Observatory reports

Australia Telescope Compact Array

Upgrades and developments

The primary development focus at the Compact Array for a number of years has been to upgrade the array to operate at high frequencies with two new observing bands at wavelengths of 12 and 3 mm. During 2003 many components of this upgrade process were completed. The millimetre systems are expected to be fully completed in 2004.

The 12-mm systems upgrade

The upgrade of the Compact Array for observations at 12 mm is now complete. During shutdowns in April and June 2003, new millimetre receiver packages containing the 12-mm systems were installed on antennas 1, 5 and 6, while interim 12-mm systems on antennas 2, 3 and 4 were upgraded. At the same time, installation of a high frequency local oscillator system was completed. This has broadened the accessible spectrum at 12 mm to 16 – 25 GHz. Tuning across the spectrum is now completely under computer control (previously a simple hardware change needed to be performed at each antenna). Fringes on all baselines were achieved on 16 April, and the first observation of ammonia lines at 12 mm was taken on 23 April. Common user access to the new 12-mm systems was provided immediately after the shutdown periods. This proved highly successful, with the systems producing good science within days of their installation.

New stations and array configurations

The millimetre upgrade included the construction of five antenna stations on a new 214-m long north spur line, and the addition of four new antenna stations on the main east-west track. These provide more effective compact array configurations and allow a reasonable Fourier coverage to be achieved in less than 12 hours. This is important for 3-mm observations as sources can be observed while they are still high in the sky. The north spur substantially improves the imaging capability for compact configurations for sources between DEC = 0° and -30°. For 3-mm observations, the Compact Array is now the best radio array in the world for observing sources south of the celestial equator.

In 2003 the last remaining new station was christened and the station upgrade program completed.

Antenna control system and on-line observing system

A major part of the millimetre upgrade has been a project to replace the computer hardware at the antennas, upgrade the communications infrastructure from the antennas to the control building, and rewrite the control and communications software in a modern language. A new system was required to support the new receiver packages and to remove limitations imposed by the previous antenna control system. The antenna control system upgrade was completed in May 2003.

The new antenna control system is quickly repaying the significant investment made in it. Apart from being far more reliable and easier to maintain, the system allows for new methods of monitoring and controlling the antenna systems. This has made new observing approaches possible and provided a greater understanding of the functioning of the antennas. This has allowed some long-standing problems to be understood and addressed.

Another major computing upgrade, still in progress, is for the on-line observing and monitoring systems. These systems have been based on VAX/VMS computers since the opening of the Compact Array. With ageing hardware that is expensive to maintain, upgrading these systems to a PC/LINUX-based environment is a priority. The monitor system also needs to be enhanced to exploit the power of the new antenna control computers. The new observing and monitoring systems are now being developed with the first successful observations achieved in September 2003.

Signal distribution upgrade

The completion of the local oscillator and antenna control systems upgrade, and the prior completion of the data return upgrade, means that essentially all communications infrastructure between the antennas and control building is now on single-mode optical fibre. The single-mode fibres have a much greater capacity than is currently used and are a strategic investment in future wideband upgrades of the array.

The only communication channels to the antennas not on fibre are the telephone lines and some "primary monitor" signals used as failsafe indicators of the basic health of the antennas.

Antenna structure

At 3-mm wavelength the reflecting surfaces of the antennas need to be accurate to tolerances that are ten times smaller than required at 3 cm. Two effects need to be attended to in order to maintain good beam efficiency and beam shape: firstly the main panels must be set to the good tolerance while secondly, account must be made of the change in the gravitational deformation of the antennas as a function of elevation. The deformations of interest include changes to the main dish shape as well as movement of the subreflector and receiver package.

During telescope shutdowns in April and June, holographic surveys and panel adjustments were performed on all antennas other than antennas 2 and 6 (similar work was performed on antenna 2 in December 2002). This improved the alignments of the panels to a surface accuracy (rms) of 0.16 mm.

Following photogrammetric analysis performed in 2002, a project was initiated to allow two-axis adjustment of the subreflector. This is to maintain good antenna efficiency and beamshape where gravitational distortions are present.

During early 2003, during a structural check of the antennas, small cracks were discovered in a structural part of several antennas. These cracks probably developed over several years. During the year, the cracks were repaired and the parts strengthened on all antennas during the shutdowns. Additionally the shutdowns were used to overhaul the elevation gearboxes on all antennas.

Operations

The millimetre observing season of 2003 (May to October) was the second year where common user observations were taken using the 3-mm systems on three antennas, and the first where the full 12-mm system was available. Given the number of new systems that were installed during 2003, and the swiftness of bringing them into common use, there was some trepidation that teething problems might cause the downtime to increase significantly. Happily the reverse happened, with successful astronomical observations and little downtime.

