Our journey to bring the SKA to Africa
“When South Africa became involved in the SKA project in mid 2001, initially as an observer, the international project had already been running for about ten years, so there was a vast amount of ground for us to cover in order to catch up. It is an enormous credit to the project leadership, the team, and the unwavering support from the NRF and Government, that within five years South Africa was shortlisted for the site selection, together with Australia, and then six years later was recommended as the preferred site for the SKA. A remarkable achievement.” — Dr. George Nicolson, former Director of the Hartebeesthoek Radio Astronomy Observatory, and co-initiator of South Africa’s involvement in the SKA

“The selection of Africa to host the mid-frequency SKA array, and the incorporation of the locally designed and built MeerKAT into the first phase of the SKA, is a clear statement by our international peers that Africa has become a destination for world-class fundamental scientific research and cutting-edge technology development. The SKA project fulfills the vision for science and technology that was developed in 1996 by our first democratic government.” — Prof. Justin Jonas, Associate Director of the SKA South Africa Project

“From the beginning, South Africa’s SKA bid has been a combined effort of the SKA bid team, the Department of Science and Technology, the National Research Foundation and other stakeholders. Contributions made by team members, both past and present, were key in ensuring the success of our bid and credit cannot go to any single individual. From the co-operation we received from role-players from the outset to the various managers, engineers, consultants and volunteers involved in the SKA bid, we can all stand proud for what we have achieved not only for Africa but also for astronomy as a whole.” — Dr. Bernie Fanaroff, Project Director of the SKA South Africa Project
Our journey to bring the SKA to Africa

On 25 May 2012 the International SKA Organisation announced that the SKA would be shared between Africa and Australia, with the extensive mid-frequency dish array coming to Africa, and the more compact low-frequency aperture array allocated to Australia. This announcement was the culmination of a decade of intensive activity within the international SKA project, and in particular within the SKA South Africa project office.

After nine years of work by the South African and Australian SKA site bid teams, an independent SKA Site Advisory Committee (SSAC) carried out an objective technical and scientific assessment of the competing sites in Africa and Australia, and identified, by consensus, Africa as the preferred site. This decision was made on the basis of its analysis of technical and scientific factors, cost factors, and implementation plans. Subsequently the SKA Organisation decided that the SKA should be shared between the two sites to maximise use of the investments already made at both the African and Australian sites.
Reflecting on the factors of our success

National vision and strategy

The development of astronomy in South Africa is part of a considered strategy that has its origins in the White Paper on Science and Technology drafted in 1996 by the first democratic government of South Africa. The White Paper contains this statement of intent with respect to fundamental scientific research, with specific reference to astronomy:

“Scientific endeavour is not purely utilitarian in its objectives and has important associated cultural and social values. It is also important to maintain a basic competence in flagship sciences such as physics and astronomy for cultural reasons. Not to offer them would be to take a negative view of our future - the view that we are a second class nation, chained forever to the treadmill of feeding and clothing ourselves.”

The essential elements of the White Paper were carried forward in the 2002 National Research Development Strategy drafted by the Department of Science and Technology. The strategy underpinning the prioritisation of investment in funda-

The SKA is a global project run from the SKA Organisation head office at Jodrell Bank, near Manchester, UK. The Board of the SKA Organisation represents the member countries. There are currently ten members of the SKA Organisation:

- UNITED KINGDOM: Science and Technology Facilities Council
- SWEDEN: Onsala Space Observatory
- SOUTH AFRICA: National Research Foundation
- NEW ZEALAND: Ministry of Economic Development
- NETHERLANDS: Netherlands Organisation for Scientific Research
- ITALY: National Institute for Astrophysics
- GERMANY: Federal Ministry of Education and Research
- CHINA: National Astronomical Observatories, Chinese Academy of Sciences
- CANADA: National Research Council
- AUSTRALIA: Department of Innovation, Industry, Science and Research

Germany is the most recent member, having joined in December 2012, and India (currently an associate member) is expected to become a full member in the near future. Four other countries are considering joining shortly - France, USA, Japan and South Korea. The SKA Board is keen to target involvement of countries in the Middle East. It is expected that the SKA Organisation will eventually have at least 14 member countries, which will share the costs and responsibilities of building and operating the SKA.
mental science is summarised in this extract from the strategy document: “One way to achieve national excellence is to focus our basic science on areas where we are most likely to succeed because of important natural or knowledge advantages. In South Africa, such areas include astronomy, paleontology and indigenous knowledge.”

