Chapter 46

RADIO ASTRONOMY

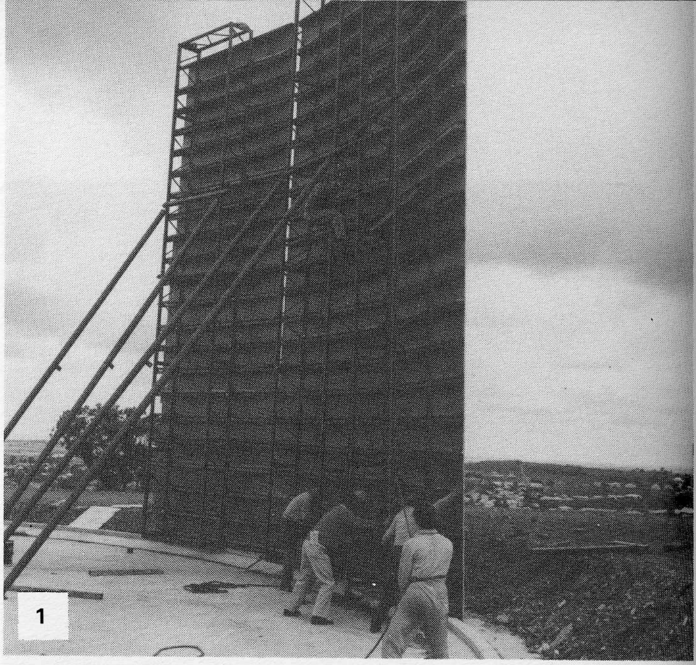
The Giant Radio Telescope, which has become the symbol of Australia's achievements in science and technology, celebrates its quarter century in service in 1986 when it plays an important role in studying Halley's Comet.

A spacecraft is proposed to be launched to intercept the comet and the Parkes Big Dish will have prime responsibility for receiving scientific data from the spacecraft as it flies through the head of the comet in March, 1986.

Halley's Comet appears every 76 years. It is believed to consist of ice and dust and the European Space Agency craft will take observations and relay information to give precise information on the comet's composition. The interception, code-named Project Giotto, will take place on March 12 and 13. Work such as this, when the world spotlight focuses on the Parkes observatory, is now very much part of the scientific routine.

Dr E. G. Bowen, as Chief of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Radiophysics was primarily responsible for Australia gaining the instrument. In July, 1954, the Carnegie Corporation provided £250 000, half the then estimated cost of the instrument. The grant recognised the reputation internationally of Australian radio astronomers and the advances they had by then achieved. They were engineers and physicists who borrowed terminology from optical astronomers to describe their sightings of radio stars which were in categories ranging from bright to faint. Early in 1946 it had been discovered that radio waves were reaching Earth from a few point sources in space and it raised the question whether these were simply visible stars being seen in a 'new light' as all hot bodies emit radio waves as well as heat and light. The finding was that the radio 'stars' were something whose existence had not been suspected previously. The first radio telescopes were little more than converted radar aerials, usually steerable, small in size with limited performance but they enabled pioneer radio astronomers to establish radio stars were not the bright visible stars. The need was to determine the position of the radio 'stars' with precision and to establish if they could be identified with known celestial bodies. Larger and highly accurate radio telescopes were required.

Dr Bowen took the concept of a giant steerable radio telescope in Australia to major international organisations and the Carnegie grant was matched by the Rockefeller Foundation of New York which made a later supplementary grant of £107 000. The Commonwealth Government backed the Australian National Radio Astronomy Observatory project then the search started for a location accessible to Sydney but sufficiently distant to be completely clear of any possible radio interference; in a relatively flat area but one not subjected to high winds.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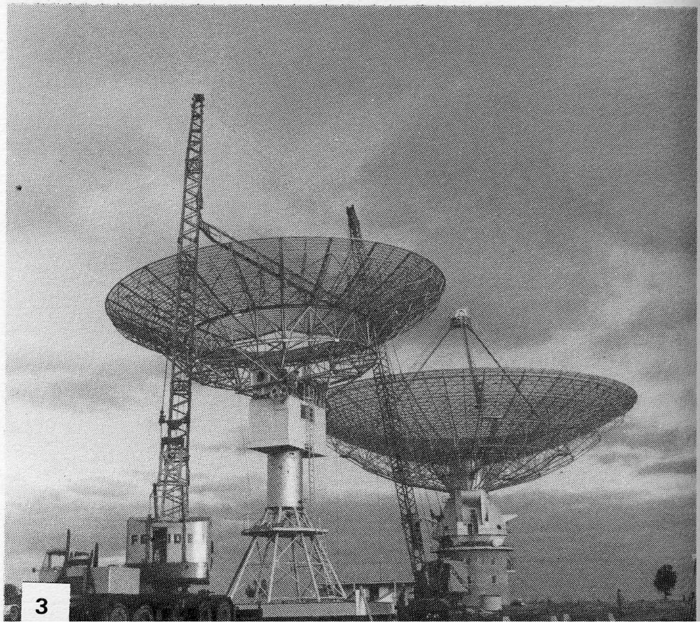
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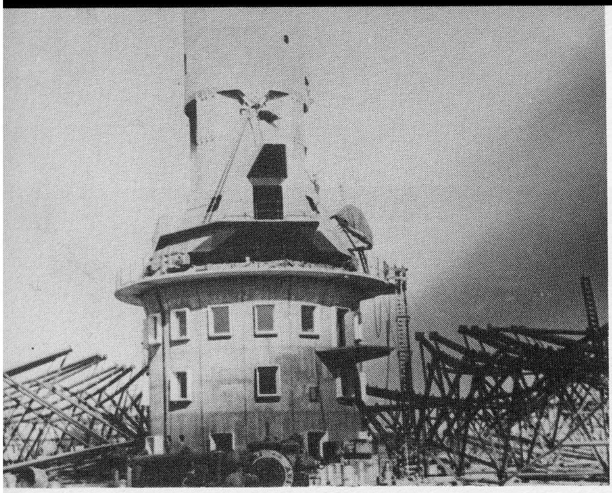