The Compact Array in a compact configuration
Photo: © David Smyth

Averaged over the entire year, the fraction of observing time undertaken at 12- and 3-mm wavelengths was 18% and 8% respectively. Approximately half of all projects scheduled during the millimetre season used the millimetre receivers. Not surprisingly the amount of 12-mm observing increased markedly in 2003, whereas the 3-mm use remained constant (in 2002 the fractions were 7% and 8% respectively).

Visitors

In addition to astronomers and the general public, the Observatory regularly receives professional visitors. A highlight of the year was a visit in February from the Minister for Science, Peter McGauran, and a group of his staff. The Minister visited an antenna vertex room, walked on an antenna surface, talked with Narrabri High School students working with the SEARFE project and toured the Control Building.

At the time of the IAU General Assembly, the Observatory encouraged a number of groups and individuals to visit the Compact Array as part of their stay in Australia. Approximately 70 professional astronomers attending the IAU visited the Observatory in July 2003. Many of these astronomers do not work in radio astronomy and had little knowledge of the Observatory before their visit.

Each year the Observatory's "work experience" program hosts several high school students for a week. The Observatory also hosts a smaller number of undergraduate students in the final years of their science or engineering degrees. These students stay for longer periods and become involved in projects of value to the ATNF. During 2003, the Observatory hosted Nicholas Ebner, Marija Vlajic and David Jones. Nicholas studied the frequency dependence of the illumination pattern of the antennas at 12 mm, Marija worked on the halos of edge-on spirals and David worked on high-resolution imaging of a class of extended radio galaxies.

Synthesis Imaging Workshop

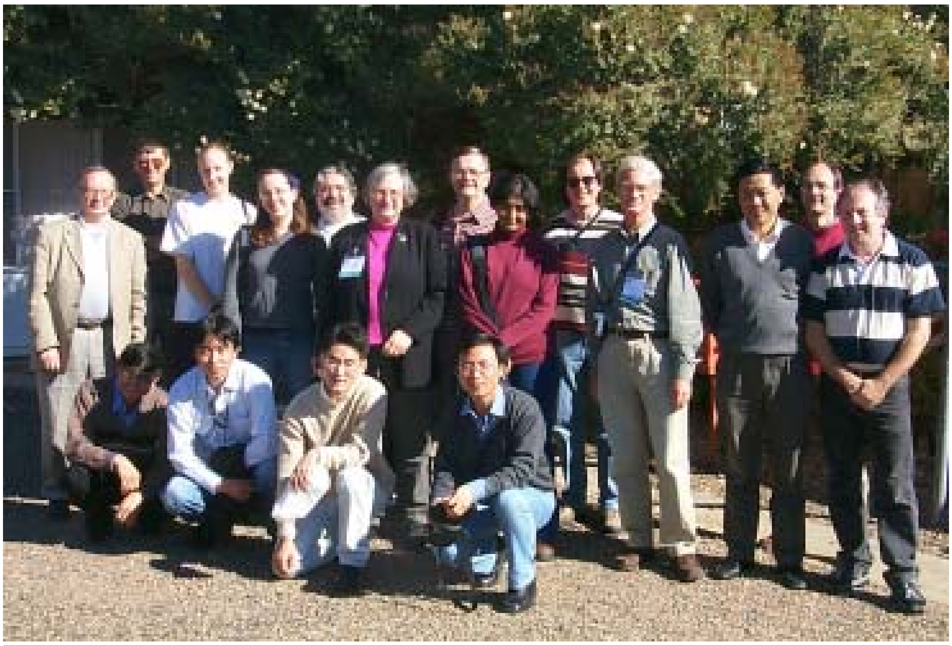
The sixth ATNF Synthesis Imaging Workshop was held at the Observatory on 12 – 16 May 2003. The workshop had a greater focus on millimetre-wavelength astronomy than in previous years. Prior to the new millimetre facilities at the Compact Array, the Australian astronomical communities involved in radio interferometry and millimetre-wavelength astronomy involved distinct groups; the Synthesis Workshop serves an important role in bringing them together.

In addition to "traditional" lectures on interferometric techniques and lectures on scientific topics, practical sessions were held where students were able to use the Compact Array and practise data reduction. There were 70 participants in total, of which about half were presenters. Of the non-presenters, two-thirds were postgraduate or undergraduate students and approximately half had no previous experience with radio astronomy or synthesis data.

