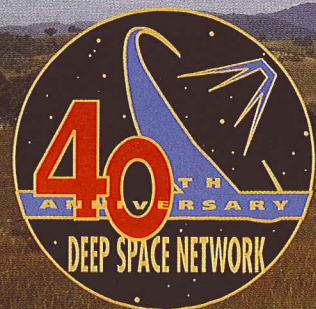


Keeping Track Down Under

Part One: Origins

By Philip Corneille FBIS



CDSCC has two 34 m Beam Waveguide antennas which have all electronics in an underground bunker. Determined to meet the ongoing demand, NASA is building two extra 34 m antennas which will be online by 2016.

NASA's Deep Space Network (DSN) is an international system of ground stations supporting interplanetary space missions and radio astronomy observations of the universe. After almost half a century in existence, the three DSN stations at Goldstone, California (USA), Robledo de Chavela, Madrid (Spain) and Tidbinbilla, Canberra (Australia) still play a vital support role in space exploration. The latter is a mission-critical enabler being the sole station in the Southern Hemisphere!

Early days

In February 1958, the US Department of Defense established the Advanced Research Projects Agency (ARPA) with responsibility to coordinate and manage all existing military and civilian space activities. The Russians had launched the first artificial satellite, Sputnik 1 in October 1957 and the first animal into space (Laika) in Sputnik 2 (November 1957) pitching the US into a space race.

The National Aeronautics & Space Administration (NASA) was officially established on 1 October 1958 in order to consolidate the separately developing non-military space programmes of the Army, Navy and Air Force into one civilian organization. In December 1958, the Jet Propulsion Laboratory (JPL), since 1954 associated with the army's missile development, was transferred to NASA, becoming the agency's primary planetary exploration centre. JPL was asked to design, operate and support the unmanned

'Tracking lunar probes required large diameter, steerable parabolic dish antennas...'

Pioneer, Ranger and Surveyor lunar missions in preparation of the manned Apollo program.

JPL engineers had the know-how to set up tracking stations, as they had been operating the Microlock tracking system to provide positional data for high altitude test rockets. To support this they had deployed portable radio stations in Nigeria, Singapore and California to receive telemetry and plot the orbit of the first US satellites. However, the system using 3 m mobile antennas (Cape Canaveral, Puerto Rico) and tracking ships soon proved insufficient.

NASA-JPL developed the concept of the Deep Space Network (DSN) as a separately managed and operated communications facility that would accommodate lunar and deep space missions, thereby avoiding the

need for each project to acquire and operate its own specialized space communications network.

Tracking lunar probes required large diameter, steerable parabolic dish antennas and JPL made use of the existing design of a radio astronomy antenna of the Carnegie Institute.

By December 1958, JPL had established ground stations with a 26 m dish antenna near the Goldstone dry lake in California, at the Island Lagoon in Woomera, Australia, and Hartebeest in South Africa. Due to political and diplomatic considerations, the latter ground station was relocated near the same longitude in Robledo de Chavela near Madrid - Spain. In Australia, the Deep Space Station was located in the Tidbinbilla Nature Reserve near Canberra.

In May 1965, just in time for the Mariner 4 Mars flyby, DSN consisted of three Deep Space Communication Complexes (DSCC), positioned at around the globe approximately 120 degrees apart to ensure a continuous data link with spacecraft in the solar system as the Earth rotates. NASA's DSN quickly matured into an integrated system of operational tracking stations, destined to become a multi-faceted science instrument and mission enabling network.

Manned Spaceflight Network

Furthermore, since 1961 each DSCC had an extra site to set up the Manned Space Flight Network (MSFN), eventually supporting NASA's Mercury (1961-1963), Gemini (1965-1966), Apollo (1968-1972) and Skylab (1973-1974) programmes. During the Apollo programme these Apollo 'wing' sites got extra control rooms as dual sets of stations were required because of the narrow beam width of the antennas using S-band when the Apollo spacecraft were near the Moon.

