MeerKAT
Lessons Learnt?

Kurt van der Heyden
On behalf of SA SKA & MIGHTEE

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The MeerKAT Programme

• Africa must have the legacy of a large radio telescope
  – Irrespective of the outcome of the SKA site competition
  – But not independent of the SKA
• MeerKAT is an SKA “precursor”
  – Engineering prototype
  – Early science (SKA “Phase 0”)
  – Until the SKA is completed, MeerKAT should be one of the most sensitive radio interferometer in the L-band
  – Phased development: KAT-7, MeerKAT, SKA$_1$, SKA$_2$
  – MeerKAT will be the first 25% of SKA$_1$ (mid-frequency dish array)
SKA South Africa
Radio Astronomy Schedule

- **Phase 1**: construction of the pathfinder KAT-7 (7 antennae) completed in December 2010 & already in operation

- **Phase 2**: construction of the MeerKAT (64 antennae), fully funded (R3Bn ~EUR250M), should be completed by late 2016 & merged with SKA₁- mid ~2020?

- **Phase 3**: construction of the SKA-mid (phases 1&2) (~3000 antennae) should be completed ~2025
Prototype: KAT 7

• More on KAT-7 by Tony Foley at SPARCS meeting
First KAT-7 Science

Circinus X-1 Monitoring
ThunderKAT team

Tr-Aus
New Radio Halo

Nadeem Oozeer & Anna Scaife
(MIGHTEE team members)

NGC 3901 in HI
Brad Frank (Mhongoose team)
Lessons Learnt
Prototype

• KAT-7 was built purely as an engineering prototype.
  ➡ been a huge learning experience and opportunity to test out ideas and systems

• KAT-7 is starting to produce science results, and this has also assisted in identifying issues and assisting with commissioning. Increasing student and PDF involvement.

• SKA does not really have a prototype (except for the precursors?)
  ➡ do science early and do it often (but engineering and commissioning takes priority)
64 antennae distributed in two components:

- An inner dense core ~70% of the antennae (baselines: 29m to 1km), distributed in a 2D Gaussian uv distribution with a $\sigma \sim 300$ m
- An outer component ~30% of the antennae (baselines: up to 8km), distributed in a 2D Gaussian uv-distribution with a $\sigma \sim 2,500$ m

Commissioning: 2014 - 2016
Science operations: 2017
Current MeerKAT Status

Plans on track to complete the 64-dish MeerKAT by the end of 2016. The projected milestones are:

- January 2014: First dish installed (following acceptance testing)
- April 2014: Two dishes installed / First receptor integrated / ready for testing
- November 2014: 6 dishes
- June 2015: 16 dishes
- November 2015: 32 working dishes
- September 2016: All 64 dishes completed & tested
• Commissioning of MeerKAT will start in 2014 and ramp up with the increasing number of antennas.

• It is anticipated that some early science may be possible/feasible once a significant fraction of the array is constructed (32 ~ Dec 2015) but commissioning activities will take priority.

• The full array will be available for commissioning in 2017; the plan is that most significant commissioning issues will have surfaced and be dealt with earlier so that there can be a rapid transition to MeerKAT science data collection by early 2018.
• The current planning is that 2018-2020 will be devoted to the MeerKAT large science (L-band) programs with some transition to SKA$_1$

• The current SKA$_1$ (190 dishes) construction is expected 2018-2021 (full array 190 + 64 dishes)

• The planning is that the sensitivity of SKA$_1$ dishes should equal that of MeerKAT around end 2020

• At that point, it may make scientific sense to integrate MeerKAT into SKA$_1$ (and use the SKA correlator, etc).

• **However, the actual SKA timelines are less certain than those for MeerKAT, at this stage.**
Current MeerKAT Status

- Longest MeerKAT baselines are 8 km
  - planning is to work with the SKAO to ensure that the first few SKA₁ dishes are built at those kind of distances and used for this science in the 2019-2020 timeframe.
  - As the MeerKAT correlator would have 64 inputs, some of the MeerKAT core antennas would be disconnected to accommodate SKA₁ inputs for this science.
Lessons Learnt
communication?

