SKA Science Update

- Commissioning and Science Verification (Robert Laing)
- Proposal Planning (Tyler)
- Science Meetings
- AOB
Plans for SKA Commissioning and Science Verification

Robert Laing
SWG, March 21 2023
## Key Dates (as of 2023 January report)

<table>
<thead>
<tr>
<th>Event</th>
<th>MID</th>
<th>LOW</th>
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</thead>
<tbody>
<tr>
<td>Integration Test Facility start</td>
<td>2023 Jan</td>
<td>2023 Feb</td>
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<tr>
<td>AA0.5 Integration and Verification start</td>
<td><strong>2024 Jun</strong></td>
<td><strong>2024 Apr</strong></td>
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<tr>
<td>AA0.5 end</td>
<td><strong>2024 Dec</strong></td>
<td><strong>2024 Aug</strong></td>
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<tr>
<td>AA1 end</td>
<td>2025 Nov</td>
<td>2025 Oct</td>
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<tr>
<td>AA2 end</td>
<td>2026 Oct</td>
<td>2026 Sep</td>
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<tr>
<td>AA* end</td>
<td>2027 Aug</td>
<td>2028 Jan</td>
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<tr>
<td>Operations Readiness Review (handover to Operations)</td>
<td>2027 Nov</td>
<td>2028 Apr</td>
</tr>
<tr>
<td>End of construction (including contingency)</td>
<td>2028 Jul</td>
<td>2028 Jul</td>
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Dates are *earliest possible*, except for the end of construction, which includes contingency. End dates are milestones from the Integrated Project Schedule (IPS).
Brief Definitions

• **Observing Mode**: A distinct type of observation applicable to a range of astronomical targets.

• **Assembly (A)**: The activities required to physically establish a product of the SKA Telescope System on-site.

• **Integration (I)**: The activities required to incorporate a product into the SKA Telescope System

• **Commissioning (C)**: All activities necessary to arrive at a working end-to-end system that can be used to perform system verification

• **Science Commissioning (SC)**: The subset of commissioning which requires specification, execution and analysis of astronomical observations.

• **Verification (V)**: All activities that are executed to formally verify the Telescope system against its Level-1 Requirements.

• **Science Verification (SV)**: All activities that are executed to verify the Telescope system against its Level-0 Requirements, i.e. to ensure that the Telescope system meets the needs of the science and operational user
(Science) Commissioning

**Commissioning**

- *All activities necessary to arrive at a working end-to-end system that can be used to perform system verification.* These include:
  - setting-to-work
  - integration testing
  - system testing
  - execution and analysis of test science observations, with the aim of debugging the system.

- Commissioning is a collaborative, interdisciplinary activity, requiring skills in astronomy / interferometry, signal processing, control and data-analysis software, as well as hardware engineering. It is a highly iterative process, usually involving several repetitions of each test.

- **Boundaries between AIV (hardware and software), Commissioning and Operations are fundamentally blurred**

**Science Commissioning**

- *The subset of commissioning which requires specification, execution and analysis of astronomical observations.*

- This is separated out, since it will be primarily performed by a different group from that responsible for engineering commissioning.
Science Commissioning Test Groups

- Basic functionality (AA0.5)
- Dish (MID) and Station (LOW) Calibration
- Array Calibration
- Interferometric Imaging
- Beamforming and non-imaging modes
- Regression and integration tests
- Calibrator and Global Sky models

- Repeat single-dish/station tests
- Single-baseline interferometry ("first fringes")
- Basic multi-element interferometry using point-source calibrators/simple fields
  - Calibrate flux, complex gain, bandpass, delay, leakage, ...
  - Array calibration and stability (dish/station locations, cable delays, ..)
- Rudimentary imaging
- Dish/station characterisation with interferometry/holography
- Single tied-array beam for pulsar timing
Commissioning Scientist Skills

- Understand the system as a whole and be able to diagnose (possibly complex) faults in collaboration with hardware and software engineers
- Collectively be able to cover all of the key test group areas
- Have experience with technically similar projects
- Have data reduction and scripting skills
- Collaborate effectively with other disciplines
- Know what the science users expect

Recruitment and retention is a concern

Intend to enable transition from commissioning to operations at the end of construction, both to provide a career path and to ensure knowledge transfer

Opportunity for early hires in South Africa → Training/experience on MeerKAT (SEAC recommendation)
Support Assumptions

- Science Commissioning and Verification Teams are based primarily at Perth and Cape Town
- Very limited travel to array sites: requires good communications with site staff
- Co-located with AIV (computing, correlator)

