Pioneer Mission Support

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The previous reports on the Jupiter-bound Pioneer F and G mission support delineated the mission description and the functional planning activities of the tracking and data system. Beginning with this current report, an account will be given of the actual management organization and engineering planning activities which were essential to assure an effective scientific data return and spacecraft control.

I. Introduction

The actual planning and implementation of the complex Deep Space Network's Mark III system was directed and controlled by a program management structure. After the specific *Pioneer F* and *G* flight support requirements were established, these requirements were merged with the network's standardized multimission "type capabilities" to assure cost-effective capabilities, which were compatible with both the *Pioneer* missions and most of the future NASA planetary and interplanetary missions. Specific management controls were applied to assure that the DSN Mark III system, as planned for *Pioneer F*, was ready for mission support, on time, within the budget, and with technical excellence. The actual management structure and techniques discussed in this report included the establishment of the appropriate level of detail for effective management control of subsystems, systems, network integration, and the optimization of all interfaces.

A description was given on the *Pioneer F* and *G* profiles, spacecraft design, and attitude control with special emphasis on tracking and data acquisition interfaces in Refs. 1–6. The last three reports described the DSN Mark III System and the *Pioneer F* and *G* Near-Earth/ Deep Space Phase Support Plan.

II. Management Structure

A. Pioneer Project Management

The management structure of the *Pioneer F* and *G* project is shown in Fig. 1. The NASA Headquarters Office of Space Sciences is responsible for the planetary programs. The *Pioneer* Program Manager heads all *Pioneer* Project related activities. NASA's Ames Research Center (ARC) located at Moffett Field, California, is in charge of all management coordination and control aspects for the *Pioneer* missions. The *Pioneer* Project Office is headed by the *Pioneer* Project Manager who is supported by a Project staff. They assist him in the areas of management control, mission analysis, launch coordination, nuclear power, scientist coordination, contracts, magnetics, reliability, and quality assurance. In addition, seven government-sponsored organizations are supporting the *Pioneer F* and *G* missions with specific services. The Space Nuclear Systems Division of the Atomic Energy Commission controls the development and production of the Radioisotope Thermoelectric Generators (RTGs). Teledyne Isotopes is the prime contractor for these generators. The Experiment System, Spacecraft System, and Mission Operations System are supported by individual teams of the Ames Research Center. The spacecraft contractor was TRW

Systems Group, TRW, Inc. The Bendix Field Engineering Corporation provides the electronic data processing support for the Mission Operations System. The Jet Propulsion Laboratory is the tracking and data acquisition center of the *Pioneer* missions, and it plans, manages, and controls the support during the near-Earth and deep space phases of the missions. The Launch Vehicle System is managed by the Lewis Research Center, and the contractors are the Convair Division of General Dynamics and McDonnell Douglas. The Unmanned Launch Operations of the Kennedy Space Center was supported by the Convair Division of General Dynamics.

B. The Tracking and Data Acquisition Function

1. Definition. The major function of the Tracking and Data Acquisition System (TDS) is the acquisition and transmission of information necessary to determine space vehicle position, velocity and direction, system and subsystem performance, and experiment measurements, all with respect to a common time base.

2. Tracking and Data Acquisition Support Center. In accordance with sections of the NASA Management Instructions (NMI 8430.1) concerning tracking and data acquisition support for unmanned space flight projects, NASA Headquarters has designated JPL as the Tracking and Data Acquisition Support Center for the *Pioneer* F and G missions. JPL is responsible for overall achievement of the tracking and data acquisition objectives and functions.

3. Tracking and Data System Manager. As required by NASA Management Instruction 8430.1 the Director of the Tracking and Data Acquisition Support Center (JPL) has designated the Tracking and Data System Manager who shall be responsible for the tracking and data acquisition function, as defined above. Basically, he acts as the interface between the Project and the Tracking and Data System Support Agencies to match requirements with the capabilities of the support agencies to establish a compatible, integrated system of tracking and data acquisition resources. The resulting composite of supporting resources is identified as the "Tracking and Data System."