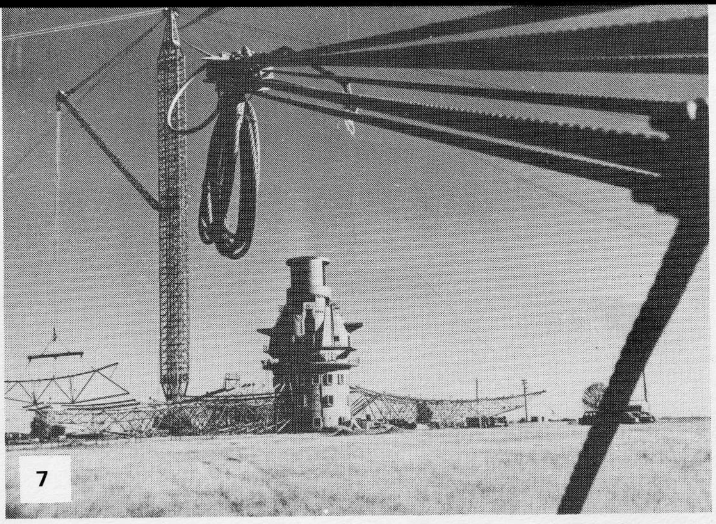

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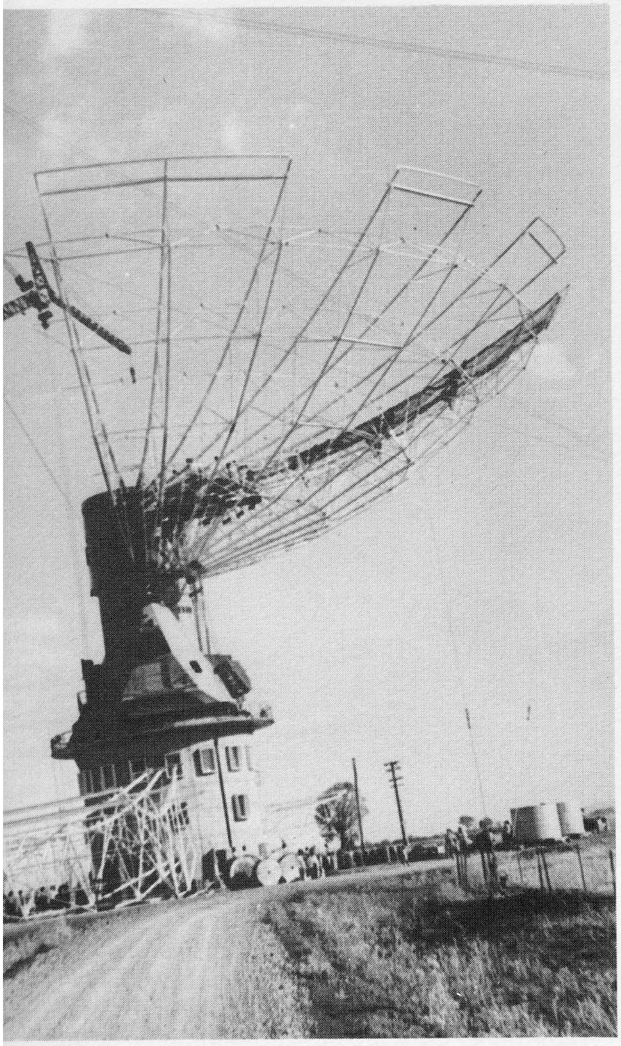
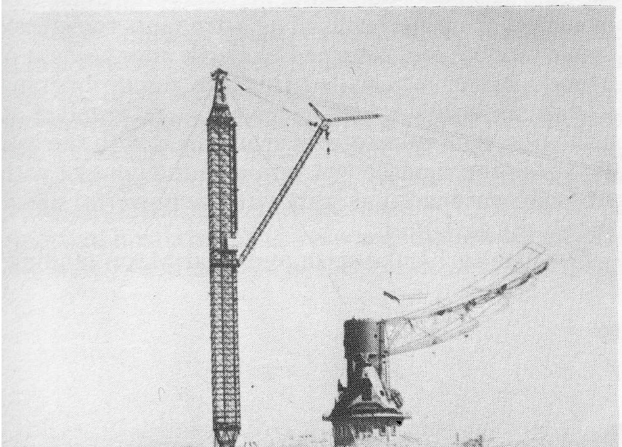
1.–7. Various stages of construction of the giant CSIRO Radio Telescope at Parkes. The formal commissioning was carried out on October 31, 1961.

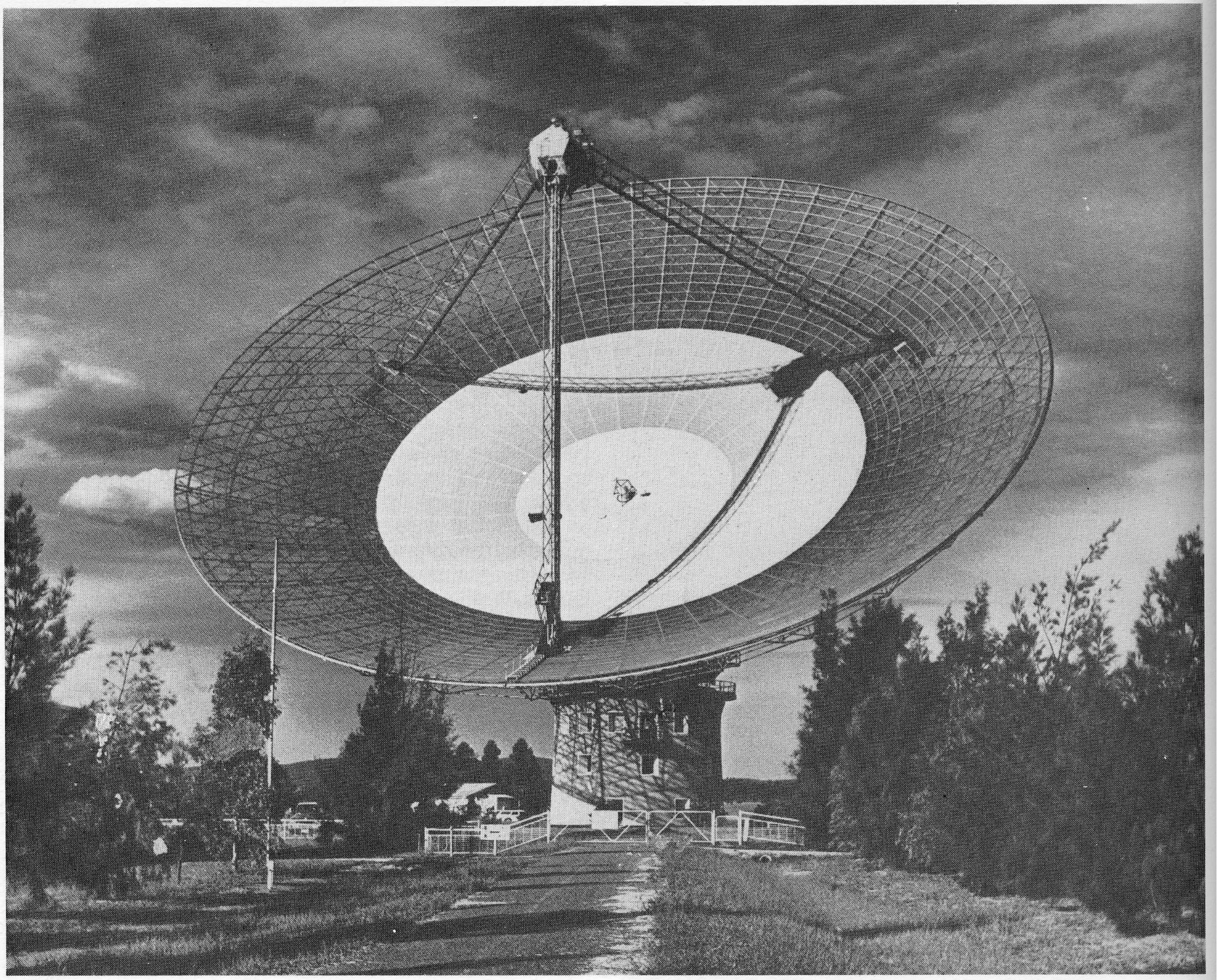
The Coobang Valley and land on the property of A. J. Helm was nominated as the ideal location. Freeman, Fox and Partners, engineering consultants famous for their bridges, carried out preliminary design studies for a receiver or dish aerial with a surface accuracy to within plus or minus half an inch and a pointing accuracy of one minute of arc in maintaining a fix on any position in the heavens. Dr Barnes Wallis, of the Vickers Company, designer of the bounce bombs of World War II dambuster fame, submitted several novel ideas towards the project. Freeman, Fox presented their report in 1957, recommending a dish aerial supported by 30 ribs attached to a strong central hub. The Hon. (later Lord) R. G. Casey, Minister for the CSIRO, on August 13, 1958, announced that the Giant Radio Telescope was to be built near Parkes. Mr Mike Jeffery, of Freeman, Fox, was supervising engineer, with Maschinenfabrik Augsburg-Nurnberg A. G. (MAN) the prime contractors.

