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Chapter 14

The CSIRO Parkes Telescope and the Deep Space Network*

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Abstract

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) Parkes Radio Telescope was commissioned on 31 October 1961. Through its early astronomical discoveries, it quickly became the leading instrument of its kind in the world. It was recognized early on by NASA's Jet Propulsion Laboratory (JPL), that the performance parameters and innovative design features of the Parkes telescope made it a near-ideal instrument for tracking spacecraft in deep space. At the time, JPL was planning the next generation of large tracking antennas for its fledgling Deep Space Network (DSN). Consequently, in July 1960, more than a year before its commissioning, NASA proposed to permanently include the Parkes Radio Telescope in the DSN. This offer was rejected by the CSIRO, but in a separate interagency agreement, it agreed that whenever a strong, stable signal was required during space missions, the Parkes telescope could provide tracking support, especially during critical moments like a planetary flyby or an impact on another planetary surface. To this day, it is still the rationale for the Parkes telescope's support of space missions. In the first few years of the telescope's operation, it was extensively studied by

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JPL. The design proved so successful that it was subsequently adapted and became the model for the large antennas of the DSN. Throughout its history, the CSIRO Parkes telescope has demonstrated its utility as a spacecraft tracking antenna. From the Mariner 2 mission in 1962, through the high point of the Apollo lunar landing missions, Voyager 2's encounters at Uranus and Neptune, Galileo at Jupiter, Huygens at Titan and the Curiosity landing on Mars, the Parkes telescope has been there from the start. This chapter will describe these efforts and the profound impact that the Parkes Radio Telescope has had on the Deep Space Network from its inception.

I. Introduction

In October 1957, the United States was jolted by the Soviet launching of Sputnik 1. Scrambling to catch up, it quickly initiated a program of satellite launches and robotic moon shots. Caltech's JPL recognized a coming need for a communications system that could satisfy not only the immediate requirements of the Pioneer lunar missions but also more demanding future missions to other planets [Ref. 1].

The first Pioneer lunar probe was scheduled to launch in November 1958. JPL initiated a crash program to design and build suitable tracking antennas. In February 1958, William (Bill) Merrick, head of JPL's Antenna Structures and Optics Group, was assigned to investigate an appropriate antenna design. Merrick quickly concluded that JPL could meet its requirements by minor modification of an existing design. Merrick consulted with John Bolton, the Professor of Radio Astronomy at Caltech, whom he knew well. Bolton had recently conducted a survey of precision radio astronomy instruments [Ref. 2]. One of the instruments he had highlighted was an 85-foot (26-meter) diameter antenna with a cantilevered equatorial mount, being built by the Blaw-Knox Company for the National Radio Astronomy Observatory (NRAO) at Green Bank, West Virginia. Merrick and his colleagues ultimately chose that design, and JPL immediately placed an order for three of the antennas. The first was delivered and installed at the Goldstone Dry Lake at the US Army's Fort Irwin, in the Mojave Desert, about 149 miles (240 km) northeast of Pasadena. The antenna was built in an astonishingly short period, from July to October 1958. From initial design to operational status, the project took only 10 months [Ref. 1].

II. Parkes Gets Involved

In March 1959, the Pioneer 4 spacecraft flew past the Moon at a distance of 59,500 km. JPL tracked the spacecraft with its 85-ft antenna at Goldstone. When the signal was finally lost on March 6, after it had been tracked for a then-record distance of 654,860 km, NASA and JPL found themselves in the frustrating position of having a fully functioning vehicle far out in space, emitting signals that they had no way of receiving [Ref. 3].

It was evident that the tracking of spacecraft at lunar and planetary distances required larger and more sensitive antennas, so JPL considered building an array of three or four large tracking antennas around the globe. The tracking characteristics of these proposed antennas were close to those of the CSIRO's planned radio telescope. One early plan, mooted in 1959, was to link existing large radio astronomy antennas with new antennas built specifically for tracking spacecraft. The plan was to use the 250-ft (76 meter) dish at Jodrell Bank with the soon-to-be built 210-ft (64-meter) dish at Parkes. Two new antennas would be built at Goldstone and another somewhere in India to complete the coverage. The two new antennas would be based on the Parkes telescope design [Ref. 3].

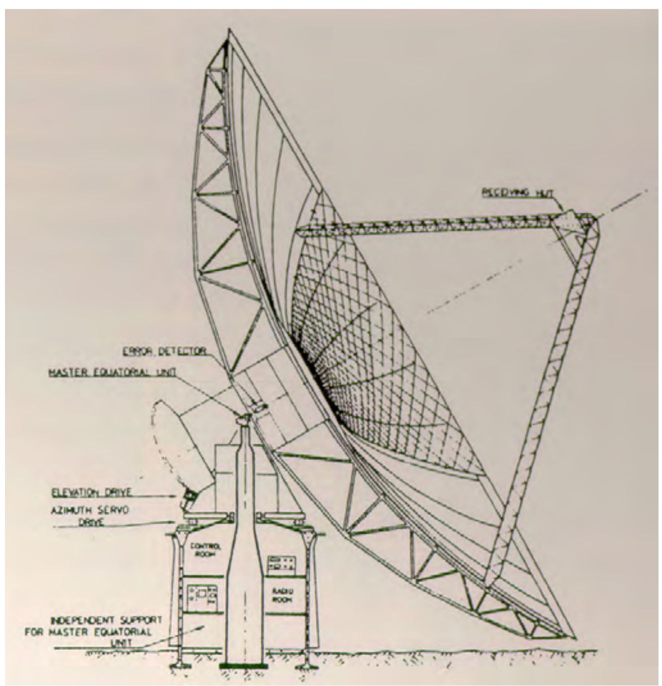


Figure 14–1: Design for the Parkes Radio Telescope by Freeman Fox & Partners. CSIRO engineer Harry Minnett supervised the design and drive system from 1956–1959. Credit: CSIRO.

