SOUTH AFRICA'S MeerKAT RADIO TELESCOPE

More than 20 MeerKAT antennas have been installed on the SKA SA Losberg site outside Carnarvon in the Northern Cape.

TECHNICAL FACT SHEET

The South African MeerKAT radio telescope, currently being built some 90 km from Carnarvon in the Northern Cape, is a precursor to the Square Kilometre Array (SKA) telescope and will be integrated into the mid-frequency component of SKA Phase 1. The SKA Project is an international enterprise to build the largest and most sensitive radio telescope in the world, and will be located in Africa and Australia.

TIMELINE FOR MeerKAT CONSTRUCTION

March 2014:	First antenna installed
June 2016:	16 antenna array ready
End 2017:	64 antenna array ready to do science

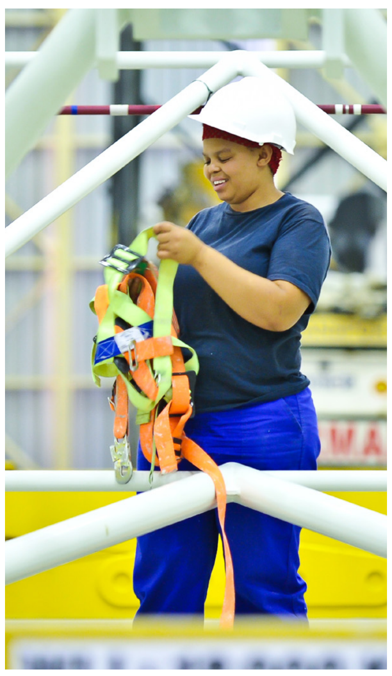
LOCAL PARTICIPATION IN THE CONSTRUCTION OF MeerKAT

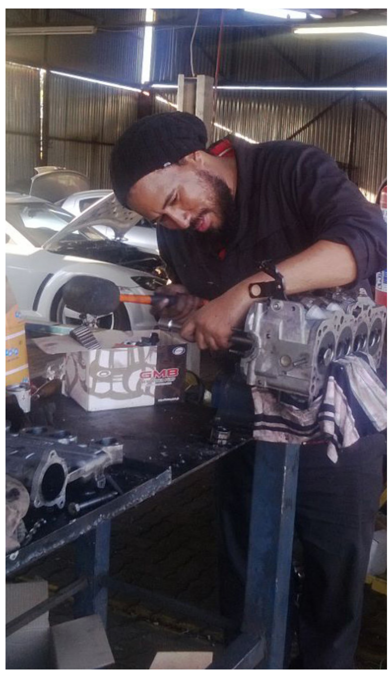
Stratosat Datacom (Pty) Ltd, the contractor for the design, manufacturing and acceptance of the MeerKAT Antenna Positioner, leads a technology consortium including international partners General Dynamics Satcom (GDSatcom, USA) and Vertex Antennentechnik (Germany).

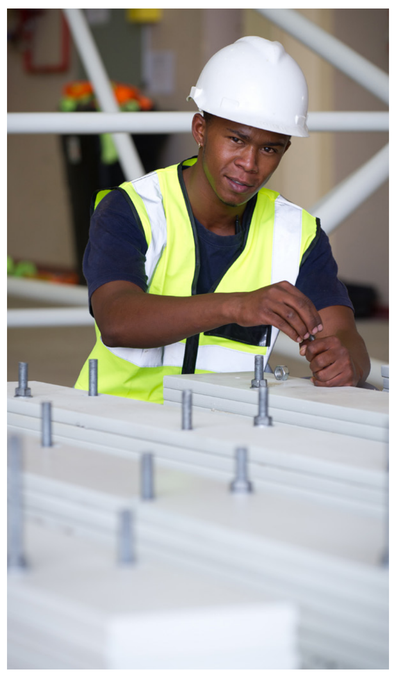
At least 75% of the contract value will be spent in South Africa resulting in most of the MeerKAT antenna components being manufactured in South Africa.

Key local suppliers include Efficient Engineering (pedestals and yokes); Titanus Slew Rings (azimuth bearing), Tricom Structures and Namaqua Engineering (back-up structure), Westarcor Engineering and General Profiling (receiver indexer); and Stratosat (reflectors).