The TDS Manager reviews the NASA Support Instrumentation Requirements Document (SIRD), which is prepared by the *Pioneer* Project manager and approved by NASA Headquarters, Office of Space Sciences and Office of Tracking and Data Acquisition. It is also the TDS manager's function to identify any inconsistencies and to insure that all requirements are identified with the Department of Defence (DOD) or NASA organizations. He also assures

the *Pioneer* Project that the NASA Network Support Plan (NSP) is prepared concurrently with the SIRD. He reviews the NSP and DOD Program Support Plan (PSP) to identify any conflicts, duplications, and possible omissions. He also certifies that all support planning is properly located and complete. The TDS Manager is accountable both to the *Pioneer* Project Manager to which he is assigned and to the assistant laboratory director for Tracking and Data Acquisition at JPL.

C. Tracking and Data System

1. General. The Tracking and Data System is an operationally unified collection of tracking and data acquisition resources. The required resources are provided by organizations under the Department of Defense, Goddard Space Flight Center (GSFC), and the Jet Propulsion Laboratory, herein referred to collectively as the Tracking and Data System Support Agencies. Although support agencies are not under the direct control of the Tracking and Data System manager, they are responsive to his needs through the systems of communication, coordination, and documentation.

2. Tracking and Data System support agencies

a. Department of Defense. Under the Department of Defense, the United States Air Force, Air Force Systems Command, manages the National Ranges: Air Force Eastern Test Range (AFETR) and Air Force Western Test Range (AFWTR). As lead range for the *Pioneer* F and G missions, the AFETR arranges for all support required from DOD resources.

b. Goddard Space Flight Center. NASA's Goddard Space Flight Center manages the Spaceflight Tracking and Data Network (STDN) network, and the NASA Communications System (NASCOM). Support required from these NASA resources is arranged through the appropriate organizational elements at GSFC.

c. Jet Propulsion Laboratory. The Jet Propulsion Laboratory is a NASA-owned installation, managed for NASA by the California Institute of Technology. With regard to the tracking and data acquisition function, JPL manages and operates the DSN. Support required from these resources is arranged through the JPL Office of Tracking and Data Acquisition.

3. Tracking and Data System configuration. Following is a general description of the Tracking and Data System. Because of support agencies' responsibilities and capabilities, the nature of project requirements, spacecraft

performance characteristics, and flight profiles, a major change in the required support configuration occurs naturally as the spacecraft proceeds from the near-Earth phase to the deep space phase of flight. Tracking and Data System preflight planning and flight operations support are oriented to coincide with these two phases. In effect, the Tracking and Data System manager established one system configuration for the near-Earth phase and another for the deep-space phase.

a. Near-Earth phase. The near-Earth phase begins with the launch countdown and ends when the spacecraft is in continuous view of the DSN stations. Normally, resources from all three support agencies comprise the configuration for the near-Earth phase. Data acquisition is provided by the AFETR land stations, ships, and aircraft; by STDN and by DSN stations in the near-Earth zone of operations. The John F. Kennedy Space Center (KSC), a field installation of NASA, manages certain instrumentation facilities available for TDA support. Support required from these sites is arranged through appropriate existing documentation. KSC is also the NASA single point-of-contact with the AFETR. Support required from the AFETR is contracted through the KSC.

For the near-Earth phase, the Tracking and Data System made available for *Pioneers F* and *G* the resources of the AFETR, KSC, the Spaceflight Tracking and Data System, the DSN, and the NASA Communications System.

b. Deep-space phase. The deep-space phase begins with deep space station continuous view and continues until the end of mission. Normally, the three facilities of the DSN are the only resources used to support data acquisition and processing requirements during this phase. The NASCOM and GCF resources are employed for data transmission. The support plan of the near-Earth and deep space phases of *Pioneer F* and *G* missions was reported in Ref. 6.

4. Tracking and Data System communication and coordination. The complexity of the Project and Tracking and Data System organization made it essential that a common means of communicating and coordinating tracking and data acquisition requirements, plans, procedures, reports, etc., existed between the Project and the Tracking and Data System, and also between support agencies. In addition to the frequent contacts which were made through the day-to-day business, two basic established methods provided the required information flow: (1) via standing committees and scheduled meetings, and (2) via formal documentation systems. Specific items under each of these categories are as follows:

a. Committees and meetings

(1) Planetary and Interplanetary Projects Tracking, Telemetry, and Communications Panel. This panel, chaired by the Tracking and Data System Office, meets approximately twice yearly, and its membership includes representatives of the *Pioneer* and other unmanned planetary and interplanetary projects, support agencies, launch vehicle agencies, and NASA Headquarters.

