.

(5) Search for the transition region of the heliosphere: the region where the influence of the Sun on interplanetary space terminates.

(6) Measure the amount of neutral hydrogen in interplanetary space and at Jupiter.

(7) Ascertain the distribution of dust particles in interplanetary space.

(8) Determine the size, mass, flux, and velocity of small particles in the asteroid belt and, thus, provide information on the possible hazard to a spacecraft passing through this belt.

Within the Jovian environment, the principal Pioneer science objectives were:

(1) Map the Jovian magnetic field, its intensity, direction, and structure.

(2) Determine how many electrons and protons of various energies are distributed along the trajectory of the spacecraft through the Jovian magnetosphere.

(3) Search for auroras in the polar atmosphere of Jupiter.

(4) Obtain information to help interpret the observed characteristics of the two main types of radio waves from Jupiter.

(5) Map the interaction of the Jovian system with the solar wind.

(6) Measure the temperature of Jupiter's atmosphere and some of the large Jovian satellites.

(7) Determine the structure of the upper atmosphere of Jupiter where molecules become electrically charged to form an ionosphere.

(8) Map Jovian thermal structure by measurement of infrared radiation.

(9) Obtain spin-scan images of Jupiter in two colors during the encounter sequence and close-up images of special planetary features, and make polarimetry measurements of Jupiter and some of its large satellites.

(10) Probe the Jovian atmosphere with S-band radio waves at occultation.

(11) Investigate as many as possible of the Galilean satellites at close range by spin-scan imaging and other measurements to aid in determining their size and physical characteristics.

(12) Determine more precisely the masses of Jupiter and its four large satellites by accurate observation of the effects of their gravitational fields on the motion of the spacecraft.

(13) Provide information to calculate with greater accuracy the orbit and ephemerides of Jupiter and the Galilean satellites.

In order to accomplish these objectives, 11 scientific instruments were carried on board the Pioneer 10 spacecraft.

The magnetic fields were measured using a Helium Vector Magnetometer deployed on the long boom extending from the spacecraft. This magnetometer operated in eight different ranges, the lowest of which covered magnetic fields from $\pm 1.00 \times 10^{-11}$ to $\pm 2.5 \times 10^{-9}$ tesla (± 0.01 to ± 2.5 gamma); the highest, fields up to 1.4×10^{-4} tesla (1.4×10^{5} gammas), which equals ± 1.4 gauss. These ranges were selected by ground command or automatically as the instrument itself reached the limits of a given range. The sensor consists of a cell filled with helium that is excited by electrical pulses at radio frequencies and infrared optical pumping. Changes in helium absorption caused by magnetic fields passing through the magnetometer are measured by an infrared optical detector.

The Plasma Analyzer was designed principally to investigate the solar wind and the heliosphere. Radiation enters the plasma analyzer apertures between two quadraspherical plates where the direction of arrival, the energy, and the number of ion and electrons making up the radiation are measured. The high resolution analyzer has 26 continuous channel multipliers to measure the number of ions per second between 100 and 8,000 electron volts. The medium resolution analyzer has 5 electrometers to count ions of 100 to 18,000 electron volts and electrons of 1 to 500 electron volts.

The Charged Particle Detector consisted of four measuring systems: two particle telescopes that operated in interplanetary space, and two that measured the intense trapped radiation inside the Jovian radiation belts. The main telescope of seven solid-state detectors measured the composition of cosmic rays from 1 to 500 million electron volts, and a 3-element, low-energy telescope measured 0.4 to 10 million electron volt protons and helium nuclei. A solid-state electron current detector detected those electrons above 3 million electron volts that generated the decimetric radiation waves emitting from Jupiter. A trapped proton detector contains a foil of thorium which undergoes nuclear fission when impacted with protons above 300 million electron volts, but is insensitive to electrons.

The Cosmic Ray Telescope could determine which of the nuclei of the ten lightest elements make up those cosmic ray particles streaming from the Sun. It was also able to make measurements in the outer portion of the Jovian environment until saturated by the high energy particles near Jupiter. The instrument consists of three 3-element, solid-state telescopes. The high-energy telescope measures the flux of protons between 56 and 800 million electron volts. The medium-energy telescope measures protons with energies between 3 and 22 million electron volts, and identifies the ten elements from hydrogen to neon. The low-energy telescope measures the flux of electrons between 0.5 and 1 million electron volts, and of protons between 0.5 and 20 million electron volts.

The Geiger Tube Telescope was designed to measure the radiation at the higher levels in the Jupiter environment. It consists of seven Geiger-Muller tubes. Three parallel tubes form a telescope; three others form a triangular array to measure the number of multiparticle events called showers. The combination of these telescopes enables a comparison of primary and secondary events in the Jovian radiation belts. The third telescope detects low-energy electrons above 40,000 electron volts and the instrument also counts protons with energies above 5 million electron volts and electrons with energies from 2 to 50 million electron volts.

The Trapped Radiation Detector covers a different range of energy from the previous experiment. It uses an unfocused Cherenkov counter to measure electrons from 0.5 to 12 million electron volts. The detectors are an electron scatter detector activated by electrons between 100 to 400 thousand electron volts and an ionization detector consisting of a solid-state diode that measures minimum ionization particles less than 3 million electron volts and protons in the range of 50 to 350 million electron volts.

The Asteroid-Meteroid Detector is composed of four telescopes with a conical overlapping field of view and photomultiplier tubes that convert light received by the telescopes into electrical signals. A single particle causes multiple events in the four telescopes and from these events the particle's distance, trajectory, velocity, and relative size can be calculated. A second meteoroid-detecting instrument consists of 13 panels mounted on the back of the high-gain antenna. Each panel contains 18 sealed cells pressurized with argon and nitrogen. When any one of the individual cells is penetrated, the gas leakage is detected and telemetered to the Earth.

The Ultraviolet Photometer investigates the ultraviolet reflective properties of hydrogen, helium, and dust. The instrument has a fixed viewing angle and uses the spin of the spacecraft to scan around the celestial sphere. The instrument measures the changes in the intensity of ultraviolet light reflected into two photocathodes, one measuring radiation at 1216 angstroms and the other at 584 angstroms, allowing the instrument to differentiate between hydrogen and helium.

The Infrared Radiometer is designed to measure radiation from Jupiter at 20 and 40 micrometer wavelengths. As with the Ultraviolet Photometer, the Infrared Radiometer uses a fixed two-channeled telescope that scans the surface of Jupiter as the spacecraft spins about its axis. Behind the cassegrainian optical system, the instrument uses an 88-element, thin-film, bi-metallic thermopile to detect the infrared radiation. This is the only instrument on board the spacecraft that does not take useful data in interplanetary space.

The remaining instrument is the Imaging Photopolarimeter, which will be described in great detail in the next section.

The scientific objectives also required the use of two ground-based experiments. The first, Celestial Mechanics, utilizes the coherent doppler tracking data augmented by optical and radar position data on Jupiter to compute the mass of the planet, information about the planet's shape, and refined information on the planet and its satellites' ephemerides. The second ground-based experiment utilizes the radio signals from the spacecraft as they pass through the Jovian atmosphere. In addition, the trajectory was designed to occult the satellite Io and this experiment also produced valuable data on the atmosphere of Io.

The experiments are listed together with the cognizant experiment team facilities in Table 1.

C. IMAGING PHOTOPOLARIMETER AND EFFECT ON GROUND DATA SYSTEM

The Pioneer 10 Jupiter encounter placed the greatest demands on total GDS reliability of any planetary mission supported by JPL to date. This is principally because of the attempt to execute a complex encounter flyby sequence without the benefit of an on-board sequencer or an on-board data recording system. The encounter sequence, which lasted for a total of 60 days, was to involve over 17,000 ground commands, essentially all of which were time-critical. The vast majority of these commands were for the operation of a single instrument, the Imaging Photopolarimeter (IPP). Failure to transmit any of the encounter commands correctly on time could have resulted in a loss of some of the science data from this instrument.

Since the science data were not recorded on board the spacecraft for later playback, outages in the real-time ground telemetry system could cause loss of science data from all 11 instruments on board the spacecraft. Such losses would be equal in length to the amount of time it took to restore or replace the failed element in the ground system. The DSN objective for the critical encounter periods was to be able to restore or replace a failed element in the telemetry or command system within 6 minutes.

1. Imaging Photopolarimeter Instrument

The encounter sequence is dominated by the IPP. The following description of that instrument is provided here, so that the origin of the large number of commands required for encounter and their time-criticality may be understood.

The Imaging Photopolarimeter measures the intensity and polarization of visible light. The instrument consists of an optical telescope, beam-splitting optical prisms, two sets of filtering optics, two channeltron detectors, and signal processing logic and control. The beam-splitting prisms produce two orthogonally polarized beams. Passage through the filtering system results in two color channels, a red and a blue. The instrument has the following operating modes and instantaneous fields of view:

Mode 1, instrument on but not in use.
Mode 2, zodiacal light mode, 40 X 40 millirad.
Mode 3, polarimetry, 8 X 8 millirad.
Mode 4, imaging, 0.5 X 0.5 millirad.

The method in which the instrument scans in order to produce an image is shown in Fig. 10. Scan lines analogous to the horizontal lines in a video system are produced by the instrument looking in a fixed direction with respect to the spacecraft as the spacecraft spins. The start of each scan as the spacecraft rotates is controlled by a series of "spoke" commands which control the start with respect to the spin position or, alternately, the scan can be started by the limb of the planet using the "start data at threshold" mode. For encounter it was planned to use the "spoke" command mode almost exclusively. The equivalent of video vertical scanning is achieved by either stepping the instrument with respect to the spin axis 0.5 millirad between each rotation of the spacecraft or, during the nearest approach to the planet, holding the telescope in a fixed position and letting the relative motion of the spacecraft and Jupiter achieve the scanning. This means that during the closest approach the scan lines could be overlapping or have gaps between them depending upon the relative motion of the spacecraft and Jupiter.

In the imaging mode, the data are converted to 64 levels of intensities (6 bits) and stored in a 6144-bit buffer. The instrument overwrites this buffer as it starts each "horizontal" scan with each rotation of the spacecraft. The memory read-in time is approximately 1/2 second and the spacecraft rotation rate is approximately 12 seconds, which means that there are approximately 11 seconds available to read out the memory. In order to read out the 6144 bits in the 11 seconds available a data rate of 512 bps is required. The IPP instrument receives about 50% service rate on the spacecraft telemetry downlink, which means that a 1024-bps telemetry downlink from the spacecraft to Earth is the minimum data rate at which all the IPP data taken can be returned to Earth.

The 1024-bps telemetry rate for the time of encounter requires 64-m-diam antenna coverage. Even with 64-m coverage it may be necessary to reduce the rate to 512 bps at low elevation angles. This will result in returning "horizontal" scans that are only half as long. In the event of a 64-m antenna failure that requires transferring the spacecraft to a 26-m antenna, the bit rate will have to be reduced to 128 bps or less, resulting in "horizontal" scan lines only one-tenth as long as would be possible at the maximum bit rate. The operation of the instrument in the polarimetry mode, Mode 3, is essentially identical to the above except that the field of view is 8 X 8 millirad and the automatic stepping is in 8-millirad steps. In addition to stepping the instrument at 0.5 or 8 millirad when in Mode 4 or 3, it is possible to slew the instrument to several fixed positions. The total range of look angles is 151 deg with respect to the spin axis. Between the stops at the limits of the 151 deg are 7 slew stops. The slew stops, referred to as slew angles 1 through 7, are each comprised of 2 stops, 1 deg apart. When the instrument is slewed to a slew angle it stops at the slew angle position closest to the direction from which it is approaching.

The IPP instrument has an automatic gain control feature. Because this feature does not operate properly on the Pioneer 10 spacecraft, more than twice as many commands were required during the Pioneer 10 encounter than were expected on the Pioneer 11 encounter.

2. IPP Encounter Sequence

It was intended to operate the IPP instrument on the order of 8 hours a day for periapsis ±30 days and 24 hours per day for periapsis ±8 days.

Figure 11 depicts a typical 24-h IPP encounter sequence. This sequence and the periapsis sequence to be described later are both typical and not the final planned sequence. The chart portrays the look angle as a function of time. The three lines labeled Jupiter are the physical disk of the planet and show its change of position as a function of time. The sinusoidal lines labeled with a J and a Roman numeral depict the look angle of the moons of Jupiter that are in the field of view. The lines labeled SLA 1 are the two stop positions of slew angle 1. The irregular line represents the instantaneous look angle of the IPP telescope. Note that this diagram represents only two dimensions in the operation of the instrument. Recall that the look angle is the angle with respect to the spacecraft spin axis and is equivalent to the vertical axis in an ordinary video system. The control of the start of data taking with respect to the roll position of the spinning spacecraft, equivalent to the horizontal scan lines in an ordinary video system, is not depicted.

The basic strategy was to take repeating imaging scans of the disk of the planet, interrupted by slews to a slew angle for polarimetry whenever one of Jupiter's moons crossed a slew angle. Starting at the left of Fig. 11, the IPP instrument is at a slew angle taking polarimetry on Jupiter's second satellite. To get to position 1, 21 commands were required, 12 of which were to overcome the gain control problem. Between points 1 and 7 in the sequence, 5 additional gain control commands are sent at 30-min intervals. At point 7 in the sequence the instrument is commanded into the Mode 3 threshold mode where the instrument slews continuously until the limb is automatically detected. This point in the sequence involves 17 contiguous commands (sent at the maximum command rate of 1 command per 22 seconds), 13 of which are gain control commands to overcome the gain control problem. At point 8 in the sequence the instrument is commanded to the imaging mode (Mode 4) at the imaging rate of 0.5 millirad per spacecraft revolution. This point in the sequence involves 7 contiguous commands, 4 of which are gain control, and 2 are "spoke" commands. Point 9 in the sequence involves a single command to reverse the stepping direction of the telescope. Point 10 in the sequence involves 17 contiguous commands, 16 of which are gain control commands. The sets of commands at points 9 and 10, comprising 1 and then 17 commands, are repeated at every similar point in the sequence that follows. Step 14 involves 26 contiguous commands, 23 of which are gain control commands, which place the instrument in the polarimetry mode at a slew angle for the crossing of Jupiter's third satellite. The commanding at point 15 in the sequence is identical to that at point 7 and the commanding at point 16 is identical to that at point 8. At point 19 in the sequence, 3 commands are sent which result in switching back to Mode 3 and stepping beyond slew angle 1. The commanding at step 20 reverses the slew to approach slew angle 1 from the correct side to stop at the position that the third satellite of Jupiter is now crossing and involves 32 contiguous commands, 23 of which are gain control.

The rest of the sequence depicted on this chart is built by repeating one of the command sequences already described at the appropriate time. In executing very similar sequences to those which were just described for 8 hours a day from periapsis -30 to +30 days, and 24 hours a day from periapsis -8 to +8 days, the origin of the requirement for 17, 000 commands during the encounter sequence is understood.

The possible effects of ground command system problems can be understood by studying this portion of the encounter sequence. When the imaging on the planet is being performed, the look angle is controlled at all points in the sequence similar to 9 and 10 by the time of transmission of the ground commands. If an interruption to command capability occurred at point 9 in the sequence so that the command did not leave, the instrument would continue to slew upward away from the disk of the planet. The recovery strategy would have to depend on the length of time it took to restore command capability. If command capability were restored a fairly short time after the schedule transmission time for the command, then the instrument would not have moved too far away from the disk of the planet and that same single command could then be sent to start slewing back toward the disk. A new time of transmission for the set of commands at point 10 in the sequence would have to be computed based on the slew rate and the new look angle that the instrument had to step through. If it took a long time to restore the system after the scheduled time of transmission for the command at point 9, then the instrument would have stepped a large number of degrees from the disk of the planet, and it would be wasting too much time to slew back to the disk. In this case it would be necessary to command the instrument back to the polarimetry mode and slew to slew angle 1 and execute the sequence of commands that would be used at a point such as 15 and 16 to get back to imaging on the disk of the planet.

In either failure case just described, clearly the instrument will end up out of phase with the rest of the planned sequence. When such failures occur, the sequence will have to be caught up at the next scheduled time for polarimetry on one of the satellites. The result will be a loss of some number of imaging scans across the disk of the planet or, to state it differently, the loss of some number of pictures. When the command failures occur near the scheduled time for a satellite observation, then that particular polarimetry viewing of the satellite may be lost.

The above paragraph describes the effect of command system outages on the encounter sequence. There is another category of command failure which has caused a great deal of concern, and that is false verification. False verification of a command means that all system and monitor indicators have indicated that the command was successfully transmitted error-free when in fact it was not. The effect of false verification could be serious. For example, if the command at point 9 in the sequence was falsely verified, that would mean that the command to reverse scan direction was indicated as successfully transmitted but in fact was not, and the instrument would continue to scan upward away from Jupiter. The round-trip light time at this point in the mission is 90 min, which means that at point 10 in the sequence there would still be no indication that the command at point 9 was not received, and the set of commands at point 10 would be transmitted. At point 11 in the sequence, a round-trip light time would still not have occurred, and the result would be the execution of the mirror image of the planned sequence but up out of the field of view of the planet Jupiter. It can be understood, then, why false verification was a greater concern for the encounter than detected interruptions to the command capability. In the course of Pioneer 10 and 11 mission support, nearly 30, 000 commands had been transmitted prior to encounter and there had been three instances of false verification.

Essentially the entire 60-day encounter sequence for the IPP instrument, with the exception of the periapsis pass, is built from the command sequences described above relating to Fig. 11. Figure 12 depicts a typical plan for the periapsis pass. Notice the rapidly changing look angle of the planet Jupiter and the satellite viewing in the near encounter. No further examination of the periapsis sequence will be offered here except to point out that, in Fig. 12, each discontinuity in the look angle of the instrument represents an average of about 15 to 20 contiguous time-critical commands.

D. TRAJECTORY CHARACTERISTICS

Volume I of this series describes the launch portion and early cruise trajectory characteristics. Pioneer 10's launch on March 3, 1972, (GMT) resulted in a velocity at injection of 51,682 kilometers (32,114 miles) an hour, faster than any previous man-made object. Major mission events en route to Jupiter are listed in a chronology in Section V of this document. The interplanetary trajectory of Pioneer 10 is shown in comparison to the planned trajectory of Pioneer 11 on Fig. 13.

There were many targeting options for the Jupiter encounter, and early in the planning of the Pioneer Program a decision was made that the encounter trajectory should be one that would provide maximum information about the radiation environment, even if it damaged the spacecraft and ended the mission at Jupiter. Therefore, imaging of Jupiter could only be assured before closest approach so an approach trajectory was selected which presented a well-illuminated planet for the pre-encounter phase and a partially illuminated crescent planet during the post-encounter phase. Although there was concern about a loss of radio communications to the spacecraft during the peak radiation period, it was decided to select a trajectory that would allow a radio occultation in order to gain additional information about the atmosphere of Jupiter.

The question of how close a spacecraft can approach Jupiter to take advantage of the gravity slingshot effect without damage to its electronics and optical equipment was one of the primary objectives of the first Pioneer flyby mission. There was a tradeoff to a certain extent in approaching closer to the planet in that the increased intensity of radiation would be offset somewhat by the fact that the spacecraft would fly by Jupiter more quickly. These two factors, which determine the integrated or total radiation dosage, were carefully weighed in the light of known information about Jupiter.

In general, the mission was designed to fly by Jupiter at three times the radius of the planet, i.e., twice the radius of Jupiter above the cloud tops, since information available suggested this was the closest the spacecraft might approach without receiving permanent damage due to radiation. The Jupiter flyby trajectory is shown in Jupiter centered coordinates in Fig. 14 and 15. The planned trajectory for Pioneer 11 is shown for comparison. Closest approach to Jupiter was on December 3, 1973, at a distance of 130,354 kilometers (81,000 miles) from Jupiter's cloud tops. At the time of closest approach, the spacecraft's velocity was accelerated to 132,000 kilometers (82,000 miles) per hour. This made Pioneer 10 break its launch record in achieving a velocity faster than any other man-made object, a record which would stand until the Pioneer 11 encounter the following year.

The tremendous acceleration experienced by Pioneer 10 resulted in extremely high doppler shifts of the frequencies received from the spacecraft and the frequency required to be transmitted to the spacecraft in order to maintain the spacecraft receiver in lock. The DSN implemented special equipment in order to compensate for these doppler shifts to maintain both the spacecraft and the ground receivers in lock during the periapsis passage. This equipment is described in F and G of this section.

E. NONPROJECT EXPERIMENTS USING PIONEER 10

Several experiments were performed using Pioneer 10 spacecraft that were not part of the Pioneer 10 Project.

One of these experiments utilized the two-way and three-way doppler data generated at two different DSS while tracking a Pioneer 10 spacecraft to assess the stability of the newer rubidium standards used in the network. Two-way doppler data are defined as data taken by transmitting a precision frequency generated by an atomic standard up to the spacecraft, which coherently turns around the received signal multiplied by a constant. This received signal is then compared to the transmitted signal and the resultant difference counted to high precision. Three-way doppler data are identical to two-way doppler data except that the receiving station is not the same as the transmitting station and, therefore, the reference frequency that is differenced from the received data is not coherent to the reference used for transmission (Refs. 2-4).

The other experiment used the manually programmed, Digitally Controlled Oscillators installed at DSS 14 and 43 to generate a range measurement even though the spacecraft does not have a ranging transponder. This experiment was performed by generating a triangular wave using the Digitally Controlled

Oscillator (DCO), transmitting the wave to the spacecraft, and then receiving the wave a round trip light-time later. The precision two-way doppler measurement was then used to estimate the time of receipt of the peaks in the triangular wave and, thus, measure the round trip light-time to the spacecraft. This technique of measuring the range to the spacecraft produced data with an accuracy of better than 10 kilometers. After this technique was demonstrated experimentally with Pioneer 10, it was used operationally during the Jupiter encounter period to enhance the navigation accuracy and the celestial mechanics experiment (Ref. 5).

The ramp ranging data described in the previous paragraph were also taken during one pass using the R&D hydrogen maser instead of the standard rubidium atomic standard in order to assess the effect of the hydrogen maser on the accuracy of the measurement.

Another radio science experiment performed using Pioneer 10 was a Quasi-Differential Very-Long Baseline Interferometry experiment that involved alternately tracking the Pioneer 10 spacecraft and an interstellar radio source. The object of this experiment was to get a measurement of the spacecraft trajectory with respect to the celestial sphere by measuring with high precision the angle between the spacecraft and an interstellar radio source using an interferometry technique. The word "quasi" is applied because this technique did not involve tracking both the spacecraft and the radio source simultaneously, but alternating quickly between them. The potential advantage of this technique is the tying of the trajectory to the celestial sphere independent of the Earth's ephemeris and Universal Time. Doppler measurements are made from the spinning Earth and, therefore, are always dependent upon the Earth ephemeris and the rate of rotation of the Earth or Universal Time.

This experiment was not entirely successful for Pioneer 10 because the radio sources used did not have the proper characteristics. If successful, this technique would have allowed a much higher precision determination of the Jupiter position at the time of encounter. Because of the potential of this experiment, it was to be repeated for the Pioneer 11 encounter and, in the intervening time, better radio sources were to be selected by direct measurement.

F. MAJOR PIONEER 10 JUPITER ENCOUNTER EVENTS

The far encounter started on November 4. Beginning on that date there was to be significant activity approximately 8 hours per day. By November 12, the disk of Jupiter would extend across approximately 15 pixels (a pixel constitutes a picture element in the imaging system). By November 18 the planet would extend across 20 pixels and by November 24, the planet would enlarge to 30 pixels. The region of 30 pixels is considered comparable to Earth-based resolution. It is at this time that the encounter sequence moved to 24-h/day operations. Even though the imaging prior to November 24 is below Earth-based resolution, it is considered valuable because it constitutes viewing of the planet Jupiter from phase angles impossible from Earth. Because Jupiter is so far from Earth, Earth observation is always of the full disk of the planet under flat light conditions. The Pioneer spacecraft was to see the planet Jupiter over a wide range of phase angles, which would be important for possible shadowing of cloud layers to enable the atmosphere to be seen in greater detail. The polarimetry measurements at these varying phase angles would contain valuable information about the particle size in the atmosphere. The Imaging Photopolarimetry resolution decreases symmetrically on the other side of closest approach.

It was expected that Jupiter would have a magnetic field anywhere from 3 to 30 times the strength of the magnetic field of Earth. Since estimates of the magnetic field strength of Jupiter varied over such a wide range, there was a large uncertainty as to the extent of the magnetosphere. It was therefore expected that the bowshock of the magnetosphere would be crossing somewhere between November 25 and December 1. Two instruments are important for measuring the fine structure of the bowshock: the Plasma Analyzer and the Trapped Radiation Detector. Upon detecting that the spacecraft had crossed through the bowshock when approaching the planet Jupiter, the spacecraft had to be commanded into a mode which replaced the imaging data in the telemetry with Plasma Analyzer measurements and gave the Trapped Radiation Detector a higher service rate. Because of the large uncertainty as to when the bowshock crossing would occur, this event had to be detected in real time by observing the output of some of the on-board instruments, and the IPP sequence interrupted in order to send the commands to the Plasma Analyzer and Trapped Radiation

Detector. Figures 16 and 17 show the major events for far and near encounter as they actually occurred.

The ultraviolet photometer was to observe the planet between November 30 and December 2 and again on December 3. The infrared radiometer was to observe the planet on December 4 during the periapsis passage. The spacecraft was expected to enter the radiation belt of Jupiter at about 2200 (GMT) on December 3 and to exit the radiation belt at about 0700 (GMT) on December 4. It was during the time period when the spacecraft was within the radiation belt that there was the most concern about damage occurring to the spacecraft. Charged-particle environments around planets are comprised of both protons, which constitute the plasma, and free electrons. Any charges that build up on a spacecraft due to the free electrons are usually bled off by the plasma. However, as has been discovered in the case of satellites orbiting the Earth, there are circumstances which arise in which the plasma can be pushed to a lower altitude than the free electrons, and it is in these circumstances that very large charges can build up on a spacecraft. Estimates of the potential charge buildup on the Pioneer spacecraft vary over a wide range. There are two possible impacts of a large charge buildup: (1) actual damage to electrical components in the spacecraft and (2) false commanding of the spacecraft because of electrical discharges taking place. The project developed contingency plans in the event that false commanding did occur. A large dosage of energetic protons can also damage solid state components.

Two Earth occultations were to take place during the Jupiter encounter. The first would be an occultation of the satellite Io, which occurred at approximately 0243 (GMT) on December 4. The Io occultation was to last from 60 to 90 seconds. It was hoped that measurements of the atmosphere of Io would be obtained as the radio link occults the satellite. The Jupiter-Earth occultation was to occur at approximately 0340 (GMT) on December 4 and was to last about 60 minutes. During the Jupiter occultation, the spacecraft was placed in a low data rate state and a limited amount of science data stored on board for readout after emergency from occultation.

The solar occultation occurred at approximately 0415 on December 14 and lasted approximately 50 min. The spacecraft had to be placed in a spin averaging mode during this time period because of the loss of solar reference.

Table 1. Pioneer 10 Experiments and Cognizant Experiment Team Facilities

Magnetometer	Jet Propulsion Laboratory
Plasma analyzer	Ames Research Center
Charged particle detector	University of Chicago
Geiger tube telescope	University of Iowa
Cosmic ray telescope	Goddard Space Flight Center
Trapped radiation detector	University of California, San Diego
Ultraviolet photometer	University of Southern California
Imaging photopolarimeter	University of Arizona
Infrared radiometer	California Institute of Technology
Asteroid meteoroid detector	General Electric
Meteoroid detector	Lewis Research Center
* S-band occultation	Jet Propulsion Laboratory
* Celestial mechanics	Jet Propulsion Laboratory