Due to schedule pressure some of the components (such as the reflector panels, sub-reflector and receiver indexer) for the first two antennas were manufactured internationally. Since then, this function has been successfully transferred to local suppliers.







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NRF National Research Foundation

SKA SQUARE KILOMETRE ARRAY Africa

SKA AFRICA SQUARE KILOMETRE ARRAY

The MeerKAT will become part of SKA phase 1.

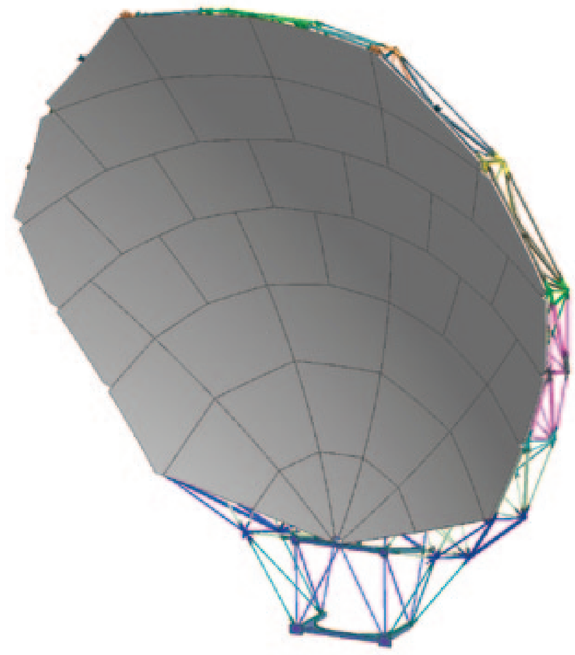
MeerKAT'S MAKE-UP

(see annotated diagram on back page):

- The MeerKAT telescope will be an array of 64 interlinked receptors (a receptor is the complete antenna structure, with the main reflector, sub-reflector and all receivers, digitisers and other electronics installed).
- The configuration (placement) of the receptors is determined by the science objectives of the telescope.
- 48 of the receptors are concentrated in the core area which is approximately 1 km in diameter.

Antenna foundations in the core of the MeerKAT array, as seen in this image from February 2014.

- The longest distance between any two receptors (the so-called maximum baseline) is 8 km.
- Each MeerKAT receptor consists of three main components:
    1. The antenna positioner, which is a steerable dish on a pedestal;
    2. A set of radio receivers;
    3. A set of associated digitisers.
- The antenna positioner is made up of the 13.5 m effective diameter main reflector, and a 3.8 m diameter sub-reflector. In this design, referred to as an 'Offset Gregorian' optical layout, there are no struts in the way to block or interrupt incoming electromagnetic signals. This ensures excellent optical performance, sensitivity and imaging quality, as well as good rejection of unwanted radio frequency interference from orbiting satellites and terrestrial radio transmitters. It also enables the installation of multiple receiver systems in the primary and secondary focal areas, and provides a number of other operational advantages.
- The combined surface accuracy of the two reflectors is extremely high with a deviation from the ideal shape being no more than 0.6 mm RMS (root mean square). The main reflector surface is made up of 40 aluminium panels mounted on a steel support framework.



- This framework is mounted on top of a yoke, which is in turn mounted on top of a pedestal. The combined height of the pedestal and yoke is just over 8 m. The height of the total structure is 19.5 m, and it weighs 42 tons.
- The pedestal houses the antenna's pointing control system.
- Mounted at the top of the pedestal, beneath the yoke, are an azimuth drive and a geared azimuth bearing, which allow the main and sub-reflectors, together with the receiver indexer, to be rotated horizontally. The yoke houses the azimuth wrap, which guides all the cables when the antenna is rotated, and prevents them from becoming entangled or damaged. The structure allows an observation elevation range from 15 to 88 degrees, and an azimuth range from -185 degrees to +275 degrees, where north is at zero degrees.
- The steerable antenna positioner can point the main reflector very accurately, to within 5 arcseconds (1.4 thousandths of a degree) under low-wind and night-time observing conditions, and to within 25 arcseconds (7 thousandths of a degree) during normal operational conditions.

