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TELECOMMUNICATIONS AND RADIO-METRIC SUPPORT FOR A MANNED MISSION TO MARS[1]

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ABSTRACT

This paper describes some general characteristics of the Deep Space Network and relates them to services needed by a manned mission to Mars. Specific details of the Network's current capabilities and those planned for the near future may be found in the reference.

DISCUSSION

NASA's Deep Space Network is a multimission telecommunications and radio-metric facility used to support space science and exploration. The Network is physically located on three continents, i.e. in southern California, U.S.A.; near Madrid, Spain; and near Canberra, Australia, and provides nearly complete coverage of deep space. It is designed and managed overall by California Institute of Technology's Jet Propulsion Laboratory (JPL), and its California facilities are installed and operated by contractors to JPL. The Network's overseas facilities are managed locally and operated by agencies of the Spanish and Australian governments via international agreements.

The Network's basic services are telemetry reception, command transmission, and radio-metric data (position and velocity) acquisition. The ability to provide these services enables the Network also to perform flight radio science, radio astronomy, very long baseline interferometry (VLBI), geodynamics measurements, and searches for extraterrestrial intelligence (SETI). It's very stable radio-metric instruments have been used to attempt gravitational wave detection, and its long-term radio-metric measurements of the Viking Landers contributed to tests of general relativity.

The Network transmits at frequencies of 2025 to 2120 MHz and receives at frequencies of 1659 to 1675 MHz, 2200 to 2300 MHz, and 8400 to 8500 MHz. Transmission at 7145 to 7190 MHz will be provided for

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Project Galileo in 1987, and spectrum space has been allocated for deep space communications in the vicinity of 32 GHz downlink and 34 GHz uplink. Space-based antennas, both microwave and optical, have been considered from time to time and may become a reality in the 21st century.

There are three or four antennas at each site, i.e. California, Madrid, and Canberra. The most sensitive antenna system at each site can receive data from Voyager-class spacecraft (20 Watts transmitter power and 48.2 dB antenna gain at 8400 to 8500 MH_z) at rates of 115.2 kbps from Jupiter or 44.8 kbps from Saturn. The Network's other antenna systems are also very sensitive. If, for example, a Mars mission has a 1.5-meter directional antenna and a 100-W transmitter operating within 8400 to 8500 MHz, the Network's regular 34-meter antenna system can simultaneously receive digital voice communications (9.6 kbps), 16 kbps telemetry, and 16.4 kbps slow scan TV (8 seconds per black and white picture of 128 x 128 pixels). Three to four times this basic total amount of data can be received using the Network's most sensitive antennas, and about five times the basic amount can be received if antennas are arrayed.

Network transmitters operate at 20 kW to 100 kW, depending upon mission need. These transmitted power levels are up to 10^{28} times greater than the received telemetry power level cited in the previous paragraph and provide ample uplink communications capability to an omnidirectional antenna at Mars and substantial signal-to-noise ratios at Mars, thereby enabling satisfactory radio-metric measurements. A transmitter capable of 400 kW is also available for emergency situations.

With present or currently planned equipment, the Network can process downlink data at rates of 6 bps to 5 Mbps with an undetected bit error rate of 1 part in 10^6 or less. The Network achieves a frequency stability of 7 parts in 10^{14}, which enables radio-metric data precisions in angle and angle rate of 50 nanoradians and 5 picoradians per second, respectively, and in range and range rate of 5 meters and 2 millimeters per second, repectively. Together, these capabilities allow important position and velocity measurements at Mars.

Beginning with its first antenna in 1958, the Network has been managed as an evolving capability. New technologies have been planned as potential needs appeared and then implemented as these needs were confirmed. Equally important, Network research and development has often identified opportunities for new telecommunications or radio-metric capabilities, which were implemented when user requirements arose. The Network's objective has always been to offer the most capable and cost-effective telecommunications and radio-metric service possible, integrated over all Network users.

Current Network research and development and planning studies are considering the following capablities: reception in selected frequency bands over the entire range of 1 to 50 GHz, 500 MHz instantaneous band-widths, communications coding techniques that will double link efficiencies, 1 part in 10^{17} frequency stability, and 5 nanoradian radio navigation by very long baseline interferometry (VLBI), as well as the orbiting antennas mentioned above. These capabilities will be developed whenever users require.

As indicated above, the Network's current technology can amply support both the communications needs and the interplanetary and local navigation needs of a manned mission to Mars. New capabilities installed to meet the requirements of future missions will extend that ability before the turn of the century.

REFERENCE

DEEP SPACE NETWORK/FLIGHT PROJECT INTERFACE DESIGN HANDBOOK, Vol. I, Existing DSN Capabilities; Vol. II, Proposed DSN Capabilities, Document 810-5, Rev. D, Pasadena, California: Jet Propulsion Laboratory, California Institute of Technology, 1984.