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THE RISE AND FALL OF THE CHRIS CROSS: A PIONEERING AUSTRALIAN RADIO TELESCOPE

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Abstract
The Chris Cross was the world's first cross-grating interferometer and the first radio telescope to provide a two-dimensional daily map of the Sun. It was constructed by the CSIRO's Division of Radiophysics at Fleurs, near Sydney, in 1957, and operated at a frequency of 1420 MHz. In 1959, an 18-m parabolic antenna was installed adjacent to the Chris Cross array, forming the world's first high-resolution compound interferometer, and this was used to survey discrete radio sources. During the 1970s the Fleurs Synthesis Telescope (FST) was developed by adding six stand-alone 13.7-m parabolic antennas. When used in conjunction with the Chris Cross, this was one of the most powerful radio telescopes in the world, and it was used for detailed studies of large radio galaxies, supernova remnants and emission nebulae. The FST was closed down in 1988, and antennas in the array continued to rust. Although a number of individual antennas were refurbished in 1991, the very survival of remaining elements of this pioneering radio telescope is in jeopardy. Astronomers need to be convinced that just like historically-important optical telescopes, early radio telescopes that made major contributions to astronomy need to be preserved for posterity.

1 INTRODUCTION

Radio astronomy is one of the newest fields of astronomy, with its founding in 1931, just a little over 70 years ago. However, radio astronomy only really began to blossom in the post-War years, when the major developments that had taken place in radar technology were applied to this new discipline. Leading the way in the late 1940s and early 1950s were two countries from diagonally opposite 'corners' of the globe, England and Australia.

In those days, radio astronomy was characterised by two different types of radio telescopes: interferometers and stand-alone parabolic antennas. Parabolic dishes were useful for all-sky surveys but because of their limited apertures lacked the resolution required for detailed studies of specific regions or individual radio sources. This was where interferometers came into their own, but (in those days) they were not suitable for detailed sky surveys. In 1953, B.Y. Mills from the CSIRO's Division of Radiophysics in Sydney came up with a new concept in radio telescope design which would overcome this: a cruciform or cross-type radio telescope.

This type of radio telescope featured two long narrow arrays aligned north-south and east-west in the form of a cross. Each array had a narrow fan beam at right angles to the orientation of the array, and by electrically combining the signals received from the two arrays one ended up with a pencil beam representing the small region where the two beams intersected. The size of this pencil beam was equivalent to the beam width associated with a single filled circular antenna having a diameter equal to the lengths of the arms of the cross. Through this ingenious concept, radio astronomers were suddenly given access to resolutions that previously had only been dreamed about.

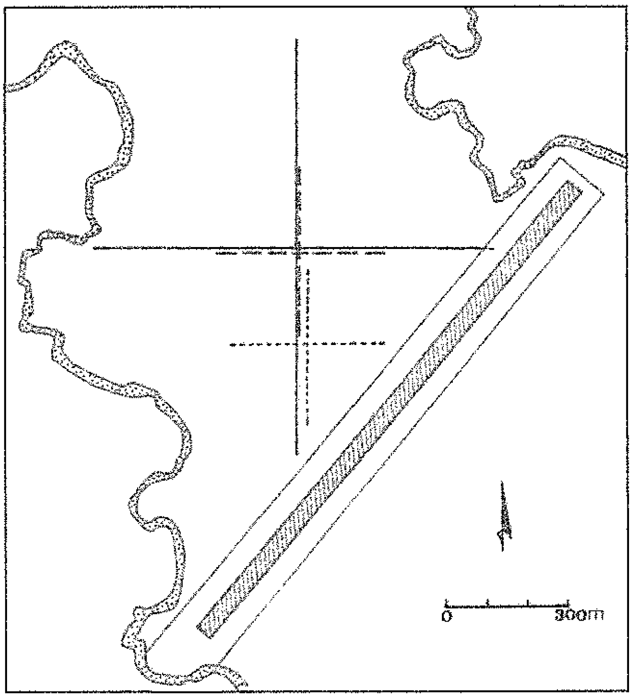

Figure 1: The Fleurs field station showing the disused WWII air strip extending from Kemps Creek in the east to South Creek in the west, and the Mills Cross (dashed lines), Shain Cross (solid lines) and Chris Cross (dotted lines).

