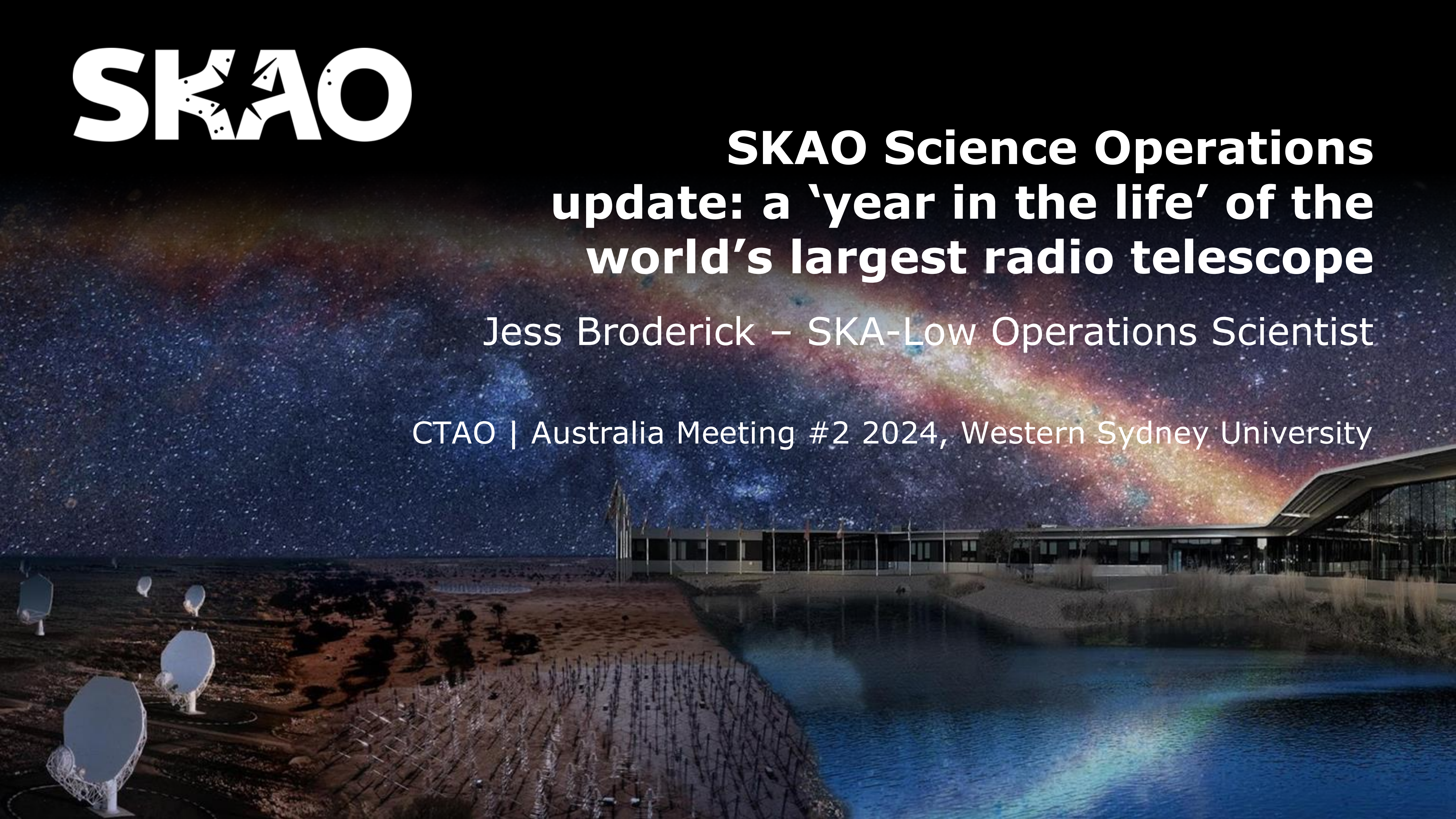


# SKAO

## **SKAO Science Operations update: a 'year in the life' of the world's largest radio telescope**

Jess Broderick – SKA-Low Operations Scientist

CTAO | Australia Meeting #2 2024, Western Sydney University





*We recognise and acknowledge the Traditional Owners of the lands on which our facilities are located, and pay our respects to their Elders past and present.*