*Ground Based

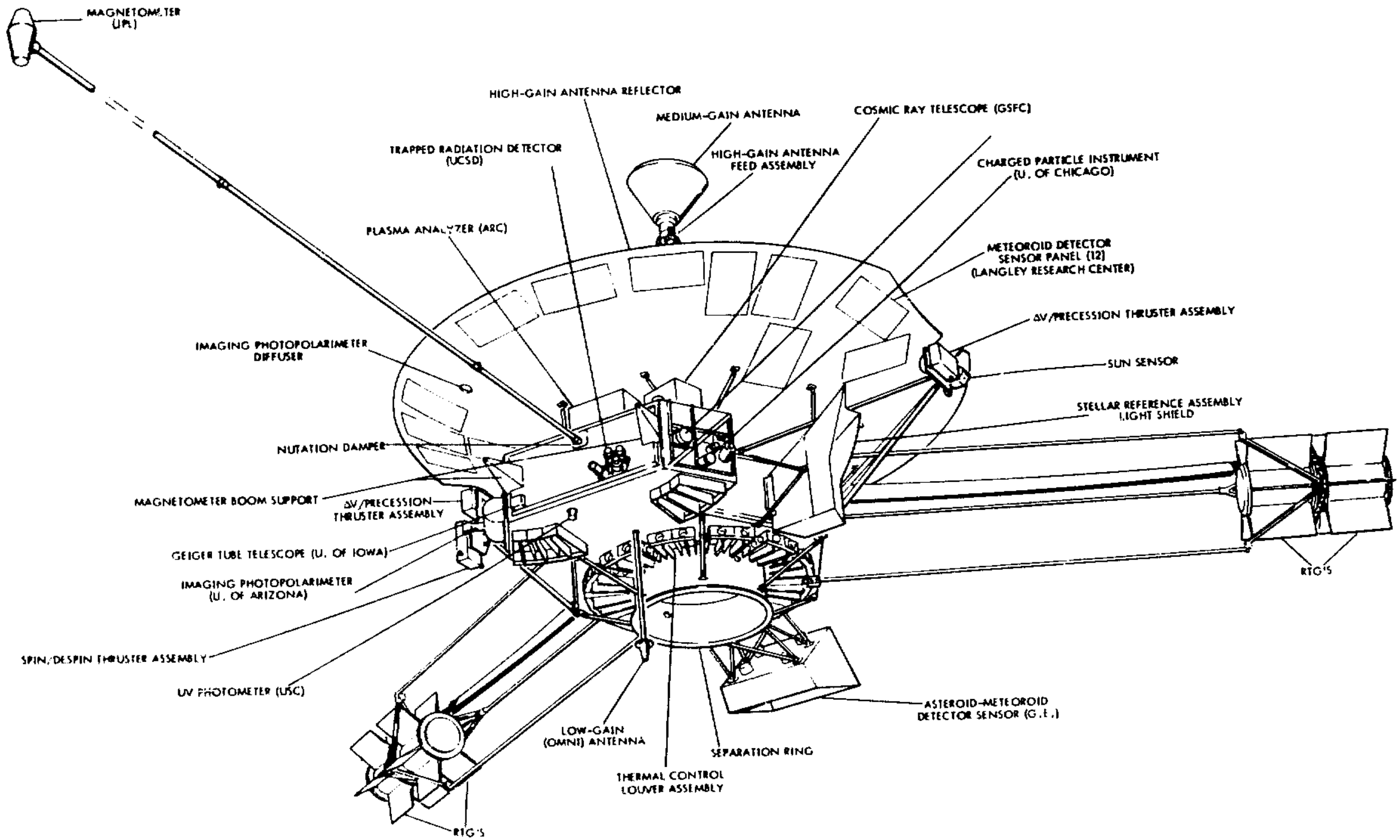


Fig. 9. Pioneer 10 and 11 spacecraft

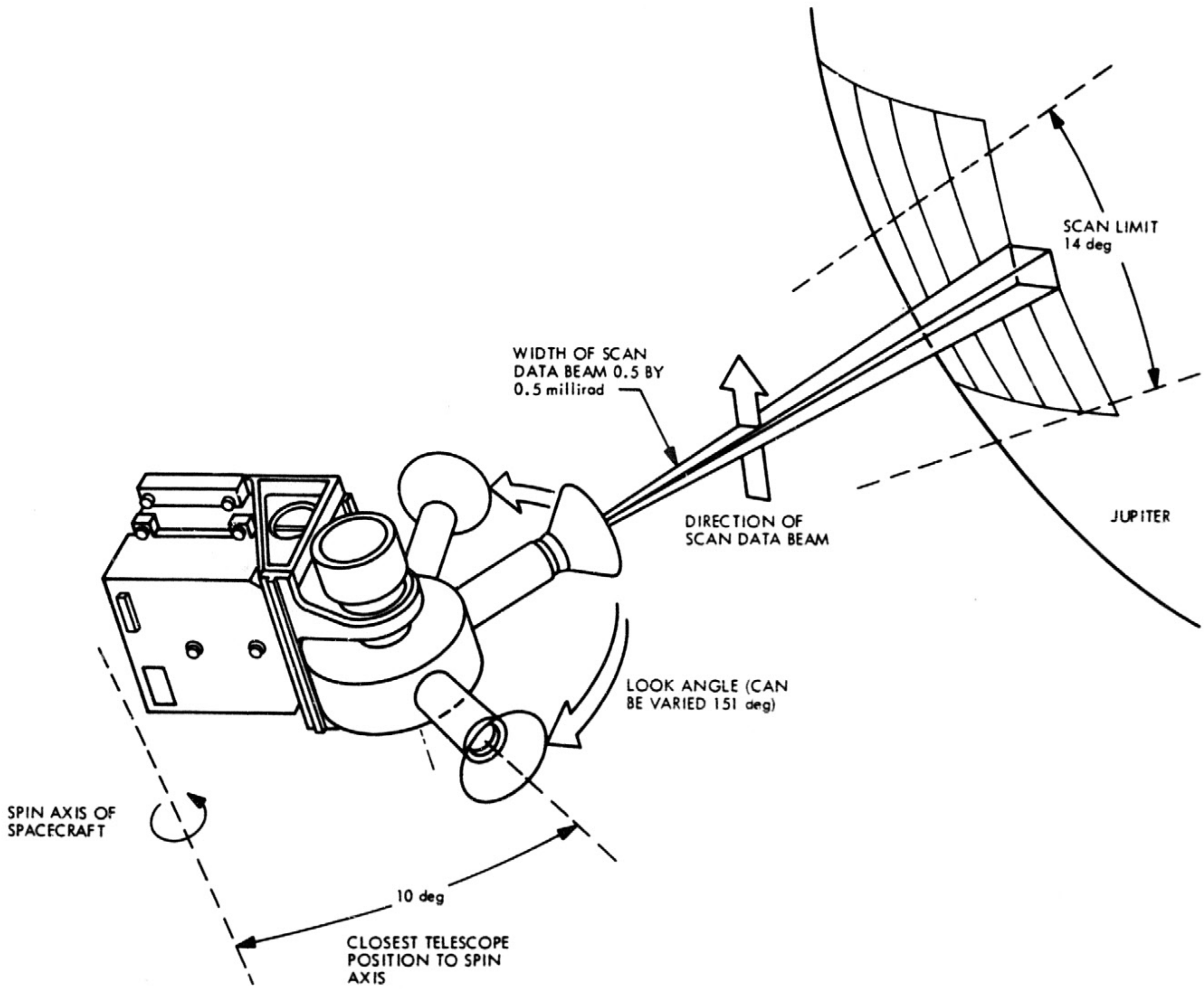


Fig. 10. IPP imaging system

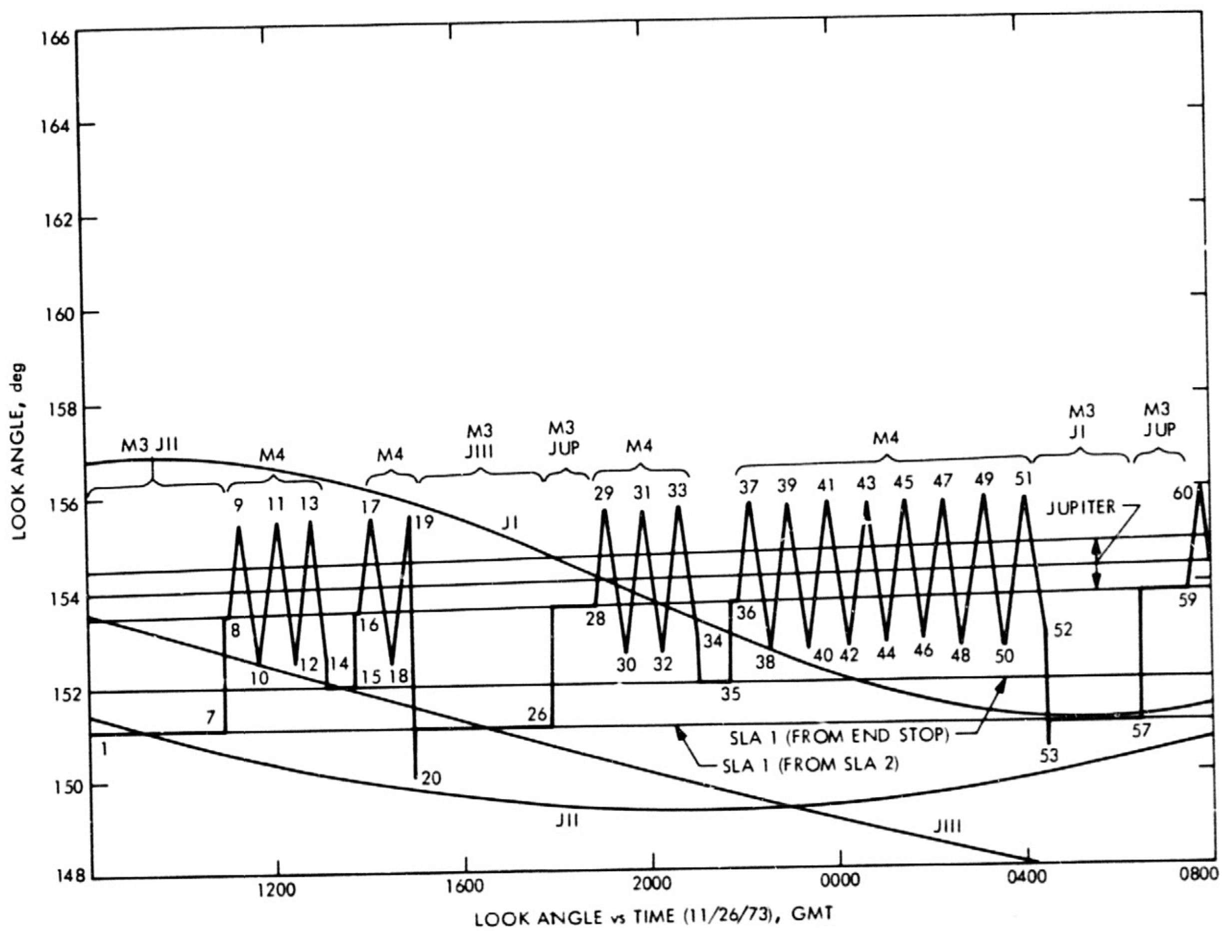


Fig. 11. Typical IPP 24-hour sequence

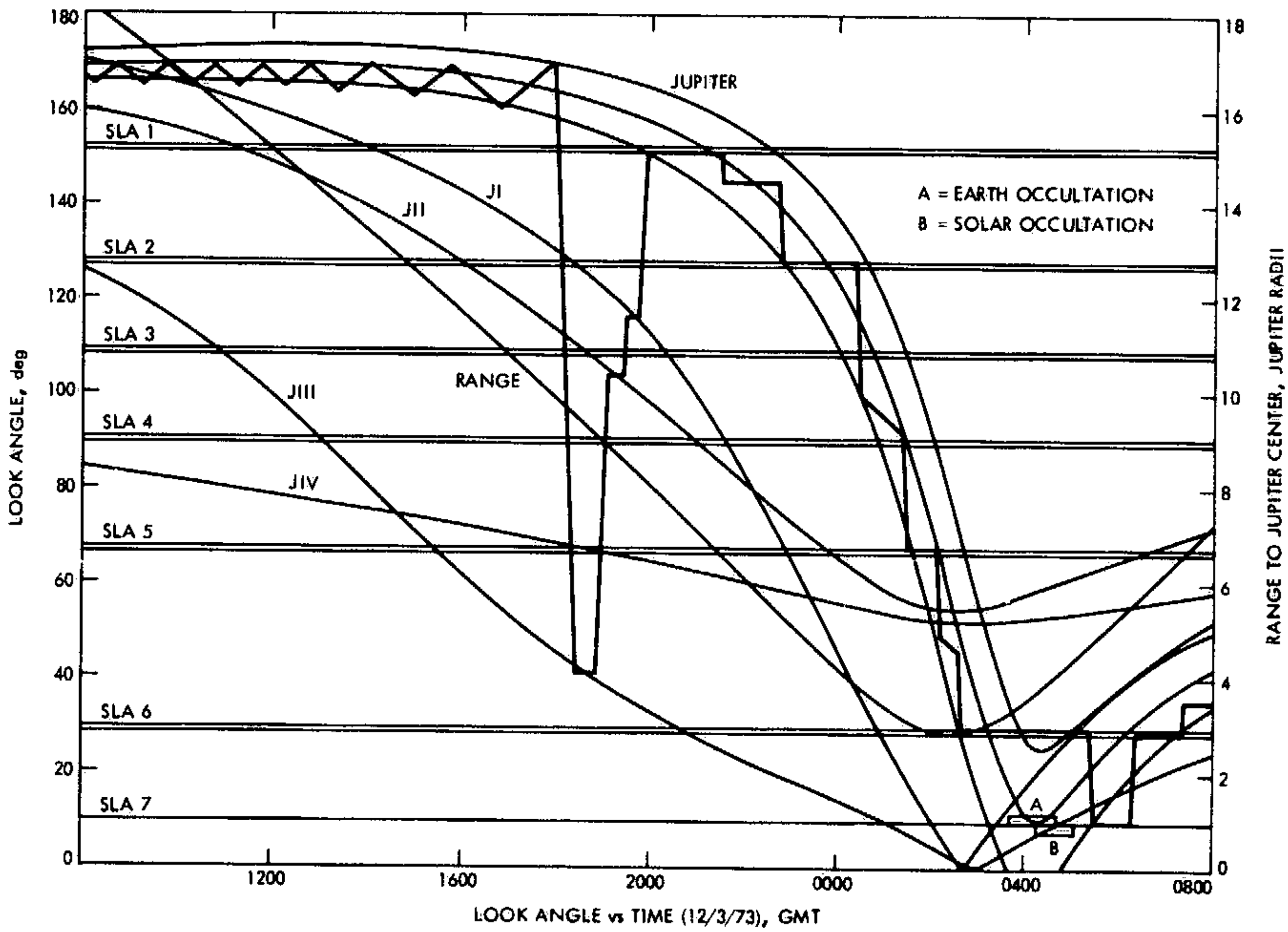


Fig. 12. Characteristics IPP periapsis sequence

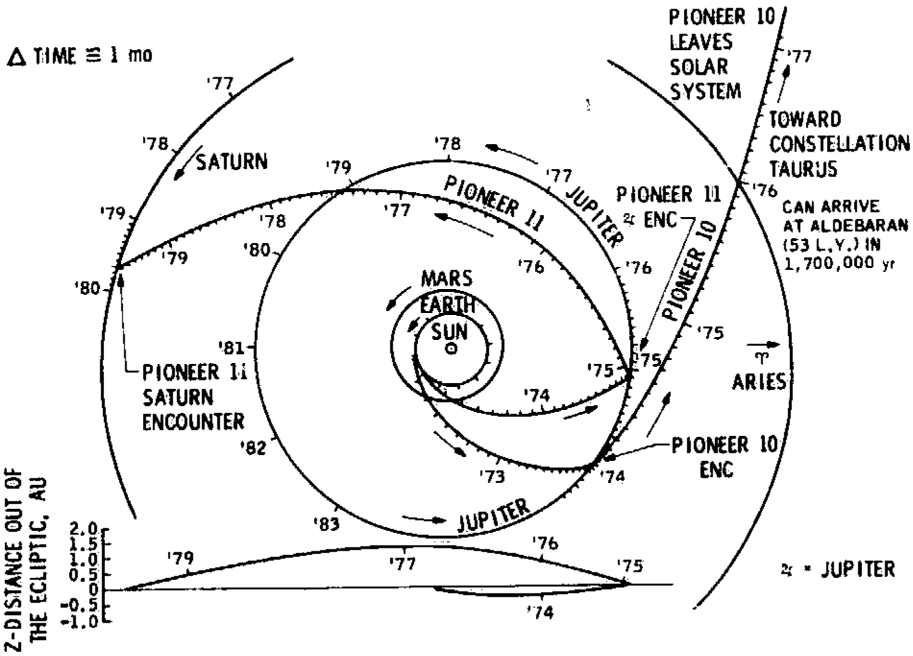


Fig. 13. Pioneer 10 and 11 heliocentric trajectories

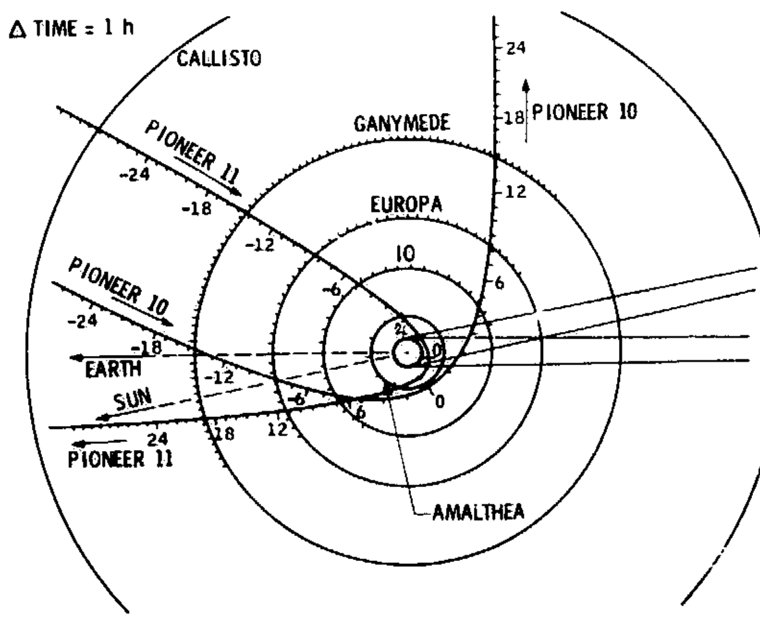


Fig. 14. Pioneer 10 and 11 Jupiter encounter (view from celestial North Pole)

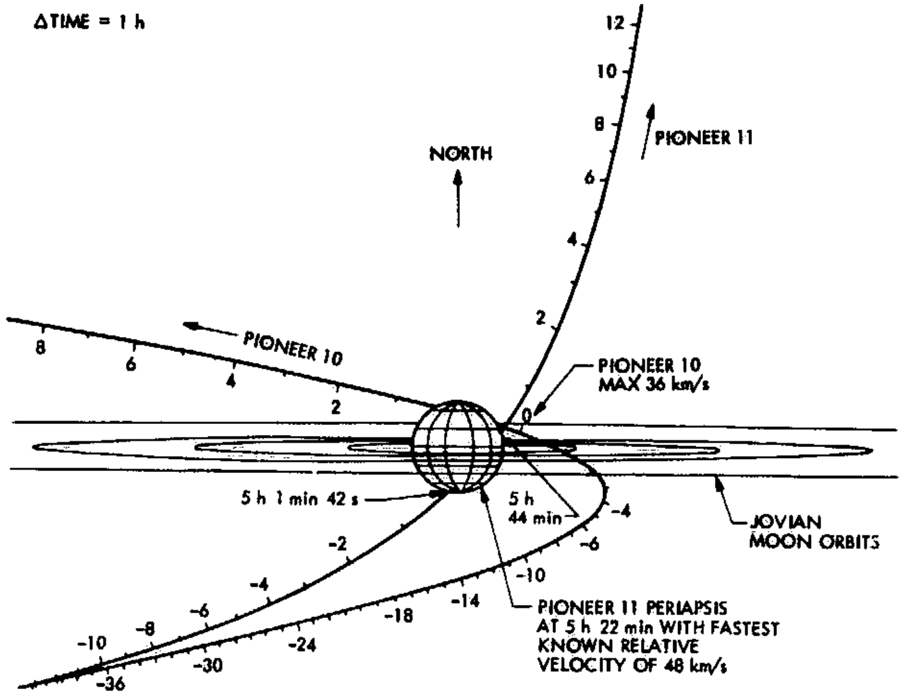


Fig. 15. Pioneer 10 and 11 Jupiter encounter (view from Earth)

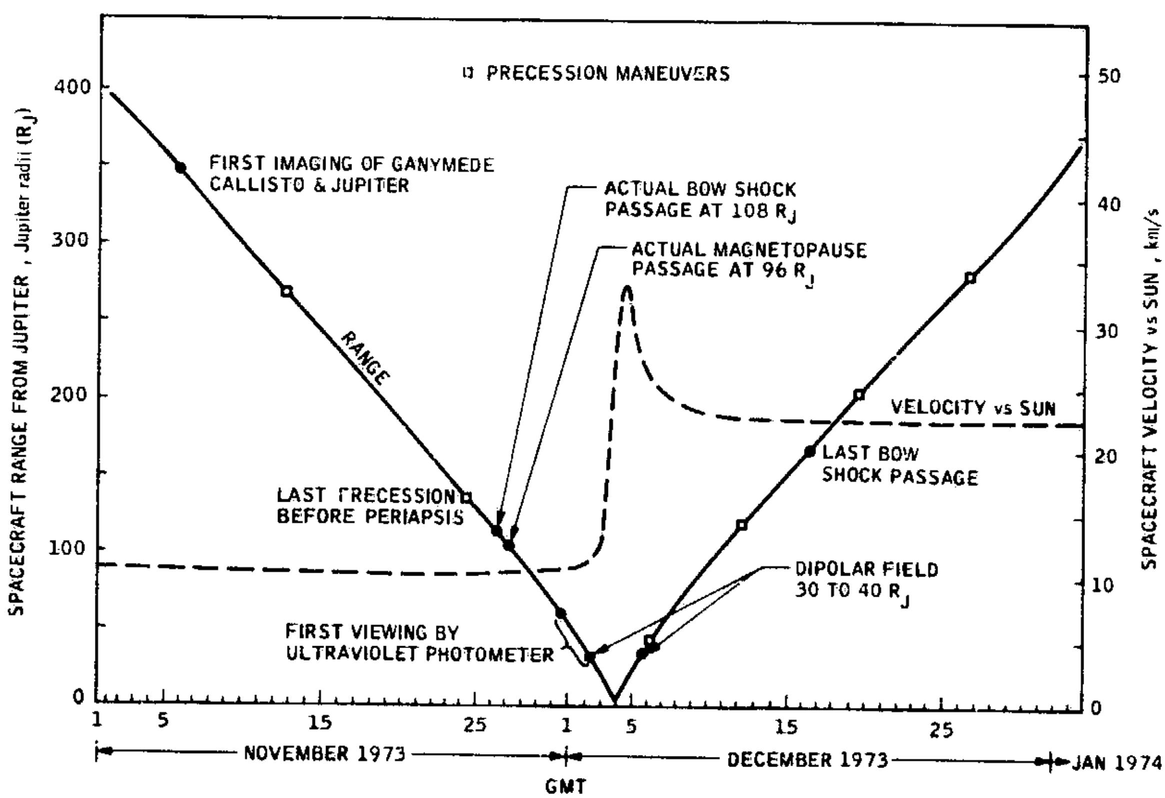


Fig. 16. Spacecraft's Jupiter related range and spacecraft's Sun relative velocity with timeline events of encounter ±30 days

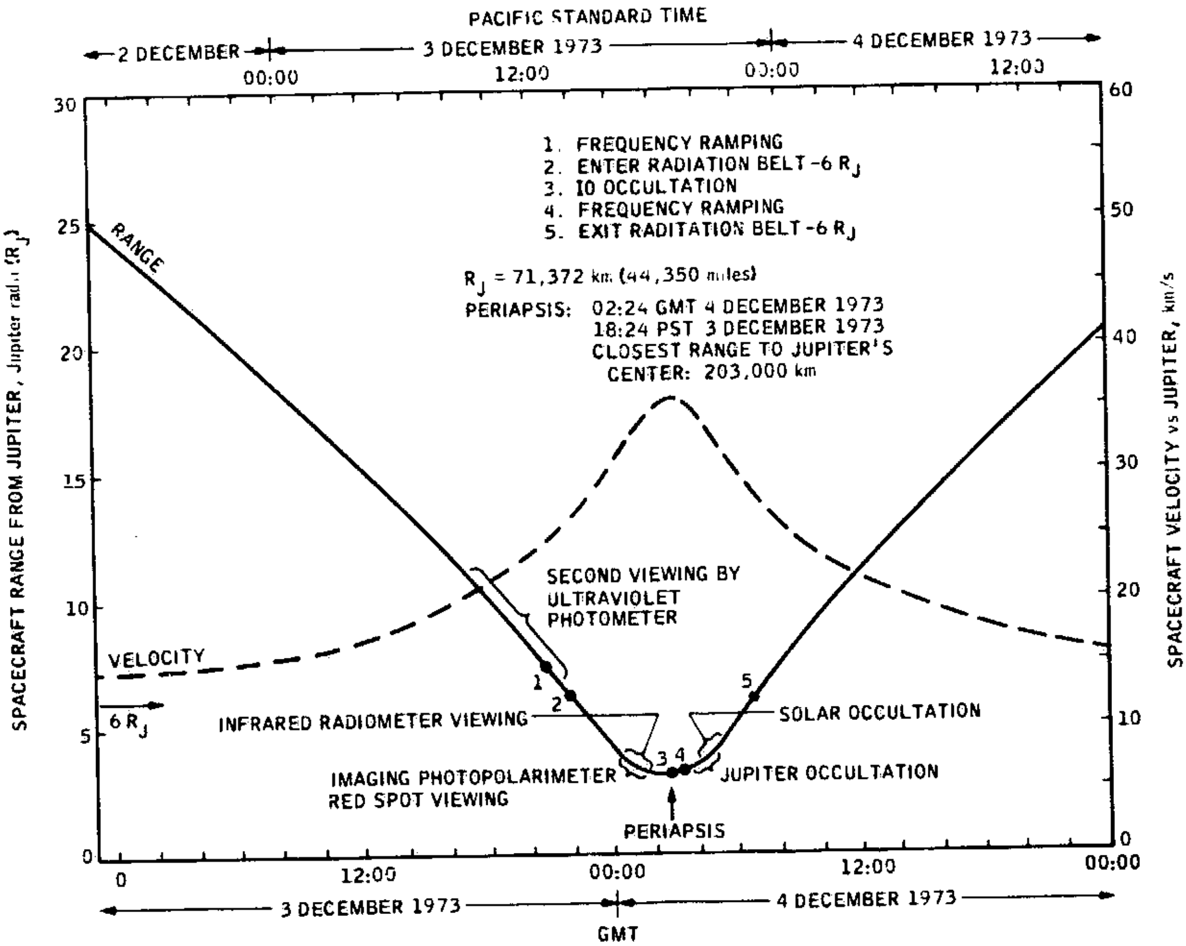


Fig. 17. Spacecraft's Jupiter related range and velocity with timeline events of near encounter

In order to maintain the capability to receive a maximum amount of telemetry at the required 1024-bit rate, it was necessary to maintain the pointing of the spacecraft 2.25-meter-diameter high-gain antenna within 1 deg of Earth. This necessitated several spacecraft precession maneuvers during the two-month encounter period. The last of the precession maneuvers prior to the periapsis pass occurred on about November 24. The precession maneuvers are shown as open squares on Fig. 16. Another effect which had to be allowed for in encounter planning was the fact that the spin rate of the spacecraft would be retarded during the approach to Jupiter and then slowly resume speed as the spacecraft left the Jupiter environment. This was due to eddy current torque and hysteresis torque induced by the strong magnetic field of the planet.

Another Project activity which caused concern and some extra effort on the part of the Navigation Team was the rather late realization that the satellites of Jupiter were going to have sizable perturbations on the trajectory and, if navigation accuracy were to be maintained, the satellite forces would have to be modeled. A Tiger Team-level activity was initiated by the Navigation Team in order to incorporate the satellite effects into the software in time for the encounter. In addition, the ramp ranging data and the use of three-way data were incorporated to enhance the navigational accuracy (Ref. 4).

IV. DSN SUPPORT PLANNING, PREPARATION, AND EXECUTION OF PIONEER 10 JUPITER ENCOUNTER

A. INTRODUCTION

1. General

By every measure, the first encounter of the planet Jupiter was a resounding success. Besides being the first spacecraft to fly by the planet Jupiter, and the first to utilize nuclear power, the Pioneer Spacecraft had another unique aspect which reflected heavily on the Earth-based system: the flying of a complex planetary encounter at a tremendous distance from Earth, and therefore, a long round trip light-time, without an on-board flight sequencer. Virtually the entire encounter sequence had to be controlled by Earth-based commands, with a 92-m round trip light-time before the effects of transmitted commands could be observed. Between November 3, 1973, the start of Jupiter encounter, and January 3, 1974, over 17,280 commands were sent to the Pioneer 10 spacecraft. By network count, 1,712 commands were sent on the day of periapsis passage alone, which corresponds to a 44% service rate for the command system, considering that each command is 22 s long and that there are 86,400 s in a day. This means that commands were radiating the day of periapsis about 4 min out of every 9, or a command was transmitted an average of every 50 s the entire day.

The high level of command loading and the potentially serious effect of interruptions in command capability on the encounter sequence were recognized, and the primary activity in preparing the ground system for this encounter was to seek means to improve total command reliability. The fruits of the preparation efforts were exceptional Earth-based system reliability during the 60 days of encounter. Prior to the encounter, there had been an interruption to command an average of about one every 30 h of heavy command activity. From November 3 to January 3, with the large volume of commanding described, there were only seven such interruptions caused by network hardware, software, or procedural problems, and, fortunately, none of these failures caused a loss of science data.

A further aspect of the spacecraft design that reflected on Earth-based system reliability was the lack of an on-board data recording system to allow for data playback. The data received in real time at the DSS were the only data acquired. In this regard, the telemetry system reliability performance was also excellent, with only a few minutes of data lost on a single day during encounter (November 9), when several antenna stoppages were experienced. Therefore, with a statistical sample of one, the capability of having a highly successful planetary encounter using a low-cost spacecraft with limited automatic operation and heavy reliance on ground system reliability was demonstrated.

2. Implementation

There was minimal additional implementation required for the Jupiter encounter beyond what was necessary for the launch and interplanetary phase of the mission. The following implementations were identified as required for Pioneer 10 encounter support:

(a) The completion of DSS 43 and 63 and their transfer to operations.

(b) The completion at DSSs 14 and 43 of wideband modifications to the open-loop receivers. These modifications were necessary in order to handle the doppler offsets that would be experienced during Jupiter encounter.

(c) The implementation at DSSs 14 and 43 of Digitally Controlled Oscillators. These units were needed to control both the exciter and the receiver in order to maintain receiver lock both at the spacecraft and on the ground during the high doppler rates of the Jupiter encounter.

(d) Installation at DSS 14 of a breadboard Digitally Controlled Oscillator. This implementation was necessary because of the late delivery of the operational units at DSSs 14 and 43. A breadboard unit was used for testing and training starting in June of 1973.

(e) Modification of the command system at the DSS to allow commanding while doing linear tuning using the Digitally Controlled Oscillators. This was necessary so that commanding could continue during the extensive periods of transmitter tuning required during the closest approach.

B. NETWORK MANAGEMENT CONTROL AND DOCUMENTATION

1. Planning Meetings

The principal vehicle for controlling network preparations for the Pioneer 10 encounter was a weekly DSN Pioneer 10 encounter planning meeting. The Manager of the DSN Operations Office had appointed an overseas DSN Resident, temporarily assigned to duty in Office 420, to establish and chair such a meeting. In order to avoid duplication of effort, the DSN Manager agreed to co-chair a single weekly meeting which involved Office 420, DSN Systems Engineering Office 430, and Division 33 representation. These meetings were held from May through September of 1973. In addition, several DSN internal reviews were held and a final DSN Operations Readiness Review with Project participation was held in mid-October 1973. The DSN also participated in GDS and Pioneer Project Readiness Reviews.

The DSN Pioneer 10 Encounter Planning Meeting's principal purpose was to identify known technical problems requiring resolution in preparation for encounter, assignment of one- to three-man teams to work on each of the problems in order to preclude duplication of effort and ensure that all of the areas of concern were covered, and assignment of action items and monitoring of process.

The DSN also participated in joint MCCC-DSN interface meetings which were chaired by the Pioneer Project Support Coordination Office. This was the principal vehicle for handling interface problems between the Deep Space Network and the Mission Control and Computing Center facility.

An additional working group suggested by the DSN was the Pioneer 10 Occultation Planning Committee chaired by the occultation experiment Principal Investigator. The committee planned the strategy and execution of the Earth-based support for the occultation experiment.

The DSN also participated in encounter planning meetings held at ARC. These meetings were the principal vehicle for coordinating all preparation activities with the Project. It was characteristic of the Pioneer Project, because of limited manpower with which the Project operates, that the majority of the detailed requirements and plans for the Jupiter encounter were developed in the last 12 months prior to the encounter.

2. Documentation

The principal documentation vehicle for directing DSN gross commitments in support of the Pioneer Project is the NASA Support Plan, which is prepared by the DSN in response to the Support Instrumentation Requirements Document prepared by the Project. Because of the rather late determination of detailed requirements by the Project, the principal vehicle for documenting detailed requirements was an exchange of letters between the Project Office and the DSN Manager.

Published minutes of each of the DSN Pioneer 10 encounter planning meetings and similar minutes for the joint DSN-MCCC meetings and the

Project planning meetings were the prime means of documenting the preparation progress. A separate volume of the Network Operations Plan for the Pioneer 10 encounter was prepared as the principal means for providing the detailed procedures and configurations to Network Operations Control and the DSS.

C. CONCERN FOR COMMAND RELIABILITY

1. Problems

As explained in Section III C, extreme reliability in commanding was a crucial concern for the success of the Pioneer 10 Jupiter encounter. This Project concern culminated in a complaint to JPL upper management in February, 1973. In response, a JPL Tiger Team was formed to study the problem of command reliability. The principal outcome of that activity, rather than any design changes in hardware or software, was an improvement in the procedures associated with the operation of the Command System.

Better communications between Project personnel and MCCC and DSN operators and the use of timed commands instead of priority commands by the Project were the major factors that resulted in improved command performance. The most important two factors in achieving a significant increase in command reliability were first, getting the Project personnel to use the existing command capabilities in a consistent and optimized mode, i.e., switching from priority commands to timed commands and using command file capabilities in the MCCC 360/75; second, and most important, ensuring that all personnel in each element of the GDS understood the importance of command reliability to the success of the mission.

The specific activities undertaken by the DSN were (1) revision of procedures jointly with the Project and MCCC, (2) heavy training activity in the command area, and (3) divising ways to make maximum use of redundancy available from the existing implementation of DSN equipment.

2. False Verifications

Recall in the discussion in Section III C that false verification of a command was the type of command failure that would have the most serious effect on the encounter sequence. (False verification was defined as a command not correctly leaving the DSS antenna while all available indications on the ground indicated that it had correctly left.) There were three instances of false verification up to January of 1973.

The incident in January of 1973 involved a disconnected cable which prevented transmission of the command, although all system indications indicated that the command would be radiated. The cable was the connection between the Command Modulation Assembly (CMA) and the exciter. Prior to this date, the command confirmation took place internal to the CMA so that a failure beyond the CMA could not be detected. Because of this single incident, it was decided to try to implement a feedback from the exciter to the CMA for the purposes of command verification. Although an extensive effort was made to implement this feedback loop, there were technical problems which developed in the line of phase stability problems that would have caused implementation as designed to unacceptably increase the abort rate. For this reason, the remote confirmation, as this is called, was not implemented in time for the Pioneer 10 encounter. Instead a special cable audit was done of all cables in the command-critical path. The cables were then labeled and sealed prior to the encounter period. The previous two instances of false verification were caused by procedural errors. After the January 1973 failure, there was no additional incident of false verification to the end of the report period of this document.

As a development experiment under Office 420 during the Pioneer 10 encounter, a command medium verification was implemented at DSS 14 only for the 60 days of Jupiter encounter. This experiment is documented in DSN Progress Report Article (Ref. 6).

3. Encounter Reliability

The reliability actually achieved during the 60 days of encounter is extremely remarkable considering the total complexity of the GDS necessary to support a Deep Space mission. The following few numbers might help gain an understanding of the complexity of just the 64-meter DSS portion of the GDS.

Each 64-meter station contains 138 racks of electronic equipment. The total length of external cables, not including all of the internal circuit wiring, is on the order of 25 miles. The total number of pieces of equipment is greater than 1500. The number of discrete components in the entire antenna and electronic systems is greater than 10^8. That would mean that, if each component were designed so that it would fail only once in five years, then a 64-meter station should experience some kind of a failure every two seconds. This should illustrate how remarkable is the degree of reliability which is actually achieved.

Prior to February 1973, the mean time between failure of the Command System was on the order of 24 hours. Heavy commanding occurred only about 4 hours every 2 days. Prior to February 1973, about every other command sequence the Project tried to execute was interrupted by a command failure. After the extensive activity to seek ways of improving command reliability before Pioneer 10 encounter, it was predicted that the mean time between failure for the Pioneer 10 Jupiter encounter period would be on the order of 25 hours. These mean-time-between-failure figures are computed based on total track time and not normalized to periods of heavy command activity.

The Command System tends to fail or be detected as failed more often when it is under heavy use. Since the encounter period represented essentially continuous heavy command and the ordinary cruise activity involved heavy commanding perhaps only 4 to 8 hours every 2 days, predicting a mean time between failure of 25 hours compared to a prior history of 24 hours during cruise actually represented predicting something like 5 times better performance.

The actual performance during the 60-day encounter was a mean time between failure of 49 hours. The total number of commands transmitted during the 60-day Pioneer 10 encounter period was 17, 286 and of these commands only 7 failed to be transmitted on time. This meant that the mean time between abort was 205. 7 hours during the 60 days of encounter. This was achieved even though the mean time between failure was 49 hours because of all the special procedures which were used during encounter to ensure rapid switchover, in the event of a failure, to redundant system elements. None of the seven failed commands during encounter caused a loss of science data.

Another measure of command reliability is statistics on the total number of system aborts, where an abort is defined as a failure of a command to transmit at the scheduled time of transmission. This does not represent the total number of system failures, since once an abort occurs, it usually interrupts a sequence of commands which then have to be replanned and rescheduled. The number of aborts is, however, still a good indication of the Command System performance. These statistics from launch to August 1974 for both Pioneer 10 and Pioneer 11 and comparison of the statistics to the commands transmitted during the Pioneer 10 60-day encounter are as follows:

	Pioneer 10	Pioneer 11
Total Commands Transmitted	65, 163	23, 266
Total Number of System Aborts	61	22
Total Command Reliability	99.91%	99.90%
Data Base (Launch to August 1974)	30 months	17 months
During Pioneer 10 60-Day Encounter		
Total Commands Transmitted	17, 286	
Total Number of System Aborts	5	
Total Number of Procedural Aborts	2	
Total Command Reliability	99.96%	

It can be noted from these statistics that the average command rate in cruise for Pioneer 10 is on the order of 1700 commands per month, and for Pioneer 11 is on the order of 1400 commands per month, while the 60-day encounter period averaged 8, 643 commands per month.

D. DATA DECODER ASSEMBLY

The Data Decoder Assembly (DDA) was the other significant reliability problem that was a concern for the encounter. Although Pioneer 10 and 11 spacecraft have a capability to transmit uncoded data, in practice all data transmitted by Pioneer 10 and 11 are convolutionally coded. The DDA functions are to receive the detected bits in the telemetry stream together with a measure of the confidence of the bit determination from the Symbol Synchronizer Assembly (SSA) and to perform the sequential decoding of the convolutionally coded data. This assembly consists of hardware and a mini-computer. In flight experience with Pioneer 10 and 11 has shown an excessive failure rate for the DDA. There were time periods in the interplanetary portion of the mission when it was common to have at least one DDA failure per station pass.

Since the Pioneer 10 and 11 spacecraft did not include the capability to store any significant amounts of data on board the spacecraft for later replay, any interruption to the real-time telemetry processing at the DSS would represent an irrecoverable loss of science data during the encounter.

A specific problem discovered during the flight with the DDA was a single bit error induced by the DDA in the 93rd bit of the telemetry format. After an xtensive effort, this problem was isolated to a timing problem in a portion of the DDA known as the selector channel. The same selector channel boards in the mini-computer were also a major source of reliability problems due principally to nonrigidity of these rather large boards and the inclusion of many daughter boards on the large boards with multiple pin connections. Simpler selector boards were designed and provided in time to be implemented in at least one DDA at each of the primary encounter stations of DSS 14, 43, and 63. For the DDAs for which new selector channel boards were not available in the time scale of encounter, a capacitor was added to modify the timing to prevent the specific 93rd bit problem.

Additional action taken to improve DDA reliability was the production of new diagnostic software for the pre- and post-tracking phases, and installation of bracing material around the selector channel board area to increase the rigidity of the chassis. The net result of all of this activity was the elimination of the specific 93rd-bit problem, and DDA reliability improvement to a failure rate of about one failure per week in the network.

E. ANALOG RECORDING QUALITY

Analog recordings of both the baseband data prior to telemetry detection and of the detected subcarrier out of the Subcarrier Demodulator Assembly (SDA) are usually made at the Deep Space Stations for DSN post-pass trouble shooting and analysis purposes. The analog recordings are not ordinarily committed to a Project. Because of the importance of the encounter data and the lack of on-board storage on the spacecraft, the DSN agreed to provide analog recordings during the encounter period as a backup for recovering significant data that may have been lost in case of a failure in the digital portion of the Telemetry System. Mostly because of the minimal use made of the analog recordings, the history of the quality of the recordings had been very poor over-all. It was estimated that only about 50 percent of the analog recordings called from the station to be used for analysis purposes were capable of being processed. A contribution to this problem was the fact that for proper processing of these analog recordings it was necessary for the tapes to be shipped from the station to the Compatibility Test Area (CTA) 21 at JPL for special processing techniques not available at each of the stations. This made it difficult for the stations to be able to monitor the quality of their analog recordings. Since the recordings were being committed for the encounter period, special action was taken to improve the quality of the recordings. Procedures were reviewed and revised for use at the stations, and a once-a-week shipment of analog tapes from each station was started on a routine basis for checkout at CTA 21 so that the stations would get more frequent feedback as to their analog recording quality.

Although there were momentary losses of telemetry data during the encounter, no data were lost that were significant enough to warrant the Project's requesting the DSN to attempt to recover the data off of the analog recordings.

F. DIGITALLY CONTROLLED OSCILLATORS

The most significant implementation for the Pioneer 10 Jupiter encounter, aside from the completion of the overseas 64-meter stations DSS 43 and 63, was the installation at DSS 14 and 43 of Digitally Controlled Oscillators (DCO) in order to enable both the transmitter and receiver to be precision-tuned during the high Jupiter doppler to maintain the spacecraft and ground receivers in lock. In the first quarter of CY-1973, it became clear that the DCOs were going to be available at DSS 14 and 43 at a date too late to allow sufficient testing and training to determine that the units were going to operate satisfactorily for the encounter. For this reason, a breadboard DCO was prepared for installation in June at DSS 14. It was the nature of the installation of the DCO that once they were installed it would be necessary to use them for all tracking of all spacecraft because it was impossible to readily switch back to the manual Voltage Controlled Oscillators (VCO). The installation of the breadboard oscillator at DSS 14 took several days.

In order to maximize the operator experience and operational use of the DCO, several sawtooth ramping passes were scheduled each week at DSS 14 after the breadboard installation. In addition, operator experience was gained at each two-way handover when the DCO would have to be manually programmed to execute the transfer. A more detailed description of the DCO is contained in the next section on "Occultation Planning and Results" (Ref. 7). As was expected, initial use of the DCO did involve several flubbed handovers between stations until the operators became more experienced in the use of this somewhat complex new device. The devices were installed in one transmitter and two receivers at both DSS 14 and 43. The operational implementation was completed by the end of September 1973. Operator use of the device and the operation of the device itself were essentially flawless during the entire 60 days of encounter. As mentioned in Section III E, the DCO were utilized to provide ranging measurements with better than 10 kilometers accuracy by providing a triangular wave on the uplink and using the precision doppler measurements to detect the time of receipt of that triangular wave (Ref. 8).

G. OCCULTATION PLANNING AND RESULTS

1. Introduction

During the near encounter period, which bracketed the closest approach time by several hours, the spacecraft was occulted in turn by the Jovian moon Io and by Jupiter itself. This encounter was complicated by a round trip light-time (RTLT) of approximately 92 minutes, which was a considerably longer RTLT than had been experienced during any of the previous planetary encounters conducted by JPL. At the same time, the DSN tracking system had entered a period of rapid expansion. For instance, new capabilities recently committed for support or expected to be shortly are: high-speed data (HSD) transmission, Block IV receivers, X-band capability, planetary discrete ranging, 10-per-second data sample rate, and the DCO. Each of these complicates tracking operations to varying degrees, and in the case of Pioneer 10 encounter with Jupiter, just the use of the DCO added greatly to the complexity of critical phase tracking operations (Ref. 10).

a. <u>Digitally Controlled Oscillator Description.</u> Basically, the DCO consists of a Dana Model 7010-S-241 Digiphase Synthesizer and a control assembly. The control assembly contains manual programming capability to generate frequency sweeps which can be manually programmed in advance to occur at specified station times in hours, minutes, and seconds. A total of four rates can be stored with corresponding start times to generate a sequence of up to four linear ramps without further adjustment during a given period. As each ramp is executed, an additional ramp can be manually programmed to bring the stored total back to four. Two other sweep control features are included to aid acquisition and station handovers. Primarily for use in the receiver is the acquisition (ACQ) mode, which generates a triangular frequency sweep at a fixed sweep rate between pre-stored upper and lower limits, and primarily for use in the exciter is the track (TRK) mode, which provides the capability to start a frequency sweep at a precise time and at a fixed sweep rate and to sweep to another fixed frequency.

b. <u>Digitally Controlled Oscillator Advantages, Complications.</u> The most obvious advantages of the DCO are apparent in its use in the exciter. Sweeps to acquire the uplink can now be set up well in advance of the actual time, and can be effected with an exact start time, an exact tuning rate, and an exact end time. Furthermore, the precision of the DCO is so great that doppler data during tuning is theoretically as good as doppler data at a constant Track Synthesizer Frequency (TSF).

The more obvious complications posed by the DCO appear in conjunction with its use in the receiver. Previous to the DCO, tuning to acquire the downlink was done manually by an operator who swept the receiver against page print predicts and waited to detect an audio beat. The flexibility of this system resided in the fact that the operator could easily reverse the direction of the sweep if he felt that he was not sweeping in the right direction or was in the wrong frequency region. The DCO in the receiver, on the other hand, must be exactly preprogrammed as to sweep rates, sweep limits, etc., and if for some reason these do not result in an acquisition, new receiver sweep limits must be calculated by hand or electronic calculator (DCO receiver predicts are not included in regular JPL tracking prediction output) and manually entered into the DCO registers. Both functions are time consuming and prone to error.

In the following sections the frequency management strategy for Io and Jupiter occultation and the ground receiver reacquisition strategy at Io and Jupiter Exit Occultation are discussed, with special attention paid to the role of the DCO in both events.

2. Io Occultation

The original intent for the Io occultation was to have DSS 14 Enter Io Occultation in the two-way mode, with DSS 43 acquiring the uplink shortly after Exit Io occultation. After the initial meeting of the Pioneer 10 Occultation Planning Committee, it became evident that something far more desirable might be attainable - Exit Io Occultation in the two-way mode. This would be of considerable importance to the occultation experimenters and would provide, as a bonus, additional two-way data for the celestial mechanics experimenters. The fortuitous combination of circumstances which allowed this enhanced goal was:

(a) The spacecraft best lock corrected for doppler (XA) during the time period surrounding Io occultation was very nearly linear.

(b) The newly installed DCOs at DSS 14 and DSS 43 could follow the XA curve during the Io occultation period almost exactly with just one linear ramp.

The general plan to attempt an Exit Io Occultation in the two-way mode was as follows. DSS 14 would begin ramping with the DCO at exactly the predicted XA and with a rate equal to the XA rate sometime prior to predicted Enter Io Occultation (this to account for the sizable uncertainties in the enter and exit times), and would continue until some time after the predicted Io Exit time. This would cause the spacecraft receiver to be left at exactly the predicted XA and subsequently would hit the spacecraft with the predicted XA at exactly the moment of Exit Occultation. Although the spacecraft would be left at the predicted XA at Enter Occultation, it would immediately begin to drift to whatever the actual XA was. However, the amount of drift would be quite small. Weeks prior to the occultation the following 3σ uncertainties were assumed:

One-way doppler (3σ) = 15 Hz (at VCO level)
Spacecraft best lock (3σ) = 25 Hz (at VCO level)

These result in a combined XA 3σ uncertainty of approximately 30 Hz. The length of Io occultation was approximately 90 seconds and the spacecraft receiver relaxation constant was 1320 seconds, so that one could calculate a total drift away from predicted XA in the 3σ case as:

define: XA_A = Actual best lock with doppler

XA_P = Predicted best lock with doppler

XA_S = Spacecraft receiver at a given time

so that at Enter:

$$XA_A - XA_P \cong 30 \text{ Hz}$$

and at Exit:

$$\begin{aligned}\Delta XA &= XA_S - XA_P \\ &= 30 \text{ Hz } (1 - e^{-\Delta t/t_0}) \\ &= 30 \text{ Hz } (1 - e^{-90/1320}) \\ &\approx 2 \text{ Hz}\end{aligned}$$

Considering a more reasonable 1σ case, one would have a total drift of only 2/3 Hz (at VCO level) away from the transmitted signal (XA_P) at Exit, so that one would expect to lock up at the spacecraft almost immediately.

After Exit, DSS 14 would be presumed to have the uplink, and a transfer to DSS 43 would be effected. Finally, in the event that DSS 14 did not reacquire the uplink, DSS 43 would sweep the uplink with their exciter DCO as a backup to insure acquisition of uplink. Using the following definitions:

let T_1 = time of 3σ earliest Enter Io Occultation at DSS 14

T_2 = time of 3σ latest Exit Io Occultation at DSS 14

T_E = nominal time of Enter Occultation at DSS 14

T_X = nominal time of Exit Occultation at DSS 14 so that:

$$T_1 = T_E - 3\sigma$$
$$T_2 = T_X + 3\sigma$$

With 3σ defined as 45 seconds, the finalized strategy was as follows:

(a) Prior to Enter, DSS 14 transmits a constant uplink DCO frequency equal to predicted XA at T_1 - 30 seconds.

(b) At time = T_1 - 30 seconds, DSS 14 begins tuning at a DCO rate equal to the predicted XA rate and continues until time = T_2 + 32 seconds, at which time the transmitter is turned off.

(c) At time = T_2 + 30 seconds, DSS 43 turns on their transmitter at a DCO frequency equal to their predicted XA at T_2 + 30 seconds, and begins tuning at a DCO frequency rate equal to their predicted XA rate until time = T_2 + 60 seconds is reached.