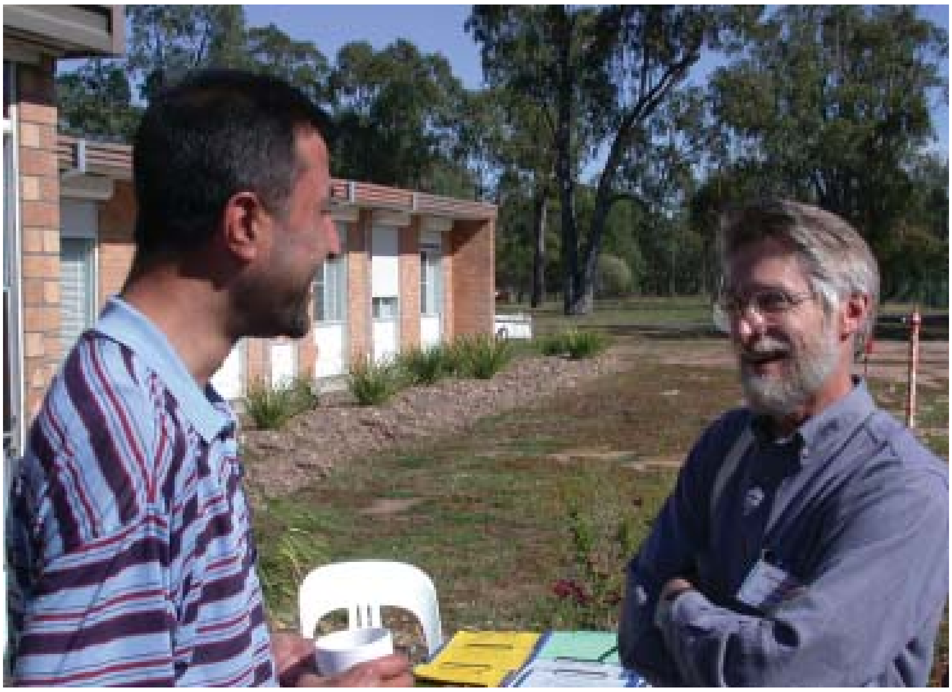
The Minister for Science, Peter McGuaran, with ATNF staff and Narrabri high school students at the Narrabri Observatory. From left to right: Ray Norris, Vikram Ravi, James Tolson, Peter McGauran, Bob Sault, Brian Boyle and Michelle Storey
Photo: © CSIRO

Staff

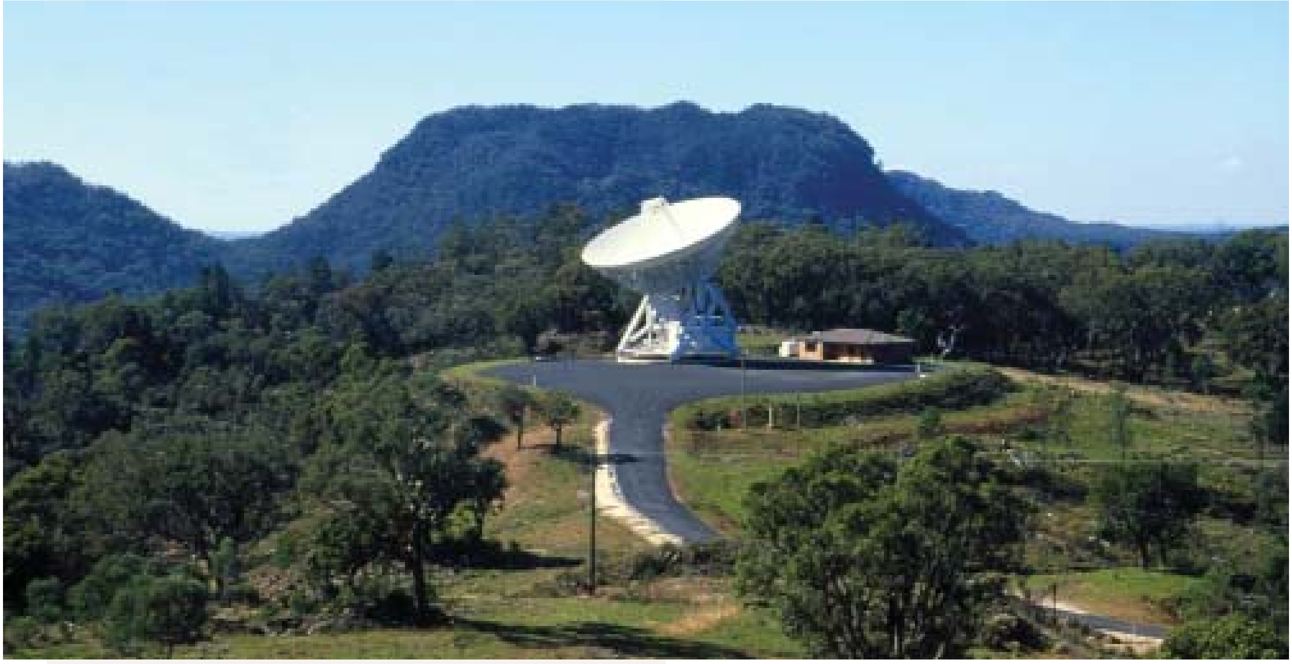
The number of staff at the Narrabri Observatory and the mix of expertise remained largely unchanged during the year. A systems scientist, Mopra operations scientist and a postdoctoral fellow joined the observatory early in the year. These, in part, made up for departures in 2002. At the end of the year Brett Hiscock was appointed as Deputy Officer-in-Charge. Brett was previously the head of the Electronics Group at the Observatory and brings to the position a wealth of experience leading large groups of engineers and technicians.



