US SPACE MISSIONS: COPING WITH TECHNOLOGY DISRUPTION[1]

MANAGING NASA'S DEPENDENCY ON 50+ YEAR OLD TIDBINBILLA

> *"It's really incredible to see in many ways, our roots have not changed. We are about doing things that no one else has ever done, we are about exploring science that no one else has explored, and we are really about accepting any challenge that comes our way to answer these very difficult science questions."*
>
> - *Lt Gen (retd) L James, Deputy Director NASA Jet Propulsion Laboratory[2]*

The Canberra Deep Space Communications Complex (CDSCC) Tidbinbilla is a NASA facility managed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) on behalf of the Australian Government, under a treaty arrangement with the US Government and NASA. The activities of the DSN, including CDSCC Tidbinbilla, are coordinated by the NASA Jet Propulsion Laboratory. The close-working Australian-US relationship has allowed opportunities for Australian scientists and operators to demonstrate innovation and coping with technology disruption in changes shared with their US colleagues in space science and operations.

Before NASA existed, the Californian Institute of Technology (CALTECH) Jet Propulsion Laboratory (JPL) interests in space systems began before the Second World War when rockets were generally perceived to be devices of fantasy, seen only in movies and comic books. In 1936, a group of young JPL researchers decided to pursue their personal interests in the research, design and successful experiments with small rockets. This motivated JPL to formally establish the research programs in rocketry systems that still define JPL today. After developing Explorer 1 as the first successful US orbital space mission, launched in 1958, JPL expanded to include space systems and was formally transferred to NASA, although it continues to remain under CALTECH management[3].

Space Flight Operations Centre at NASA JPL, Pasadena, California[4].

As the 'space race' drove the pace of US and Soviet space research, NASA needed a 'satellite tracking and data acquisition network' (STADAN) to continuously track and communicate with its orbiting spacecraft. Thus began

Australia's space history, in the 1950s, when the first US space tracking facility was established outside of the US at Island Lagoon, Woomera. Additional NASA tracking stations were sited in Australia at Muchea, Carnarvon, Cooby Creek, and Orroral Valley. In 1967, the Honeysuckle Creek Tracking Station was established to support the Apollo program and, in 1969, received the downlink from Apollo 11 with the video of Neil Armstrong's first steps on the Moon.

As NASA lunar and deep space exploration mission accelerated, so did the need for expanding its tracking networks around the world. NASA JPL needed a new Deep Space Network (DSN) [5] to provide continuous dedicated coverage for its new robotic deep space exploration missions, as the world rotated in its orbit, and the fixed site antennas were rotated over the Earth's horizon. NASA searched for another location for siting a DSN station that was located approximately 120 degrees longitude away from the Goldstone tracking station in California and, under a 1960 US-Australian treaty arrangement, established the a DSN facility at CDSCC Tidbinbilla, ACT[6].

In 2015, CDSCC Tidbinbilla celebrated 50 years of Australian operations in space tracking and data acquisition. During this period, CDSCC Tidbinbilla operations have supported NASA's first close-up pictures of the Martian surface from Mariner 4 (July 1965), communications and telemetry with hundreds of space missions, including the NASA Apollo lunar missions. In 2012, it provided confirmation of the successful landing of the NASA rover Curiosity on Mars and, in 2015, it downlinked some of the first images of Pluto gained from the New Horizons mission. In 2017, CDSCC received the final transmissions from the Cassini spacecraft as it was steered to burnup in Saturn's atmosphere. Today, CDSCC is the only DSN station that can achieve line-of-sight communications with both the Voyager 1 and Voyager 2 space probes, which have both exceeded design requirements and are predicted to function until at least 2020[7].

Having been successfully operating for over 50 years, CDSCC Tidbinbilla is an example of the successful management of innovation and disruption in tracking space missions. The 90 Australian CSIRO staff working at CDSCC Tidbinbilla have self-initiated and managed a number of changes in response to disruptive technology changes and demands for efficiency improvements in operations, including the following examples:

