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On Eagle's Wings: The Parkes Observatory's Support of the Apollo 11 Mission

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Abstract: At 12:56 p.m., on Monday 21 July 1969 (AEST), six hundred million people witnessed Neil Armstrong's historic first steps on the Moon through television pictures transmitted to Earth from the lunar module, *Eagle*. Three tracking stations were receiving the signals simultaneously. They were the CSIRO's Parkes Radio Telescope, the Honeysuckle Creek tracking station near Canberra, and NASA's Goldstone station in California. During the first nine minutes of the broadcast, NASA alternated between the signals being received by the three stations. When they switched to the Parkes pictures, they were of such superior quality that NASA remained with them for the rest of the 2½-hour moonwalk. The television pictures from Parkes were received under extremely trying and dangerous conditions. A violent squall struck the telescope on the day of the historic moonwalk. The telescope was buffeted by strong winds that swayed the support tower and threatened the integrity of the telescope structure. Fortunately, cool heads prevailed and as Aldrin activated the TV camera, the Moon rose into the field-of-view of the Parkes telescope. This report endeavours to explain the circumstances of the Parkes Observatory's support of the Apollo 11 mission, and how it came to be involved in the historic enterprise.

Keywords: history and philosophy of astronomy — radio astronomy

1 Introduction

It was one giant leap for mankind, and it was taken at 12:56 p.m. Australian Eastern Standard Time (AEST) on Monday 21 July 1969.

Six hundred million people, or one fifth of mankind at the time, watched Neil Armstrong's first steps on the Moon. Three tracking stations were receiving the signals simultaneously. They were CSIRO's Parkes Radio Telescope, the Honeysuckle Creek tracking station outside Canberra, and NASA's Goldstone station in California.

The signals were relayed to Mission Control at Houston. During the first few minutes of the broadcast, NASA alternated between the signals from its two stations at Goldstone and Honeysuckle Creek, searching for the best quality images. When they switched to the Parkes pictures, they were of such superior quality, that NASA remained with the Parkes TV pictures for the remainder of the 2½-hour telecast.

But it almost didn't happen.

In late 1968 NASA had asked for Parkes to be used in the Apollo 11 mission. The giant telescope would be the prime receiving station for the reception of telemetry and TV from the surface of the Moon. Using it also provided extra gain in signal strength from the Moon. This meant that during the tightly scheduled first moonwalk the astronauts would not have to spend time setting up a large antenna to get the necessary signal strength.

The then Director of the Parkes Observatory, John Bolton, insisted on a one-line contract with NASA: 'The [CSIRO] Radiophysics Division would agree to support the Apollo 11 mission'.

At 6:17 a.m. (AEST) on 21 July, astronauts Neil Armstrong and Edwin (Buzz) Aldrin landed their LM, *Eagle*, on the Sea of Tranquillity. It was still some seven hours before the Moon would have risen high enough to be seen from Parkes.

The schedule required the astronauts to rest before attempting the moonwalk, by which time the Moon would have been high overhead at Parkes. However, Armstrong departed from the original plan, opting for an immediate moonwalk instead. To the astronomers at Parkes, it looked as though the moonwalk would be all over before the Moon even rose over Parkes. However, it took the astronauts such a long time to don their spacesuits and depressurise the LM cabin that as they left the module the Moon was just rising over Parkes. It seemed as though they would get the signals after all.

But suddenly troubled loomed. While fully tipped over waiting for the Moon to rise, the telescope was struck by a series of severe, 110 km per hour gusts of wind, which made the control room shudder. The telescope was slammed back against its zenith axis gears. This was a dangerous situation, threatening the integrity of the telescope structure. Fortunately, cool heads prevailed, and as the winds abated, Buzz Aldrin activated the TV camera just as the Moon rose into the telescope's field of view, and tracking began.

Using a less sensitive 'off-axis' detector, Parkes was able to receive the TV pictures just as the LM TV camera was switched on. Less than nine minutes later the Moon had risen into the field of view of the Parkes telescope's main detector. Because Parkes was a larger telescope, it

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captured more signal and so produced better pictures. Houston switched to Parkes and remained with those pictures for the rest of the 2½-hour broadcast.

Parkes staffer Neil 'Fox' Mason, who was seated at the control desk, drove the telescope without being allowed to once turn around and see the incoming pictures on the TV monitor. It was essential for him to monitor the tracking of the telescope, in case the winds picked up again, threatening the signal reception. The weather remained bad at Parkes, with the telescope operating well outside safety limits for the entire duration of the moonwalk.

The signals were sent to Sydney via specially installed microwave links. From there the TV signal was split. One signal went to the Australian Broadcasting Commission (ABC) studios at Gore Hill for distribution to Australian television networks. The other went to Houston for inclusion in the international telecast, where a six second delay was introduced by NASA in case an accident occurred to the astronauts. Because the international broadcast signal had to travel halfway around the world from Sydney to Houston via the INTELSAT geostationary communications satellite over the Pacific Ocean, a further 300 millisecond delay was added to the signal. Australian audiences therefore witnessed the moonwalk, and Armstrong's historic first step, some 6.3 seconds before the rest of the world.

This report endeavours to explain the circumstances of the Parkes Observatory's support of the Apollo 11 mission. The success of the support was a result of the dedication and professionalism of the CSIRO and NASA staff at the observatory, and of the technicians and workers of Australia's communication network, notably from the Post Master General's office (PMG), the Overseas Telecommunications Commission (OTC), the ABC, and the Australian Department of Supply.

2 Parkes Gets Involved

In late 1966, NASA put forward a proposal to include the Parkes 64 metre dish permanently into its worldwide tracking network. Until then, the network of 26 metre dishes had met most of NASA's requirements. Plans to send probes to more distant planets as well as the upcoming manned Apollo missions to the Moon demanded a network of larger dishes. NASA was near to completing the construction of its 64 metre dish at Goldstone, California, but budget cutbacks meant that the second and third stages of its 64 metre network, in Australia and Spain respectively, had to be postponed until the early 1970s. The dishes were all modelled on the Parkes Telescope (see Figure 1). These developments made Parkes' inclusion an attractive alternative, at least until the other two 64 metre dishes were constructed. This proposal was, however, turned down owing to the fact that a growing number of observing requests from Australian astronomers meant that many would have missed out on getting precious observing time on the telescope (Robertson 1992).

Figure 1 The Parkes Telescope as it appeared in the 1960s (Photo: CSIRO).

In October 1968 the Director of Parkes Observatory, John Bolton, and his wife Letty, while on a trip to the USA attended a dinner party at the home of Bob Leighton. Bob was a brilliant Caltech engineer who was a colleague of John's when John was a professor of astronomy at Caltech in the 1950s. Also present at the party was the Head of the Goldstone Project, Eb Rechtin of NASA's Jet Propulsion Laboratory (JPL). During the course of the evening, John was asked if he could make available the observatory's 64 metre telescope for reception of signals from the Apollo 11 spacecraft, particularly during the most critical phases of the mission when the 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 Edward 'Taffy' Bowen, the Chief of CSIRO's Radiophysics Division, and John Bolton to support the mission (Goddard & Milne 1994).

Following high level representations, Cabinet level meetings approved the Parkes Observatory's involvement in the upcoming Apollo 11 mission. In February 1969 a meeting was convened with the Australian Department of Supply to arrange contract details. John Bolton had spent the previous evening with Robert Taylor, the American engineer who was to manage the NASA operations at Parkes. They had discussed their respective roles extensively, and the problems to be overcome. John Bolton ended the meeting by insisting that he could work with Taylor, and that he would only accept a one-line contract: 'The Radiophysics Division would agree to support the Apollo 11 mission' (see Figure 2). Financial return was to be $3500 per day to cover costs at Parkes, plus $15 000 to cover additional work on the telescope.

For the tracking operations at Parkes, NASA provided the S-band front-end receiving equipment. Also provided

Figure 2 The three principle players at Parkes (L–R): John Bolton, Robert Taylor and Taffy Bowen (Photo: CSIRO).

were tape recorders and 'translating' equipment for converting the incoming signals into a TV picture so that the operators could check that everything was functioning correctly.

The Observatory provided the feeds, cabling, power, weatherproofing of the aerial platform, and facilities for the OTC link equipment. In addition, the PMG established a network of microwave links and voice communication channels to relay both the Parkes and Honeysuckle Creek signals to Houston (Goddard & Milne 1994).

3 The Plan

The original mission plan of Apollo 11 had Parkes acting as a backup during the moonwalk for NASA's two tracking stations, the 64 metre dish at Goldstone in California, and the 26 metre dish at Tidbinbilla near Canberra, Australia. This was in case of a delayed moonwalk, or some other reason. The 26 metre dish at Honeysuckle Creek tracking station, also near Canberra, would track the command module, *Columbia*, and co-ordinate the effort between the Australian stations. The Goldstone dish was to be the prime receiving station.

The flight plan had the astronauts performing the Extra Vehicular Activity (EVA), or moonwalk, shortly after landing. The Moon was not due to rise at Parkes until 1:02 p.m. (AEST), by which time the EVA would have been completed. In addition, the astronauts were to deploy a 3 metre, erectable, S-band antenna, as was later done on Apollo 12 and 14. The purpose of this was to provide greater signal strength from the Moon.

All this was 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 lunar EVA. This would have given the astronauts an opportunity to adjust to the Moon's 1/6th gravity, and to start the EVA refreshed. The new plan had the EVA starting about ten hours after landing, at 4:21 p.m. (AEST), which was some twenty minutes after the Moon had set for the Goldstone dish, but which had the Moon high overhead at Parkes. Parkes' role was consequently upgraded from backup to prime receiving station.

The subsequent upgrading from backup to prime station meant that all equipment had to be duplicated at Parkes. Two sets of receivers, two sets of microwave relays, two sets of voice and command links etc. were installed.

Since Parkes could only receive and not transmit, it was regarded as an auxiliary station to Honeysuckle Creek and was assigned the honorary designation of station number 23 in the Manned Space Flight Network (MSFN).

Originally, only voice communications and spacecraft and biomedical telemetry were to be received. Mission planners had not included a broadcast of television pictures of the first moonwalk until quite late in the planning. For them, what mattered most was the vital telemetry on the status of the astronauts and the LM systems. Television was an unnecessary secondary concern. The LM was severely weight restricted, which meant that every additional kilogram it carried required many times more its weight in fuel. These weight restrictions had already delayed the development of the LM by several months. In order to include a television camera, other equipment had to be modified and lightened accordingly. Stan Lebar, the Program Manager for the Westinghouse Lunar Surface Camera, describes the decision:

> Probably one of the most amazing meetings on this subject occurred at NASA's Manned Spacecraft Centre, Houston, some time in the early part of 1969. The meeting was convened to determine if the television camera should be taken to the moon on the Apollo 11 mission, which was only a few months away. The session was attended by just about every manager at NASA and anyone else who knew how to spell TV. It was, to say the least, a very large audience. The basic information about how the television was to be used, and the timelines for its use, was covered by a gentleman by the name of Ed Fendell. Ed was part of NASA operations and responsible for the use and scheduling of the television during the flight to the Moon and on the lunar surface. Ed concluded his presentation by saying, in summary, that there is no reason to have television on the moon and the camera should not be taken. The audience en masse rose to its feet and objected loudly to Ed's conclusions. The old timers in the audience who had brought this program to where it was, stood up and delivered impassioned speeches about how NASA owed it to the people to be able to witness this historical event live as it unfolded. When it was all done, it was unanimous that the Apollo would carry a television camera.

Once the decision had been made to include television, the addition of Parkes was even more desirable. The large collecting area of the Parkes telescope provided for extra gain in signal strength from the Moon. This meant that the astronauts would not have to deploy their 3 metre, erectable, S-band antenna. The tight schedule of the first moonwalk was such that NASA planners had decided the extra time and effort needed in deploying the antenna (about 20–45 minutes) was not warranted. Instead, the smaller 0.66 metre S-band antenna, located at the top of the LM ascent stage, was used, and having Parkes in the link would provide the extra gain in signal strength. NASA wanted TV pictures of Armstrong descending to the lunar surface, which of course would have been before he could deploy the erectable S-band antenna. Parkes thus provided the maximum reliability and quality for the telemetry, which the mission planners demanded.