During the tender and construction phase of Parkes, from 1959–1961, regular discussions occurred between JPL and the CSIRO's Radiophysics Division about the possibility of using Parkes for tracking spacecraft. During this period, John Bolton, who had previously been a leading member of the Radiophysics Division, and Bruce Rule, facilitated contacts between CSIRO and JPL. Rule helped enormously on critical aspects of the Parkes design, suggesting changes that helped improve the telescope's overall performance [Ref. 40]. In a letter to JPL Director William Pickering, dated May 12 1960, Edward "Taffy" Bowen, the Chief of the Radiophysics Division, suggested that the CSIRO could cooperate with JPL in designing and building its proposed large tracking antennas [Ref. 4].

Figure 14–2: CSIRO Radiophysics Division Chief Edward "Taffy" Bowen with the newly-opened Parkes telescope in 1961. Credit: CSIRO.

By 1960, JPL had settled on a plan to build a three-station ground system for communications with lunar and planetary vehicles. Initially the stations were to be equipped with one or more 85-ft antennas. These stations were referred to as Deep Space Instrumentation Facilities (DSIFs). One of these stations would be located at the Woomera Rocket Range, in South Australia. However, the need for larger antennas was anticipated [Ref. 5].

In July 1960 Edmond C. Buckley, NASA Assistant Director of Space Flight Operations, proposed a cooperative US-Australian space exploration program based on the occasional use of the Parkes Radio Telescope for short-term data acquisition when an extremely strong and reliable signal was desirable—for example, during the terminal phase of a spacecraft impact on the surface of another planetary body [Ref. 5]. The proposal was favorably received by Bowen and the CSIRO [Refs. 6, 7]. To this day, it is still the rationale for Parkes' inclusion in NASA tracking operations.

On 26 February 1960, the governments of Australia and the United States had formally agreed to cooperate in spacecraft tracking and communications through an "Exchange of Notes," generally referred to as the Space Cooperation Agreement. In this treaty, NASA and Australia jointly established a management policy that has proved successful and remains virtually unchanged to the present day. In his letter to Bowen [Ref. 5], Buckley had suggested two approaches to cooperation: amend the Space Cooperation Agreement to allow Parkes to participate, or arrange a service contract between the CSIRO and NASA based on a similar contract with the University of Manchester, operator of the Jodrell Bank telescope. For simplicity, the latter arrangement was adopted [Ref. 6]. It remains in place to the present day.

III. Parkes as a Prototype for the JPL Large Aperture Antennas

On September 15, 1960, JPL issued a document, "Project Description, Advanced Antenna System for the Deep Space Instrumentation Facility, Engineering Planning Document No. 5," describing requirements for its new antennas [Ref. 8]. The new antennas were to provide a 6–12 decibel (dB) improvement over JPL's existing 85-ft diameter dishes, bringing them up to the 200–260-ft diameter (60–80 meter) class.

The surface accuracy of the dishes would require optimum performance around 2200 MHz (S-band). The pointing accuracy was to be 1.2 arc-minutes, slightly less demanding than the Parkes telescope's 1 arc-minute. The dishes would need to be tipped to the horizon, much lower than the Parkes telescope's 30-degree elevation limit. Slew rates would not be substantially different from the Parkes telescope. Finally, the new antennas would need to withstand higher wind speeds of 70 miles per hour (112 kph) [Ref. 8]. These requirements matched those for Parkes so closely that, by the inauguration of Parkes in October 1961, JPL was showing intense interest in the instrument [Ref. 11]. During an inspection visit to Parkes on September 29, 1961, Buckley was shaken by the economy of the telescope, which had cost substantially less than NASA's 85-ft antenna at the Woomera DSIF station [Refs. 9, 10].

JPL had set itself the target of constructing a giant dish at Goldstone by 1963 and up to two more for the DSN by 1964. This tight schedule could only be met by making virtual copies of Parkes. JPL eventually decided on a redesign, adapting some of the more innovative features of the Parkes telescope while incorporating Cassegrain optics, full tracking accuracy in winds of up to 70 mph, and coverage down to the horizon. This redesign meant that JPL would not meet its original target dates but would instead take up to five years to complete the job. Eberhardt Rechtin, chief of JPL's Electronics Research Section, was the head of the project to design the JPL antennas.