A group of IAU delegates on a visit to the Narrabri Observatory
Photo: © CSIRO



Ravi Subrahmanyan with invited speaker Rick Forster (University of California, BIMA) at the Narrabri millimetre synthesis imaging workshop.
Photo: © CSIRO



Mopra

Development

New developments for the Mopra radio telescope are closely tied to those at the Compact Array. In some cases, the Mopra telescope is used as a testbed for new technology, whereas at other times, technology is first used at the Compact Array and then transferred to Mopra. This synergy is well illustrated by two major developments currently underway at Mopra: a new 3-mm wavelength receiver package and a new 8-GHz correlator. While the millimetre receiver package will duplicate much of the design of the Compact Array systems, it is hoped that it will contain the next generation of low-noise amplifiers with improved performance. The 8-GHz filterbank reuses some of the design of the Parkes wideband correlator, but also uses technology that will be used for a wideband Compact Array correlator. Both these systems are in a development stage with completion due in 2004.

Other significant developments during the year included the adjustment of the subreflector to reduce a coma-lobe problem, the readjustment of the antenna surface to improve the surface accuracy to approximately 0.16 mm, and some improvements in the tuning software.

At the end of the millimetre observing season, the antenna control system successfully installed at the Compact Array was also installed at Mopra. The first spectrum, taken using the new Mopra antenna control computer was obtained in late November. Work also began on the development of a mapping package to improve the efficiency of the telescope.

The Mopra radio telescope
Photo: © CSIRO

Operations

In 2003 Mopra was again operated in partnership with the University of New South Wales. As in 2002, the use of Mopra was restricted to Very Long Baseline Interferometry (VLBI) and millimetre observations. VLBI observations were taken as part of the Long Baseline Array (LBA), for a total of 21 days. In previous years, Mopra has been used to take data for the VSOP project, a Japanese-led space-VLBI experiment. However a failure in the VSOP spacecraft caused the cancellation of most VSOP observing during 2003.

The Mopra millimetre observing season was scheduled from 2 June – 7 October 2003. Millimetre single-dish observations were taken using the 3-mm SIS receiver system. A total of 59 days were allocated by the ATNF Time Assignment Committee as National Facility time. An additional 53 days were allocated to the University of New South Wales.

As in previous years a two-day workshop was held at Mopra at the start of the observing season. This so-called "Mopra Indoctrination Weekend" aimed at introducing observers to the facilities and to the use of the telescope. Nine people took part in this workshop in 2003.

Support for Mopra was enhanced in 2003 by the appointment of a Mopra Operations Scientist. Although based in Narrabri, this position requires significant presence at Mopra during the observing season. The technical improvements to the telescope and higher level of support led to a signficiant improvement in Mopra's productivity.

Engineering support for Mopra continued to be provided by Narrabri staff with some additional support from engineering personnel at the Anglo-Australian Observatory.

Parkes

NASA tracking agreement

An agreement between NASA and CSIRO to provide tracking support at Parkes commenced in earnest in 2003. The support was intended to assist NASA's Deep Space Network (DSN) during their "Asset Contention Period" over the New Year period 2003/2004, during which time the DSN was heavily subscribed with many simultaneous deep-space missions, most notably those to Mars.

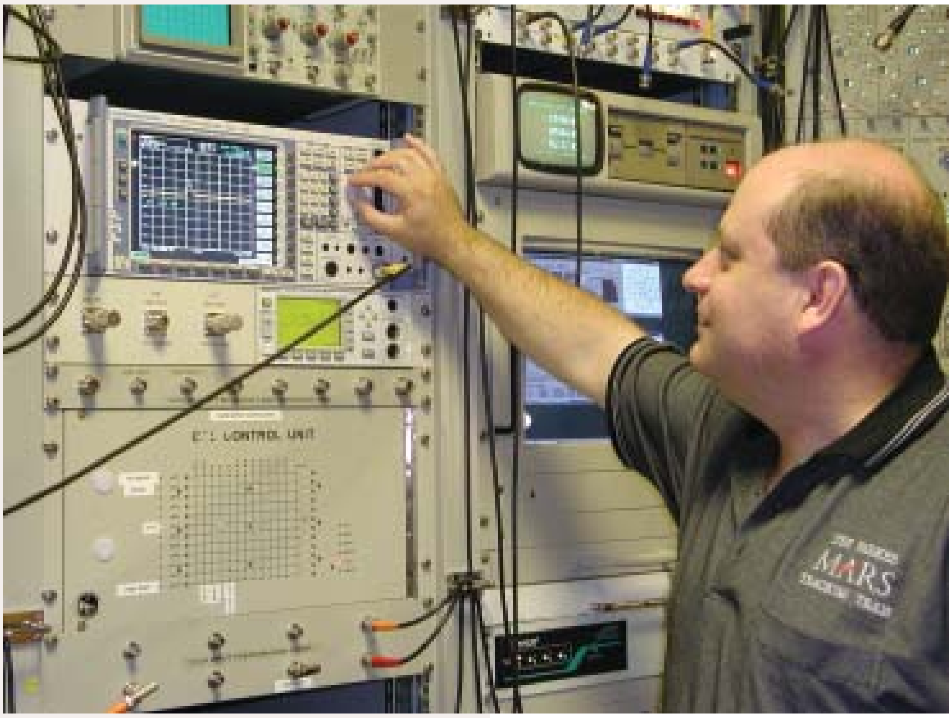
The agreement was for three principal items to be delivered by ATNF: an upgrade to the surface of the Parkes 64-m radio telescope; a new cryogenically-cooled receiver, including feedhorn, for 8.4-GHz observations designed specifically for the project, and, thirdly, approximately 1000 hours of tracking time on the Parkes telescope itself. The total value of the contract was approximately A$3M.