Access to the Array
- LOW: Assume contractors working 0700-1700, 7 days/week
- MID: Assume contractors working 0700-1900, weekdays
- Cannot guarantee RFI levels during these times
- Primary science commissioning/verification periods at night
  - What fraction of night-time will be available in practice? Current assumption is 50%
  - Will need daytime access for some tests: live with RFI or negotiate access

Operator and on-call technical support consistent with this assumption
- Array Operator executes observations
- Science Commissioning Team plans observations; reduces data (again, some special cases)
Science Verification

*All activities that are executed to verify the Telescope system against its Level-0 Requirements, i.e. to ensure that the Telescope system meets the needs of the science and operational users.*

- Science verification will be implemented as a set of end-to-end tests of the system from proposal submission to data delivery.
- Each test verifies one or more *observing modes*.
- There will be a range of targets, with an emphasis on comparison with results from other telescopes.
- Modes may be verified periodically as array capabilities mature.
- The Science Operations Team performs Science Verification supported by the Commissioning and AIV teams.
- Science Verification is used to test reduction tools as well as observational procedures.
- SV provides feedback to the Commissioning and Operations teams.
Science Verification Process

- Based on ALMA/ESO model
- Announcement to the Community inviting short proposals to utilise specific modes and capabilities of the SKA.
- Internal technical appraisal of the proposals received by the Observatory to ensure that they meet the stated objectives.
- Light-touch priority assessment, which could be by external group (SEAC?) or internal to the Observatory.
  - Pool of suitable proposals, not a scientific ranking
  - Comparison with observations of the same targets with other arrays if sensible
- Execution of a full end-to-end test, starting with a mock proposal and ending with Quality Assurance and data delivery.
  - Partial in early phases
- Data releases will be public and announced in advance.
  - Made by the Regional Centres.
  - Fully processed data products (e.g. image cubes, averaged visibilities)
  - Visibility data in earlier phases

Each SV observation generates a report which can be used to assess the status of the associated observing mode.
Stages of Science Verification

- Early
  - Worthwhile from later phases of AA2, when capabilities become comparable with existing arrays.
  - Interspersed with science commissioning; no long, dedicated SV blocks
  - ~200 hr for each array in AA2, ~Q3-4 2026 on the current schedule
- Preparation for Cycle 0: first open call, shared risk
  - Observing Modes Review to decide what to offer in Cycle 0
  - Dedicated block of SV observations scheduled to inform this review (~9 months before end AA*)
- Handover to Operations
  - The formal end of construction is signified by a successful Operations Readiness Review (ORR). This will demonstrate the ability of the Observatory to execute a set of key observing modes, illustrated by end-to-end tests of representative Science Verification projects from proposal preparation to (public) data delivery.
  - Requires a second dedicated SV block (“Dress Rehearsal”) at the end of AA*
  - Also acts as the Observing Modes Review for Cycle 1
How do the parts fit together?

Integrated Engineering + Science Teams for MID and LOW

For a given observing mode:

- AI → C → fix problems → C → V → SV → additional IV, C, SV → Operations
- with iteration until the performance is good enough to meet user expectations.
- Overall balance of activities tends to change between AIV and science commissioning as the array develops, with the latter increasing in importance as the system matures.
- Similarly with science commissioning and verification
- Flexible work assignments: “all hands to the pumps”
- Not the classical “V diagram”

- **Planning Cadence**
  - Longer-term planning on a three-monthly cycle, synchronised with SAFe programme increments.
  - Group leaders meet weekly (chaired by the Engineering Lead) to coordinate work on site
  - Daily planning/fault triage meetings with delegated responsibilities.
Science Commissioning Management

- Head of System Science
- Commissioning Support
- Science Team
- Science Ops
- SAFe PM
- SKA-LOW Director
- Lead Commissioning Scientist (LOW)
- Science Commissioning Team (AUS)
- Science Ops
- Community Support
- SRC Support

Functional

Line Management
Hiring

- Plan is to have the first Commissioning Scientists in post 3-6 months before the start of AA0.5 tests on the sky.
  - Advertise ~June 2023 for LOW and ~August 2023 for MID
  - SEAC recommendation to hire junior commissioning scientists early to work on precursors – currently under discussion
Community Involvement in Commissioning

- Experienced commissioning astronomers from the community contribute a huge amount, but are very rare.
- SKA needs to attract them.
- Degree of involvement in hands-on commissioning varies a lot between sub-fields.
- Not usually effective to offer observing time in exchange for commissioning effort, but motivating/rewarding commissioning scientists with access to the array is beneficial.
- Substantial commitments of time are needed (usually >3 months) with at least some f2f contact with the core commissioning team initially.
  - Involving outside people/groups can be a major effort for the core team.
  - “No Astro-tourists”
  - Structured training and management of community effort is essential.
- SKAO will be flexible in supporting community engagement in commissioning.