This strategy is put into effect in the Department of Science and Technology’s Strategic Plan (2011–2016), and its ten-year plan (2008–2018), with specific goals being set for astronomy: “In growing its knowledge base, South Africa also needs to build on its niche strengths, especially those in which it has a geographic or natural advantage, such as astronomy, biodiversity, Antarctic research, minerals processing and paleontology... become the preferred destination for major astronomy projects and associated international investment in construction and operations... construct a powerful radio astronomy telescope and use it for world-class projects...”

Unprecedented support

“Our commitment to the SKA is firm and steadfast. It is our hope that others will emulate this engagement.”

This statement, made by the former Minister of Science and Technology, Mrs. Naledi Pandor, highlights the level of support that the SKA instrument and science programme have enjoyed in Africa, since 2000. This unprecedented commitment allowed the South African SKA team to work uninterrupted, to fulfil its goal of hosting the SKA.

Government support has also led to significant achievements in the design and construction of radio telescopes in South Africa, and the development of the human capital necessary for sustainable participation in the SKA project. A dynamic and vibrant base of world-class scientists and engineers is being grown to populate the SKA South Africa team and academic departments at universities in South Africa, and increasingly in other African countries.

At their 2010 African Union Assembly, the Heads of State and Government adopted a declaration expressing unequivocal support for South Africa to lead the bid to locate the SKA in Africa. This declaration also committed Africa to participate in the global SKA project. This high-level endorsement has lead to the SKA being recognised as a flagship project by the African Ministerial Council on Science and Technology.

In 2012, the Square Kilometre Array Project was announced to be the 16th Strategic Integrated Project (SIP 16) in South Africa. Reporting directly into the Presidential Infrastructure Coordinating Commission (PICC), the SKA South Africa Project is one of 17 SIPs that form the backbone of the National Infrastructure Plan for South Africa. High-level PICC interventions and coordination across all sectors of infrastructure delivery in South Africa will ensure the smooth and efficient construction, and operation, of the SKA telescope.

The data collected by the SKA in a 24-hour period, would take nearly two million years to play back on an iPod.
“Welcoming the SKA to Africa is a major step towards using science and technology to transform African economies and allowing African countries to participate fully in the global knowledge economy. The SKA will propel our continent to the frontline of radio astronomy and it will open many doors for Africa in decades to come.”
— President Jacob Zuma

“This is a fabulous celebration of the SKA project that we are proud to share with the people of Carnarvon and neighboring towns, all South Africans and the rest of the continent.”
— Derek Hanekom, Minister of Science and Technology, during a presidential visit to the SKA site in the Karoo and community event in Carnarvon, October 2012

“This project is giving effect to our dream that Africa must become a global science and technology destination and that cutting-edge science will be done in Africa by African scientists. Our SKA success is also reversing the brain drain into brain gain by bringing top researchers to the continent to do cutting edge work on African soil. This could be a game-changer for Africa, bringing about a science Renaissance across the continent. Let’s use it to make South Africans proud and to inspire young people about a future in science and technology.”
— Naledi Pandor, former Minister of Science and Technology (held office from 2009 to 2012)

