Australian research institutions currently involved in the SKA project include CSIRO, the University of Sydney, the Australian National University and Swinburne University of Technology.

The SKA community is keen to forge alliances with commercial partners interested in sharing research and development opportunities flowing from this exciting project.

To learn more about the SKA see http://www.atnf.csiro.au/SKA

For more information, or to discuss involvement in the SKA development, contact:

Dr Peter Hall, CSIRO SKA Program Leader
Australia Telescope National Facility
PO Box 78 Epping NSW 1710

Telephone: +61 2 9372 4195
Facsimile: +61 2 9372 4167
E-mail: Peter.Hall@atnf.csiro.au
The SKA

- Is a proposed radio telescope expected to be operating around 2015
- Will have 1 million square metres of effective collecting area and will be 100 times as sensitive as present-day radio telescopes
- Will revolutionize the study of the early Universe and many other fields of astronomy
- Will require major technology shifts to build the instrument within the $A1000M budget
- Will observe over bandwidths much wider than those allocated to radio astronomy, requiring a radio-quiet site and new, active interference-mitigation techniques
- Will offer research and commercial partners the opportunity to develop and test leading-edge technology in a benign, yet highly sophisticated, environment
- May be sited in Australia, offering unparalleled local opportunities in areas ranging from advanced microwave technologies to site and infrastructure development.
The proposed Square Kilometre Array (SKA) will be a radio telescope operating from 200 MHz to above 12 GHz. At 1.4 GHz it will have an effective collecting area of 1 million square metres, making it 100 times as sensitive as existing radio telescopes and very large deep-space earth stations. To get an impression of the scale of the collecting area, imagine a couple of hundred dishes 100 m in diameter. Even with the expertise of an international consortium, it is a huge challenge to translate the area and other specifications into practice within the budget of $A1,000M. However, with new technology now under development, the cost per unit SKA collecting area will be only a tenth that of existing telescopes. The convergence of radio and software engineering accounts for some of the gain, and an obvious general strategy is to use technologies with rapidly increasing functionality-to-cost ratios. (Moore’s Law for computing power is an example of such growth.)

While the SKA will be a telescope of unparalleled versatility with the potential for many discoveries, early Universe studies are major science drivers. Astronomers want to use the faint, Doppler-shifted, microwave radiation from very distant hydrogen to observe the formation of the first stars and galaxies, only a million years after the Big Bang. With the precise frequency of the radiation determined by natural processes, the SKA must be able to observe outside the narrow frequency bands presently allocated to radio astronomy. This means that it must be located away from high-level transmitters and that new, active interference-mitigation techniques are required. As well as pure astronomy, the SKA has enormous potential application in related areas such as deep-space communications and geodesy.

### Background

**PARAMETER**

- **Design Goal**
  - **Sensitivity**
    - Effective area/system temperature = $2 \times 10^4 \text{ m}^2K^{-1}$ (or $G/T \approx 68 \text{ dBK}^{-1}$)
  - **Frequency range**
    - $f = 0.2$ to $\geq 12$ GHz
  - **Number of simultaneous beams**
    - $\sim 100$
  - **Field of view**
    - 1 degree square at 1.4 GHz
  - **Angular resolution**
    - 0.1 arcsecond at 1.4 GHz
  - **Instantaneous bandwidth**
    - $0.5 + (f/5)$ GHz
  - **Number of spectral (frequency) channels**
    - $10^4$
  - **Number of simultaneous bands**
    - 2
  - **Polarization purity**
    - $< 40 \text{ dB coupling}$
  - **Synthesized image dynamic range**
    - $> 10^6$ at 1.4 GHz
An international consortium, which includes radio science institutions from 11 countries, is developing and evaluating a number of design concepts, each of which may represent a viable path to the SKA. The consortium is actively promoting synergies between concepts, and between SKA requirements and commercial capabilities. For example, some of the antenna concepts being investigated are shown on the right. They range from variants of existing reflector antenna technology to refracting radio lenses or planar arrays. Astronomy is an international pursuit and collaboration in projects such as the SKA offers commercial partners access to a wealth of global expertise in areas ranging from communications and IT, through to science and engineering education.

A decision on which major concepts are to be used in the SKA will be made by 2005; a choice of site will be made on the same timescale. The instrument will probably be built in several stages, ranging from an advanced prototype (~2008) to a fully operational facility (~2015).

### Status

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Formal expressions of interest from countries interested in hosting the SKA</td>
<td>Final decisions on concept and location</td>
<td>Likely construction of advanced prototype</td>
<td>SKA operational</td>
</tr>
</tbody>
</table>

### Timescale

Astronomy, giving high-efficiency, widely placeable beams.

