SAMPLE

Cosmic Explorers: The Deep Space Network

How We Talk to Probes Billions of Kilometers Away

Aira Astralis

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Conclusion

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Introduction

The NASA Deep Space Network (DSN) is a worldwide network of spacecraft communication ground segment facilities, located in the United States (California), Spain (Madrid), and Australia (Canberra), that supports NASA's interplanetary spacecraft missions. It also performs radio and radar astronomy observations for the exploration of the Solar System and the universe, and supports selected Earth-orbiting missions. DSN is part of the NASA Jet Propulsion Laboratory (JPL).

DSN currently consists of three deep-space communications facilities located such that a distant spacecraft is always in view of at least one station. They are: the Goldstone Deep Space Communications Complex (35 degrees25'36"N 116 degrees53'24"W) about 60 kilometres (37 mi) north of Barstow, California.

The others are the Madrid Deep Space Communications Complex (40 degrees25'53"N 4 degrees14'53"W), 60 kilometres (37 mi) west of Madrid, Spain; and the Canberra Deep Space Communication Complex (CDSCC) in the Australian Capital Territory (35 degrees24'05"S 148 degrees58'54"E), 40 kilometres (25 mi) southwest of Canberra, Australia near the Tidbinbilla Nature Reserve. Each facility is situated in semi-mountainous, bowl-shaped terrain to help shield against radio frequency interference.

The strategic placement of the stations permits constant observation of spacecraft as the Earth rotates, which helps to make the DSN the largest and most sensitive scientific telecommunications system in the world. The DSN supports NASA's contribution to the scientific investigation of the Solar System: It provides a two-way communications link that guides and controls various NASA uncrewed interplanetary space probes, and brings back the images and new scientific information these probes collect. All DSN antennas are steerable, high-gain, parabolic reflector antennas.

The antennas and data delivery systems make it possible to:

Other countries and organizations also run deep space networks.

The DSN operates according to the standards of the Consultative Committee for Space Data Systems, as do most other deep space networks, and hence the DSN is able to inter-operate with the networks of other space agencies. These include the Soviet Deep Space Network, the Chinese Deep Space Network, the Indian Deep Space Network, the Japanese Deep Space Network, and the ESTRACK of the European Space Agency. These agencies often cooperate for better mission coverage.

In particular, DSN has a cross-support agreement with ESA that allows mutual use of both networks for more effectiveness and reduced risk. In addition, radio astronomy facilities, such as the Parkes Observatory, the Green Bank Telescope, and the Very Large Array, are sometimes used to supplement the antennas of the DSN. The antennas at all three DSN Complexes communicate directly with the Deep Space Operations Center (also known as Deep Space Network operations control center) located at the JPL facilities in Pasadena, California.

In the early years, the operations control center did not have a permanent facility. It was a provisional setup with numerous desks and phones installed in a large room near the computers used to calculate orbits. In July 1961, NASA started the construction of the permanent facility, Space Flight Operations

Facility (SFOF). The facility was completed in October 1963 and dedicated on May 14, 1964.

In the initial setup of the SFOF, there were 31 consoles, 100 closed-circuit television cameras, and more than 200 television displays to support Ranger 6 to Ranger 9 and Mariner 4. Currently, the operations center personnel at SFOF monitor and direct operations, and oversee the quality of spacecraft telemetry and navigation data delivered to network users.

In addition to the DSN complexes and the operations center, a ground communications facility provides communications that link the three complexes to the operations center at JPL, to space flight control centers in the United States and overseas, and to scientists around the world. Tracking vehicles in deep space is quite different from tracking missions in low Earth orbit (LEO).

Deep space missions are visible for long periods of time from a large portion of the Earth's surface, and so require few stations (the DSN has only three main sites).

The wing would include a MSFN control room and the necessary interface equipment to accomplish the following:

Permit tracking and two-way data transfer with either spacecraft during lunar operations.

Chapter 01: The Discovery of The Deep Space Network

Like every other deep space network, the DSN follows the standards of the Consultative Committee for Space Data Systems, which is what lets its stations inter-operate with those of other agencies. Because a distant spacecraft remains in view for hours at a stretch from much of the planet, the network needs only a handful of stations, and the DSN keeps just three main sites.

These few stations, however, require huge antennas, ultra-sensitive receivers, and powerful transmitters in order to transmit and receive over the vast distances involved. Deep space is defined in several different ways.

According to a 1975 NASA report, the DSN was designed to communicate with "spacecraft traveling approximately 16,000 km (10,000 miles) from Earth to the farthest planets of the solar system." JPL diagrams state that at an altitude of 30,000 km (19,000 mi), a spacecraft is always in the field of view of one of the tracking stations.

