I. Introduction

A. Description of the DSN

The Deep Space Network (DSN), established by the NASA Office of Tracking and Data Acquisition under the system management and technical direction of JPL, is designed for two-way communications with unmanned spacecraft traveling approximately 10,000 mi from earth to planetary distances. It supports, or has supported, the following NASA deep space exploration projects: *Ranger*, *Surveyor*, *Mariner* Venus 1962, *Mariner* Mars 1964, *Mariner* Venus 67, *Mariner* Mars 1969, *Mariner* Mars 1971 (JPL); *Lunar Orbiter* and *Viking* (Langley Research Center); *Pioneer* (Ames Research Center); *Helios* (West Germany); and *Apollo* (Manned Spacecraft Center), to supplement the Manned Space Flight Network (MSFN).

The DSN is distinct from other NASA networks such as the MSFN, which has primary responsibility for tracking the manned spacecraft of the *Apollo* Project, and the Space Tracking and Data Acquisition Network (STADAN), which tracks earth-orbiting scientific and communications satellites. With no future unmanned lunar spacecraft presently planned, the primary objective of the DSN is to continue its support of planetary and interplanetary flight projects.

To support flight projects, the DSN simultaneously performs advanced engineering on components and systems, integrates proven equipment and methods into the network,[1] and provides direct support of each project through that project's Tracking and Data System. This management element and the project's Mission Operations personnel are responsible for the design and operation of the data, software, and operations systems required for the conduct of flight operations. The organization and procedures necessary to carry out these activities are described in SPS 37-50, Vol. II, pp. 15–17.

By tracking the spacecraft, the DSN is involved in the following data types:

(1) *Metric:* generate angles, one- and two-way doppler, and range.

(2) *Telemetry:* receive, record, and retransmit engineering and scientific data.

[1]When a new piece of equipment or new method has been accepted for integration into the network, it is classed as Goldstone duplicate standard (GSDS), thus standardizing the design and operation of identical items throughout the network.

(3) *Command:* send coded signals to the spacecraft to activate equipment to initiate spacecraft functions.

The DSN operation is characterized by six DSN systems: (1) tracking, (2) telemetry, (3) command, (4) monitoring, (5) simulation, and (6) operations control.

The DSN can be characterized as being comprised of three facilities: the Deep Space Instrumentation Facility (DSIF), the Ground Communications Facility (GCF), and the Space Flight Operations Facility (SFOF).

1. Deep Space Instrumentation Facility

a. Tracking and data acquisition facilities. A worldwide set of deep space stations (DSSs) with large antennas, low-noise phase-lock receiving systems, and high-power transmitters provide radio communications with spacecraft. The DSSs and the deep space communications complexes (DSCCs) they comprise are given in Table 1.

Radio contact with a spacecraft usually begins when the spacecraft is on the launch vehicle at Cape Kennedy, and it is maintained throughout the mission. The early part of the trajectory is covered by selected network stations of the Air Force Eastern Test Range (AFETR) and the MSFN of the Goddard Space Flight Center.[2] Normally, two-way communications are established between the spacecraft and the DSN within 30 min after the spacecraft has been injected into lunar, planetary, or interplanetary flight. A compatibility test station at Cape Kennedy (discussed later) monitors the spacecraft continuously during the launch phase until it passes over the local horizon. The deep space phase begins with acquisition by either DSS 51, 41, or 42. These and the remaining DSSs given in Table 1 provide radio communications to the end of the flight.

To enable continuous radio contact with spacecraft, the DSSs are located approximately 120 deg apart in longitude; thus, a spacecraft in deep space flight is always within the field-of-view of at least one DSS, and for several hours each day may be seen by two DSSs. Furthermore, since most spacecraft on deep space missions travel within 30 deg of the equatorial plane, the DSSs are located within latitudes of 45 deg north or south of the equator. All DSSs operate at S-band frequencies: 2110–2120 MHz for earth-to-spacecraft transmission and 2290–2300 MHz for spacecraft-to-earth transmission.

To provide sufficient tracking capability to enable useful data returns from around the planets and from the edge of the solar system, a 210-ft-diam-antenna network will be required. Two additional 210-ft-diam-antenna DSSs are under construction at Madrid and Canberra, which will operate in conjunction with DSS 14 to provide this capability. These stations are scheduled to be operational by early 1973.

[2]The 30-ft-diam-antenna station established by the DSN on Ascension Island during 1965 to act in conjunction with the MSFN orbital support 30-ft-diam-antenna station was transferred to the MSFN in July 1968.