(d) At time = T_2 + 60 seconds, DSS 43 sweeps their DCO frequency up to predicted XA + 40 Hz, down to XA - 20 Hz, and then remains at that DCO frequency until Jupiter occultation.

The above strategy is shown in Fig. 18. This graph was prepared from predictions based on Orbit Determination (OD) solution (actually Probe Ephemeris Tape (PET) Number) 6526, which was available approximately five days prior to encounter. One problem remained - how to recompute the transmit to the stations, in a timely fashion, all the new frequencies, rates, and times based on each new OD solution as it might become available. This problem turned out to be amenable to a very simple procedure. The key to this procedure was the fact that XA (upon which the ramps were based) was essentially linear during this period, and the degree of linearity was essentially independent of OD solution (whereas event times and doppler were definitely not):

$$\frac{d(XA)}{d_t} \propto C_0$$

where C_0 is relatively insensitive to differing OD solutions.

Since the above was true, none of the ramp rates need be changed, regardless of the OD solution. Choosing the center of Io occultation (time of, XA of) as a reference point, one only need plot this one event point from each new solution to update the strategy - the horizontal displacement between the new solution and reference point gives the time bias to be applied to all times and the vertical displacement between the reference point and the new solution similarly gives the frequency bias to be added to all frequencies. Center of Io points from solutions (PET) 6527 through 6530 can be seen plotted on Fig. 18. Solution (PET) 6529 was that actually used during the encounter (it was available approximately 48 hours prior to encounter) and biases from the reference OD solution (6526) were:

$$\Delta\text{frequency} = -4 \text{ Hz}$$

$$\Delta\text{time} = +80 \text{ seconds}$$

The results of this effort were not immediately known as the closed loop ground receivers failed to acquire the downlink immediately following Exit Io Occultation; however, subsequent investigation of the open loop receiver data taken during Exit Io Occultation shows that the downlink was indeed two-way at Exit.

3. Tuning to Acquire the Uplink After Exit Jupiter Occultation

A simple sweep of predicted XA ±50 Hz (at VCO level) was planned to acquire the uplink after Exit Jupiter Occultation (note: this sweep takes place before ground observed Enter Occultation); this sweep can be seen in Fig. 19, based on solution 6526. It was planned to keep both the ramp times and rate fixed and only adjust the start and end frequencies based on each solution, thus, the doppler at 04:12:00 GMT from each new solution was plotted on Fig. 19. A conflict within the Sequence of Events (SOE) necessitated a last minute change to the times of the sweep also so that the final biases applied to the sweep were:

$$\Delta\text{frequency} = +33 \text{ Hz}$$

$$\Delta\text{time} = -4 \text{ minutes}$$

The frequency bias was composed of the XA change between solutions 6526 and 6529, plus the XA change caused by a time shift of four minutes. This uplink sweep successfully acquired the spacecraft.

4. Fast Ground Receiver Acquisitions

As previously mentioned, use of the ground receivers in time critical reacquisitions of the downlink is somewhat complicated by the DCO as compared to the previous manual timing performed by the receiver operator, and Pioneer 10 encounter marked the first use of the DCO during a critical phase. The three events when rapid reacquisition of the downlink was of considerable importance were (in order of importance):

(a) Jupiter Exit Occultation

(b) Io Exit Occultation

(c) One-way out-of-lock condition at transmitter off time prior to Jupiter Enter Occultation

It was decided that the DCO ACQ mode would provide the best chance for a fast reacquisition in the above events. In the ACQ mode, the DCO drives the receiver back and forth over a fixed frequency range with a fixed sweep rate. This has one obvious drawback in that for the most optimum case of a ground receiver search, one wishes to sweep back and forth about a doppler profile which is not a fixed frequency but more usually a strongly varying function of time. The trade-off with the ACQ mode is that one must increase the sweep range to encompass the amount of doppler change as well as doppler and other uncertainties during the period in which one expects to lock up.

As noted, the most important fast reacquisition was that upon Exit Jupiter Occultation. Figure 20 shows the one-way doppler and the one-way doppler with expected atmospheric corrections as of solution 6526 approximately five days before Encounter. Successive solutions 6527 through 6530 are also plotted as Exit Occultation points (time of, D1 of). In this particular case it was felt that a sweep of ±3000 Hz (S Band) about both D1 and D1 plus atmospheric corrections would suffice to include both uncertainties due to doppler and the spacecraft auxiliary oscillator; however, since there was also a large uncertainty in time of Exit Occultation, it was decided to increase the sweep to

±4500 Hz to account for change of doppler with time. This allowed both the doppler and atmospherically corrected doppler to be swept ±3000 Hz from a time of nominal Exit -135 seconds to a time of nominal Exit +135 seconds.

A sweep rate of 300 Hz/second (S-band) was selected which meant that with both station receivers beginning swept asynchronously one could expect a lockup of the downlink no later than 60 seconds after Exit. The receivers were started at Exit Occultation - 12:00 minutes and the center point of the sweep corresponded to the doppler at exactly Exit Occultation. The time and doppler were chosen from solution 6529 (Fig. 20).

Two changes were made to this procedure in near-real-time -- the center doppler value was adjusted just prior to Enter Occultation and because of slow ground receiver lockup times at Io Exit Occultation and at the transmitter off time (one-way out of lock), one of the two receivers was swept at 100 Hz/second (S Band) instead of 300 Hz/second. As it turned out, the receiver sweeping at 300 Hz/second locked first at approximately 05:30:24 GMT, which was 33 seconds after the best estimate of Exit Jupiter Occultation at 5:29:51. This falls within the expectation of ground receiver lock no later than 60 seconds after Exit Occultation.

The results of downlink reacquisition at Io Exit and especially at the Transmitter Off time are less satisfactory. In both cases the doppler at Exit Io Occultation and at the one-way out-of-lock condition (an RTLT after transmitter Off) were swept ±4500 Hz at 300 Hz/second. The best estimate of Exit Io Occultation was 03:29:18 GMT and DSS 43 locked up receiver 1 at 03:29:40 GMT or 22 seconds later. However, the doppler extractor was connected to receiver 2 and it did not lock up until 03:31:06 GMT or 108 seconds after Io Exit. DSS 14 was not able to reacquire the downlink until 03:35:35 or 6 minutes 17 seconds after Exit. Note that the open-loop receiver data were usable by the experimenter. Finally, reacquisition of the one-way downlink after Transmitter Off, which should have been the easiest of the three reacquisitions, turned out to be the most difficult. The ground-received time of Transmitter Off was 04:03:56 GMT, and the first station to reacquire lock was DSS 14 at 04:05:33 GMT or 97 seconds later. DSS 43 was not able to confirm good one-way until 04:10:40 GMT or 6 minutes 44 seconds after Transmitter Off (Ref. 9).

In summary, this first occultation of the planet Jupiter and the occultation of its moon Io were highly successful and yielded interesting scientific results.

H. NETWORK ALLOCATION CONFLICTS

1. IPP Requirements

Early in 1973, it became known that in order to maximize the science value of the Pioneer 10 Jupiter encounter, continuous 64-meter coverage would be required for the ±30 days around closest approach. The principal requirement in November and December of 1973 for the 64-meter coverage came from the characteristics of the IPP instrument. As was described in Section III C, the IPP instrument requires a 1024-bit rate in order to return complete pictures and 1024 bps required 64-meter coverage at Jupiter. The Pioneer 10 Jupiter encounter period was officially designated as extending from November 3, 1973, to January 3, 1974.

2. MVM'73 Conflict

Mariner Venus-Mercury 1973 was planning on a late October or early November launch. MVM'73 had rather extensive 64-meter coverage requirements which were in direct conflict with the November-December Pioneer 10 Jupiter encounter. The Mariner 64-meter coverage requirements included 64-meter passes immediately after launch and at intervals throughout 30 days in order to do TV calibrations using imaging of both the Earth and the Moon, radio science requirements for Venus and Mercury radar to collaborate with on-board spacecraft observations of the planets, and orbit determination critical coverage requirements including ranging data around each of the planned spacecraft midcourse maneuvers.

In order to work on resolving these DSN allocation conflicts between the MVM'73 and Pioneer 10 Projects, the DSN Managers for the two projects established a Working Group involving the DSN Scheduling Office representatives, representatives from each of the involved Flight Projects, and the DSN Managers in order to have a forum for face-to-face negotiations between the Flight Projects and negotiate acceptable compromises in the project requirements. This Working Group first met in February 1973.

3. Viking Conflict

Subsequent to the first Allocation Conflict Working Group Meeting, an additional requirement on DSN resources was identified for the Viking

Project: 64-meter antenna Goldstone tracks were required for Mars radar observations with the goal of determining the surface characteristics of selected landing sites. Unfortunately, the best time for making these radar observations would be in November 1973. In March 1973, two meetings of the Network Allocation Working Group were held. Representatives of the Viking Project and Radio Science users were included. At these meetings, agreements were reached and guidelines established that were sufficient to resolve the majority of the allocation conflicts through the end of CY-1973.

4. Allocation Meetings

The Network Allocation Working Group continued to meet periodically to resolve the details of the network allocation as more subtle aspects of the requirements became understood. It also covered the areas of conflict outside November and December, which included the test and training period leading up to the Mariner launch and the Pioneer 10 encounter, and also the Mariner Venus-Mercury 1973 Venus and Mercury encounter periods. which happened to occur during the time of Pioneer 10 and 11 solar conjunction.

The Network Allocation Working Group meetings slowly evolved over the course of the year into the Joint TDA/OCIS/Projects Schedule Review meetings which became formal, regularly scheduled meetings under the auspices of the Operations Support Coordination Office under the Flight Projects Division of JPL. These formal meetings then became the recognized primary forum for resolving all conflicting requirements between Flight Projects, whether on the DSN or on the MCCC, by face-to-face meetings with representatives of the Flight Projects and the support facilities.

5. Compromises

The Network Allocation compromise, which was reached for the November and December Jupiter encounter period, involved Pioneer's relinquishing some full 64-meter passes to Mariner Venus-Mercury, and the utilization of partial passes taking advantage of slight differences in view period and station overlaps to satisfy some of the Mariner Venus-Mercury requirements and provide the Viking required radar observations of Mars. The last part of the allocation agreement reached involved some partial passes for Mariner inside the critical near-encounter time period, which was defined as extending from November 26 to December 10. It was finally agreed by Pioneer to decide on a few Mariner partial passes inside this critical time period based on the Pioneer in-flight experience up to November 26. All of these agreements are documented schematically in Fig. 21. Based on the early far-encounter experience, Pioneer Project was willing to let Mariner have a partial pass on November 27 and on December 10, but was unwilling to allow the passes on December 6 and 7.

The multiplicity and complicated nature of the conflicting requirements starting in the Pioneer 10 Jupiter encounter/MVM'73 launch time frame were the most severe conflicts in project requirements that the DSN has ever had to deal with. The nature of future missions for the rest of this decade indicates that these complex kinds of conflicting requirements and rather complex coverage patterns are probably facts of life for the DSN from now on. The DSN will probably never again be able to afford the luxury of allocating specific subnets of DSS to particular projects. Instead, from day to day each station will have to track a different project and may have to accommodate within a single day several passes with several different spacecraft. The machinery that evolved in preparing for the Pioneer 10 Jupiter encounter for negotiating the compromises between conflicting project requirements has proved to be a very satisfactory way for settling project conflicts by advanced planning and face-to-face negotiation under the auspices of the Flight Project Division of JPL.

I. DSN TEST AND TRAINING PLAN

1. Over-All Plan and Schedule

The Test and Training Plan for the Pioneer 10 Jupiter encounter was developed through an initial bilateral agreement between the DSN Manager and the Pioneer Project. Basic test and training strategy and schedule were necessary to develop the requirements for network allocation leading up to encounter. The final Test and Training Plan was evolved by joint DSN, MCCC, and Flight Project effort, which was coordinated by the GDS Project Engineer in Section 295. The over-all plan and schedule are shown in Fig. 22.

A very small amount of DSN internal testing was deemed necessary because the DSN configuration for the Jupiter encounter period was little changed from the configuration necessary to support the interplanetary portion of the mission. DSN testing, therefore, concentrated on certification of the new precision ramping capability due to the implementation of the DCOs at DSS 14 and 43 and Mission Configuration Testing to certify the newly completed DSS 63 for the Pioneer configuration, and finally, Configuration Verification Tests leading up to the Operational Readiness Test (ORT). These DSN internal tests are shown in the upper portion of Fig. 22.

First, there were ramping installation and certification tests that required noncommitted tracking support of Pioneer at DSS 14 to certify the proper operation of the DCOs, and then a repeat demonstration pass at DSS 43 in September after the completion of the DCO installation at that station. Less installation testing was required at DSS 43, because of the experience and debugging achieved during the Station 14 installation. There were mission configuration tests performed and completed by early September at DSS 63 in order to certify that newly completed station for operational support of Pioneer. Configuration Verification Tests were performed at each of the 64-meter stations prior to the time period of going into modified configuration control for the Jupiter encounter. A more detailed schedule of the DSN internal activity leading up to the Pioneer 10 Jupiter encounter is shown in Fig. 23. The original Mission Operations System (MOS) Test and Training Plan is shown in Fig. 22. As the actual testing progressed, some test dates and test objectives were modified.

2. Tests

The first tests shown are ranging capability tests which involved tracking of the Pioneer 10 and 11 spacecraft with ramping of the uplink during the tests to gain both operator proficiency and operational experience with the new hardware in order to understand its reliability and operational characteristics.

The next series of tests were called "sawtooth tests" and were executed twice a week in July and August. These tests involved ramping with a triangular wave pattern, again to further exercise the station operators and gain experience with the equipment, and these tests also served to produce the ramp ranging data which was discussed previously.

The next category of tests was called "project personnel proficiency tests". These tests were specifically for training the individual operators at Ames Research Center, but utilized the entire Ground Data System with the DSS transmitting into a dummy load in order to have a realistic simulation.

The original basic MOS encounter training strategy for the entire GDS was to have a series of 8-hour tests testing with each 64-meter DSS, one station at a time. These tests were to be followed with a series of 24-hour tests which would utilize all three 64-meter DSSs. The final part of the plan involved two 48-hour tests that would involve exercising two continuous days of the encounter sequence. These two tests were to have the identical configuration, the first to be called an MOS Demonstration Test and the second one the ORT prior to encounter. This basic plan was modified as other test and training requirements became recognized.

3. Modifications

The first modification was that the Pioneer Project personnel wanted to have maximum exposure to training involved with the complex procedure of continuing the encounter sequence during station handover. To accommodate this requirement, the majority of the 8-hour tests were shifted to include two stations at a time so that a handover could take place during the test. Some minor changes in dates took place: the tests shown on September 5 were cancelled, the 8-hour tests (which now involved two stations instead of one) continued through September 18, and the 24-hour test took place on September 25 and 27 as planned and additionally on October 1 and October 25. The 24-hour tests were renamed MOS Demonstration Tests.

The remaining significant adaptations of the original Test and Training Plan were to satisfy MCCC requirements that became identified. The major requirement was to understand whether MCCC 360/75's could support the entire load that would be experienced during the encounter. The principal complication this introduced was that it was necessary to do some joint testing with MVM'73 project in order to have the full load in the 360/75 that would be experienced during the encounter. The first such cohabitation test was included as part of the 24-hour test on September 27.

4. Test Summary

A total of 328 hours of MOS testing and training was accomplished prior to the start of the Pioneer 10 Jupiter encounter. It should be noted that all of the tests were performed utilizing actual Pioneer 10 tracks, and, therefore, any problems that developed were real system or procedural problems, although some simulated failures were introduced to enhance the training. The only notable problem during all of the test and training was that test procedures were not ready for each test far enough in advance to allow comfortable time to properly coordinate the test activities. This problem was caused by the limited number of Project personnel available to work on the test plans.

J. DATA RECORD SUPPORT

1. Planning

Complex negotiations and planning were required in order to establish a total plan for handling data records during the encounter time period. Data record production involved MCCC producing Master Data Records (MDRs) from a combination of data logged and received in real time, and data recalled from the Deep Space Station to fill gaps in the real-time data. The MDRs were then shipped from MCCC to the Pioneer Project at ARC where further processing took place in order to produce the Experimenter Data Records (EDRs) for shipment to the experimenters.

2. Quality Concern

Early in the Pioneer mission there was considerable concern over the quality of the records that were thus provided. Some of the experiments were highly sensitive to momentary outages in data if those outages occurred too frequently. This was a result of some of the experiments having calibration or synchronization data which appeared in very low subcommutation in the telemetry data. Depending upon data rate, it could take upwards of two hours of continuous data in order for one particular experiment to receive one complete cycle of that instrument's data. An ill-timed data gap within that time period could cause all of the data received for that instrument to be useless.

3. Tiger Team Effort

An extensive Tiger Team effort was undertaken under OCIS direction to determine what was causing the data gaps and what could be done to recover the data. The principal problem seemed to be gaps that occurred in the act of high-speed transmission of the data from the stations. Although the high-speed data system was operating completely normally and within specification, the number of outages resulting were incompatible with some of the experiments' requirements.

A specification was finally arrived at that the MDR should be produced to be an exact image of the data contained on the Digital Original Data Record (DODR) at the DSS. This necessitated a large amount of analysis by MCCC operators and an extensive amount of data recalls from the stations.

In order to minimize the amount of time required to do these recalls, an automatic telemetry recall system was designed which involved a closed-loop system of doing recalls between the DSS and MCCC. This program involved an automatic accountability in MCCC of the missing data which would then be requested from the DSS. Each recall request for a particular gap in the data would be iterated between the two software packages until all of the missing data for that gap had either been recalled or determined to be unavailable. Such an interactive software system could be expected to be difficult to produce and to get to operate properly.

It took several months of effort to get the automatic telemetry recall system to operate satisfactorily prior to the Pioneer 10 Jupiter encounter. Even so, the system as it operated during the Pioneer 10 encounter was not error free and the MCCC operators would sometimes have to resort to manually recalling some parts of the data. At various times during the mission, the MCCC would develop a considerable backlog of passes which required further recall. The ordinary plan was to try to accomplish all recalls in the hour after pass with each station. In order to help work off these backlogs of recall data, the DSN provided on a limited basis the second Telemetry and Command Processor (TCP) computer at each station so that recalls could be accomplished during an actual track.

The process of producing a complete MDR ready for shipment to ARC involved as much as seven days total time from the time of the end of track until the tape was shipped. The Pioneer experimenters had a requirement for the most critical encounter period of receiving data as soon as possible in order to enable them to do quick analysis of their science results and possibly modify the remaining encounter sequence.

4. Data Record Agreement

The following was the data record agreement finally reached between MCCC, the DSN, and the Project for the 60 days of Jupiter encounter: Outside of the critical near-encounter period, MCCC would produce the MDRs by recalling from the DSS as quickly as could be accommodated. The DSN would provide Analog Original Data Record recordings for backup purposes during the 60 days of encounter. For the time period of critical near-encounter operations defined as ±10 days from periapsis, MCCC agreed to provide with less than one-day turnaround, quick-look System Data Records to ARC. These data records were comprised of just that data which could be received in real time from the DSSs and, therefore, were of lower quality than the final MDRs. So MCCC would have the resources to produce these quick-look System Data Records (SDRs), and DSN agreed to ship the DODRs for encounter ±10 days. For the remaining part of the Jupiter encounter, MCCC would produce the critical encounter MDRs directly from the shipped DODRs, and that processing would have priority over the MDR production involving recalls for the remaining 40 days of encounter.

The over-all Data Record production during the actual Pioneer 10 encounter proceeded according to plan and the Project was well satisfied with the quality and speed with which the data records were produced.

K. NASCOM AND GROUND COMMUNICATION FACILITY PLANNING

1. Special Coverage

The DSN originally requested NASCOM to provide special coverage for the entire 60 days of encounter. NASCOM was unable to fully satisfy that request because of manpower limitations. Instead, NASCOM agreed to provide the following NASCOM Network coverage: special surveillance from November 4 to January 3 except for those periods of time between 2600Z on December 3 to 2000Z on December 4, when special coverage was provided. Special surveillance consists of the Goddard Space Flight Center Communications Manager transmitting a message to request all support switching centers to pay extra close attention to the circuits in support of the Pioneer mission. Special coverage consists of the designated centers operating emergency power systems, providing dual configuration at switching centers whenever possible, having NASCOM computer programmers and computer engineers on standby, having first-line supervisors on duty during the key periods, and having commercial carriers notified of the impending mission requirement and requesting them to provide critical support.

2. Goldstone Circuits

Specific actions taken with regard to those portions of the GCF that are the responsibility of JPL were:

(1) The commercial carrier involved between Goldstone and JPL was asked to have maintenance personnel in position during the critical mission period.

(2) Goldstone communications personnel were augmented by supervisory personnel.

(3) GCF switching center schedules were modified to provide increased manning to support the Communications Chief.

(4) The Comm Processor maintenance and program personnel were asked to be on site during the most critical time periods.

L. MISCELLANEOUS ADDITIONAL PREPARATION ACTIVITY

1. Levels of Ground Data System Support

Levels of total GDS support were defined to provide varying degrees of redundancy and resulting speed of recovery as a function of mission requirements. The principal definitions which applied to the Pioneer 10 Jupiter encounter were Critical, Special 1, and Special 2.

Critical coverage involved providing every level of redundancy available within the total GDS. It also involved loading backup Telemetry and Command Procession streams at the stations supporting Pioneer 10. The resulting restoration time, based on available on-site redundant equipment, was on the order of 6 minutes for critical coverage. Special 1 coverage was virtually identical to Special 2 coverage except that higher operator emphasis is placed on the telemetry data than in Special 2 coverage and the backup TCP is maintained at a higher level of readiness than during Special 2. Maximum restoration time for redundant equipment is 20 minutes in the case of both Special 1 and Special 2 support. The support periods for the Pioneer 10 encounter were defined as follows: November 4 through 23, Special 1 support was required 8 hours per day; November 24 and 25, and December 13 and 14, critical support was provided 8 hours per day; from the time period of November 26 to December 12 critical support was provided 24 hours per day; and from December 15 to January 3, Special 1 was provided 8 hours per day. Special 2 coverage was provided at all other times during the 60 days.

2. Configuration Control

It was believed to be impractical to freeze the 64-meter network for the entire 60 days of encounter, particularly because of work necessary to prepare for the planetary encounters of Mariner Venus-Mercury and because of the shared coverage that was agreed to for Mariner Venus-Mercury and Pioneer. Instead, a modified configuration control concept was developed which is a stricter form of the configuration control ordinarily imposed on operational stations.

A modified configuration control was to apply from October 24, the completion of the Operational Readiness Test, to January 4. Under modified configuration control, the DSN Managers, Network Operations Project Engineers, and Station Directors must approve the installation of any Engineering Change Order at the affected stations. A freeze was imposed at DSS 43 and 63 from November 24 to December 14. In order to accommodate necessary work on Mariner Venus-Mercury, the freeze period for DSS 14 was slightly less, from November 26 to December 11.

3. Antenna Stoppages

Because of the very short time that DSS 43 and 63 had been operational prior to the Jupiter encounter, there was concern for what was developing as a fairly high rate of antenna stoppages during the Pioneer tracks. Analysis of the problem determined that the majority of the antenna stoppages were a result of false alarms from systems which were designed to detect when the film height on the hydrostatic bearing had become too thin to safely operate. The higher instance of false alarm from film height at DSS 43 and 63 was deemed a result of a higher concentration of small particles that would trigger the film-height sensors.

Investigation provided that DSS 14 had overridden the automatic shutdown from film height for some time without serious incident. It was therefore decided to implement at DSS 43 and 63 an antenna mechanical battle short which would enable the stations to inhibit the automatic shutdown from film height as well as inhibit antenna shutdown for limited time periods due to inadvertently activated emergency stop buttons.

In addition, other interlocks were bypassed to the servo power supplies, and the brake and gear reducer lubrication units. A control panel was installed with a key lock at all three 64-meter stations which would give a red light indication when the battle short condition was being exercised.

4. Additional Command Activity

An additional action taken with regard to total command reliability was an effort by the Project to design a subset of recovery sequences which could be produced ahead of time on paper tape and distributed to the Pioneer support stations. A set of 14 different recovery sequences was developed by the Project and paper tapes produced by the DSN and distributed to each station. These sequences would allow the Project to continue with minimum voice traffic to execute the majority of the imaging sequences in the event there was a failure in any element of the GDS prior to the DSS which would prevent the Project from commanding.

An additional contingency developed by the Project to help guard against possible radiation damage to the spacecraft and false commanding was the design of a set of contingency commands to be transmitted every half hour during the 24 hours of closest approach. This was a set of commands which would put the spacecraft into the proper configuration from a data systems and telecommunications standpoint in the event that a false command caused an unexpected switching of a spacecraft subsystem.

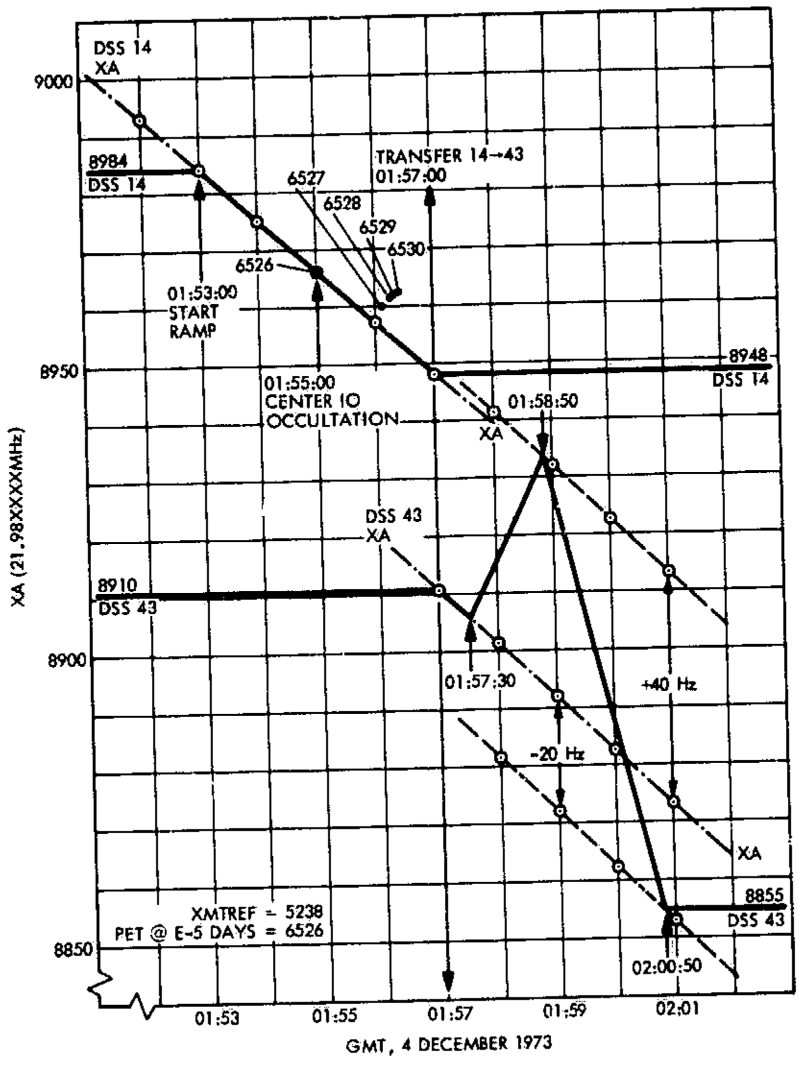


Fig. 18. Frequency strategy for Pioneer 10 Io Occultation

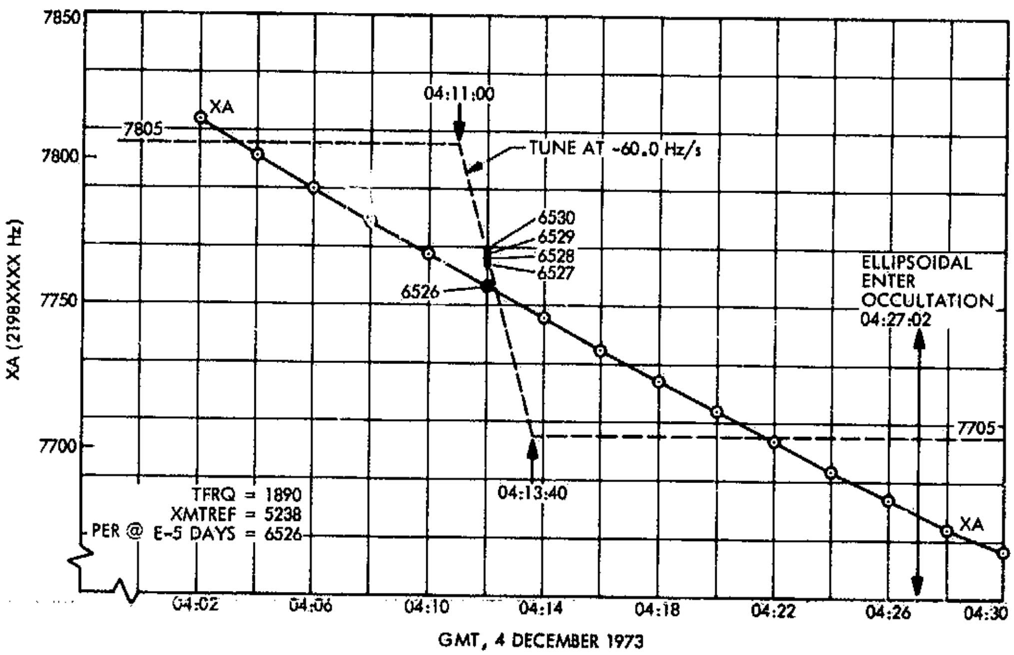


Fig. 19. DSS 43 tuning pattern prior to observed Jupiter Enter Occultation

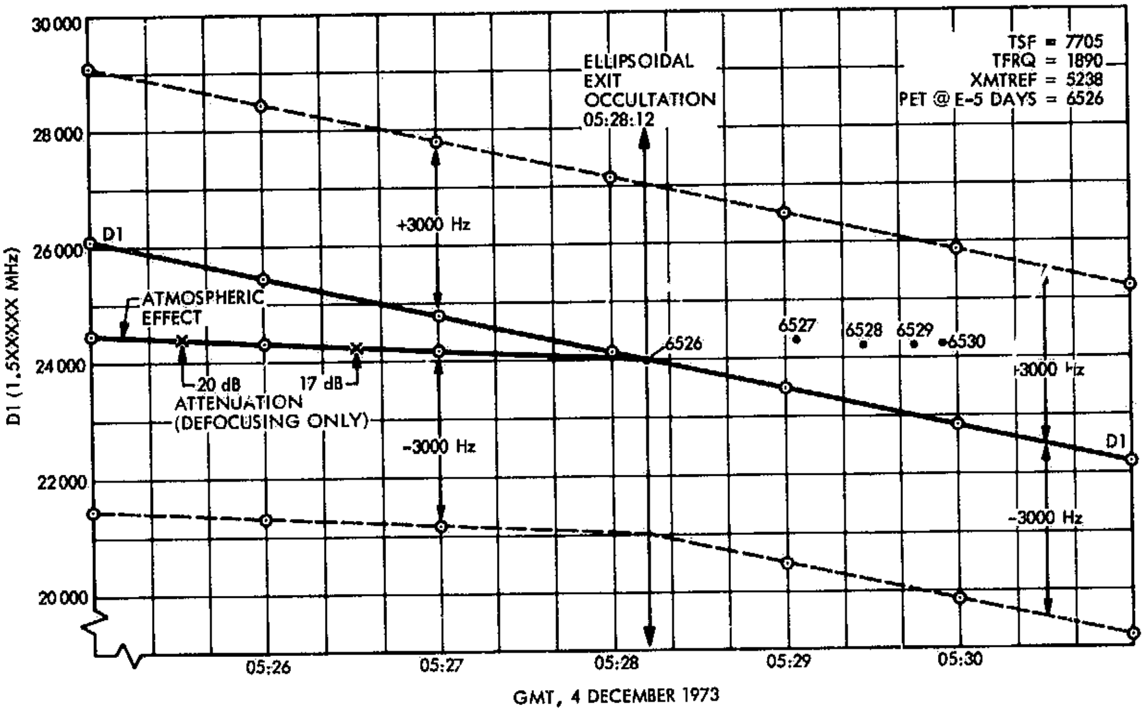


Fig. 20. DSS 43 Jupiter Exit Occultation, D1 and D1 plus atmosphere

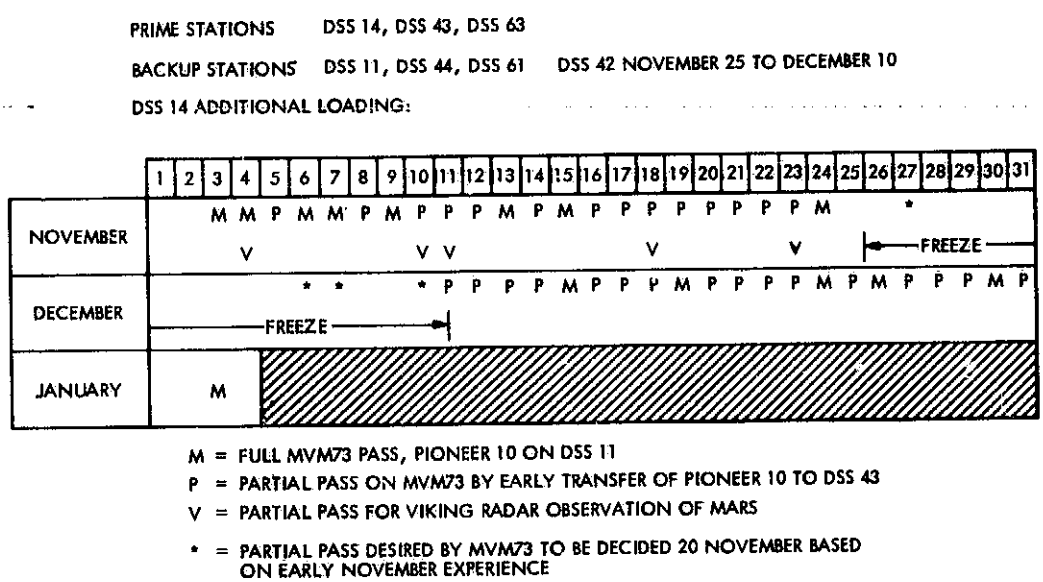
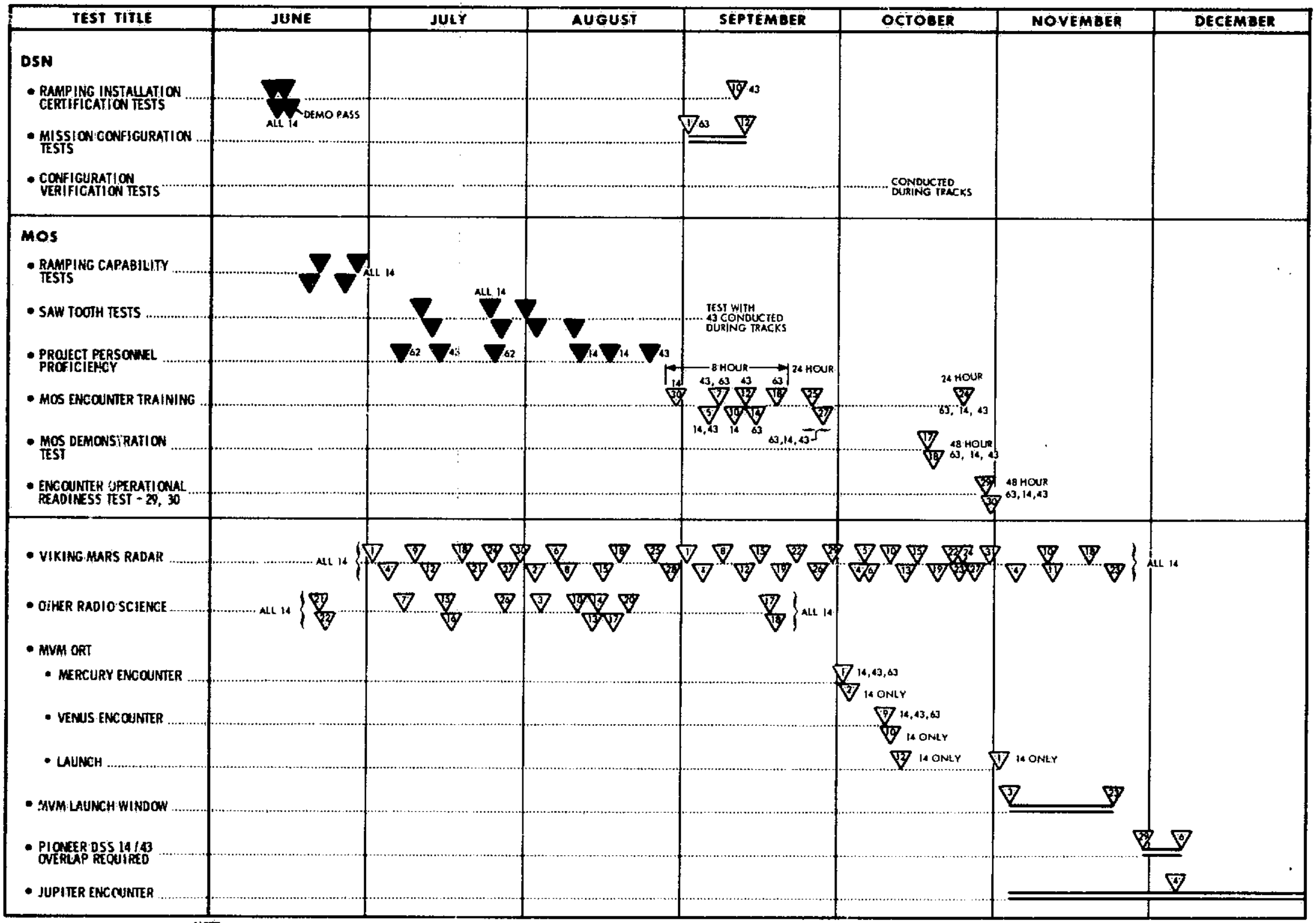


Fig. 21. DSN network allocation



NOTE: DATES ARE GMT DATE IN WHICH MAJORITY OF THE STATION VIEW PERIOD FALLS

Fig. 22. Pioneer 10 encounter test and training and 64-meter resource allocation

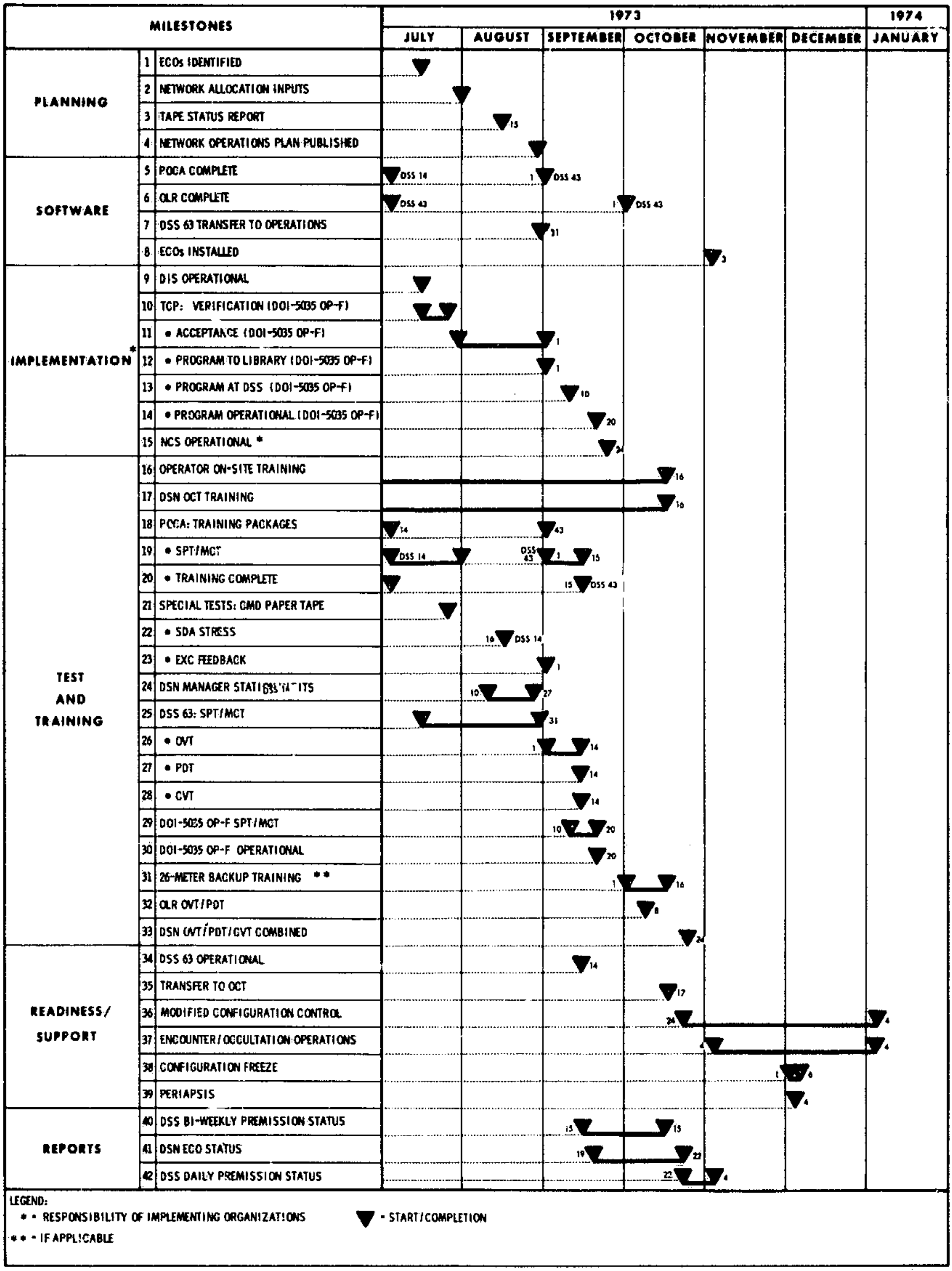


Fig. 23. Network operations schedule for Pioneer 10 encounter

V. DSN SUPPORT ANALYSIS

A. MISSION ACHIEVEMENTS

DSN support has enabled Pioneer Project to demonstrate that a low-cost spacecraft can attain a highly successful planetary encounter at a great distance from Earth. Because of ground system reliability, Pioneer 10 spacecraft's performance was excellent through cruise and Jupiter encounter despite its limited automatic operation.