3.1 The Roles of the Other Australian Stations

Honeysuckle Creek was the main NASA tracking station in Australia for all the manned Apollo missions and co-ordinated the tracking effort between the various NASA stations and Parkes. The stations were operated for NASA by the Department of Supply and manned by Australians.

In the pre-mission planning, Tidbinbilla was scheduled to track the LM, *Eagle*, on the lunar surface, and Honeysuckle Creek was to track the command module, *Columbia*, in lunar orbit. Tidbinbilla had a maser low noise amplifier (LNA) that gave it greater sensitivity than Honeysuckle Creek.

A third NASA tracking station at Carnarvon in Western Australia was scheduled to track the LM with its 9 metre antenna and receive the telemetry from the surface experiments the astronauts were to deploy. The signals were then to be sent to Houston via the INTELSAT III Pacific geostationary satellite.

The CSIRO Radiophysics Division's Culgoora radioheliograph, near the town of Narrabri in northern NSW, was used to observe the Sun and warn NASA of impending solar flares. Because the astronauts would be outside the protection of the Earth's radiation belts, a sudden eruption of a solar flare could expose the astronauts to lethal doses of radiation. The radioheliograph would give them sufficient warning to abandon the EVA and return to the relative safety of the LM.

3.2 A Fire Leads to a Change of Plan

The personnel at Tidbinbilla, under the directorship of Don Grey, were looking forward to receiving the historic television of the EVA. Unfortunately for Tidbinbilla, a fire in the transmitter just one day into the mission on 18 July altered the plan drastically. Despite engineers being able to repair the damage in just 12 hours, the incident dented NASA's confidence in the station, so its role was switched with Honeysuckle Creek. This was a great disappointment to the engineers at Tidbinbilla who had worked tirelessly to get the system back up and running in such a short time. For Honeysuckle Creek however, this twist of fate would prove to be significant.

4 The Unified S-band Communication System

The LM spacecraft telemetry operated at S-band with a carrier frequency of 2282.5 MHz. The S-band steerable antenna, located at the top of the LM ascent stage, was used to transmit the television signals and other telemetry. Communications from the LM were limited by the available power and bandwidth. Consequently, the full spectrum of the signal contained both the telemetry and the TV; a separate commercial-standard TV telecast was not possible. The TV was frequency modulated (FM) on the carrier, and the subcarriers, which were phase modulated (PM) at several different frequencies, contained the telemetry information. Table 1 shows the various frequencies.

This was collectively referred to as the Unified S-band Communication System (Kelly 1969).

Parkes had two receivers installed in the focus cabin of the telescope (an excellent example of NASA's policy of building system redundancy, which later proved to be fortuitous). One receiver was placed at the focus of the telescope, and the other was offset a small distance, in one of the four off-axis positions. The receivers were supplied by JPL, and were commercial units built by the US company Micromega. They had room temperature parametric amplifiers and system temperatures of less than 100 K (most probably T_{sys} of 80 K).

Dr Bruce Thomas of the CSIRO Radiophysics Division designed the feed horns for the receivers. The horn for the main (on-axis) receiver was a one wavelength, two hybrid-mode corrugated horn. The horn for the off-axis receiver had a smooth circular cross-section with a flared tapered aperture, and a corrugation surrounding the aperture of the horn. The main receiver horn was the first experimental test bed corrugated horn which was used to verify the operation of a two hybrid-mode horn (see Figure 3). This innovative CSIRO-designed feed horn increased the sensitivity and bandwidth of the receivers. It was originally designed to operate at 2700 MHz, which was a routine operating frequency in those days. Bruce was able to change the tapered section to operate at the lower frequency of 2282.5 MHz. The corrugated section remained unchanged.

NASA calculated the relative velocity of the spacecraft, and the amount the carrier frequency was Doppler shifted

Figure 3 The CSIRO-designed Apollo feed horn (Photo: CSIRO).

Table 1. The unified S-band (USB) frequencies

Information	Frequency or rate (in kilobits/sec)	RF Carrier modulation	Subcarrier modulation	Subcarrier frequency
LM Telemetry (PCM non-return zero)	High bit rate: 51.2 Low bit rate: 1.6	PM	Phase Shift	1.024 MHz
Voice	300 Hz–3000 Hz	PM	FM	1.25 MHz
Biomedical	14.5 KHz subcarrier	PM	FM	1.25 MHz
Television	10 Hz–500 KHz	FM baseband		

was determined. These frequency predicts were then used to tune the receivers (by altering the LO frequencies) in order that the down-converted carrier be centred in the bandpass of the 50 MHz IF. These frequency predicts were supplied by NASA on teletype machines, just hours before the tracks commenced.

5 The Parkes Communication Network

Once received at Parkes, the composite signal was sent by microwave link to the PMG Waverley exchange in Sydney, then onto the OTC Paddington terminal just a few kilometres from Waverley. The PMG microwave link at Parkes was located on the east-west service tower, about 100 metres due east of the telescope. Two AWA microwave dishes transmitted the signal to Mt Coonambro about 30 km southeast of the telescope. Each of the dishes operated at different frequencies — the main link was at a frequency of 4 GHz, and the backup was at 7 GHz. They operated on a hot-standby mode, which meant that in the event of a failure in the main link, the signal would immediately switch to the backup without any loss of data. From Mt Coonambro the signal was sent on a 4 GHz link to the West Orange repeater, and from there it was fed down the 6 GHz PMG bearers to Redfern, and on to the Waverley exchange.

At Paddington, the TV and telemetry were separated and distributed. Since the TV was modulating the baseband, the telemetry subcarriers were first removed from the TV signal by using notch filters to null them. The television pictures were then scan-converted and forwarded on to Houston. The filtered voice, telemetry and biomedical subcarriers were sent on to Honeysuckle Creek via PMG microwave link and the Deakin telephone exchange in Canberra.

5.1 In Sydney

In Sydney, the Parkes composite signal had the voice and telemetry subcarriers filtered out with a subcarrier cancellation device. This device eliminated the subcarriers by a locally generated subcarrier locked to the incoming signal and 180° out of phase with it. There was a very narrow range of frequency loss on the video as a result, but the video was unusable without filtration. The television pictures were produced and then scan-converted to the US EIA (NTSC) commercial television standard at Paddington. The TV signals received and scan-converted at Honeysuckle Creek were also sent on to Paddington. A NASA Goddard Spaceflight Centre employee, Charlie Goodman, also located at the Paddington terminal, then selected the best quality television picture from the Parkes and Honeysuckle Creek signals, and passed it on to Houston via the OTC Moree Earth Station and the INTELSAT III Pacific satellite. A split of this selected TV was then passed on to the ABC studios at Gore Hill, Sydney, for conversion and distribution to the Australian television networks. The OTC Paddington terminal was referred to as 'Sydney Video' in the NASA communications network. Charlie Goodman, whose call sign in the network was also 'Sydney Video', was 68 years old and had delayed his retirement so he could work on Apollo 11. Shortly after the mission he retired.

Figure 4 illustrates the scene in the OTC Paddington terminal. Charlie Goodman is seated to the left of Verne McGlynn (his surname is uncertain) who is operating the switch that selects the Parkes or Honeysuckle Creek TV. The console has four small monitors and one large monitor. Of the four small monitors, the top left one had the TV from the Honeysuckle Creek scan-converter and the top right monitor had the TV from the Parkes scan-converter. The bottom left monitor displayed the TV from the ABC and the lower right monitor had the TV from Houston. The large monitor was displaying the output of the switch.

Richard Holl, seen standing with his back to camera, was the Bendix Field Engineering Corporation engineer who helped design modifications to the RCA scan-converters. He was the first to arrive in Sydney, and with the help of OTC technician, Wayne Ozarko, he installed all the equipment seen in the photograph. Elmer Fredd is seated at the scan-converter. To his right is Ted Knotts standing at an oscilloscope. Ray Louve is sitting in front of an Ampex VR660 video recorder.

Behind Charlie, just out of view, was another room known as the International Telecommunications Operating Centre (ITOC). Here the OTC personnel controlled the relays that fed the signals to Charlie Goodman and his team. In charge of ITOC was Bob Goodman (who was no relation to Charlie). Bob was the OTC International Co-ordinator for all the transmissions between Australia and the USA. There was a glass-panelled wall separating the two rooms that allowed the OTC and ABC personnel to monitor the broadcast from the Moon.

Figure 4 The scene in the OTC Paddington terminal. (L–R) Charlie Goodman, Verne McGlynn, Richard Holl, Elmer Fredd, Ted Knotts, and Ray Louve (Photo courtesy of Richard Holl).

5.2 At Honeysuckle Creek

At Honeysuckle Creek, the signal from Parkes was fed into the S-band Data Demodulation System (SDDS) and the telemetry was extracted. The Parkes main signal was fed into the demodulator DEMOD 4 and the backup (off-axis signal) was fed into DEMOD 2. The Parkes telemetry was synchronised and blocked with the Honeysuckle Creek telemetry, and sent on to Houston via the Deakin Telephone Exchange. The entire ground floor of the exchange was given over to NASA and it was known as the NASA Communication Centre in Canberra (NASCOM). From there the telemetry was sent back to ITOC at Paddington, Sydney, and then on to the OTC Moree Earth Station, in northern NSW. Finally, from there the signal was transmitted via the INTELSAT III (3F4) Pacific geostationary communications satellite to Jamesberg, California. From there the signal went to Houston via San Francisco along the lines of the AT&T company.

5.3 Voice and Command

Voice and command communications between Parkes, Honeysuckle Creek, and Sydney Video were provided by existing PMG telephone circuits. Two local telephone exchanges were used at Parkes. The main circuit was from the Observatory to the country automatic exchange at Beargamil about five km to the east of the telescope. The alternative, stand-by circuit was the Alectown manual exchange about 10 km north of the telescope. A senior PMG technician, Brian Coote, was present in the control room of the telescope and his task was to monitor the communications network. This network was referred to as NET 7.

5.4 Post Master General's Department Involvement

The whole range of facilities of the Post Office was used — coaxial cable, microwave radio, and open wires. Alternative circuits, sometimes even a third circuit, were available in case of a failure. Experts had checked and double-checked all the security aspects of the relays.

Sixteen thousand kilometres of trunk circuits were used for over a week. Just the television relay network over the eastern states covered 8046 km, all looked after by more than 100 engineers and technicians working around the clock (see Figure 5). These links were being carried free of charge by the PMG as the Apollo 11 relays were regarded as programs of national importance (Lindsay 1998).

6 Television from the Moon

6.1 The Apollo Lunar Television Camera

The lunar television camera was a black-and-white, slow-scan TV (SSTV) with a scan rate of 10 frames per second at 320 lines per frame. It weighed 3.29 kg (7.25 lb) and drew 6.5 watts of 24–32 volts of DC power. The camera body was 26.9 cm long, 16.5 cm wide, and 8.6 cm deep (10.6 × 6.5 × 3.4 inches). The bayonet lens mount permitted lens changes by a crewman in a pressurised suit. Two lenses were provided: a wide-angle lens for close-ups and large areas, and a lunar day lens for viewing lunar surface features and activities in the near field of view with sunlight illumination (NASA 1969).