In order to bridge the gap in its capabilities until JPL's large antennas were built, JPL Director William Pickering proposed, in December 1961, that the

Parkes telescope be formally included in NASA's fledgling DSN [Ref. 12]. The intention was to use Parkes for 6–8 hours per day, particularly for planetary probe operations from late 1964 onwards. Astronomical research took precedence at Parkes, so CSIRO could not take up the offer. However, Bowen encouraged JPL to consider building a similar large antenna in the vicinity of Parkes, arguing that the value of two large telescopes near to one another exceeded that of two telescopes taken individually [Refs. 13, 15, 22]. This proved to be a prophetic statement because, two years later, NASA selected a site at the Tidbinbilla nature reserve near the Australian capital, Canberra, just 300 km south of Parkes, for a new DSN antenna. The value of this decision was not fully realized until 1986, with the Voyager 2 encounter of Uranus, when the Parkes and Tidbinbilla antennas were linked, or arrayed, to increase receiving sensitivity [Ref. 39].

An alternative proposal offered by Pickering was to use the Parkes telescope as a passive listening device, supplementing JPL's DSN antennas. Parkes would be used to listen to the planned Mariner R probe (later renamed Mariner 2) as it neared Venus. Pickering also suggested that the CSIRO could provide technical consulting on JPL's large-aperture antenna [Ref. 12]. Bowen enthusiastically supported both of these recommendations [Ref. 13].

Figure 14–3: Comparison view of the Parkes Radio Telescope and the 210-ft (64-meter) antenna at Goldstone, which was based on the Parkes design. The Goldstone dish was commissioned in 1966. Credit: CSIRO.

IV. NASA Research Grant NsG-240-62

In February 1962, CSIRO was awarded a NASA research grant, NsG-240-62, to report on the detailed characteristics of the newly commissioned Parkes telescope. CSIRO engineer Harry Minnett was appointed Officer-in-Charge of Advanced Antenna Design to head the study [Ref. 14]. JPL's proposed large-aperture antennas had the basic form and dimensions of the Parkes telescope and incorporated the master equatorial precision-pointing system.

Under the grant, the CSIRO participated in feasibility studies and specification reviews of the JPL antennas. Detailed performance parameters of the Parkes telescope were determined in regards to structural behavior, characteristics of the drive master control systems and radio frequency performance. In addition, vibration characteristics and dish shape in the zenith and tilted positions were measured [Refs. 14, 15]. This information was deemed to be of critical importance in the design of the JPL antennas.

During the period of the grant, CSIRO and JPL established a close working relationship, with many visits and exchanges by key personnel. By the time the grant expired in December 1966, over 30 research papers had been published on the design and performance of the telescope. At that point Parkes was not only the most advanced radio telescope in the world but also the most extensively studied.

V. Mariner 2

On August 27, 1962, the Mariner 2 spacecraft was launched toward an encounter with the planet Venus. The 85-ft antennas of the DSN were considered sufficient to satisfy NASA's requirements during the encounter [Ref. 19]. However, NASA considered it extremely vital that a coordinated program of ground-based observations, both radio and optical, be carried out in conjunction with the Mariner encounter at Venus in order to maximize the scientific return. In June 1962, Parkes was invited to participate in this program [Ref. 16].

Both Taffy Bowen and Harry Minnett, decided that tracking the Mariner 2 spacecraft would be an excellent demonstration of the Parkes Radio Telescope's capabilities for communication at great distances [Refs. 17, 18]. In addition, it would provide the observatory personnel with valuable experience in tracking and receiving signals from spacecraft, which the observatory might be called on to do in future cooperative experiments [Ref. 18]. Since the observations would provide valuable performance characteristics of the Parkes telescope that would be of interest in the design of the JPL antennas, the tracking costs were included as part of the NASA research grant.

Essentially, the experiment was to be a simple one involving the measurement of spacecraft position, signal level and Doppler frequency to establish the technique [Ref. 21]. It did not include the reception of telemetry. The Mariner 2 carried an L-band (960 MHz) transmitter, and for these test tracks, JPL loaned Parkes a modified version of the GSDS 960 MHz transportable phase-lock receiver [Refs. 20, 22].

Attempts to detect the Mariner 2 signals began on December 12, 1962, two days before the closest approach. Parkes had a gain advantage of 8 dB (about 6 times) over the 85-ft antennas of the DSN, and should have detected the signals easily. However, Parkes experienced great difficulty in finding and locking on to the Mariner signal [Ref. 21]. There were two reasons for this. One was that the narrow beamwidth of the 210-ft antenna made the accurate pointing of the dish absolutely crucial. The other reason was that the receiver had to be tuned very precisely since it had only had a 20 Hz-wide gate [Refs. 20, 21]. The Doppler shift of the signal had to be known precisely so that the receiver could be tuned manually to the received frequency. Once the signal was detected, the receiver could lock on to it and automatically track the signal.

As a result of these requirements, the Parkes team of Doug Cole and Harry Minnett needed to know both the position and frequency very accurately. Unfortunately, this proved to be very difficult, especially since they were calculating the position and Doppler shift by hand. They found that they could have an accurate position but incorrect frequency, or vice versa, and they had no way of knowing which [Ref. 21]. Either way they couldn't see the signal at all. After 100 frustrating hours of searching, they contacted the Woomera DSIF and arranged to have their predicted positions and Doppler shifts telexed to them. Using these predicts they succeeded in finding Mariner 2 at around 7:00 am on December 20, 1962. They were then able to track the spacecraft for several hours until it set at about 1:30 pm later that day [Refs. 21, 22, 23].