“We wanted to make South Africa a big science country. I worked closely with the Directors General that served with me, Roger Jardine and Dr. Rob Adam, toward achieving this goal. We set out to use South Africa’s strategic advantages — our unparalleled southern skies and our unique geographical position — to make the country a world player in science, via astronomy and astrophysics. The Southern African Large Telescope at Sutherland took us forward towards our goal and now, winning the SKA bid, takes us all the way there.”
— Dr. Ben Ngubane, former Minister of Arts, Culture, Science and Technology (held office from 1994 to 1997 and again from 1999 to 2004)
“We feel extremely honoured to host the SKA, and are very excited about the prospects of this project to help South Africa make the transition to a knowledge-based economy. The SKA will not only attract top scientists and students, but is already helping to create new research infrastructure in the country.”
— Dr. Phil Mjwara, Director General of the Department of Science and Technology

“What I wanted to do was make Southern Africa the world’s number one astronomy hub. We already had optical (SALT) and gamma (HESS). What was left was radio, so SKA was a no-brainer. When I heard about it I made the decision to go for it almost instantly.”
— Dr. Rob Adam, former Director General of the Department of Science and Technology (1999 to 2006) and Chair of the South African SKA Project

“The National Research Foundation is delighted with the progress made in the construction of the 64-antenna MeerKAT telescope, while the emergence of the first science results from the KAT-7 pilot instrument demonstrates functionality, and the exciting prospects that the full SKA instrument holds.”
— Dr. Albert van Jaarsveld, Chief Executive Officer of the National Research Foundation

“I am absolutely thrilled that our country is reaping the rewards for daring to think and act big. The building and hosting of such a huge and sophisticated science facility, as the SKA is, will be a boon to science and technology in our country and continent.”
— Mosibudi Mangena, former Minister of Science and Technology (held office from 2004 to 2009)

“Our quest to house the Square Kilometre Array in Africa will greatly increase the capacity of all humanity to study and understand the origins of our universe.”
— Thabo Mbeki, former South African President
A clear, and well thought-out strategy

1. Identify, and protect, an ideal location for the core of the SKA - a site that combines a low radio frequency interference (RFI) environment, ready access to infrastructure, and a benign climate.

2. Demonstrate the suitability of the site for radio astronomy by constructing South Africa’s precursor telescopes on the site, and making the site available to other radio astronomy experiments.

3. Demonstrate South Africa’s ability to design, construct, operate and maintain a radio astronomy facility, and the associated infrastructure.

4. Employ a risk-reducing, system engineering approach to ensure that the MeerKAT, once fully constructed and operating, delivers the best science results possible.

5. Align the MeerKAT design with SKA technologies, for easy integration with the SKA.

6. Align the MeerKAT science objectives with the SKA, and listen to what the local and international radio astronomers need from the MeerKAT.

7. Design infrastructure to be scalable for the SKA.

8. Lay the ground for radio astronomy science and engineering capacity development and infrastructure, in Africa, through the construction of a network of radio telescopes on the continent.

9. Use the excitement of the SKA and MeerKAT to attract young people into science and engineering studies.

10. Create large and dynamic radio astronomy research groups in African universities.

11. Showcase Africa’s talent, and ability to deliver, to attract internationally recognised scientists to work with, and in Africa.

12. Employ the best and brightest to work in the South African SKA Project.

13. Retain support by delivering MeerKAT and the associated infrastructure within schedule and budget, and to specification.
A world-leading, talented and committed team

Under the leadership of Dr. Bernie Fanaroff, a relatively small, but highly talented and committed team of South African engineers, scientists, project managers and administrators has worked hard to realise the ambitious goals specified by the South African government through the Department of Science and Technology. The major deliverables of the SKA South Africa project office include the African SKA site bid, the design and construction of MeerKAT and its prototypes, and the creation of large and dynamic research groups in the universities in South Africa and the rest of Africa.

Against competitors with teams of hundreds of people, and long histories in radio astronomy, the South African team, in a very short period of time, gained the admiration and respect of international leaders, and with the involvement of the universities and industry, took the lead in a number of areas of radio astronomy science and engineering. In science research South Africa is leading the way in the study of the universe in neutral hydrogen, galaxy evolution, radio transients and observational cosmology. In addition, we have dominated the development of high performance computing, calibration and imaging, control and monitoring, cryogenic receivers, digital signal processing, antenna design and system engineering for radio astronomy.

