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ENGINEERING NEWS Online

An array of technology spin-offs emerges as the ‘MeerKAT’ radio telescope gains traction

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Published: 03 Apr 09

In the wide, empty spaces of the Karoo, concept is becoming concrete. The casting of the foundations for the first dish antennas for what will become the biggest scientific instrument in South African history is now under way.

That instrument will be the MeerKAT radio telescope, which will consist of up to 80 dishes. By the end of this year, or early next, its first phase, known as KAT-7, should be built.

KAT stands for Karoo Array Telescope, while the suffix number indicates that it will be composed of seven dishes. It is intended to serve as a test-bed for the MeerKAT instrument. MeerKAT is a play on the name of the lovable African mammal and the Afrikaans word meer, which translates into English as ‘more’. Thus, MeerKAT = MoreKAT, a bigger Karoo Array Telescope.

And the MeerKAT, although it will be a major scientific instrument in its own right, is intended as a precursor to the biggest radio telescope ever planned: the €1,5-billion international Square Kilometre Array (SKA), which South Africa hopes to host. (The only other candidate to host the SKA is Australia.)

Overseeing KAT-7, MeerKAT and this country’s bid for the SKA is the South African SKA Project, which falls under the aegis of the Department of Science and Technology.

In March last year, the project bought 14 000 ha of Karoo land, west of the small town of Carnarvon, in the Northern Cape province, to establish a reserve for the MeerKAT and (hopefully) the SKA. Since then, a road from Carnarvon to the KAT-7/MeerKAT site (which is roughly 100 km from the town) has been constructed, as have the roads on the site.

A support base has been established at a property called Klerefontein, some 11 km from Carnarvon. This has accommodation for scientists, engineers and technicians, and also houses workshops.

And much else besides has been happen-ing. “We’ve built what we call the dish shed, which is the facility in which the dishes for the antennas will be assembled, on site.

We’ve built the accommodation there and we are in the process of getting containers, which will house our plant – our computing equipment – and so on; we’re not going to put these in buildings yet.

Later, when necessary, we’ll expand into buildings,” reports South Africa SKA Project director Dr **Bernie Fanaroff**. “We’re in the process of doing the specifications for our cooling plant, and a lot of work has been done [to make] sure that no radio interference leaks out of any of these facilities. We’ve also reached agreement with Eskom on putting in a 33-kV power line from Carnarvon to our site.

This includes a substation. We’re putting this out to tender because we will be doing it as what is called ‘self-build’ – so we’ll build it and hand it over to Eskom, but, obviously, it has to comply with Eskom’s requirements.

"In case Eskom should ever cut the power supply to the radio telescope, diesel generators will be installed as backup, and consideration is being given to establishing a pilot solar energy plant as well.

Arrangements are being finalised for the laying of optical fibre lines to Carnarvon and to the MeerKAT site. The development of the dishes, the radio receivers, the feeds, and related systems is continuing in the South African SKA offices in Cape Town (the project has its head office in Johannesburg).

A tender for the construction, on site, of the seven dishes for KAT-7 was awarded to Land Systems Dynamics (part of BAE Systems Land Systems South Africa and formerly known as IST Dynamics). "They have already started," states Fanaroff.

"The dish pedestals are being manufactured near Pretoria and the foundations are being cast on the site in the Karoo. The first dish will probably be put in place this month. We'll start prototyping once we have the first dish up.

With one dish, we can see certain things. Once two dishes are up, we'll link them and this will enable us to test other things. With three dishes, we will be able to go further, and so on, until we have all seven. This will enable us to reduce the risks on the MeerKAT."

Initial tests on some systems are already being run on the Experimental Demonstrator Model (XDM) dish, erected on the grounds of the Hartebeeshoek Radio Astronomy Obser-vatory, west of Johannesburg. Each KAT-7 and MeerKAT dish will be 12 m in diameter, manufactured from composites, and mounted on a simple steel framework.

The XDM has pioneered the use of a composite dish, but is 15 m in diameter. Hitherto, all radio telescope dishes were made entirely from metal. The use of composites is an attempt to significantly reduce the cost of the dishes.

This is just one of the technological innovations being developed by South Africa in support of the MeerKAT and SKA projects.

RECEIVERS AND ROACHES

Thus, for example, the South Africans are developing new radio receivers, with cryostats, which will have to be tested on KAT-7. And the antennas will have to be linked to the computers in the containers by optical fibres; these fibres will be buried, but tests will have to be run to see if ambient temperature changes will affect the signals travelling through them.

The project team is also looking at new kinds of optical transmitters and receivers, and at new low-noise amplifiers.