The upgrade to the antenna surface was undertaken during March and April 2003, and involved removal of half the remaining coarse steel mesh panels, beyond a diameter of 45 metres, and replacing them with precision panels of perforated aluminium sheet, out to a diameter of 55 metres. The laborious process of removing the 360 old panels and installing new panels, all by hand, was undertaken by staff from Sydney Engineering, the manufacturers of the panels, supervised and assisted by ATNF staff. The repanelling took approximately five weeks, with another week for final alignment and testing. Holography at 12 GHz was used to fine-tune the panel adjustment. The results were excellent, with a surface precision (rms) of 0.8 mm achieved over the 55-m diameter inner surface, completed within budget and on time.

This upgrade to the antenna surface yields an improvement in efficiency of approximately 30% at 8.4 GHz, and potentially greater yields at frequencies up to 26 GHz, once appropriately redesigned feeds become available.

The new 8.4-GHz receiver was designed and constructed by the Marsfield receiver group and commissioned on the telescope in August. The receiver employed some novel features designed for the lowest possible system temperature, and ultimately exceeded this specification by a considerable margin, with an on-sky system temperature of 25 Kelvin. Together with the surface upgrade, the telescope is now about two and a half times more sensitive at 8.4 GHz than before the upgrade, a new capability which will be of great value, particularly within the Australian VLBI network.

Tracking operations began smoothly in September, after installation and testing of telemetry and network equipment by personnel from the Canberra Deep



ATNF operations scientist, John Sarkissian, in the Parkes control room during NASA tracking.
Photo: © John Sarkissian

Space Communications Complex, Tidbinbilla. Daily tracking support of six – eight hours began in October, scheduled to run until mid February 2004.

The agreement with NASA drew much favourable press coverage, particularly of the official opening of the tracking operations on 31 October by the US Ambassador to Australia.

Double pulsar

The discovery at Parkes of the first double-pulsar system was published in Science Express in January 2004, following closely on a publication in Nature in December 2003 of the detection of the first pulsar in this close binary system, also made at Parkes. The discovery of the double pulsar is exciting for several reasons, including the possibility of new tests of gravity, and the chance to probe deeply into the immediate environments and emission mechanisms of pulsars. The discovery attracted favourable press coverage both within Australia and for the several international groups collaborating in the discovery (page 19).

Performance and time use

The percentage of time scheduled for astronomy in 2003 was significantly lower than in previous years (64.5% of all time, compared to 82.0% in 2002). This drop was due to a one-month shutdown to install the new surface under the NASA contract, and to the time scheduled for NASA tracking itself. (In addition to the 64.5% scheduled time, a significant quantity of time requested and paid for by NASA as 'hot-standby' time was picked up for astronomy, though often at relatively short notice).

Performance statistics for the NASA tracking were very good, with only 2.8% of scheduled time lost (mostly to high wind). The figure for all scheduled operations in 2003 was 5.1% of time lost, comprising 1.3% lost to equipment faults and 3.8% lost to high wind. These figures are very similar to those for 2002. As expected, the repanelling of the 64-m surface has not measurably increased the susceptibility of the telescope to high wind.

User feedback

The web-based fault reporting and user-feedback system continue to serve critical roles in monitoring and maintaining Observatory performance levels. A healthy increase in the number of user responses in 2003 again confirmed generally excellent scores across most categories. Radio frequency interference (RFI) remains the area of greatest concern with users.

Multibeam refurbishment

The 21-cm multibeam receiver was removed in October 2003 for replacement of all 26 low-noise amplifiers (LNAs), to return it to original (or better) performance specifications. The receiver had run essentially non-stop for seven years, a testament to the quality of its design and construction. It is planned to return it to service as soon as possible in 2004 for HI imaging, further pulsar surveys, and numerous other projects which require it.