Mills developed a prototype cross at the Division's Potts Hill field station in 1953, and proved the viability of his design concept. The following year this led to the founding of another field station, at Fleurs, about 40km due west of central Sydney and adjacent to a disused WWII air strip. This site would ultimately be home to three cross-type radio telescopes (see Figure 1), and over the next decade these innovative antennas would be responsible for major advances in international radio astronomy (see Orchiston and Slee, 2002).

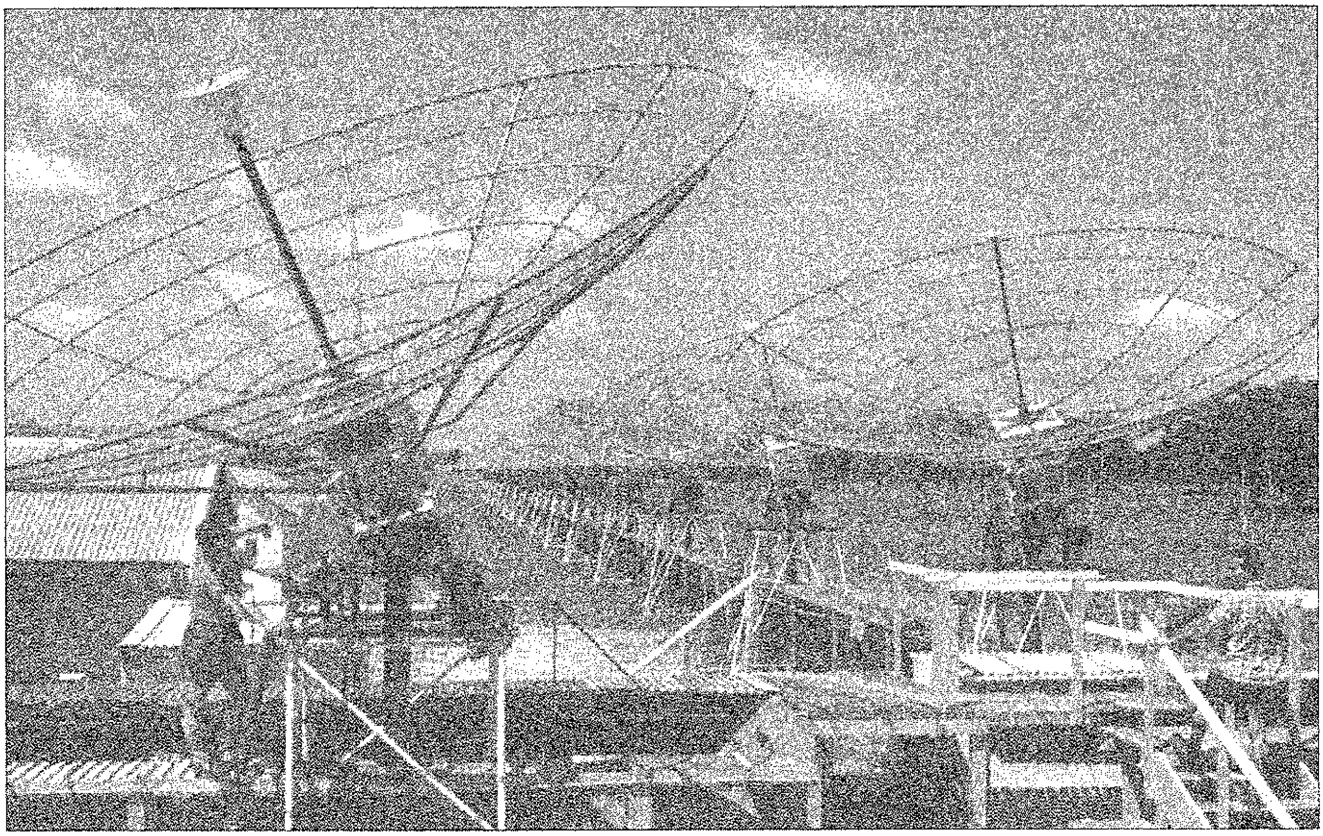

Figure 2: View from the centre of the Chris Cross, looking south along the N-S arm. The receiver hut is on the extreme left. (ATNF Historic Photographic Archive: 9097-12).

A new Mills Cross was erected at Fleurs in 1954, and was designed to conduct an all-sky survey at 85 MHz (3.5m). Two years later, in 1956, the very much larger low frequency (19.7 MHz) Shain Cross was constructed, and this was used for a survey of the Milky Way and to study Jovian decametric emission. The third major radio telescope to be constructed at Fleurs was the Chris Cross, which was designed for solar radio astronomy and was erected in 1957.

This paper briefly discusses the design, observational programs and subsequent development of the Chris Cross, before focussing on the closure of the field station and preservation of the remaining elements of this historic radio telescope.

2 THE CHRIS CROSS: A UNIQUE RADIO TELESCOPE

The Chris Cross was named after Dr W.N. ('Chris') Christiansen, and was the world's first crossed-grating interferometer (Christiansen and Mathewson, 1958). It ingeniously combined the concepts of the Mills Cross developed by Mills in 1953 (see Mills and Little, 1953) and the grating interferometer, which was first developed by Christiansen in 1952 (see Christiansen, 1953).