The South African SKA infrastructure team designed, and implemented, an infrastructure plan that surpassed all expectations. The team is currently bidding to lead the infrastructure project for the Square Kilometre Array, in South Africa.

The SKA will generate enough raw data every day to fill 15 million 64 GB iPods.
An excellent and affordable region for radio astronomy

The Karoo Radio Astronomy Reserve was identified as a suitable location for the SKA core region, and for the MeerKAT, because of these characteristics:

- Distance from RFI and EMI sources, but proximity to bulk infrastructure (roads and utility power grid) and small towns.
- Benign, dry climate and suitable physical characteristics.
- Flat-topped escarpment and hills providing natural RFI and EMI shielding.
- The core, spiral arms and most of the remote stations are at an elevation of 1 000 m, or higher, thus reducing the atmospheric opacity.
- Low economic activity in the area.

To ensure the long-term viability of the Karoo Radio Astronomy Reserve, the South African Parliament passed the Astronomy Geographic Advantage Act, in 2007 - a unique and powerful piece of legislation.

The RFI-quiet environment, favourable physical site characteristics, the availability of the installed infrastructure and technical assistance, as well as the convenience of the location, attracted other radio astronomy consortia to locate their experiments in the Radio Astronomy Reserve; C-BASS and PAPER selected the Karoo, in preference to other competing sites.
C-BASS (the C-Band All-Sky Survey) is a project to map the sky in microwave (short-wavelength radio) radiation. C-BASS is the latest in a long line of efforts to measure the properties of the oldest light in the universe, the cosmic microwave background (CMB). In order to observe the entire sky, C-BASS needs to use two telescopes, one located in the northern hemisphere and one in the southern hemisphere. The northern telescope is already operating in California, while the southern system is now undergoing final commissioning at the Hartebeesthoek Radio Astronomy Observatory. C-BASS highlights the growing collaboration between South Africa and the rest of the world in radio astronomy. South African radio astronomer Prof. Justin Jonas was a member of the group, which conceived the project, and two South African students have studied for doctorates at Oxford University in the UK, where the radio receivers were designed and built. The southern receiver also uses digital hardware developed by the MeerKAT team in Cape Town.

**BIG NUMBER FACTS**

The **SKA** will use enough optical fibre to wrap twice around the Earth.
Antenna design for the 64-dish MeerKAT.
A proudly South African, world-class radio telescope — what scientists need now!

South Africa’s MeerKAT telescope was initiated with full funding commitment from the South African government. MeerKAT will be completed by 2016, and will be the largest and most sensitive radio telescope in the southern hemisphere, until the full SKA is completed around 2024. Already, five years of time on MeerKAT has been allocated to scientists from Africa and around the world – MeerKAT is what radio astronomers have been waiting for!

The MeerKAT research and development programme has employed a risk-reducing, system engineering approach, which has included the construction of incremental prototypes, to ensure that the MeerKAT, once fully constructed and operating, delivers the best science results possible. Although the prototypes were initially intended to be engineering test beds for MeerKAT, both are operating and producing radio astronomy data.

The XDM prototype was built and commissioned at the Hartebeesthoek Radio Astronomy Observatory (HartRAO) in June 2007. The XDM allowed the team to develop and test antenna and receiver technologies, verify performance models, and generally increase knowledge and capacity in radio astronomy science and technology. The return on investment from the XDM continues; it has since been converted by the radio astronomers at HartRAO into an operational radio telescope, which is being used for pulsar timing research, and S/X-band VLBI observations.

The KAT-7 array has been constructed and commissioned in the Karoo. KAT-7 has proved to be an invaluable engineering platform for refining the technology systems, developing the software and science processing, and the control and monitoring systems for MeerKAT, and indeed for the SKA. Insight into the support requirements, logistics and maintenance of a facility of this nature was also gained, as well as expertise in the construction, commissioning and operations of an interferometer. Although originally intended to be an engineering prototype, local and international scientists have recognised KAT-7 as a valuable science instrument in its own right, and have started using the data from KAT-7 for radio astronomy research. Papers from internationally collaborating teams are already being published.
KAT-7 will be used to do science until at least 2015, at which time the focus will shift to MeerKAT.