New 10/50-cm receiver

A new 10/50-cm dual-frequency receiver, designed and built by staff of ATNF and CTIP, at the Radiophysics Laboratory in Marsfield, was successfully commissioned in October 2003 with assistance from Observatory staff. The receiver was immediately put to good use observing the newly-discovered relativistic binary pulsar system J0737-3039 (page 19).

The new receiver is designed primarily for precision pulsar timing measurements, a field in which Parkes Observatory currently holds a pre-eminent international position. The receiver will also be used for pulsar searches, mainly for observations at a wavelength of 50 cm, though the task of avoiding RFI in this band is becoming increasingly onerous. The arrival of the new 10/50-cm dual-frequency receiver coincided with a further degradation of the RFI environment in the 50-cm band due to the rollout of Digital TV services.

RFI mitigation

Significant resources continue to be committed in this area across the ATNF, addressing the problem on several parallel fronts including advanced software excision techniques using reference antennas, regulatory protection and local mitigation measures such as shielding.

Site

A major renovation of the Parkes Observatory access road, at a total cost of A$1.2M, is about to begin. The road has deteriorated badly over the last few years, and, with the increasing number of visitors to the Observatory, has become a serious hazard. Parkes Shire Council has committed 50 per cent of the funding required from its Federal "Roads to Recovery" funding allocation. CSIRO Corporate Property will fund the remaining 50 per cent of the cost of reconstructing 2.5 km of the road most in need of repair during 2004/2005.