Mr John G. Bolton, a Cambridge physics graduate and the first man to identify radio 'stars', was appointed observatory director. Grote Reber, a pioneer radio astronomer and representatives of America's National Aeronautics and Space Administration (NASA) were among the earliest international visitors to the site. His Excellency, the Rt Hon. Viscount De L'Isle, Governor General of Australia, commissioned the telescope on October 31, 1961, but windy conditions prevented the Big Dish dipping in salute. A small flag was broken out from the cabin atop the tripod on the dish.

The Champion-Post ran the banner heading 'Moon calling Earth . . . Come in Moon' in its supplement coinciding with the commissioning and it was in the era of space voyages and Moon walks that the telescope repeatedly captured world attention. While logging a list of radio astronomy firsts the observatory was involved in turning science fiction into fact as NASA proceeded with its Apollo flights and moon landing missions. For one month from mid-July 1973, a sample of microbreccia (10048,49) collected from the Moon's Sea of Tranquility by the first men on the Moon, Neil Armstrong and Edwin Aldrin, was displayed at Parkes Municipal Council Chambers. Other moonrock samples







The finished product—a major scientific and tourist facility which cemented Parkes' integral role in world astronomy.

had been shown in world capitals, but in tribute to the role of its astronomers, Parkes was the first regional centre in which a moonrock sample went on public display.

When Neil Armstrong made his 'giant leap for mankind' by setting foot on the Moon his main link with Earth was through the Parkes Radio Telescope. Pictures received at Parkes and ultimately beamed via a Pacific communications satellite to Apollo Mission Command Centre at Houston, Texas, were eventually seen by 600 million viewers in 49 countries. Although never designed as a communications link the telescope proved critical in a number of projects. CSIRO contracted to support Apollo missions subsequent to Apollo 11 and was brought directly into the manned space flight network when emergencies arose on missions 13 and 16. The telescope had no real role for Apollo 13 until about mid-point on the flight oxygen tanks in the command module exploded, damaging the spacecraft and cutting power supply from fuel cells. The astronauts transferred to the lunar module and returned to Earth after going around the Moon. Parkes was called into the rescue operations and within six hours NASA receivers were installed at Parkes and voice communications established with the astronauts. Power in the module was rationed and contact with the astronauts was marginal even with the powerful signal receiving ability at Parkes.

On Apollo 17, the sixth and final Moon landing, Parkes

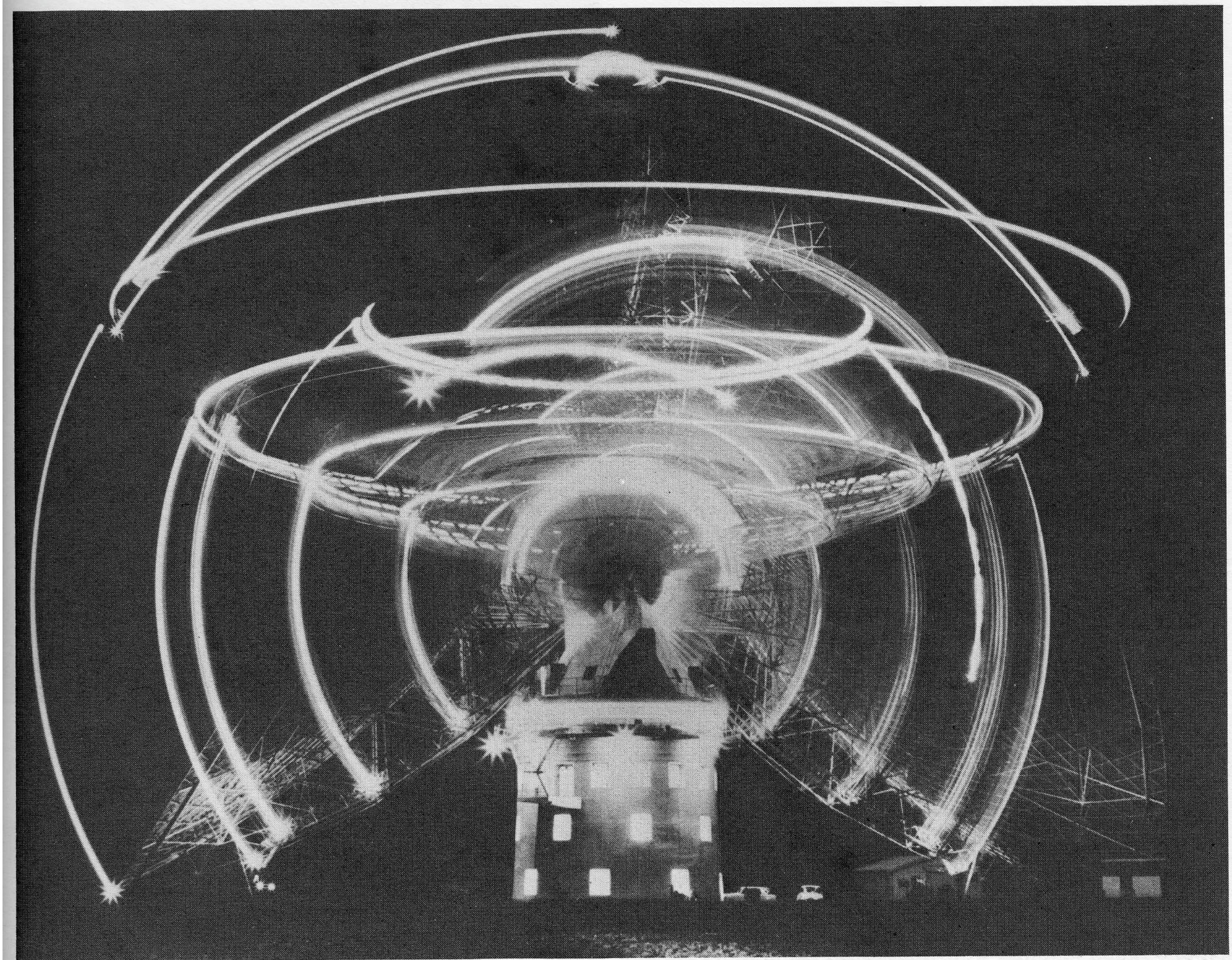


Illustration of the classic photographic techniques emanating from night time observation with the Radio Telescope.