“KAT-7 was intended as a prototype, but these dishes are working so well that they are being used for serious science, and they are demonstrating what can be done on a much larger scale with MeerKAT and the SKA.”
— Derek Hanekom, Minister of Science and Technology

MeerKAT construction will take place in phases from 2013 to 2016, and will consist of 64 antennas, each with a diameter of 13.5 m. The antenna design will have what is known as an “offset configuration”. This configuration provides uncompromised optical performance and sensitivity, excellent imaging quality, rejection of unwanted radio frequency interference, and facilitates the installation of multiple receivers. Because the offset configuration is the reference design for the mid-band SKA concept, the MeerKAT will easily be integrated into of the SKA mid-frequency antenna array.

Five years of observing time on MeerKAT has already been allocated to radio astronomy research groups from around the world. Strategically, the objectives of the MeerKAT science projects are the prime science drivers for the first phase of the SKA.

MeerKAT science projects

- Testing Einstein’s theory of gravity by investigating the physics of neutrons stars
- Deep surveys of neutral hydrogen gas in the early universe
- Searching for CO to investigate the role of molecular hydrogen in the early universe
- Absorption line survey for atomic hydrogen, and OH lines of absorption, which may give clues to changes in the fundamental constants in the early universe
- Investigations of different types of galaxies, dark matter and the cosmic web
- Galaxy formation and evolution
- Galactic structure and dynamics
- Deep observations of the earliest radio galaxies
- Search for dynamic and transient bursts
- Participation in VLBI operations
- Search for extraterrestrial intelligence

The SKA central computer will have the processing power of about one hundred million PCs.
An established and operating science facility

The Karoo site is already an operating observatory, supporting three new-generation radio telescopes: KAT-7, C-BASS and PAPER. The rapid deployment and commissioning of these instruments was facilitated by the access to electrical power and data connectivity, on-site facilities, such as workshops, cranes and comfortable accommodation, and the technical support from on-site technicians, and high-level scientists and engineers.

To align with the MeerKAT schedule, the necessary infrastructure is now being installed.

To accommodate the power requirements of MeerKAT, the Karoo substation has been upgraded from 5 MVA to 10 MVA capacity, and has been handed over to Eskom to maintain, and the existing power line has been switched over from 22 kV to 33 kV.

The construction of 35 km of internal roads, a new all-weather landing strip on site, earthworks, pilings, sewers, pumping equipment and chlorination plants are nearing completion, as is the provision of transformers, mini substations, 35 km of electrical cabling and optical fibre ducting.

MeerKAT will need new on-site buildings, and extensions to the existing buildings. The existing dish assembly shed is being extended to accommodate the dimensions of the offset MeerKAT antennas, and a pedestal integration shed – where all the antenna components are integrated – is nearing completion.

The most exciting, and innovative building to be constructed is the Karoo Array Processor building, and its on-site power facility. It is in this building where the on-site data processing will be done, and where the centralised telescope equipment will be housed. To protect the MeerKAT receivers from the radio frequency interference generated by the equipment in the processor building, and the power facility, the building will be constructed 5 m underground, in a bunker, (the underground construction will also protect the building from the variable Karoo climate). In addition, the doors, penetrations for power, cooling and fibre connections of the building will be shielded and screened to prevent RFI leakage, and the soil excavated for the bunker will used as a berm, to further shield the radio telescope receivers from the RFI generated by the equipment in the on-site buildings.