Dutch researchers are investigating whether electronically phased planar arrays can be extended to the higher SKA frequencies. The UK has recently become involved in the international SKA consortium and is currently focussing on arrangements for linking stations in the Array.
An unwanted signal from a navigation satellite reduced using post-correlation processing based on subtraction of a computed template.

Some SKA interference-mitigation research involves wideband adaptive filtering but this new, highly computationally efficient approach is effective in applications where time averaging is permitted.

The scale of the SKA is unprecedented and there are many technological, data processing and operational challenges, including:

- Efficient, broadband, low-cost antennas capable of multiple beam operation—in effect, smart antennas of unparalleled performance
- Low-cost, low-noise radio-frequency amplifiers and highly integrated receiving systems
- Low-cost optical-fibre signal transport systems able to convey broadband (> 5 GHz) radio-frequency signals from SKA stations and, possibly, from individual elements within stations
- Fast analog-to-digital converters (10 giga-samples per second) with integrated photonic interfaces
- Computers and programmable digital signal processing engines for operations within signal paths—the SKA will be a “software radio telescope” in which many traditional analogue stages are replaced by software-defined blocks on fast, flexible processors
- Techniques for active interference mitigation and suppression to minimize the effect of unwanted man-made signals from terrestrial transmitters and satellites
- New algorithms for instrument calibration, data reduction and visualization (probably using data-mining techniques) to yield radio images of the sky with the required $10^6$ (60 dB) dynamic range
- Establishment of a radio-quiet reserve of about 50 km in diameter to protect the central portion of the SKA from interference
- Construction and operation of a geographically distributed instrument in what will probably be a remote location.

As well as specific challenges, the SKA demands something of a mind-shift from its designers and their collaborators. Because the SKA will be able to place many beams simultaneously on the sky, many users, both research and commercial, will be able to share the instrument. For example, SETI searches, reception of radar, deep-space and remote-sensing signals, and communications or navigation satellite monitoring, could all be done simultaneously with astronomy.
A few examples of technologies now under development within the SKA consortium are:

- Very low-cost manufacture of small-to-medium diameter (5–20 m) dish antennas and mounts
- Active, broadband planar array antennas for use as either primary receivers or feeds
- Low-cost, low-loss artificial dielectrics for use in refracting antennas such as the Luneburg Lens being investigated by CSIRO
- Active surface adjustment techniques for very large (> 100 m diameter) reflectors
- Low-noise amplifiers and integrated receivers based on monolithic microwave integrated circuit (MMIC) technology using GaAs, InP and SiGe materials
- Integrated photonic elements combining signal transmission and processing
- High-speed analog-to-digital converters for wideband signal processing
- Interference mitigation using a variety of new coherent and incoherent signal processing approaches (including null steering, reference signal modelling and parametric estimation)
- Very high dynamic range (> 60 dB) image formation using linear and nonlinear operations on sparsely sampled Fourier plane data.
Existing radio telescopes use custom-engineered systems to achieve the ultimate in low-noise performance. The SKA will achieve its performance goals in a slightly different way, invoking its huge collecting area, multiple beams, wide bandwidths and sophisticated signal processing. The scale and budget constraints of the instrument will make it essential to use low-cost technologies normally associated with commercial production. Spin-offs from commercial technology (cellular phones, pay TV distribution systems, real-time digital signal processors, etc.) will be central to the success of the SKA. As in the past, though, the flow back to telecommunications and related sectors from astronomy is likely to be significant, especially in areas such as efficient multi-beam antennas, highly integrated RF/optical systems, photonic signal processing, and interference mitigation.

Since World War II, radio astronomy has provided a demanding, yet benign, development and test environment for state-of-the-art devices, systems and algorithms. The SKA will continue this tradition.

Artist’s impression of a multiple-beam station using a Luneburg lens array.

Photonic bandstop filter for use in radio astronomy. (Image courtesy of R. Minasian, University of Sydney.)
By the end of 2001 the international consortium will have sought formal expressions of interest from governments interested in hosting the SKA. Detailed reports will then be prepared in time for the 2005 decision date. A series of site evaluation tests has begun in Western Australia and similar tests will commence soon in other parts of the world. Site and infrastructure development is a huge project in itself and the criteria list for choosing the site includes factors such as political stability, radio quietness and proximity to usable power and optical-fibre communications systems.

Although a dedicated central allocation of a few square kilometres is required, most of the the SKA could probably coexist with, for example, agriculture or environmental reserves.

SKA researchers are investigating the possibility of establishing a radio-quiet reserve in inland Australia. This reserve would be a world-recognised area that could be made available for various applications requiring a radio-quiet environment.