BACK TO THE FUTURE

STORY Kitty Drok
ILLUSTRATION Emma Thomson

The Square Kilometre Array is a mega-fast radio telescope set to revolutionise science and technology; unravelling the mysteries of the Universe and providing the next big wave of technological advancement, with significant economic benefits for Australia.

WHAT do mobile phones, wireless networks and supercomputers have in common with pulsars, black holes and the cosmic microwave background of the Universe? Developments and improvements in the former have resulted from research carried out in radio astronomy, a science studying the Universe and its origins. According to Professor Peter Hall, Curtin's newly appointed Professor of Radio Astronomy Engineering, radio astronomy has always returned technology to industry.

"This is because the demands of radio astronomy are so tough," he explains.

"The receivers have to be so sensitive, data transmission has to be so fast, computers have to be so advanced – and all of that is directly applicable to other industries."

Associate Professor Mervyn Lynch, of the Department of Imaging and Applied Physics at Curtin, agrees: "The astounding thing is that you can now get a mobile phone for free. Zero dollars for all of that technology! But wireless technology has arisen from radio frequency engineering, and the cutting edge of that happens in astronomy."

A recent example is the 802.11 wireless technology that underpins several current Wi-Fi standards. It was patented by a CSIRO group in 1996, working on a radio astronomy initiative.

The next big wave of technological advancement is likely to come from the development of the Square Kilometre Array (SKA), set to become an iconic mega-science instrument of the 21st century. It regularly makes media headlines because the scope of the project is truly enormous, and it might be built in Western Australia.

The SKA has a nominal €1.8 billion (AUD $3 billion) price tag, and annual operating costs of €100 million (AUD $1.69 million) over a projected 50-year lifespan. It will be a new-generation radio telescope, 50 to 100 times more sensitive and 10,000 times faster than any radio telescope available today.

It will essentially be a vast network of individual antenna stations, with a total signal-collecting area of one square kilometre. But the telescope itself will be much bigger than a square kilometre. Much, much bigger. The individual antennas, numbering in the thousands, will be grouped in a few hundred locations known as stations. Approximately half of the collecting area will be concentrated in an inner array spread over an area of about five kilometres. Another 25 per cent of the collecting area will be placed within a diameter of 150 kilometres, and the remainder as far away as 3000 kilometres or more. If the SKA is sited in Western Australia, some antennas may be as far away as New Zealand, or even South Africa – but still be part of the one instrument. This distribution of antennas gives a combination of ultra-high sensitivity for the detection of very faint (and therefore very distant) objects, and very high resolution, to provide images with a large amount of detail.

The concept for the SKA was first developed in 1991, with an International Working Group (now comprising 17 countries) formed in 1994. Professor Hall (then of CSIRO and until recently the International Project Engineer for the SKA) and Professor Ron Ekers, now an adjunct professor at Curtin but then the Director of the CSIRO Australia Telescope National Facility, began Australia's research and development involvement in 1999. Their foundation work resulted in Australia being shortlisted in 2005 as a proposed site for the SKA. The field has since been narrowed to only two sites, Western Australia and Southern Africa, with a final decision expected to be made in 2011. Phase 1 of construction will start in 2012, and part of the array will be available for research by 2015. Complete construction and operation of the SKA is expected by 2020.

IMAGE CREDITS CLOCKWISE FROM TOP LEFT: ROB MILLENAAR, SETI INSTITUTE, XILOSTUDIOS, NRAO, T.A. OOSTERLOO/ASTRON, XILOSTUDIOS, W.J. KLEPPE, ASTRON, ATA.

UNDERSTANDING THE MYSTERIES OF THE UNIVERSE

The SKA will address five key astronomy areas:

ONE

Evolution of the early Universe
Determining star formation, galaxy evolution, clustering and the development of the large-scale structure of the Universe.

TWO

Dark energy
Through studying the clustering of galaxies over cosmological time, 'dark energy', believed to compose 70 per cent of the current energy density of the Universe, can be measured indirectly.

THREE

Search for life in the Universe
Studying the processes of planet building around young stars, identifying Earth-like planets, and probing for 'leakage' radio emissions from other civilisations.

FOUR

Einstein's theory of general relativity
Pulsars are the Universe's most accurate 'clocks', and are very sensitive to gravitational and relativistic effects. Through identifying and timing many of the pulsars in the galaxy, Einstein's theory can be tested at the ultra-strong field (high gravity) limit, transforming our understanding of gravitational physics.

FIVE

Cosmic magnetism
Magnetic fields fill interstellar space, are essential for the onset of star formation and affect the evolution of galaxies and clusters, but their origins and evolution are unknown. Three-dimensional maps of cosmic magnetism will be generated across different Universal epochs, for comparison with the predictions of various models.

Due to its unprecedented sensitivity, speed, and wide field of view, the SKA will be able to map vast areas of the sky very quickly, in much more detail than was previously available. By detecting very faint objects it will allow astronomers to see much further back in time, receiving signals from the early Universe, and revealing how distant stars and galaxies formed after the 'Big Bang'.

Using the SKA, scientists will be able to probe the most fundamental questions in the physical Universe (see inset left).