The telescope's measured threshold was –150 dBm and the Mariner 2 signal was about 4 dB above this (–146 dBm). This was consistent with the known signal strength at the time and the measured parameters of the antenna and receiver. Also, a penalty of 3 dB was incurred because a circularly polarised feed was unavailable (Parkes was using a linearly polarized astronomy feed) [Ref. 22]. Overall, Parkes had a 5 dB advantage over the DSIF 85-ft antennas.

Doug Cole continued to track Mariner 2 at intervals during the Christmas holiday period until the signals ceased on 3 January 1963 [Refs. 21, 22]. The experiment was a success and many lessons were learnt from it that contributed greatly to the success of future cooperative experiments.

VI. Mariner 4

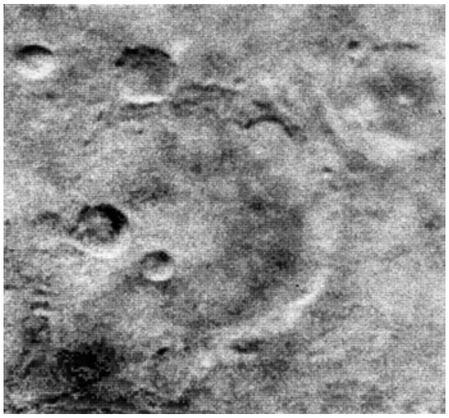
In 1962, NASA had a plan to launch a spacecraft to Mars in November 1963 and deliver a 125-pound (57 kg) capsule to the surface of Mars in July 1964. However, NASA postponed this mission in favor of a flyby experiment which became the Mariner 4 mission [Ref. 24]. When the mission was first proposed, it was envisaged that the Goldstone 210-ft antenna would be ready in time to track the spacecraft at Mars. However, by the time of the Mariner 4 flyby of Mars in July 1965, the Goldstone dish was still about a year away from completion. Consequently, Parkes was approached to provide a 210-ft capability as a backup to the DSN.

Mariner 4 carried an S-band transmitter centered on 2300 MHz. The GSDS 960 MHz receiver, previously loaned to Parkes for the Mariner 2 tracks, was converted to operate at the higher frequencies, and a parametric amplifier from JPL was installed to increase the sensitivity of the receiver. In addition, a circularly polarized feed was constructed. The data rate from Mariner 4 was just 8 bits per second, and the receiver had a bandwidth of 11 Hz. Pointing and frequency predicts as a function of time were telexed to Parkes on a daily basis. As with the Mariner 2 test tracks, Harry Minnett and Doug Cole were responsible for the Parkes operations, and the cost of the tracks was assumed by the NASA research grant [Refs. 25, 26].

On June 21, Parkes began receiving the Mariner transmissions. Daily tracks were carried out during two-hour periods each afternoon, centred approximately on Mariner's meridian transit. Horizon-to-horizon observations were obtained on July 3, 14, 15 and 16. Regular telemetry recordings were made from July 8 to August 27 [Refs. 28, 29]. The telemetry was recorded on a Pemco instrumentation tape recorder using five-and-one-half-inch inch reels with a play time of about 30 minutes [Ref. 31].

The closest approach to Mars was scheduled to occur about two-and-a-quarter hours below the Parkes horizon on 15 July, and soon after that the spacecraft was targeted to pass behind the planet [Refs. 27, 29]. The exit from the occultation occurred just above the telescope's 30 degree-elevation horizon. These occultation observations were considered important since they were intended to probe the atmosphere and ionosphere of Mars.

The experiments on Mariner 4 with the Parkes telescope showed that the 210-ft dish equipped with a standard S-band parametric amplifier had a margin of



about 2.5 dB over a maser equipped 85-ft dish. The resulting gain in data transmission performance was demonstrated: using identical receivers, the increase in performance with the 210-ft dish was close to the theoretical figure of 7.7 dB [Ref. 29].

Figure 14–4: One of the twenty-two images captured by Mariner 4, the first successful Mars mission. Data obtained via the Parkes telescope was combined with data from NASA's DSN stations to produce an improved picture quality. Credit: NASA/JPL.

In early September, the tapes with the telemetry recordings were shipped to JPL [Ref. 30]. These tapes contained the data for the 22 images of the Martian surface captured by Mariner 4. The Parkes data was combined with the data from the smaller 85-ft antennas to produce a considerable improvement in the quality of the pictures of the Martian surface.

VII. Apollo 11

The high point of the Parkes Radio Telescope's role in space tracking was undoubtedly the Apollo lunar landing missions from 1969–1972 [Ref. 32]. Parkes was heavily involved in the Apollo 11, 12, 13 and 15 missions, and was available in case emergencies arose in the other missions. The two most critical supports were for the Apollo 11 and 13 missions.

In October 1968, John Bolton was visiting Caltech for the dedication of the new 130-ft radio telescope at the Owens Valley Radio Observatory. One evening, he and his wife Letty were invited to a dinner party at the home of Bob Leighton. Bob had been a Principal Investigator on the Mariner 4 mission and a colleague of John's during his Caltech period. Also at the party was JPL's Eberhardt Rechtin, the head of the Goldstone project. During the course of the evening, John was asked if he could make the observatory's 210-ft telescope available for reception of signals from the Apollo 11 spacecraft, particularly during the most critical phases of the mission when the Lunar Module (LM), *Eagle*, was on the lunar surface. The historic nature of the mission, combined with the fact that human lives were at risk in space, convinced both Bolton and Taffy Bowen to support the mission [Ref. 33].