- Principles of Access to SKA Resources
- Proposal Types
  - KSPs ...
- Telescope Access
- Proposal submission & review
- Extras
  - Policy/regulation documents
  - Definitions
  - Member share accounting
  - Road to science (indicative timeline)
Guiding Principles

• Access is proportional to Member share

• Allocation is based on science merit and technical feasibility

• Access and allocation of SKA “Schedulable Resources”
  
  • Schedulable Resources include:
    
    • telescope time on sky (traditional resource)
    
    • associated computing resources needed to process the data, for example the Science Data Processor (SDP)
Access to SKA Resources

• SKAO resources are made available to scientists from Member and non-Member states
  
  • For members, allocation is proportion to their share in the project
  
  • For non-members, allocation is capped at a percentage defined as Open Time
  
  • Time allocation for all is based on scientific merit and technical feasibility, evaluated by a common proposal review process

• Calibrated data will be automatically generated by SKAO, these are called Observatory Data Products (ODPs)

• Scientists will access ODPs via SKA Regional Centres (SRCs)
  
  • may require further processing (e.g., co-adding) to produce Advanced Data Products (ADPs) for analysis

X Raw Data, ✓ See next page
## SKA Observatory Data Products

- Currently foreseen Data Products that can be produced by SDP at both single observation and project level

<table>
<thead>
<tr>
<th>Data Product</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Image Cubes</strong></td>
<td>Calibrated restored images, residuals, etc</td>
</tr>
<tr>
<td><strong>uv Grids</strong></td>
<td>Calibrated gridded visibilities</td>
</tr>
<tr>
<td><strong>Calibrated Visibilities</strong></td>
<td>With time and frequency averaging</td>
</tr>
<tr>
<td><strong>LSM Catalogue</strong></td>
<td>Sky Model of FoV</td>
</tr>
<tr>
<td><strong>Imaging Transient Source Catalogue</strong></td>
<td>Alerts from fast imaging pipeline</td>
</tr>
<tr>
<td><strong>Pulsar Timing Solutions</strong></td>
<td>ToA and timing model residuals</td>
</tr>
<tr>
<td><strong>Transient Buffer Data</strong></td>
<td>Voltage data following trigger</td>
</tr>
<tr>
<td><strong>Pulsar and Transient Candidates</strong></td>
<td>Output of search pipeline</td>
</tr>
<tr>
<td><strong>Science Alerts Catalogue</strong></td>
<td>Searchable IVOA record of alerts</td>
</tr>
<tr>
<td><strong>Science Product Catalogue</strong></td>
<td>Searchable record of data products</td>
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</table>
Proposal Types

**Key Science Projects (KSPs)**
- Large programs that require the allocation of significant observing time (a few x 100h ? - TBC) and resources, performed over multiple cycles (nominally 1 cycle = 1 year)
- PI & leadership team from SKA-member countries; co-Is from any country (latter may be limited)
- Expected to provide added-value data products and tools back to SKAO
- Regular reviews to track progress toward goals

**Principal Investigator (PI) Projects**
- Smaller programs (< KSP) performed within a single cycle

**Director-General’s Discretionary Time**
- Time allocated by the D-G outside of the normal TAC process

Indicative allocation split over first 5 years of normal operations:
- KSPs (~50-70%)
- PI-led (~30-50%)
Possible Proposal Attributes

**Target of Opportunity (ToO)**
- rapid response triggered internally or externally
- may override currently executed observations
- may be awarded by normal review process, or by D-G as a DDT proposal outside of this process

**Long Term Projects (LTP)**
- requires more than one proposal cycle, but don't qualify as a KSPs

**Joint SKA Project (JSP)**
- requires both SKA-Mid and SKA-Low, and may require simultaneous observations (or very near in time)

**Coordinated Project**
- of SKA observations with other facilities (ground or space based). Example is VLBI

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KSPs (~50-70%)
PI-led (~30-50%)

Indicative allocation split over first 5 years of normal operations
Key Science Projects (KSPs)

- must demonstrate they address **extremely compelling science questions**
- may take up to 5 proposal cycles to complete (nominally 1 cycle = 1 year)
- requires a **Leadership Team** to oversee the delivery of the scientific outcomes
- Leadership Team will normally be no more than 10 individuals (one member will be the main contact for communications with SKAO, in place of a PI)
- Leadership roles are only **open to scientists from Member countries**; co-Investigators may come from any country
- Progress will be reviewed regularly by an expert panel; if the science goals are unlikely to be achieved the D-G may terminate or reduce the project

