Telescope Wars

BY PETER POCKLEY

Australia is at the forefront of developments towards the world's most ambitious astronomical project, the Square Kilometre Array radiotelescope, but there is serious competition from South Africa to host the massive instrument, which will be able to hear the faintest hisses from the dawn of cosmic time. The verdict is due in 2010–11 with construction to commence in 2012.

For astronomers to explore the universe back to its first 100 million years they calculated in 1985 that they needed a radiotelescope with an equivalent collecting area of a square kilometre, recalls Prof Ron Ekers of CSIRO, who has been an influential participant in the project from that first meeting. Now, 23 years on, the slow momentum of a global cooperative of 17 nations for a Square Kilometre Array (SKA), with its huge price tag of $2.0–2.4 billion, has led to visible signs of progress.

Since *Australasian Science* last reported comprehensively on the project (August 2006, pp 16–19), remote areas of Australia and South Africa have been short-listed as sites for the SKA. Australia has proposed the Murchison Radio-astronomy Observatory site 350 km north-east of Geraldton in Western Australia, while South Africa's bid is for "The Karoo", 90 km from Carnarvon in the Northern Cape Province.

The SKA will spread tens of thousands of separate radio receivers over 3000 km and link them electronically to simulate a single dish 1 km across. The area covered by dishes and fixed antennas will spread out to the full 3000 km baseline (and 6000 km if Australia wins the site and adds dishes in New Zealand). The South Africans plan to site outlying antennas of the SKA in five other African countries (Botswana, Namibia, Mozambique, Kenya and Ghana) and two Indian Ocean nations (Madagascar and Mauritius).

Pathfinders in Parallel

The factors favouring Australia and South Africa are broadly similar. Competition is restrained and polite on the international stage, but is quietly intense within each nation. The respective governments are backing their bids with directed funding and regulations to protect the quiet radio background at their sites.

Australian astronomers successfully lobbied for support from the former Coalition government, which committed $100.9 million over 4 years towards an Australian SKA Pathfinder telescope (ASKAP). This grant compares with the $70 million (in 1988 dollars) for Australia's largest radiotelescope, the Australia Telescope National Facility at Narrabri, NSW – a Bicentennial project.

Their South African counterparts have attracted more support from their national and provincial governments, as well as the national lottery, of 1 billion Rand ($142 million) towards involvement in the SKA, including construction of their MeerKAT pathfinder telescope.

The competing sites are similar in many respects but differ in orientation. The Australians say that their east–west distribution of receivers gives greater overlap in viewing times than South Africa's north–south axis. The South Africans say that their elevation of around 1000 metres is superior for astronomy than the lower 380 metres of the Australian site.

Construction of a test antenna for ASKAP is under way at Parkes. When completed, an array of up to 45 steerable dishes will be the first SKA-oriented instrument installed at the site proposed for the SKA – the newly named Murchison Radio-telescope Observatory at Boolardy Station in Western Australia. A remote

The site of the new Murchison Radio-astronomy Observatory, which could house the central hub of the SKA. Photo: Dragonfly Media

array station for ASKAP will be built in NSW to demonstrate linkage of the dishes by fibre optic cable to the array in WA.

Experience with operating ASKAP remotely by astronomers sitting in the Sydney headquarters will provide invaluable guidance for the designers of the SKA. Reliable, high-bandwidth communications between greatly spaced receivers of the SKA will be crucial for combining the multitude of signals.

ASKAP is designed to be ten times faster at surveying the radio universe than any current telescope. It will be able to detect two million hydrogen-rich galaxies in its first year of operation and will study very short-lived radio sources like gamma ray bursts and radio supernovae. By surveying polarised radiation from over 500,000 galaxies, it will determine the structure and magnetic field of our own galaxy, the Milky Way.