The International Telecommunication Union, which sets aside various frequency bands for deep space and near Earth use, defines "deep space" to start at a distance of 2 million km (1.2 million mi) from the Earth's surface. The NASA Deep Space Network can both send and receive in all of the ITU deep space bands-S-band (2 GHz), X-band (8 GHz), and Ka-band (32 GHz).

Frequency usage has in general moved upward over the life of the DSN, as higher frequencies have higher gain for the same size antenna, and the deep space bands are wider, so more data can be returned. However, higher frequencies also need more accurate pointing (on the spacecraft) and more precise antenna surfaces (on Earth), so improvements in both spacecraft and the DSN were required to move to higher bands. Early missions used S-band for both uplink and downlink.

Viking (1975) had X-band as an experiment, and Voyager (1977) was the first to use it operationally. Similarly, Mars Observer (1994) carried a Ka-band experiment, Mars Reconnaissance Orbiter (2005) had a Ka-band demo, and Kepler (2009) was the first mission to use Ka-band as the primary downlink. However, not all space missions can use these bands.

The Moon, the Earth-moon Lagrange points, and the Earth-Sun Lagrangian points L1 and L2 are all closer than 2 million km from Earth (distances are here), so they are considered near space and cannot use the ITU's deep space bands. Missions at these locations that need high data rates must therefore use the "near space" K band (27 GHz).

Since NASA has several such missions (such as the James Webb Space Telescope and the Lunar Reconnaissance Orbiter), they have enhanced the Deep Space Network to receive (but not transmit) at these frequencies as well. The DSN is also pursuing optical deep space communication, offering greater communication speeds at the cost of susceptibility to weather and the need for extremely precise pointing of the spacecraft. This technology is working in prototype form.

On December 3, 1958, JPL was transferred from the US Army to NASA and given responsibility for the design and execution of lunar and planetary exploration programs using remotely controlled spacecraft. Shortly after the transfer, NASA established the concept of the Deep Space Network as a separately managed and operated communications system that would accommodate all deep space missions, thereby avoiding the need for each flight project to acquire and operate its own specialized space communications network.

The DSN was given responsibility for its own research, development, and operation in support of all of its users. Under this concept, it has become a world leader in the development of low-noise receivers; large parabolic-dish antennas; tracking, telemetry, and command systems; digital signal processing; and deep space navigation. The Deep Space Network formally announced its intention to send missions into deep space on Christmas Eve 1963; it has remained in continuous operation in one capacity or another ever since.

The largest antennas of the DSN are often called on during spacecraft emergencies. Almost all spacecraft are designed so normal operation can be conducted on the smaller (and more economical) antennas of the DSN, but during an emergency the use of the largest antennas is crucial.

A closing note belongs in the discovery account about what discovery meant for a network rather than a world. The founding decision, made in the first months of NASA's existence, was to build a facility rather than a series of mission-specific stations, and the decision was argued at the time on grounds of economy: one shared network would cost less than a ground station per mission. The economy proved real, but the greater return was invisible in 1958: a facility built for all missions had to be engineered for no particular mission, which meant generous margins, general-purpose electronics, and a staff whose job was the art of communication itself. Every later chapter of this book is a consequence of that choice, and the discovery chapter's final word is that the network's real founding was not the tracking of a satellite but the decision to make the tracking permanent.

The early organizational history carries one more fact worth keeping: the network's independence was argued and won. The first proposal for a shared facility, advanced in the founding year, was resisted by mission project offices that preferred their own dedicated stations, on the reasonable ground that a project should control its lifeline, and the counter-argument, that a network's shared hours would cost less and outperform any single mission's private system, prevailed only because the early missions' needs arrived before their stations could have been built. The network thus began with a queue, and the queue, more than any technical document, is the true founding charter: the first missions learned that the ground segment was a place in line, and the line has been the network's everyday reality ever since.

One discovery-era fact belongs in the account precisely because it was invisible at the time: the network's first decade of tracking data still serves the science of the present. The orbit fits, Doppler records, and station logs of the early missions have been revisited by researchers testing the long-term behavior of the planets, the wobble of the Earth's own rotation, and even the faint tests of gravitational theory, and the archive, kept continuously from the first passes, has quietly become one of the longest unbroken scientific data sets in existence. The founders who mandated the logging of everything built a second instrument without knowing it, and the discovery chapter's last word is that the network's first discovery, still in progress, has been the value of its own memory.

The discovery chapter's last paragraph belongs to the first generation of operators, because the network was discovered by them as much as built by them. The men and women who tracked the first missions invented the profession of deep-space tracking as they went, writing the procedures they would use the next day, debugging receivers with oscilloscopes, and passing the craft to the next shift in handwritten logs; the professionalism the network shows today, the drilled sequences, the quiet control rooms, the confidence of an institution that has heard everything, is the inheritance of those first winters in the California desert, and the account of the network's discovery is properly the account of the profession they founded.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.