Indicative allocation split over first 5 years of normal operations:

- **PI-led (~30-50%)**
- **KSPs (~50-70%)**
Key Science Projects (KSPs)

Each KSP proposal will be required to include:

• a detailed management plan describing the roles and responsibilities of each member of the KSP Leadership Team and the qualities they bring to the proposed science

• a plan for the reduction and analysis of Observatory Data Products (giving details of any secured resources at SRCs)

• a plan for the dissemination of scientific results to emerge from the project

• a justification for any investigators on the KSP proposal from non-Member countries¹

• a plan for the submission of ADPs into the SKAO Science Archive.

¹a limit may be set on the fraction of investigators from non-Member countries.
Key Science Projects (KSPs)

Planning for KSPs:

- SKAO will run at least one planning workshop and issue a call for Letters of Intent (preliminary co-ordination), starting > 2 years before first KSP observations
- Workshops provide a forum for co-ordination and perhaps collaboration of proposals with similar science goals and technical needs
- Data Challenges, to help the community get used to working with SKA sized data
Telescope Access

Commensal Science
- Maximizes the use of SKA resources
- Commensal science is not “free”, will be counted against member share
  - Data: different projects use same data products for different science goals
  - Observing: difference projects use same signal/data for different data products (e.g., cont., line)
  - Multiplex: different subarrays observing at the same time

Members (and Associate Members)
- Can lead any program (KSP, PI)
- Can be part of KSP leadership teams
- Access in proportion to member share

Non-Members
- Can lead PI programs
- Can be team members of KSPs, but not part of leadership team
- Access capped at 5% ("Open Time"; TBC by Council)
- Access to any individual non-member entity may be capped

Member Access

Open Time

PI-led (~30-50%)
KSPs (~50-70%)
Telescope Access

**NO time has been allocated for ANY project**

SWGs are NOT proto-KSPs, although they are intended to be a forum for KSP planning

There are NO guaranteed KSPs

Time allocation will be based on **SCIENTIFIC MERIT** and technical feasibility through a common proposal review process (while accounting for member share)

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**Major dates**

- **2021**: Start of construction
- **2024**: Start of science commissioning
- **2026**: Start of science verification
- **2026-29**: Key Science Project (KSP) planning & proposals
- **2028**: Commencement of PI-led programmes
- **2029**: Commencement of KSPs
Proposal Submission & Review

Proposal Review

• All proposed reviewed and assessed by a Time Allocation Committee (TAC)
• SKAO will undertake a technical feasibility review, including evaluation of SRC resources that will be required
• TAC members appointed by D-G with advice from SKAO staff
• Proposal assessment shall be:
  • driven by scientific merit and technical feasibility
  • be fair and transparent, informed by peer review
  • be able to resolve conflicts of interest
• The TAC shall:
  • rank each proposal according to scientific merit and technical feasibility
  • provide a recommendation of telescope time and resources for each proposal
  • present a ranked list of proposals to the D-G
• The SKAO shall construct the science program, considering:
  • sky coverage
  • scheduling feasibility
  • observatory resources
  • opportunities for commensality
  • members’ share of the project
Science Meetings


  • White paper now being written, draft by July


• Joint SKAO/ngVLA Science Conference, Vancouver, 1 – 5 May 2023, (see next slide), http://go.nrao.edu/ngVLASKA


• Community of European Solar Radio Astronomers (CESRA) Workshop, 3 – 7 July 2023, https://star.herts.ac.uk/cesra/

• EAS 2023, Krakow, 10 – 14 July 2023, SKAO Lunch Session (1.5 hour) approved, now being planned

• URSI GASS 2023, Sapporo, 19 – 26 August, New Facilities session, 41 abstract submissions received
New Eyes on the Universe: SKA & ngVLA
Vancouver 1 – 5 May 2023

Important Dates:

Abstracts
Dec 2, 2022 – Abstract submission open
Feb 10, 2023 – Abstract submission deadline (Oral)

Registration
Jan 16, 2023 – Opens
Apr 7, 2023 – Closes
** If planning to attend in person, please check if you need a Canadian visa, and the processing time in your country **

Programme
Mar 13, 2023 – Announced

Hotel
Apr 7, 2023 – cutoff for conference rate. Please stay at the hotel if you can.

http://go.nrao.edu/ngVLASKA
Any Other Business

- News from SWG Chairs?
- ...
We recognise and acknowledge the Indigenous peoples and cultures that have traditionally lived on the lands on which our facilities are located.