At the completion of the successful mission climactic encounter activities, Pioneer Project commended JPL and contractor personnel in the DSN, the MCCC, and the FPO for the excellence of their effort. The exceptional ground system reliability was credited to additional personnel training, special operating procedures, temporary new equipment configurations, and imaginative managerial direction. Not a single picture was lost because of a ground system malfunction or DSN procedural error. The scientific data obtained were considered to more than justify the additional TDA efforts expended.

1. Events

Pioneer 10 mission events, accomplished and future, are listed here. Times are GMT.

Event		Date
Lift Off	01:49	March 3, 1972
First Midcourse		March 7, 1972
Second Midcourse		March 24, 1972
Inferior Conjunction		May 11, 1972
Cross Mars Orbit		May 21, 1972
Enter Asteroid Belt		July 15, 1972
Superior Conjunction		January 11, 1973
Depart Region of Asteroid Belt		January 20, 1973
Inferior Conjunction		July 31, 1973
Jupiter Encounter Period		November 4, 1973 – January 4, 1974
Cross Orbit of Outermost Moon, Hades (J IX)		November 4, 1973
Cross Orbit of Poseidon (J VIII)		November 8, 1973

Event	Date
Cross Orbit of Pan (J XI)	November 9, 1973
Cross Orbit of Andrastea (J XII)	November 11, 1973
Cross Orbits of Demeter (J X), Hera (J VII) and Hestia (J VI)	November 22, 1973
Cross Bow Shock	November 26, 1973
Cross Magnetopause and into Magnetosphere	November 27, 1973
Cross Orbit of Callisto (J IV)	December 2, 1973
Periapsis Day (Earth - S/C Distance 5.53 AU) Cross Orbits of Ganymede (J III), Europa (J II), Io (J I) and Encounter with Amalthea (J V)	December 4, 1973
Closest Approach (Periapsis)	02:25:28
Enter Io Occultation	02:41
Exit Io Occultation	02:42
Enter Jupiter Occultation	03:43
Exit Jupiter Occultation	04:43
Enter Planet's Shadow	04:19
Exit Planet's Shadow	04:59
Pass Out of Magnetosphere into Magnetosheath between Magnetosphere and Bow Shock	December 10, 1973
Cross Bow Shock into Interplanetary Medium	December 12, 1973
Due to Solar Activity Bow Shock Changed Position Placing Spacecraft back in Magnetosphere	December 13, 1973
Final Exit from Magnetosphere and Bow Shock	December 18, 1973
Cross Saturn's Orbit (Earth-S/C Distance 9.5 AU)	January 26, 1976 (est.)
Cross Uranus' Orbit (Earth-S/C Distance 19.9 AU)	July 14, 1979 (est.)
Distance from Sun as far as Neptune and Pluto (Sun-S/C Distance 30 AU)	March 1983 (est.)

Attained after a 641-day journey, periapsis was at a range of 203, 250 km measured from Jupiter's center (this range is equivalent to 2.86 Jupiter radii). Closest approach relative to Jupiter's atmosphere was 132, 250 km, assuming the radius to Jupiter's visible surface to be 71, 000 km. Estimated measurement uncertainity of the periapsis range is 10 km. The Earth-to-spacecraft distance was 5.53 AU. During the Jupiter encounter, the one-way light propagation time was 46 minutes and the two-way light trip time 92 minutes - a communication range of 5.5 AU.

The spacecraft was approximately 22×10^6 km from Earth and 161×10^6 from the Sun on April 1, 1972, the beginning of this report. At the close of the encounter period (January 4, 1974), the spacecraft was more than 890×10^6 km from Earth and 760×10^6 from the Sun. Relative to the Earth, the spacecraft was traveling at approximately 51 km/s.

2. Support Summaries

Table 2 gives a summary of Pioneer 10, Pass 31 through Pass 674, the passes covered by this document. The complete pass chronology for the 60-day encounter period is given in Appendix A.

Eleven DSN stations (Table 3) gave more than 171, 000 man hours and 21, 000 station hours in making nearly 2, 000 tracks during the report period of this document. During the launch and early trajectory correction period (March 3, 1972, through March 31, 1972) seven DSN stations expended more than 12, 000 man hours and 1, 300 station hours (see JPL TM 33-584, Vol. 1).

The support by individual DSN stations from April 1, 1972, through January 4, 1974, (period of this report) was:

DSS	Total Tracks	Man Hours	Station Hours
11	144	9800	1509.5
12	266	16823.5	2835
14	245	29043	2603
41	143	12868	1616
42	273	23924	3080.5
43	182	23322.5	2580
44	3	25	15.5
51	163	17444	1730
61	163	13065	1755
62	203	16002.5	2453.5
63	100	8846	1269

B. NETWORK CHANGES

The DSN was strengthened during 1973 with two new 64-meter stations, DSS 43 (Australia) and DSS 63 (Spain) and the 26-meter DSS 44 (Australia) becoming operational. DSS 43 became operational in April, DSS 44 in May, and DSS 63 in September. DSS 44 (Honeysuckle) was activated two months earlier than expected and helped fill Pioneer coverage gaps caused by radial bearing repairs at DSS 43. On 19 June, DSS 44 demonstrated a capability to support both Skylab and Pioneer operations. Thus, the certification to meet all requirements of DSN/STDN interface was completed ahead of schedule.

A major milestone in the preparation for Jupiter encounter by Pioneer 10 occurred in June of 1973 with installation and testing of the manually programmed Digitally Controlled Oscillator (DCO) at DSS 14. Ramping tests were conducted with the spacecraft. The ranging data were obtained from Pioneer 10 by using the Digitally Controlled Oscillator to ramp the transmitter frequency. The results were that range to Pioneer 10 could be established to an accuracy of 10 km by the ramp ranging techniques.

Final DSS 41 support was given December 12, 1972, and the station was retired from the Network.

C. PIONEER 10 SOLAR OCCULTATION (SUPERIOR CONJUNCTION)

1. Plans

The agreed support plan for the Pioneer 10 Solar Occultation was daily DSS 14 tracks from December 29, 1972, through January 21, 1973. The 26-meter stations were to fill in so as to provide continuous coverage. A minimum blackout period of the 26-meter network was expected from 12 to 18 January.

The DSS 14 requirement was to provide a daily uplink signal, using 200-kW transmitter power. This uplink was necessary to prevent actuation of the spacecraft receiver switching circuitry. The receiver circuitry works such that, if a signal present is not detected for a period of 36 hours, a transfer switch reconfigures the receivers to different antennas.

Dr. R. M. Goldstein was to provide the use of an open-loop receiver at DSS 14 to confirm that the uplink signal was reaching the spacecraft during the telemetry blackout period.

2. Summary

A precession maneuver was performed on January 11 to offset the spacecraft Earth-look angle so as to obtain proper pointing during the exit phase.

The spacecraft offset maneuver effectively started the 26-meter net telemetry blackout. This lasted until January 20 when DSS 61 was able to obtain signal lock.

During occultation the Pioneer Project required DSS 14's high power transmitter to maintain the capability to determine, using the Medium Gain Antenna (MGA) and CONSCAN processor, the spacecraft's spin axis. To obtain a spin axis measurement accuracy of approximately ±0.2 degree, the spacecraft receiver operates in the linear AGC range of -70 to -120 dBm. The high power transmitter broke down on January 10 and the DSN, together with Division 33, decided to change the klystron during the night hours. A special repair crew was dispatched and worked on the tube change between Pioneer 10 passes. The 400-kW was again operational on January 13. A few kickoffs were experienced, but the causes were found and corrective measures taken.

The midpoint of the occultation was on January 16. On January 15, 16, and 17, the spacecraft telecommunications link passed through the solar corona with a Sun/Earth/Probe angle of between 1.25 and 1.5 degrees. No usable telemetry was obtained during this period.

The uplink requirement was met each day during the blackout. Verification was obtained using the open loop receiver. Dr. Goldstein obtained one- and two-way spectra of the Pioneer 10 carrier.

A precession maneuver was performed on January 19 from DSS 14 to move the spacecraft Earth-look angle ahead approximately one degree to reduce the solar noise effect. Maneuvers were performed on January 23 and 24 to maintain near-Earth pointing to compensate for the relative body motion.

In each case, two-way operation was positively verified. The expected broadening induced by the solar corona shows up clearly as does an unexpected broadening two days after closest approach (Figs. 24 and 25). Some of the parameters are listed in Table 4. Downlink power was consistently 0.7 dB higher in the one-way mode.

D. OTHER SPECIAL SUPPORT (PRE-ENCOUNTER).

On September 20, 1972, the Project exercised a ΔV maneuver during the DSS 14 view period. The burn started at approximately 2205 and was concluded at approximately 0210 (Fig. 26). The expected ΔV was 0.227 m/s or +3.47 Hz along the Earth line of site. Actual ΔV was 0.227 $\pm$0.0007 m/s or +3.47 $\pm$0.01 Hz. The pseudoresiduals were a prime indicator of the effect of the burn and were used extensively by the Pioneer Navigation Team and the Project at ARC. Travel time to Jupiter was shortened by 14 minutes.

On June 21, 1973, a burn was effected that resulted in a change of spacecraft velocity of 1.267 m/s (decrease) or a two-way doppler shift of -1.937 Hz.

Several solar radial alignments were supported during the report period of this document. These were Pioneer 9-10 alignment in August and December of 1972 and a Pioneer 8-10 solar radial alignment in May of 1973.

The 26-meter support was discontinued from January 12 through 20, 1973. This was the result of the decrease of the Sun-Earth-Probe (SEP) angle for Pioneer 10 and the elimination of good data at the 26-meter sites. A minimum of 1.2 SEP angle was reached on January 16. It was suggested that the observed increase in doppler noise was a result, at least in part, of the increased density of charged particles along the path the signal travels, and the increase in system noise temperature a result of pointing directly in the Sun. The noise increase as the SEP angle decreased was more gradual than the sharp noise decrease after January 16. Near nominal noise values were prevalent in February. A brief period of high doppler noise around February 20 was believed the result of solar activity. Figure 27 shows a composite of all stations for January and February.

Another effect observed in the data was a rapid change in phase between the modulation and carrier. To demonstrate this effect, the following procedure was followed:

(1) Two short periods of good doppler data were taken from (1) DSS 14 (two-way doppler) with DSS 42 (three-way doppler), and

(2) DSS 14 (two-way doppler) with DSS 12 (three-way doppler). The doppler data were taken on 10-second centers; however, DSS 14 data lag DSS 42 data by 2 seconds. Data taken from DSS 14 and DSS 12 were synchronous; however, DSS 12's doppler resolver was not functioning correctly.

(2) Pseudoresiduals were computed by the 360/75 on each data stream.

(3) The average offset from zero for each data stream was computed by averaging each station's doppler residual as calculated by the 360/75 Pseudoresidual program.

(4) The offset was then subtracted from each doppler residual.

(5) The normalized doppler residual was then multiplied by 10 seconds (residual cycles/10 s) to leave only cycles.

(6) The cycles were then summed, and plotted on 10-second centers.

(7) The slope or rate of change in cycles/s was computed over numerous areas during which a significant change in cycles was observed.

The rate of change in cycles per second, if multiplied by 360 degrees, yields the phase shift observed in degrees per second.

E. SYSTEMS SUPPORT

1. Tracking

a. Significant Support. During November and December, 1973, there was a total of 193 Pioneer 10 tracks: DSS 11 - 7 tracks; DSS 12 - 16 tracks; DSS 14 - 46 tracks; DSS 42 - 2 tracks; DSS 43 - 61 tracks; and DSS 63 - 61 tracks. There were no data point acquisitions.

(A special report on tracking system support of encounter by the Network Operations Tracking Analyst (NOTA) is covered in Section IV.)

Considerable effort was provided to real-time operations and to Project in preparation, support, and analysis of returned tracking data for the Jupiter encounter. The encounter was generally successful. However, a large shift was seen in the channel 6 rest frequency (best lock). Consequently, numerous data point operations were performed on channel 6 (one-way acquisition followed by two-way acquisition) following the encounter. Pioneer 10 support, as well as that of Mariner 10, was improved when the Skylab Project agreed to cancel a track at DSS 44 during the Pioneer 10 closest approach. This allowed DSS 44 to support Mariner and DSS 42 and DSS 43 to support Pioneer 10.

Throughout November, a number of detailed studies of the Pioneer 10 encounter period had been accomplished. The most significant study resulted in the procedures for Frequency Management during the critical time periods of Io occultation, the DSS 14 to DSS 43 transfer, and Jupiter occultation. These procedures basically provided the guidelines for computation of exciter and receiver DCO tuning rates, start and stop tune times, and for real-time adjustments resulting from changes in frequencies and times. These efforts were integrated with the requirements of the project and occultation experimenters to produce a complete package that helped make the many time critical encounter events more manageable.

b. Trend Analysis. Doppler residuals and doppler noise values computed by the pseudoresidual program indicated that the Probe Ephemeris Tapes (PET) provided by the Pioneer Navigation Team were reasonably accurate. PET deliveries began to increase as encounter approached, and predicted generations for both analysis purposes and for use by the Network occurred frequently (often several times a day). In November, the magnitude of the doppler residuals began to increase. It appeared that small modeling errors existed in the program used by the Navigation Team and that the affect of Jupiter was slightly different than expected.

Late in December 1972, and through January 1973, doppler noise levels were high as the result of a decrease in the angle between the Sun and Pioneer 10. This situation again occurred in late 1973 and doppler noise levels increased. This effect was observable on both Pioneer 10 and Pioneer 11. The angle between the two spacecraft was approximately 5 degrees, and both spacecrafts were within 30 degrees of the Sun. Doppler noise levels were expected to continue to increase until the angle increased. A study of this situation was made.

c. Pioneer 10 Doppler Data. A composite of the pass average doppler noise levels (Fig. 28) indicates the doppler noise levels observed during the year. As can be seen from this plot, there were intermittent periods of high noise. These occurrences of high noise did not impact the mission. (Figure 29 indicates the doppler noise levels observed during 1972.)

Figures 30 and 32 plot the measured frequency values for auxiliary oscillator (TFREQ) and Channel 6 best lock were prepared for December. Frequency predictions based upon such plots were used in the generation of tracking predicts and for spacecraft acquisitions, and had proved both reasonably accurate and reliable. The plots were used to establish expected center frequencies during the encounter period. Measurements taken immediately after encounter indicated that there had been a large shift in both auxiliary oscillator and best lock. These changes eventually appeared to stabilize. (Figures 31, 33, and 34 plot the frequency values for 1972.)

d. Station Problems. An elevation drive gear box on the DSS 43 64-meter antenna exhibited significant mechanical noise which indicated a potential for imminent failure, but a reduction of the hydraulic pressure to the drive motor decreased the noise level. It was then decided to continue its use until after Pioneer 10 encounter because of the time required to make the repair, leaving the possibility that the gear box bearing would freeze and stop the antenna. An emergency procedure was developed to permit torching the shaft if the bearing froze; however, the gear box survived the encounter and the emergency procedure was not needed.

e. Transatlantic Cable Problem. October 18, 1972, the DSN was faced with an emergency situation when all voice and high speed data communication with DSS 51 were lost because of a failure in the transatlantic submarine cable. Communication with DSS 51 was re-established over existing landline teletype circuits but not before the field of view of the Imaging Photo Polarimeter (IPP) instrument had passed through Jupiter. Twenty gain decrement commands were transmitted to the spacecraft in time to avoid sun damage to the IPP and initial indications from the spacecraft indicate that any sun damage was minimal.

Immediately after loss of communications with DSS 51, the DSN requested DSS 61 to provide emergency support. Although DSS 61 was not scheduled for support of Pioneer 10, they responded to the emergency and were operational within one hour and, if necessary, could have provided the balance of DSS 51 support.

On December 29, 1972, MCCF experienced almost complete power failure. At the time, DSS 12 was tracking Pioneer 9 and DSS 14 was supporting a precession maneuver on Pioneer 10. Within a few minutes, telephone communication was established with ARC and DSS 14. The high speed data line from DSS 14 was patched through to ARC also. One manual command was transmitted from DSS 14 in this mode. Restoration was started within 18-minutes on the high speed data circuit and complete system restoration was accomplished in 2 hours. No serious consequences resulted and data loss was restricted to real time data only.

2. Telemetry

Engineering signal-to-noise (SNR) and downlink signal level data plotted during the period covered by this document are given in Tables 5 and 6.

There were no problems during the critical Pioneer 10 encounter period, and problems during Pioneer 10 tracks were minimal for all of November and December 1973. Pioneer 10 had 1695 hours of tracking time and the system had a reliability of approximately 99.95 percent.

a. Engineering SNR Ratio. For November, the Pioneer 10 data plotted contain 89 SNR readings that were found to have an arithmetic mean of 0.7 dB, a variance of 0.2 dB, and a standard deviation of 0.4 dB. Of these observations, 71 percent were less than 1.0 dB of predicted values, and 20 percent were less than 0.3 dB of the predicted values. The most often observed value was between 0.7 and 0.8 dB.

For December, the data plotted contain 92 SNR readings that were found to have an arithmetic mean of 0.5 dB, a variance of 0.1 dB, and a standard deviation of 0.4 dB. Of these observations, 86 percent were less than 1.0 dB of predicted values, and 29 percent were less than 0.3 dB of the predicted values. The most often observed value was between 0.2 and 0.3 dB.

b. Downlink Signal Level. For November, the Pioneer 10 data plotted contain 89 readings of downlink signal levels that were found to have an arithmetic mean of 0.8 dB, a variance of 0.3 dB, and a standard deviation of 0.6 dB. Of these observations, 61 percent were less than 1.0 dB of predicted values, and 21 percent were less than 0.3 dB of predicted values. The most often observed value was between 0.2 and 0.3 dB.

For December, the data plotted contain 92 readings of downlink signal levels that were found to have an arithmetic mean of 0.6 dB, a variance of 0.2 dB, and a standard deviation of 0.5 dB. Of these observations, 83 percent were less than 1.0 dB of predicted values, and 20 percent were less than 0.3 dB of predicted values. The most often observed value was between 0.4 and 0.5 dB.

c. Solar Occultation, Pioneer 10. While the spacecraft was in solar occultation, January 12 through January 20, no significant trends were observed. No data were received at 26-meter sites during the occultation period.

Four days' telemetry data compiled (Tables 7 - 10) show the degradation of the downlink signal strength, signal-to-noise rates, and system temperature T_s from approximately 6.5 degrees on January 8 to 3.0 degrees on January 1. The data are compared with data from a previous Pioneer 9 solar occultation at approximately the same angles as Pioneer 10 on the four dates.

Explanation of data Tables 7 - 10:

(1) SNR at 90 elevation is calculated using the equation SNR = Total Power + 20 log sin θ - 10 log T_s - 10 log SPS (symbol per second) System Loss + 198.6 ± 0.5 dB.

(2) Bias for elevation is taken from Figs. 2 and 3.

(3) Predicted SNR = SNR at 90 degrees elevation minus bias for elevation.

(4) SNR actual is taken from DTV format 815, 360/75 processed data ± 0.5 dB.

(5) Predicted Solar Occultation System Temperature T_s taken from previous Pioneer 6 and Pioneer 9 solar occultations.

(6) Pioneer 9 occultation system temperature T_s.

(7) Pioneer 10 actual system temperature taken from station post track report.

C-2

(8) Predicted degradation is 10 log of the ratio of predicted T_s for elevation and solar occultation predicted T_s.

On January 10, DSS 14 declared both DDAs red (nonoperational) and could not process data in the coded mode. The spacecraft was switched to 64 bits per second noncoded, and later to 128 bps with very little change noted in the SNR. On day 11, the spacecraft was switched from 64 bps coded to 128 bps coded, over DSS 14; there was approximately 0.5 dB change in SNR. This could be a result of the higher modulation index of 1.1 radians for Pioneer 10 versus 0.9 radian for Pioneer 9.

3. Command

The Command System was at its best during encounter despite the large volume of commanding required (1,712 commands sent day of periapsis passage, for example). Only seven interruptions to commanding were caused by DSN hardware, software, or procedural problems during encounter. Prior to that time, command interruption was on an average of about one every 30 hours of heavy command activity. None of the failures during encounter were a cause of loss of science data.

a. Mean Time Between Failures. An updated mean time between failures table (Table 11) has a base period of 6 months (June - November 1973), considered a long enough period for statistical fluctuation to have dampened out. The table includes data for Pioneer 10 and 11 and Mariner 10, which was launched November 3, 1973.

Pioneer 10 mean time between failures calculations for December are given in Table 12. Mean time between failures for the aggregate of station failures in December for Pioneer 10 was:

DSS	M (h)
12	11.5
14	28.5
42	0
43	36.4
63	50.7
Subnet	34.6

Formula used:

$$M = \frac{T-(O_x + O_a + O_t)}{N_x + N_a + N_t}$$

where terms used are as defined in Table 11.

b. Problem Areas. Transmitter noise spikes were a problem at DSS 43 throughout encounter. On Pass 661, these spikes caused the track to be terminated, and they caused a command outage of 295 minutes. On numerous other occasions, transmitter power had to be reduced. These reductions are not counted in the calculation of DSS 43 mean time between failures. Also at DSS 43, there were two data quality failure alarms on Pass 658. Additionally, on Pass 663 there was a bit error alarm. The station also had 11 high-speed data line outages for a down time of 116 minutes. DSS 63 had 10 HSDL outages for a down time of 77 minutes.

The average percentage of downtime for November and December 1973 is listed in Tables 13 and 14.

4. Command Activity Summaries.

Tables 15 and 16 give Pioneer 10 Command activity totals for the months of November and December 1973. Table 17 gives the cumulative command activity from launch through December 1972. Cumulative command activity from launch through January 4, 1974, is reported in Table 18.

5. Monitor.

Summaries of DSN Monitor System support during the encounter period are given in Tables 19 and 20.

For Pioneer 10, the monitor software program DOI-5046-OP-B continued in use as the standard operational program, despite a printer problem. Work-arounds and modifications were studied. The DOI-5046-OP-B became operational in October 1973.

Table 2. Summary of Pioneer 10 Support - Passes 31 through 674

Month, Year	Supporting Stations	No. of Tracks	Tracking Time (hr:min)	Telemetry Bit Rate (bps)	Average Downlink (dBm)	Commands Transmitted
1972 April	11, 12, 14, 41, 51	92	667:19	256, 512, 2048	-152.5	1223
May	11, 12, 41, 42, 61	95	871:14	256, 512, 2048	-140.5	1303
June	11, 12, 41, 42, 51, 61, 62	96	772:47	1024, 2048	-144.6	2147
July	11, 12, 41, 42, 51, 61, 62	95	830:36	512, 1024, 2048	-149.1	1621
Aug.	11, 12, 14, 41, 42, 51, 61, 62	97	711:52	512, 1024, 2048	-151.2	1668
Sept.	11, 12, 14, 41, 42, 51, 61	90	765:20	512, 1024	-154.6	1994
Oct.	11, 12, 14, 41, 51, 61	97	790:19	128, 256, 512, 1024, 2048	-155.9	2401
Nov.	11, 12, 14, 41, 42, 51, 62	87	767:52	128, 256, 1024, 2048	-157.7	1591
Dec.	12, 14, 41, 42, 51, 62	95	751:29	128, 256, 1024	-157.9	1311
1973 Jan.	12, 14, 42, 61, 62	82	636:23	64, 128, 256, 512, 1024	-158.2	1092
Feb.	11, 12, 14, 42, 43, 61, 62	85	703:21	64, 128, 256, 1024	-159.6	1261
Mar.	11, 12, 14, 42, 51, 61, 62	97	733:01	64, 128, 256, 1024	-159 -159	1197 1197
April	11, 12, 14, 42, 43, 51, 61, 62	94	769:05	64, 128, 1024	-155	14[illegible]
May	11, 12, 14, 42, 43, 44, 61, 62	97	760:27	128, 256, 1024, 2048	-156.5	1379
June	12, 14, 43, 51, 61, 62	93	754:27	128, 256, 1024, 2048	-154.7	1206
July	11, 12, 14, 42, 43, 44, 61, 62	102	815:54	256, 1024, 2048	-157.4	1980
Aug.	11, 12, 14, 42, 43, 61, 62	92	823:49	128, 256, 512, 1024	-157.1	1727
Sept.	11, 12, 14, 42, 43, 61, 62, 63	103	838:00	128, 256, 1024, 2048	-158.2	1340
Oct.	12, 14, 42, 43, 61, 62, 63	97	808:16	128, 256, 512, 1024, 2048	-159.5	2537
Nov.	11, 12, 14, 43, 62, 63	95	788:43	128, 512, 1024	-155.1	6380
Dec.*	11, 12, 14, 42, 43, 63	98	906:43	64, 128, 512, 1024	-154	12219
through Jan. 4**	12, 14, 43, 62, 63	12	85:21	64, 128, 512, 1024	-157.1	251

*Closest approach to Jupiter occurred on Pass 643, DOY 338 (4 Dec. 1973); command total was 6712.

**End of encounter period (Pass 674), which began on Pass 613, DOY 308 (4 Nov. 1973)

Note: Totals for January, which also included support by DSS 11, 42, and 51, were: 72 tracks, 588 h:55 min, -158.5 dBm average downlink, and 2855 commands.

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Table 3. Tracking and Data Acquisition Stations of the DSN

DSCC	Location	DSS	DSS Serial Designation	Antenna: Diameter, m (ft)	Antenna: Type of Mounting	Year of Initial Operation
Goldstone	California	Pioneer	11	26 (85)	Polar	1958
		Echo	12	26 (85)	Polar	1962
		(Venus)[a]	13	26 (85)	Az-El	1962
		Mars	14	64 (210)	Az-El	1966
Tidbinbilla	Australia	Weemala (formerly Tidbinbilla)	42	26 (85)	Polar	1965
		Ballima (formerly Booroomba)	43	64 (210)	Az-El	April 1973
—	Australia	Honeysuckle Creek[b]	44	26 (85)	X-Y	1973
—	South Africa	Hartebeesthoek	51	26 (85)	Polar	1961
Madrid	Spain	Robledo	61	26 (85)	Polar	1965
		Cebreros	62	26 (85)	Polar	1967
		Robledo	63	64 (210)	Az-El	Sept. 1973

[a]A maintenance facility. Besides the 26-m (85-ft) diameter Az-El mounted antenna, DSS 13 has a 9-m (30-ft) diameter Az-El mounted antenna that is used for interstation time correlation using lunar reflection techniques, for testing the design of new equipment, and for support of ground-based radio science.

[b]Shared with STDN until January 1974.

Table 4. Parameters for Solar Occultation Support

Date (Jan)	Time (GMT)	2-way* Power (dBm)	2-way** BW (Hz)	1-way** BW (Hz)
12	1930	-160.5	1.0	0.6
13	2200	-157.5	1.8	0.6
14	1900	-156.7	4.5	1.0
15	1800	-155.6	5.5	1.6
16	1900	-154.0	5.3	1.4
17	1830	-153.0	7.8	3.7
18	1800	-151.5	2.3	0.8
19	1830	-152.2	0.8	0.2

*accurate to about 0.5 db

**width of central band which contains half of the received power

Table 5. Monthly Engineering SNR Readings for Pioneer 10

Month	No. of Readings	Arithmetic Mean (dB)	Variance (dB)	Standard Deviation (dB)	% Less Than 1.0 of Predict Value	% Less Than 0.3 of Predict Value	Most Observed Value (Between) (dB)
1972							
April	85	0.5	0.1	0.4	89	24	0.4-0.5
May	92	1.0	0.5	0.7	57	12	>1.0
June	81	0.5	0.1	0.3	91	23	0.7-0.8
July	72	0.3	0.7	0.2	95	34	0.1-0.2
August	95	0.4	0.1	0.4	91	35	0.1-0.2
September	90	0.3	0.08	0.2	98	40	0.1-0.2
October	84	0.3	0.05	0.2	100	49	0.1-0.2
November	91	0.4	0.2	0.4	89	40	0.1-0.2
December	92	0.5	0.2	0.4	87	34	0.1-0.2
1973							
January	56	0.9	0.5	0.7	66	16	0.3-0.4
February	85	0.5	0.1	0.3	90	25	0.6-0.7
March	93	0.6	0.2	0.5	75	32	0.1-0.2
April	92	0.6	0.1	0.3	86	21	0.6-0.7
May	92	0.5	0.1	0.4	84	27	0.4-0.5

Table 5. (contd)

Month	No. of Readings	Arithmetic Mean (dB)	Variance (dB)	Standard Deviation (dB)	% Less Than 1.0 of Predict Value	% Less Than 0.3 of Predict Value	Most Observed Value (Between) (dB)
June (1973)	91	0.7	0.2	0.4	68	16	0.6-0.7
July	93	0.9	0.2	0.4	53	8	>1.0
August	91	1.0	0.3	0.5	43	11	>1.0
September	97	0.9	0.2	0.4	49	9	0.8-0.9
October	95	0.8	0.2	0.5	57	9	0.9-1.0
November	89	0.7	0.2	0.4	71	20	0.7-0.8
December	92	-0.5	0.1	0.4	86	29	0.2-0.3

Table 6. Monthly Downlink Signal Level

Month	No. of Readings	Arithmetic Mean (dB)	Variance (dB)	Standard Deviation (dB)	% Less Than 1.0 of Predict Value	% Less Than 0.3 of Predict Value	Most Observed Value (Between) (dB)
1972							
April	79	0.5	0.1	0.3	91	33	0.1-0.3
May	92	1.0	0.4	0.6	49	12	>1.0
June	81	0.5	0.2	0.4	84	25	0.2-0.3
July	72	0.6	0.2	0.5	70	27	0.2-0.3
August	95	0.7	0.3	0.6	68	20	0.2-0.3
September	90	0.3	0.07	0.2	97	42	0.2-0.3
October	84	0.5	0.1	0.3	89	29	0.1-0.2
November	90	0.6	0.2	0.4	84	28	0.1-0.2
December	92	0.8	0.2	0.5	67	13	0.6-0.7
1973							
January	62	0.7	0.2	0.5	73	18	0.5-0.6
February	85	0.8	0.4	0.6	64	19	0.7-0.8
March	93	0.8	0.3	0.5	61	23	0.2-0.3
April	92	0.7	0.2	0.5	71	15	0.6-0.7
May	92	0.6	0.2	0.5	80	30	0.2-0.3

Table 6. (contd)

Month	No. of Readings	Arithmetic Mean (dB)	Variance (dB)	Standard Deviation (dB)	% Less Than 1.0 of Predict Value	% Less Than 0.3 of Predict Value	Most Observed Value (Between) (dB)
June (1973)	91	0.9	0.3	0.5	55	11	>1.0
July	93	0.8	0.3	0.5	68	22	0.2-0.3
August	91	0.8	0.3	0.5	--	64	0.6-0.7 & 0.9 to 1.0 Equally
September	97	0.7	0.3	0.5	73	25	>1.0
October	95	0.7	0.4	0.6	73	25	0.2-0.3
November	89	0.8	0.3	0.6	61	21	0.2-0.3
December	92	0.6	0.2	0.5	83	20	0.4-0.5

Table 7. Pioneer 10 Occultation Data Compiled January 8, 1973*

		DSS 42	DSS 62	DSS 14
	AGC Predicted	-159.1 dBm	-159.1 dBm	-151.0 dBm
	AGC Actual	-159.9	-158.6	-150.9
	AGC Resid	-0.8 dB	+0.5 dB	+0.1 dB
A	SNR @ 90° EL	5.3 dB @ 128C	8.1 dB @ 64C	9.2 dB @ 512C
B	Bias for EL	0	-0.8	-0.7
C	Predicted SNR	5.3	7.3	8.5
D	SNR Actual	3.5	4.0	5.7
*E	SNR Resid C-D	-1.8 dB	-3.3 dB	-2.8 dB
			(Pioneer 9	-3.2 dB)
F	T_s @ 90° EL	33°K ±3°	33°K ±3°	24°K ±3°
G	Predicted T_s for EL	33°K ±5°	40°K ±5°	28°K ±5°
H	Predicted Solar OCC T_s	45°K	48°K	40°K
I	PN-9 OCC T_s			37°K ±10°
J	PN-10 ACT T_s		50°K ±10°	32°K +10°
K	Predicted Deg. $10_L H - 10_L G$	-1.3 dB	-0.8 dB	-1.5 dB
L	Total Resid E-K	-0.5 dB	-2.5 dB	-1.3 dB

*(See explanation Subsection E-2-c)

Table 8. Pioneer 10 Occultation Data Compiled January 9, 1973*

		DSS 42	DSS 62	DSS 14
	AGC Predicted	-159.2 dBm	-159.2 dBm	-151.0
	AGC Actual	-160.2 dBm	-158.8	-152.2
	AGC Resid	-1.0 dB	+0.4 dB	-1.2
A	SNR @ 90° EL	5.2 dB @ 128C	8.1 dB @ 64C	12.0 dB @ 256
B	Bias for EL	0	-0.8	-1.5
C	Predicted SNR	5.2	7.3	10.5
D	SNR Actual	2.4	4.0	5.7
*E	SNR Resid C-D	-2.8 dB	-3.3 dB	-4.8 dB
			(Pioneer 9	-4.1 dB)
F	T_s @ 90° EL	$33^{\circ}K \pm 3^{\circ}$	$33^{\circ}K \pm 3^{\circ}$	$24^{\circ}K \pm 3^{\circ}$
G	Predicted T_s for EL	$33^{\circ}K \pm 5^{\circ}$	$40^{\circ}K \pm 5^{\circ}$	$34^{\circ}K \pm 5^{\circ}$
H	Predicted Solar OCC T_s	$50^{\circ}K$	$52^{\circ}K$	$45^{\circ}K$
I	PN-9 OCC T_s			$49^{\circ}K \pm 15^{\circ}$
J	PN-10 ACT T_s	$39^{\circ}K +25^{\circ}$	$50^{\circ}K +25^{\circ}$	$42^{\circ}K +10^{\circ}$
K	Predicted Deg. $10_L H - 10_L G$	-1.8 dB	-1.2 dB	-1.2 dB
L	Total Resid E-K	-1.0 dB	-1.1 dB	-3.6 dB

*(See explanation Subsection E-2-c)

Table 9. Pioneer 10 Occultation Data Compiled January 10, 1973*

		DSS 42	DSS 62	DSS 14
	AGC Predicted	-159.2 dBm	-159.2 dBm	-151.1 dBm
	AGC Actual	-159.3	-159.0	-152.4
	AGC Resid	-0.1 dB	+0.2 dB	-1.3 dB
				Non Coded
A	SNR @ 90° EL	5.2 dB @ 128C	8.1 dB @ 64C	17.5 dB @ 128NC
B	Bias for EL	0	-0.8 dB	-0.7
C	Predicted SNR	5.2	7.3 dB	16.8
D	DNR Actual	3.1	2.8	2.8
*E	SNR Resid C-D	-2.1 dB	-4.5 dB	14.0 dB
			(Pioneer 9	-5.7 dB)
F	T_s @ 90° EL	$33^{\circ}K \pm 3^{\circ}$	$33^{\circ}K \pm 3^{\circ}$	$24^{\circ}K \pm 3^{\circ}$
G	Predicted T_s for EL	$33^{\circ}K \pm 5^{\circ}$	$40^{\circ}K \pm 5^{\circ}$	$28^{\circ}K \pm 5^{\circ}$
H	Predicted Solar OCC T_s	$54^{\circ}K$	$55^{\circ}K$	$65^{\circ}K$
I	PN-9 OCC T_s			$65^{\circ}K$
J	PN-10 ACT T_s	$35^{\circ}K +32^{\circ}$	$45^{\circ}K +34^{\circ}$	$28^{\circ}K +47^{\circ}$
K	Predicted Deg $10_L H - 10_L G$	-2.1 dB	-1.4 dB	-3.6 dB
L	Total Resid E-K	0	-3.1	-10.4

*(See explanation Subsection E-2-c)

Table 10. Pioneer 10 Occultation Data Compiled January 11, 1973*

		DSS 42	DSS 62	DSS 14
	AGC Predicted	-159.2 dBm	-159.2 dBm	-151.1
	AGC Actual	Conscan ON	-160.4	-153.3
	AGC Resid	S/C ANT OFF set	-1.2 dB	-2.2
		No Data Available		
A	SNR @ 90° EL		8.0 dB @ 64C	14.7 dB @ 128C
B	Bias for EL		-0.8 dB	-0.7
C	Predicted SNR		7.2	14.0
D	DNR Actual		2.1	4.9
*E	SNR Resid C-D		5.1 dB	9.1 dB
			(Pioneer 9	-6.6)
F	T_s @ 90° EL		$33^{\circ}K \pm 3^{\circ}$	$24^{\circ}K \pm 3^{\circ}$
G	Predicted T_s for EL		$40^{\circ}K \pm 3^{\circ}$	$28^{\circ}K \pm 5^{\circ}$
H	Predicted Solar OCC T_s		$65^{\circ}K$	80°
I	PN-9 OCC T_s			80°
J	PN-10 ACT T_s		$54^{\circ}K +8^{\circ}$	$30^{\circ}K +31^{\circ}$
K	Predicted Deg $10_L H - 10_L G$		-2.1 dB	-4.5 dB
L	Total Resid E-K		-3.0 dB	-4.6

*(See explanation Subsection E-2-c)

Table 11. Mean Time Between Failures - Calculations (June-November, 1973 — Pioneer 10 and 11, plus Mariner 10)

DSS	Total Track Time (T)	Outage Time (min)				Number of Failures				Mean (hrs)			
		O_x	O_a	O_t	O_h	N_x	N_a	N_t	N_h	M_x	M_a	M_t	M_h
11	65,930	47	19	86	80	4	3	7	5	275	366	157	220
12	57,208	215	30	386	9	4	3	29	1	238	318	33	953
14	52,165	169	155	141	14	8	5	15	1	108	173	58	869
42	83,651	105	64	63	66	3	14	6	19	464	100	232	73
43	71,084	35	288	284	198	11	17	11	27	108	69	109	44
44	52,287	123	113	255	62	7	7	9	13	124	124	96	67
51	109,236	103	46	91	752	3	2	12	67	606	910	152	27
61	23,724	18	0	46	31	3	0	2	7	132	*	197	56
62	57,187	37	5	128	119	1	1	9	27	953	953	106	35
63	32,027	40	113	23	59	2	7	2	10	267	76	267	53
Total	604,499	892	833	1503	1390	47	58	102	177	219	171	99	57

$$M_x = \frac{T - O_x}{N_x} \qquad M_a = \frac{T - O_a}{N_a}$$

Subscripts:
- x = transmitter/exciter subsystem
- a = antenna/tuning subsystem
- t = TCP/CMA subsystem, not including failures during Data Transfer Test
- h = high speed data line and Comm equipment
- * = no failures occurred in this category at this DSS

Table 12. Pioneer 10 Mean Time Between Failures Calculations for December 1973

DSS	Total Track Time (T)	Outage Time (min)				Number of Failures				Mean (hrs)			
		O_x	O_a	O_t	O_h	N_x	N_a	N_t	N_h	M_x	M_a	M_t	M_h
11													
12	2,073	0	0	9	9	0	0	3	2	*	*	11.4	17
14	8,579	6	25	4	29	1	1	3	2	143	142.5	48	71
42	185	0	0	0	0	0	0	0	0	*	*	*	*
43	22,347	298	168	59	116	2	1	7	11	184	370	53	34
44													
51													
61													
62													
63	15,246	0	3	35	77	0	1	4	10	*	254	63	25
Total	48,430	304	196	107	231	3	3	17	25	268	268	47	32

$$M_x = \frac{T - O_x}{N_x} \qquad M_a = \frac{T - O_a}{N_a}$$

Subscripts:
- x = transmitter/exciter subsystem
- a = antenna/tuning subsystem
- t = TCP/CMA subsystem, not including failures during Data Transfer Test
- h = high speed data line and Comm equipment

* = no failures occurred in this category at this DSS

Table 13. Average Percent Down in November 1973

DSS	11	12	14	42	43	51	61	62	63
(From HSDL Failures)									
Avg (%)	0	0	0.22	0	0.08	0	0	0	0.15
(From Station Failures)									
Avg (%)	0	0.30	0.81	0	0.31	0	0	0	0.38
Mission Avg (%)	1.36	1.97	2.09	0.3	0.89	0.55	0.60	0.36	0.52
Total Average Percent Down									
November	0	0.30	1.03	0	0.38	0	0	0	0.53

Table 14. Average Percent Down in December 1973

DSS	11	12	14	42	43	51	61	62	63
(From HSDL Failures)									
Avg (%)	0	0.43	0.33	0	0.51	0	0	0	0.50
(From Station Failures)									
Avg (%)	0	0.43	0.46	0	2.34	0	0	0	0.26
Mission Avg (%)	1.36	1.94	1.95	0.3	1.17	0.55	0.60	0.36	0.43
Total Average Percent Down									
December	0	0.87	0.80	0	2.86	0	0	0	0.26

Table 15. Summary of Pioneer 10 Command Activity for November 1973

DSS	11	12	14	42	43	51	61	62	63
Commands	0	249	1416	0	2274	0	0	0	1195
System Aborts*	0	0	0	0	1	0	0	0	0
Project Aborts**	0	0	0	0	0	0	0	0	0

*Aborts due to command system failure
**Commands aborted by Project (commands disabled while active)

Table 16. Summary of Pioneer 10 Command Activity for December 1973

DSS	11	12	14	42	43	51	61	62	63
Commands	0	10	2810	0	5587	0	0	0	3745
System Aborts*	0	0	1	0	3	0	0	0	2
Project Aborts**	0	0	2	0	0	0	0	0	1

*Aborts due to command system failure
**Commands aborted by Project (commands disabled while active)

Table 17. Cumulative Command Activity through December 1972

Activity	DSS								Total Since Launch
	11	12	14	41	42	51	61	62	
Commands	1994	2899	785	2257	2861	3107	2111	861	17,175
Aborts	5	3	16	11	10	1	4	0	43

Table 18. Cumulative Command Activity through January 4, 1974

DSS	11	12	14	42	43	44	51	61	62	63
Commands	2262	4741	9768	4960	11,188	2	3321	3051	3516	3769
System Aborts	3	2	26	8	4	0	1	2	0	3
Project Aborts	2	3	6	4	0	0	0	2	3	3

Totals for DSS 41 are 2557 commands, 7 system aborts, and 4 Project aborts. Total of commands since launch is 51,398. Total of system aborts is 56.