ABOUT MeerKAT – HOW IT WORKS:

- Electromagnetic waves from cosmic radio sources bounce off the main reflector, then off the sub-reflector, and are then focused in the feed horn, which is part of the receiver.
- Each receptor can accommodate up to four receivers and digitisers mounted on the receiver indexer. The indexer is a rotating support structure that allows the appropriate receiver to be automatically moved into the antenna focus position, depending on the desired observation frequency.
- The main function of the receiver is to capture the electromagnetic radiation and convert it to a voltage signal that is then amplified by cryogenic receivers that add very little noise to the signal. The first two receivers will be the L-Band and UHF-Band Receivers.
- Four digitisers will be mounted on the receiver indexer, close to the associated receivers. The function of the four digitisers is to convert the radio frequency (RF) voltage signal from the receiver into digital signals. This conversion is done by using an electronic component called an analogue to digital converter (ADC). The L-band digitiser samples at a rate of 1 712 million samples every second. (The amount of data that is generated by the digitiser for a receiver is equivalent to approximately 73 000 DVDs every day or almost 1 DVD per sec.)
- Once the signal is converted to digital data, the digitiser sends this data via buried fibre optic cables to the correlator, which is situated inside the Karoo Array Processor Building (KAPB) at the Losberg site complex.

- A total of 170 km of buried fibre cables connect the receptors to the KAPB, with the maximum length between the KAPB and a single antenna being 12 km.
- The fibre cables run inside conduits buried 1 m below the ground for thermal stability.
- At the KAPB, the signals undergo various stages of digital processing, such as correlation – which combines all the signals from all the receptors to form an image of the area of the sky to which the antennas are pointing – and beam-forming, which coherently adds the signals from all the receptors to form a number of narrow, high sensitivity beams used for pulsar science. The science data products are also archived at the KAPB with a portion of the science archive data moved off site via fibre connection and stored in Cape Town (with possibilities of reprocessing the data).
- Time and frequency reference signals are distributed, via buried optical fibres, to every digitiser on every receptor, so that they are all synchronised to the same clock. This is important to properly align the signals from all receptors.
- The control and monitoring system is responsible for monitoring the health of the telescope and for controlling it to do what the operators want it to do. A large number of internal sensors (more than 150 000) monitor everything from electronic component temperatures to weather conditions and power consumption.

WHY MeerKAT?