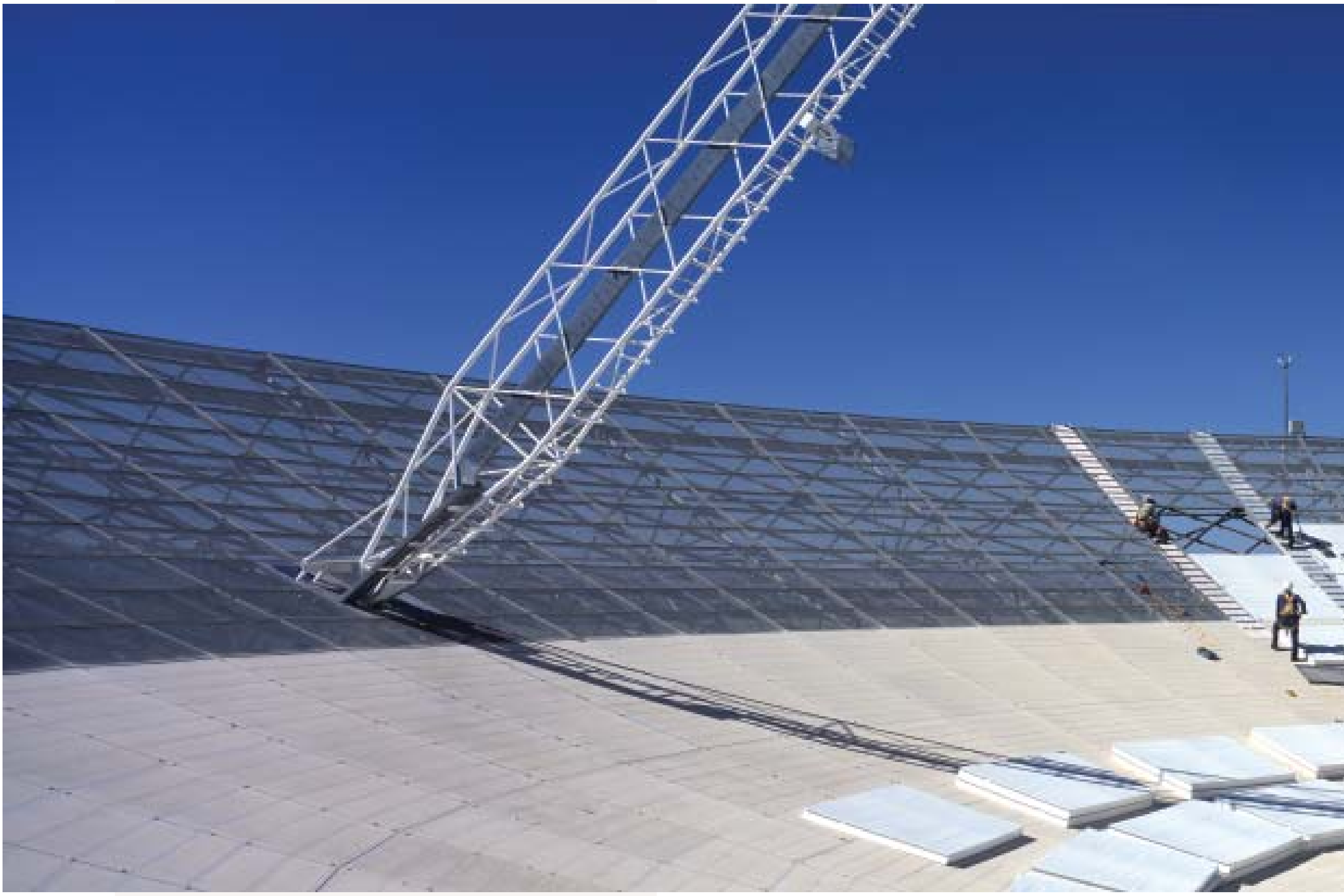
The Australian Long Baseline Array

The Australian Long Baseline Array operates as a VLBI array using most radio telescopes around Australia. It includes all the ATNF antennas (Parkes, Mopra, Compact Array), the Hobart and Ceduna antennas of the University of Tasmania and antennas of NASA's Canberra Deep Space Communications Complex at Tidbinbilla. It also frequently operates in collaboration with overseas antennas, in particular the Hartebeesthoek antenna in South Africa, the Kokee Park antenna in Hawaii and the Kashima antenna in Japan.

Operational support

In 2003, casual operators were employed for the LBA correlator. The operators succeeded in correlating all observations between sessions, as well as making significant progress in correlating some of the backlog of earlier LBA observations. This has allowed the reuse of many VCR tapes. With the addition of about 1000 surplus Canadian tapes from the Penticton correlator at the Dominion Radio Astrophyscial Observatory, the tape stock of unrecorded tapes is now sufficient to obviate the need to acquire any new VCR tapes.

The University of Tasmania saw the official retirement of Professor Peter McCulloch, who has been instrumental in the development of the LBA. However, Professor McCulloch will continue some involvement with the observatories and the LBA. The ATNF agreed to assist the Tasmanian group with Ceduna operations and supported one session in 2003. In late 2003 an arrangement was set up for the Ceduna antenna to be supported by a local operator from 2004. Operating the Ceduna telescope is now straightforward and reliable.



Work in progress to replace some of the panels on the surface of the Parkes radio telescope, in preparation for the NASA Mars tracking program.
Photo: © Tim Ruckley

VSOP

The VSOP satellite operated only intermittently in 2003. Altitude control of the spacecraft was lost in January 2003 and operations did not resume until August. Control was lost again in October and was not recovered again before the end of the year. In August 2003, the Dominion Radio Astrophyscial Observatory ceased providing correlation support for VSOP and correlations have since been done at Mitaka in Japan.

The main VSOP program in 2003 was the mission-led survey of active galactic nuclei, with Mopra, Hobart and Hartebeesthoek as the main ground-based antennas. The observations typically involved one or two short tracks of up to six hours per week during the short periods of VSOP operation.