The original mission plan for Apollo 11 had Parkes acting as a backup during the Moonwalk for NASA's two tracking stations: the 210-ft dish at Goldstone in California, and the 85-ft dish at the DSN station at Tidbinbilla near Canberra, Australia. This was in case of a delayed Moonwalk, or some other reason. The flight plan had the astronauts performing the moonwalk shortly after landing. The Moon was not due to rise at Parkes until 1:02 pm Australian Eastern Standard Time (AEST), by which time the Extra Vehicular Activity (EVA) would have been completed. A third 85-ft antenna at the Manned Space Flight Network's (MSFN) Honeysuckle Creek station, also near Canberra, was to track the Command Module, *Columbia*, in lunar orbit.

All this changed some two months before the mission. In May 1969, it was decided to alter the Apollo 11 mission plan and allow a rest period before commencing the EVA. The new plan had the EVA starting about ten hours after landing, at 4:21 pm (AEST). This was some twenty minutes after the Moon had set for the Goldstone dish, but the Moon would be high overhead at Parkes. Parkes' role was consequently upgraded from backup to prime receiving station, since the telescope provided the maximum reliability and quality for the telemetry, which the mission planners demanded.

One day into the mission, a fire in the power supply at Tidbinbilla, severely damaged the transmitter. Despite having repaired the damage in 12 hours, NASA lost confidence in the station and switched its role with Honeysuckle Creek.

On Monday July 21, 1969, at 6:17 am (AEST), astronauts Armstrong and Aldrin landed the *Eagle* on the Sea of Tranquillity. Armstrong then diverted from the plan when he exercised his option for an immediate Moonwalk—five hours before the Moon was to rise at Parkes. As the hours passed, it became evident that the process of preparing to exit the LM was taking more time than planned. The astronauts were being deliberately careful in their preparations.

Figure 14–5: The Parkes telescope control room during the Apollo 11 mission. In the background, staff watch the live television from the lunar surface on a monitor. Credit: CSIRO.

The weather at Parkes on the day of the landing was miserable. While the Parkes dish was fully tipped over, waiting for the Moon to rise, a violent squall hit the telescope. Two sharp gusts exceeding 70 mph (112 kph) struck the dish, subjecting the telescope to wind forces ten times stronger that it was considered safe to stand. The control tower shuddered and swayed from this battering creating concern in all present. Fortunately, the winds abated and as the Moon rose into the beam of the telescope, Aldrin activated the television camera at 12:54 pm (AEST).

Six hundred million people, one sixth of Mankind at the time, watched Neil Armstrong's first steps on the Moon. Three tracking stations were receiving the signals simultaneously: Parkes, Honeysuckle Creek and Goldstone. Using its less sensitive "off-axis" detector, Parkes was able to receive the TV pictures just as the Lunar Module television camera was switched on. Eight minutes later the Moon had risen into the field of view of the Parkes telescope's main detector, and the picture quality improved still further.

During the first 9 minutes of the broadcast, NASA alternated between the signals from its two stations at Goldstone and Honeysuckle Creek, searching for the best quality images. Finally, 8 minutes and 51 seconds into the broadcast Houston switched to the transmissions from Parkes, which were of such superior quality, that NASA stayed with the Parkes television for the remainder of the two-and-a-half-hour telecast. In this instance alone, the US investment in Parkes had payed off in spades.

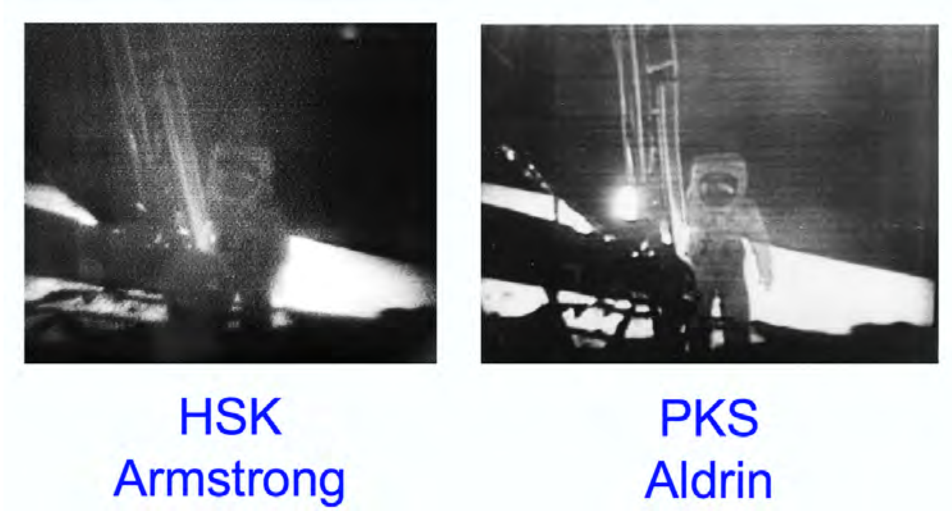


Figure 14–6: A comparison of the Apollo 11 television image quality received at NASA's Honeysuckle Creek tracking stations (HSK) and the Parkes Radio Telescope (PKS) as seen on the station monitors. Credit: www.honeysucklecreek.net.