For Australia, MSFN commissioned the 26 m antenna at Honeysuckle Creek, 20 km south of the Tidbinbilla DSCC. The redundancy provided in this way was vital as one antenna tracked the orbiting CSM (Command & Service Module), the other covered the LM (Lunar Module) and activities on the lunar surface.

The 26 m antenna, equipped with both S-band receive & transmit capability, was versatile as it could slew fast enough to track spacecraft in Low Earth Orbit (LEO) and be accurate enough to follow spacecraft at lunar distances for extended periods of time.

The antenna control room operated on a Univac 1218 computer and in 1974 the 26 m antenna joined the DSN as Deep Space Station 44 (DSS). Several upgrades allowed the use of the 26 m Honeysuckle Creek antenna up to the summer of 2009. At various stages during the Apollo missions, the 64 m radio dish at Goldstone (DSS-14 nicknamed 'Mars Station'), the 8.7 m Cassegrain antenna at Carnarvon and the 64 m moveable radio telescope at Parkes, New South Wales, were called in to assist. The latter was the primary observing instrument of the Parkes observatory and was the brainchild of the British physicist Edward Bowen (1911-

In April 2013, the 70 m Deep Space Station 43 marked its 40th anniversary of space communications operations.



1991), who made major contributions to the development of radar.

The 64 m Parkes radio telescope, commissioned in 1961 and completed in 1963, proved timely for the US space programme, especially during the Apollo 11 moonwalk and the Apollo 13 emergency. During the 20th July 1969 Apollo 11, the surface TV pictures routed through Parkes were superior to those received at the 64 m Goldstone DSS-14 station, so NASA stayed with Parkes as the source for the TV coverage for the remainder of the 2.5 hour broadcast.

Until 1973, the Parkes radio telescope, known as 'the dish' remained the prime receiving station in the Southern hemisphere. The observatory is part of the Australia Telescope National Facility of the Commonwealth Scientific & Industrial Research Organization

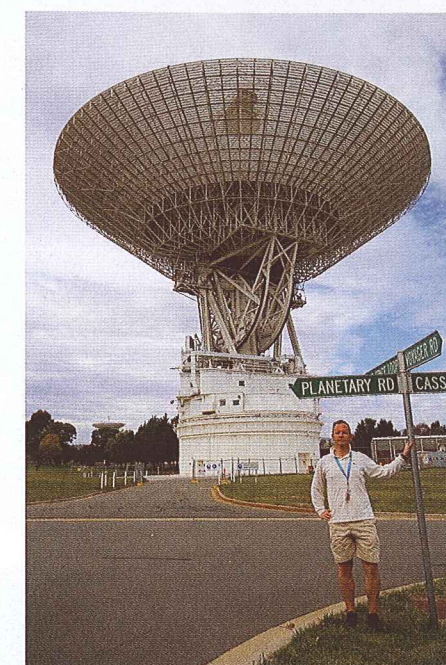
'...British physicist Edward Bowen...made major contributions to the development of radar.'

(CSIRO).

Between 1969 and 1973, Collins Radio constructed a 64 m radio antenna at the Canberra Deep Space Communication Complex (CDSCC). This 64m Deep Space Station (DSS-43) was named 'Ballima', an Aboriginal name meaning 'very far away' and although it was designed for interplanetary missions, its first operational role was to ensure back-up voice support for the Apollo 17 mission in December 1972.

In 1975, the MSFN and Spacecraft Tracking And Data Acquisition Network (STADAN - satellite network) were merged into the Spaceflight Tracking and Data Network (STDN), which in turn was replaced

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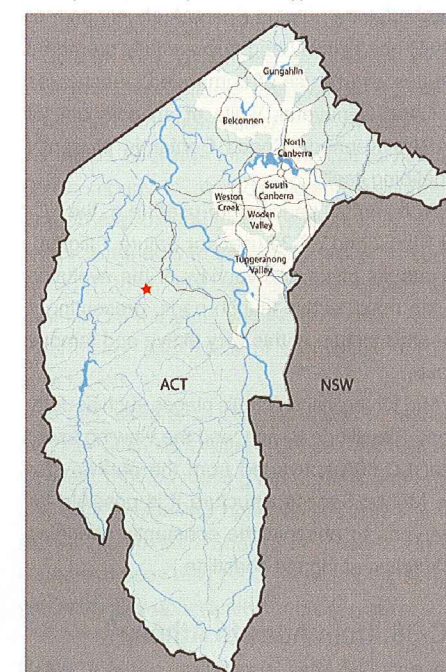
The author at the crossroads of Voyager and Cassini roads near the 70 m antenna at CDSCC. Just like NASA-JPL, the Australian engineers named the roads after historic robotic space flight missions.