The Chris Cross consisted of 378m long N-S and E-W arms, each containing 32 equatorially-mounted parabolic antennas 5.8-m in diameter (Figure 2). The array operated at a frequency of 1420 MHz.

Antennas in the E-W arm produced a series of N-S fan beams, and antennas in the N-S arm a series of E-W fan beams. Combining the signals from the two alternatively in phase and out of phase, produced a network of pencil beams at the junction points of the fan beams. Each pencil beam was 3 arc-minute, and was separated from its neighbours by 1°. Since the Sun has an angular diameter of 30 arc-minutes, it was only possible for one pencil beam to fall on the Sun at any one time (see Figure 3).

The basic principle of the Chris Cross was simple: as the Earth rotated, the network of pencil beams moved together across the sky and different pencil beams scanned successive strips of the Sun, producing a series of E-W profiles (Figure 4). It took about half an hour for the whole Sun to be scanned in this way.

By analysing these scans and measuring the relative amplitudes of different peaks, one could generate a radio map of the Sun, with isophotes indicating the relative flux levels of the different active regions (Figure 4). The first solar maps were produced in 1957 June (see Christiansen, Mathewson and Pawsey, 1957), and from that date on the Chris Cross was used to generate daily 1420 MHz maps which were distributed to interested observatories world-wide.

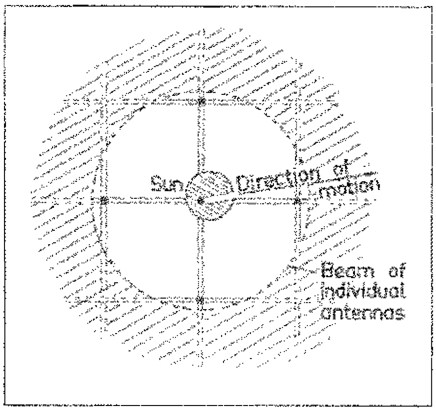

Figure 3: The network of pencil beams (after Christiansen et al., 1957: 945).