• Have firm constraints on what can be done and be clear on what people can expect.
  - Don’t promise what you can’t afford
  - eg. The longer baselines or X-band receivers on MeerKAT
  - Somebody has to make the tough decisions. (eg. long baselines)
Karoo L-band RFI (Satellite)
• RFI is a problem
• will need to flag lots of data
  ➡ observing times/sensitivity adjustments
  ➡ mostly short baselines will be affected (array layout?)
MeerKat’s antennae

- Development of MeerKAT antennas on track by Stratosat Datacom / GDSatcom
- 1st antenna to be assembled on site and handed over to SKA SA for testing end of January 2014
- 2nd antenna to be handed over in April 2014
- Followed by extensive engineering testing by SKA SA for 6 months
MeerKat antennae

- Offset Gregorian design: metal instead of composite dishes
Doesn't completely restrict the FoV – only attenuates the rest of the sky, but the *PB sidelobes* are non-zero!
“Restricted” FoV?

- Sidelobes *attenuate* the rest of the sky, but don't completely eliminate it
- Example from a WSRT 300MHz observation: CasA and CygA (~60 and ~90 degrees away!):
MeerKat’s Feeds & Receivers

- The L-band feeds and cryo receivers (0.9-1.67 GHz) development is on track (by EMSS)
- Functional prototypes with measured performance were demonstrated June 2013
- The first two production systems will be deployed on the first two MeerKAT antennas
MeerKat’s Feeds & Receivers

- Based on the modeling and the actual performance tests to date, MeerKAT is expected to achieve a sensitivity in excess of 300 m$^2$/K rather than the originally specified 220 m$^2$/K at L-band.
- The UHF cryo receiver (0.58-1.015 GHz) development has started. A decision on whether these will be included in MeerKAT at the end of 2016 will be made in the near future.
- The X-band receiver (8-14.5 GHz) remains in the plans, but is not currently funded.
Lessons Learnt
systems engineering

• Receiver Choice - Single Pixel feeds
  – mature systems can still perform well & there is room for further development

• don’t consider a single subsystem in isolation, but consider the entire system.
  – eg. new technologies might be beneficial in one area, but might affect other subsystems (eg computing costs or energy consumption)
MeerKat’s Infrastructure

MeerKAT related infrastructure on site to be completed end 2013. Currently under construction:

- Roads
- Reticulation (power & fiber)
- Foundations for MeerKAT antennas
- On-site tarred landing strip
- Extension of the site complex assembly building
- Karoo Array Processor Building (KAPB)
- Pedestal Assembly building
+ additional workshops at the Klerefontein support base
MeerKat: start of construction
July 25 2012
Site Complex extension for MeerKAT

- Dish Assembly shed
- Pedestal integration shed
- Bunkered & RFI shielded processor building and power room

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Power and Infrastructure
Lessons Learnt
Communication again!

- The MeerKAT team are all in 1 location & there has been a strong systems engineering approach.
  - This helps to keep people on the same page, but even so communication is not always efficient.
- If people are spread over several institutes then it is important to have a strong central system
- Everyone has to be on the same critical path, and not only a best effort basis
- Keep communication channels open! (even with essentially one team, MeerKAT communication has not always been easy)
Important milestones for MeerKAT:
1. First antenna: January 2014
2. First receptor test system: April 2014
3. Antennas construction completed: June 2016
4. MeerKAT large science programmes (L-band + baselines up to 8 km): 2018 - 2019
5. MeerKAT large science programmes (continuum + baselines up to 20 km) 2019 - 2020
Synopsis: Lessons Learnt

- Keep the communications channels open
- Do science early & do it often
- Somebody has to make the hard decisions (not all science can be done)
  - Also don’t promise what you cannot deliver
- systems wide evaluations - don’t evaluate subsystems in isolation
African VLBI Network
30-m class antennas in Africa
The African VLBI Network

- Convert existing communications antennas into radio astronomy facilities.
  - Maintain existing staff.
  - Install new receivers and instrumentation.
  - Create a VLBI array that will link with
    - MeerKAT
    - HartRAO
    - Europe, the USA and Australasia.
Nkutunse - Ghana
EVN + AVN