ASKAP will "see" 30 square degrees of sky at once (the Moon is half a degree across). To achieve this, ASKAP will use an array of 100 receiving elements situated at the focal plane of each dish. The technologically demanding "chequerboard" array is being developed by CSIRO .

"ASKAP will be a world-class instrument to address how you make a good enough, big enough image," says Dr David DeBoer, ASKAP Theme Leader within CSIRO. "We are looking towards a new kind of 'radio camera' to survey the sky very rapidly. This will be the fastest survey instrument in its observing band, so we shall put it on one of the very best sites in the world at Australia's candidate SKA site. South Africa is addressing other issues."

The Murchison Widefield Array (MWA), a stand-alone facility that also acts as a companion pathfinder for the SKA in Australia, has recently installed the first field of 32 dipole antennas, or "tiles", at the proposed SKA site. These receivers, which will expand to 8000 antennas, have no moving parts, and are designed for the low-frequency band of 80–300 MHz.

The current SKA design incorporates a mixture of steerable parabolic dishes like ASKAP and tiles like MWA. It is a project of the Massachusetts Institute of Technology's Haystack Observatory, CSIRO, seven Australian universities and the Raman Research Institute in India.

South Africa's MeerKAT pathfinder is being built in three phases. A single-dish prototype has been built already at the Hartebeesthoek Radio Astronomy Observatory in the Gauteng Province. A seven-dish test bed will be installed near Carnarvon in the Northern Cape Province and commissioned towards the end of 2009. Finally, a full array of 50 or more steerable dishes will be ready in the Karoo to do scientific research by 2012.

Like ASKAP, it will be linked to a remote operations facility by high speed data transfer. Its scientific agenda is similar to ASKAP's. MeerKAT will be a major facility irrespective of the choice of site for the SKA.

Dr Bernie Fanaroff, Director of South Africa's SKA Office, explains the differences between MeerKAT and ASKAP:

A 12-metre antenna is being built at Parkes to test equipment for ASKAP. The antenna itself is "off-the-shelf" from a commercial firm, and does not reflect what the final ASKAP antennae will look like.

Photo: Barry Turner

Dr Richard Schilizzi, Director of the newly formed SKA Program Development Office (left) and Prof Peter Hall of Curtin University of Technology, Perth, with the prototype dish for South Africa's MeerKAT pathfinder telescope.

Photo: Mike Gaylard, Hartebeesthoek Radio Astronomy Observatory

"The major difference is that we have chosen to develop cooled wide-band single pixel feeds, which will give us high sensitivity and dynamic range with relatively lower development risk. The ASKAP plans to use phased array feeds, which will give them a very wide field of view instantaneously and so will enable them to survey the sky very quickly. While both types of feeds are very innovative, we have chosen a relatively lower risk option."

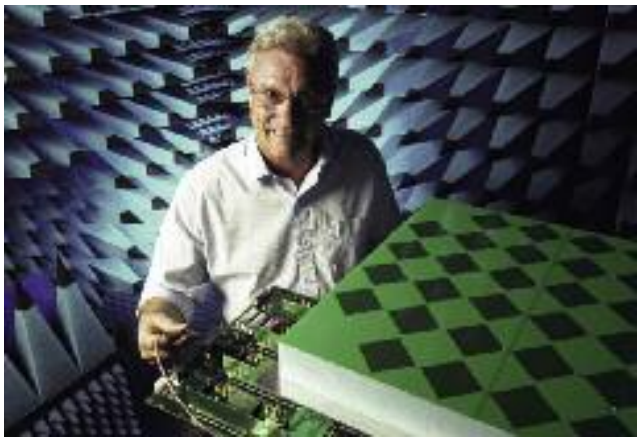
Thus, even if the SKA project becomes stalled due to lack of funding, it is already spawning two powerful radiotelescopes for studying the Southern Hemisphere sky.