Table 19. DSN Monitor System Support Summary, November 1973

DSS	11	12	14	42	43	44	51	61	62	63
Passes w/DIS (PN 10 & 11)	35	9	20	0	31	31	0	0	0	30
Total Track Hours w/DIS	252.48	51.94	124.63	0.00	394.97	250.68	274.86	0.00	0.00	245.55
Passes w/o DIS (PN 6-9)	2	0	0	0	4	0	4	0	0	30
Total Track Hours w/o DIS	3.78	0.00	0.00	0.00	17.03	0.00	21.59	0.00	0.00	13.43
No. DIS Outages	2	2	2	0	3	N/A*	0	N/A*	1	1
Average % DIS Down	0.2	0.1	0.1	0.0	2.0	N/A	0.0	N/A*	2.1	1.0
Mean Time Between Failures - DIS (hours)	125.97	121.7	121.76	264.01	131.65	N/A	274.86	N/A	296.72	243.00
Station Total Track Hours	256.26	152.00	124.63	0.00	412.00	250.68	296.45	0.00	0.00	258.98

*DSS 44 has no DIS capability.

Table 20. DSN Monitor System Support Summary, December 1973

DSS	11	12	14	42	43	44	51	61	62	63
Passes w/DIS (PN 10 & 11)	33	7	24	2	30	29	0	0	0	31
Total Track Hours w/DIS	285.21	30.74	140.49	14.77	359.75	227.49	256.99	0.00	0.00	257.38
Passes w/o DIS (PN 6-9)	0	0	0	0	6	0	2	0	0	3
Total Track Hours w/o DIS	0.00	0.00	0.00	0.00	20.42	0.00	10.16	0.00	0.00	10.08
No. DIS Outages	1	0	1	0	2	N/A*	0	N/A*	1	1
Average % DIS Down	0.2	0.0	0.1	0.0	1.9	N/A	0.1	N/A*	0.1	0.1
Mean Time Between Failures - DIS (hours)	285.21	30.74	140.49	14.77	192.08	N/A	133.57	N/A	N/A	257.38
Station Total Track Hours	285.21	30.74	140.49	14.77	384.17	227.49	267.15	0.00	0.00	267.46

*DSS 44 has no DIS capability.