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by the satellite-based Tracking and Data Relay Satellite System (TDRSS) during the Space Shuttle programme. First launched in April 1983, TDRSS now consists of a network of 10 geostationary communication satellites and a single ground station at White Sands Test Facility in New Mexico, USA. Since 2010, NASA operates three separate networks: DSN, TDRSS and the Near Earth Network (NEN).

The Tidbinbilla tracking station (designated by the red star) is located 20 km outside Canberra in ACT (Australia Capital Territory).

David Baker



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Part Two: Interplanetary spacecraft

By Philip Corneille FBIS



Canberra's Deep Space Communication Complex lies amid a picturesque backdrop in Australia Capital Territory.

Australian Tourist Board

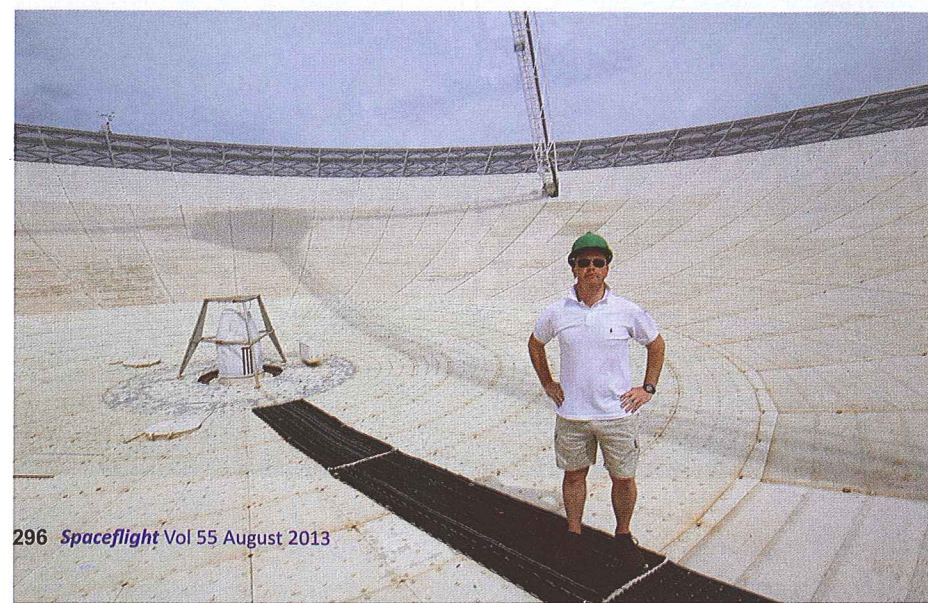
Since the late 1960s, the Deep Space Network (DSN) got simultaneously involved with several interplanetary projects directed by NASA-JPL or by other NASA centres. In several ways it was to be the busiest time with increasing demands.

Mars missions

By 1970, NASA had several missions to the planet Mars in the pipeline and also approved a series of unmanned gravity-assisted interplanetary space missions to explore the outer solar system. NASA Ames Research Center designed and managed the twin Pioneer 10/11 spacecraft (1972-1980) to the planets Jupiter and Saturn. NASA-JPL was in charge of the twin Viking 1 and 2 orbiter/lander probes (1975-1982) sent to Mars and the twin Voyager 1 and 2 spacecraft dispatched to conduct the grand tour of the outer solar

The author on the surface of the 64 m moveable radio telescope at Parkes, NSW Australia. This famous dish was the prime receiving station for the Apollo 11 Moonwalk TV-images and can act as spare 'ear' for NASA DSN.