**The infrastructure for MeerKAT was strategically designed to be scalable, for the SKA.**
Laying the foundation for radio astronomy in Africa

Through the activities of the SKA SA Project, the African VLBI Network (AVN) project has been initiated. Due to growing optical fibre connectivity in Africa, large antennas previously used for satellite communications have become obsolete. The AVN’s plan is to convert these redundant communication antennas to radio astronomy telescopes. The telescopes will be connected to each other and will form a giant radio telescope network in Africa - the AVN. The AVN will participate in the various global VLBI experiments, and the extra stations in Africa will provide improved image quality and resolution to the existing VLBI experiments.

Following the signing of a bilateral agreement on science and technology, involving the Ghana Space Sciences and Technology Centre (GSSTC) and SKA SA, technical work on the Kutunse site in Ghana is currently underway. SKA SA contracted GDSatcom, the original equipment manufacturer of the antenna, to be involved in the investigations to scope the extent of the structural and mechanical engineering modifications to be done in the antenna conversion.

The technical work in South Africa, where the 7.6 m antenna conversion for Mozambique will be done, is making good progress. The South African team has completed an audit of the telecommunications antenna system, and established a baseline from which to do the design of the radio telescope system for Mozambique.

Preliminary discussions with the Ministry of Higher Education, Science and Technology (MHEST), Kenya, were held. The Kenyan government is enthusiastic about the AVN project and has secured the use of the Longonot 30 m antenna for science use and conversion into a VLBI-capable telescope as part of the AVN.

Preliminary discussions have been initiated with Botswana and Zambia, and it is expected that these efforts will ramp up during 2013. The science community in Mauritius has engaged with the SKA SA team to collaborate in developing of the user requirements specifications for new-build antennas.
Reflecting on the benefits, opportunities and investments of the SKA in Africa

Future scientists and engineers from Africa

In 2005, the SKA SA Project initiated a capacity development programme aimed at creating the required skills for MeerKAT and the SKA. In order to design, construct, operate and maintain these radio telescopes for scientific research, highly skilled radio astronomy researchers and engineers are required. As importantly, the operation and maintenance of the facilities require large numbers of technicians and artisans.

To date, the SKA SA Project has provided nearly 500 grants and bursaries to postdoctoral fellows and postgraduate and undergraduate students doing science and engineering degrees and research at universities, and universities of technology, and to FET students training to be artisans. In addition the project is supporting five research chairs at South African universities. The research chairs will further increase the number of researchers and supervisors able to supervise postgraduate students, manage SKA- and MeerKAT-related research projects and contribute to undergraduate course development in radio astronomy.

Although SKA SA’s capacity development programme aims primarily at producing skills for MeerKAT and the SKA, the programme is, inter alia, increasing the number of highly skilled people available to the general economy in South Africa and the region.

Mega-science projects create motivating and intellectually stimulating environments that attract young people into science and technology fields, and the involvement of universities. By increasing human capacity, mega-science projects stimulate new research and new knowledge, and an economy that is focused on the generation of new knowledge is an economy that is able to innovate — an important factor in accelerating economic growth and international competitiveness.

The dishes of the SKA will produce 10 times the current global Internet traffic.
Benefits to the local communities

Since 2005 the SKA SA project office has worked with the schools in the towns near the SKA site in the Karoo. The schools programme aims to assist with improving the quality of the mathematics and science education, so that students from this area can become active participants in the MeerKAT and SKA science and engineering programmes.

- The schools programme has facilitated the recruitment of qualified mathematics and science teachers, the construction and equipping of a Cyberlab and science laboratories, astronomy talks, career guidance, teacher training, role modeling, holiday programmes, sky viewing sessions, field trips and exchange programmes.
- SKA SA has provided bursaries to 27 Grade 12 students, to study towards an FET certification. Eight of these students have been employed by the project as assistant technicians, and report to the site operations team.
- 24 Grade 9 students from the area have been awarded bursaries by the project to study at Carnarvon High School, the only high school in the area teaching mathematics and science.
One of the conditions, specified by the SKA SA project office, for the MeerKAT infrastructure service providers, is to invest a percentage of the contract price into the local community.