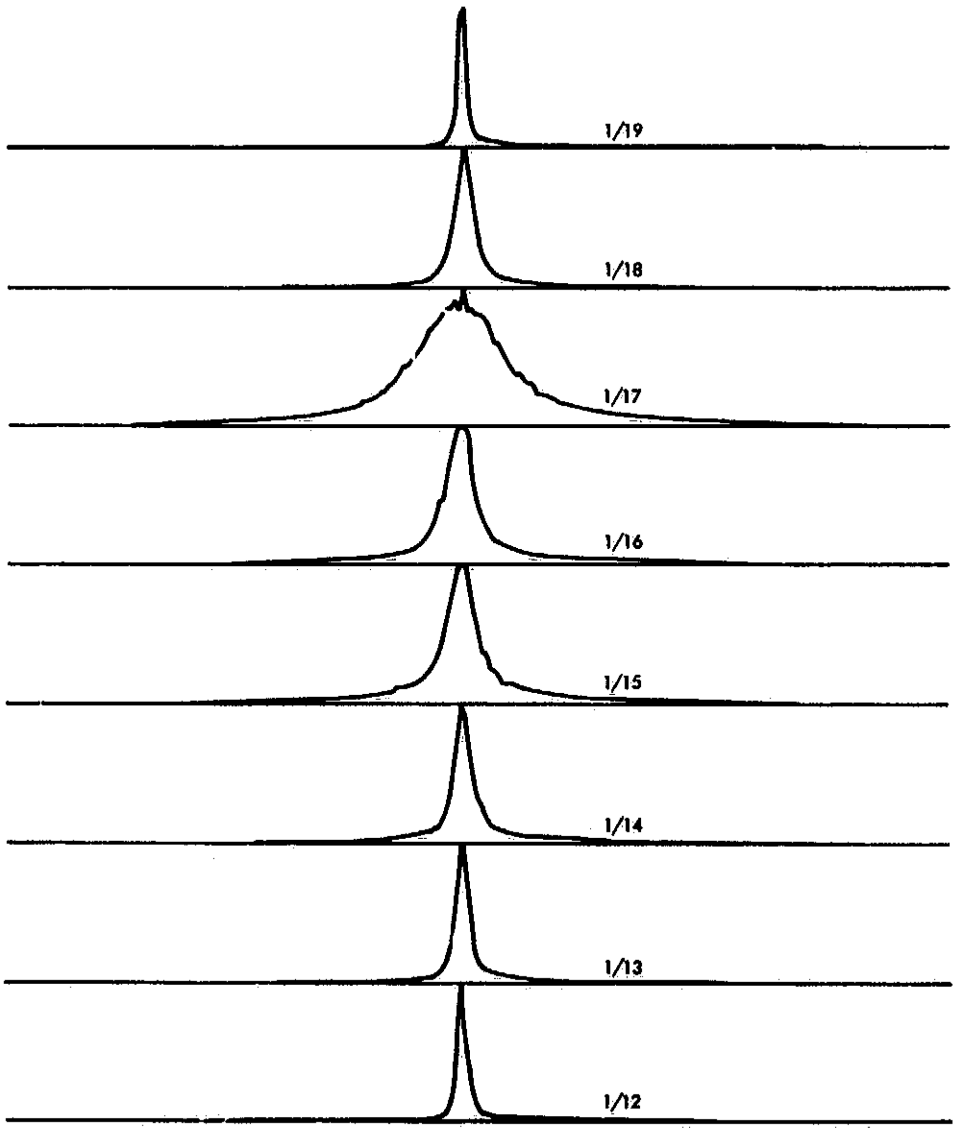

Fig. 24. One-way spectra of Pioneer 10 carrier

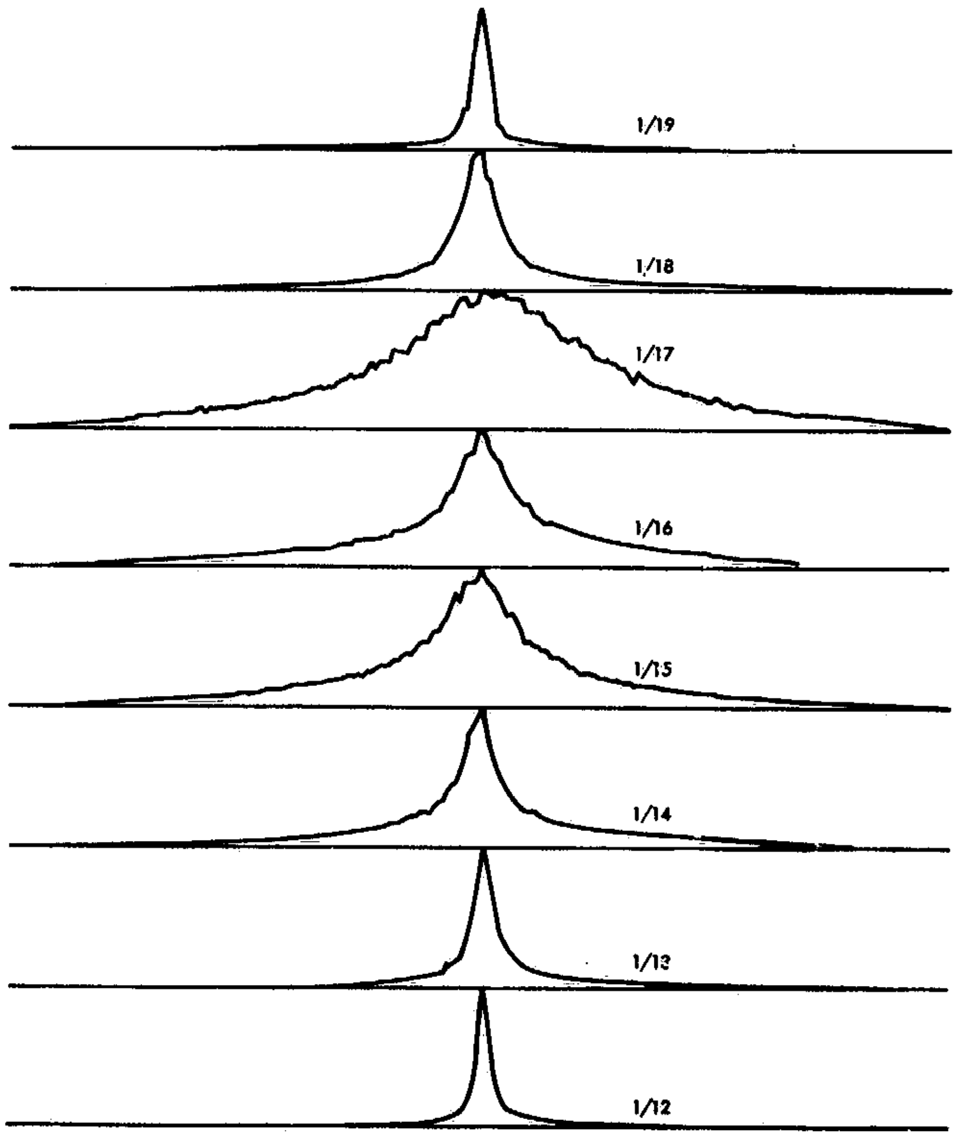

Fig 25. Two-way spectra of Pioneer 10 carrier

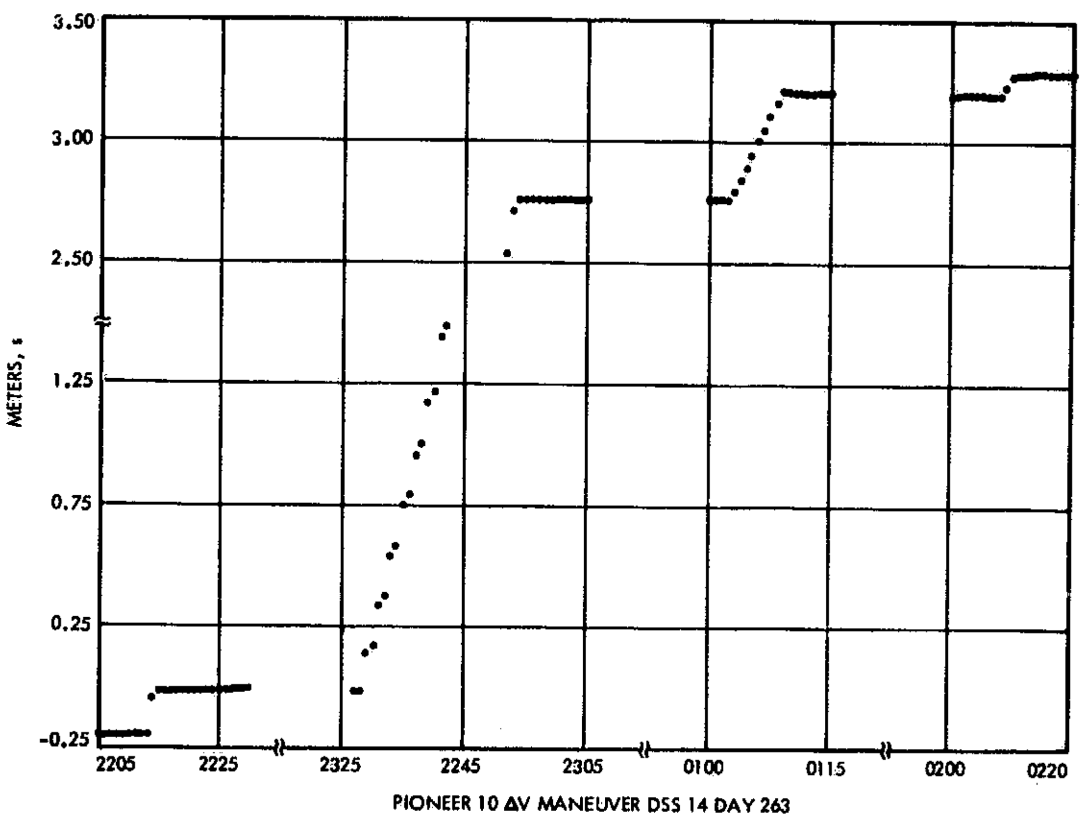

Fig. 26. Pioneer 10 delta velocity maneuver

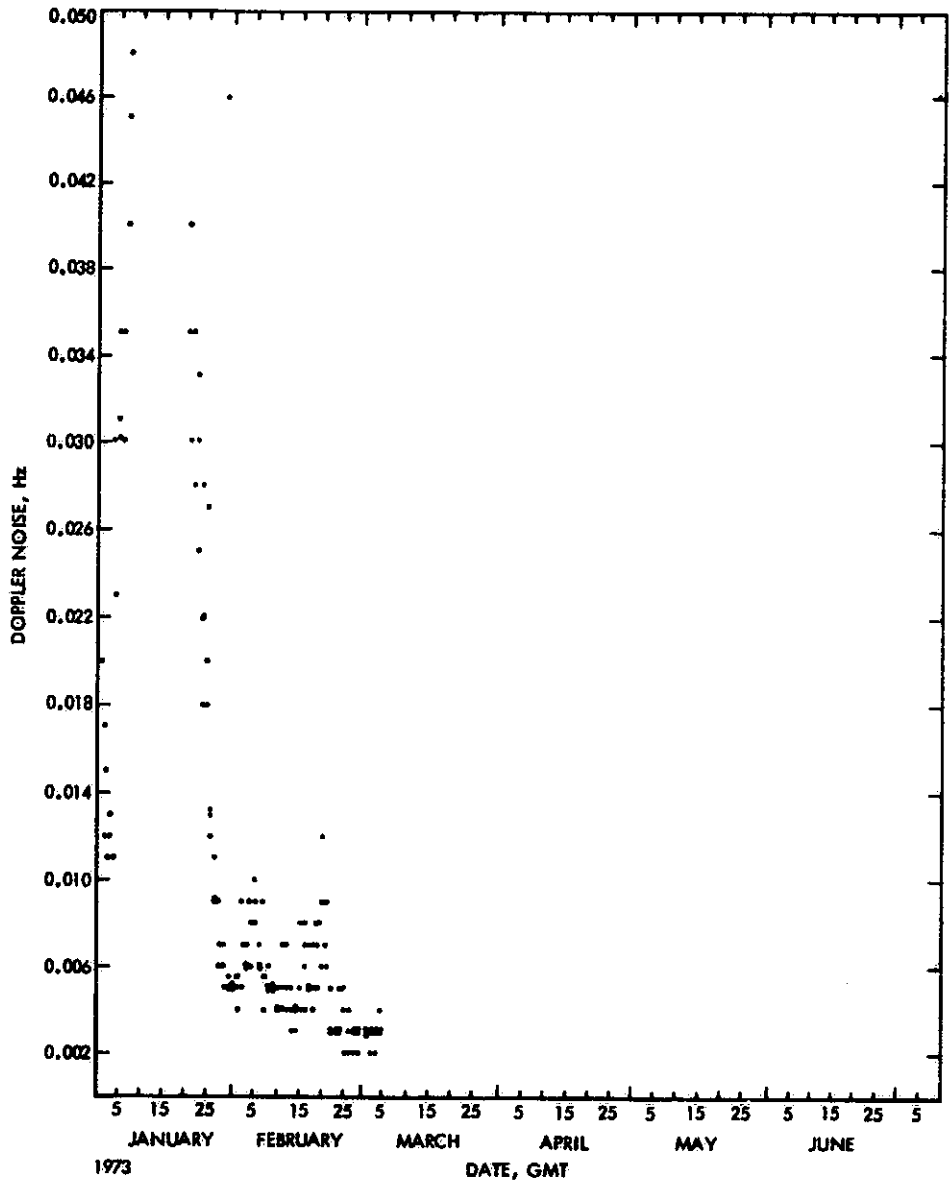

Fig. 27. Pioneer 10 doppler noise composite for January and February 1973

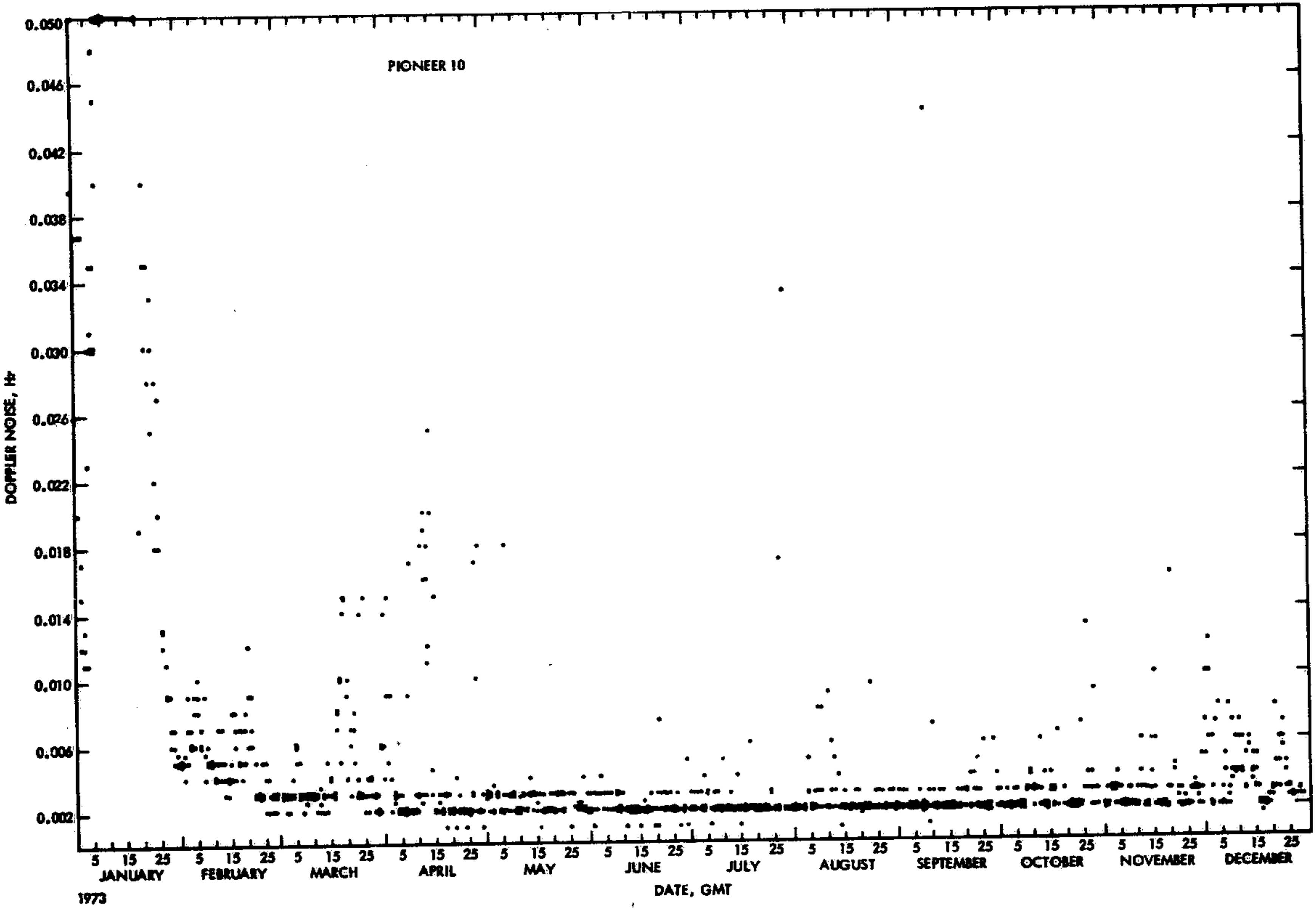

Fig. 28. Pioneer 10 doppler noise plot 1973

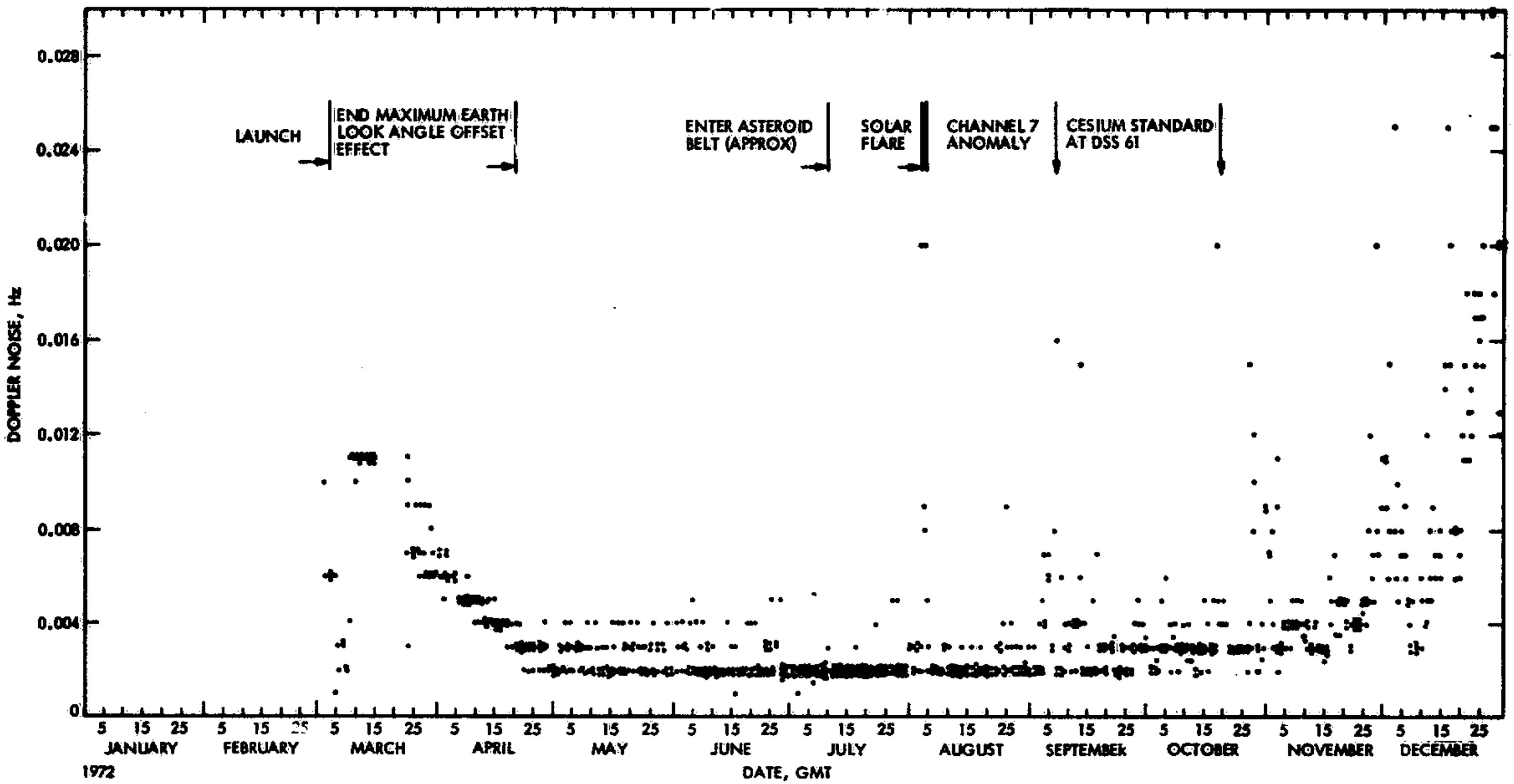

Fig. 29. Pioneer 10 doppler noise composite from launch through December 1972

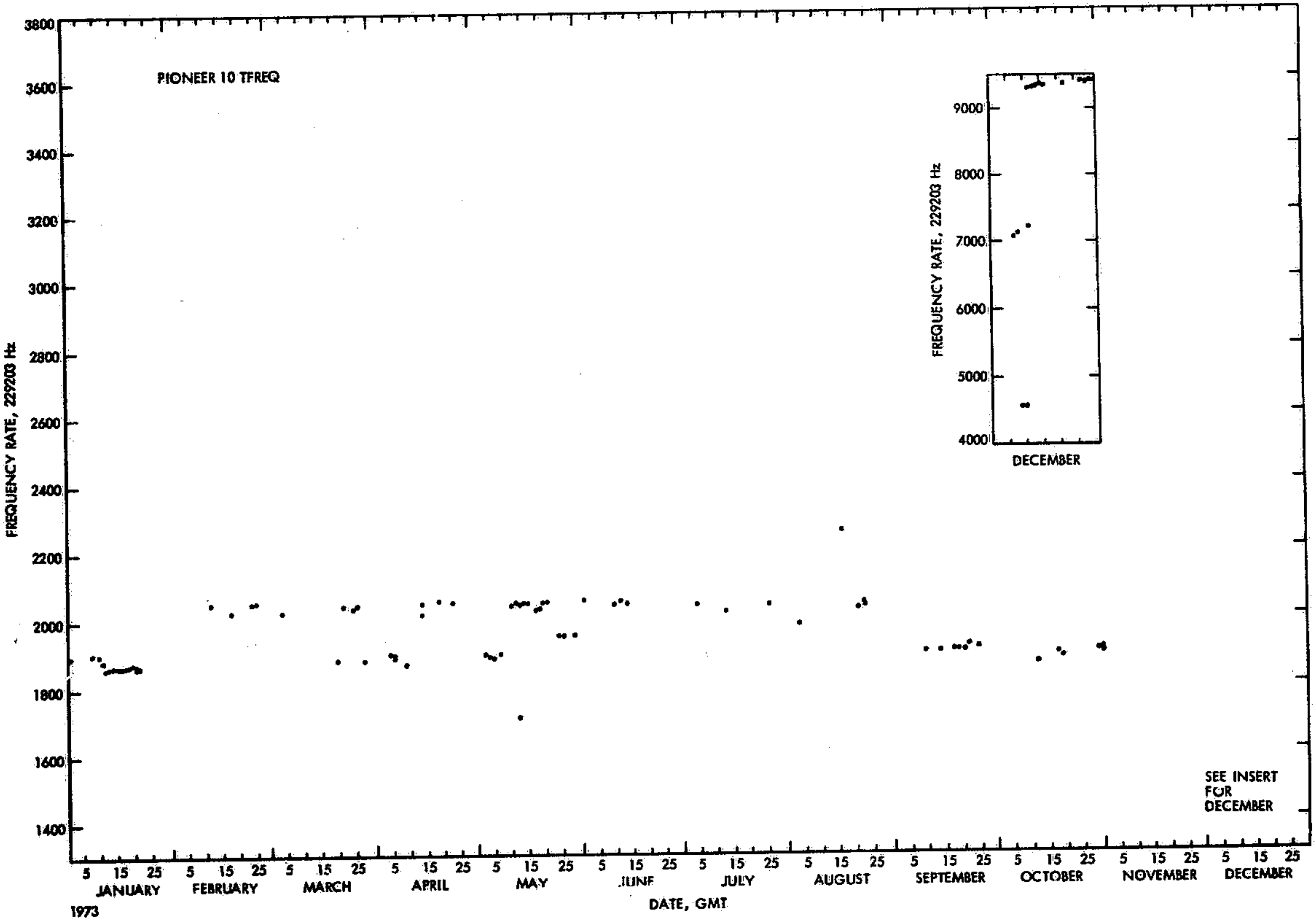

Fig. 30. Pioneer 10 auxiliary oscillator frequency, 1973

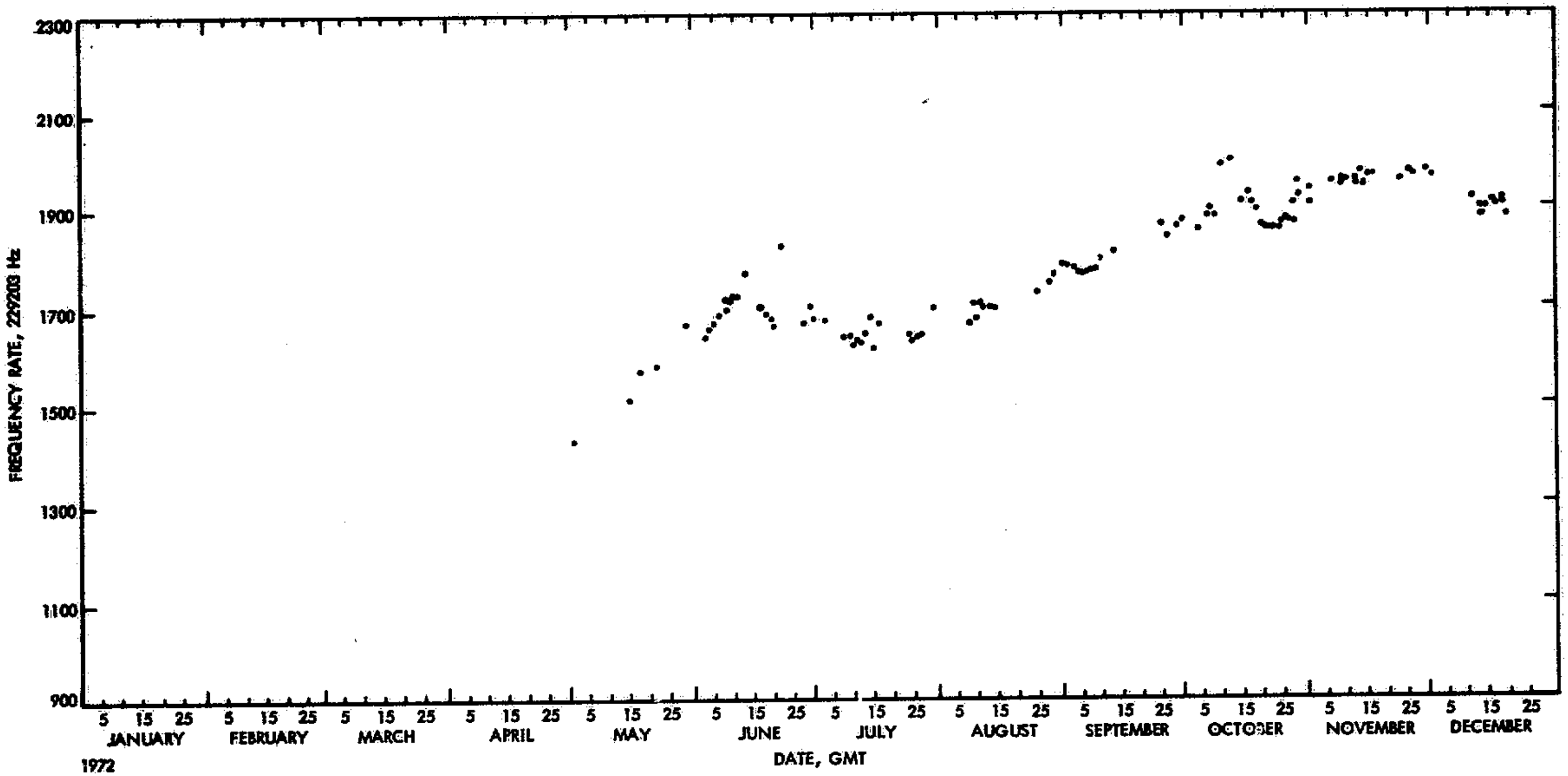

Fig 31. Pioneer 10 auxiliary oscillator frequency, 1972

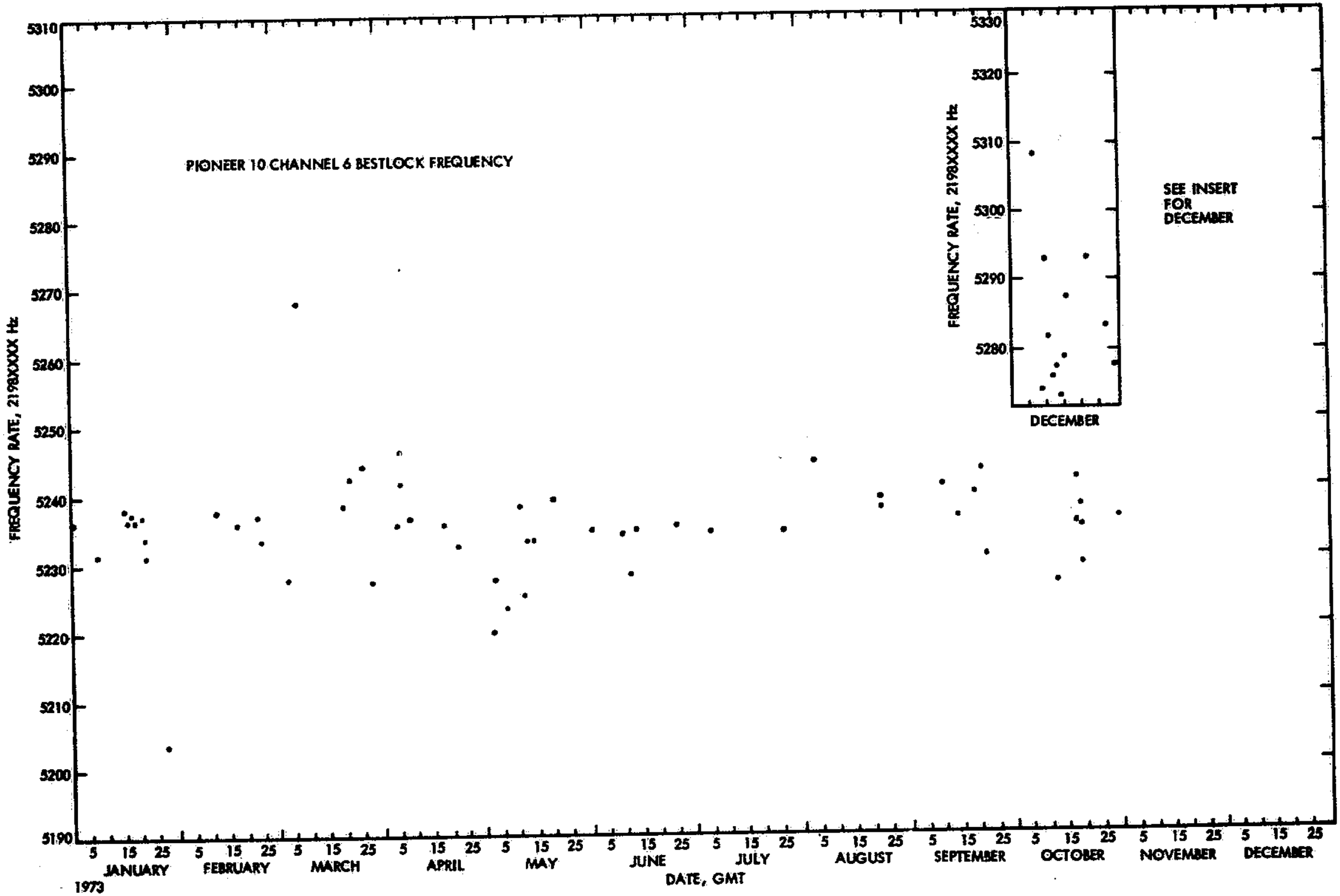

Fig. 32. Pioneer 10 channel 6 best lock frequency, 1973

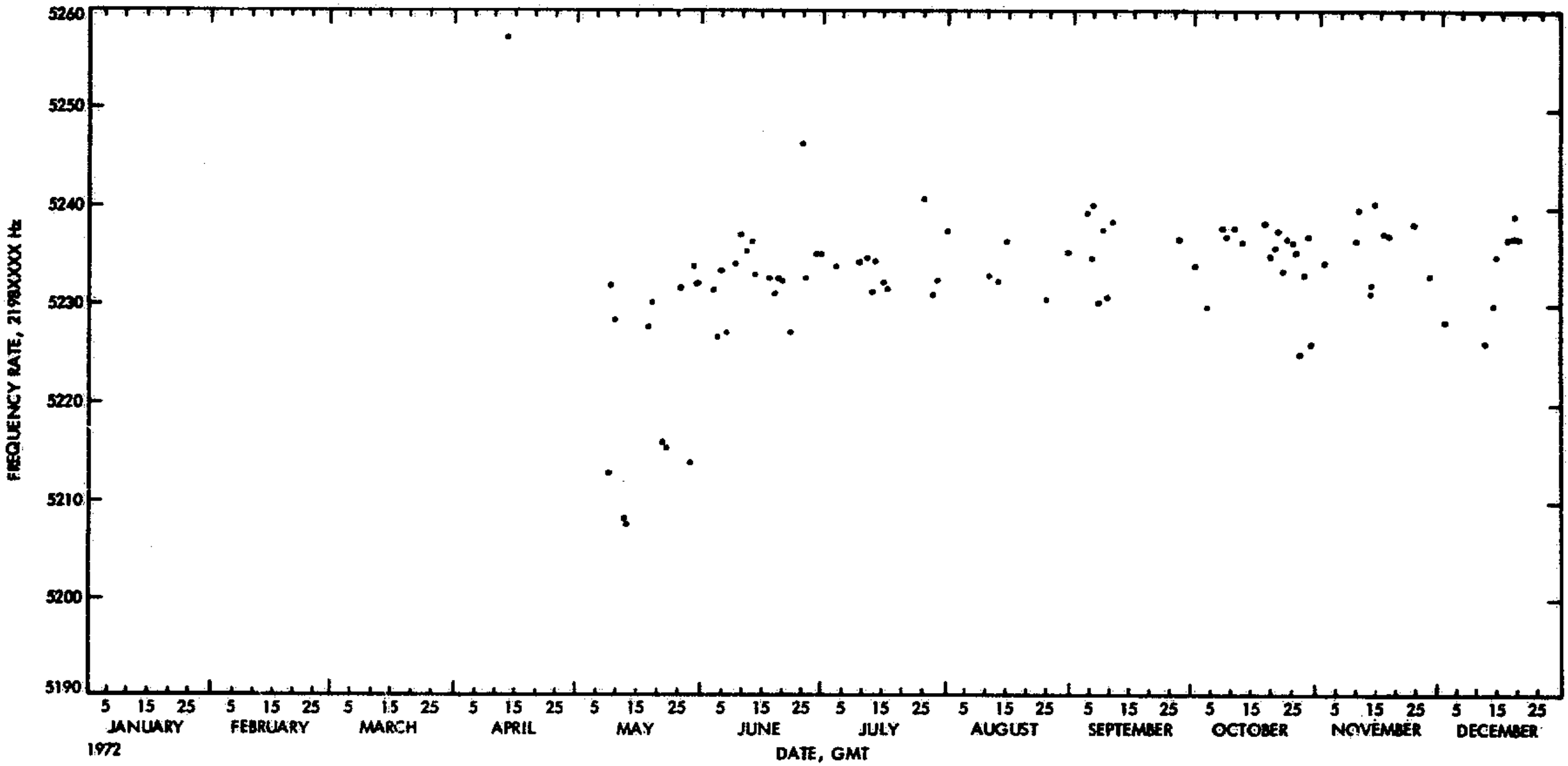

Fig. 33. Pioneer 10 channel 6 best lock frequency, 1972

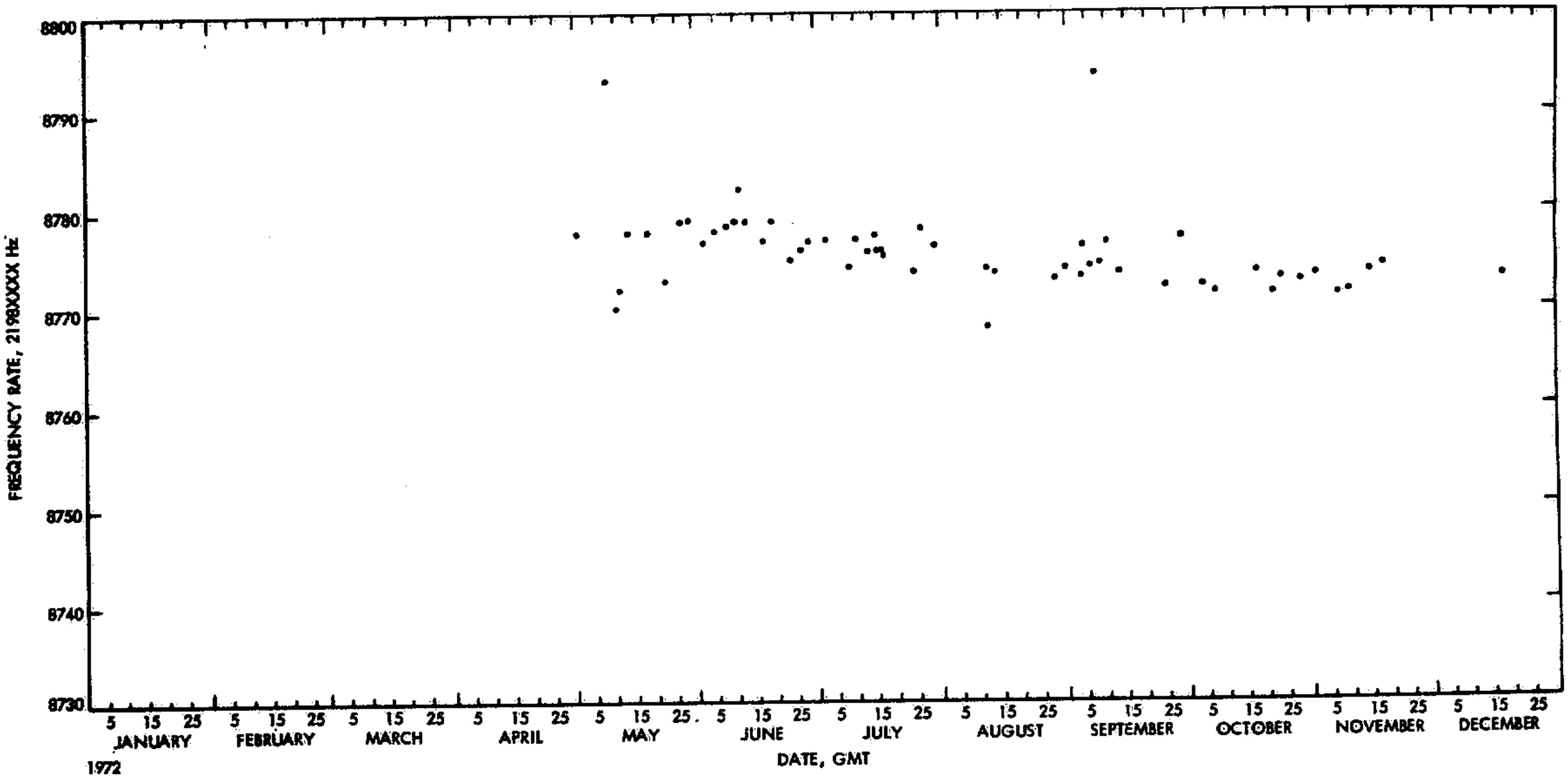

Fig. 34. Pioneer 10 channel 7 best lock frequency, 1972

DEFINITION OF ABBREVIATIONS AND SYMBOLS

ACS	Attitude Control System
ACQ	acquisition
ADSS	Automatic Data Switching System
AFETR	Air Force Eastern Test Range
AGC	automatic gain control
ANT	Antigua
AOS	acquisition of signal
APS	Antenna Pointing Subsystem
ARC	Ames Research Center
ASC	Ascension
BDA	Bermuda
BER	bit error rate
CCF	Central Computing Facility
CDC	Command and Data Handling Console
CKAFS	Cape Kennedy Air Force Station
CLT	communications line terminal
CMA	Command Modulator Assembly
CRO	Carnarvon
CTA	Compatibility Test Area
Conscan	Conical Scan System
CMO	Chief of Mission Operations
CP	Communications Processor
CPS	Central Processing System
CTRVC	Corrected time required velocity correction
DCO	Digitally Controlled Oscillator

DDA	Data Decoder Assembly
DIS	Digital Instrumentation Subsystem
DODR	Digital Original Data Record
DOY	Day of Year
DPTRAJ	Double Precision Trajectory Program
DSIF	Deep Space Instrumentation Facility
DSN	Deep Space Network
DSS	Deep Space Station
EDR	Experiment Data Record
ELA	Earth look angle
EOM	end of mission
EOT	end of track
FD	Flight Director
FPAC	flight path analysis and computation
FTS	Frequency and Timing Subsystem
GCF	Ground Communications Facility
GBI	Grand Bahama Island
GDS	Ground Data System
GMT	Greenwich Mean Time
GOE	ground operations equipment
GSFC	Goddard Space Flight Center
GTK	Grand Turk
HSD	high speed data
HSDL	high speed data line
IPP	Imaging Photopolarimeter
IRS	Information Retrieval System
IRV	Inter-range Vector

JPL	Jet Propulsion Laboratory
LTDS	Launch Trajectory Data System
LOS	loss of signal
MCCC	Mission Control and Computing Center
MCD	monitor criteria data
MDE	mission dependent equipment
MDF	Master Data File
MDR	Master Data Record
MMC	Multiple Mission Command
MMT	Multiple-Mission Telemetry
MOS	Mission Operations System
MRL	Maneuver Readiness Log
MSA	Mission Support Area
MSFN	Manned Space Flight Network
MUX Line	Multiplexed Communication Line
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NAA	Network Analysis Area
NAT	Network Analysis Team
NOC	Network Operations Control
NOPE	Network Operations Project Engineer
NSP	NASA Support Plan
OC	Operations Chief
OCIS	Office of Computing and Information Systems
OCT	Operations Control Team
OD	orbit determination
ODC	Operations Data Control

ODR	Original Data Record
ORT	Operational Readiness Test
OVT	Operational Verification Test
PDS	polarimeter diplexed S-band
PE	Project Engineer
PER	parity error rate
PET	probe ephemeris tapes
PMSA	Pioneer Mission Support Area
POGASIS	Planetary Orbiting Geometry and Scientific Simulation Computer Program
PPO	Pioneer Project Office
PRE	Pretoria
PSE	Pioneer Storage and Execution
RCC	Remote Control Center
RIC	Remote Information Center
RIS	Range Instrumentation Ship
RMD	Radio Metric Data
RTCS	Real Time Computing System
RTLT	round-trip light time
S/C	spacecraft
SCT	SFOF Communications Terminal
SCU	S-band Cassegrain Ultracone
SDA	Subcarrier Demodulator Assembly
SDCC	Simulation Data Conversion Center
SDL	System Development Laboratory
SDR	System Data Record
SFOF	Space Flight Operations Facility

SFOP	Space Flight Operation Plan
SIRD	Support Instrumentation Requirements Document
SIMCEN	Simulation Center
SLA	Sun look angle
SMT	S-band megawatt transmit
SNR	signal-to-noise ratio
SNT	system noise temperature
SOE	Sequence of events
SOPM	Standard Orbital Parameters Messages
SPU	S-band polarized ultracone
SSA	Symbol Synchronizer Assembly
SWCEN	Switching Center
TCD	Telemetry and Command Data Handling Subsystem
TCP	Telemetry and Command Processor
TDA	Tracking and Data Handling Subsystem
TDS	Tracking and Data System
TLM	telemetry
TRR	track
TSF	Track Synthesizer Frequency
T_s	system temperature
TTY	teletype
TWT	traveling wave tube
UPS	Uninterruptible Power System
USB	unified S-band
VAN	Vanguard (Apollo Ship)
VCO	Voltage controlled oscillator
VOCA	Voice Operational Communications Assembly

REFERENCES

1. Fimmel, R.O., et al, "Pioneer Odyssey — Encounter With a Giant," National Aeronautics and Space Administration SP-349, U.S. Gov't. Printing Office, Washington, D.C., 1974.

2. Chao, C.C., Preston, R.A., and Nance, H.E., "Short Baseline QVLBI Doppler Demonstrations — Part II," The Deep Space Network Progress Report 42-20, p. 20, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1974.

3. Chao, C.C., Wong, S.K., and Lukely, A., "Short Baseline QVLBI Demonstrations — Part I," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XVIII, p. 47, Jet Propulsion Laboratory, Pasadena, Calif., December 15, 1973.

4. O'Reilly, B.D., and Chao, C.C., "An Evaluation of QVLBI OD Analysis of Pioneer 10 Encounter Data in the Presence of Unmodeled Satellite Accelerations," The Deep Space Network Progress Report 42-22, p. 66, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1974.

5. Liu, A.S., "Range Measurements to Pioneer 10 Using the Digitally Controlled Oscillator," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XIX, p. 63, Jet Propulsion Laboratory, Pasadena, Calif., February 15, 1974.

6. Lesh, J.R., "Verification of Commands from the Transmitting Medium," The Deep Space Network Progress Report, Technical Report 42-20, p. 186, Jet Propulsion Laboratory, Pasadena, California, April 15, 1974.

7. Wick, M.R., "DSN Programmed Oscillator," The Deep Space Network Progress Report, 42-20, p. 167, Jet Propulsion Laboratory, Pasadena, California, April 15, 1974.

8. Liu, A.S., "Range Measurements to Pioneer 10 Using the Digitally Controlled Oscillator," The Deep Space Network Progress Report 42-20, Technical Report 32-1526, Volume XIX, p. 63, Jet Propulsion Laboratory, Pasadena, California, February 15, 1974.

9. Wick, M.R., "Operational Procedure -- Block III High Rate Doppler Receiver/Exciter Subsystem," JPL Specification OP509255A, Jet Propulsion Laboratory, Pasadena, California, August 15, 1973.

10. Berman, A.L., "Tracking Operations During the Pioneer 10 Encounter," The Deep Space Network Progress Report, 42-20, p. 190, Jet Propulsion Laboratory, Pasadena, California, April 15, 1974.

PIONEER PROJECT

BIBLIOGRAPHY

Berman, A.L., "Tracking Operations During the Pioneer 10 Encounter," The Deep Space Network Progress Report 42-20, p. 190, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1974.

Chao, C.C., Preston, R.A., and Nance, H.E., "Short Baseline QVLBI Doppler Demonstrations — Part II," The Deep Space Network Progress Report 42-20, p. 20, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1974.

Chao, C.C., Wong, S.K., and Lukely, A., "Short Baseline QVBLI Demonstrations — Part I," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XVIII, p. 47, Jet Propulsion Laboratory, Pasadena, Calif., December 15, 1975.

Fimmel, R.O., et al., Pioneer Odyssey — Encounter With a Giant, National Aeronautics and Space Administration SP-349, U.S. Government Printing Office, 1974.

Lesh, J.R., "Verification of Commands from the Transmitting Medium," The Deep Space Network Progress Report, Technical Report 42-20, p. 186, Jet Propulsion Laboratory, Pasadena, California, April 15, 1974.

Liu, A.S., "Range Measurements to Pioneer 10 Using the Digitally Controlled Oscillator," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XIX, p. 63, Jet Propulsion Laboratory, Pasadena, Calif., February 15, 1974.

Liu, A.S., "Three Topocentric Range Measurements to Pioneer 10 Near Jupiter Encounter and a Preliminary Estimate of an Earth Barycenter to Jupiter Barycenter Distance," The Deep Space Network Progress Report, Technical Report 42-21, p. 32, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1974.

Miller, R.B., "Pioneer 10 and 11 Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XV, p. 22, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1973.

Miller, R.B., "Pioneer 10 and 11 Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XVI, p. 15, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1973.

Miller, R.B., "Pioneer 10 and 11 Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XVII, p. 14, Jet Propulsion Laboratory, Pasadena, Calif., October 15, 1973.

Miller, R.B., "Pioneer 10 and 11 Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XVIII, p. 16, Jet Propulsion Laboratory, Pasadena, Calif., December 15, 1973.

Miller, R. B., "Pioneer 10 and 11 Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume XIX, p. 23, Jet Propulsion Laboratory, Pasadena, Calif., February 15, 1974.

Miller, R. B., Tracking and Data System Support for the Pioneer Project, Pioneers 6-9. Extended Missions: July 1, 1972-July 1, 1973, Technical Memorandum 33-426, Vol. XII, Jet Propulsion Laboratory, Pasadena, Calif., March 1, 1974.

O'Reilly, B. D., and Chao, C. C., "An Evaluation of QVLBI OD Analysis of Pioneer 10 Encounter Data in the Presence of Unmodeled Satellite Accelerations," The Deep Space Network Progress Report 42-22, p. 66, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1974.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project Pioneer VI, Prelaunch to End of Nominal Mission, Technical Memorandum 33-426, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., February 1, 1970.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer VII, Prelaunch to End of Nominal Mission, Technical Memorandum 33-426, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., April 15. 1970.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer VIII, Prelaunch through May 1968, Technical Memorandum 33-426, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1970.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer IX, Prelaunch through June 1969, Technical Memorandum 33-426, Vol. IV, Jet Propulsion Laboratory, Pasadena, Calif., November 15, 1970

Renzetti, N. A., Tracking and Data System Report for the Pioneer Project, Pioneer VI, Extended Mission: July 1, 1966-July 1, 1969, Technical Memorandum 33-426, Vol. V, Jet Propulsion Laboratory, Pasadena, Calif., February 1, 1971.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer VII, Extended Mission: February 24, 1967-July 1, 1968, Technical Memorandum 33-426, Vol. VI, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1971.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer VII, Extended Mission: February 24, 1967-July 1, 1968, Technical Memorandum 33-426, Vol. VII, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1971.

Renzetti, N. A., Tracking and Data System Support for the Pioneer Project, Pioneer VIII, Extended Mission: June 1, 1968-July 1, 1969, Technical Memorandum 33-426, Vol. VIII, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1971.

Renzetti, N. A., Tracking and Data System Report for the Pioneer Project, Pioneers VI-IX. Extended Missions: July 1, 1969-July 1, 1970, Technical Memorandum 33-426, Vol. IX, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1971.

Renzetti, N.A., Siegmeth, A.J., Tracking and Data System Support for the Pioneer Project, Pioneers 6-9. Extended Missions: July 1, 1971-July 1, 1972, Technical Memorandum 33-426, Volume XI, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1973.

Siegmeth, A.J., "Pioneer Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume II, p. 6, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1971.

Siegmeth, A.J., "Pioneer Mission Support," The Deep Space Network Progress Report, Technical Report 32-1526, Volume III, p. 7, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1971.

Siegmeth, A.J., Purdue, R.E., and Ryan, R.E., Tracking and Data System Support for the Pioneer Project, Pioneers 6-9. Extended Missions: July 1, 1970-July 1, 1971, Technical Memorandum 33-426, Vol. X, Jet Propulsion Laboratory, Pasadena, Calif., August 15, 1972.

Siegmeth, A.J., Purdue, R.E., and Ryan, R.E., Tracking and Data System Support for the Pioneer Project, Pioneer 10-Prelaunch Planning Through Second Trajectory Correction, December 4, 1969, to April 1, 1972, Technical Memorandum 33-584, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., April 1, 1973.

Wick, M.R., "DSN Programmed Oscillator," The Deep Space Network Progress Report 42-20, p. 167, Jet Propulsion Laboratory, Pasadena, California, April 15, 1974.

Wick, M.R., Operational Procedure -- Block III High Rate Doppler Receiver/Exciter Subsystem, JPL Specification OP509255A, August 15, 1973 (JPL Internal Document).

Bibliography

Anderson, J. D., Null, G. W., and Thornton, C. T., *The Evaluation of Certain Astronomical Constants from the Radio Tracking of Mariner II*, Technical Report 32-476, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Progr. Astronaut. Aeronaut.*, Vol. 14, 1964.

Anderson, J. D., *Determination of the Masses of the Moon and Venus and the Astronomical Unit from Radio Tracking Data of the Mariner II Spacecraft*, Technical Report 32-816, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1967.

Anderson, J. D., et al., "The Radius of Venus as Determined by Planetary Radar and Mariner V Radio Tracking Data," *J. Atmos. Sci.*, pp. 1171–1174, Sept. 25, 1968.

Anderson, J. D., and Hilt, D. E., "Improvement of Astronomical Constants and Ephemerides from Pioneer Radio Tracking Data," *AIAA J.*, Vol. 7, No. 6, pp. 1048–1054, June 1969.

Anderson, J. D., "Determination of Astrodynamic Constants and a Test of the General Relativistic Time Delay With S-Band Range and Doppler Data From Mariners 6 and 7," *Space Research*, Vol. XI, pp. 105–112, Akademie-Verlag, Berlin, 1971.

Barnum, P. W., et al., *Tracking and Data System Support for the Mariner Mars 1971 Mission: Orbit Insertion Through End of Primary Mission*, Technical Memorandum 33-523, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., May 15, 1973.

Barnum, P. W., and Renzetti, N. A., *Tracking and Data System Support for the Mariner Mars 1971 Mission: Extended Mission Operations*, Technical Memorandum 33-523, Vol. IV, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1973.

Bathker, D. A., *Radio-Frequency Performance of an 85-ft Ground Antenna: X-Band*, Technical Report 32-1300, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1968.

Bathker, D. A., *Radio Frequency Performance of a 210-ft Ground Antenna: X-Band*, Technical Report 32-1417, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1969.

Bathker, D. A., *Predicted and Measured Power Density Description of a Large Ground Microwave System*, Technical Memorandum 33-433, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

Baumert, L., et al., *Coding Theory and Its Applications to Communications Systems*, Technical Report 32-67, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 31, 1961.

Baumgartner, W. S., *High-Power CW Radar Transmitter*, Technical Report 32-656, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1964.

Berman, A. L., *Tracking System Data Analysis Report, Ranger VII Final Report*, Technical Report 32-719, Jet Propulsion Laboratory, Pasadena, Calif., June 1, 1965.

Biber, K. W., and Whittlesey, A. C., *Description and Analysis of 890-MHz Noise-Measuring Equipment*, Technical Report 32-898, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 31, 1966.

Brockman, M. H., and Posner, E. C., *Power Requirements for Deep-Space Telecommunication Links*, Technical Report 32-1395, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Spectrum*, Vol. 6, No. 3, pp. 95–99, Mar. 1969.

Bunce, R. C., *Unified S-Band Receiver-Exciter Subsystem*, Technical Report 32-809, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1968.

Butman, S., "A General Formulation of Linear Feedback Communication Systems with Solutions," *IEEE Trans. Inform. Theor.*, Vol. IT-15, No. 3, pp. 392–400, May 1969.

Butman, S., "Rate Distortion Over Band-Limited Feedback Channels," *IEEE Trans. Inform. Theor.*, Vol. IT-17, No. 1, pp. 110–112, Jan. 1971.

Butman, S., and Timor, U., "Interplex—An Efficient Multichannel PSK/PM Telemetry System", *IEEE Trans. Commun.*, Vol. COM-20, No. 3, pp. 415–419, June 1972.

Cain, D. L., and Hamilton, T. W., *Determination of Tracking Station Locations by Doppler and Range Measurements to an Earth Satellite*, Technical Report 32-534, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1, 1964.

Carey, C. N., and Sjogren, W. L., *Gravitational Inconsistency in the Lunar Theory: Confirmation by Radio Tracking*, Technical Report 32-1290, Pt. II, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Science*, Vol. 160, No. 3830, pp. 875–876, May 24, 1968.

Carpenter, R. L., *Study of Venus by CW Radar—1964 Results*, Technical Report 32-963, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Astron. J.*, Vol. 71, No. 2, pp. 142–152, Mar. 1966.

Chadwick, H. D., and Springett, J. C., "The Design of a Low Data Rate MSFK Communication System," *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 6, pp. 740–750, Dec. 1970.

Chaney, W. D., *Final Mariner II Tracking System Data Analysis Report*, Technical Report 32-727, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1965.

Charles, F. J., and Lindsey, W. C., *Some Analytical and Experimental Phase-Locked Loop Results for Low Signal-to-Noise Ratios*, Technical Report 32-1027, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Proc. IEEE*, Vol. 54, No. 9, pp. 1152–1166, Sept. 1966.

Clark, B. G., et al., "High Resolution Observations of Compact Radio Sources at 13 cm," *Astrophys. J.*, Vol. 161, pp. 803–809, Sept. 1970.

Clauss, R. C., et al., *Total System Noise Temperature: 15°K*, Technical Report 32-691, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 1964.

Clauss, R. C., *A 2388-Mc Two-Cavity Maser for Planetary Radar*, Technical Report 32-583, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Microwave J.*, Vol. 8, pp. 74–77, May 1965.

Clauss, R. C., *A Traveling Wave Maser for Deep Space Communication at 2295 and 2388 MHz*, Technical Report 32-1072, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1967.

Cohen, M. H., et al., "Compact Radio Source in the Nucleus of M87," *Astrophys. J.*, Vol. 158, No. 2, Pt. 2, pp. L83–L85, Nov. 1969.

Coyner, J. V., Jr., *Radial Rib Antenna Surface Deviation Analysis Program*, Technical Memorandum 33-518, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1971.

Curkendall, D. W., and McReynolds, S. R., "A Simplified Approach for Determining the Information Content of Radio Tracking Data," *J. Spacecraft Rockets*, Vol. 6, No. 5, pp. 520–525, May 1969.

Curkendall, D. W., and Stephenson, R. R., "Earthbased Tracking and Orbit Determination—Backbone of the Planetary Navigation System," *Astronaut. Aeronaut.*, Vol. 7, No. 5, pp. 30–36, May 1970.

Curkendall, D. W., "Planetary Navigation: The New Challenges," *Astronaut. Aeronaut.*, Vol. 7, No. 5, pp. 26–29, May 1970.

"The Deep Space Network—An Instrument for Radio Navigation for the Mariner Mission to Mars—1969," *Proceedings of the Second International Conference of STM and AERA*, Reidel Publishing Company, Holland, May 1969.

Description of the Deep Space Network Operational Capabilities as of January 1, 1966, Technical Memorandum 33-255, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1966.

Didday, R. L., and Lindsey, W. C., *Subcarrier Tracking Methods and Communication System Design*, Technical Report 32-1317, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-16, No. 4, pp. 541–550, Aug. 1968.

Downs, G. S., and Reichley, P. E., "Observations of Interstellar Scintillations of Pulsar Signals at 2388 MHz," *Astrophys. J.*, Vol. 163, No. 1, Pt. 2, pp. L11–L16, Jan. 1971.

Downs, G. S., et al., "Mars Radar Observation, A Preliminary Report," *Science*, Vol. 174, No. 4016, pp. 1324–1327, Dec. 24, 1971.

Easterling, M., *A Long-Range Precision Ranging System*, Technical Report 32-80, Jet Propulsion Laboratory, Pasadena, Calif., July 10, 1961.

Easterling, M., *Methods for Obtaining Velocity and Range Information from CW Radars*, Technical Report 32-657, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1964.

Easterling, M., and Goldstein, R., *The Effect of the Interplanetary Medium on S-Band Telecommunications*, Technical Report 32-825, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1965.

Efron, L., and Solloway, C. B., *Proceedings of the Conference on Scientific Applications of Radio and Radar Tracking in the Space Program*, Technical Report 32-1475, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1970.

Esposito, P. B., and Wong, S. K., "Geocentric Gravitational Constant Determined from Mariner 9 Radio Tracking Data," paper presented at the International Symposium on Earth Gravity Models (American Geophysical Union, NASA), St. Louis, Aug. 1972.

Fearey, J. P., and Renzetti, N. A., "Navigation Results on the Mariner Mars Mission to Mars 1969," International Navigation Conference, Hamburg, Oct. 1969.

Fjeldbo, G., Kliore, A. J., and Seidel, B. L., "Bistatic Radar Measurements of the Surface of Mars with Mariner 1969," *Icarus*, Vol. 16, No. 3, pp. 502–508, June 1972.

Fjeldbo, G., and Eshleman, V. R., "Radio Occultation Measurements and Interpretations," in *The Atmospheres of Venus and Mars*, p. 225, Gordon and Breach, Science Publishers, Inc., New York, N.Y., 1968.

Flanagan, F. M., et al., *Deep Space Network Support of the Manned Space Flight Network for Apollo: 1962–1968*, Technical Memorandum 33-452, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., July 1970.

Flanagan, F. M., et al., *Deep Space Network Support of the Manned Space Flight Network for Apollo: 1969–1970*, Technical Memorandum 33-452, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1971.

Fredricksen, H., *Error Correction for Deep Space Network Teletype Circuits*, Technical Report 32-1275, Jet Propulsion Laboratory, Pasadena, Calif., June 1, 1968.

Georgevic, R. M., *Mathematical Model of the Solar Radiation Force and Torques Acting on the Components of a Spacecraft*, Technical Memorandum 33-494, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1971.

Goldstein, R., Stevens, R., and Victor, W. K., *Radar Exploration of Venus: Goldstone Observatory Report for October–December 1962*, Technical Report 32-396, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 1, 1965.

Goldstein, R. M., *The Analysis of Uncooperative Radar Targets*, Technical Report 32-658, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1964.

Goldstein, R. M., et al., *The Superior Conjunction of Mariner IV*, Technical Report 32-1092, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 1, 1967.

Goldstein, R. M., "Radar Time-of-Flight Measurements to Venus," *Astron. J.*, Vol. 73, No. 9, Aug. 1968.

Goldstein, R. M., et al., "Preliminary Radar Results of Mars," *Radio Sci.*, Vol. 5, No. 2, pp. 475–478, Feb. 1970.

Goldstein, R. M., and Rumsey, H., "A Radar Snapshot of Venus," *Science*, Vol. 169, Sept. 1970.

Goldstein, R. M., "Radar Observations of Mercury," *Astron. J.*, Vol. 76, No. 10, pp. 1152–1154, Dec. 1971.

Golomb, S. W., "New Problems of Space Communications: Part I. Beware of the Tigers," *Astronautics*, Vol. 7, No. 6, p. 19, June 1962.

Golomb, S. W., "New Problems in Space Communications: Part 3," *Astronautics*, Vol. 7, No. 8, p. 26, Aug. 1962.

Golomb, S. W., "Ferreting Signals Out of Noise," *Int. Sci. Technol.*, No. 22, pp. 72–82 and 120, Oct. 1963.

Gordon, H. J., et al., *The Mariner 6 and 7 Flight Paths and Their Determination From Tracking Data*, Technical Memorandum 33-469, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1970.

Gottlieb, P., et al., "Lunar Gravity over Large Craters from Apollo 12 Tracking Data," *Science*, Vol. 168, No. 3930, pp. 477–479, Apr. 1970.

Gray, R. M., and Tausworthe, R. C., "Frequency-Counted Measurements, and Phase Locking to Noise Oscillators," *IEEE Trans. Commun. Technol.*, Vol. COM-19, No. 1, pp. 21–30, Feb. 1971.

Gubbay, J., et al., "Variations of Small Quasar Components at 2,300 MHz," *Nature*, Vol. 224, No. 5224, pp. 1094–1095, Dec. 1969.

Gulkis, S., and Gary, B., "Circular Polarization and Total-Flux Measurements of Jupiter at 13.1 cm Wavelength," *Astron. J.*, Vol. 76, No. 1, pp. 12–16, Feb. 1971.

Hall, J. R., *Tracking and Data System Support for Lunar Orbiter*, Technical Memorandum 33-450, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 1970.

Hamilton, T. W., et al., *The Ranger IV Flight Path and Its Determination From Tracking Data*, Technical Report 32-345, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1962.

Hartop, R. W., *Power Loss Between Arbitrarily Polarized Antennas*, Technical Report 32-457, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1964.

Havens, W. F., et al., *Scan Pointing Calibration for the Mariner Mars 1971 Spacecraft*, Technical Memorandum 33-556, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1, 1972.

Heftman, K., and Renzetti, N. A., "Data Return Capabilities of the Deep Space Network in the 1970's," AIAA Paper 67-648, *Proceedings of the AIAA Space Program Issues of the 70's Meeting*, Aug. 1967.

Higa, W. H., *Low-Level Microwave Mixing in Ruby*, Technical Report 32-1016, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Proc. IEEE*, Vol. 54, No. 10, p. 1453, Oct. 1966.

Higa, W. H., "Time Synchronization via Lunar Radar," *Proc. IEEE*, Vol. 60, No. 5, pp. 552–557, May 1972.

Holmes, J. K., "On a Solution to the Second-Order Phase-Locked Loop," *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 2, pp. 119–126, Apr. 1970.

Holmes, J. K., "First Slip Times Versus Static Phase Error Offset for the First and Passive Second-Order Phase-Locked Loop," *IEEE Trans. Commun. Technol.*, Vol. COM-19, No. 2, pp. 234–235, Apr. 1971.

Holmes, J. K., and Tegnelia, C. R., *Digital Command System Second-Order Subcarrier Tracking Performance*, Technical Report 32-1540, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1971.

Holmes, J. K., "Performance of a First Order Transition Sampling Digital Phase-Locked Loop Using Random-Walk Models," *IEEE Trans. Commun.*, Vol. COM-20, No. 2, pp. 119–131, Apr. 1972.

Hurd, W. J., and Anderson, T. O., *Digital Transition Tracking Symbol Synchronizer for Low SNR Coded Systems*, Technical Report 32-1488, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 2, pp. 141–147, Apr. 1970.

Jaffe, R., and Rechtin, E., *Design and Performance of Phase-Lock Loops Capable of Near-Optimum Performance over a Wide Range of Input Signal and Noise Levels*, Progress Report 20-243, Jet Propulsion Laboratory, Pasadena, Calif., Dec.

1, 1954; also available in *IRE Trans. Inform. Theory*, No. 1, pp. 66–67, Mar. 1955.

Jordan, J. F., "Orbit Determination for Powered Flight Space Vehicles on Deep Space Missions," *J. Spacecraft Rockets*, Vol. 6, No. 5, pp. 545–550, May 1969.

Kellerman, K. I., et al., "High Resolution Observations of Compact Radio Sources at 13 Centimeters," *Astrophys. J.*, Vol. 161, No. 3, pp. 803–809, Sept. 1970.

Kelly, A. J., *Microwave Probe for Plasma Plumes*, Technical Report 32-625, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1965.

Kliore, A., Cain, D. L., and Hamilton, T. W., *Determination of Some Physical Properties of the Atmosphere of Mars from Changes in the Doppler Signal of a Spacecraft on an Earth-Occultation Trajectory*, Technical Report 32-674, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1964.

Kliore, A., and Tito, D. A., *Radio Occultation Investigations of the Atmosphere of Mars*, Technical Report 32-1157, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *J. Spacecraft Rockets*, Vol. 4, No. 5, pp. 578–582, May 1967.

Kliore, A., "Radio Occultation Measurements of the Atmospheres of Mars and Venus," in *The Atmospheres of Venus and Mars*, edited by J. C. Brandt and M. B. McElrow, p. 205, Gordon and Breach Science Publishers, Inc., New York, N.Y., 1968.

Kliore, A. J., et al., "Summary of Mariner 6 and 7 Radio Occultation Results on the Atmosphere of Mars," *Space Research*, Vol. XI, pp. 165–175, Akademie-Verlag, Berlin, 1971.

Kliore, A. J., et al., "Mariner 9 S-Band Martian Occultation Experiment: Initial Results on the Atmosphere and Topography of Mars," *Science*, Vol. 175, No. 4019, pp. 313–317, Jan. 1972.

Labrum, R. G., et al., *The Surveyor V, VI, and VII Flight Paths and Their Determination from Tracking Data*, Technical Report 32-1302, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1968.

Laeser, R. P., et al., *Tracking and Data System Support for the Mariner Mars 1971 Mission: Prelaunch Phase Through First Trajectory Correction Maneuver*, Technical Memorandum 33-523, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 15, 1972.

Layland, J. W., "On Optimal Signals for Phase-Locked Loops," *IEEE Trans. Commun. Technol.*, Vol. COM-17, No. 5, pp. 526–531, Oct. 1969.

Layland, J. W., and Lushbaugh, W. A., "A Flexible High-Speed Sequential Decoder for Deep Space Channels," *IEEE Trans. Commun. Technol.*, Vol. COM-19 No. 5, pp. 813–820, Oct. 1971.

Leavitt, R. K., *The Least-Squares Process of MEDIA for Computing DRVID Calibration Polynomials*, Technical Memorandum 33-542, Jet Propulsion Laboratory, Pasadena, Calif., May 15, 1972.

Levy, G. S., Otoshi, T. Y., and Seidel, B. L., *Ground Instrumentation for Mariner IV Occultation Experiment*, Technical Report 32-984, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1966.

Levy, G. S., et al., *Lunar Range Radiation Patterns of a 210-Foot Antenna at S-Band*, Technical Report 32-1079, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Antennas Propagation*, Vol. AP-15, No. 2, pp. 311–313, Mar. 1967.

Levy, G. S., et al., *The Ultra Cone: An Ultra-Low-Noise Space Communication Ground Radio-Frequency System*, Technical Report 32-1340, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Microwave Theor. Tech.*, Vol. MTT-16, No. 9, pp. 596–602, Sept. 1968.

Levy, G. S., et al., "Pioneer 6: Measurement of Transient Faraday Rotation Phenomena Observed During Solar Occultation," *Science*, Vol. 166, No. 3905, pp. 596–598, Oct. 1969.

Lieske, J. H., and Null, G. W., "Icarus and the Determination of Astronomical Constants," *Astron. J.*, Vol. 74, No. 2, Mar. 1969.

Lieske, J. H., et al., "Simultaneous Solution for the Masses of the Principal Planets from Analysis of Optical Radar and Radio Tracking Data," *Celest. Mech.*, Vol. 4, No. 2, pp. 233–245, Oct. 1971.

Lindsey, W. C., *Optimum and Suboptimum Frequency Demodulation*, Technical Report 32-637, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1964.

Lindsey, W. C., *Improvements to be Realized Through the Use of Block-Coded Communication Systems*, Technical Report 32-947, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Aerosp. Electron. Syst.*, Vol. AES-2, No. 3, pp. 364–366, May 1966.

Lindsey, W. C., *Phase-Shift-Keyed Signal Detection with Noisy Reference Signals*, Technical Report 32-968, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Aerosp. Electron. Syst.*, Vol. AES-2, No. 4, pp. 393–401, July 1966.

Lindsey, W. C., *A Theory for the Design of One-Way and Two-Way Phase-Coherent Communication Systems: Phase-Coherent Tracking Systems*, Technical Report 32-986, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1969.