Table 1. Tracking and data acquisition stations of the DSN

DSCC	Location	DSS	DSS serial designation	Antenna		Year of initial operation
				Diameter, ft	Type of mounting	
Goldstone	California	Pioneer	11	85	Polar	1958
		Echo[a]	12	85	Polar	1962
		(Venus)[b]	13	(85)	(Az–El)	(1962)
		Mars	14	210	Az–El	1966
Canberra	Australia	Woomera[c]	41	85	Polar	1960
		Tidbinbilla[c]	42	85	Polar	1965
—	South Africa	Johannesburg[c]	51	85	Polar	1961[d]
Madrid	Spain	Robledo[c]	61	85	Polar	1965
		Cebreros[c]	62	85	Polar	1967

[a]Established in 1959 to support NASA's *Echo* Project to explore the feasibility of transcontinental two-way communications using a passive satellite; DSS 12 was originally configured with an 85-ft-diam az–el-mounted antenna. In 1962, when the need arose for a second 85-ft-diam polar-mounted antenna at the Goldstone site, the 85-ft-diam az–el-mounted antenna was moved to DSS 13, and an 85-ft-diam polar-mounted antenna was constructed at DSS 12.

[b]A research-and-development facility used to demonstrate the feasibility of new equipment and methods to be integrated into the operational network. Besides the 85-ft-diam az–el-mounted antenna, DSS 13 has a 30-ft-diam az–el-mounted antenna that is used for testing the design and operation of the feed system for the DSS 14 210-ft-diam antenna.

[c]Normally staffed and operated by government agencies of the respective countries (except for a temporary staff of the Madrid DSCC), with some assistance of U.S. support personnel.

[d]Between 1958 and 1962, a temporary mobile tracking station was located near Johannesburg to provide L-band communications required by the *Ranger* and *Mariner* Venus 1962 spacecraft.

b. Compatibility test facilities. In 1959, a mobile L-band compatibility test station was established at Cape Kennedy to verify flight-spacecraft DSN compatibility prior to the launch of the *Ranger* and *Mariner* Venus 1962 spacecraft. Experience revealed the need for a permanent facility at Cape Kennedy for this function. An S-band compatibility test station with a 4-ft-diam antenna became operational in 1965. In addition to supporting the preflight compatibility tests, this station monitors the spacecraft continuously during the launch phase until it passes over the local horizon.

Spacecraft telecommunications compatibility in the design and prototype development phases was formerly verified by tests at the Goldstone DSCC. To provide a more economical means for conducting such work and because of the increasing use of multiple-mission telemetry and command equipment by the DSN, a compatibility test area (CTA) was established at JPL in 1968. In all essential characteristics, the configuration of this facility is identical to that of the 85- and 210-ft-diam-antenna stations.

The JPL CTA is used during spacecraft system tests to establish the compatibility with the DSN of the proof test model and development models of spacecraft, and the Cape Kennedy compatibility test station is used for final flight spacecraft compatibility validation testing prior to launch.

2. Ground Communications Facility

The GCF, using, in part, facilities of the worldwide NASA Communications Network (NASCOM),[3] provides voice, high-speed data, and teletype communications between the SFOF and all DSSs, except those of the Goldstone DSCC. Communications between the Goldstone DSCC and the SFOF are provided by a microwave link leased from a common carrier. Early missions were supported with voice and teletype circuits only, but increased data rates necessitated the use of wide-band circuits from all DSSs.

[3]Managed and directed by the Goddard Space Flight Center.

3. Space Flight Operations Facility

Network and mission control functions are performed by the SFOF at JPL. (Prior to 1964, these functions were performed in temporary facilities at JPL.) The SFOF receives data from all DSSs and processes that information required by the flight project to conduct mission operations. The following services are provided: (1) real-time processing and display of metric data; (2) real-time and non-real-time processing and display of telemetry data; (3) simulation of flight operations; (4) near-real-time evaluation of DSN performance; (5) operations control, and status and operational data display; and (6) general support such as internal communications by telephone, intercom, public address, closed-circuit TV, documentation, and reproduction of data packages. Master data records of science data received from spacecraft are generated. Technical areas are provided for flight project personnel who analyze spacecraft performance, trajectories, and generation of commands.

The SFOF is equipped to support many spacecraft in flight and those under test in preparation for flight. Over a 24-h period in 1967, as many as eight in-flight spacecraft or operational-readiness tests for flight were supported by the SFOF.