"The engineering that is going on now is really fantastic. Our team is doing great work," enthuses Fanaroff. A leading example is provided by the South African digital signal processing team, which has been working with researchers at the University of California, Berkeley, and at the US National Radio Astronomy Observatory, on reconfigurable computing hardware and architecture.

As a result, they have developed what they call Roach boards – reconfigurable open architecture computer hardware boards. "This uses very, very fast hardware to do specialised computing applications, in parallel," he explains. "So it has enabled us to do much more flexible design and to do very, very fast computing.

And it is really taking off. The Italians asked us to help them to implement this, and we have done so. The Indians have asked us to help them, and we are doing so. We're actually building some Roach boards for the Australians as well.

And we are now starting to get questions from the telecommunications industry. And our people are playing a leading role in this. It is not that we are merely helping the Americans. Our people are actually leading most of the work, and one of our engineers chairs the consortium that has been doing this."

The South Africans are also working with the National Radio Astronomy Observatory on developing algorithms for imaging. "Again, it's not a question of them helping us," he affirms. "We're working together as equals on this."

At home, the project team is working with Stellenbosch company EMSS to develop wideband single-pixel feeds. "These are feeds that work across a very wide range of frequencies – we're hoping to get from 1 GHz to 10 GHz, and if it is successful, it will be a very innovative product," he highlights.

South African and Australian researchers also jointly developed a number of valuable software tools and codes, under the 18-month-long Convergent Radio Astronomy Demonstrator programme. However, significant divergences in the design philosophies of the MeerKAT and its counterpart, the Australian Square Kilometre Array Pathfinder (Askap), led to the termination of this programme in January 2008, although both sides keep in contact and continue to exchange ideas and information.

MEERKAT AND SKA

Once the prototyping starts on the KAT-7, the final MeerKAT design stage will start. The plan is to roll out the 80 dishes by 2012, and start "doing science with them". "This is because most sensitive testing occurs when you try to do the science," says Fanaroff.

"You can do all the engineering tests in the laboratory, you can integrate all the different components in the lab, but when you go out into the field, you find all kinds of things that you couldn't test for in the lab.

That's why we are doing as much prototyping as we can with KAT-7. Even so, once you get out to 80 dishes, things that were trivial with seven dishes become quite big. So there will be more prototyping and commissioning with MeerKAT, but we hope that, using our systems engineering processes, we'll have shaken out most of the risks by that time.

"It should be noted that the use of systems engineering processes is itself innovative in terms of a radio telescope project; most other such projects have been treated, in engineering terms, as one-offs.

KAT-7 will not be used for advanced scientific research but will be employed for simpler science projects. It is hoped that such research will start during next year. Its main purpose is to act as a very sensitive test-bed for engineering systems for MeerKAT. In due course, KAT-7 will be absorbed into MeerKAT.

Regarding the SKA, this project now involves 55 scientific institutions in 19 countries, including Australia, Canada, China, France, Germany, India, Italy, the Netherlands, Portugal, South Africa, Spain, Sweden, the UK and the US. It is expected that 40% of the cost will be borne by the US, and another 40% shared between the eight European countries, with the remaining ten states sharing the final 20%.

Because of different budgetary cycles, the Europeans are expected to provide the bulk of the funding at the start of the project, and the Americans most at the end.

An international SKA Forum was held in Cape Town in February. "The preparation study for the SKA is really getting under way now," affirms Fanaroff.

"One of the very big parts of it is the engineering design study, which involves many people in many countries. So the responsibility for different parts of it has been allocated to different leading agencies.

South Africa is participating in the development of the feeds, of the composite dishes, and of the algorithms for image processing and various other things."

The international SKA Project Office is now up and running in Manchester, in the UK, with many key posts now filled.

The University of Manchester is one of the world's leading centres for radio astronomy – it owns and operates the renowned Jodrell Bank observatory – and this office will integrate all the SKA projects and programmes around the world.

"The funding agencies are having meetings, roughly every six months, to discuss the funding plan and governance and the legal vehicle that will own the SKA," reports Fanaroff. The last meeting was in Cape Town, in February, and, before that, in Washington, in November.

It is expected that the announcement of the site for the SKA will be made in 2011.
South Africa proposes to host the core of the instrument in the Karoo, with out stations scattered across the country and in eight other African countries.

Australia will host the entire instrument – core and out stations – itself (with the possible exception of some out stations in New Zealand).

The design of phase one of the SKA will start from about 2012, using lessons gained from both MeerKAT and Askap. Construction of the first phase of the SKA is earmarked for 2016, with completion in 2021.

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