Lindsey, W. C., *Optimal Design of One-Way and Two-Way Coherent Communication Links*, Technical Report 32-988, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-14, No. 4, pp. 418–431, Aug. 1966.

Lindsey, W. C., and Charles, F. J., *A Model Distribution for the Phase Error in Second-Order Phase-Locked Loops*, Technical Report 32-1017, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-14, No. 10, pp. 662–664, Oct. 1966.

Lindsey, W. C., *Performance of Phase-Coherent Receivers Preceded by Bandpass Limiters*, Technical Report 32-1162, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1967.

Lindsey, W. C., "Block Coding for Space Communications," *IEEE Trans. Commun. Technol.*, Vol. COM-17, No. 2, pp. 217–225, Apr. 1969.

Lindsey, W. C., *Block-Coded Communications*, Technical Report 32-1380, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1969.

Lindsey, W. C., *Nonlinear Analysis of Generalized Tracking Systems*, Technical Report 32-1453, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Proc. IEEE*, Vol. 57, No. 10, pp. 1705–1722, Oct. 1969.

Lindsey, W. C., and Simon, M. K., "The Effect of Loop Stress on the Performance of Phase-Coherent Communication Systems", *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 5, pp. 569–588, Oct. 1970.

Lindsey, W. C., and Simon, M. K., "Carrier Synchronization and Detection of Polyphase Signals," *IEEE Trans. Commun.*, Vol. COM-20, No. 3, pp. 441–454, June 1972.

Lindsey, W. C., *Synchronization Systems in Communication and Control*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1972.

Lindsey, W. C., and Simon, M. K., *Telecommunication Systems Engineering*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1973.

Lorell, J., Anderson, J. D., and Sjogren, W. L., *Characteristics and Format of the Tracking Data to Be Obtained by the NASA Deep Space Instrumentation Facility for Lunar Orbiter*, Technical Memorandum 33-230, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1965.

Lorell, J., Sjogren, W. L., and Boggs, D., *Compressed Tracking Data Used for First Iteration in Selenodesy Experiment, Lunar Orbiters I and II*, Technical Memorandum 33-343, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1967.

Lorell, J., and Sjogren, W. L., *Lunar Orbiter Data Analysis*, Technical Report 32-1220, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 15, 1967.

Lorell, J., *Lunar Orbiter Gravity Analysis*, Technical Report 32-1387, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1969.

Lorell, J., et al., "Icarus: Celestial Mechanics Experiment for Mariner," *Int. J. Sol. Sys.*, Vol. 12, Jan. 1970.

Lorell, J., and Laing, P. A., *Compilation of Lunar Orbiter Tracking Data Used for Long-Term Selenodesy*, Technical Memorandum 33-419, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1, 1970.

Ludwig, A. C., et al., *Gain Calibration of a Horn Antenna Using Pattern Integration*, Technical Report 32-1572, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1972.

Madrid, G. A., et al., *Tracking System Analytic Calibration Activities for the Mariner Mars 1971 Mission*, Technical Report 32-1587, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 1, 1974.

Martin, D. P., *A Combined Radar–Radiometer With Variable Polarization*, Technical Memorandum 33-570, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1972.

McEliece, R. J., *Optimal Communications Nets*, Technical Report 32-697, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1965.

McNeal, C. E., *Ranger V Tracking Systems Data Analysis Final Report*, Technical Report 32-702, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1965.

Melbourne, W. G., et al., *Constants and Related Information for Astrodynamical Calculations*, Technical Report 32-1306, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1968.

Melbourne, W. G., "Planetary Ephemerides," *Astronaut. Aeronaut.*, Vol. 7, No. 5, pp. 38–43, May 1970.

Merrick, W. D., et al., *Deep Space Communications*, Technical Release 34-10, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 29, 1960; also available in *IRE Trans. Mil. Electron.*, Vol. MIL-4, No. 2-3, pp. 158–163, April–June 1960.

Miller, L., et al., *The Atlas-Centaur VI Flight Path and Its Determination from Tracking Data*, Technical Report 32-911, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1966.

Moyer, T. D., *Mathematical Formulation of the Double-Precision Orbit Determination Program (DPODP)*, Technical Report 32-1527, Jet Propulsion Laboratory, Pasadena, Calif., May 17, 1971.

Muhleman, D. O., *Relationship Between the System of Astronomical Constants and the Radar Determinations of the Astronomical Unit*, Technical Report 32-477, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 15, 1964.

Muhleman, D. O., Goldstein, R., and Carpenter, R., *A Review of Radar Astronomy—Parts I, II*, Technical Report 32-824, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 30, 1966, reprinted from *IEEE Spectrum*, Oct. and Nov. 1965.

Muhleman, D. O., et al., *JPL Radar Range and Doppler Observations of Venus, 1961–1966*, Technical Report 32-1123, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1968.

Mulhall, B. D., et al., *Tracking System Analytic Calibration Activities for the Mariner Mars 1969 Mission*, Technical Report 32-1499, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 15, 1970.

Mulholland, J. D., and Sjogren, W. L., *Lunar Orbiter Ranging Data*, Technical Report 32-1087, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Science*, Vol. 155, No. 3758, pp. 74–76, Jan. 6, 1967.

Mulholland, J. D., *Proceedings of the Symposium on Observation, Analysis and Space Research Applications of the Lunar Motion*, Technical Report 32-1386, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 1969.

Muller, P. M., and Sjogren, W. L., *Consistency of Lunar Orbiter Residuals With Trajectory and Local Gravity Effects*, Technical Report 32-1307, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1968.

Muller, P. M., and Sjogren, W. L., *Mascons: Lunar Mass Concentrations*, Technical Report 32-1339, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Science*, Vol. 161, No. 3842, pp. 680–684, Aug. 16, 1968.

Newburn, R. L., Jr., et al., *Earth-Based Research on the Outer Planets During the Period 1970–1985*, Technical Report 32-1456, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 15, 1970.

Null, G. W., et al., *Mariner IV Flight Path and Its Determination From Tracking Data*, Technical Report 32-1108, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1, 1967.

O'Neil, W. J., et al., *The Surveyor III and Surveyor IV Flight Paths and Their Determination From Tracking Data*, Technical Report 32-1292, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1968.

O'Neil, W. J., et al., *Mariner 9 Navigation*, Technical Report 32-1586, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 13, 1973.

Otoshi, T. Y., *The Effect of Mismatched Components on Microwave Noise-Temperature Calibrations*, Technical Report 32-1345, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Microwave Theor. Tech.*, Vol. MTT-16, No. 9, pp. 675–686, Sept. 1968.

Otoshi, T. Y., Stelzried, C. T., and Yates, B. C., "Comparisons of Waveguide Losses Calibrated by the DC Potentiometer, AC Ratio Transformer, and Reflectometer Techniques," *IEEE Trans. Microwave Theor. Tech.*, Vol. MTT-18, No. 7, pp. 406–409, July 1970.

Otoshi, T. Y., and Stelzried, C. T., "A Precision Compact Rotary Vane Attenuator," *IEEE Trans. Micro. Theor. Technique*, Vol. MTT-19, No. 11, pp. 843–854, Nov. 1971.

Pease, G. E., et al., *The Mariner V Flight Path and Its Determination From Tracking Data*, Technical Report 32-1363, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1969.

Posner, E. C., *Properties of Error-Correcting Codes at Low Signal-to-Noise Ratios*, Technical Report 32-602, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1964.

Potter, P. D., *The Design of a Very High Power, Very Low Noise Cassegrain Feed System for a Planetary Radar*, Technical Report 32-653, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 24, 1964.

Potter, P. D., Merrick, W. D., and Ludwig, A. C., *Large Antenna Apertures and Arrays for Deep Space Communications*, Technical Report 32-848, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 1, 1965.

Potter, P. D., *A Computer Program for Machine Design of Cassegrain Feed Systems*, Technical Report 32-1202, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1967.

Potter, P. D., et al., *A Study of Weather-Dependent Data Links for Deep Space Applications*, Technical Report 32-1392, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 15, 1969.

Rechtin, E., "Communication Techniques for Space Exploration," *IRE Trans. Space Electron. Telem.*, Vol. SET-5, No. 3, pp. 95–98, Sept. 1959.

Rechtin, E., Stevens, R., and Victor, W. K., *Data Transmission and Communications*, Technical Release 34-55, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 30, 1960.

Rechtin, E., *Space Communications*, Technical Release 34-68, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1960.

Rechtin, E., Rule, B., and Stevens, R., *Large Ground Antennas*, Technical Report 32-213, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 20, 1962.

Rechtin, E., *Lunar Communications*, Technical Memorandum 33-133, Jet Propulsion Laboratory, Pasadena, Calif., June 28, 1963.

Rechtin, E., "Surprises on Venus," *Int. Sci. Technol.*, No. 20, pp. 13–14, Aug. 1963.

Renzetti, N. A., et al., "Radio Tracking Techniques and Performance of the U.S. Deep Space Instrumentation Facility," *Space Research II, Proceedings of the Second International Space Science Symposium*, Florence, Italy, April 1961, North Holland Publishing Company, Amsterdam.

Renzetti, N. A., and Ostermier, B. J., *Communications with Lunar Probes*, Technical Report 32-148, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 23, 1961.

Renzetti, N. A., *Tracking and Data Acquisition for Ranger Missions I–V*, Technical Memorandum 33-174, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1964.

Renzetti, N. A., *Tracking and Data Acquisition for Ranger Missions VI–IX*, Technical Memorandum 33-275, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1966.

Renzetti, N. A., *Tracking and Data Acquisition Support for the Mariner Venus 1962 Mission*, Technical Memorandum 33-212, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1965.

Renzetti, N. A., *Tracking and Data Acquisition Report, Mariner Mars 1964 Mission: Near-Earth Trajectory Phase*, Technical Memorandum 33-239, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 1, 1965.

Renzetti, N. A., *Tracking and Data Acquisition Report, Mariner Mars 1964 Mission: Cruise to Post-Encounter Phase*, Technical Memorandum 33-239, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1967.

Renzetti, N. A., *Deep Space Network Support, Atlas/Centaur Missions 1–9*, Technical Memorandum 33-347, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1967.

Renzetti, N. A., "Tracking and Data Acquisition System for Mariner Missions," *Proceedings of the Seventh International Symposium on Space Technology and Science*, Tokyo, 1967.

Renzetti, N. A., *Tracking and Data Acquisition Report, Mariner Mars 1964 Mission: Extended Mission*, Technical Memorandum 33-239, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1968.

Renzetti, N. A., and Fearey, J. P., "The Deep Space Network: An Instrument for the Radio Navigation for the Mariner Mission to Mars 1969," IInd International Conference on Space Engineering, Venice, Italy, D. Reidel Publishing Co., Dordrecht, Holland, May 1969.

Renzetti, N. A., *Tracking and Data System Support for Surveyor: Missions I and II*, Technical Memorandum 33-301, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1969.

Renzetti, N. A., *Tracking and Data System Support for Surveyor: Missions III and IV*, Technical Memorandum 33-301, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for Surveyor: Mission V*, Technical Memorandum 33-301, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for Surveyor: Mission VI*, Technical Memorandum 33-301, Vol. IV, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for Surveyor: Mission VII*, Technical Memorandum 33-301, Vol. V, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for the Mariner Venus 67 Mission: Planning Phase Through Midcourse Maneuver*, Technical Memorandum 33-385, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for the Mariner Venus 67 Mission: Midcourse Maneuver Through End of Mission*, Technical Memorandum 33-385, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1969.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VI. Prelaunch to End of Nominal Mission*, Technical Memorandum 33-426, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1, 1970.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VII. Prelaunch to End of Nominal Mission*, Technical Memorandum 33-426, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1970.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VIII. Prelaunch Through May 1968*, Technical Memorandum 33-426, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1970.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer IX. Prelaunch Through June 1969*, Technical Memorandum 33-426, Vol. IV, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 15, 1970.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VI. Extended Mission: July 1, 1966–July 1, 1969*, Technical Memorandum 33-426, Vol. V, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 1, 1971.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VII. Extended Mission: February 24, 1967–July 1, 1968*, Technical Memorandum 33-426, Vol. VI, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VII. Extended Mission: July 1, 1968–July 1, 1969*, Technical Memorandum 33-426, Vol. VII, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneer VIII. Extended Mission: June 1, 1968–July 1, 1969*, Technical Memorandum 33-426, Vol. VIII, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1971.

Renzetti, N. A., *Tracking and Data System Support for the Pioneer Project: Pioneers VI–IX. Extended Missions: July 1, 1969–July 1, 1970*, Technical Memorandum 33-426, Vol. IX, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1971.

Renzetti, N. A., and Siegmeth, A. J., *Tracking and Data System Support for the Pioneer Project: Pioneers 6–9. Extended Missions: July 1, 1971–July 1, 1972*, Technical Memorandum 33-426, Vol. XI, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1973.

Renzetti, N. A., et al., *Tracking and Data System Support for the Mariner Mars 1969 Mission: Planning Phase Through Midcourse Maneuver*, Technical Memorandum 33-474, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., May 15, 1971.

Renzetti, N. A., et al., *Tracking and Data System Support for the Mariner Mars 1969 Mission: Midcourse Maneuver Through End of Nominal Mission*, Technical Memorandum 33-474, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1971.

Renzetti, N. A., Linnes, K. W., and Taylor, T. M., *Tracking and Data System Support for the Mariner Mars 1969 Mission: Extended Operations Mission*, Technical Memorandum 33-474, Vol. III, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1971.

Renzetti, N. A., *A History of the Deep Space Network: From Inception to January 1, 1969*, Technical Report 32-1533, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 1, 1971.

Renzetti, N. A., "Radio Communications at Planetary Distances," paper presented at the International Convention on Radio Communication, Rome and Bologna, Italy, Mar. 1974.

Richter, H. L., Rechtin, E., and Walter, W. K., *National Ground-Based Surveillance Complex (U)*, Publication 146, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 16, 1959 (Confidential).

Rusch, W. V. T., *Phase Error and Associated Cross-Polarization Effects in Cassegrainian-Fed Microwave Antennas*, Technical Report 32-610, Jet Propulsion Laboratory, Pasadena, Calif., May 30, 1965.

Rusch, W. V. T., and Stelzried, C. T., *Observations of the Lunar Eclipse of December 19, 1964, at a Wavelength of 3.3 MM*, Technical Report 32-1097, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *Astrophys. J.*, Vol. 148, No. 1, pp. 255–259, Apr. 1967.

Rusch, W. V. T., *Applications of Two-Dimensional Integral-Equation Theory to Reflector-Antenna Analysis*, Technical Memorandum 33-478, Jet Propulsion Laboratory, Pasadena, Calif., May 1, 1971.

Sanger, D. K., *Digital Demodulation with Data Subcarrier Tracking*, Technical Report 32-1314, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1, 1968.

Siegmeth, A. J., Purdue, R. E., and Ryan, R. E., *Tracking and Data System Support for the Pioneer Project: Pioneers 6–9. Extended Missions: July 1, 1970–July 1, 1971*, Technical Memorandum 33-426, Vol. X, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1972.

Siegmeth, A. J., et al., *Tracking and Data System Support for the Pioneer Project: Pioneer 10—Prelaunch Planning Through Second Trajectory Correction December 4, 1969 to April 1, 1972*, Technical Memorandum 33-584, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 1, 1973.

Simon, M. K., "Nonlinear Analysis of an Absolute Value Type of an Early-Late Gate Bit Synchronizer," *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 5, pp. 589–596, Oct. 1970.

Simon, M. K., "Optimization of the Performance of a Digital-Data-Transition Tracking Loop," *IEEE Trans. Commun. Technol.*, Vol. COM-18, No. 5, pp. 686–689, Oct. 1970.

Simon, M. K., and Lindsey, W. C., "Data-Aided Carrier Tracking Loops," *IEEE Trans. Commun. Technol.*, Vol. COM-19, No. 2, pp. 157–168, Apr. 1971.

Simon, M. K., "On the Selection of an Optimum Design Point for Phase-Coherent Receivers Employing Bandpass Limiters," *IEEE Trans. Commun.*, Vol. COM-20, No. 2, pp. 210–214, Apr. 1972.

Simon, M. K., "On the Selection of a Sampling Filter Bandwidth for a Digital Data Detector," *IEEE Trans. Commun.*, Vol. COM-20, No. 3, pp. 438–441, June 1972.

Sjogren, W. L., et al., *The Ranger V Flight Path and Its Determination From Tracking Data*, Technical Report 32-562, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 6, 1963.

Sjogren, W. L., et al., *The Ranger VI Flight Path and Its Determination From Tracking Data*, Technical Report 32-605, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1964.

Sjogren, W. L., *The Ranger III Flight Path and Its Determination From Tracking Data*, Technical Report 32-563, Jet Propulsion Laboratory, Pasadena, Calif., Sept. 15, 1965.

Sjogren, W. L., et al., *Physical Constants as Determined From Radio Tracking of the Ranger Lunar Probes*, Technical Report 32-1057, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 30, 1966.

Sjogren, W. L., *Proceedings of the JPL Seminar on Uncertainties in the Lunar Ephemeris*, Technical Report 32-1247, Jet Propulsion Laboratory, Pasadena, Calif., May 1 1968.

Sjogren, W. L., "Lunar Gravity Estimate: Independent Confirmation," *J. Geophys. Res.*, Vol. 76, No. 29, Oct. 10, 1971.

Sjogren, W. L., et al., "Lunar Gravity via Apollo 14 Doppler Radio Tracking," *Science*, Vol. 175, No. 4018, pp. 165–168, Jan. 14, 1972.

Slobin, S. D., "Beam Switching Cassegrain Feed System and Its Applications to Microwave and Millimeterwave Radioastronomical Observations," *Rev. Sci. Instr.*, Vol. 41, No. 3, pp. 439–443, Mar. 1970.

Spier, G. W., *Design and Implementation of Models for the Double Precision Trajectory Program (DPTRAJ)*, Technical Memorandum 33-451, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1971.

Springett, J. C., and Simon, M. K., "An Analysis of the Phase Coherent-Incoherent Output of the Bandpass Limiter," *IEEE Trans. Commun. Technol.*, Vol. COM-19, No. 1, pp. 42–49, Feb. 1971.

Stelzried, C. T., *Post-Amplifier Noise Temperature Contribution in a Low-Noise Receiving System*, Technical Report 32-446, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 1964.

Stelzried, C. T., Reid, M. S., and Petty, S. M., *A Precision DC-Potentiometer Microwave Insertion-Loss Test Set*, Technical Report 32-887, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 15, 1966.

Stelzried, C. T., Reid, M. S., and Nixon, D., *Precision Power Measurements of Spacecraft CW Signal With Microwave Noise Standards*, Technical Report 32-1066, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1968.

Stelzried, C. T., and Reid, M. S., *Precision Power Measurements of Spacecraft CW Signal Level With Microwave Noise Standards*, Technical Report 32-1070, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Instrum. Measurement*, Vol. IM-15, No. 4, pp. 318–324, Dec. 1966.

Stelzried, C. T., and Rusch, W. V. T., *Improved Determination of Atmospheric Opacity From Radio Astronomy Measurements*, Technical Report 32-1115, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *J. Geophys. Res.*, Vol. 72, No. 9, pp. 2445–2447, May 1, 1967.

Stelzried, C. T., and Otoshi, T. Y., "Radiometric Evaluation of Antenna-Feed Component Losses," *IEEE Trans. Instrumen. Measurement*, Vol. IM-18, No. 3, pp. 172–183, Sept. 1969.

Stelzried, C. T., "Precision Microwave Waveguide Loss Calibrations," *IEEE Trans. Instrum. Measurement*, Vol. IM-19, No. 1, pp. 23–25, Feb. 1970.

Stelzried, C. T., *A Faraday Rotation Measurement of a 13-cm Signal in the Solar Corona*, Technical Report 32-1401, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1970.

Stelzried, C. T., et al., "The Quasi-Stationary Coronal Magnetic Field and Electron Density as Determined From a Faraday Rotation Experiment," *Sol. Phys.*, Vol. 14, No. 2, pp. 440–456, Oct. 1970.

Stelzried, C. T., "Operating Noise-Temperature Calibrations of Low-Noise Receiving Systems," *Microwave J.*, Vol. 14, No. 6, pp. 41–46, 48, June 1971.

Stelzried, C. T., et al., "Transformation of Received Signal Polarization Angle to the Plane of the Ecliptic," *J. Space. Rock.*, Vol. 9, No. 2, pp. 69–70, Feb. 1972.

System Capabilities and Development Schedule of the Deep Space Instrumentation Facility 1963–1967, Technical Memorandum 33-83, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 2, 1962.

Tardani, P. A., *Madrid Site Selection Report*, Technical Memorandum 33-149, Jet Propulsion Laboratory, Pasadena, Calif., July 17, 1963.

Tausworthe, R. C., *A Precision Planetary Range-Tracking Radar*, Technical Report 32-779, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Space Electron. Telem.*, Vol. SET-11, No. 2, pp. 78–85, June 1965.

Tausworthe, R. C., *Theory and Practical Design of Phase-Locked Receivers*, Technical Report 32-819, Vol. I, Jet Propulsion Laboratory, Pasadena, Calif., Feb. 15, 1966.

Tausworthe, R., *Cycle Slipping in Phase-Locked Loops*, Technical Report 32-1127, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-15, No. 3, pp. 417–421, June 1967.

Tausworthe, R. C., Easterling, M. F., and Spear, A. J., *A High-Rate Telemetry System for the Mariner Mars 1969 Mission*, Technical Report 32-1354, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 1, 1969.

Tausworthe, R. C., *DSS Subsystem Implementation by Time-Shared Computer*, Technical Memorandum 33-420, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 1, 1969.

Tausworthe, R. C., "Convergence of Oscillator Spectral Estimators for Counted-Frequency Measurements," *IEEE Trans. Commun.*, Vol. COM-20, No. 2, pp. 213–217, Apr. 1972.

Tausworthe, R. C., "Simplified Formula for Mean-Slip Time of Phase-Locked Loops With Steady-State Phase Error," *IEEE Trans. Commun.*, Vol. COM-20, No. 3, pp. 331–337, June 1972.

Telecommunications Systems Design Techniques Handbook, Technical Memorandum 33-571, edited by R. E. Edelson, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1972.

Textor, G. P., Kelly, L. B., and Kelly, M., *Tracking and Data System Support for the Mariner Mars 1971 Mission: First Trajectory Correction Maneuver Through Orbit Insertion*, Technical Memorandum 33-523, Vol. II, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1972.

Thornton, J. H., Jr., *The Surveyor I and Surveyor II Flight Paths and Their Determination From Tracking Data*, Technical Report 32-1285, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1, 1968.

Timor, U., "Equivalence of Time-Multiplexed and Frequency-Multiplexed Signals in Digital Communications," *IEEE Trans. Commun.*, Vol. COM-20, No. 3, pp. 435–438, June 1972.

Titsworth, R. C., and Welch, L. R., *Power Spectra of Signals Modulated by Random and Pseudorandom Sequences*, Technical Report 32-140, Jet Propulsion Laboratory, Pasadena, Calif., Oct. 10, 1961.

Titsworth, R. C., *The Algebra of Periodic Sequences*, Technical Report 32-381, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 7, 1963.

Titsworth, R. C., *Correlation Properties of Cyclic Sequences*, Technical Report 32-388, Jet Propulsion Laboratory, Pasadena, Calif., July 1, 1963.

Titsworth, R. C., *Optimal Ranging Codes*, Technical Report 32-411, Jet Propulsion Laboratory, Pasadena, Calif., Apr. 15, 1963.

Titsworth, R. C., *Equivalence Classes of Periodic Sequences*, Technical Report 32-568, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1964, reprinted from *Ill. J. Math.*, Vol. 8, No. 2, June 1964.

Titsworth, R. C., *The Role of Pseudorandom Codes in Communications*, Technical Memorandum 33-185, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 3, 1964.

"Tracking and Data Acquisition System for Mariner Missions," *Proceedings of the Seventh International Symposium on Space Technology and Science*, Tokyo, May 1967.

Vegos, C. J., et al., *The Ranger IX Flight Path and Its Determination From Tracking Data*, Technical Report 32-767, Jet Propulsion Laboratory, Pasadena, Calif., Nov. 1, 1968.

Victor, W. K., Stevens, R., and Golomb, S. W., *Radar Exploration of Venus: Goldstone Observatory Report for March-May 1961*, Technical Report 32-132, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 1, 1961.

Victor, W. K., Titsworth, R. C., and Rechtin, E., *Telecommunication Aspects of a Manned Mars Mission*, Technical Report 32-501, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 20, 1963.

Viterbi, A. J., *Acquisition Range and Tracking Behavior of Phase-Locked Loops*, External Publication 673, Jet Propulsion Laboratory, Pasadena, Calif., July 14, 1959.

Viterbi, A. J., *On Coded Phase-Coherent Communications*, Technical Report 32-25, Jet Propulsion Laboratory, Pasadena, Calif., Aug. 15, 1960.

Viterbi, A. J., *Classification and Evaluation of Coherent Synchronous Sampled-Data Telemetry Systems*, Technical Report 32-123, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1961.

Viterbi, A. J., *Phase-Locked Loop Dynamics in the Presence of Noise by Fokker-Planck Techniques*, Technical Report 32-427, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 29, 1963; also reprinted in *IEEE Proc.*, Vol. 51, No. 12, pp. 1737–1753, Dec. 1963.

Viterbi, A. J., *Orthogonal Tree Codes for Communication in the Presence of White Gaussian Noise*, Technical Report 32-1120, Jet Propulsion Laboratory, Pasadena, Calif., reprinted from *IEEE Trans. Commun. Technol.*, Vol. COM-15, No. 2, pp. 238–242, Apr. 1967.

Winn, F. B., "Selenographic Location of Surveyor VI," in *Surveyor VI Mission Report: Part II. Science Results*, Technical Report 32-1262, Jet Propulsion Laboratory, Pasadena, Calif., Jan. 10, 1968.

Winn, F. B., "Post Landing Tracking Data Analysis," in *Surveyor VII Mission Report: Part II. Science Results*, Technical Report 32-1264, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 15, 1968.

Winn, F. B., "Surveyor Post-Touchdown Analysis of Tracking Data," in *Surveyor Project Final Report: Part II. Science Results*, Technical Report 32-1265, Jet Propulsion Laboratory, Pasadena, Calif., June 15, 1968.

Winn, F. B., *Surveyor Posttouchdown Analyses of Tracking Data*, NASA SP-184, National Aeronautics and Space Administration, Washington, D.C., p. 369.

Wollenhaupt, W. R., *Tracking System Data Analysis Report, Ranger 4 Final Report*, Technical Report 32-523, Jet Propulsion Laboratory, Pasadena, Calif., Mar. 1, 1964.

Wollenhaupt, W. R., et al., *The Ranger VII Flight Path and Its Determination From Tracking Data*, Technical Report 32-694, Jet Propulsion Laboratory, Pasadena, Calif., Dec. 15, 1964.

APPENDIX
PASS CHRONOLOGY
FOR THE
PIONEER 10 JUPITER ENCOUNTER PERIOD

Table A-1. Pioneer 10 Pass Chronology, November 1973

GENERAL									
DSS	43	63	14	43	63	12	43	63	12
PASS	0610	0611	0611	0611	0612	0612	0612	0613	0613
DOY	305	305	305	306	306	306	307	307	307
AOS	01:48	13:53	21:45	03:30	13:52	21:44	04:16	13:48	21:35
LOS	14:15	22:05	02:56	14:10	22:13	05:46	14:10	22:07	05:35
TOT	12:27	08:12	05:11	10:40	08:21	08:02	09:54	08:18	08:00
DSS T	15:59	08:30	08:39	10:55	09:50	08:52	11:10	09:32	09:12
COMMAND									
=TOT	32	47	27	56	66	23	0	49	93
TELEMETRY									
DL	151.8	151.9	152.9	151.8	152.3	159.0	151.3	152.4	159.4
RES	.2	.1	-.9	.2	-.3	1.1	.8	-.3	.8
BR	1024	1024	1024	1024	1024	128	1024	1024	128
SNR	4.9	4.9	5.4	5.3	4.7	4.4	5.3	4.6	4.3
RES	.2	.5	.7	.6	.5	1.0	.8	.6	1.1
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	10	20	20	10
D RES	-.114	-.112	-.125	-.113	.100	-.126	.102	-.095	-.110
D NOS	.002	.003	.002	.003	.003	.003	.003	.002	.003
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0611	DR T-3011 XMTR DOWN DUE TO BAD INTERLOCK SWITCH. DR WAS CLOSED OUT IN REAL TIME.
DSS 14/P0611	DR T-3013 TRACK TERMINATED DUE TO STEADY WINDS OF 50 KNOTS AND GUSTS OF 60 KNOTS-ANT TAKEN TO STOW.
DSS 43/P0611	DR T-3012 RCVR1 SIGNAL LEVEL DROPPED BY 3DB SWITCHED TO RCVR 2.
DSS 12/P0613	2201Z-2204Z LOST DATA DUE SDA HALT. DR T-3022.

Table A-1 (contd)

GENERAL									
DSS	43	63	12	43	63	14	43	63	12
PASS	0613	0614	0614	0614	0615	0615	0615	0616	0616
DOY	308	308	308	309	309	309	310	310	310
AOS	05:01	13:42	21:35	04:50	13:37	20:51	01:17	13:33	20:30
LOS	14:05	21:55	05:30	13:55	21:32	01:55	13:50	21:26	01:45
TOT	09:04	08:13	07:55	09:05	07:55	05:04	12:33	08:07	05:15
DSS T	10:55	10:57	09:52	11:32		05:45	14:37	09:17	07:00
COMMAND									
TOT	12	1	2	0	7	80	73	31	39
TELEMETRY									
DL	151.9	152.5	159.3	151.9	152.1	151.6	152.0	152.3	159.7
RES	.2	-.4	.9	.2	.0	.5	1.2	-.1	.3
BR	1024	1024	128	1024	1024	1024	1024	1024	128
SNR	5.5	4.6	4.1	4.3	4.5	4.7	3.8	4.6	5.0
RES	.8	.4	.8	-0.5	.1	.7	.0	.6	.0
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	10	20	20	20	20	20	10
D RES	.94	.085	-.092	-.083	-.074	-.092	-.068	-.066	-.083
D NOS	.004	.003	.002	.003	.002	.002	.002	.002	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0613 RCVR 1 FAILURE FROM 0400-1100Z,DUE TO FAULTY 10 MHZ FILTER AMP MODULE REPLACED DURING TRACK.

Table A-1 (contd)

GENERAL									
DSS	43	63	12	43	63	14	43	63	12
RASS	0616	0617	0617	0617	0618	0618	0618	0619	0619
DOY	311	311	311	312	312	312	313	313	313
AOS	00:51	13:44	21:20	01:17	13:27	21:18	0113	13:25	21:15
LOS	13:50	21:41	01:48	13:45	21:40	01:50	1340	21:36	01:35
TOT	12:59	07:57	05:28	12:28	08:13	04:32		08:11	04:20
DSS T	03:20	09:30	05:33	15:03	09:43	05:00		09:31	04:32
COMMAND									
TOT	72	5	20	134	0	60	54	2	2
TELEMETRY									
DL	151.9	151.0	159.3	151.9	152.4	150.2	152.0	152.3	159.9
RES	.3	1.2	1.0	.3	-2.0	2.0	.3	.0	.5
BR	1024	1024	128	1024	1024	1024	1024	1024	128
SNR	3.8	4.2	2.8	4.8	3.6	3.8	4.1	3.2	3.1
RES	-0.8	.2	-0.5	.1	-2.1	-0.4	-0.5	-0.6	.0
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	10	20	10	20	20	20	10
D RES	.183	.300	-.320	-.308	2	-.331	-.316	-.318	-.339
D NOS	.002	.002	.003	.003	.002	.002	.002	.002	.002
E NOS	.002	.002	.002	.003	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0617 DR 0502=ANT STOPPED=APS FAILURE=MEMORY PARITY ALARM.

DSS 63/P0618 DR-0507 SERVO MAIN PUMP 2 SHUT DOWN. RESTARTED. DR-0505 CMD DATA TRANSFER CMD ABORTED-SUBCARRIER FREQ OUT OF LIMIT.

DSS 14/P0618 DR 0508 ANT TO EMGNCY STOP. REASON UNKNOWN.

DSS 43/P0618 DR 0509 ANT TO BRAKE-NO ALARMS. CMD MOD OFF TO PRE-VENT FURTHER CMDING. ABORTED CMD 014-04.

Table A-1 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	14
PASS	0619	0620	0620	0620	0621	0621	0621	0622	0622
DOY	314	314	314	315	315	315	316	316	316
AOS	01:13	13:20	21:10	02:02	13:20	21:00	01:15	13:15	21:00
LOS	13:40	21:30	02:45	13:35	21:30	01:55	13:35	21:25	01:55
TOT	12:27	08:10	05:35	11:33	08:10	04:55	12:20	08:10	05:55
DSS T	15:35	09:45	06:14	13:27	09:49	05:40	14:05	09:37	05:14
COMMAND									
TOT	75	4	78	16	26	65	101	4	74
TELEMETRY									
DL	152.4	153.5	152.9	152.5	153.6	150.2	152.3	152.5	151.8
RES	-.1	-1.2	-.6	-.2	-1.3	2.1	-.1	.7	.8
BR	1024	1024	1024	1024	512	1024	1024	1024	1024
SNR	4.0	3.9	3.8	4.2	4.4	4.4	4.4	3.5	4.6
RES	-0.5	-0.8	-0.4	.3	2.8	.1	-0.1	.5	.8
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	20	20	20	20
D RES	.332	-.334	-.347	-.341	-.339	-.366	-.362	-.364	-.393
D NOS	.002	.002	.003	.003	.006	.004	.003	.002	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0619 DR 0513 CPR ERROR ON CIL A/D1 CLCSED IN REAL TIME.

DSS 43/P0621 OCCASIONAL DDA ALMS 001 ON STRING 1.

Table A-1 (contd)

GENERAL									
DSS	43	11	63	12	43	63	14	43	11
PASS	0622	0622	0623	0623	0623	0624	0624	0624	0624
DOY	317	317	317	317	318	318	318	319	319
AOS	01:18	02:17	13:08	21:00	01:15	13:10	20:50	01:28	02:43
LOS	13:30	05:35	21:21	01:45	13:25	21:11	01:55	13:20	05:30
TOT	12:12	05:18	08:13	04:45	12:10	08:01	05:05	11:52	02:47
DSS T	14:15	03:18	12:37	05:26	14:15	09:43	06:06	13:11	02:47
COMMAND									
TOT	27	N/A	1	65	119	0	73	30	N/A
TELEMETRY									
DL	152.1	/A	151.7	159.0	152.3	151.9	149.5	150.3	/A
RES	.3	N/A	.7	.9	.1	.5	2.9	2.1	N/A
BR	1024	N/A	1024	128	1024	1024	1024	1024	N/A
SNR	4.7	N/A	4.3	1.9	4.3	3.8	4.9	4.8	N/A
RES	.3	N/A	.2	-1.2	.0	.2	1.0	.5	N/A
TRACKING									
MODE	2	3	2	2	2	2	2	2	3
T PWR	10	N/A	20	10	5	20	20	20	N/A
D RES	-.378	N/A	-.375	-.406	-.391	-.387	-.425	-0.406	.430
D NOS	.002	.003	.002	.002	.003	.002	.006	.003	.010
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0623 RECURRENCE OF NOISE SPIKE PROB. (REF DR T-2991)

DSS 43/P0624 DIS TAKEN OFF LINE DUE TO DSS REQUEST TO RUN MVM TEST

Table A-1 (contd)

GENERAL									
DSS	63	12	43	63	14	43	63	14	43
PASS	0625	0625	0625	0626	0626	0626	0627	0627	0627
DOY	319	319	320	320	320	321	321	321	322
AOS	13:05	20:50	00:53	13:00	20:50	01:07	12:55	20:50	01:43
LOS	21:27	01:10	13:20	21:10	01:40	13:15	21:10	02:15	13:10
TOT	08:22	04:20	12:27	08:10	04:50	12:08	08:15	05:39	11:27
DSS T	09:44	05:37	14:30	09:34	05:10	13:43	09:45	05:52	13:02
COMMAND									
TOT	175	3	6	1	72	40	1	131	138
TELEMETRY									
DL	152.0	160.0	152.0	151.7	151.1	152.1	151.4	151.3	151.8
RES	.5	.6	.5	.8	1.4	.4	7.1	1.2	.8
BR	1024	128	1024	1024	1024	1024	1024	1024	1024
SNR	3.6	3.5	4.9	3.9	5.0	5.0	4.2	5.1	4.8
RES	-0.1	-0.4	.5	.3	1.1	.6	.8	1.3	.5
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	10	20	20	20	20	20	20	20
D RES	.412	-.337	.425	.431	-.425	.453	-.463	.400	-.482
D NOS	.003	.002	.003	.002	.	.002	.002	.002	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0625 DR 0529 OPTR ERROR ON FMT AD 3 ENTRY.

DSS 14/P0626 DR 0766 1 SEC TDH PUT TO LINE LATE (PROC ERROR) DR 0530 RCVR 1 POCA RAMP STOPPED (PROC ERROR)

Table A-1 (contd)

GENERAL									
DSS	11	63	14	43	63	14	43	63	14
PASS	0627	0628	0628	0628	0629	0629	0629	0630	0630
DOY	322	322	322	323	323	323	324	324	324
AOS	02:25	12:56	20:45	00:53	12:48	20:31	00:30	12:44	20:25
LOS	05:20	21:05	01:15	13:05	21:00	01:26	13:04	20:50	01:40
TOT	02:55	08:09	03:33	12:12	08:12	04:55	12:34	08:06	05:15
DSS T	02:55	09:34	03:38	13:48	09:02	05:14	13:39	C9:43	05:35
COMMAND									
TOT	N/A	1	57	150	26	119	0	34	66
TELEMETRY									
DL	/A .	152.2	150.0	151.6	152.6	150.7	152.1	152.1	151.5
RES	N/A	.4	2.6	1.0	.9	1.9	.5	.5	1.1
BR	N/A	1024	1024	1024	1024	1024	1024	1024	1024
SNR	N/A	4.2	5.5	4.9	4.2	5.4	4.5	4.3	5.3
RES	N/A	.8	1.6	.7	.8	1.5	.4	.9	1.5
TRACKING									
MODE	3	2	2	2	2	2	2	2	2
T PWR	N/A	20	20	20	20	20	20	20	20
D RES	N/A	-.490	-.525	-.514	-.524	-.558	-.514	-.602	N/A
D NOS	N/A	.002	.002	.002	.003	.002	.002	.013	N/A
E NOS	N/A	.002	.002	.002	.002	.002	.002	N/A	.002

COMMENTS

DSS 43/P0628 DR 0535 MAIN BREAKER FOR POWER DISTRIBUTION TO RECEIVERS,EXCITER AND ANTENNA ELECTRONICS TRIPPED.

DSS 43/P0629 DR 0538 NO CMD CONFIRMATION DUE TO HSDL HIT.