The camera was stowed in an instrument pallet known as the MESA (Modular Equipment Stowage Assembly) in the LM descent stage. The MESA was to the left of the ladder as viewed from the front of the LM. When Armstrong was at the top of the ladder, he pulled a lanyard to swing open the MESA, which was hinged at

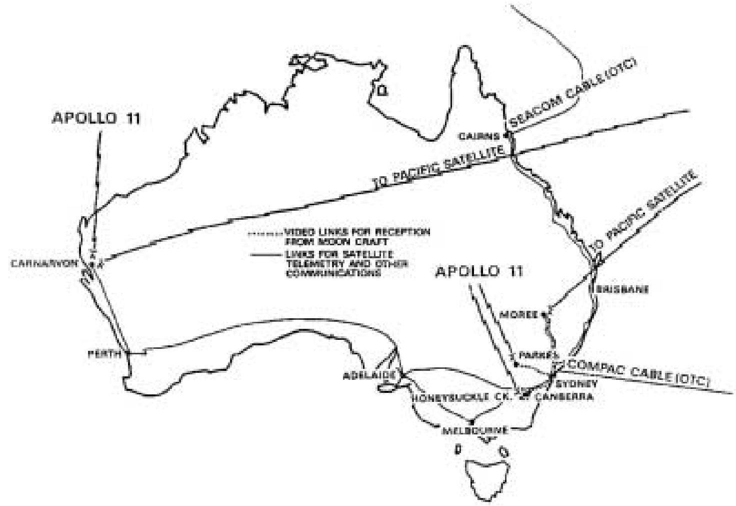

Figure 5 The communications links provided by Australia for the Apollo 11 mission (Photo: Hamish Lindsay).

the bottom. The TV camera, which was attached to it, would also swing down. It was mounted upside-down so as to secure it firmly to the MESA with vibration isolators and to also simplify its removal by the astronaut. Aldrin then switched on the camera by pushing in the TV circuit breaker in the cabin of the LM. The camera was pointing at the ladder of the LM, so that TV pictures of Armstrong's initial steps on the Moon could be relayed to the world. Later, after Aldrin had descended to the surface, Armstrong mounted the TV camera on a tripod, and placed it some 10 metres from the LM. The camera was left unattended to cover the crew's activities during the remainder of the moonwalk.

The camera was also capable of operating in a high resolution mode which was 5/8 frames per second with 1280 lines per frame (non-interlaced). This mode was designed to telecast a high resolution image in case the astronauts were not able to return to Earth with photographs. The camera had a switch located on the top surface that would allow the astronauts to operate it in either mode. Back on Earth, 10-inch monitors with yellow-green high persistence phosphor screens were equipped with Polaroid cameras for shooting directly off the screens. However, because of time constraints this high resolution mode was never used in flight.

The Apollo lunar television camera was built by Westinghouse Electric Corporation, Aerospace Division, Baltimore, Md, USA.

6.2 Scan-converting the TV Pictures

The TV pictures from the Moon were narrow band slow-scan TV, that is, 10 frames per second (non-interlaced) and 320 lines per frame. In order to broadcast them to the waiting world, the pictures had to first be converted to the commercial TV standards. In the US, the standard was the EIA (NTSC) standard of 30 frames per second (60 interlaced fields per second) at 525 lines per frame. In Australia, the standard was the higher resolution, CCIR 25 frames per second (50 interlaced fields per second) at 625 lines per frame.

For Apollo 11, an RCA scan-converter was used, which operated on an optical conversion principle. The pictures were displayed on a 10-inch black-and-white monitor and a Vidicon TK22 camera was pointed at the screen. As each frame of the 10 frames per second picture was received, it was displayed on the monitor. The camera was gated to scan a single field at the EIA (NTSC) rate of 1/60th of a second, that is it did not take a picture until the 10-inch monitor had completed displaying a full frame. The output of the camera was transmitted and simultaneously recorded on magnetic disc. The disc recording was then played back a further five times and transmitted. While the disc recorder was playing back, the monitor screen was blacked out and the next frame started displaying. The monitor had enough persistence that it retained the picture, and RCA built special circuits to adjust for any loss of brightness between the top and bottom of the picture. In this way, a 30 frames per second (60 interlaced fields per second) TV was produced — with only one in six fields being live.

While the TV camera was upside-down in the MESA, the pictures were also upside-down. When Armstrong removed the camera to plant it on the lunar surface, the pictures would be the right way up again. A simple technique was employed to invert the images during the scan-conversion process on the Earth. This involved modifying the scan-converter by installing a toggle switch on its front panel (see Figure 6). The switch was connected to the deflection coils of the Vidicon camera by means of a relay, which then inverted the picture by the simple expedient of reversing the vertical scans. Richard Holl, who was a Bendix Field Engineering Corporation engineer responsible for television ground support, helped design and implement the inverter switch.

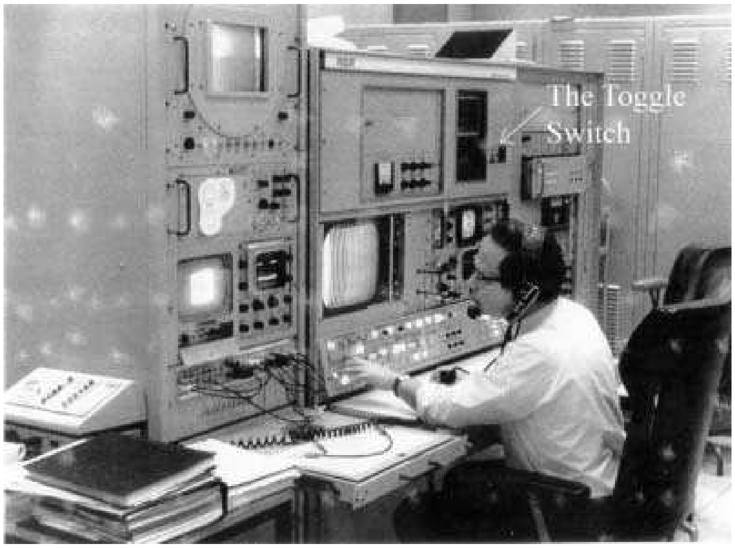

Figure 6 The Honeysuckle Creek RCA scan-converter. Ed von Renouard is at the desk. The toggle switch can be seen directly above his head (Photo: Hamish Lindsay).

The images at Goldstone and Honeysuckle Creek were scan-converted on-site to the EIA (NTSC) standard TV (Honeysuckle Creek only ever had US standard equipment of any kind). The Parkes pictures were scan-converted in Paddington, Sydney, to the NTSC standard also.

When Sydney Video selected the Parkes or Honeysuckle Creek pictures for Houston, the selected signal was split and sent to the ABC Gore Hill studios in Sydney for electronic standards conversion to the Australian CCIR standard. The ABC then distributed the pictures to all Australian networks for broadcast to an estimated audience of 10 million.

In Houston, NASA introduced a six second delay before releasing the TV worldwide. This was to give NASA enough time to cut the broadcast in case an accident occurred to the astronauts — NASA didn't want the world to witness a disaster. The ABC on the other hand didn't have this delay; it broadcast the TV live. Also, because the signal for the Australian broadcast did not have to travel to Houston (via satellite) and then back again as it did for the rest of the world, a further delay of 300 milliseconds was avoided. As a result of these, Australian audiences saw the pictures some 6.3 seconds before the rest of the world.

As the video and telemetry downlink was being received at Parkes, it was recorded onto ½ inch magnetic tapes on a Mincom M22 instrumentation recorder at a rate of 120 inches per second. These tapes had to be changed every 15 minutes during the whole period of the moonwalk. The scan-converted commercial NTSC standard television at Sydney Video was recorded on an Ampex VR660 two-head helical recorder using 2-inch tape.

6.3 Image Artefacts

A number of peculiar image artefacts were seen on the images broadcast to the world. One set of artefacts was produced by sunlight reflecting off the astronauts and the LM, directly onto the lens of the lunar TV camera. One prominent bright streak appeared to the right of the US flag. It was a reflection of the bright, sunlit, rear leg of the LM. Whenever the astronauts walked in front of the portion of the picture that coincided with the bright streak, it appeared to be visible through them. These reflections produced the ghostly effects remembered by the public (see Figure 7).

Another set of prominent artefacts were small 'white spots' seen in the images scan-converted from the Goldstone and Parkes pictures. These were a result of the optical conversion system. According to John Bolton, following tests of the system the 10-inch monitors were left on and burned spots on their screens. However Ed von Renouard, the Honeysuckle Creek video operator, suggested they may have been reflections from ceiling lights that somehow got into the matte black enclosures of the scan-converters through cracks and other areas. Bill Wood, the Goldstone lead video engineer, thinks they were defects in the targets of the Vidicon camera tubes and Richard Holl, the Parkes scan-converter designer and operator, agrees with him. Whatever their origin, when the images from Goldstone and Parkes were scan-converted, the spots were always present. The Goldstone pictures had a white spot located just below the centre of the screen, whereas the Parkes pictures had the spot located just above the middle of the right hand edge of the screen. The author has not been able to find any such spots on the pictures from Honeysuckle Creek. This has been fortuitous, since it has enabled the author to easily identify the sources of the pictures in the broadcasts of the moonwalk.

6.4 An Explosion in the Scan-converter

A few weeks before the launch of Apollo 11, the scan-converter at OTC Paddington exploded when it was switched on by Richard Holl following a test. The

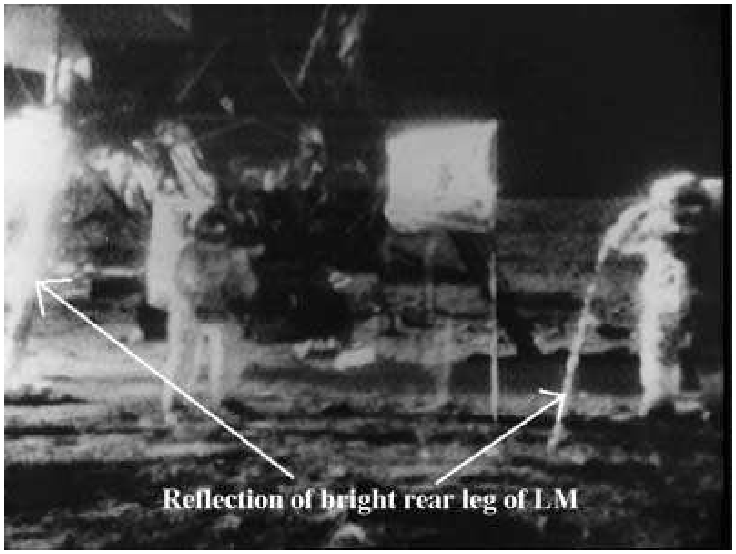

Figure 7 Photograph sourced from the Parkes TV, showing the most prominent image artefact — the reflection of the rear LM leg. Just below the flag can be seen the faint vertical streaks reflected from the astronauts' spacesuits.

explosion occurred because the scan-converter was wrongly rewired one evening. Weeks of frantic work by Richard Holl and his team resulted in the scan-converter being completely rebuilt. It wasn't until a few days into the mission that their work was completed in time for the historic broadcast. Richard Holl explains:

> The scan-converter used three phase power. It was the only piece of equipment in the room that did. All the other equipment was running on a 110 volt panel that was well labelled. Black is hot and green is ground in the USA, but in Australia black is neutral. It had originally been hooked up correctly to the US standard as we had just completed a full blown simulation the day before. The unit was fused for 240 volts as it had a three phase power supply, but it was the out of phase power that caused the massive current that did all the damage. Apparently an OTC technician working on other circuits thought the black wire was wrongly connected and changed it. When the scan-converter was switched on the next day it blew up. I got a meter out and checked the incoming power and found the mistake.
>
> I repaired or replaced the slow scan monitor, NTSC monitor, camera, disc recorder, power supplies, and Grass Valley video equipment. The camera in the scan-converter was totally fried. The new camera did not have the inversion modification in it. I couldn't take the hardware out of the bad one to modify the new one, so I had to buy all the components in Sydney. I couldn't get the exact relays, so I had to specially design the one for Sydney. It was different to the others. Ted Knotts and Elmer Fredd came over from the USA to help with the repairs. Ted did all the logistics like getting Hewlett Packard in Sydney to fix the waveform monitor and Tektronix to fix the oscilloscope, and getting us the spare parts and tools we needed. Elmer and I would never have gotten it all done without Ted taking care of our needs. I had to perform a lot of magic, but nothing compared to the magic Elmer performed when he started working on the converter logic. I bet we replaced over a hundred transistors (all discrete components) and we were still replacing them while the boys were on their way to the Moon. We made it and so did they.