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'After the launch of both Voyager spacecraft, the DSN resources were stretched to the limit.'

system (1977-1989).

Multi-mission tracking required significant changes in the structure, technical capabilities and operational management of the DSN. All data, telemetry and mission control functions were delivered through the Ground Communications Facility (GCF) to the central Mission Control & Computing Center (MCCC) at NASA/JPL in Pasadena, California. Besides

gathering spacecraft and science data, DSN also monitored the performance of the entire network via the Network Operations Control Center at JPL.

In April 1973, the Canberra Deep Space Communication Complex (CDSCC) got its own 64 m (210 ft) dish (DSS-43) and by 1975, the DSN was negotiating tracking time between the Pioneer 10/11 spacecraft, the Mariner 10 mission to Mercury, Viking 1/2 probes to Mars and the German Helios 1 solar probe. After the launch of both Voyager spacecraft, the DSN resources were stretched to the limit. Moreover, the Pioneer 11 flyby of the planet Saturn pointed out that the downlink telecommunications limit at minimum bit-rate (16 bps) of the 64 m stations would be reached by the mid-1980s. The predicted downlink performance initiated an upgrade to extend and resurface the large antennas to 70 m diameter.

The CDSCC completed its first 34 m (112 ft) high efficiency antenna (DSS-45) in 1986. The DSN 34 m antennas use four wheels to quickly rotate on a circular track. For Medio 1986, the Voyager 2 Uranus encounter and the European Giotto encounter with Halley's comet, both NASA and the European Space Agency (ESA) got the support of CSIRO to increase the downlink capability by using the upgraded 64 m Parkes radio telescope. At the end of 2003 and in early 2004, Parkes gave a helping ear during the European Mars Express mission, for which it was designated as DSS-49.

By 1987, DSS-43 was extended to a 70 m (230 ft) radio dish and became the largest

steerable parabolic antenna in the southern hemisphere. The aperture enhancement resulted in an increase of more than 60 percent in the effective collecting area of these large antennas. Half of this increase was attributed to the dual-shape design, wherein both the surfaces of primary and secondary reflectors were modified. Although completed in time for the 1989 Voyager 2 Neptune encounter, the DSN requested support from other international facilities including the Very Large Array (VLA) equipped with twenty-seven 25 m (82 ft) dishes and the 64 m Usuda antenna operated by the Japanese Institute of Astronautical Sciences.

In 1997, the CDSCC completed its second 34 m antenna (DSS-34) with the transmission and reception equipment underground rather than on the surface of the dish. This reduced the weight of the dish and allowed for maintenance of the sensitive electronics while the antenna is tracking.

It is remarkable that Australia's CDSCC played a vital role during crucial sequences of many unmanned space missions. The Australian 26 m (85 ft) stations performed the initial acquisition sequences and the lander separation stages for Viking 1 and 2. The Australian 64 m (DSS-43) antenna had prime responsibility for the probe entry events of Pioneer-Venus in December 1978, the Voyager 2 Neptune encounter in 1989, the Stardust-NExT encounter with comet Tempel 1 in February 2011 and the entry, descent and landing phase of the Mars Science Laboratory 'Curiosity' in August 2012.

Moreover, on 14 July 2015, the 70 m DSS-43 will have a direct view toward the New

Horizons encounter with dwarf planet Pluto and its five moons when its radio signals will take 4.5 hours to reach the DSN antennas.

The future of CDSCC

In 2001, a comprehensive study of the over-subscribed DSN concluded that new antennas were needed to meet the growing demand on the network in the near future. NASA concurred with the report by making changes to the DSN roadmap and planned the construction of additional advanced 34 m Beam Wave Guide (BWG) antennas. At the CDSCC, excavation groundwork for the construction of two new 34 m antennas (DSS-35 & DSS-36) began in 2010, with work on the base pedestal and power distribution system commencing in mid-2011. DSS-35 will be operational in late 2014 and DSS-36 by the end of 2016.