(2) Project/Tracking and Data System Quarterly Reviews. Project and Tracking and Data System personnel met quarterly with NASA Headquarters representatives, reviewed progress, and resolved problem areas.

(3) Ad Hoc Committees. The representation and frequency of meetings varied as required for the stated purposes.

b. Applicable documents. Support Agency and Tracking and Data System documents which were pertinent to the tracking and data acquisition function are only briefly discussed in this paragraph.

As separate entities supporting the Tracking and Data System, each support agency maintained its own internal documentation system. Without altering or controlling these internal documentation systems (e.g., DSN Documentation System, National Range Universal Documentation System, and Goddard Space Flight Center Documentation), the Tracking and Data System Manager has defined a Tracking and Data System documentation system which encompassed and supplemented the Support Agency documents. The Tracking and Data System Documentation System provided a comprehensive, unified description of the various documents produced in meeting the Project's tracking and data acquisition requirements. An outline of the documentation system is included here for general information:

(1) Tracking and Data System Standard Practices. These were prepared by the Tracking and Data System Manager. Of particular importance to the Project was the Tracking and Data System/Project Standard Technical Interface Document.

(2) Tracking and Data System Estimated Capabilities for the *Pioneer F* and *G* Missions. (607-96, dated December 15, 1969). This document was prepared by the Tracking and Data System Manager, based on inputs from the Near-Earth and Deep Space Support Agencies.

(3) Tracking and Data System Support Plan for the *Pioneer F* and *G* Missions. In actuality, this is comprised of the NASA Support Plan (NSP) and the Program Support Plan (PSP) for the *Pioneer F* and *G* Missions. It was prepared by the DSN Manager and by AFETR, respectively.

(4) Tracking and Data System Test Plan for the *Pioneer F* and *G* Missions. This document provided guidelines to and encompassed the near-Earth phase and the Deep Space Network test plans. It consisted of plans, procedures, and reports.

(5) Tracking and Data System Operation Plan for the *Pioneer F* and *G* Missions. This encompassed the near-Earth phase and Deep Space Network operations plans. Each plan contained numerous volumes regarding detailed commitments, interfaces, system descriptions, operational procedures, and directives. It included the Air Force Eastern Test Range Operations Directive and the Manned Space Flight Network Operations Plan.

(6) Tracking and Data System Support Reports for *Pioneer F* and *G*. These reports will be comprised of Tracking and Data System periodic progress reports and a final report.

D. TDS/Pioneer Project Planning Organization

The *Pioneer F* and *G* premission planning period spanned from project inception through operational readiness testing prior to launch.

The JPL Field Station, Air Force Eastern Test Range (JPL/ETR) organization operated by JPL Section 293, had the responsibility to plan and coordinate the required support by agencies involved in the support of the near-Earth phase of the *Pioneer F* and *G* missions. This organization advised the *Pioneer* Project on the long-term near-Earth TDS capabilities, and reviewed the TDA requirements and interface problems. They provided near-Earth phase assistance on the SIRD, NSP, Program Requirement Document (PRD), PSP, Operations Directive (OD), OR, Operations Plan (OP), and Tracking Instruction Manual (TIM). This organization planned and conducted the preflight compatibility verification and operational tests of the near-Earth system. They supported all interface reviews, analyzed plans and test results, and provided the required reports and documents. The near-Earth phase Project Engineer also acted collectively as an Assistant TDS Manager in matters related with the near-Earth function.

For the preparation and operation of the Deep Space Network a DSN/*Pioneer F* and *G* Operational Support and Planning Group was established. This organization consists of a DSN Manager, a DSN Project Engineer and a team of systems and facility-oriented project engineers.

Each position is devoted to supporting the *Pioneer F* and *G* Project. This organization is directly responsible to the Tracking and Data System Manager.

The DSN Manager is responsible for the planning and implementation of DSN support for the *Pioneer* Project. He was appointed for the *Pioneer* Project by the Jet Propulsion Laboratory. The DSN Manager is responsible for developing the support necessary to meet all flight project tracking and data acquisition requirements and for the operational readiness of the DSN. In addition, his functions will cover the flight operations to the end of the mission to be supported within the capabilities and resources of the DSN. The DSN Manager is responsible for the reviewing and clarification of the *Pioneer F* and *G* SIRD, for the preparation of the DSN portion of the NASA Network Support Plan, progress reports, and final report on implementation and readiness of the DSN for flight support. He conducts and documents pre- and post-flight operational readiness reviews and actual performance reviews of the network. He recommends changes to requirements and/or resources in order to meet mission objectives; observes and critiques the qualitative and quantitative performance of the DSN during flight operations, and terminates DSN support with approval of the flight project in a manner appropriate to the original commitment. He certifies to the TDS Manager the completion of task assignments and recommends actions in case of uncompleted tasks; prepares recommendations for improvements in flight project support, and provides the necessary interfaces between the Deep Space Network and other elements of the Tracking and Data System. The DSN Manager also functions as assistant TDS Manager, when requested.