- **Follow-the-Sun-Operations (FtSO)[8].** With new computers and remote operating systems, NASA automated the operation of all three DSN stations, under the "Follow the Sun Operations" project. In the new FtSO paradigm, each one of the three DSN sites is now responsible, in turn, for operating the entire global DSN of three stations during their day shift, handing off control to the next site as the sun sets. This contrasts with the pre-2017 work paradigm, where each DSN site only operated their local antennas.[9]
- **Motivating the Future Space Science Workforce[10].** CDSCC Tidbinbilla has developed a space science education outreach program for school students called 'STARS' – Space, Technology, Astronomy, Research Students to attract the future workforce. The pilot program was successfully conducted in 2013 to encourage students in science, technology, engineering and mathematics (STEM) to realise hands-on experiences of real-world space science applications in Australia.
- **Asteroid Tracking and Characterisation[11].** In 2015, under a new Australian initiative with NASA, CDSCC Tidbinbilla coordinated the first Southern Hemisphere Planetary Radar System to detect and characterise passing asteroids. Normally operated as a transmitter/receiver to communicate with deep space probes, CDSCC Tidbinbilla was used as the transmitter in a bi-static radar system with the radio telescope stationed at Parkes and Narrabri acting as receivers. This expands NASA's capabilities, filling in a blind spot, in the global network of asteroid sensors used to catalogue Near-Earth Objects (NEO) with a trajectory to potentially impact the Earth within the next 100 years[12].

CDSCC Tidbinbilla was known initially as the "Tidbinbilla Deep Space Instrumentation Facility 42" (DSIF42), in 1963, with its one 26-metre diameter dish antenna. CDSCC Tidbinbilla has since been expanded to operate four antennas: one 70-metre and three 34-metre radio dishes that receive data from, and transmit commands to, spacecraft deployed into deep space missions[13].

[1] This information flyer is drafted to support the APDC Air Power Seminar, *"US Space Missions: Coping with Technology Disruption,"* by Lt Gen L James, Deputy Director, NASA Jet Propulsion Laboratory, held at Fairbairn on 18 October 2018

[2] Hill, T (2018). *A celebration of America's first satellite,* Universe, Jet Propulsion Laboratory, February 2018, Vol 48. No 2. Online www.jpl.nasa.gov/universe/archive/universe1802.pdf. Accessed 9 October 2018.

[3] Conway, E (2018). *JPL History*, NASA Jet Propulsion Laboratory. Online www.jpl.nasa.gov/jplhistory/early/index.php. Accessed 9 October 2018.

[4] NASA (2017). *Cassini End of Mission,* NASA Image and Video Library. Online https://images.nasa.gov/details-NHQ201709150002.html. Accessed 9 October 2018.

[5] CDSCC (2017). *Canberra Deep Space Communication Complex History*. NASA Deep Space Network, Canberra Deep Space Communication Complex. Online www.cdscc.nasa.gov/Pages/cdscc_history.html. Accessed 1 September 2018.

[6] CSIRO (2017). *About Canberra Deep Space Communication Complex.* Online www.csiro.au/en/Research/Facilities/CDSCC/About-CDSCC. Accessed 1 September 2018.

[7] NASA JPL (2018). *Voyager*. Interstellar Mission. Online https://voyager.jpl.nasa.gov/mission/interstellar-mission/. Accessed 31 August 2018.

[8] Johnson, M et al (2015). *NASA Deep Space Network: Automation Improvements in the Follow-the-Sun Era,* NASA Jet Propulsion Laboratory. Online https://ai.jpl.nasa.gov/public/papers/johnston_ijcai2015_dsn.pdf. Accessed 1 September 2018.

[9] Marshall, L (2017). *Few Australians know the unique role the country plays in the global space network,* CSIROscope. Online https://blog.csiro.au/larry-marshall-australians-know-unique-role-country-plays-global-space-network/. Accessed 31 August 2018.

[10] Nagle, G (2013). *Students Served Science on NASA Dishes,* CSIROscope. Online https://blog.csiro.au/students-served-science-on-nasa-dishes/. Accessed 1 September 2018.

[11] Benson, C et al (2017). *First Detection of Two Near-Earth Asteroids with a Southern Hemisphere Planetary Radar System,* Radio Science – An AGU Journal. Online https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1002/2017RS006398. Accessed 1 September 2018.

[12] NASA Jet Propulsion Laboratory (2018). *Sentry: Earth Impact Monitoring,* Centre for Near Earth Object Studies. Online https://cneos.jpl.nasa.gov/sentry/. Accessed 1 September 2018.

[13] CSIRO (2017). *About Canberra Deep Space Communication Complex*. Online www.csiro.au/en/Research/Facilities/CDSCC/About-CDSCC. Accessed 1 September 2018.