- To date, approximately 900 jobs have been created in infrastructure and site operations. These jobs include the civil works for the construction of buildings, roads, the landing strip and the construction camps, as well as for the electrical and optical fibre ducting reticulation.
- Skills training programmes funded and facilitated by the contractors have included courses on manhole construction, layerworks, excavation, health and safety, first aid, fire fighting, kerb laying, concrete handling, and road workers safety. Entrepreneurial courses in contractual rights, statutory obligations and financial control are also being provided.

The Bonteheuwel Knowledge Centre is being established to provide the Carnarvon community with access to the Internet, and to training programmes.

- CBI Electric (Pty) Ltd has provided and installed the optical fibre to the centre
- Fifteen computers have been donated by CISCO
- Siyafunda will provide all the software, programmes and training for the centre manager, and provide continuous support to the centre.
- SKA SA has committed to contributing towards the cost of two facilitators for the first six months of operation.

The SKA SA is in the process of donating 22 windmills, to be used on its site, to the Northern Cape Department of Agriculture Research Station. These windmills will be used by the Department to train local people on the principles of windmill maintenance. Participants in this programme will be trained over a five-year period.

The SKA SA has partnered with various public and private sector organisations and companies to invest further in healthcare, social welfare and education in the area.
Opportunities

The SKA is driving cutting-edge technology development within South African industry and academia, and is promoting multi-national collaboration.

The benefits of the SKA in Africa are already being felt across a broad spectrum of society. In the precursor phase, South African construction and engineering contracts have been awarded for the establishment of the Karoo site, and the design and construction of the KAT-7 and MeerKAT arrays. With the future rollout of Phase 1 and 2 of the SKA, it is anticipated that there will be significant opportunities for local business with their local knowledge and presence in the construction and on-going operations of the enormous facility.

With the remote stations in African partner countries, opportunities will exist for appropriately skilled local businesses to provide support and maintenance.

Perhaps more significant, however, are the longer term and broader reaching benefits associated with the development of the skills and technologies needed for the SKA. On the higher-tech side of the project, engineers from SKA SA and South African businesses are engaging in the design phase of the SKA which is to be a worldwide effort, organised through participation in work package consortia.

A financial assistance programme has been established to encourage the participation of local business and institutions in this effort.

In addition, the well-funded SKA SA Human Capital Development Programme is already playing a major role in transforming the science and technology landscape in South Africa at local universities and other tertiary institutions. South Africa is experiencing a reverse brain drain in the area of astronomy and associated technologies, and opportunities exist for young students to not only have access to world-leading supervisors locally, but also access to leading scientists and engineers globally.

The SKA is seen as an entry point and catalyst for the involvement of companies that see the potential of Africa, and African markets, and are prepared to make investments in research and technology in South Africa and Africa in general. There is significant interest from the larger ICT players, for example, in establishing joint research projects in South Africa, linked to SKA technologies, but with aspirations of longer term, broader application in areas outside of astronomy. New technology and skills development projects are now possible with potential large spin-offs in the establishment of new local high-tech business and with application to both government and business alike.
The focus provided by the SKA is unlocking funding opportunities for such projects and generates the high level of interest and impetus required for successful execution.

**Technology development**

The SKA SA project is pushing technology boundaries in a number of key areas. Large radio telescopes, including our own MeerKAT, require unprecedented performance across all subsystems, and this performance must be delivered at an affordable cost. Areas of technology development covered by the MeerKAT project include:

- Advanced mechanical manufacturing and fabrication processes
- High sensitivity, cryogenically cooled radio receivers
- High-speed digitisation of radio frequency signals
- Reconfigurable computing
- Supercomputing and machine learning
- Data transport and storage

This development is carried out in-house, in conjunction with local companies, and within academic faculties of local universities.