7 The Parkes Telescope's Characteristics

The Parkes telescope is a parabolic, prime focus dish antenna with a diameter of 64 metres. When commissioned in 1961, it utilised many innovative design features that have allowed it to remain at the forefront of radio astronomy. The design was so successful that it became the model for the large antennas of NASA's Deep Space Tracking Network. These antennas, which were initially also 64 metres in diameter, are located at Goldstone in California, Madrid in Spain, and at Tidbinbilla near Canberra. The Goldstone antenna was known as the 'Mars dish', since it was to be used to track the Mariner 6 and 7 spacecraft as they flew by the planet Mars, shortly after the Apollo 11 mission, in August 1969. Bill Merrick, a JPL antenna engineer and collaborator of John Bolton's, spent many months at Parkes in the early 1960s testing the antenna structure.

The Parkes telescope is an astronomical instrument, and is designed to track radio sources across the sky at a sidereal rate. Its maximum rates of motion in azimuth and elevation are 25°/min and 10°/min respectively. This is far too slow to track low Earth orbit satellites, but is ideal for tracking deep space objects moving at near sidereal rates, such as Apollo 11.

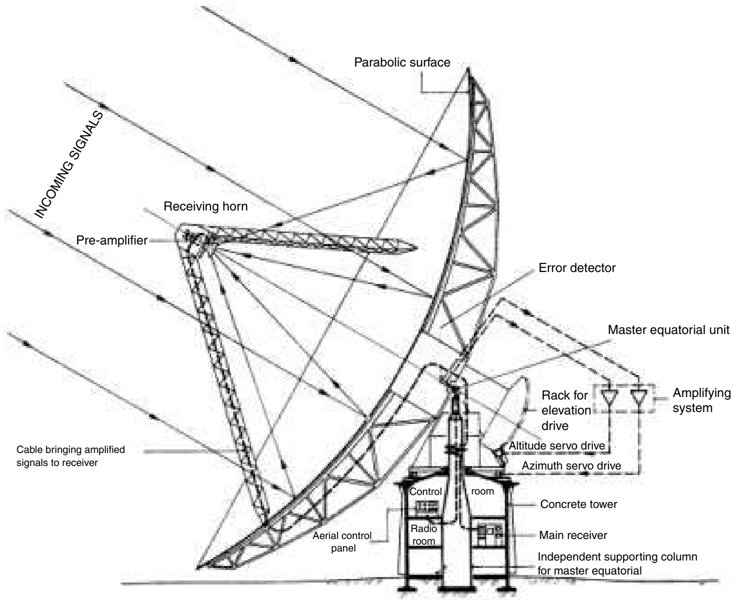

Figure 8 Schematic diagram of the Parkes Telescope. Note the telescope's 30° horizon.

The horizon of the Parkes telescope is some 29°38′ above the true horizon (see Figure 8). This was an intentional design feature that allowed the telescope to see the South Celestial Pole and hence observe the portion of the sky not well covered by dishes in the northern hemisphere. Also, the cost in constructing a tower tall enough to allow the dish to tip fully to the true horizon would have been too great. On 21 July 1969, the Moon was set to rise above the telescope's horizon at 1:02 p.m. (AEST).

The focus cabin of the telescope contained a turntable device with five holes in it. This was known as the feed rotator. The hole at the centre was at the focus of the telescope and was used to support the main observing receiver. The other four holes were arranged around the central hole, 90° apart. They could support other receivers which would have been offset a short distance from the focus. However, the attenuation of the signals at these off-axis positions would have been just a few decibels (~3 dB) down from the focus position — a useable signal was obtainable at these points. As its name suggested the feed rotator could be rotated, which was very useful since the telescope was an altazimuth mounted instrument and thus suffered from field rotation, that is, its field-of-view would appear to rotate as it tracked objects across the sky. By turning the feed rotator, the field-of-view of the on-focus receiver could be kept constant and thus polarimetry experiments conducted. A by-product of this technique was that as the feed rotator was turned, the field-of-view of the off-axis receivers would appear to move about the field-of-view, or beam, of the central, on focus, receiver along a circular arc opposite to the receivers. It was thus possible to move the telescope, and turn the feed rotator, in order to track objects with the off-axis receivers.

On 21 July 1969, the Parkes telescope had two receivers installed — one at the focus and another, less sensitive receiver, in one of the four off-axis positions. The precise offset position of the off-axis receiver has not been recorded, but according to Bruce Thomas there were two possible positions: one gave a field-of-view 1.2° from the main beam, and the other gave a field-of-view 1.43° from the main beam.

8 Operations at Parkes

8.1 Pre-launch

On Tuesday, 13 May 1969, the Minister of Supply, Senator Ken Anderson, and the Minister for Education and Science, Mr Malcolm Fraser, released a joint statement in Canberra announcing the Parkes Observatory's involvement in the Apollo 11 mission.

From 9 to 12 June 1969, AWA technicians arrived at the Observatory to begin installing the microwave equipment on the east-west service tower. They then returned on 1 July to continue the installation and testing of the equipment, staying until the end of the mission. At the same time PMG technicians, working under the Divisional Engineer, Mr W. Nankivell, began installing the communications network using existing telephone circuits between the telescope and the Beargamil and Alectown exchanges.

On 23 June 1969, a four-man team of NASA engineers arrived in Parkes to install the Unified S-band front-end receiving and monitoring equipment. The equipment suffered a few breakages during transport from the US, but these were repaired shortly after arriving at Parkes. The team was led by the Operations Manager, Mr Robert Taylor. The other three engineers were Mr Alfred Stella, Mr George Kropp, and Mr William Reytar (see Figure 9). Their task was to receive, record and relay the full set of voice, television, telemetry, and biomedical signals to Houston. Also during this period Richard Holl, from

Figure 9 NASA personnel at Parkes (L–R): Alfred Stella, George Kropp, William Reytar, and Robert Taylor (seated at front). They are posing in front of the receiver backend and SSTV monitoring equipment installed in the Parkes control room (Photo: CSIRO).

the OTC Paddington terminal, made three visits to the observatory to install the TV equipment.

According to Jasper Wall, a young PhD student at Parkes at the time:

> John Bolton's preparation for this event was immaculate. He pored over the NASA procedures and flow charts until he knew the mission by heart. He tried to understand and anticipate every eventuality. The NASA team arriving with receivers, duplicates, double monitoring systems, everything down to spare resistors (they didn't trust these foreign countries much!) found that they were interfacing with someone who knew the mission better than they did.

In the weeks leading up to the launch of Apollo 11, several tests of the equipment and procedures were carried out.

Telescope pointing during the mission was to be supplied by NASA a few hours ahead of time by lists of equatorial and altazimuth coordinates as a function of time. These were sent using teletype machines. In order to test emergency procedures such as visual guiding on the Moon from the hub room, and manual drive from the altazimuth gearboxes, trial sets of computations for the landing were requested from NASA by John Bolton. These were sent back, for the sets neither agreed with each other nor with the position of the Moon. A second lot had the equatorial and altaz coordinates agreeing but not the Moon. A third attempt was based on Parkes being located at 33° latitude north rather than south. Eventually, a correct set of coordinates was received, and on 1 July a Moon pointing test was successfully conducted with the S-band (13 cm) NASA receivers (see Figure 10).

Again Jasper Wall relates:

> One aspect of this preparation I remember was cranking the dish. Yes, following the spacecraft by hand cranking in both azimuth and elevation; could we do this in case the mains failed? (The NASA receivers had standby battery systems.) So there we were, out under the Parkes sun (glad it was July and not January), with teams of two guys each on the hand cranks for el and az, me with a stopwatch (I guess I was judged too small to man the cranks), JB with the set of coordinates and times, and away we went. We spent about three hours at this exercise. It did turn out to be possible and in fact the guys, Sid Horner, Ben Lam, Cliff Smith, Derek and Les Fellows, and others, could indeed crank fast enough even to get ahead of the spacecraft. But I don't think we ever established whether we could do it accurately enough to keep the spacecraft in the beam.

Figure 10 The Parkes Telescope tracking the Moon during a test several weeks before the mission (Photo: CSIRO).

On 14 July an exhaustive 10-hour test was carried out on tracking, recording and relaying operations. These operations were shown to the visiting press contingent. On the day before launch, 16 July, a pointing accuracy check was performed as well as sensitivity checks of the two feed and receiver systems.

8.2 The Press Arrives

On 14 July 1969, news-gathering organisations were granted 'the freedom of the radio telescope' as they prepared background material associated with the Parkes involvement in the tracking operations. The press were flown into Parkes and spent about four hours interviewing the CSIRO and NASA personnel, as well as photographing the telescope, control room, and receiving equipment (see Figure 11). Accompanying the press party were

Figure 11 Mr Wilson Hunter (on phone) and John Bolton (seated back) during the press conference (Photo: CSIRO).

Wilson Hunter, the NASA director of Australian operations, and Dr E.G. 'Taffy' Bowen, chief of the CSIRO's Radiophysics Division. The press party included representatives from 'The Daily Telegraph', 'The Sydney Morning Herald', 'The Sun', 'The Australian', 'The Women's Weekly', ATN Channel Seven, the Australian News and Information Service, and the ABC (who had two television teams in attendance).

During the press conference the ABC reporter, Tom McKay, asked John Bolton what the chances were of a technical breakdown during the mission. In a stunningly prophetic reply, John answered:

> We have a number of 100 to 1 chances and a number of 1000 to 1 chances. All these have been backed up. Perhaps our biggest weakness is the weather. If we get a very severe storm with very high winds then we'll no longer be able to keep tracking. But this period of the year is the best we have for this kind of situation at Parkes.

8.3 Site Access Restrictions

For a period of five days, from 17 to 21 July, the Observatory, Visitors' Centre, and all access roads for several kilometres from the telescope were closed to the general public. This was to prevent any outside interference from cars and other devices from disrupting the signal reception. Federal Police officers secured the site, and to gain access staff members were issued keys with 'A 11' inscribed on a small aluminium key-tag.

8.4 Cruise to the Moon

The tracks to the Moon were to test the tracking operations at Parkes, and to ensure that all the receiving equipment and relays functioned as planned. The responsibility of John Bolton, the Director of the Observatory, was to ensure that the telescope followed a precise tracking programme, and that all of the telescope's functions performed flawlessly.

The tracking data provided by NASA was in the form of a list with the predicted positions of Apollo 11 given in four-minute intervals. The telescope operator (known as the driver) would point the dish at the first predicted position. He would then move the dish in both axes at the correct rates so that four minutes later the dish would arrive at the next predicted position on the list. Often however, if the dish wasn't on position at the assigned time, the driver would have to move the dish quickly in order to catch up. Also, the driver could monitor the track on the signal strength indicator, and if required, move the dish to maximise the signal strength received. The drivers during the cruise to the Moon were Neil Mason, Bill Butler, and Ben Lam.

The journey to the Moon was uneventful, apart from errors of up to 25 arcmin in the NASA pointing data. On the day of the launch, 17 July, a pointing check was performed before the spacecraft was acquired some 13.6 hours after launch at 3:00 p.m. (AEST). The logbook entry indicates that a search for the spacecraft was required for an hour before it was picked up. There is no indication why this was so, but it may have been an error in the NASA pointing data. The tracks to the Moon were intended to provide back-up to the Deep Space Tracking Network (DSN). This overlap with the DSN may be why the provision of accurate pointing data was so lax. NASA's main concern for Parkes was the lunar EVA, and pointing data for that was accurate.

For the next two days the telescope continued to track Apollo 11 flawlessly to the Moon. Mrs Letty Bolton would visit the operators, delivering them sandwiches packed in a picnic basket.

One interesting observation made at this time was the variation in signal strength as the spacecraft performed its passive thermal control roll, or barbecue roll. This involved the spacecraft slowly spinning around its long axis, like a barbecue spit, in order to stabilise its thermal response to solar heating, that is, to prevent one side from overheating and the other from freezing. This slow spinning motion showed up as a slow, rhythmic variation of signal strength as the antennas on the command module, Columbia, rotated with the spacecraft. The period of the variations in signal strength was exactly the period of the thermal control roll.