Table A-1 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	14
PASS	0630	0631	0631	0631	0632	0632	0632	0633	0633
DOY	325	325	325	326	326	326	327	327	327
AOS	00:49	12:41	20:35	00:59	12:37	19:59	01:02	12:35	20:30
LOS	13:00	20:50	01:25	12:57	20:34	01:35	12:53	20:51	00:55
TOT	12:11	08:09	04:50	10:02	07:57	05:36	11:51	C8:16	04:25
DSS T	13:52	09:36	05:20	13:37	09:40	06:21	13:38	10:13	05:03
COMMAND									
TOT	49	45	78	36	66	66	27	139	00073
TELEMETRY									
DL	151.6	151.7	151.3	151.8	152.4	151.5	152.3	151.9	152.6
RES	.1	1.0	+1.4	.9	.3	+1.2	.4	.8	.1
BR	1024	1024	1024	1024	1024	1024	1024	1024	1024
SNR	4.2	4.3	5.1	4.7	3.7	+5.0	4.5	3.5	4.3
RES	-0.1	.7	+1.3	.4	-0.2	+1.2	.3	.1	+0.6
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	20	20	20	20
D RES	N/A	.334	-.337	.332	-.330	.356	.338	-.338	-.368
D NOS	.009	.004	.003	.002	.003	.002	.003	.002	.002
E NOS	N/A	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0630	NO CHAR. NOISE DUE TO ONE WAY MODE AND CNE PER SECCND SAMPLE RATE.
DSS 14/P0632	202848 TCP A FAILED. FOUND BAD POWER SUPPLY ON TAPE UNIT. TRANSFERRED TO TCP B

Table A-1 (contd)

GENERAL									
DSS	43	63	12	43	63	14	43	63	14
PASS	0633	C634	0634	0634	0635	0635	0635	C636	0636
DOY	328	328	328	329	329	329	330	330	330
AOS	00:25	12:31	19:34	00:18	12:27	20:15	02:50	12:26	20:20
LOS	12:50	20:54	00:45	12:46	20:45	03:20	12:45	20:50	04:35
TOT	12:29	08:23	05:11	12:28	08:18	07:05	09:55	08:24	08:20
DSS T	14:02	09:29	05:24	14:32	C9:45	08:13	11:36	09:30	09:03
COMMAND									
TOT	9	1	2	62	00011	00053	156	00039	42
TELEMETRY									
DL	150.1	153.0	160.7	151.7	152.0	152.4	152.6	152.0	152.8
RES	.0	-.2	.2	1.1	.8	.4	.2	.8	.
BR	1024	1024	128	1024	1024	1024	1024	512	1024
SNR	4.2	3.7	2.2	4.3	3.3	3.8	3.9	1.2	3.8
RES	.2	.3	-.4	.3	-0.2	.0	-0.2	-1.4	.2
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	10	20	20	20	20	20	20
D RES	-.365	-.373	.402	-.402	-.418	-.451	-.455	-.498	-.556
D NOS	.003	.002	.002	.002	.002	.002	.002	.003	.003
E NOS	.002	.002	.002	.002	.002	.002	.002	.003	.002

COMMENTS

DSS 12/P0634 DR 0544 DDA-A HUNG UP RELOAD REQUIRED. DR 0545 ROL DUE TO RTLT CALCULATION ERROR. DR 0546 SDA-1 UNABLE TC ATTAIN SOLID LOCK.

Table A-1 (contd)

GENERAL									
DSS	43	11	63	11	14	43	63	14	43
PASS	0636	0636	0637	0637	0637	0637	0638	0638	0638
DOY	331	331	331	331	331	332	332	332	333
AOS	00:10	01:12	12:19	19:43	20:10	00:05	12:16	20:05	00:13
LOS	12:35	04:45	20:35	00:21	04:34	12:35	20:31	04:30	12:30
TOT	12:25	03:33	08:16	04:38	08:24	12:30	09:15	08:25	12:17
DSS T	14:15	N/:A	09:38	05:14	09:19	14:01	10:25	09:31	13:51
COMMAND									
TOT	208	0	110	00003	00090	193	155	51	192
TELEMETRY									
DL	152.5	N/	153.5	158.4	153.1	152.4	152.2	152.0	152.0
RES	.3	N/A	.7	-.5	-.3	.5	.7	.9	.9
BR	1024	N/A	1024	256	1024	1024	1024	1024	1024
SNR	4.2	N/A	3.3	2.9	3.8	3.9	3.4	4.2	4.7
RES	.2	N/A	-0.1	.0	.3	.0	.1	.5	4.9
TRACKING									
MODE	2	3	2	2	2	2	2	2	2
T PWR	20	N/A	20	10	20	20	20	20	20
D RES	-.565	N./A	-.626	.402	-.695	-.870	-1.010	.624	-.667
D NOS	.003	.003	.003	.003	.003	.003	.002	.003	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002
COMMENTS									

Table A-1 (contd)

GENERAL					
DSS	63	14	43	63	14
PASS	0639	0639	0639	0640	0640
DOY	333	333	333	334	334
AOS	12:15	20:05	23:57	12:08	19:35
LOS	20:40	04:27	12:27	20:01	04:24
TOT	08:25	08:22	12:30	07:53	08:49
DSS T	09:15	09:58	13:10	08:44	10:11
COMMAND					
TOT	144	45	155	136	48
TELEMETRY					
DL	153.0	151.7	153.5	152.8	151.8
RES	-.1	1.2	-.6	.1	1.1
BR	1024	1024	1024	1024	1024
SNR	3.2	3.9	4.7	3.1	3.9
RES	-0.1	.4	.9	-0.6	.6
TRACKING					
MODE	2	2	2	2	2
T PWR	20	20	10	20	20
D RES	.804	-.979	-1.128	-1.465	.460
D NOS	.003	.006	.004	.005	.008
E NOS	.002	.002	.002	.002	.002

COMMENTS

DSS 14/P0639 2033Z,RECALL'S FROM TCP-B RECEIVED AS TCP-A OR 0778.

DSS 43/P0639 033716 TXR PWR REDUCED TO 10KW. 035930 TXR PWR REDUCED TO 5KW. 045058 TXR PWR INCREASED TO 10KW TO MINIMISE NOISE SPIKES.

Table A-2. Pioneer 10 Pass Chronology, December 1973

GENERAL									
DSS	43	11	63	14	43	11	63	14	43
PASS	0640	0640	0641	0641	0641	0641	0642	0642	0642
DOY	334	335	335	335	335	336	336	336	336
AOS	23:51	00:47	12:03	19:31	23:46	00:42	12:00	19:52	23:50
LOS	12:25	04:39	20:05	04:21	12:20	04:35	20:21	04:26	12:25
TOT	12:34	03:52	07:52	08:50	12:32	03:53	08:21	08:34	12:35
DSS T	14:46	03:55	08:47	10:25	13:44	03:56	09:15	09:15	15:05
COMMAND									
TOT	164	N/A	190	159	143	N/A	136	119	617
TELEMETRY									
DL	152.4	N/A	153.1	151.4	153.1	N/A	152.4	151.9	152.9
RES	.6	N/A	-.1	1.6	-.1	N/A	.6	1.1	.1
BR	1024	N/A	1024	1024	1024	N/A	1024	1024	1024
SNR	4.1	N/A	*3.0	3.9	2.4	N/A	3.5	3.9	3.5
RES	.2	N/A	-0.1	.6	-1.4	N/A	.5	.6	-0.3
TRACKING									
MODE	2	3	2	2	2	3	2	2	2
T PWR	20	N/A	20	20	20	N/A	20	20	20
D RES	-.398	N/A	-.505	-.669	-.850	N/A	-1.566	-1.918	-5.142
D NOS	N/A	.006	.008	.003	.002	N/A	.003	.002	.002
E NOS	N/A	.002	.002	.002	.002	N/A	.002	.002	.002

COMMENTS

DSS 11/P0640	DSS-43 PRIME.
DSS 43/P0640	0727Z WRONG DOY IN IFM STATEMENT DR 0557. TXR PWR VARIED TO MINIMIZE NOISE SPIKES: 20KW FROM 0035-0420 10KW FROM 0420-0421 5KW FROM 0421-0459 10KW FROM 0459-1042 5KW FROM 1042-1226.
DSS 43/P0641	0757Z HIGH WINDS;HEAVY RAINS CAUSED MYLAR WINDOW ON CONE TO RUPTURE-WATER IN WAVE GUIDE;SNR DOWN TO APPRX 1.5DB DR 0560.
DSS 11/P0641	DSS 43 PRIME.
DSS 43/P0642	ONE-WAY TRACK FROM 091105-093652Z

Table A-2 (contd)

GENERAL									
DSS	63	14	43	42	63	14	43	63	14
PASS	0643	0643	0643	0643	0644	0644	0644	0645	0645
DOY	337	337	337	338	338	338	338	339	339
AOS	12:02	19:52	23:46	02:59	11:53	19:48	23:39	11:50	19:41
LOS	20:26	04:25	12:13	06:00	20:15	04:12	12:10	20:00	03:36
TOT	08:24	08:33	12:27	03:01	08:22	08:24	12:31	08:10	07:55
DSS T	08:46	09:17	13:31	04:38	08:34	09:43	13:42	08:38	09:11
COMMAND									
TOT	534	00429	535	N/A	537	345	265	232	174
TELEMETRY									
DL	151.2	152.2	152.9	N/A	152.4	152.7	152.8	152.9	152.4
RES	1.8	.8	.2	N/A	.7	.4	.3	.2	.7
BR	1024	1024	1024	N/A	1024	1024	1024	1024	1024
SNR	3.8	3.3	3.3	N/A	2.8	3.9	3.8	2.7	3.6
RES	.7	+0.1	-0.3	N/A	-0.2	.6	.4	-.2	.2
TRACKING									
MODE	2	2	2	3	2	2	2	2	2
T PWR	20	20	10	N/A	20	20	20	20	20
D RES	-20.630	-103.599	N/A	N/A	28.429	22.898	20.728	18.814	18.090
D NOS	.007	N/A	N/A	N/A	.008	.002	.003	.003	N/A
E NOS	.002	N/A	.002	N/A	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0643	DR 3779 AT 1234542 CMD MSG 002 SUB 05 ABORTED ON BIT 9 DUE TO DATA QUALITY ERROR.
DSS 14/P0643	2 MANUAL CMD ABORTS PER PROJ REQUEST.NO DR. DR 0781: DIS LOG TAPE HALTED
DSS 43/P0643	0203Z,CMD ABORT,EXCITER FREQ WRONG,DR 0782.
DSS 63/P0644	CMD 066-01 IPW4,ABORTED BIT-07,PROJ. REQ CMD MOD OFF

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	14
PASS	0645	0646	0646	0646	0647	0647	0647	0648	0648
DOY	339	340	340	340	341	341	341	342	342
AOS	23:37	11:47	19:40	23:42	11:44	19:30	23:32	11:45	19:20
LOS	12:07	20:13	03:50	12:03	20:19	01:00	12:05	19:50	00:40
TOT	12:30	08:26	08:10	12:21	08:35	05:30	12:33	08:05	05:20
DSS T	13:35	09:07	09:07	13:18	09:39	06:31	14:05	08:42	05:42
COMMAND									
TOT	340	28	147	204	219	163	277	210	137
TELEMETRY									
DL	153.1	154.1	153.6	153.4	152.7	152.4	152.4	152.8	152.7
RES	.0	-1.0	-.5	-.3	.4	.7	.3	.4	.5
BR	1024	512	512	1024	1024	1024	1024	1024	1024
SNR	3.7	6.1	5.3	3.7	2.5	4.0	3.9	3.3	4.3
RES	.0	-.3	-1.4	.1	-0.5	.6	+0.3	.3	1.0
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	20	20	20	20
D RES	-.387	.349	-.365	-.030	-.288	-.299	.025	.052	.071
D NOS	.002	.004	.005	.003	.002	.002	.003	.003	.004
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0646 FAILED TO ACQUIRE S/C ON CH 6 ON INITIAL SWEEP-DR0564

DSS 14/P0647 DR 0567/0568 341/1950Z MISSED,UPLINK ACQUISITION/RETUNE REQ (PROC ERR) DR 0786 341/2331Z BIT RATE ERROR/CLEAR.

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	14
PASS	0648	0649	0649	0649	0650	0650	0650	0651	0651
DOY	342	343	343	343	344	344	344	345	345
AOS	23:30	11:37	19:20	23:30	11:34	19:35	23:27	11:32	19:35
LOS	12:00	19:50	00:25	11:50	20:10	00:15	11:50	20:05	00:10
TOT	12:30	08:13	05:05	12:20	08:36	04:40	12:23	08:37	04:35
DSS T	13:46	09:08	05:43	13:40	09:29	05:28	13:34	09:03	05:03
COMMAND									
TOT	214	228	134	299	232	88	244	11	51
TELEMETRY									
DL	153.0	152.2	152.7	153.2	152.6	151.9	152.6	152.7	153.6
RES	.2	1.0	.5	.0	.6	1.3	.6	.5	-.4
BR	1024	1024	1024	1024	1024	1024	1024	1024	1024
SNR	4.0	3.4	4.3	4.1	3.3	4.3	4.1	3.0	4.1
RES	.3	.3	1.0	+0.5	.2	.9	.6	.2	.1
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	20	20	20	20
D RES	.078	.132	.118	.145	.180	.163	.233	.224	.213
D NOS	.007	.004	.005	.003	.004	.006	.006	.005	.003
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 14/P0650 DR 0573 LOST WATCH DOG TIMER (HUNG UP ON SUB ROUTINE, NO INDICATION ON I.O.)

DSS 43/P0650 TXR REDUCED TO 10KW 085800 (NOISE SPIKES)

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	14
PASS	0651	0652	0652	0652	0653	0653	0653	0654	0654
DOY	345	346	346	346	347	347	348	348	348
AOS	23:35	11:28	19:30	23:21	11:24	19:25	00:10	11:20	19:26
LOS	11:50	20:00	00:21	11:45	19:55	00:22	11:40	19:56	00:30
TOT	12:15	08:32	04:51	12:24	08:31	04:57	11:30	08:36	05:04
DSS T	14:00	09.30	05:38	13:53	09:30	04:34	12:08	09:25	05:29
COMMAND									
TOT	154	55	21	194	25	75	73	0	71
TELEMETRY									
DL	153.1	152.7	152.6	153.2	154.1	154.8	153.7	152.3	152.1
RES	.1	.5	.6	.0	-.9	1.6	-.5	.9	1.1
BR	1024	1024	1024	1024	1024	512	1024	1024	1024
SNR	3.7	2.9	3.8	2.9	1.9	4.5	3.3	3.0	4.0
RES	+0.2	-0.1	.5	-0.7	-0.6	1.3	-0.3	.0	.7
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	20	20	20	20
D RES	.625	-.665	-.684	-.672	-.680	-.721	-.700	-.713	-.750
D NOS	.004	.002	.003	.003	.004	.005	.004	.003	.003
E NOS	.002	.002	.002	.002	.002	.003	.002	.002	.002

COMMENTS

DSS 43/P0651 TCP 1 FAILED WITH LOSS OF TLM AND CMD DUE TO TRIPPING CIRCUIT BREAKER TB5-E-11. BREAKER RESET,TCP RELOADED AND PRIME AGAIN AT 091830.

DSS 43/P0652 DR 0577 INCORRECT IFM ENTRY ON FRAME CHANGE LOSS OF DATA FROM 013105Z TO 013300Z CLOSED OUT REAL TIME. OPTR ERROR.

Table A-2 (contd)

GENERAL									
DSS	43	63	12	43	63	14	43	63	14
PASS	0654	0655	0655	0655	0656	0656	0656	0657	0657
DOY	348	349	349	349	350	350	350	351	351
AOS	23:41	11:20	18:58	23:25	11:14	19:15	23:25	11:13	19:07
LOS	11:40	19:59	23:42	11:35	19:31	23:35	11:34	19:50	23:43
TOT	11:59	08:39	04:44	12:10	08:17	04:20	12:09	08:37	04:36
DSS T	12:48	09:28	04:57	13:02	09:07	05:07	13:13	10:11	05:10
COMMAND									
TOT	84	7	1	189	13	126	315	284	132
TELEMETRY									
DL	153.4	152.7	161.6	153.2	152.7	152.6	153.7	152.3	153.2
RES	-.1	.6	.0	.1	.6	.7	-0.4	1.0	.1
BR	1024	1024	128	1024	1024	1024	1024	1024	1024
SNR	3.7	3.0	2.5	3.8	3.1	4.5	3.9	3.0	4.4
RES	.1	.1	.5	.2	.1	.9	.5	.2	1.2
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	10	20	10	20	20	20	20	10	20
D RES	-.727	-.735	-.762	-.750	-.755	-.791	-0.776	-.775	-.795
D NOS	.003	.003	.004	.003	.003	.002	.002	.002	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0655 DR 0578 ANT HALT EMERGENCY STOP HIT ACCIDENTALLY.

DSS 43/P0655 DR 0583 B/R CHANGE TYPE-IN NOT ACCEPTED AT 001143 (OPERATOR ERROR.)

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	12	43	63	14
PASS	0657	0658	0658	0658	0659	0659	0659	0660	0660
DOY	351	352	352	352	353	353	353	354	354
AOS	23:17	11:11	18:57	23:21	11:09	18:50	23:05	11:04	18:54
LOS	11:28	19:31	23:41	11:25	19:48	23:30	11:21	19:26	23:45
TOT	12:17	08:21	04:44	12:04	08:39	04:40	12:16	08:22	04:51
DSS T	12:53	09:47	05:45	12:38	10:01	05:13	14:02	09:56	06:33
COMMAND									
TOT	128	8	6	369	11	1	77	5	116
TELEMETRY									
DL	152.8	153.0	152.3	153.4	153.5	162.1	153.5	153.9	153.2
RES	.5	.3	1.0	-0.1	-.2	-.7	-.2	-.5	.2
BR	1024	1024	1024	1024	1024	128	1024	1024	1024
SNR	3.9	2.9	4.0	3.6	2.2	2.5	3.5	2.3	2.9
RES	.5	0	.8	.2	-.7	.4	.1	-.6	-0.2
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	20	20	10	5	20	20
D RES	-.800	-.799	-.834	-0.823	-.835	1.942	-.852	-.764	-.884
D NOS	.002	.002	.002	.002	.002	.003	.002	.002	.003
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0657	DR 0587 HR NOISE SPIKES.
DSS 14/P0658	DR 0588 XMTR AND CMD MOD ON LATE.
DSS 43/P0658	I-040535Z CMD MSG 023-01 ABORTED;CMD MSG 034-01 ABORTED 043602 DUE DATA QUAL FAIL. DR 0793.
DSS 12/P0659	DR 0794 SUBCARRIER FREQ EO ALARM AT 21:53:17,CLRED 21:53:19. 0358Z-BAD XFER, DR 0594.

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	14	43	63	12
PASS	0660	0661	0661	0661	0662	0662	0662	0663	0663
DOY	354	355	355	356	356	356	356	357	357
AOS	23:26	11:06	18:47	00:35	11:10	18:55	23:18	10:51	18:55
LOS	11:18	19:20	01:05	11:21	19:20	23:45	11:11	19:15	23:35
TOT	11:52	08:14	06:18	10:46	08:10	04:50	11:53	08:24	04:40
DSS T	13:28	09:39	06:55	12:47	09:38	05:23	13:30	09:36	04:57
COMMAND									
TOT	90	0	141	7	13	129	80	109	1
TELEMETRY									
DL	153.7	153.5	153.0	153.1	153.2	153.0	153.9	153.2	160.4
RES	-.3	.7	.4	.3	.2	.4	-.6	.2	-1.1
BR	1024	1024	1024	1024	1024	1024	1024	1024	64
SNR	2.5	2.2	3.8	3.2	2.7	. 3.7	3.4	3.1	6.2
RES	-0.8	0	+0.5	-.4	-0.2	. 0.4	.0	.4	1.2
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	20	10	20	20	5	20	10
D RES	-.879	-.868	.927	-.894	-.909	-.940	-.934	-.943	1.813
D NOS	.002	.003	.004	.007	.006	.004	.004	.006	.005
E NOS	.002	.002	.002	.002	.004	.002	.002	.004	.002

COMMENTS

DSS 63/P0661 DR 0595-STA. TIME IN ERROR PLUS 8 SECONDS, 1106-1124Z.

DSS 14/P0661 DR 0795 CMD MSG 004-01 ABORTED ON BIT 09 DUE TO SUB-CARRIER FREQ (FO) OUT OF LIMITS. 195622Z-195825Z.

Table A-2 (contd)

GENERAL									
DSS	43	63	12	43	63	14	43	63	12
PASS	0663	0664	0664	0664	0665	0665	0665	0666	0666
DOY	357	358	358	358	359	359	359	360	360
AOS	23:22	10:50	18:50	23:25	10:48	18:50	23:29	10:42	18:45
LOS	11:08	19:12	23:30	11:05	19:10	23:38	11:02	19:06	23:10
TOT	11:46	08:22	04:40	11:40	08:22	04:48	11:33	08:24	04:25
DSS T	13:13	08:52	05:24	12:49	09:37	05:30	12:53	10:20	05:07
COMMAND									
TOT	184	17	1	7	100	0	184	9	3
TELEMETRY									
DL	15.92	153.0	160.9	152.8	153.2	152.6	152.8	153.9	161.7
RES	-.62	.4	.6	.6	.2	.8	.6	-.5	-.2
BR	1024	1024	64	1024	1024	1024	1024	1024	64
SNR	3.7	3.0	6.3	4.1	3.5	3.9	3.5	2.4	2.8
RES	.1	.3	+1.3	.9	.6	1.5	.1	-0.4	.8
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	5	20	10	5	20	20	5	20	10
D RES	-.964	-.976	1.793	-.981	-.990	-1.016	-.797	-.805	-.832
D NOS	.004	.004	.003	.004	.003	.003	.002	.003	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0663 DR 0601-DDA POWER SUPPLY FAILURE.

DSS 12/P0666 DR 0796-WRONG EXCIT FREQ ENTERED BY NAT CMD.

Table A-2 (contd)

GENERAL									
DSS	43	63	14	43	63	12	43	63	14
PASS	0666	0667	0667	0667	0668	0668	0668	0669	0669
DOY	360	361	361	361	362	362	363	363	363
AOS	22:47	10:40	18:30	23:25	10:35	18:35	00:24	10.29	18:24
LOS	10:59	19:00	23:15	10:55	19:17	01:00	10:52	18:55	23:15
TOT	12:12	08:20	04:45	11:30	08:42	06:25	10:28	08:26	04:51
DSS T	12:49	09:45	05:13	12:50	09:24	07:52	11:43	09:17	05:27
COMMAND									
TOT	85	4	0	31	163	2	6	149	0
TELEMETRY									
DL	153.1	154.2	152.8	153.6	154.0	161.1	154.1	153.3	153.3
RES	.3	-.4	.7	-.1	-.5	.5	-.6	.2	.2
BR	1024	1024	1024	1024	1024	128	1024	1024	1024
SNR	3.1	2.6	3.1	3.3	2.5	2.6	3.8	3.1	3.9
RES	-.4	-0.1	.1	.1	-0.3	.6	.3	.8	.8
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	5	20	20	10	20	10	20	20	20
D RES	-.816	-.825	-.862	-.837	-.873	-.905	-.898	-.903	-.936
D NOS	.003	.002	.002	.003	.003	.003	N/A	.003	.002
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0666	DR 0604 TCP "A" SWITCHED TO "B" NO CIL
DSS 63/P0667	DR 0797:CMD ALM 0100 DUE TO WORK ON RANGING SYSTEM.
DSS 12/P0668	212803Z-BIT RATE ERROR ALARM-DR 0799. DR 0607: DDA-B CEASED PROCESSING 2032Z.
DSS 43/P0668	0433Z ANTENNA HALT (LUBE FAIL) DR 0608.
DSS 63/P0669	DR 0800 BLOCK REJECTED TCP-A WHEN STDL TABLE XMITTED PROBLEM CLEARED AFTER SECOND RELOAD. (BACK-UP TCP)

Table A-2 (contd)

GENERAL							
DSS	43	63	12	43	63	14	42
PASS	0669	0670	0670	0670	0671	0671	0671
DOY	364	364	364	364	365	365	365
AOS	00:52	10:28	18:30	23:34	13:39	18:29	22:55
LOS	10:49	18:50	00:20	10:55	18:50	00:30	10:40
TOT	09:57	08:32	05:50	11:21	05:11	06:01	11:45
DSS T	12:26	10:34	06:29	11:26	05:29	07:21	11:59
COMMAND							
TOT	22	81	2	6	102	113	83
TELEMETRY							
DL	154.0	153.8	160.7	153.2	153.9	152.3	162.6
RES	.5	-.4	.9	.3	-.4	1.2	-1.0
BR	1024	1024	64	1024	1024	1024	128
SNR	3.5	3.0	3.0	3.8	3.4	4.1	2.3
RES	.1	.3	1.0	.4	+0.5	1.0	.1
TRACKING							
MODE	2	2	2	2	2	2	2
T PWR	10	20	10	5	20	20	20
D RES	-.922	-.927	-.955	-.954	.963	-.986	-.654
D NOS	.003	.003	.002	.003	.002	N/A	.003
E NOS	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0669 TXR REDUCED IN STAGES TO 2.5KW FROM 004550Z TO 035400Z AND REMAINED AT 2.5KW FOR REMAINDER OF PASS.

DSS 14/P0671 HIGH DOPPLER NOISE. DR 0804 HIGH DOPPLER NOISE AND RESID FLUCTUATIONS.

Table A-3. Pioneer 10 Pass Chronology, January 1974

GENERAL									
DSS	63	14	43	62	14	43	63	12	43
PASS	0672	0672	0672	0673	0673	0673	0674	0674	0674
DOY	001	001	001	002	002	003	003	003	004
AOS	10:22	18:20	23:55	10:34	18:15	23:57	10:25	18:10	00:29
LOS	19:05	22:47	10:45	18:40	22:44	10:40	18:55	00:30	10:40
TOT	08:43	04:27	10:50	08:06	04:29	10:43	08:30	06:20	10:11
DSS T	10:16	04:55	12:20	10:18	05:15	11:57	09:50	07:32	11:25
COMMAND									
TOT	0	0	22	0	3	10	24	40	139
TELEMETRY									
DL	153.9	152.9	154.4	160.5	151.5	153.9	155.3	162.5	154.3
RES	-.4	.6	-.8	1.3	2.1	.3	1.8	-.8	-.9
BR	1024	1024	1024	128	1024	1024	512	64	1024
SNR	3.2	4.0	3.0	2.2	3.8	2.9	3.6	4.5	2.6
RES	.5	1.0	-0.3	.4	.7	1.1	-2.1	-0.3	-1.1
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	2.5	10	20	20	20	10	5
D RES	-.667	-.672	-.655	-.699	-.713	-.673	-.710	-.751	-.702
D NOS	.002	.003	.003	.003	.004	.006	.006	.006	.008
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 63/P0672	1759Z XMTR SPIKES (RCUR GLITCH) DR 0613.
DSS 62/P0673	DR 0805 CONTINUOUS EXCIT FREQ WRONG ALARMS "A" AND "B" CMD SYSTEMS SWAP OUT OF BCD CONVERTER IN RCVR/EXCITER PACK AT STN DIDNT HELP. DR 0616 INTERMITTANT TIME CORRECTIONS.DDA-X.
DSS 43/P0673	TXR OFF 0521-0840 DUE TO EXCESSIVE NOISE SPIKES.
DSS 12/P0674	DR 0619-XMTR FAILURE (HEAT EXCHANGE PROBLEM) AT 003/23-46-49Z UNTIL EOT.

Table A-3 (contd)

GENERAL									
DSS	62	12	14	42	62	12	42	62	62
PASS	0675	0675	0675	0675	0676	0676	0676	0677	0678
DOY	004	004	004	005	005	005	005	006	007
AOS	14:11	17:32	23:30	02:15	10:20	22:21	23:04	10:05	10:10
LOS	18:05	23:40	02:50	10:40	19:15	23:31	10:30	19:10	18:40
TOT	04:34	05:08	03:20	08:25	09:35	01:10	11:26	09:05	08:35
DSS T	05:13	07:02	02:04	09:43	10:04	01:14	11:33	09:53	09:21
COMMAND									
TOT	4	0	9	1	5	1	12	19	13
TELEMETRY									
DL	161.1	162.8	152.3	162.3	160.6	163.0	161.9	160.6	160.9
RES	.6	-1.1	1.3	-.6	1.1	-1.3	-.2	1.1	.8
BR	128	64	1024	128	128	64	128	128	128
SNR	1.5	4.9	2.6	1.1	2.4	5.8	2.3	2.7	2.7
RES	.2	-.4	.5	-1.7	.2	.8	.1	.9	.9
TRACKING									
MODE	2	1	2	2	2	2	2	2	2
T PWR	10	N/A	20	20	10	10	20	10	10
D RES	N/A	N/A	.860	.704	-.779	N/A	-.780	.260	-.821
D NOS	.004	N/A	.004	.004	.005	N/A	.004	.002	.002
E NOS	.002	N/A	.002	.002	.002	.002	.002	.002	.011

COMMENTS

DSS 12/P0675	ONE-WAY TRACK. DIS RED.
DSS 14/P0675	DR 0621 TCP-B HALTED AT 005/01:02:54Z;SWITCHED TO TCP-A.
DSS 42/P0675	DR 0623 RAISED ON SNR DISCREPANCY AT 128BPS.
DSS 42/P0676	DR 0625 ANT DROVE OFF WHILE IN REAL TIME DRIVE 0855Z-0905Z ANT DROVE OFF ON SIDEREAL TAPE DRIVE 0950Z-0952Z.

Table A-3 (contd)

GENERAL									
DSS	12	62	12	63	14	63	12	63	12
PASS	0678	0679	0679	0680	0680	0681	0681	0682	0682
DOY	007	008	008	009	009	010	010	011	011
AOS	17:50	10:00	17:49	09:56	18:00	09:53	17:50	09:49	17:50
LOS	02:55	18:30	02:53	18:20	02:35	18:20	02:48	18:15	02:45
TOT	09:05	08:34	09:04	08:24	08:35	08:27	08:58	08:26	08:55
DSS T	10:40	09:17	11:34	09:13	09:41	10:26	10:21	11:09	10:18
COMMAND									
TOT	15	127	76	62	130	47	141	80	16
TELEMETRY									
DL	162.1	161.1	161.4	153.0	152.3	153.4	162.3	152.9	161.9
RES	-.4	.7	.4	.7	1.4	.3	-.5	.8	-.1
BR	64	128	128	1024	512	512	128	1024	64
SNR	5.2	2.7	2.0	2.8	3.9	4.9	1.5	2.0	3.5
RES	.5	.9	.2	-0.2	.1	.5	-.2	-.4	-.8
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	10	10	10	20	20	20	10	20	10
D RES	-.823	.868	-.856	-.873	-.886	-.920	-.922	N/A	-.950
D NOS	.010	.010	.005	.005	.004	.003	.004	N/A	.003
E NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 12/P0678 DR 0627 XMTR FAIL TRIPPED.
DSS 62/P0679 RCVR 1 FAIL DR 0630 1745Z.
DSS 14/P0680 DR 0632-LOST TCP/DDA INTERFACE AT B/R CHANGE,SWITCHED TO B/U TCP.
DSS 12/P0681 DR 0633.
DSS 63/P0682 NO PSEUDO-RESID.

Table A-3 (contd)

GENERAL									
DSS	62	63	63	12	44	63	12	51	11
PASS	0683	0684	0685	0685	0685	0686	0686	0687	0687
DOY	012	013	014	014	015	015	015	016	016
AOS	09:45	09:43	09:40	17:45	07:44	09:36	17:45	10:10	16:49
LOS	18:15	18:15	18:05	02:39	09:40	18:04	02:31	17:45	02:37
TOT	08:30	08:32	08:25	08:54	01:56	08:28	08:46	07:35	09:48
DSS T	09:10	09:59	10:07	10:36	02:02	10:20	10:15	08:23	10:54
COMMAND									
TOT	5	63	8	16	53	141	43	8	6
TELEMETRY									
DL	160.9	152.9	152.9	160.9	160.7	153.3	161.7	161.6	161.9
RES	.9	.9	.9	.9	1.2	.5	.1	.2	-.1
BR	128	1024	1024	128	64	1024	128	128	128
SNR	2.5	2.0	3.0	2.9	1.2	3.0	2.9	2.2	1.1
RES	.9	-.2	.5	1.2	.9	.3	1.0	-1.1	-0.6
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	10	10	20	10	20	20	10	10	20
D RES	-.970	-1.008	-1.029	-1.029	N/A	-1.051	-1.067	-1.042	-1.103
D NOS	.003	.003	.005	.005	N/A	.005	.005	.005	.005
E NOS	.002	.002	.002	.002	N/A	.002	.002	.002	.002

COMMENTS

DSS 12/P0686 DR 0638-TCP ANOMALY AT B/R CHANGE AT 1827.

DSS 11/P0687 DR 0641-COMPLEX-WIDE POWER FAILURE AT 0026.

Table A-3 (contd)

GENERAL									
DSS	62	63	12	62	12	62	43	63	42
PASS	0688	0689	0689	0690	0690	0691	0691	0692	0692
DOY	017	018	018	019	019	020	020	021	022
AOS	09:34	09:27	17:15	09:30	17:18	09:30	22:07	09:20	21:41
LOS	17:56	17:50	02:29	17:46	02:25	18:00	09:40	18:25	09:35
TOT	08:22	08:23	09:14	08:16	09:07	08:30	11:33	09:05	11:54
DSS T	09:40	09:49	10:02	09:40	09:41	09:23	13:32	09:26	13:41
COMMAND									
TOT	159	9	9	9	10	7	249	2	3
TELEMETRY									
DL	160.8	152.8	162.1	160.9	161.8	160.7	153.7	153.2	161.5
RES	1.0	1.0	.1	.9	.0	1.2	.1	.6	.4
BR	128	1024	64	128	64	64	1024	1024	64
SNR	2.6	1.9	4.4	1.5	4.5	4.8	3.3	2.7	4.8
RES	.4	-.6	.2	-.3	.1	.3	.4	.1	.2
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	10	20	10	10	10	20	20	20	20
D RES	-1.130	-1.150	-1.137	-1.179	-1.174	-1.199	-1.188	-1.229	-1.221
D NOS	.006	.004	.004	.004	.004	.006	.003	.004	.006
F NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 62/P0688	DR 0643 TCP A TLM HUNG UP AT B/R CHANGE AT 114025Z. DR 0644 TCP B TLM PORTION HUNG-UP AT B/R CHANGE.
DSS 12/P0689	DSS 12 DR 0646-OPTR ERROR DUE TO TYPE-IN WRONG WHEN DISABLING CONSCAN-AGC.
DSS 12/P0690	DR 0651: 011408 TXR OFF DUE TO ARC DETECTOR INTERLOCK
DSS 43/P0691	DR 0654: W/G SWITCH TRIPPED XMTR OFF AT 020-23-06-18Z (PRESSURE LOW) XMTR BACK ON AT 021-00-10-00Z.
DSS 42/P0692	DR 0657 TCR PROG DOWN.

Table A-3 (contd)

GENERAL									
DSS	62	43	62	42	63	12	42	62	14
PASS	0693	0693	0694	0694	0695	0695	0695	0696	0696
DOY	022	022	023	024	024	024	025	025	025
AOS	09:15	21:37	09:19	01:47	09:09	17:15	01:43	09:15	17:13
LOS	17:45	09:41	17:50	09:35	17:37	02:05	09:40	17:35	00:00
TOT	08:30	12:04	08:31	07:48	08:26	08:50	07:57	08:20	07:13
DSS T	10:25	13:47	10:01	09:05	10:11	09:51	10:38	10:12	07:35
COMMAND									
TOT	0	172	0	10	21	203	176	67	85
TELEMETRY									
DL	160.8	154.2	160.8	161.4	154.7	163.4	162.6	161.4	153.2
RES	1.1	-.4	1.1	.5	-.9	-1.5	-.7	.5	.6
BR	64	1024	64	64	1024	64	128	64	1024
SNR	4.9	3.2	4.6	3.7	1.6	2.6	1.2	4.4	2.9
RES	.5	N/A	.2	-1.1	-.6	-1.9	-.8	+0.1	.1
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	20	10	20	20	10	20	10	20
D RES	.837	.497	.473	.481	.470	.468	N/A	.459	.459
D NOS	.004	.005	.005	.005	.005	.006	.008	.010	.010
F NOS	.002	.002	.002	.002	.002	.002	.002	.002	.002

COMMENTS

DSS 43/P0693 DR 0660 DDA 2 GIVING CONSTANT ALARM,DATA BLOCK LOST DDB COUPLER UNDER INVESTIGATION.

Table A-3 (contd)

GENERAL									
DSS	42	63	12	43	63	14	42	51	12
PASS	0696	0697	0697	0697	0698	0698	0698	0699	0699
DOY	026	026	026	027	027	027	028	028	028
AOS	23:34	09:01	17:13	01:21	08:58	16:50	01:27	08:45	16:50
LOS	09:30	17:32	02:00	09:20	17:20	01:45	09:30	17:22	02:00
TOT	09:56	08:31	08:47	07:59	08:22	08:55	08:03	08:37	09:10
DSS T	11:40	09:32	09:00	09:22	10:08	10:10	09:30	N/A	11:08
COMMAND									
TOT	3	149	25	8	7	4	1	0	11
TELEMETRY									
DL	162.8	153.8	161.6	154.9	153.9	153.0	162.1	N/A	161.3
RES	-.9	.0	.3	-1.1	-.1	.8	-.2	N/A	.6
BR	64	1024	128	1024	1024	1024	64	N/A	64
SNR	4.4	2.8	1.5	2.9	2.8	3.8	2.3	N/A	4.3
RES	-.4	N/A	-0.3	-.2	+0.2	1.1	.4	N/A	.3
TRACKING									
MODE	2	2	2	2	2	2	2	N/A	2
T PWR	20	20	10	20	20	20	20	N/A	10
D RES	.440	.499	.476	.436	.466	.505	.453	N/A	.641
D NOS	N/A	.016	.014	.020	.015	.020	.015	N/A	.050
E NOS	N/A	.002	.002	N/A	.002	.002	N/A	N/A	.002

COMMENTS

DSS 42/P0696 DR 0826 DOPPLER COUNTER RESET AT APPROX 0714Z.

DSS 43/P0697 DR 0666 SPURIOUS PEDESTAL EMERGNCY STOP CAUSED DATA GNTAGE.

DSS 12/P0699 1758Z DIS TO LINE AFTER HSD/WB I/O SWAPPED AND RE-LOADED DR 0668 REFERS.

Table A-3 (contd)

GENERAL									
DSS	42	62	11	43	51	12	11	43	63
PASS	0699	0700	0700	0700	0701	0701	0701	0701	0702
DOY	029	029	029	030	030	030	030	031	031
AOS	01:22	09:05	16:24	00:48	08:52	17:00	18:43	01:45	08:47
LOS	09:25	17:13	01:35	09:15	07:15	19:05	01:50	09:20	17:20
TOT	08:03	08:08	09:11	08:27	08:23	02:05	05:07	07:35	08:33
DSS T	10:04	09:34	11:06	10:22	09:09	02:42	05:08	09:57	09:24
COMMAND									
TOT	2	0	2	149	28	0	2	22	12
TELEMETRY									
DL	162.0	160.8	162.5	153.8	161.5	156.0	162.8	154.6	157.1
RES	-.1	+1.1	-.6	.0	.4	1.9	-.9	-.7	N/A
BR	64	64	64	1024	128	64	64	64	512
SNR	3.1	5.6	3.2	3.2	1.4	5.1	2.6	2.2	2.9
RES	-0.2	+1.2	-1.3	.3	-.3	.6	-1.0	1.0	N/A
TRACKING									
MODE	2	2	2	2	2	2	2	2	2
T PWR	20	10	20	5	10	10	20	5	20
D RES	.476	.544	-2.361	.497	.466	N/A	N/A	.463	21.209
D NOS	.022	.025	.018	.015	.002	N/A	N/A	.016	.010
E NOS	N/A	.002	.002	N/A	.012	.002	N/A	N/A	.002

COMMENTS

DSS 11/P0701 NO DSS 11/PN10 PREDICTS. RESIDS FROM DSS 12 PREDICTS.

DSS 43/P0701 DR 0830 OPENED ON BAD RTLT ON PRDX PRINT.

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