VIII. Apollo 13

Parkes was not initially required for the Apollo 13 mission. The Moon's northerly declination meant that Parkes only had two hours of coverage per day and this occurred at unimportant times [Ref. 37]. All this changed when just two days into the mission, on April 14, 1970 (AEST), one of the spacecraft's oxygen tanks exploded, severely crippling the Command Module, *Odyssey*.

John Bolton just happened to be in his office at the time, and was listening to the air-to-ground conversations when he heard the mission commander, Jim Lovell report; "Houston, we've had a problem here." From his thorough understanding of the flight plan, John realized that the LM would be used as a lifeboat and that the immediate return to Earth would be in the Parkes coverage time. He anticipated that Parkes would almost certainly be called in to assist [Ref. 33]. Luckily, CSIRO Radiophysics engineers were present at the telescope conducting a special experiment at the time, so he was able to get them to quickly uninstall their equipment and reinstall the NASA equipment instead. Other equipment was flown to Parkes from the Radiophysics head office in Sydney. The observatory staff accomplished in just ten hours what normally took close to a week [Ref. 33].

Figure 14–7: A tense moment in the Parkes control room during the Apollo 13 mission. Credit: CSIRO.

When the request for Parkes' support finally arrived from NASA, they were astonished to learn that Parkes was already aware of the problem and well on its way to being up and running for the next pass of the spacecraft. Parkes' senior receiver engineer, David Cooke, had the receiving equipment operating in time for Parkes to begin tracking Apollo 13. The extremely weak voice signals from the *Odyssey* were sent by landline to Sydney then onto Houston. The microwave links, which had been previously established for Apollo 11 and 12, were not operational at this stage. Shortly afterward, engineers from Tidbinbilla, headed by Bruce Window, arrived at the telescope. Working all night, they were able to complete the set-up, while technicians from the Post Master General's Department (the Australian domestic communications agency) reestablished the microwave links to Sydney before the next pass of the spacecraft. The critical nature of Parkes' support was evident in the fact that *Odyssey's* feeble signals were a thousand times weaker than those received from Apollo 11 [Ref. 33].

Meanwhile, Mike Dinn, the Deputy Director in charge of Operations at Honeysuckle Creek, was coordinating the efforts of all the Australian stations. At one point he had up to ten receivers tracking the spacecraft [Ref. 39]. The greater sensitivity of the Parkes telescope meant that it was able to download the telemetry data more quickly, thus saving precious time and spacecraft power. The 210-ft Goldstone dish was able to do the same in the non-Parkes coverage periods and the two together were able to extract the weak but vital telemetry and save the mission from disaster.

In a generous gesture of friendship to the United States, Sir Frederick White, the Chairman of the CSIRO, decided that NASA would not be charged for the use of the Parkes telescope, and that the CSIRO would assume the costs of bringing the telescope into commission to help Apollo 13 [Ref. 38].

Parkes continued to support the remaining Apollo missions. In particular, it played a major role in the Apollo 15 mission to Hadley Rille. By the time of Apollo 17 in December 1972, the 210-ft antenna at Tidbinbilla was finally completed and used for the first time with that mission.

With the formal commissioning of the Tidbinbilla dish in 1973, Parkes was no longer required for tracking operations. It was the end of an era.

IX. A New Era Begins

For the next 14 years, Parkes was no longer required for tracking operations, but this changed in 1986. The Voyager 2 spacecraft was nearing Uranus for a once-in-a-lifetime encounter, in January 1986. In order to maximize the scientific return of the mission, NASA decided to array, or link, the Parkes and Tidbinbilla 210-ft (64-meter) dishes via a two-million-dollar microwave link to double the sensitivity of the instruments. It was the realization of Taffy Bowen's vision of having the two dishes work together and justified the decision to locate the DSN station at Tidbinbilla. The Voyager 2 mission to Uranus was a resounding success and represented the first time that arraying was used to track a spacecraft. The technique was later repeated at Neptune in August 1989. Between the missions, in 1987, the DSN antennas were enlarged to 70-meters (230-ft) to give them even greater sensitivity at Neptune.

X. A Year with Galileo

In 1989, the Galileo spacecraft was launched from the Space Shuttle toward Jupiter. The spacecraft had a large high-gain antenna that operated at 8.4 GHz (X-band). Once it was safely enroute to Jupiter, it was supposed to unfurl, umbrella-like, and transmit at data rates of 139,000 bits-per-second (bps). Unfortunately, the antenna jammed and failed to open fully. Despite many attempts to release it, it remained stuck in its partially open state. This rendered the antenna useless and threatened the billion dollar Galileo mission with disaster. Fortunately, the circuitous route to Jupiter meant that it would take six years to get there. This gave the mission planners time to think of a solution. Once again, they called on Parkes to help.

Their solution was to array as many of the DSN antennas as possible with Parkes. A less powerful S-band, omnidirectional antenna on the spacecraft would be used to transmit the data instead. Because of the lower power of this antenna, the bit rate would normally only be 10 bps if a single DSN antenna was tracking it (as was planned). However, by arraying several dishes together, the bit rate could be modulated, up or down, depending on how many were tracking the spacecraft. At those times when Parkes was included in the array, the bit rate could be increased to the maximum rate of 160 bps. This was still way down on 139 kbps, but it was better than the 10 bps without the array. By further using clever data compression algorithms, 70% of the planned science could be salvaged. These arraying operations meant that Parkes was needed for tracking duties for periods of up to ten hours a day for one year; the period of the initial 11-orbit tour of Jupiter.