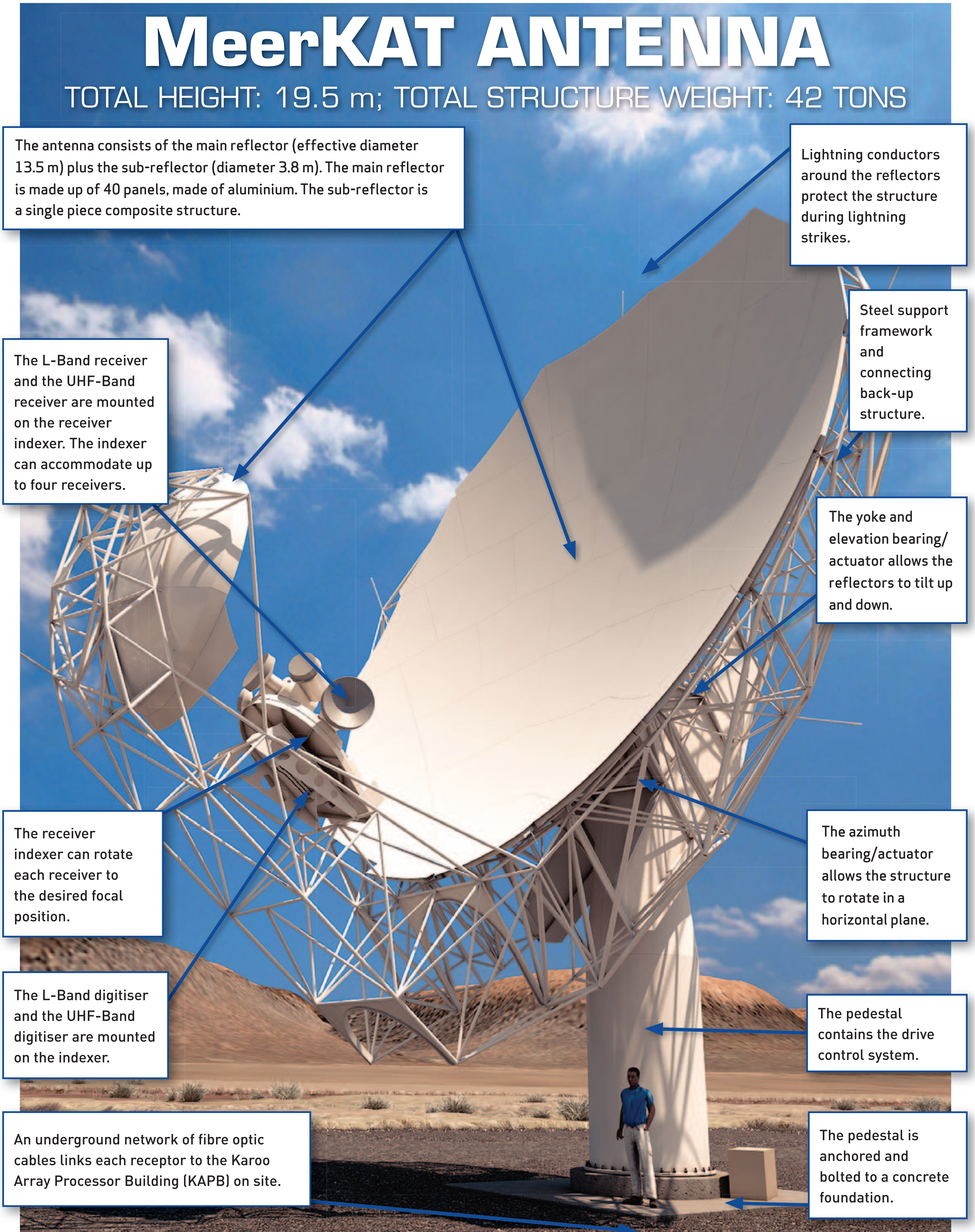
The telescope was originally known as the Karoo Array Telescope (KAT) that would consist of 20 receptors. When the South African government increased the budget to allow the building of 64 receptors, the team re-named it "MeerKAT" – i.e."more of KAT". The MeerKAT (scientific name *Suricata suricatta*) is also a much-beloved small mammal that lives in the Karoo region.

MeerKAT TECHNICAL SPECIFICATIONS

Number of antennas	64
Configuration	Offset Gregorian
Diameter of main reflector (dish)	13.5 m
Diameter of sub-reflector	3.8 m
Surface accuracy (main and sub-reflector combined)	0.6 mm RMS (root mean square)
Wind optimal (mean/gust)	10/15 km/h
Wind operating (mean/gust)	35/48 km/h
Wind stow (gust)	68.4 km/h
Wind survival 3 sec gust	144 km/h
Azimuth speed/range	2 deg/s (-185 to +275 deg)
Elevation speed/range	1 deg/s (15 to 88 deg)
Lowest elevation	15 deg
Continuum imaging dynamic range at 1.4 GHz	60 dB
Line-to-line dynamic range at 1.4 GHz	40 dB
Mosaicing imaging dynamic range at 14 GHz	27 dB
Linear polarisation cross coupling across -3 dB beam	-30 dB
Sensitivity UHF-Band (0.58 – 1.015 GHz)	220 m^2/K required (expect to achieve better)
Sensitivity L-Band (0.9 – 1.67 GHz)	220 m^2/K required (>300 m^2/K achievable)
Sensitivity X-Band (8 – 14.5 GHz)	200 m^2/K required
Aperture phase efficiency	0.91 (at 14.5 GHz)
Surface accuracy	0.6 mm RMS
Pointing accuracy	5" (optimal conditions, 20 min); 25" (normal conditions, 24 h)
Pointing jitter	<15" RMS
Reflector noise contribution	<1K
Reflector reflecting efficiency	>99.5% (main and sub)
Indexer	4 receivers, 1 min switchover

MeerKAT ANTENNA

TOTAL HEIGHT: 19.5 m; TOTAL STRUCTURE WEIGHT: 42 TONS



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