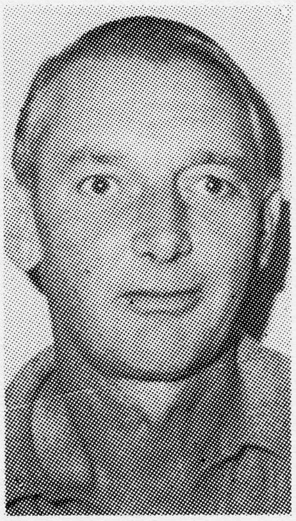
played a prime role during the critical stages of the moonwalk, carrying television, audio and vital telemetry on spacecraft and astronaut performance.

With scientists contemplating the question of extraterrestrial intelligent life, radio telescopes were brought into the work after vast clouds of ammonia then water vapour were detected in space by US scientists in the mid-1960s. Parkes had almost exclusive access to the southern skies as radio astronomers tuned to frequencies to plot the location of these chemicals. Parkes in 1971 added thioformaldehyde and in 1972 methanimine to the list of discoveries. Methanimine was discovered in the region of Sagittarius B2, the area of other important breakthroughs. New speculation on the origins of life were raised in 1974 as the search went on for the amino acid group with chemists at Monash University working with the Parkes astronomers. A small amount of time was devoted to one deliberate search for actual signals from other civilisations in a scan of a dozen nearby stars similar to the Sun. One unexplained phenomenon was discovered but no signal was detected.

In pure research Mr Bolton's team produced discoveries which forced a rethink of well accepted scientific theories. Some of the discoveries were pure accident, others because of brilliant and painstaking work.

Quasars, pulsars, x-ray and neutron stars and blackholes were added to the radio astronomy vocabulary.

Dr Jon Ables took charge of the observatory on Mr Bolton's retirement, the observation program continuing night



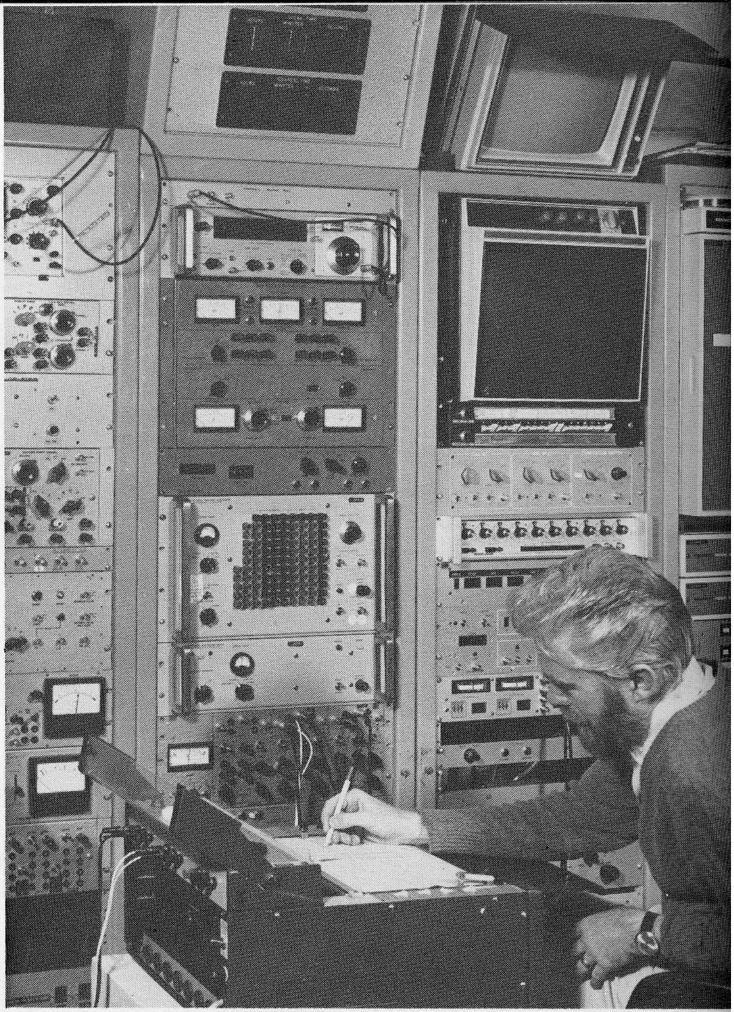
John Bolton.

and day with data appearing as graphs, charts, tables, the picture of the universe being built up in the minds of the radio astronomers with the telescope extending the senses of man to find out how the universe works and man's place in it.

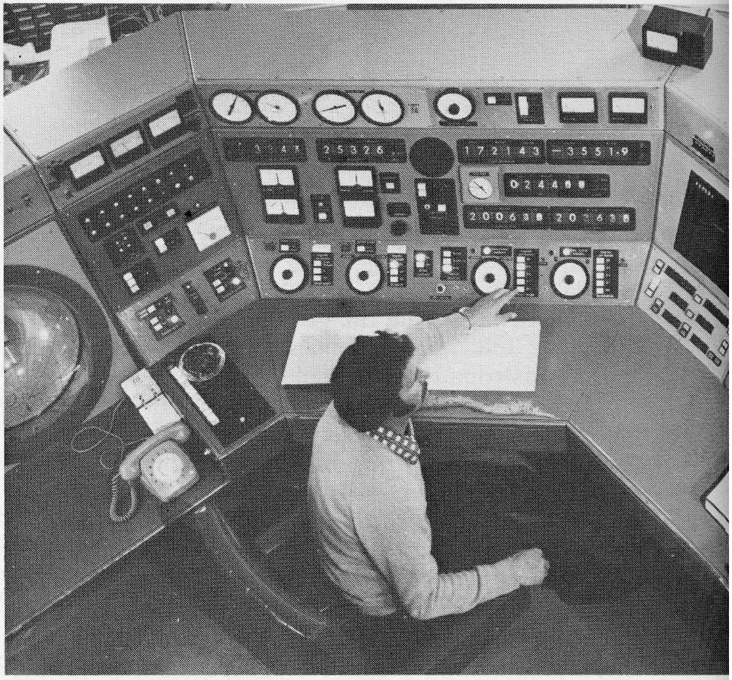
Mr John Bolton—was honoured in the 1982 Queen's Birthday Honours with a CBE—an Order of the British Empire denoting a Commander in the Civil Division of the Most Excellent Order of the British Empire. Now in retirement in Buderim, Queensland, Mr Bolton was one of the pioneers of radio astronomy in Australia, beginning his career at the Dover Heights Division where he discovered and identified radio sources which contributed to the launching of radio astronomy. After a period in California, he rejoined the Division during construction of the Parkes Telescope and was appointed director of the ANRAO five years later. His research on quasars and his support of the Apollo moon landings won widespread admiration. He retired in May 1981 after 25 years with the CSIRO.