SKA Science

With 50 times higher sensitivity than the most powerful telescopes of today and much finer resolution than the optical images created by the space-borne Hubble Telescope, the SKA will be uniquely capable for:

- studying the evolution of galaxies, cosmology, dark matter and energy;
- searching for life and planets in deep space;
- conducting "extreme tests" of general relativity with pulsars and black holes;
- probing the so-called "Dark Ages" for the first black holes and stars;
- unravelling the origin and evolution of cosmic magnetism; and
- making the totally unexpected discoveries that always come from new instruments.

David Herne (left) and Mervyn Lynch of Curtin University of Technology at the Murchison Radio-astronomy Observatory deploying tiles for the Murchison Widefield Array (MWA) telescope, a forerunner of technology for the SKA. Photo: Dragonfly Media



Systems engineer Dr John O'Sullivan is developing a combined receiver–detector array at CSIRO for Australia's SKA Pathfinder telescope. Photo: Chris Walsh

Electronics, Computing and Communications

The technical demands of the SKA are breathtaking, and challenge the proponents to come up with revolutionary electronic designs, massive computing power and communication of unprecedented volumes of data across a continent. CSIRO engineers have built some powerful processors suitable for the SKA that are concentrated on minute silicon chips and control a whole radiotelescope.

The need for extremely powerful computing to integrate the signals from the multitude of receivers and boil down the masses of data is also being addressed. Linking the antennas in the most remote locations require communications via fibre optics over long distances in the Terabit per second range, millions of times faster than broadband. Key partners with CSIRO in these tasks include the University of WA, Curtin University of Technology and the University of Melbourne

Australasian Science asked Ekers if these capabilities might make it possible for the SKA to be shared between Australia and South Africa, linked by fibre optic cables across the Indian Ocean. He said: "We could have the core antennas in Australia and some in South Africa or vice versa, but there are very strong scientific reasons for not splitting the dense core of antennas in two. We could have 90% in one country and 10% in the other." Whether this would be acceptable would probably come down to politics.

Raising the Funds

A new SKA Program Development Office based in Manchester, UK, is headed by expatriate Australian Prof Richard Schilizzi. He says the SKA has been accepted on the agenda for the European Strategic Forum for Research Infrastructures. Through this the project has received grants for a Preparatory Phase that is charged with reporting by 2011 on options for funding the SKA.

An Australian coordination committee of six government officials and two radioastronomers has assumed responsibility for negotiating Australia's involvement, and list the cost at $2.0 billion. However, Schilizzi told *Australasian Science*: "For the last year we have set an upper limit to the construction cost of €1.5 billion" (about $2.4 billion). South Africa is quoting this figure.

The reality for Australia's contribution is that the timetable for substantial funding steps into the life of the next Parliament, and progressive grants would need to be committed for at least another three more parliaments. This presents a unique challenge for the astronomical lobbyists and the filtering bureaucrats in securing such a highly unusual, long-term commitment from a government of any political flavour.

Ekers spent more than two decades in championing the SKA by keeping its planning centred on the well-articulated "science case" it will address. But he has become concerned that political influences are now overtaking the scientific. "The reason to keep the site decision technical was my observing that international collaborations in science are often seriously disrupted by site decision arguments and the politics that enter at that stage," he said. "We have only half-succeeded. In fact, we [the former International SKA Steering Committee] were instructed by the funding agencies of a number of countries not to go [alone] because eventually their politicians want to make the decisions". Ekers said he has mixed feelings because "as a practical matter, this spurred the South African and Australian governments to spend a lot more money than they would have if the competition had not involved them."

An Australian SKA Industry Consortium has been formed to demonstrate the economic benefit through spin-offs to the private sector for building SKA telescopes and high performance instruments. So far, it has listed more than 100 companies. Ekers says that experience with other major telescope projects overseas shows that, with adequate linkages, it would be no great disadvantage to local industry if Australia does not win the SKA site.

The SKA project is holding major international meetings in Perth in early April. This story clearly has a long life-span with many twists along the way.