The DSN project engineer is responsible for planning and coordinating all interface engineering. His function is to bring the DSN to a state of readiness and thus fulfill commitments which were made by DSN management in response to the particular *Pioneer* Project requirements. He is required to participate on the TDS planning team, under the TDS Manager and the DSN Manager during the early planning phases of the TDS DSN/Project activities. He assists in the definition of the data flow interfaces between the DSN and the other elements of the TDS. The DSN Project Engineer participated on the DSN Capabilities Planning Team and assisted the DSN Manager in defining DSN Systems Functional Specifications for *Pioneers F* and *G*. In response to the TDS and DSN milestone schedule, he produced and maintained a detailed implementation schedule reflecting the plan and status of DSN implementation, integration testing, training, documentation and operations. He coordinates the Interface Engineering Team; initiates actions necessary to complete events and tasks to meet the requirements of the NSP. He will evaluate the DSN performance by comparing actual

flight support with DSN commitments and Project requirements. The DSN Project Engineer is also responsible for assuring that scheduling inputs necessary for flight project support are submitted for the DSN Network Scheduling Office. He also participated in Mission Operations Working Group meetings established by the *Pioneer* Project. The DSN Project Engineer is accountable to the DSN Manager and to the Chief of *Pioneer* Mission Operations during all flight support activities.

The membership of the *Pioneer* F and G Interface Engineering Team consists of engineering representatives of the following organizations: DSIF Operations Engineering, DSIF Operations Planning, DSIF System Data Analysis, GCF Operations, SFOF/GCF Development, SFOF Data System, SFOF Data Processing, SFOF Support, DSN Simulation, and DSN System Engineering.

To assure that all Project/DSN interfaces are properly identified, the *Pioneer* Project was encouraged to participate in the team's activities. The Interface Team produced Volumes II through VIII of the DSN Operations Plan, DSN Test Plan, and Operations Reports. The team also performed detailed design functions pertaining to hardware/software and procedural interfaces. The team members are also performing advisory and operational roles during mission operations.

The efforts of the systems- and facility-oriented Project Engineers are coordinated by the DSN Project Engineer. Through this organization, talents available in the DSN can be applied to problems confronting the *Pioneer* planning organization. These people also support mission design teams, as follows:

(1) A Capability Planning Team staffed by DSN design personnel with a spacecraft telecommunication design and a mission operations representative from ARC. This team developed functional block diagrams and mission control interfaces of the DSN to a detail below that presented in this document.

(2) A Telecommunication Design Team chaired by ARC which consisted of spacecraft telecommunication engineers from ARC and TDS representatives from JPL.

(3) A Mission Operations Design Team chaired by ARC, with the DSN Project Engineer acting as a member of this team, for developing specific requirements for all elements of the ground system supporting the deep-space phase of these missions.

Figure 2 shows a part of JPL's organizational structure and identifies the Laboratory Divisions which support the major tracking and data acquisition functions for *Pioneers* F and G.

Under the Director of the Jet Propulsion Laboratory, the Assistant Laboratory Director for Tracking and Data Acquisition heads the system- and project-oriented functional organizations responsible for the Deep Space Network. The Engineering and Operations Section provides the System and Project Engineering functions and the DSN Operations Organization. The DSN Residents act as liaison between the DSN and the Deep Space Stations. The Mission Support Office is headed by the Tracking and Data System Manager. The DSN Managers provide the support for the specific current and future planetary and interplanetary missions. The DSN Systems Manager is responsible for the design of the DSN systems. The Tracking and Data Acquisition Program Control Office is engaged in the financial, budgeting and control functions.