In 1981 the Australian Government faced a decision on the future direction of the Parkes observatory. Three times the Big Dish had been upgraded—first by replacement of the original panels on the acre surface of the dish with more accurate aluminium panels out to 37 metres diameter to facilitate observations from 21 cm down to one cm wavelength. Then the central 17 metres of the dish were resurfaced with solid aluminium panels permitting studies down to a wavelength of 3 mm. For a decade the Parkes telescope was the most powerful in the world; today it still ranks with the best and is used in conjunction with the 18 metre dish as an interferometer for higher resolution studies.

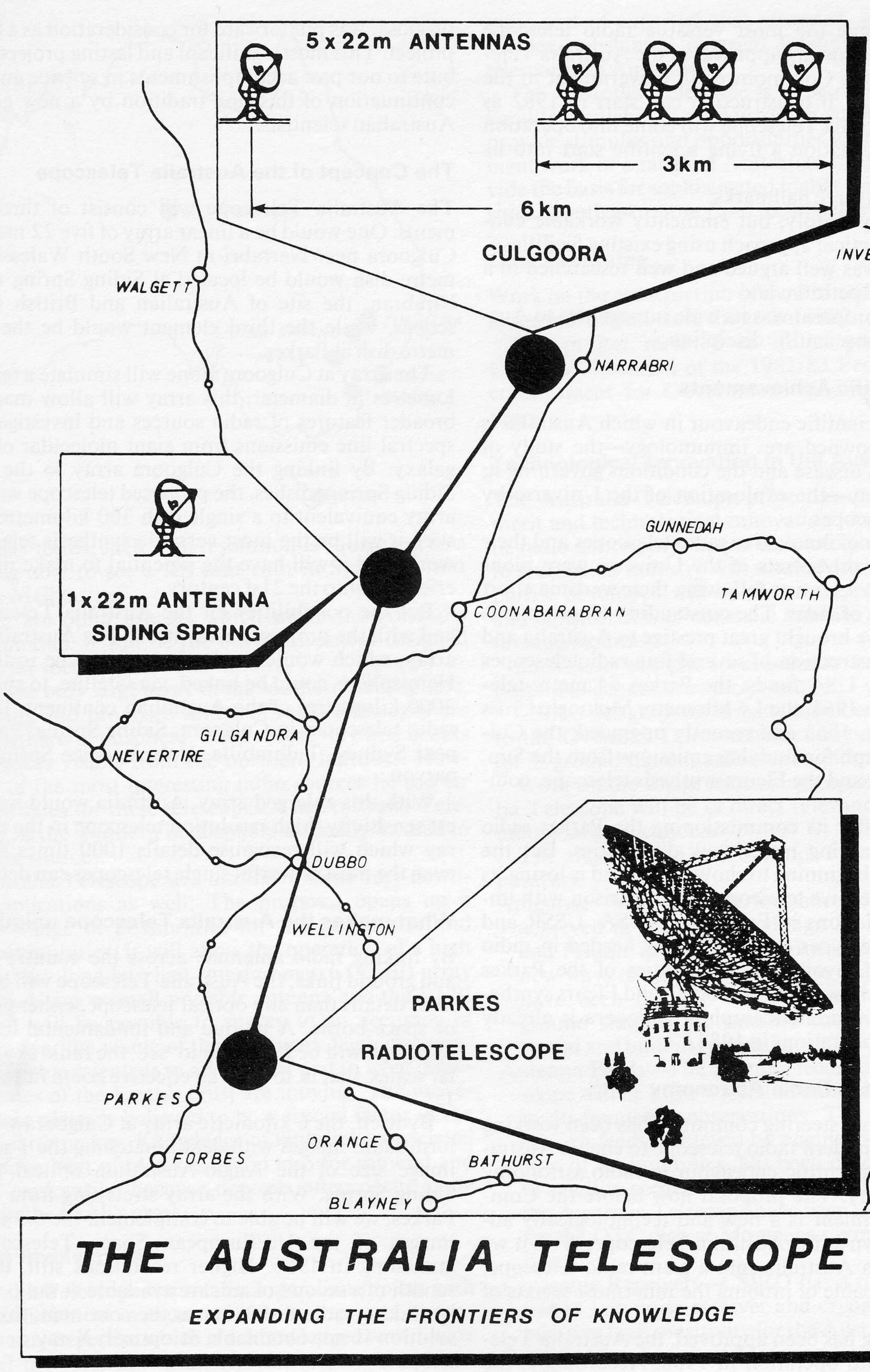
However, after two decades the Parkes instrument still has the ability to return to world supremacy by becoming the central feature in the Australia Telescope, a collection of seven radio telescopes designed to produce even sharper pictures of the radio sources in space.



Dr A. E. Wright plotting data in the main tower.



Local identity Derek Fellows on duty in the control room.


5 x 22m ANTENNAS
3 km
6 km
CULGOORA
INVERELL
WALGETT
NARRABRI
GUNNEDAH
TAMWORTH
COONABARABRAN
1 x 22m ANTENNA
SIDING SPRING
GILGANDRA
NEVERTIRE
DUBBO
WELLINGTON
PARKES
RADIOTELESCOPE
PARKES
ORANGE
FORBES
BATHURST
BLAYNEY
THE AUSTRALIA TELESCOPE
EXPANDING THE FRONTIERS OF KNOWLEDGE

Australia will have the most versatile radio telescope array in the world following approval of the Australia Telescope proposal by the Commonwealth Government in the 1982 Federal budget. If construction can start in 1982 as scheduled, the Australia Telescope will come into operation in 1988 to give the nation a flying scientific start into its third century.

The proposal has three hallmarks:

- It is an elegantly simply, but eminently workable concept, based on a practical approach using existing facilities;
- The case for it was well argued and well researched in a spirit of intense competition; and
- Inherent in the proposal was its wide importance to Australia, not just to one scientific discipline.

Australian Scientific Achievements

The two fields of scientific endeavour in which Australia is internationally renowned are: immunology—the study of the immunity from disease and the conditions governing it; and radio astronomy—the exploration of the Universe by means of radio telescopes.

The construction of innovative radio telescopes and their role in unravelling the secrets of the Universe were pioneered by Australian scientists following their wartime effort in the development of radar. The outstanding achievements of the scientists have brought great prestige to Australia and have led to the construction of several fine radiotelescopes financed largely by USA funds: the Parkes 64 metre telescope, completed in 1961; the 1.6 kilometre Molonglo Cross array, completed in 1965 and recently upgraded; the Culgoora radioheliograph for studying emissions from the Sun, completed in 1967; and the Fleurs synthesis telescope, commissioned in 1973.

Even 20 years after its commissioning the Parkes radio telescope is still making major new discoveries. But the Parkes telescope is beginning to show its age and is losing its standing as a competitive telescope in comparison with important new installations in Europe, the USA, USSR and Japan. By 1990 the types of observations needed in radio astronomy will be beyond the capabilities of the Parkes telescope and also those of the Molonglo and Fleurs synthesis telescopes. The radioheliograph at Culgoora is already scheduled to cease operations in 1984.

Australia's Future in Radio Astronomy

Since 1975 a national steering committee has been working on proposals for a modern radio telescope to enable Australia to continue its scientific endeavour in radio astronomy into the 21st century. The proposal now before the Commonwealth Government is a new and technologically advanced design known as the Australia Telescope. With it we will be able to turn Australia into a giant radio telescope, one that will be capable of probing the innermost secrets of the Universe.