On 20 July, Apollo 11 was in lunar orbit. Pointing and sensitivity checks were performed on the spacecraft in preparation for the landing and EVA. During this period an interesting observation was performed by the Observatory's senior receiver engineer, Dave Cooke (who later became the Director of the Parkes Observatory), and a young PhD student, Jasper Wall (who later became the Director of the Royal Greenwich Observatory). As the spacecraft moved behind the Moon and the signal was lost, they fed the signals directly into the observatory's new PDP-9 computer (the observatory's first computer, purchased by John Shimmins in 1967 and arriving in

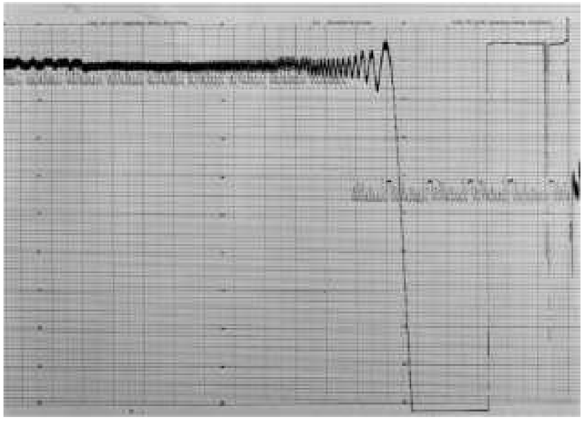

Figure 12 The Apollo 11 lunar occultation observations by Cooke and Wall (Photo: CSIRO).

April 1968). They produced plots of a classic Fresnel diffraction pattern as the point source signal passed behind the Moon's knife edge (see Figure 12).

Jasper Wall relates the following:

> The occultation trace was made by Dave Cooke and myself. We noticed how the chart record produced this superb pattern as we tracked the spacecraft's disappearance behind the moon and its reappearance. We'd just got the PDP-9 computer system up and running and were working hard on making it sample so that we could record and analyse survey data on-line. But it was in a primitive state. We could make it sample, but not display what it was sampling. Thus for the next occultation, we set up to record it by sampling the receiver output (a novel concept) and hammering it all onto punch tape. With no display, we then had to read back hundreds of meters of punch tape, looking at numbers to find where the occultation was ... it took us hours I remember, and the punch tape dripped from the control room down the gap in the stairs to the ground floor, where it piled up ...

All the spacecraft and telescope systems were fully checked and were now ready for the great day.

9 One Giant Leap

9.1 The Landing

On Monday 21 July 1969, at 6:17 a.m. (AEST), astronauts Armstrong and Aldrin landed their LM, *Eagle*, on the Sea of Tranquillity. The landing was an eventful one, in more ways than one.

The landing occurred during the coverage period of the Goldstone station. As the LM undocked from the command module to begin the descent, Armstrong reported, 'The *Eagle* has wings'. As the descent continued, the on-board guidance computer was being overloaded by information from both its landing and rendezvous radar. A series of alarms alerted Mission Control of the problem, and for a short time it appeared the landing might have to be aborted. The 64 metre dish at Goldstone was able to pull the very weak and variable LM signals out of the noise. The problem was diagnosed to be within safety limits, and the go to continue the landing was given. Had the 64 metre dish not been used, the mission would have been aborted at this stage since the neighbouring 26 metre dish at Goldstone had no usable signal at all.

Very soon, however, it was evident to Armstrong that the guidance system was not performing as expected. Landmarks were appearing about 2 seconds ahead of schedule, indicating that the LM was overshooting its planned landing spot. Mission rules dictated that if the error reached 4 seconds, then the landing would have to be aborted, since it would have brought them down in a very rugged part of the Moon. Apparently, MASCONS, or areas of mass concentration, were gravitationally pulling the *Eagle* ahead of the planned landing site.

As the *Eagle* approached the surface, Armstrong could see that it was heading straight for a large rocky crater (West Crater) surrounded by a large boulder field — a crash seemed inevitable. He immediately took over manual control of the landing, and stopped the descent of the LM while continuing the forward motion. With fuel running dangerously low, he desperately searched for a safe landing place to bring the LM down. Finally, with less than 50 seconds of fuel remaining, the *Eagle* touched down. With his heart pounding at 150 beats per minute, Armstrong uttered the now famous words, 'Houston, Tranquillity base here, the *Eagle* has landed'. Mission Control erupted with joy, the tension of the last few minutes suddenly released. The *Eagle* had landed some 6.5 km (4 miles) down range from the planned landing site at lunar coordinates $0°41'15''$ N and $23°26'$ E — close to the terminator of the six day old Moon.

9.2 Preparing for the EVA

After landing, the LM was checked out and the go was given to remain on the surface. The flight plan originally had the astronauts sleeping for six hours before preparing to exit the LM. It was thought that following a rest the astronauts would be refreshed and would have had enough time to adapt to the 1/6th gravity. About ten hours after landing, at 4:21 p.m. (AEST), the EVA would have commenced. At that time the Moon would have set at Goldstone 24 minutes earlier, at 3:57 p.m. (AEST). Parkes would have been the only large antenna tracking the LM, and thus the prime tracking station for the reception of the moonwalk TV — with the Moon high above the telescope's horizon at 1:02 p.m. (AEST).

All this changed when Armstrong exercised his option for an immediate walk — five hours before the Moon was to rise at Parkes. With hindsight, the plan to have the astronauts rest before commencing their EVA was a bad one, since sleeping would have been near impossible after the excitement and adrenalin rush of the landing. With this change of plan, it seemed to the Observatory staff that the labour of the last few months was in vain, and the moonwalk would be over before the Moon even rose at Parkes. Suddenly, Goldstone assumed the role as the prime tracking station for the reception of the EVA TV.

As the hours passed, it became evident that the process of donning the portable life support systems, or backpacks, the lunar boots, gloves, etc. took much more time than anticipated. The astronauts were being deliberately careful in their preparations. Furthermore, they experienced some difficulty in depressurising the cabin of the LM. The air pressure in the cabin took much longer to drop than expected. The hatch could not be opened until the pressure in the cabin was below a certain level since the pressure inside tended to prevent the hatch from opening easily — the astronauts didn't want to risk damaging the thin metal door by tugging on it.

The weather at Parkes on the day of the landing was miserable. It was a typical July winter's day — grey overcast skies with rain and high winds. During the flight to the Moon and the days in lunar orbit, the weather at Parkes had been perfect, but today, of all days, a violent squall hit the telescope (Bolton 1973). Present in the control room were the NASA personnel, John Bolton, Dr Taffy Bowen, the PMG senior technical officer, Brian Coote, and Neil 'Fox' Mason, who was the driver given the responsibility to operate the dish at this historic moment. Seated next to Fox was Denis Gill, the technician responsible for the control desk. Also present was an assortment of other CSIRO staff. They included Harry Minnet, John Shimmins, Dave Cooke, and Jasper Wall (see Figure 13). Other staff members were present downstairs in the tea room and on the azimuth track, ready to swing into action if anything untoward should happen. According to Jasper:

> The atmosphere in the control-room was surreal. The walk and the famous words, 'One small step for (a) man . . .', happened suddenly after what seemed like hours of waiting while endless checklists were dealt with, and, for much of this time, we were not clear what was happening. (We could hardly expect the NASA guys to keep us up to date with a running commentary.)

As the hours passed, the mood at Parkes became more buoyant, for it seemed they would be able to receive the TV pictures after all.

9.3 Receiving the TV Pictures

The giant dish of the Parkes Radio Telescope was fully tipped to its zenith axis limit, waiting for the Moon to rise and ready to receive the television pictures once the TV circuit breakers in the LM were pushed in. John Bolton realised that the TV would begin during the ten-minute coverage period of the off-axis receiver. By turning a dial on the control desk, he turned the feed rotator and positioned the off-axis receiver so that it lay directly above the main, on-focus, receiver. This gave it its maximum field-of-view below the main beam.

As the moment approached, dust was seen racing across the country from the south. The giant dish, being fully tipped over, was at its most vulnerable. Two sharp gusts of wind exceeding 110 kph (70 mph) struck the dish, slamming it back against the zenith angle drive pinions, and causing the gears to change face. The telescope was subjected to wind forces ten times stronger that it was considered safe to withstand. The control tower shuddered and swayed perceptively from this battering, creating concern in all present. John Bolton rushed to check the strain gauges around the walls of the control room. The atmosphere in the control room was tense, with the wind alarm ringing and the telescope ominously rumbling overhead. Fortunately, cool heads prevailed and as the winds abated the Moon rose into the off-axis beam of the telescope just as Aldrin activated the TV at 12:54:00 p.m. (AEST).

Figure 13 A scene in the control room during the EVA. Front (L–R): John Shimmins, Taffy Bowen, and Harry Minnet (behind Taffy). Back (L–R): John Bolton, Jasper Wall (looking up), and NASA personnel (Photo: CSIRO).

Both John Bolton and Fox Mason were riveted to the controls of the telescope at this most critical period. John operated the feed rotator while Fox moved the dish. Tracking a radio source with an off-axis receiver was a tricky and complicated procedure. Essentially, it involved turning the feed rotator so that the off-axis receiver was directly above the main receiver. This gave the off-axis receiver its maximum field-of-view below the main beam. Then by slowly moving the telescope in azimuth angle, while simultaneously turning the feed rotator, one could keep the off-axis beam centred on the radio source. A signal strength indicator (a voltmeter), located on the top of the control panel, was used to determine the pointing of the off-axis beam on the source. If they tracked off the source, then the signal strength indicator would register a drop in voltage. The telescope would then be moved appropriately to centre the beam on the source and maximise the signal strength again.

Once the off-axis beam was level with the main, on-focus, beam, the telescope was moved quickly in azimuth to lock onto the radio source and track it in the main beam of the telescope. This then was the procedure employed to receive the pictures of Armstrong's first step on another world, by the Parkes Radio Telescope.

Jasper Wall relates:

> There were no cheers amongst us, just the sudden realisation that bloody hell there's a man on the moon. We could see all the data, like heart monitors on the astronauts, and in fact there was so much information that what was really going on was hard to discern. Nevertheless none of us present will ever forget it.

John Bolton was a pioneer of radio astronomy, and an expert in optically identifying radio sources in the sky. His success in acquiring the Apollo 11 TV signal in very trying conditions, even before the source had risen in the main beam of the telescope, was surely one of the most breathtaking examples of his expertise in action.

Years later, John Bolton would insist that he had acquired the signal simultaneously with the Goldstone and Honeysuckle Creek stations. At the time, he was engrossed with the process of tracking the source in the off-axis beam. Only after it was acquired in the main beam did he relax and view the pictures being received at Parkes on the 10-inch SSTV monitor, located at the far end of the control room. Robert Taylor, who had been monitoring the TV pictures from the outset, assured John that the TV was acquired just as Aldrin pushed in the TV circuit breaker. He also viewed the replay of the telescope's master tape, and saw no difference with it and the ABC version replayed later that evening. Indeed, a small television set in the control room allowed the staff to view the relayed signal via the live-to-air ABC broadcast.

Fox Mason had the important task of maintaining the pointing of the telescope by keeping close watch on the signal strength indicator, and moving the telescope accordingly (see Figure 14). Owing to the critical nature of the moment, John Bolton would not allow him to take a short break and view the pictures as they were coming in live, lest the winds pick up again and threaten the signal reception. The 10-inch monitor was located on the far side of the control room, with the central support column blocking the view from the control desk. It was ironic that he had to wait until later that evening at home to watch the replay of the moonwalk on the ABC. Asked why he didn't take a quick peek, Fox remarked:

Figure 14 Neil 'Fox' Mason at the control desk. This photo was taken in 1970 (Photo: CSIRO).

> I was disappointed, but I had an important job to do. Besides, I had to be on my best behaviour because all the bosses were there looking over my shoulder!

The weather remained bad at Parkes, with the telescope operating well outside safety limits for the entire duration of the moonwalk.