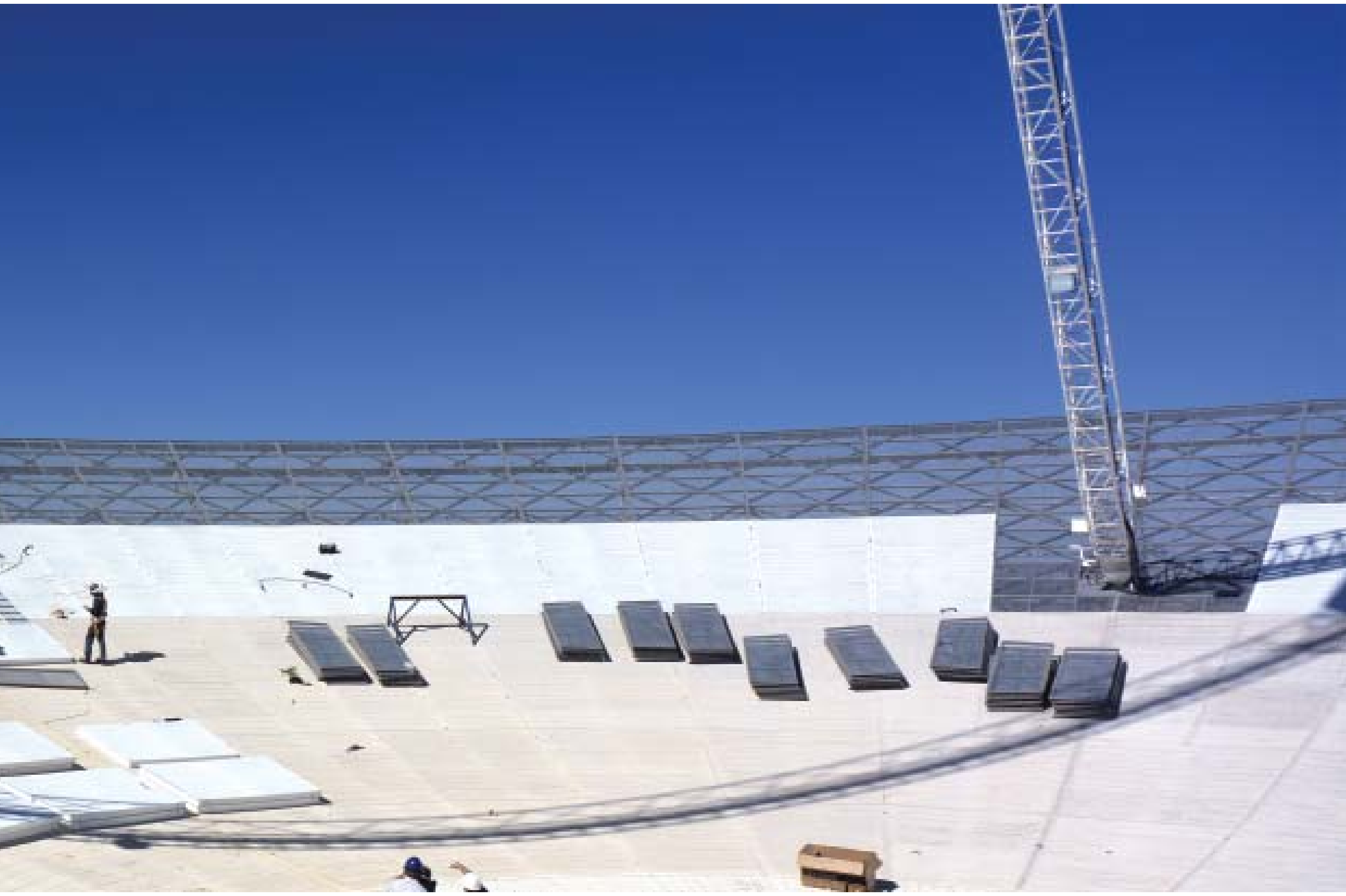
Technological developments

New technologies for VLBI are under development world-wide, with implications for the future of the LBA. A one-day meeting was held at the ATNF in March 2003 to review the LBA status and discuss possible future developments.

An important overseas development was the adoption of disk-based recording systems to replace tapes, increasing the bandwidth and reliability. Some tests were carried out to implement network transfers of the data, potentially leading to direct connectivity without recorders (e-VLBI).

The Hobart antenna was converted to a Mk5a disk system for its astrometry observations. Tests were done on the LBA with disk-based systems provided by the Swinburne University of Technology. Data were recorded at Parkes and the Compact Array, transferred slowly over the internet and correlated on the Swinburne supercomputer. "First fringes" were detected on the Vela pulsar in November 2003.

The LBA also participated in worldwide network tests for e-VLBI, led by the Haystack observatory. A



permanent connection was provided at ATNF. The network tests are continuing.

Proposals and scheduling

Proposal demand for the LBA in 2003 was strong, with an effective oversubscription rate of 1.9, similar to previous years. A significant amount of time was allocated to the ATNF-USNO astrometric program.

Access to the Tidbinbilla facilities for LBA observations, especially for the large and sensitive 70-m antenna, remained difficult. However, in 2003 the ATNF-USNO astrometric program established a new agreement for regular access to the 70-m antenna and the first observations under this agreement were taken in August 2003. The VLBA program SCHED was adopted as the recommended scheduling program for the LBA, and this has become the standard scheduling program for all VLBI networks worldwide. A set of templates and examples for common LBA modes was also provided to assist users. These developments will facilitate VLBI scheduling.

The LBA scheduler changed in 2003. After more than a decade of scheduling the LBA, John Reynolds passed this responsibility to Jim Lovell.

Operations

There were four major LBA observing sessions in 2003, the usual one-week sessions in February and November and two shorter four-day sessions in June and August. The August session was severely affected by strong winds at multiple sites and many of the projects had to be repeated.

Tidbinbilla spectroscopy

Starting with the 2003 January term, time allocated to ATNF at the Tidbinbilla 70-m antenna was made available as a National Facility for single-dish observations. The time, provided under a Host Country agreement with NASA, was used in a service observing mode for spectroscopic observations.

The 70-m antenna is equipped with 1, 3, 13 and 18-cm receivers. In particular the 1-cm system is the most sensitive in the southern hemisphere, covering 18.0 to 26.5 GHz at a system temperature of 60 Jy. Tidbinbilla is equipped with an ATNF multibeam correlator block capable of two polarisation products, with up to 2048 channels, each with 32 or 64 MHz bandwidth, or up to four polarisation products with a total of 8192 channels and bandwidth of 16 MHz or less.

In 2003 a total of 320 hours were available for spectroscopy observations. Of that, 62 hours were used for test observations, 36 hours were lost due to hardware problems or weather and 222 hours of observations were successfully completed for 8 proposals. The times available for service observations in 2003 were generally restricted to times when Mars was below the horizon, due to the high priority given by NASA to Mars tracking. Unfortunately, Mars was close to the direction of the southern Galactic plane for most of 2003. As the majority of proposed targets were Galactic the observing efficiency was low. It is expected that this situation will improve as Mars moves away from the Galactic plane direction. The oversubscription rate during 2003 was approximately 2.0.