Now that funding has been approved, the Australia Telescope will come into operation in 1988. Accordingly, the proposal was put forward for consideration as a bicentennial project. This most significant and lasting project will pay tribute to our past accomplishments in science and ensure the continuation of this fine tradition by a new generation of Australian scientists.

The Concept of the Australia Telescope

The Australia Telescope will consist of three main elements. One would be a linear array of five 22 metre dishes at Culgoora near Narrabri in New South Wales. Another 22 metre dish would be located at Siding Spring near Coonabarabran, the site of Australian and British optical telescopes, while the third element would be the existing 64 metre dish at Parkes.

The array at Culgoora alone will simulate a telescope 6 kilometres in diameter; this array will allow mapping of the broader features of radio sources and investigations of the spectral line emissions from giant molecular clouds in our galaxy. By linking the Culgoora array to the Parkes and Siding Springs dishes, the proposed telescope would form an array equivalent to a single dish 300 kilometres across. As such it will be the most versatile synthesis telescope in the world and it will have the potential to make major discoveries well into the 21st century.

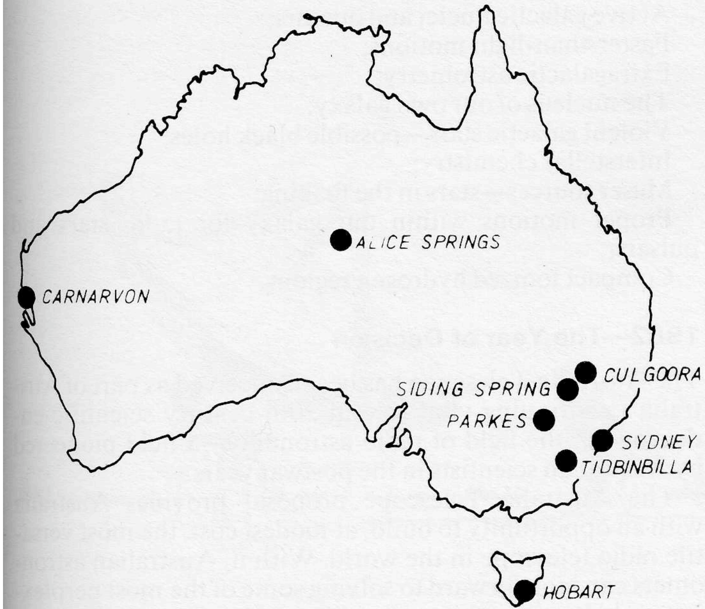
But the possibilities for the Australia Telescope do not end with the proposed array itself. The Australia Telescope array, which would be the first of its type in the Southern Hemisphere, could be linked, via satellite, to span the entire 3000 kilometres of the Australian continent. It would link radio telescopes in Culgoora, Siding Spring, Parkes, Fleurs near Sydney, Tidbinbilla, Hobart, Alice Springs and Carnarvon.

With this enlarged array, Australia would have the highest sensitivity, high resolution telescope in the world, an array which will recognise details 1000 times smaller than even the most powerful single telescopes can detect.

What makes the Australia Telescope unique?

By linking radio antennae across the country via satellite and ground links, the Australia Telescope will be able to see finer details than any optical telescope, either ground-based or space-borne. A unique and fundamental feature of the telescope will be its ability to 'see' the radio sky on all angular scales, that is, to have an effective zoom ratio of 10 000 to 1.

By itself, the 6 kilometre array at Culgoora will be able to form radio images with detail matching the 1 second of arc image size of the Anglo-Australian optical telescope at Siding Spring. With the array stretching from Culgoora to Parkes, we will be able to complement the 0.1 second of arc images of the US/European Space Telescope due for launching in 1986. Higher resolutions still, to one thousandth of a second of arc, are available at radio wavelengths by linking radio dishes across the continent; this level of resolution is not obtainable at optical, X-ray or other wavelengths.



In everyday terms, such high resolution is equivalent to a person being able to see a ten cent coin in Sydney whilst stationed in Melbourne.

But there are other aspects which make the Australia Telescope unique. It will be the only instrument designed specifically for spectral line observations.

It will be the only large array in the southern hemisphere. Other existing and proposed arrays of radio telescopes are all in the northern hemisphere. They reveal very fine details of radio sources visible from the northern latitudes. However many of the most interesting radio sources lie too far south in the skies for these telescopes. The Australia Telescope array in the southern hemisphere is ideally located to explore these sources.

The Australia Telescope will also have some very down-to-earth applications as well. The proposal opens up a whole new range of possibilities for the geophysics and geodetic communities. It will allow the operation of a high sensitivity, very long baseline interferometry (VLBI) array in Australia. Using a small portable antenna and the VLBI technique it will be possible to survey to an accuracy of millimetres over the whole of the continent. Such measurements will enable scientists to see how far and in what direction the plates of the Earth's crust are moving. The movement of these plates is believed to be a crucial factor in the causing of earthquakes. Knowledge of fault lines associated with the movement of plates is useful also for mineral and petroleum exploration because deposits often occur along fault lines in the Earth's crust.

Australian Involvement

The Australia Telescope is a totally Australian project with an Australian content in excess of 80%. It draws on Australian astronomy expertise which is acknowledged world-wide as being at the forefront in all relevant areas. This is the same sort of expertise that attracted, in different circumstances, substantial overseas funding for previous major telescopes in Australia.

The Australia Telescope is to be operated as a National Facility available to all Australian scientists. Hence, it will provide stimulus and opportunities for continuing development work in a range of Australian institutions. It will provide the basis for sophisticated higher degree work at universities in both astronomy and technical areas.

Cost Estimates

Work on the construction of the $25 million Australia Telescope will begin before the end of 1982.

The project received an initial grant of $820 000 in CSIRO's allocation of the 1982/83 Federal Budget—and a commitment for Government funding over the next six years.

Technological Innovation in the Australia Telescope

The Australia Telescope project is one of great scientific merit and technological innovation. As with past advances in radio astronomy, major technological spin-offs relevant to Australian industry will result. Much of the skill and expertise developed will be directly applicable to the design and construction of domestic satellite reception and transmission facilities.

Such skills will give local industry a stake in the very important telecommunications market.

CSIRO designs have already provided substantial benefits to the Overseas Telecommunications Commission (OTC) for its ground stations at Moree and Carnarvon.

Work on the image processing capabilities of the Australia Telescope will be of direct relevance to biomedical and industrial applications.

The major design studies which form the basis of the proposal are:

Antennae—Very high performance-to-cost ratio has been achieved in the antenna design by Macdonald, Wagner and Priddle in association with Ir B. G. Hooghoudt, and new ways of achieving precision dish surfaces at low cost have been devised. The expertise will allow efficient ground stations for satellite communication to be designed and built in Australia.

Antenna Feeds—The antenna feeds for the Australia Telescope will be ultra-wideband and will allow simultaneous multi-frequency observations. The 'polarization purity' of such feeds, achieved by engineers of the CSIRO Division of Radiophysics, has been crucial for developments in satellite communication. New ideas in feed design for the Australia Telescope have been used to build new feeds for the OTC dish at Moree, so saving OTC some $4 million.