The EVA lasted a total of 2 hours 31 minutes and 40 seconds, hatch open to hatch closed. The telescope continued tracking the LM and receiving TV pictures from the camera until it was shut off by the astronauts about ½ an hour after the end of the EVA. The tracking continued at Parkes until 6:17 p.m. (AEST).

Following the EVA the master tapes were replayed in the control room, and it was during this period that Dave Cooke stepped outside. The weather was finally beginning to clear and the Moon was visible for the first time that day. The realisation that two men were actually on the Moon suddenly overwhelmed him:

> I went outside, looked at the Moon and thought, how amazing, there are men up there.

He took a photograph of the dish, with the passing storm clearly visible on the horizon (see Figure 15). It had been a dramatic day!

9.4 Armstrong's First Step on Another World

Armstrong gingerly stepped onto the Moon at 12:56:20 (AEST). His heart rate was being monitored, along with other biomedical data, at Honeysuckle Creek. The Parkes and Honeysuckle Creek signals were synchronised and blocked. A recording was made of Armstrong's heart rate.

Figure 15 Dave's blurred image of the famous wind storm on the Parkes horizon. This is the only known photograph of the storm ever taken (Photo: courtesy of David Cooke).

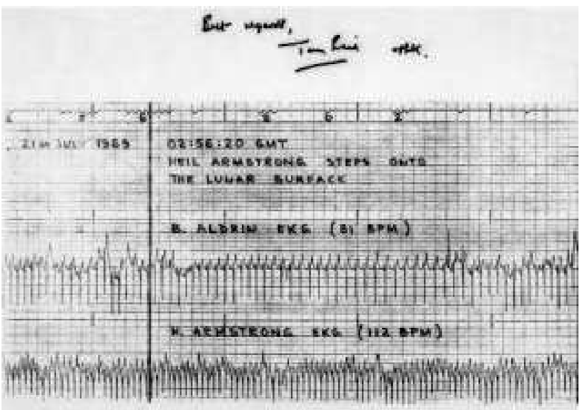

Figure 16 Armstrong's heart rate as he stepped onto the Moon. This was recorded at Honeysuckle Creek and sent to Parkes. It was signed by Tom Reid the Honeysuckle Creek station director, and the annotation is by Ed von Renouard (Photo: CSIRO).

As can be seen in Figure 16, it peaked at 112 beats per minute (bpm) as he stepped onto the Moon. He was obviously nervous, and this may account for why he forgot to include the article, 'a', when he uttered his now famous words:

> That's one small step for [a] man, one giant leap for mankind.

Contrary to popular belief, he wasn't instructed by NASA on what he would say at that point. Armstrong later recounted that he hadn't thought about it until after he had landed (there wasn't any point if the landing failed), and that he hadn't decided on the final form of his words until he was on the porch of the LM, beginning his descent. Apparently, he had the thought of saying something along the lines of the well-known children's game 'baby steps, giant steps'.

10 The Television Broadcasts

There were two versions of the broadcast of the Apollo 11 moonwalk — the international and Australian versions. The international version was supplied to the US networks by NASA, and was then distributed worldwide. The Australian version was supplied by the ABC and distributed to Australian networks.

10.1 The International Telecast via Houston TV

On 21 July 1969 at 12:54:00 (AEST) Aldrin pushed in the TV circuit breakers and activated the lunar television camera. Three stations were tracking the LM at that time: the 64 metre antennas at Parkes and Goldstone as well as the 26 metre antenna at Honeysuckle Creek. All three stations received the TV simultaneously. At Goldstone and Honeysuckle Creek the pictures were scan-converted to the EIA (NTSC) commercial standard TV at the tracking stations themselves, but the Parkes pictures were scan-converted at the OTC Paddington terminal in Sydney. The converted Honeysuckle Creek pictures were passed on to Paddington, where the NASA Goddard Spaceflight Centre employee, Charlie Goodman (Sydney Video), selected the best quality picture from the Parkes and Honeysuckle Creek signals, and passed it on to Houston TV. At Houston TV a controller then selected the best quality TV picture from the Australian and Goldstone pictures. His selection was distributed to the US television networks for international broadcast.

Since the lunar EVA was commencing earlier than planned, the Goldstone dish assumed the role of prime receiving station for the lunar EVA TV. Consequently, as the broadcast commenced, NASA began by using the Goldstone pictures.

A videotape of the original international broadcast, and videotapes of telerecorded kine footage provided by NASA have been carefully studied. Before the general advent of videotapes, a television broadcast was usually recorded by simply filming the TV screen with a 16 mm movie camera. This process was referred to as 'telerecording' and the resultant recording was known as 'kine'. From an analysis of these videotapes and of a recording of the NASA NET 2 communications loop (the communications loop that controlled the TV reception), timings were obtained and are presented in Table 2.

The timings from the NET 2 dialogue don't quite match the timings from the video broadcast. The NET 2 tape obtained by the author was provided by Mike Dinn, who was the Deputy Director of Operations at Honeysuckle Creek, so it has mixed with it the internal Honeysuckle Creek intercom ('Alpha'). The mistimings on NET 2 could simply be due to a poor recording of the master tapes. Whatever the case, the comparative timings are sufficiently close and the number and sequence of the video switches correspond. According to the NET 2 dialogue, in the first eight to nine minutes of the broadcast Houston TV was alternating between the pictures from its two stations at Goldstone and Honeysuckle Creek, searching for the best picture. Goldstone were having terrible problems with their TV, and the Honeysuckle Creek pictures had a very low signal-to-noise ratio, so both pictures were comparatively poor. When the Parkes main beam signals came in, they were of such superior quality that Houston

Table 2. Comparative timings from the EVA video and the NET 2 communications loop

Video transmission	Time (mm:ss)	NET 2 Dialogue	Time (mm:ss)
TV on (upside-down) Picture is from GDS. Time is 12:54:00 (AEST)	00:00	GDS TV on line HSK video on line	00:00
Picture is inverted	00:27	We are in reverse	00:31
Picture switched to HSK	01:39	We have just switched video to HSK	01:50
Armstrong steps onto the Moon (the timing is vague, since it isn't clear when he actually steps on the Moon). The time is 12:56:20 p.m. (AEST)	02:20		
Picture switched to GDS (GDS picture is negative)	04:42	We have just switched to GDS video	05:15
Picture switched to HSK	05:36	HSK, Houston TV. We have switched back to you again	06:04
		GDS TV, Houston TV Would you check your polarity switch please	06:10
Picture back to GDS (GDS picture is positive again)	06:49	All stations, Houston TV switching to GDS	07:10
		Houston TV, Sydney Video Please be advised I have a good picture from PKS, shall I give it to you?	09:09
		Roger, beautiful picture	
Picture from Parkes Main Beam. Time is 13:02:51 (AEST)	08:51	We are switching to PKS at this time	09:16
Quick change back to GDS to see difference	08:55		
Back to PKS, since it's much better	08:57		
		Network HSK	11:05
		Right, you might pass on to the PKS people that their labour was not in vain, they've given us the best TV yet	

did not hesitate to switch to them. They stayed with the Parkes main-beam pictures for the remainder of the 2½ hour moonwalk.

Why wasn't Parkes used earlier? Unfortunately, recollections are imperfect on this point. The author has obtained two differing accounts. The truth no doubt lies somewhere in between, so they are presented without alteration. According to Richard Holl, there was a tense debate at the OTC Paddington terminal over which picture should be sent to Houston. Richard Holl was sitting at the Parkes scan-converter when the Parkes TV pictures appeared. He had the inverting switch correctly set for the lunar camera being upside-down. He saw a good picture coming from the Parkes off-axis receiver and it was the right way up. He says that he looked over to the monitors on his right where the Parkes and Honeysuckle Creek scan-converted pictures were being displayed. He noticed that the Honeysuckle Creek picture was upside-down and that it was of lower quality than the Parkes picture. He naturally assumed that Charlie Goodman had selected the better Parkes pictures for Houston. After Armstrong had stepped onto the surface, he was astonished to realise that Charlie was feeding Houston the Honeysuckle Creek pictures instead. He asked Charlie to select the Parkes pictures, but Charlie refused. Richard was uneasy with this decision. When the much improved Parkes main beam pictures came in, Charlie hesitated. Richard Holl demanded that he switch to Parkes, and said that if he didn't do so, he would reach over and switch it himself. Vern McGlynn, who was seated next to Charlie, convinced him to make the switch. It was at that point that Charlie Goodman called Houston TV and informed them of the Parkes main beam pictures. Richard Holl recalls:

> Ours was the only converter which had the designer tweaking it and we had a good picture shortly after the

> panel deployed. I know I watched all of Armstrong's descent down the ladder after his feet came in view and it was a very good picture. I just wish I had seen he was sending Honeysuckle Creek video sooner. If Houston had Parkes from the start I think they would have used it.

Bob Goodman, the OTC International Co-ordinator for all the transmissions between Australia and the USA, was in the glass-panelled room located directly behind Charlie. The room was sealed off so he could not hear the exchange between Charlie and Richard Holl. Bob was preoccupied with the large press contingent present, but recalls that at the beginning of the broadcast only one of the stations was sending TV to Paddington. There was a delay of a few minutes before the other Australian station came through. He remembers that there was a small window of opportunity of between two to three minutes at most when only one station was sending the pictures. He is certain that it was Parkes that came on-line first, and that it was Parkes that Charlie Goodman had selected from the start. Bob and his team had been working constantly for weeks, and in the days leading up to the EVA they had slept very little; he recalls they were running on adrenalin. Bob may have the roles of Parkes and Honeysuckle Creek confused here. If there was a slight delay, then it was more likely due to Parkes, since Parkes had to first acquire and centre the LM in its off-axis beam in very dangerous conditions.

As contradictory as the above recollections may be, it is clear that the Parkes TV pictures were being received well before the acquisition on the main feed. Why did Charlie Goodman hesitate then in switching to the better Parkes pictures? Bob Goodman recalls that Charlie felt the enormous responsibility and pressure of world expectations — the world was watching his decision. It was his opinion that Charlie's technical competency was first rate, and that he just wanted to do the best job possible and to make no mistakes. Richard Nafzger, the Goddard Spaceflight Centre engineer who was responsible for all the systems hardware in support of TV (Richard's and Charlie's boss), thinks that perhaps Charlie wanted to be sure that the Parkes relays were stable and functioning well before switching away from a picture he already knew to be okay. Bob Goodman was aware of the high winds at Parkes and so was Charlie. The possibility that the Parkes dish may be stowed at any moment may have loomed large in Charlie's mind, that is, he may not have wanted to switch to Parkes knowing he could lose the picture just as Armstrong was to step onto the Moon. Whatever the reason, the better Parkes pictures were not sent to Houston until well after Armstrong had stepped onto the Moon.

According to Bob Goodman, high resolution pictures of Armstrong stepping onto the Moon were taken by press photographers who queued to use pre-mounted Rolex cameras shooting the black-and-white monitors in his room. These pictures were later distributed worldwide by the wire services. Richard Holl recalls that shortly after Armstrong stepped onto the surface, Ted Knotts took high resolution Polaroid pictures off the slow-scan monitor. These were later given to the press for worldwide distribution also.

What happened at Goldstone? This has been a matter of conjecture ever since the day of the broadcast. The dish at Goldstone was 64 metres in diameter like the Parkes dish, so it should have had the best signal of all since the LM was in the main beam of the antenna. The fact that Goldstone wasn't scheduled to be receiving the TV pictures in the first place may have contributed to the problems.

Nonetheless, what appears to have happened is that the video settings were all preset to the expected signal levels, and the problems began when they realised the signal was much more modulated than expected. As the transmission began, two things were evident: the picture was upside-down and it had a very high contrast. Apparently someone at Goldstone had forgotten to set the inverting switch on the scan-converter's front panel. Since their picture was going out live, the operators were reluctant to throw the switch until prompted to do so by Houston TV.