Under the Assistant Laboratory Director for Technical Divisions, the Telecommunications Division is responsible for research, design, and implementation of the Deep Space Stations. The Mission Analysis Division is in charge of the space navigation and orbit determination functions. It assists DSN in the areas of research related to the radio metric tracking function. The Office of Computing and Information Systems heads the Data Systems Division which is responsible for the research, design, and implementation of the SFOF, and the Ground Communications Facility. The Facility System Engineers who handle the DSN Telemetry, Command, Tracking, Monitoring, Simulation, and Operations Control Systems are resident in the Telecommunications and Data Systems Divisions and interface with the corresponding DSN Systems engineers resident in the DSN Engineering and Operations Sections.

The JPL Systems Test and Launch Operations Section (not shown in Fig. 2) supports the JPL/ETR Station. This station was engaged in the Near-Earth Phase planning activities of the *Pioneer* F and G Missions.

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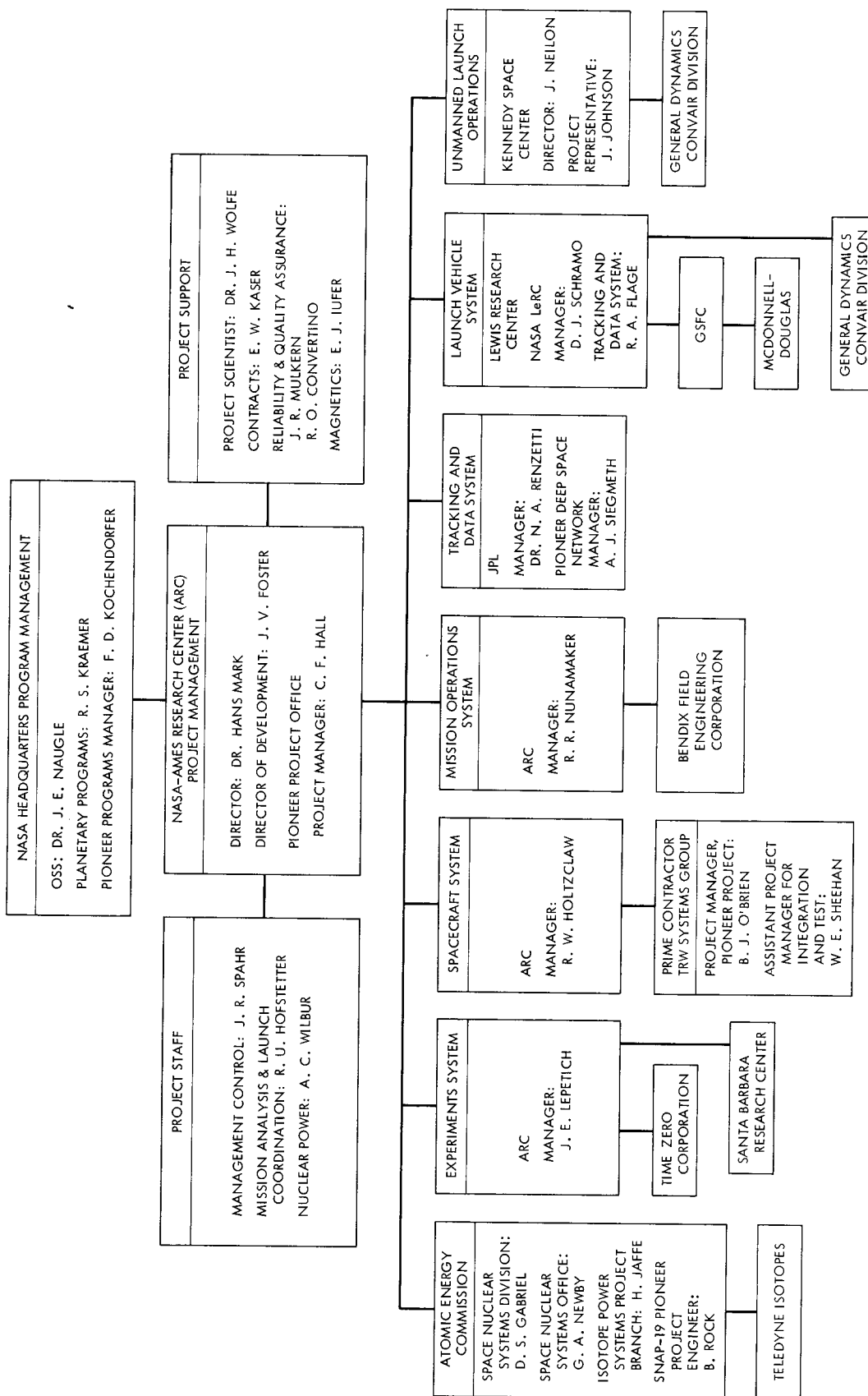
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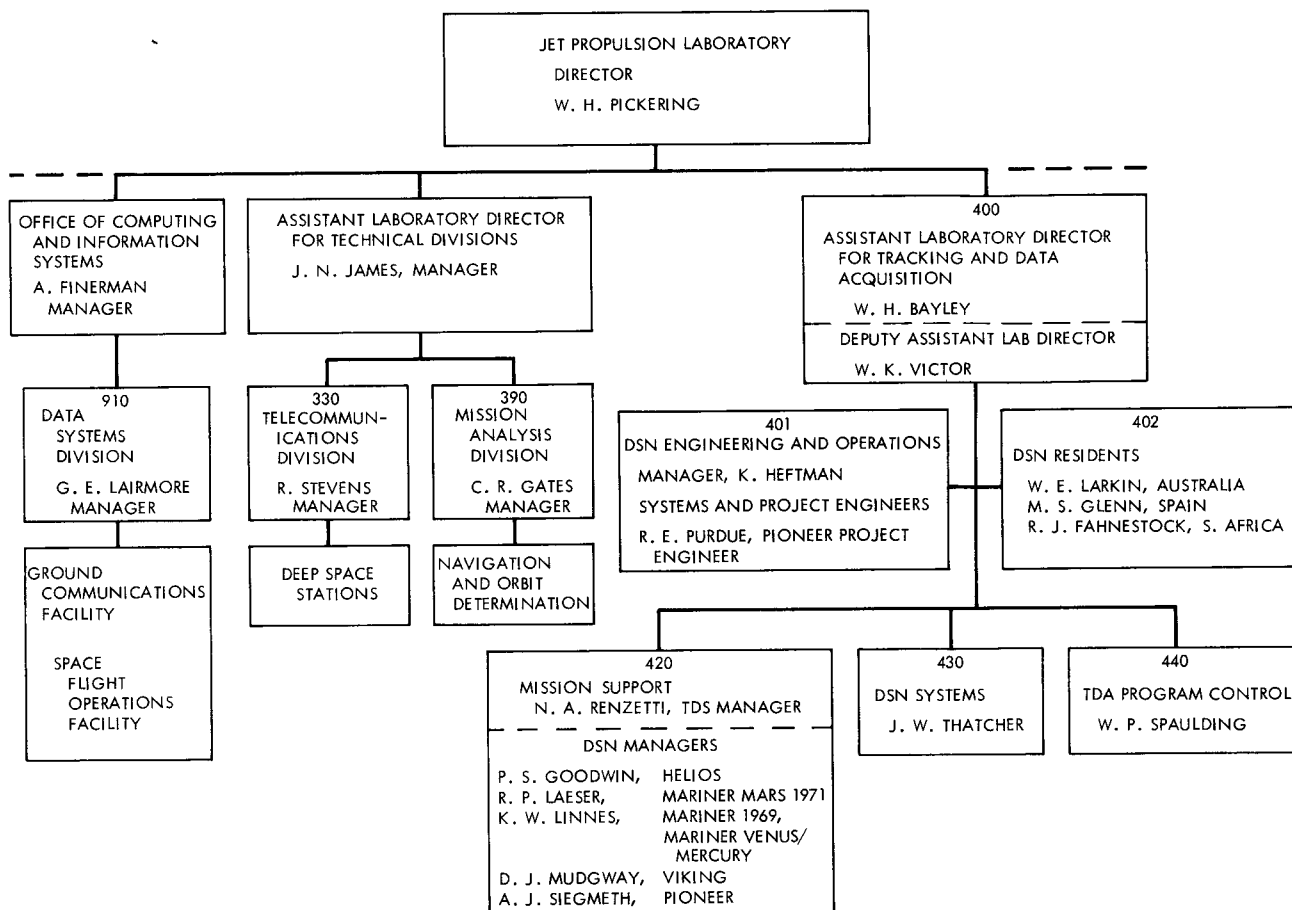**Fig. 1. Pioneer F and G Program Management Team**

Fig. 2. JPL divisions engaged in tracking and data acquisition support of *Pioneers F and G*