The Parkes telescope could only house one receiver in its focus cabin at any one time for radio astronomy observations. If the dish was required for tracking operations, it meant that the normal radio astronomy observations could not be undertaken in the remaining 14 hours of the day. To get around this problem, NASA funded an upgrade that allowed a new, larger focus cabin to be built and installed on the dish. This new focus cabin was capable of housing up to four receivers, any one of which could be placed on the focus within minutes. This increased “frequency agility” was a boon to radio astronomers. The larger focus cabin also meant that larger and more complex receivers could be built and used for innovative radio astronomy projects. The CSIRO readily agreed to support the mission.

Figure 14–8: Installation of the NASA-funded enlarged focus cabin on the Parkes telescope. This enabled Parkes to support the Galileo mission at Jupiter, while still undertaking its regular radio astronomy observation program. Credit: CSIRO.

The formal tracks commenced on 28 October 1996 and continued until November 6, 1997. Remarkably, the operations team achieved a 96.95% uptime, greatly exceeding all expectations, with no tracking time lost due to operator error or equipment break-down. It was a resounding success.

XI. A Traffic Jam at Parkes

In 2003–2004, a traffic jam at Mars was looming. NASA termed this an Asset Contention Period (ACP). Up to seven spacecraft were scheduled to be at Mars with several more were strewn across the Solar System. They were all clustered close to the same celestial longitude as Mars and they all needed to be tracked. Unfortunately, there were too few antennas at Tidbinbilla to cope with this “traffic jam.”

In order to augment the tracking capabilities of the DSN at Tidbinbilla, Parkes was contracted to provide an extra receiving capability. This freed the Tidbinbilla antennas to track those spacecraft requiring two-way communication (as a radio telescope Parkes cannot transmit, only receive). However, because these spacecraft transmitted at X-band, it was essential to increase the Parkes telescope’s sensitivity at these frequencies. Once again, NASA funded an upgrade to the dish surface. In March 2003, the surface of the dish was repanelled. This upgrade extended the perforated aluminum panels on the antenna to 55 meters diameter (from 45 meters) and increased the sensitivity of the dish by 1 dB at X-band.

On October 31, 2003, the 44th anniversary of the dish, the US Ambassador to Australia, His Excellency, J. Thomas Shieffer, visited Parkes and officially launched the Parkes Mars Tracks. Over the next four months, Parkes tracked mainly Voyager 2, Mars Global Surveyor and the Mars Exploration Rovers, Spirit and Opportunity, while enroute to Mars.

Figure 14–9: Before and after comparison of the upgrade to the Parkes antenna in 2003, showing the additional aluminum paneling added to increase the dish's sensitivity to X-band signals. Credit: CSIRO.

XII. Huygens Heroes

The NASA/ESA Cassini-Huygens mission was launched on October 15, 1997 and spent seven years cruising to Saturn. It arrived on July 1, 2004 and went into orbit about the planet. The spacecraft was in two parts: The Cassini spacecraft was an orbiter built by NASA and is still in orbit studying the planet, its rings and retinue of Moons. The Huygens probe was built by the European Space Agency (ESA) and was intended to study the atmosphere of Titan as it descended to the surface on January 14, 2005.

The Huygens probe was designed to transmit its data to Cassini in two separate channels, one at 2040 MHz and the other at 2090 MHz. Since the descent of the probe would occur in view of the Pacific Ocean, Leonid Gurvits of the Joint Institute for VLBI in Europe (JIVE) organized a VLBI network around the Pacific Rim to take advantage of this fortuitous alignment. The plan was to track the weak channel A (2040 MHz) signal and pinpoint the position of Huygens to within just one kilometer, and to obtain the transverse velocity (on the plane of the sky) as well as the Doppler (radial) velocity.

JIVE arranged for up to 17 antennas to be linked together in a VLBI network. Five of these antennas were located in Australia. Other antennas were located in the United States including the 100-meter telescope at Green Bank, West Virginia. The Green Bank and Parkes telescopes were essential for the observation because of their large collecting areas.

The first part of the descent of the Huygens probe would be visible from Green Bank and the second part from Parkes. Twenty minutes before the probe was scheduled to land on Titan, it would set at Green Bank. But at Parkes, the expected landing time was just one minute after it was scheduled to rise: that is, the critical events at Parkes would occur right on the telescope's horizon.

In late 2004, JPL contacted the CSIRO and asked if they could piggyback their Doppler Wind Experiment (DWE) on the Parkes observations. JPL planned to install Radio Science Receivers (RSR) at Green Bank and Parkes to enable them to detect the Doppler data in real time, rather than to wait weeks or months to get it from the VLBI data. The JPL DWE measurements would enable the determination of Titan's wind speed in the Earth-probe direction as a function of altitude. This experiment was planned as a backup to a similar experiment on the Cassini mother craft. When Huygens entered the atmosphere of Titan, the giant Green Bank telescope in West Virginia, USA, was poised to detect the signal when the transmitters sprang to life. Sure enough, right on schedule, JPL's Dr. Sami Asmar, who was based at Green Bank, reported the detection of the signal.