Bill Wood, the lead video engineer at Goldstone, explained that the high contrast may have been a result of the picture running into clipping. Clipping results when the video signal is stronger than expected. Normally, TV pictures have a voltage fluctuation of 1 volt peak-to-peak. If the signal is greater than this, then the top part of the signal is chopped off, or clipped. This has the effect of stretching the contrast in the image; the darker areas appear black and the lighter areas appear white. There is very little shading in between. Bill explains:

> Before the Apollo 11 mission, the Goddard Spaceflight Centre installed 5 MHz wide bandpass filters in the 50 MHz IF of our Block III receivers. The reason why these were installed was to reduce the beat note produced when the command module (2287.5 MHz) and lunar module (2282.5 MHz) transmitters were in the same antenna beamwidth at the Moon. When the TV camera was powered up, the total deviation was somewhat in excess of the 5 MHz bandwidth allowed by the filters. When we checked the signal with a spectrum analyser before the 5 MHz filters, the total peak-to-peak bandwidth was more like 10 MHz. The result was a clipping of the white and black peaks on the output of the early series Motorola 50 MHz wideband demodulators that we used. I suspect that the signal from Parkes was not bandpass limited and would produce a good signal with no clipping.
>
> Another possibility was that the alignment of the black level on the slow-scan monitor was less than ideal. When I investigated the problem after the Moon had set, I found that a composite FM signal with the same bandwidth as the LM downlink would cause clipping. Since there was no further TV from the lunar surface, there was no way that we could prove whether or not the problem was caused by the 5 MHz filter or the less than ideal adjustment of the scan-converter.

> Since we had no idea of what to expect in the way of TV quality, the much improved signal through Honeysuckle and later Parkes surprised us. I saw the network TV here — we were picking up the commercial television out of Los Angeles — and when we saw the switch from Goldstone to Honeysuckle there was a pronounced improvement in video quality. 'Hey, look at the picture from Honeysuckle!', I thought. 'Good Lord there's something wrong with our system' — they are getting it better than we are.

In the process of correcting the switch settings, it appears that the operators at Goldstone somehow inverted the polarity of their picture, producing a negative image. Again, Houston TV switched away to give them time to correct the problem. By the time they returned to them, the Parkes main beam signal came in, and that was it for Goldstone. NASA has since corrected this negative image anomaly in the videotapes it provides the public. They have simply re-inverted the polarity and made the negative image appear positive. However, an unedited videotape of the original international broadcast clearly shows the negative image.

One peculiarity with the Goldstone TV was that the pictures always had a small white spot on them, located just above the centre of the broadcast image. In the videotapes of the doctored NASA versions of the EVA, this white spot suddenly appears black when the negative image segment is made positive. This confirms that the correction on these tapes was indeed made later by NASA.

Ed von Renouard, the Honeysuckle Creek video technician, also noticed that his picture was upside-down at first. However, Ed was a former ABC employee and had worked on many live television shows in his time. He was used to the live show atmosphere, and felt no apprehension in playing with switch settings as his pictures went out live. Within a few seconds of his noticing the upside-down image, he threw the scan-converter's inverter switch and inverted the Honeysuckle Creek picture. He also adjusted the brightness and contrast settings to try to correct the high contrast of the picture. He related the following to the author:

> . . . I heard Aldrin say 'TV circuit breaker in', when suddenly the picture became visible. No one had ever seen TV from the Moon before, so it took me a few seconds to realise what I was seeing. There was a white diagonal streak near the top, and black at the bottom. I realised the sky on the Moon should have been black, so I threw the toggle switch and inverted the image. This whole process took at most about 20 seconds to do. Also, in adjusting the brightness and contrast, the picture flared momentarily, but I was able to correct it before it went out to Houston.

He had no other problems with the TV pictures after that.

Like Goldstone, the Parkes pictures had a small white spot on the broadcast image. Parkes' spot was less prominent and located just above the middle of the right-hand edge of the scan-converter's screen. When the camera was in the MESA, the inverted (upside-down) image caused the white spot to appear just below the middle of the left-hand edge of the broadcast image, superimposed on one of the shadowed struts of the LM ladder leg. When the camera was positioned on the surface, the spot was visible just above the lunar horizon on the right-hand edge of the image. It was easily mistaken for a star. Pictures from Honeysuckle Creek do not appear to have any spots on them. The presence and locations of these spots confirm the above sequence of inclusion of the TV pictures from the various sources.

Eleven minutes after the transmission began the Network Controller, Ernie Randall, working in Mission Control, reported the following:

> Right, you might pass on to the Parkes people that their labour was not in vain, they've given us the best TV yet.

One last point to note is that even though the pictures alternated between the three stations before settling on Parkes, the voice downlink that was used throughout the broadcast was exclusively from Goldstone.

10.2 The Australian Telecast via the ABC

Trying to determine what happened with the Australian telecast is an extremely difficult task, owing to the fact that footage of the broadcast is very difficult to obtain.

Up until about five hours before the moonwalk, Parkes was fully expected to be the prime receiving station for the TV signals. The ABC and other media outlets had advertised for several weeks before the event that the pictures to be broadcast to Australian and international audiences would be coming from Parkes. Everything had been prepared in advance based on this plan. But did it happen?

At times throughout the mission, Australian networks received telecasts from the American networks and from the 'Voice of Apollo' programs. These were included in local telecasts at appropriate times.

The author has obtained videotapes of kine footage of the ABC Australian broadcast. Unfortunately, much of the first few minutes of the broadcast is missing, owing to the film being cut and edited for use in news programs. However a short segment is available. It starts about 45 seconds after the TV transmission from the Moon begins. It lasts 2 minutes and 42 seconds, which is equivalent to it ending 3 minutes and 27 seconds after the start of the transmission. This period includes Armstrong's first step on the Moon.

Fortuitously, the first frame of the segment contains a small white spot, just above the centre of the screen. This indicates that the source of the picture is Goldstone. It appears that at this point the ABC was using the feed from the American networks. Now, OTC was supposed to provide the ABC with the 'return leg' feed from Houston which had the six second delay introduced by

NASA. However, Bob Goodman and OTC took a punt that there would be no accident with the astronauts, so they fed the ABC the live signals they were receiving from the Australian stations instead. It was at that point that the picture is seen to switch away to either Parkes or Honeysuckle Creek, since the white spot disappears in the next frame. This switch was some 57 seconds before the international broadcast first switched away from Goldstone. The telerecording cameras did not photograph the entire screen, but instead cropped the edges of the images in order to hide the edges of the TV screen. This has meant that the region in the image that would have had the white spot from Parkes is not visible. However, since the ABC was receiving the same Sydney Video TV selection as was Houston, then according to NET 2 and the international version video the switch away from Goldstone must have been to Honeysuckle Creek. In addition, the picture appears to flare or brighten momentarily, immediately after the switch away. It appears that this is the result of Ed von Renouard adjusting the picture settings. Because the ABC received these pictures before Houston switched to them, Australians saw Ed's adjustments while the rest of the world did not.

Parkes was clearly in a position to be the source of the broadcast pictures of Armstrong's first step on the Moon, but for whatever reason, first Goldstone then Honeysuckle Creek, 45 seconds later, appear to have been the sources of the Australian telecast until Parkes acquired on main beam.

10.3 Confusion

Over the years a considerable amount of confusion has surrounded the timing of the inclusion of the signals from the various tracking stations into the broadcasts of the EVA. Several factors have contributed to this.

1. Parkes didn't have the NET 2 network coming through speakers and did not hear the switch-over or the message from Ernie Randall about '... the best TV yet'. The Parkes control room only had access to NET 7, as well as the up and down links to the spacecraft through speakers (NET 1). The Parkes personnel had assumed that Goldstone would be prime, since it had a clear view of the Moon in its main beam. According to John Bolton, the first indication that Parkes had that it was going out world wide was from Walter Cronkite's US commentary overlaid on the ABC relay:

   > That white spot on your screen is coming from Parkes.

   Jasper Wall recalls:

   > I do recollect watching live TV transmission at one point when a bright spot appeared on the right of the screen. The NASA pundits told the watching world that it was due to a problem at Parkes. John Bolton was furious. This was at a time when Goldstone was supposed to be prime.

2. Following the EVA, John Bolton and Taffy Bowen were having a quiet congratulatory beer together when they decided to call Bill Merrick at Goldstone to find out what had happened with their signal. Bill had built the 64 metre dish and was a former collaborator of John Bolton's, so he was able to get hold of him fairly easily. Bill informed them that they had a very good picture at the dish itself, but that it had disappeared into the ground some 20 miles from the site. John Bolton took that to mean that it had been substantially degraded.

   Why did Bill Merrick say they had a good picture when they didn't? Was he fully aware of the problems?
3. It is entirely probable that John Bolton also phoned OTC Paddington to enquire about what had happened with his signals. He may have been informed that his pictures were used from the start. When the author asked Bob Goodman if John Bolton had phoned him after the EVA, he said that he may have but couldn't remember.
4. Following the telecast, Australian media outlets (newspapers, TV, radio) gave differing reports of when the Parkes signals were included in the telecast. Some had the signal included shortly after Parkes acquired it in the main beam at 1:05 p.m. (AEST), others had it included just before President Richard Nixon spoke to the astronauts at 1:50 p.m. (AEST). Other reports stated that Goldstone wasn't used at all!
5. When Aldrin activated the TV camera, the LM was just entering the beam of the off- axis receiver. A weak, but usable, signal was received at Parkes. It would have taken about a minute or so longer for the LM to be fully centred in the beam and a strong signal received. The first switch away from Goldstone, in both versions of the broadcast, occurred at approximately the time the LM was fully centred in the beam. It therefore gave the impression that the picture switched to Parkes.
6. NASA and Houston were unaware that Parkes had acquired the signal before the predicted acquisition on the main feed.

Mike Dinn, who is a seasoned tracking professional, has stated that:

> Real-time ops, especially manned flight, and especially in the 1960s, was all about making quick, best decisions in your area of expertise and responsibility, and assuming and trusting that others did the same.

Confusion is therefore all the more likely when the situation is as fluid and complex as it was for the first lunar landing.

Shortly before his death John Bolton, in his final correspondence with Mike Dinn, wrote:

> It would be of interest to have everything cleared up. As you imply you couldn't care less about the priorities and neither do I. The same is probably true of everyone else who was involved in the operation at the time, we collectively succeeded and that was all that mattered to us — unfortunately this is something that historians never seem to understand; for them A has to have beaten B.

The success of the Apollo 11 mission was due to the combined effort, dedication, and professionalism of many hundreds of thousands of people around the world. John Bolton's sentiments surely ring true.

10.4 Other TV

Because there was no broadband link across the country at the time, Bob Goodman from OTC arranged to send the ABC's live broadcast via satellite to the Carnarvon station in Western Australia. From there the signal was sent on to Perth for distribution in Western Australia. In the town of Carnarvon, a 14-inch (35.6 cm) monitor was installed in the local theatre. Hundreds of people from the town and surrounding districts crowded into the hall to watch the moonwalk. Those in the back of the hall resorted to using binoculars and rifle telescopes to view the moonwalk (Lindsay 1998).

At Tidbinbilla, following the disappointment of the receiver fire and the switch in its tracking role with Honeysuckle Creek, the controllers were busy tracking the command module, *Columbia*. The beamwidth of the 26 metre dish was so large that the LM was within the beam and the TV signals were being received also. The controllers, working under Don Grey, the Director of Tidbinbilla, were able to jury rig a system, whereby the TV signals were extracted from the LM signal and the pictures displayed on television sets at the station. This was all unofficial.

At Honeysuckle Creek Kevin Gallegos, the technical officer responsible for the SDSS, was working away in the bowels of the control building, unable to see the TV pictures he was processing. He wasn't allowed to view the video in real-time since he had important work to concentrate on. Eager to view the live transmission, and unable to contain his curiosity any longer, he fed the TV signals from the demodulators straight into the video input of his small oscilloscope and was able to view the moonwalk live in glorious black and green. As he related to the author:

> There I was in the bowels of the building monitoring the signals coming in. This most historic event was unfolding and I couldn't see it since I had no TV — I wasn't allowed. So I decided to feed the TV signals into the video input of my small oscilloscope and there it was. I saw the pictures of Armstrong and Aldrin on the Moon on the small black and green screen of my CRO.