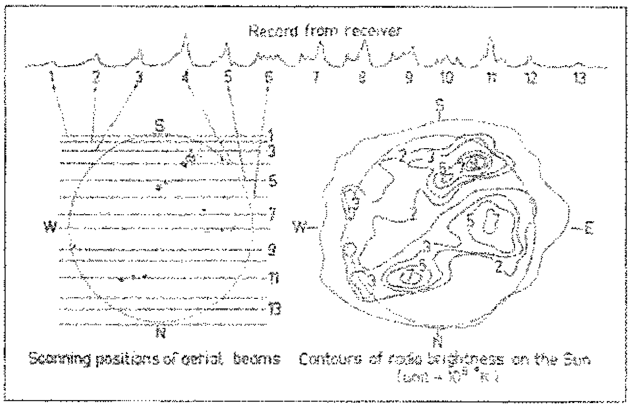

Figure 4: Diagram showing a succession of E-W scans, their positions on the solar disk, and the resulting isophote map (after Anonymous, 1960: 6)

The 1420 MHz emission recorded on these maps originated in the corona, and the regions of enhanced emission were found, in most instances, to correlate with photospheric sunspots and chromospheric H and Ca plage regions visible in spectroheliograms. As a result, they were dubbed 'radio plages'. In addition to monitoring the behaviour and duration of individual radio plages, the Chris Cross was used to investigate the radio brightness of the quiet Sun, major solar bursts, and very short-term events termed 'solar microwave transients' (see Christiansen and Mullaly, 1963). Christiansen (1984:124) has his own perspective on the significance of the Chris Cross solar investigations: "They led to a better understanding of the Sun's outer atmosphere, but to no spectacular discoveries. Their real excitement was in the development of new instruments superior in resolving power to any in existence."

3 THE FLEURS COMPOUND INTERFEROMETER

In 1959, an American prefabricated 18-m reflector was installed at Fleurs just beyond the eastern end of the E-W arm of the Chris Cross (Figure 5), and was linked to the E-W arm of the Cross to form the world's first compound interferometer (see Labrum et al., 1963). The Fleurs Compound Interferometer, which had a $1° \times 1.5''$ fan beam, was used for the first high-resolution surveys of selected southern sources at 1420 MHz (Mathewson et al., 1962; Labrum et al., 1964).

At about the same time, other radio astronomers used the E-W arm of the Cross alone for an investigation of selected discrete sources (see Twiss, Carter and Little, 1962).

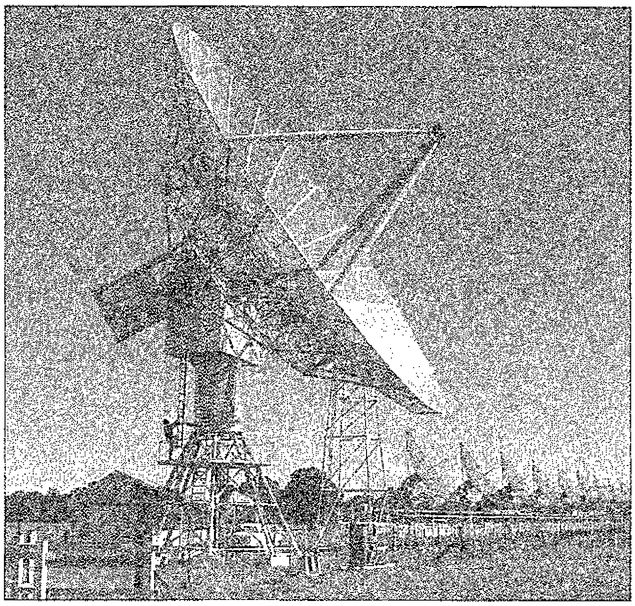

Figure 5: The 18-m antenna, and part of the E-W arm of the Chris Cross (ATNF Historic Photographic Archive: 6499-7).