Cryogenic Receivers—CSIRO has a major centre of expertise in low-noise receiver and cryogenic technology thus assuring high sensitivity for the Australia Telescope.

Satellite Distribution of Time and Frequency—The Australia Telescope will pioneer the use of satellites for the distribution of precision time and frequency references for local oscillator synchronization.

Data Transmission using Optical Fibres—The Australia Telescope will employ high-speed digital techniques to transmit information from the antennae to the central control area. Optical fibres and higher-speed links than those used in current practice will be required.

Very Large-Scale Integrated Circuits—Specific new VLSI circuits have been designed for the correlation system and for the signal processing and display systems for the Australia Telescope.

Image Processing—The Australia Telescope will use unique image processors and display systems of Australian invention to provide better facilities and faster turn-around in processing of images.

Exploring the Universe with the Australia Telescope

Important exploratory astrophysical projects await the Australia Telescope at the end of this decade. Many of these projects arise because of our privileged position in the southern sky.

Some of the most interesting radio galaxies will be within the field of view of the Australia Telescope. At present astronomers have only a limited ability to probe the critical central regions of the southern radio galaxy Centaurus A. This galaxy is closer than any other radio galaxy and offers unparalleled opportunities for studying the energy source in such luminous objects. With the Australia Telescope such galaxies will be studied in detail.

The centre of our own galaxy passes almost overhead in northern New South Wales and thus this area is ideally situated as a base for detailed studies of the galaxy. The Australia Telescope will have unrivalled power to investigate the spectral-line emission from giant molecular clouds in our galaxy. The richest of these clouds, which are the birthplace of stars, lie in the Southern Hemisphere.

The Telescope will permit detailed studies of the structure and dynamics of distant galaxies. The nearest galaxies—the Magellanic Clouds—are only visible from the Southern Hemisphere and provide unique opportunities for research.

Another very important research area in astronomy is that related to the major discrepancy between the apparent birthrate of supernova remnants and pulsars—the two products of a supernova explosion. Such objects can best be studied in the Southern Hemisphere. Scientists from the CSIRO Division of Radiophysics and the University of Tasmania have recently discovered pulsars in the Magellanic Clouds. The Einstein orbiting X-ray observatory has discovered 80 possible new supernova remnants in the Clouds. Initial radio observations of these sources being made with the Molonglo telescope will lay the basis for a major program with the Australia Telescope.

The Australia Telescope is an essential tool in the study of the following:

Active galactic nuclei and quasars;
Faster-than-light motions;
Extragalactic astrometry;
The nucleus of our own galaxy;
Violent galactic stars—possible black holes;
Interstellar chemistry;
Maser sources—stars in the making;
Proper motions within our galaxy for radio stars and pulsars;
Compact ionized hydrogen regions.

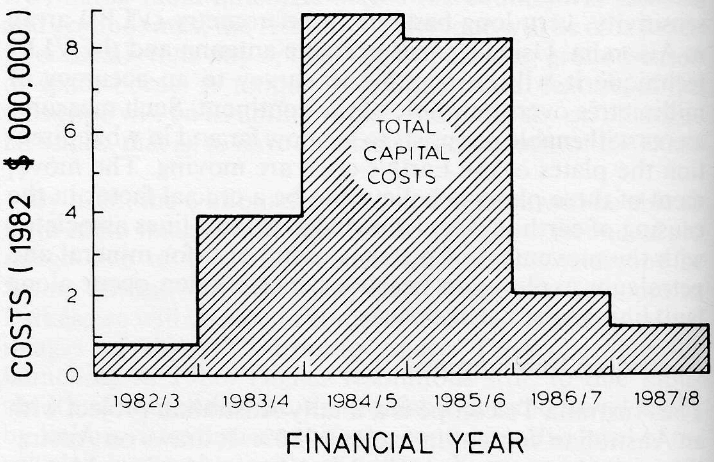
1982—The Year of Decision

The Australia Telescope has been conceived as part of Australia's continuing vital role in 20th century scientific endeavour in the field of radio astronomy—a field pioneered by Australian scientists in the postwar years.

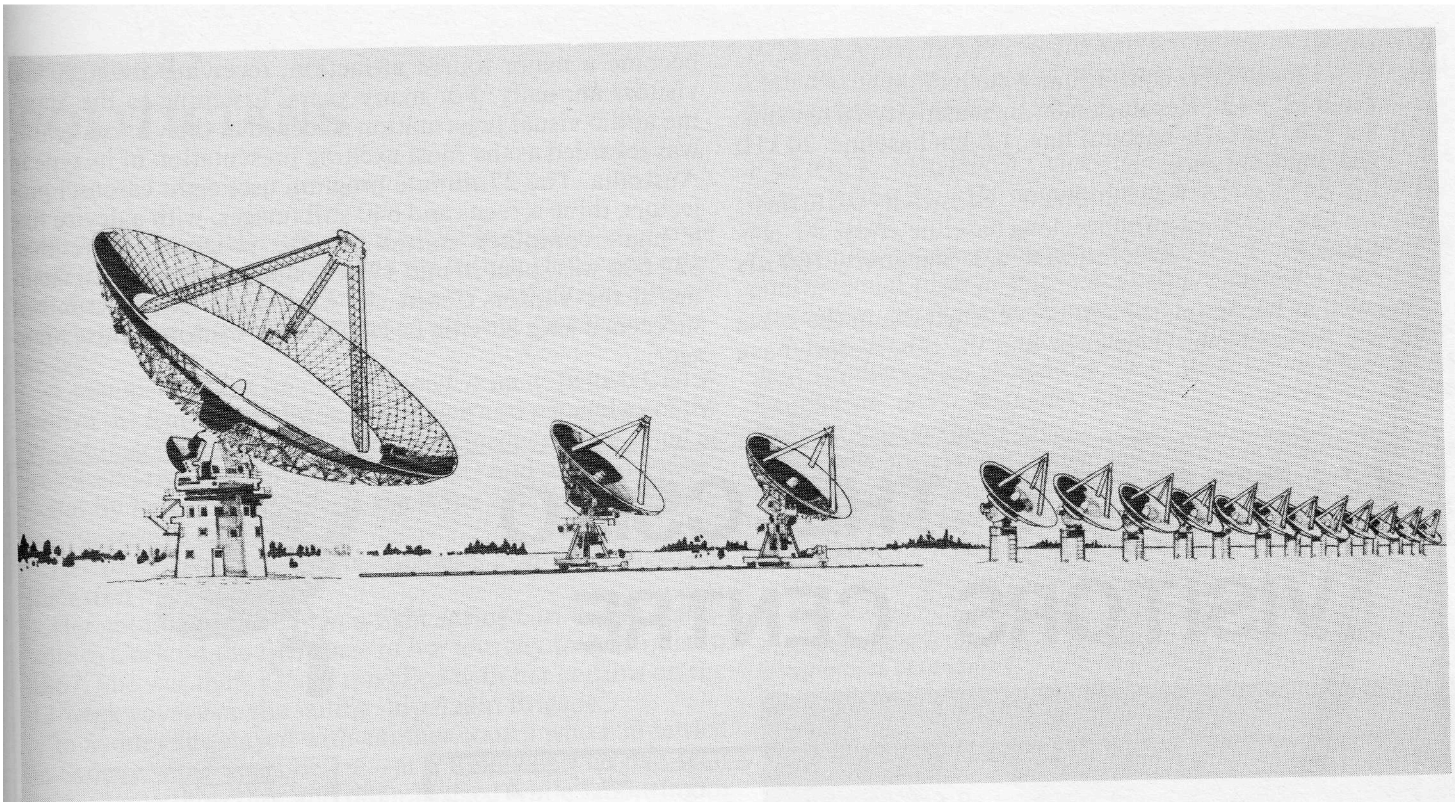
The Australia Telescope proposal provides Australia with an opportunity to build, at modest cost, the most versatile radio telescope in the world. With it, Australian astronomers can look forward to solving some of the most perplexing problems in astronomy today; without it, one of Australia's most eminent fields of science will die.