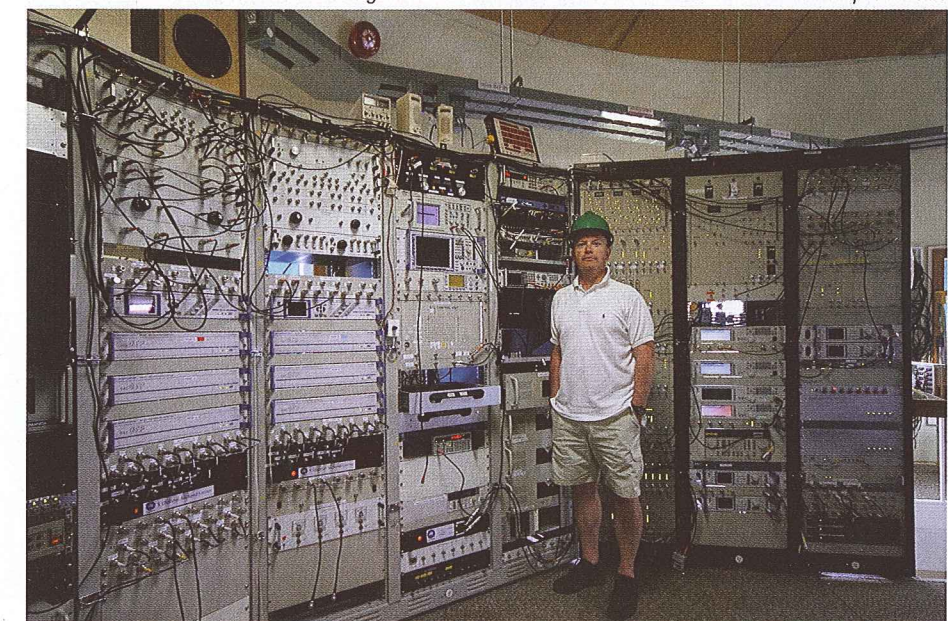
The primary roles of the new antennas consist of telemetry, tracking, spacecraft command and provision for monitoring and control capabilities to the DSN operators. Together with the new antennas, cost-effective network technology is used to operate the antennas in arrays, to control all system components and to relay all data via dedicated fibre cable to NASA-JPL.

Currently, the CDSCC employs 120 engineers and the complex is staffed around the clock by four teams on a rotating 12-hour shift. In spite of the Australian DSN complex, coverage of the Southern Hemisphere remains limited and NASA is examining the possibility of expanding the network to limit data loss events and to get full redundancy of its Northern Hemisphere facilities.

In addition to serving as a communication

Receiving equipment for the 64 m telescope at Parkes. Although mostly used for radio astronomy, the dish can assist NASA DSN and is designated DSS-49.

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instrument for deep space exploration, the DSN can be used as an advanced technological instrument for scientific research. The antennas may be used for radio astronomy in support of the Very Long Baseline Interferometry (VLBI) arrays for imaging distant cosmic radio sources such as active galactic nuclei around black holes in distant galaxies. Einstein's theory of general relativity can be tested through radio frequency experiments performed between spacecraft and the DSN radio science system.

Despite its relative isolation, clustered in the valleys of the Tidbinbilla Nature Reserve, the CDSCC manages an extensive outreach program and its impressive visitor centre hosts over 70,000 school children on excursion, students and tourists each year. The visitor center exhibits actual flight hardware and memorabilia covering the history of manned and unmanned space exploration. It has a

'...NASA is examining the possibility of expanding the network to limit data loss...'

multimedia conference area where the latest NASA applications can be demonstrated to the general

public. Outreach and communication manager Glen Nagle sees the education of the next generation of space explorers, scientists and engineers as an important role for the station.

As the CDSCC nears its 50th anniversary, NASA continues to maintain the DSN as the largest and most sensitive scientific telecommunications system in the world so as to meet the continuing demand for deep space communication services. Technology, science and engineering excellence are obviously critical but the real key to getting the job done for NASA is the quality of the Australian and international personnel keeping all aspects of CDSCC running smoothly.