4 THE FLEURS SYNTHESIS TELESCOPE

In 1963, the 18-m antenna was transferred to Parkes to be used in conjunction with the 64-m Parkes Radio Telescope, and the Fleurs site and remaining equipment were presented to the University of Sydney. Over the next two decades, the Chris Cross underwent a metamorphosis as staff and graduate students from the School of Electrical Engineering set about constructing the Fleurs Synthesis Telescope (see Anonymous, 1972). In its final form, this comprised the Chris Cross, plus six stand-alone 13.7-m parabolic antennas at the eastern and northern ends of the Chris Cross and to the north and west of the Cross. Figure 6 shows an aerial view of the entire Chris Cross and three of the six 13.7-m antennas (the other three are off the picture, to the right), while Figure 7 provides a close-up view of one of the 13.7-m antennas.

The Fleurs Synthesis Telescope had a resolving power of 20 arc seconds, and up until the construction of the Australia Telescope Compact Array was the most powerful radio telescope in the southern hemisphere. During the 1970s and 80s it was used to study individual radio sources, but particularly large radio galaxies, supernova remnants and emission nebulae (Bunton et al., 1985), and it was the success of this array that partly inspired radio astronomers to proceed with the Australia Telescope concept.

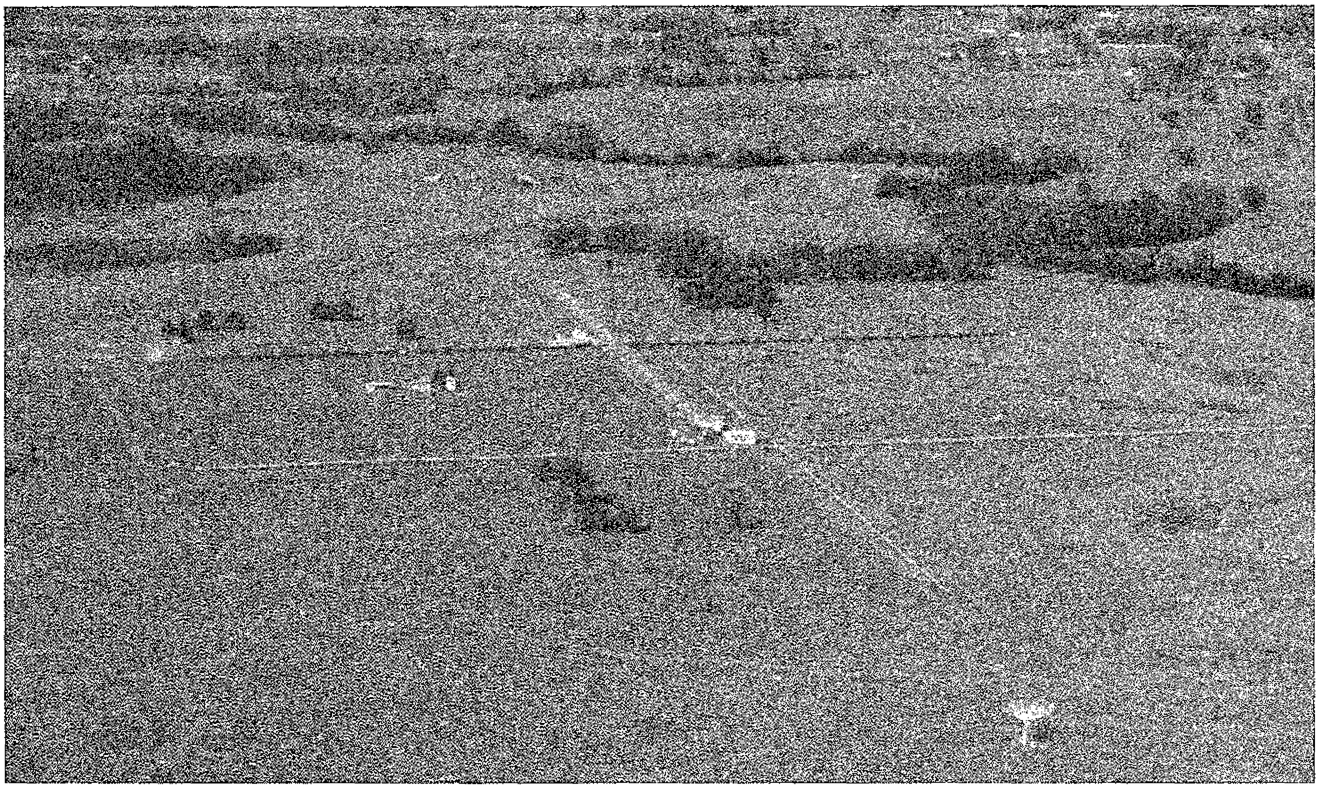

Figure 6: View of the Chris Cross and Mills Cross from the north, showing three 13.7-m antennas, in the foreground, and at the northern and eastern ends of the Chris Cross. In the background is the disused WWII air strip (ATNF Historic Photographic Archive: 9097-35).

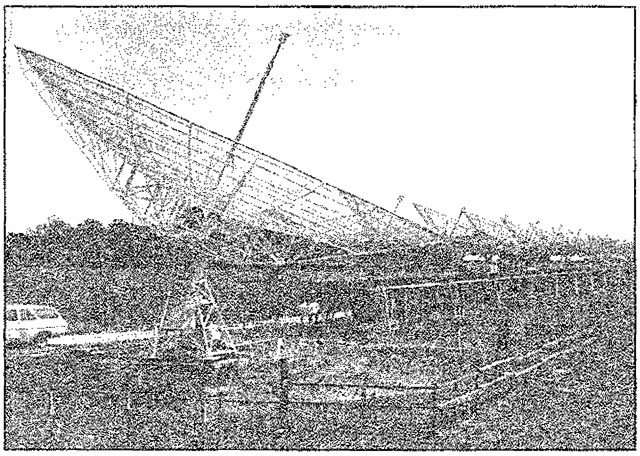

Figure 7: The 13.7-m antenna at the eastern end of the Chris Cross (ATNF Historic Photographic Archive: 9097-11).

5 THE DEMISE OF FLEURS

At the very moment that the Australia Telescope was officially opened in 1988, the Fleurs Synthesis Telescope was closed down, thus bringing to an end 32 years of contributions to solar, galactic and extra-galactic radio astronomy.

The site was then handed over to the Engineering Faculty at the University of Western Sydney, and for some years was used as a teaching facility for undergraduate students. During this time, the Mills and Shain Crosses rapidly deteriorated, and the Chris Cross dishes and larger antennas of the Fleurs Synthesis Telescope continued to rust (e.g. see Figure 8).

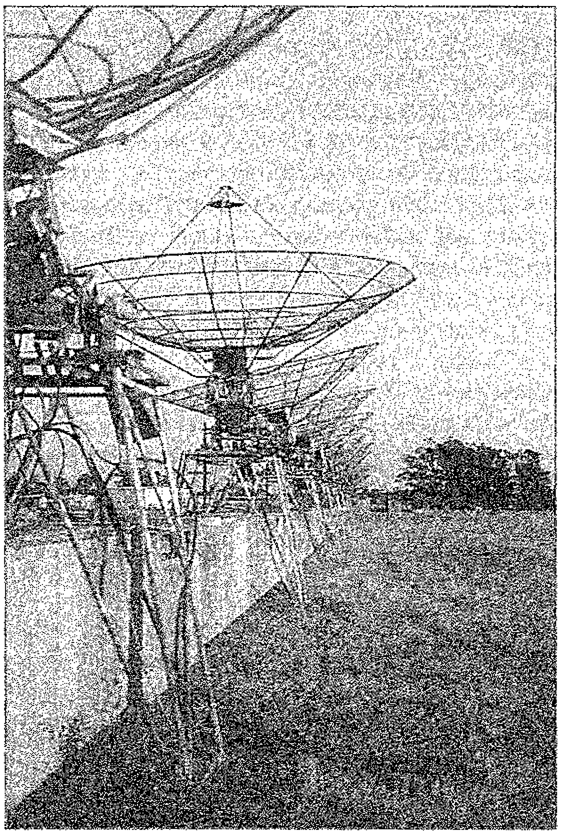

Figure 8: Rusting Chris Cross antennas.