11 Post EVA

11.1 Congratulations

Following the EVA and close out for the day, people at Parkes were finally able to relax with the knowledge that they had succeeded in what Clifford E. Charlesworth, the Apollo 11 Flight Director, described in a congratulatory telex as 'the greatest television spectacular of all time'.

The day following the EVA NASA handed over a cheque for $60 000. In 1973, with the Apollo missions completed, this money was used to upgrade the surface of the Parkes dish, giving it the capability to observe at higher frequencies (see Figure 17).

Figure 17 John Bolton and Fox Mason resurfacing the dish in 1973 (Photo: CSIRO).

Parkes was not required for the remainder of the Apollo 11 mission.

Following splashdown of Apollo 11 and the great success of the Parkes support, the Parkes Observatory was contracted by NASA to support all subsequent manned missions to the Moon.

11.2 Post Apollo 11

Prior to Apollo 11, John Bolton and consultants Freeman Fox had been actively engaged in a study of the tower which had been recognised as seriously weak. With the memory of the Apollo 11 windstorm still fresh in his mind, Taffy Bowen decided that the tower had to be reinforced before the Apollo 12 mission in November 1969. Seven weeks of working two shifts a day saw the tower stiffened and major modifications made to the air conditioning (Goddard & Milne 1994). Jasper Wall relates:

> I remember the strengthening well, all of us were involved of course, JB mixing the track grout to ensure that it was the correct strength, me operating the crane, typical Bolton team.

The control room was completely rearranged, and equipment from one of the previously down-range tracking ships, the *USNS Vanguard*, was installed for a period that was to last nearly four years (see Figure 18). Instead of American personnel to operate the back-ends of the receivers and tape recorders, the technical staff came from NASA's Deep Space tracking station at Tidbinbilla near Canberra. Dave Cooke was responsible for the focus cabin equipment.

Parkes was a station in the link between the Earth and the Apollo spacecraft for the Apollo 12, 14, 15, and 17

Figure 18 The Parkes control room as it appeared during the Apollo 14 mission: PMG Senior Technician Brian Coote (centre), John Bolton seated at the PDP-9 computer (right), and the NASA receiving equipment from the USNS Vanguard (left) (Photo: CSIRO).

missions. It was brought into the Manned Space Flight Network when emergencies occurred in the flights of Apollo 13 and 16 (Bolton 1973).

In the early missions, tracking data from Houston was often hopelessly inaccurate and location of the spacecraft required an inspired guess plus a 'square search'. In the later missions the predictions improved, which was especially fortunate for Apollo 13.

With Apollo 13, Parkes actually played a vital role at critical phases of the rescue effort, which allowed the valuable and extremely weak telemetry signals from the command module *Odyssey* to be downlinked and the problems correctly diagnosed. But that's another story!

12 Conclusion

From 8 minutes and 51 seconds after the TV was switched on (and some 6 minutes and 42 seconds after the first step), the world witnessed the historic 2½ hour Apollo 11 moonwalk from pictures received by the Parkes Radio Telescope.

Following the mission the NASA Administrator, Thomas O. Paine, sent the following message of commendation to the Australian Minister for Education and Science, Mr Malcolm Fraser:

> I wish to express my sincere appreciation to you and the Commonwealth Scientific and Industrial Research Organisation for making available the Parkes facility during the Apollo 11 mission. Its participation, and spectacular performance, provided the entire world with a chance to experience, with astronauts Armstrong and Aldrin, this historic event.

Before the mission, John Bolton had agreed to a one-line contract with NASA: 'The Radiophysics Division would agree to support the Apollo 11 mission'. In meeting his commitment to NASA, both he and the staff of the observatory displayed great nerve and courage in their decisions and ensured that mankind was able to witness the historic event with the greatest possible clarity.

For five magnificent days in July 1969, the Parkes Observatory contributed to the success of the greatest voyage of discovery and achievement in the history of science. As it tracked Apollo 11 on its journey to the Moon it was, in a sense, carried along on *Eagle*'s wings.

Acknowledgments

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Other Resource Material and Acknowledgments

1. *Parkes Telescope Observing Log Book.* Entries for June and July 1969.
2. *Honeysuckle Creek Log Book*. Entry for 21 July 1969.
3. *Videotapes of telerecorded footage provided courtesy of NASA Johnson Space Center.* Thank you to Kathleen Richard, Librarian from the Media Resource Center.
4. *Videotapes of telerecorded excerpts of the ABC's Australian broadcast of the Apollo 11 lunar EVA.* Thank you to Charles Sammut from ABC Video Sales, Gore Hill, Sydney.
5. *Original video recording of the international broadcast of the Apollo 11 lunar EVA.* Thank you to Andrew Constantine, Education Officer at Sydney Observatory, for providing the tapes.
6. *Audio recording of NASA's NET 2 communications loop.* Thank you to Mike Dinn for providing the tape.
7. *Apollo 11 audio downlink provided courtesy of NASA Johnson Space Center.* Thank you to Carlos Fontanot, Gayle Frere and Bob Roberts of the Public Affairs Office.
8. *Correspondence from Mike Dinn to Dr Ron Ekers of the CSIRO ATNF.* Dated 28 November 1991.
9. *Correspondence from John Bolton to Mike Dinn.* Dated 11 December 1991.
10. *Parkes Champion Post.* Articles in the local Parkes district newspaper, 1969.
11. *The Sydney Morning Herald.* News stories carried by the paper in 1969.
12. *Information supplied by, and interviews with, Hamish Lindsay.* Hamish Lindsay was a Senior Technical Officer at Honeysuckle Creek in July 1969. He also, kindly granted permission to reproduce extracts from his unpublished book 'Tracks to the Moon'.

13. *Interviews with, and correspondence received by, Richard Holl.* Richard was the Bendix Field Engineering Corp. engineer stationed at the OTC Paddington terminal and was the Parkes scan-converter operator and designer.
14. *Information supplied by, and interviews with, Mike Dinn.* Mike was the Deputy Director of Operations at Honeysuckle Creek in July 1969.
15. *Interview with, and correspondence received by, Dr Jasper Wall.* Jasper was John Bolton's PhD student at Parkes in 1969.
16. *Interviews with Neil 'Fox' Mason.* Fox was the driver at the controls of the Parkes telescope on 21 July 1969.
17. *Interviews with Dr David Cooke.* David was the Senior Receiver Engineer at Parkes in 1969.
18. *Information supplied by Dr Bruce MacA Thomas.* Bruce was the antenna engineer who designed the innovative Apollo feed horns.
19. *Interview with Richard Nafzger.* Richard was an engineer with the Manned Flight Engineering Division of the Goddard Spaceflight Centre, and was responsible for all ground systems hardware in support of TV.
20. *Information supplied by, and interviews with, Bill Butler.* Bill was the Senior Technical Officer responsible for the PDP-9 Computer at Parkes in July 1969, and was also a telescope driver during the cruise to the Moon of Apollo 11.
21. *Interview with Dr John Shimmins.* John was the Deputy Director of Parkes Observatory in 1969.
22. *Interview with Brian Coote.* Brian was the PMG Senior Technical Officer stationed in the Parkes control room on 21 July 1969.
23. *Information supplied by, and interviews with, Gordon Bennett.* Gordon was the PMG Technical Officer stationed at the Mt Coonambro relay station on 21 July 1969.
24. *Conversations with Mrs Letty Bolton.*
25. *Conversation with Don Grey.* Don was the Director of the Tidbinbilla tracking station in July 1969.
26. *Conversations with Ben Lam.* Ben was the site electrician in 1969, and was also a telescope driver during the cruise to the Moon of Apollo 11.
27. *Interviews with John Saxon.* John was at the desk at Honeysuckle Creek on 21 July 1969. He was a Senior Technical Officer and was Mike Dinn's assistant.
28. *Interview with Tom Reid.* Tom was the Director in charge of the Honeysuckle Creek station in 1969.
29. *Interview with Kevin Gallegos.* Kevin was a Technical Officer at Honeysuckle Creek in 1969. He was responsible for the S-band Data Demodulation System. His call sign was 'SUDS'.
30. *Interviews with Ed von Renouard.* Ed was the Video Technician at Honeysuckle Creek in July 1969.
31. *Interviews with Bob Goodman.* Bob was the International Co-ordinator of all OTC transmissions between Australia and the USA. He was present in the OTC Paddington terminal during the EVA.
32. *Interviews with Kevyn Westbrook.* Kevyn was the Director of the NASA Communications Centre (NASCOM) located in the PMG Canberra Telephone Exchange at Deakin in 1969.
33. *Correspondence received from Bill Wood.* Bill was the Lead Video Engineer at Goldstone in July 1969.
34. *Correspondence received from Stan Lebar.* Stan was the Program Manager for the Westinghouse Apollo Lunar Surface Camera.
35. *Video of ABC News program interview with Charles Goodman.* Thanks to Debra Choate of Working Dog Productions for supplying the video footage.
36. *Film 'Parkes Receiving' by Ken Nash of CSIRO's Radiophysics Division.* Thanks to Helen Sim and Lucia Gambaro-Bromley of the CSIRO's Australia Telescope National Facility for providing the footage.
37. *Photographs by John Masterson.* John was the senior photographer of the CSIRO's Radiophysics Division.
38. *Information supplied by Peter A. Pokorny*. Peter was a Group Leader with OTC/Telstra Perth TTCM (1995–1997). He supplied the author with the Electronics Australia article on the Apollo S-band Communication System.
39. *National Film and Sound Archive, Canberra.* Thanks to Tamara Osicka for providing the Australian News and Information Service footage of 'Moon Shoot'.
40. *Stewart Duff and Mark Greentree of CTIP.* Stewart and Mark digitised many of John Masterson's original photographs used in this report.
41. *Information provided by Allan Hullett.* Allan was the ABC TV Supervising Engineer in Perth directly involved in the Apollo II transmission. Thanks to Derric Wright and Tim Law for contacting Allan.
42. NASA web pages related to the Apollo missions.
43. *The Apollo II Lunar Surface Journal.* Web pages maintained by Eric M. Jones.

Acronyms

ABC: Australian Broadcasting Commission — the national radio and television broadcaster.
AEST: Australian Eastern Standard Time: +10 hours from Greenwich Mean Time(GMT).
AM: Amplitude Modulated.
AT&T: American Telephone and Telegraph Company.
AWA: Amalgamated Wireless Australasia.
CCIR: International Radio Consultative Committee, an International Telecommunication Union (ITU) agency.
CSM: Command/Service Module.
CSIRO: Commonwealth Scientific and Industrial Research Organisation.
DEMOD: A data demodulator in the S-band Data Demodulation System (SDDS).
DSN: NASA's Deep Space Tracking Network.
EASEP: Early Apollo Surface Experiments Package.

EIA: Electronic Industries Association.
EVA: Extra-Vehicular Activity (in the case of Apollo 11 this refers to the moonwalk).
FM: Frequency Modulated.
IF: Intermediate Frequency.
INTELSAT: International Telecommunications Satellite Organisation.
JPL: Jet Propulsion Laboratory — contracted by NASA to conduct planetary exploration.
LM: Lunar Module.
LNA: Low Noise Amplifier.
LO: Local Oscillator — a signal generator.
LOS: Loss Of Signal.
MASCONS: Mass Concentrations.
MESA: Modular Equipment Stowage Assembly — the LM instrument pallet.
MSFN: Manned Space Flight Network. NASA's worldwide network of 22 tracking antennas.
NASA: National Aeronautics and Space Administration.
NASCOM: NASA Communications Centre in Canberra.
NSW: New South Wales — a state of Australia.
NTSC: National Television System Committee. Television standard used in North America and Japan.
OTC: Overseas Telecommunications Commission.
PCM: Pulse Code Modulated.
PLSS: Portable Life Support System — the astronaut's backpacks.
PM: Phase Modulated.
PMG: Post Master General's Department — combined postal and telecommunications.
RCA: Recording Company of America.
RF: Radio Frequency.
S-BAND: An observing band centred around 2300 MHz.
SDDS: S-band Data Demodulation System.
SSTV: Slow Scan Television.

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