The RSRs at Green Bank and Parkes were capable of measuring the Doppler shift of the signal in real time. By comparing the observed Doppler shifts to those predicted from a smooth atmospheric descent model, any variation from them was an indication of what the real atmosphere of Titan was doing, that is, it was a measure of the winds on Titan. As the probe descended, the deviations of the Doppler shifts increased and fluctuated. The winds on Titan were furiously blowing the little probe about.

After about an hour and a half, the probe set at Green Bank. Seventeen minutes later it rose at Parkes, right on schedule. The signal was 2.5 times stronger than expected. About 15 minutes after it had received the signal, Parkes reported that the probe had landed on Titan, a little later than expected. It was a second moon landing for Parkes!

The Huygens batteries were designed to last for only about one hour after the landing. But, as the track continued, the signal remained strong and showed no indication of weakening. As the one-hour mark passed, followed by the two-hour mark, it was obvious that the batteries would last much longer than expected. The Parkes dish continued to perform flawlessly throughout the track until at 1:56 am (AEST) Huygens finally set at Parkes, still transmitting strongly. The champagne was duly popped open in celebration. For this moon landing, the high winds were thankfully on Titan and not at Parkes. It had been a magical night!

Shortly after the end of the track, it became apparent that the data being played back by Cassini was missing the 2040 MHz (channel A) telemetry. Apparently, a sequencing error by the ESA controllers in Germany, had resulted in the 2040 MHz receiver on board Cassini not being switched on. This meant that although the data from channel A was transmitted by Huygens it was not received by Cassini. Since it was this beacon that Parkes was tracking, the Parkes and Green Bank recordings of the channel A signal assumed greater significance in the DWE. In fact, the Parkes and Green Bank observations salvaged the entire experiment: "sometimes it pays to eavesdrop" declared Dr. Sami Asmar of JPL.

XIII. A Little Curiosity Goes a Long Way

On Monday, August 6, 2012, at 3:31 pm (AEST), the Mars Science Laboratory rover, Curiosity, safely landed on Mars. The CSIRO's Parkes telescope was tracking the rover's UHF beacon during the Entry, Descent and Landing (EDL). Right on schedule at 3:16 pm (AEST) the signal was detected. It was slightly stronger than expected. Parkes tracked the descent of the rover until just after the parachute deployment and heat shield separation. Less than two minutes before it was scheduled to land, it dropped below the Martian horizon, out of sight of Earth at 3:30 pm (AEST). Throughout the descent, Parkes was acting as a backup for the Canberra Deep Space Communication Complex (CDSCC) at Tidbinbilla, which was the prime station for the mission.

In order to support the mission, an existing 70 cm radio astronomy receiver was modified by CSIRO engineers and technical staff to operate at the UHF frequency of 401.58 MHz employed by the rover. Two weeks before the EDL, the Radio Science Receiver was delivered to Parkes from Tidbinbilla and installed in the control room. Sami Asmar of JPL, was at Parkes to operate the RSR. John Reynolds setup the VLBI recording system to backup the JPL RSR.

The dish was focused on Mars in preparation for the signal reception. Right on schedule, at 3:15 pm (AEST), the cruise stage separated and then a minute later at 3:16 pm, the UHF beacon appeared in the passband of the RSR data. The signal was strong, giving confidence that the spacecraft was operating as expected. As the rover continued the descent, the signal being Doppler shifted in the plots produced by JPL. The parachute deployment and heat shield separation were clearly evident on the plots. The Parkes loss of signal (LOS) occurred at 3:30 pm (AEST) as the spacecraft was occulted by Mars. Less than two minutes later, Sami reported that Curiosity had landed safely. A cheer went up in the control room. Within a few minutes, the first pictures from the rover on the Martian surface were received at Tidbinbilla, confirming that the landing was a total success. This was the cue to pop open the champagne. The success of the mission was toasted and congratulations sent to NASA, JPL and the CSIRO crews at Tidbinbilla and Parkes for jobs well done.

A few days earlier, Dr. Phil Diamond, the Chief of the CSIRO Astronomy and Space Science Division, stated; "The expertise of Australian personnel in space communications and CSIRO's partnership with NASA will be showcased during this critical event in the Mars Science Laboratory's mission. All of our technology and our people are ready." Indeed, it was an amazing achievement.

XIX. Conclusion

On October 31, 2003, the United States Ambassador to Australia, Thomas Shieffer, remarked; " … the Parkes Telescope is like a trusted friend, 'always there when we need a hand.' The relationship between the CSIRO and NASA is very much like that between the United States and Australia, as friends that share common values and dreams." The history of the CSIRO Parkes Telescope's support of space missions is a testament to this special relationship.

Parkes was the inspiration and model for the large antennas of NASA's DSN, and has always been there whenever NASA has needed extra support. The relationship between CSIRO and NASA has benefited both sides equally. The CSIRO has been able to maintain the Parkes telescope's leading role in world radio astronomy, largely through the support of NASA/JPL over the years. Partly because of this, it is still arguably the finest single-dish radio telescope in the world. In return, NASA has had a reliable partner, always available to help when it was needed. The upgrades to the telescope have meant that a better and more reliable instrument was available when it was needed next time.

Acknowledgement

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