In 1990, action was finally taken to rationalise the site. A decision was made to retain the six 13.7-m large antennas of the Fleurs Synthesis Telescope and the twelve centrally-located Chris Cross antennas, but all of the remaining Chris Cross antennas—including the superstructure linking the antennas—were removed from the site. Undergraduate students were then given the task of cleaning and painting the twelve small parabolas and one of the six large antennas, and on 1991 November 22 a ceremony was held to mark the refurbishment of these remaining radio telescopes. It was only appropriate that one of the speakers on this occasion was Professor W.N. Christiansen. Figure 9 shows six of the central Chris Cross antennas at this time.

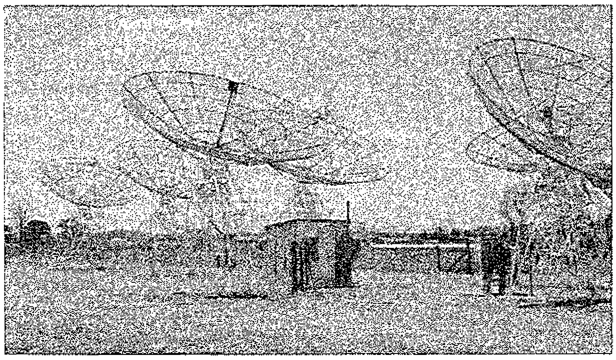

Figure 9: Six of the twelve refurbished Chris Cross antennas (Photograph: courtesy John Leahy).

In 1998, the Fleurs field station became "surplus to requirements" (as the economists would say) and was closed down by the University of Western Sydney, bringing into sharp focus the very survival of the remaining elements of the Fleurs Synthesis Telescope, including the refurbished Chris Cross antennas.

6 DISCUSSION

At one time or another during the period 1945-1965, the CSIRO's Division of Radiophysics maintained radio astronomy field stations at Badgerys Creek, Dover Heights, Fleurs, Georges Heights, Hornsby Valley, Murraybank, Penrith, and Potts Hill, in or near Sydney, and at Dapto, near Wollongong (see Figure 10). Important radio telescopes, many of novel design, were sited at these field stations, and pioneering studies were undertaken in solar, galactic and extra-galactic radio astronomy. It is a sobering fact that of all of these radio telescopes, the only ones that have survived through to the present day are the twelve central elements from the Chris Cross at Fleurs.

What we have witnessed is the wholesale destruction of most of these early radio telescopes, and this raises the issue of preserving Australia's radio astronomical heritage. Optical telescopes that have made important contributions to science are automatically cherished and preserved for posterity, but the same sentiment is rarely encountered in radio astronomy. Too often, historically-significant radio telescopes are viewed merely as tools that were used to address specific research issues, and their importance as heritage instruments *per se* is all but ignored.

This is to be a mind-set that permeates international astronomy, and one that urgently needs changing if we are to save old radio telescopes, worldwide, from ultimate destruction. Some colleagues may suggest that radio telescopes are mere engineering constructions, and as such are simply too large and too difficult to preserve, yet we manage to successfully preserve historic bridges, aircraft, ships and even entire buildings, so this is no argument. What is needed is a change in attitude.

Historically-significant radio telescopes *are* important objects in their own right, and they *do* deserve to be preserved. Perhaps through the combined efforts of IAU Commissions 40 (Radio Astronomy) and 41 (History of Astronomy) we can begin to bring that message to our astronomical colleagues, and at the same time we should aim to promote this philosophy through URSI.[1]

Already too much of our precious radio astronomical heritage has been lost. In Australia, this is our last chance to act, while the 18-m antenna at Parkes, and remnants of the Fleurs Synthesis Telescope and the Culgoora Radioheliograph, still exist!