1982 was the year of decision for radio astronomy in Australia. If the Australia Telescope had not been funded, we were clearly left in a situation where the present radio telescopes would run down over five to seven years. A decision not to fund the Australia Telescope would have been seen by the Australian and the world scientific community as a policy decision to discontinue radio astronomy in Australia.

Alternatively, if a start on the Australia Telescope can commence on schedule in 1982, the Telescope will come into operation in 1988, Australia's Bicentennial Year. It would be a scientifically and technologically demanding project which would symbolize our past achievements in science and, more importantly, ensure the continuation of this outstanding tradition by a new generation of Australians.



AUSTRALIA TELESCOPE PROJECT



Artist's impression of arrangement of antennae for AST.

The Australia Telescope

Technical Specifications (as at 1 May 1982)

Antennas:
5 of 22m diameter at Culgoora
1 of 22m diameter at Siding Spring
1 of 64m diameter at Parkes

Antenna types:
All antennas alt-azimuth mounting
Culgoora antennas movable on rail-track
22m antennas, Cassegrain optics
64m prime focus optics

Antenna pointing accuracy:
22m : 15″ rms
64m : 10″ rms

Antenna frequency limits:
1 GHz to 45 GHz

Antenna spacings:
Culgoora array: 40m to 3120m (20m increments)
40m to 6000m (40m increments)
Long baseline array: Culgoora—Siding Spring 115 km
Culgoora—Parkes 321 km
(Culgoora—Tidbinbilla 568 km)

Antenna links:
Culgoora array: Optical fibres/coaxial cable
Long baseline array: Radio

Receiver frequency bands and types:
1.35–1.75 GHz (min.) Cooled FET $T_{sys} \lesssim 30K$
4.5–6.1 GHz (min.) Cooled FET $T_{sys} \lesssim 35K$
8.4–10.7 GHz (min.) Cooled FET $T_{sys} \lesssim 40K$
22–25 GHz (min.) Maser $T_{sys} \lesssim 50K$
40–45 GHz (min.) Maser $T_{sys} \lesssim 65K$

Feed type:
On axis, dual frequency, dual polarization

Receiver polarization:
All Stokes parameters available

Correlator system:
Number of complex correlators: 48
Number of frequency channels per correlator: 128
Bandwidths available: 100 kHz–50 MHz

Maximum field sizes:
Culgoora array: 1°.5 × 1°.5 at 1.4 GHz
3′ × 3′ at 45 Ghz
Long baseline array: 2′ × 2′ at 1.4 Ghz
4″ × 4″ at 45 GHz

Maximum map resolution:
1024 points × 1024 points

Resolution:
Culgoora array: 6″ at 1.4 GHz (max.)
0″.2 at 45 GHz (max.)
Long baseline array: 0″.12 at 1.4 GHz
0″.004 at 45 GHz

Observation time per map:
Culgoora array: 12^h to 18×12^h
Long baseline array: 12^h

Sensitivity:

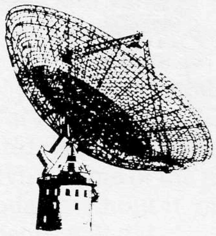
(i) 10×12^h, 10 GHz continuum, 6km baseline:
Field $12' \times 12'$, Resolution $0''.8$, Sensitivity 28 μJy rms

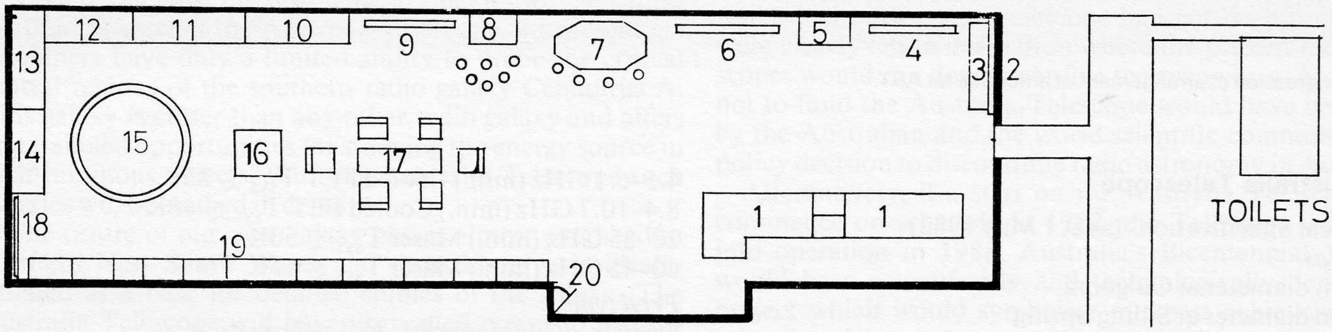
(ii) 8×12^h, 1.4 GHz spectral line, 1.6 km baseline, 20 kHz spectral resolution:
Field $1^\circ.5 \times 1^\circ.5$, Resolution $20''$, Sensitivity 0.5K rms

(iii) 1×12^h, 5 GHz continuum, long baseline array:
Field $35'' \times 35''$, Resolution $0''.03$, Sensitivity 100 μJy rms

As well as becoming the symbol of Australia in the space age, the Parkes Radio Telescope and the observatory have become a major tourist attraction, receiving about 80 000 visitors annually. For many years 'Listening to the Stars', the audio visual presentation screened at the visitors centre, was regarded as the most exciting presentation of its type in Australia. The 27-minute program uses eight carousel projectors, three screens and 640 still images, with a device like a small computer controlling the program. More than $22 000 was spent in mid 1982 to update educational facilities at the Visitors Centre. In April 1981 David Krumlauf succeeded long Serving Les Fellows as Visitors Centre Manager.

GUIDE TO THE CSIRO VISITORS CENTRE





1) SALES COUNTER
2) CURRENT EVENTS BOARD
3) COMMENTS BOOK
4) A.T. DISPLAY
5) VISITORS BOOK
6) DISPLAY
7) RESOURCE TABLE
8) VIDEO TOUR
9) INFORMATION BOARD
10) COMPUTER
11,12,13,14, DISPLAY
15) TELESCOPE MODEL
16) OPTICAL TELESCOPE
17) LOUNGE
18,19, DISPLAY
20) THEATRE