**Industrialisation and manufacturing**

Building the SKA will be a unique challenge, because of the scale of the telescope. Significant industry involvement will be necessary to develop the cost-effective and high-quality manufacturing processes required to roll out this massive scientific infrastructure. SKA SA has pioneered the use of formal system engineering methodologies to keep the project on schedule and within budget while ensuring that the technical specifications are achieved. A large component of an array telescope is the infrastructure segment, and the SKA SA has worked closely with local civil engineering companies to provide a cost-effective infrastructure for MeerKAT and the SKA.

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**Big Number Facts**

The SKA will contain thousands of antennas with a combined collecting area of about one square kilometre (that’s one million square metres).
What is the SKA?

The largest and most sensitive radio telescope in the world

The Square Kilometre Array Radio Telescope (SKA) will be the largest telescope in the world, and will revolutionise our understanding of the universe and the laws of fundamental physics. Amongst other things, it will help us understand dark energy and dark matter, how and when the first stars and galaxies formed and evolved over the age of the universe, test Einstein’s theory of general relativity and search for signs of life on other planets. It may even detect evidence of extraterrestrial intelligent life. Like previous very large telescopes, it will discover entirely new and unexpected phenomena that were unimagined at the time of its design and construction.
The SKA operates in two frequency ranges, and two different sets of receptors (antennas) will be used for each of these frequency ranges. This has allowed the SKA to be split between Africa and Australia without compromising the science capability of the telescope. SKA-mid will be located in Africa, and SKA-low will operate in Australia.

SKA-mid will consist of about 3,000 receptors linked together across distances of up to 3,000 km. The total collecting area of the receptors will be about one square kilometre, giving 50 times the sensitivity, and 10,000 times the survey speed of the best current-day radio telescopes. The SKA-mid receptors will be dish antennas each about 15 m in diameter, as well as an innovative radio wave receptors, known as dense aperture-arrays. The outer stations of the antenna array will be arranged in spiral arms extending out to at least 3,000 km from the core.

SKA-low will employ arrays of crossed-dipole antennas arranged in a sparse aperture array configuration. This array will extend out to about 200 km. This array will also have a total collecting area of about one square kilometre, and will have unprecedented sensitivity and survey speed.

The SKA will be built in two phases

SKA Phase 1
The first phase will implement about 10% of the total collecting area of the second phase. Construction of SKA Phase 1 will commence in 2016, and full science operations are expected in 2020. SKA Phase 1 will be split between South Africa and Australia:

South Africa
190 SKA-mid dishes will be built and South Africa’s 64-antenna, mid-frequency radio telescope array, MeerKAT, will be incorporated into the array to provide a 254-dish array. The MeerKAT dishes are very similar to the SKA dishes, and the design of the SKA dishes will be strongly influenced by the MeerKAT design.

Australia
The first 10% of the SKA low-frequency, sparse aperture array, will be constructed in Australia. In addition, if technology readiness of the ASKAP receivers is proved, Australia’s 36-antenna, mid-frequency radio telescope array, ASKAP, will also be expanded out to a 96-dish array, creating the SKA survey instrument.

SKA Phase 2
Construction of SKA Phase 2 will commence in about 2018, with full science operations expected in 2025. In Phase 2, approximately 3,000 SKA mid-frequency antennas will be built in Africa. The highest concentration of the antennas will be in the Northern Cape of South Africa, with stations of about 40 antennas each in Namibia, Botswana, Zambia, Mozambique, Kenya, Ghana, Madagascar and Mauritius. In addition, the dense aperture array will also be built in South Africa. This array will consist of a large number of flat receptors, each 60 m in diameter. In Australia, the low frequency aperture array will be expanded out to its full size, but the SKA survey instrument will not be expanded.
Dr. Bernie Fanaroff, SKA SA Project Director:
“The SKA is not an answer, but rather a catalyst for development. It is an opportunity for the whole country to contribute to putting us on a developmental path. Eventually what will count is what the country makes of this iconic project. It is a wonderful opportunity.”

Derek Hanekom, Minister of Science and Technology:
“Hosting the bulk of the SKA places Africa at the centre of one of the largest scientific projects of our time. It places our country and our continent on a very exciting and challenging platform for scientific and economic development.”

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