AUSTRALIA'S bid to host the SKA has been recently bolstered by a Western Australian Government pledge of $20 million to establish an International Radio Astronomy Research Centre in the State. Premier Alan Carpenter said that the Centre would "add to Western Australia's already significant radio astronomy research capability, and will be a comprehensive centre for pure radio astronomy science as well as developing new ICT and engineering systems". The Centre will involve Curtin University of Technology, The University of Western Australia (UWA), CSIRO, research institutions and industry, with involvement from other national and international research institutions and industry partners.

Curtin and UWA, via the new Curtin Institute of Radio Astronomy (CIRA), will also lead a $2.3 million Centre of Excellence for Radio Astronomy and Engineering. The Centre will help to establish Western Australia as a major science and engineering hub for the development and deployment of the SKA.

Given that construction of the SKA will require unprecedented amounts of money, time and breakthrough technologies not yet developed, the international partners in the SKA project are currently undertaking a range of 'Pathfinder' projects, to smooth the path of its development. Pathfinder projects aim to develop and prove the innovative technologies needed for the SKA, and will be used to help finalise the SKA design. Pathfinders are demonstrating what the technology can deliver and what it will cost to implement. Once built they will be used to undertake some fundamental science experiments. Several questions about the Universe still need to be answered before the SKA design can be finalised. As Hall explains, "sometimes you need enough information to be sure of the right questions to ask, before you can build the instrument capable of answering them".

The SKA Pathfinders, while mitigating the risks (both economic and scientific) of the SKA project, will also have lives of their own. As powerful new-generation telescopes, they will be used in the longer term for research in their own right (see inset right).

The proposed Australian site for the SKA, the Murchison Radio-Astronomy Observatory (MRO) at Boolardy Station, 300 kilometres north-east of Geraldton, is hosting a number of Pathfinder projects, with Curtin playing a significant role in most of them. ASKAP, the Australian Square Kilometre Array

Pathfinder, is an international collaboration led by Australia to build an array of dishes using wide field-of-view, phased array feed technology.

"It is quite pivotal to the development of the SKA," Hall says.

"It is one of only two projects worldwide trying to prove this reference design technology, and will give us a lot of information about building and operating this type of instrument in a hostile environment."

If the SKA is built at the MRO at Boolardy Station, the economic benefits for Australia will be enormous.

"A consortium of 17 governments will be contributing the funds to build this instrument," says Professor Steven Tingay, Professor of Radio Astronomy, from the Department of Imaging and Applied Physics at Curtin.

"But Australian companies will be in a unique position to tender for a lot of the infrastructure work – there will be thousands of kilometres of fibre optic cable to be laid, buildings to construct, and site works for all of the antenna stations, power systems and communications, not just supply and installation of high-tech electronics. The project is just so big, it's a bit like building the entire Perth CBD from scratch over 10 years."

Lynch concurs: "It will take teams of people, engineering and design studies – the works. Entire businesses can come and go over that timeframe. And the ongoing maintenance and technical support once the SKA is built will also have a huge economic impact for the host nation. For example, the SKA will be driven by one of the biggest supercomputing centres in the world – just running that will be a huge business. And the influx of people, talent and expertise that will be attracted to Perth as a result of the SKA will have enormous benefits for our local industries and institutions – it's hard to put a value on that."

Regardless of where the SKA is built, Australia will be able to tender for development, supply and installation of many of the components for the SKA, and will directly benefit from the technological advances made along the way. With improvements in supercomputing, managing and archiving massive data sets, data mining, fibre-optics, communications, wireless networks, engineering, construction and manufacturing, development of the SKA is set to revolutionise the science and technology that affects us every day.

And, as always, advances in our fundamental understanding of the Universe may lead to as yet unimagined real-world applications. So next time we look up at the night sky, who knows what brave new world we might envisage? c

For more information:
astronomy.curtin.edu.au

PATHWAYS TO PRACTICAL APPLICATIONS

ASKAP, the Australian Square Kilometre Array Pathfinder, is developing a network of receivers with over 100 detectors sitting in a cluster on each antenna, rather than just one. The technical challenges are significant, explains Associate Professor Mervyn Lynch, of Curtin's Department of Imaging and Applied Physics: "We need to overcome problems caused by radiofrequency interference between the detectors, and correlate data from all of the detectors and separate antennas in real time – over half a million correlations at each frequency. But once these issues are addressed, the ASKAP will be able to work 100 times faster than conventional radio telescopes, while providing a wide field of view – both attributes required by the SKA." Another SKA Pathfinder project at the Murchison Radio-Astronomy Observatory (MRO) is the Murchison Wide-field Array (MWA).

Professor Steven Tingay, Professor of Radio Astronomy from the Department of Imaging and Applied Physics at Curtin, is enthusiastic about the practical outcomes to come from research using the MWA. "It will be used to study coronal mass ejections from the sun, which shoot highly charged particles into space," he says. "When they strike Earth, they cause geomagnetic storms, evidenced by the spectacular auroras at the poles. But they can also damage oil pipelines, undersea telecommunication cables and communication satellites, by inducing large electric currents in them. They could even harm an astronaut on a spacewalk, or working in an unshielded part of a spacecraft.

"The MWA will be used to track these events, with the potential to provide early warning of massive geomagnetic storms on Earth. With this information you can warn astronauts to get to shielded areas, turn satellites to protect their electronics, and modify the way you operate urban power grids and communication systems to protect the multi-billion-dollar infrastructure. Radio astronomy applications don't get much more practical than that."