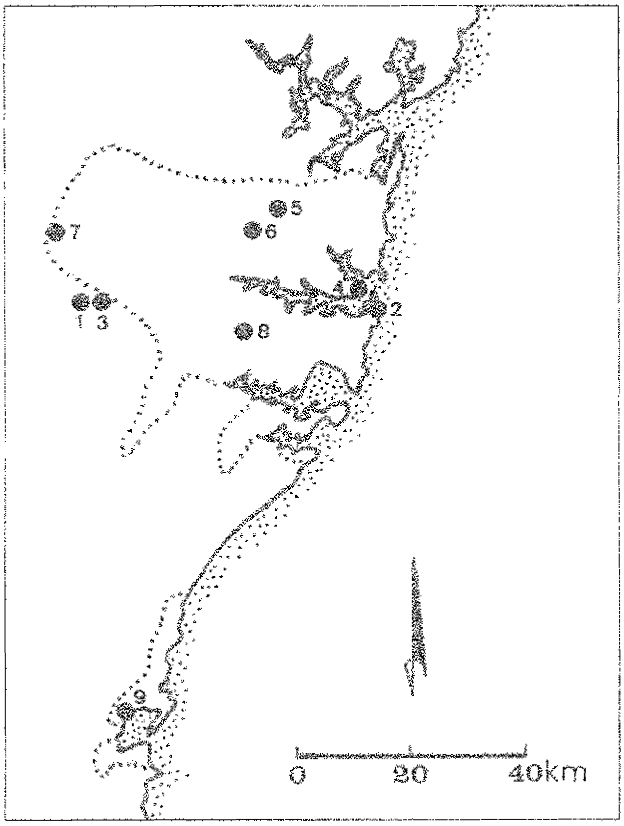

Figure 10: Major radio astronomy field stations in and near Sydney (Key: 1 = Badgerys Creek, 2 = Dover Heights, 3 = Fleurs, 4 = Georges Heights, 5 = Hornsby Valley, 6 = Murraybank, 7 = Penrith, 8 = Potts Hill, and 9 = Dapto; the dotted boundaries indicate the present-day Greater Sydney and Wollongong regions).

7 CONCLUDING REMARKS

The Chris Cross is a remarkable radio telescope with a remarkable history. When it was constructed in 1957 it was the world's first cross-grating interferometer, and the first radio telescope to provide a two-dimensional daily radio map of the Sun. Then as the world's first high-resolution compound interferometer and later as the Fleurs Synthesis Telescope it provided important new perspectives on discrete radio sources, but particularly large radio galaxies, supernova remnants and emission nebulae.

After the FST ceased operations in 1988, the field station served for a time as a teaching instrument, and antennas in the array continued to rust. It was at this time that twelve of the Chris Cross antennas and one of the six 13.7-m stand-alone antennas were restored. However, with the closing of the Fleurs field station in the late 1990s the very survival of these remaining elements of a once-proud radio telescope is now under threat. Ways should be found to preserve the remnants of this historic radio telescope for posterity, and to convince astronomers that radio telescopes used to achieve ground-breaking research are as much a part of our international astronomical heritage as any historically-significant optical telescope.

8 NOTES

1. Since this paper was presented, a first step in this direction has in fact been taken. As a result of the combined efforts of Commissions 40 and 41, an Historical Radio Astronomy Working Group was formed during the 2003 July General Assembly of the IAU, in Sydney. The primary objectives of the new Working Group are the identification, documentation, and (where practicable) preservation of extant historically-significant radio telescopes and ancillary instrumentation. The author of this paper is Chairman of the Working Group Committee, and all other members of the Committee are also members of Commissions 40 *and* 41. This is an important new initiative for all those involved in the history of radio astronomy.

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