*Australia's Indigenous people are the first scientists and have long standing knowledge of the Universe that we continue to build on today.*

*We acknowledge the Wajarri Yamaji as the Traditional Owners and native title holders of Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, where we are building the SKA-Low telescope in Australia.*

*We acknowledge the Whadjuk Noongar as the traditional owners of the land where our Science Operations Centre is situated in Perth, and the Southern Yamatji as the traditional owners of the land where our Engineering Operations Centre is situated in Geraldton.*

*I also pay my respects to all First Nations people in attendance.*



A collaborative painting from Aboriginal Yamaji artists from WA for the SKAO *Shared Sky* exhibition. Credit: Yamaji Arts Centre.





# SKA project timeline

(As of 2024 October 10. Note: timeline subject to change)

Milestone event (earliest)		SKA-Mid (end date)	SKA-Low (end date)
AA0.5	4 dishes 4 stations	2026 Feb	2024 Dec
AA1	8 dishes 18 stations	2026 Oct	2026 Jan
AA2	64 dishes 64 stations	2027 Aug	2026 Nov
AA*	<b>144 dishes</b> <b>307 stations</b>	<b>2028 Jun</b>	<b>2028 Feb</b>
<b>Operations Readiness Review</b>		<b>2028 Sep</b>	<b>2028 May</b>
Formal end of construction		2029 Mar/Apr	
AA4	197 dishes 512 stations	TBD	TBD

## Construction happening now!



- **Commissioning (AA0.5 +)**
- **Science Verification (AA2, AA\*)**
  - Community involvement!
  - Data immediately public.
  - Full dress rehearsal!
  - Some SRCNet resources for analysis.
  - Observed in dedicated ~week-long blocks + single observations interspersed throughout.
- **Cycle 0 + (AA\*)**

→ **The time for detailed planning is now!**



# SKA project timeline

(As of 2024 October 10. Note: timeline)

Milestone event (earliest)	SKA-M (end date)
AA0.5 4 dishes 4 stations	2026 F
AA1 8 dishes 18 stations	2026 O
AA2 64 dishes 64 stations	2027 A
<b>AA*</b> <b>144 dishes</b> <b>307 stations</b>	<b>2028 J</b>
<b>Operations Readiness Review</b>	<b>2028 S</b>
Formal end of construction	2029 M
AA4 197 dishes 512 stations	TBD

→ **The time for**



## Access Rules and Regulations for the SKA Observatory

SKAO-GOV-0000127  
 Classification: 01 UNRESTRICTED  
 Document type: POL  
 Date: 2024-10-17  
 Status: RELEASED

Role	Name	Designation	Affiliation	Signature	Date
Author	Antonio Chrysostomou	Deputy Director of Operations	SKAO	<i>Antonio Chrysostomou</i>	2024-10-21
Author	Shari Breen	Head of Science Operations	SKAO	<i>Shari Breen</i>	2024-10-22
Author	Tyler Bourke	Project Scientist	SKAO	<i>Tyler Bourke</i>	2024-10-21
Owner	Lewis Ball	Director of Operations	SKAO	<i>Lewis T Ball</i>	2024-10-21
Approver	Robert Braun	Science Director	SKAO	<i>Robert Braun</i>	2024-10-21
Released by	Philip Diamond	Director-General	SKAO	<i>Philip Diamond</i>	2024-10-21

[https://www.skao.ac.za/118/ska-telescope-specifications](#)  
 e: Braun et al. 2019 (arXiv:1912.12699)

**Opening now!**

**Commissioning (AA0.5 +)**

**Science Verification (AA2, AA\*)**

Community involvement!  
 Data immediately public.  
 Full dress rehearsal!  
 Some SRCNet resources for analysis.  
 Observed in dedicated week-long blocks + single observations interspersed throughout.

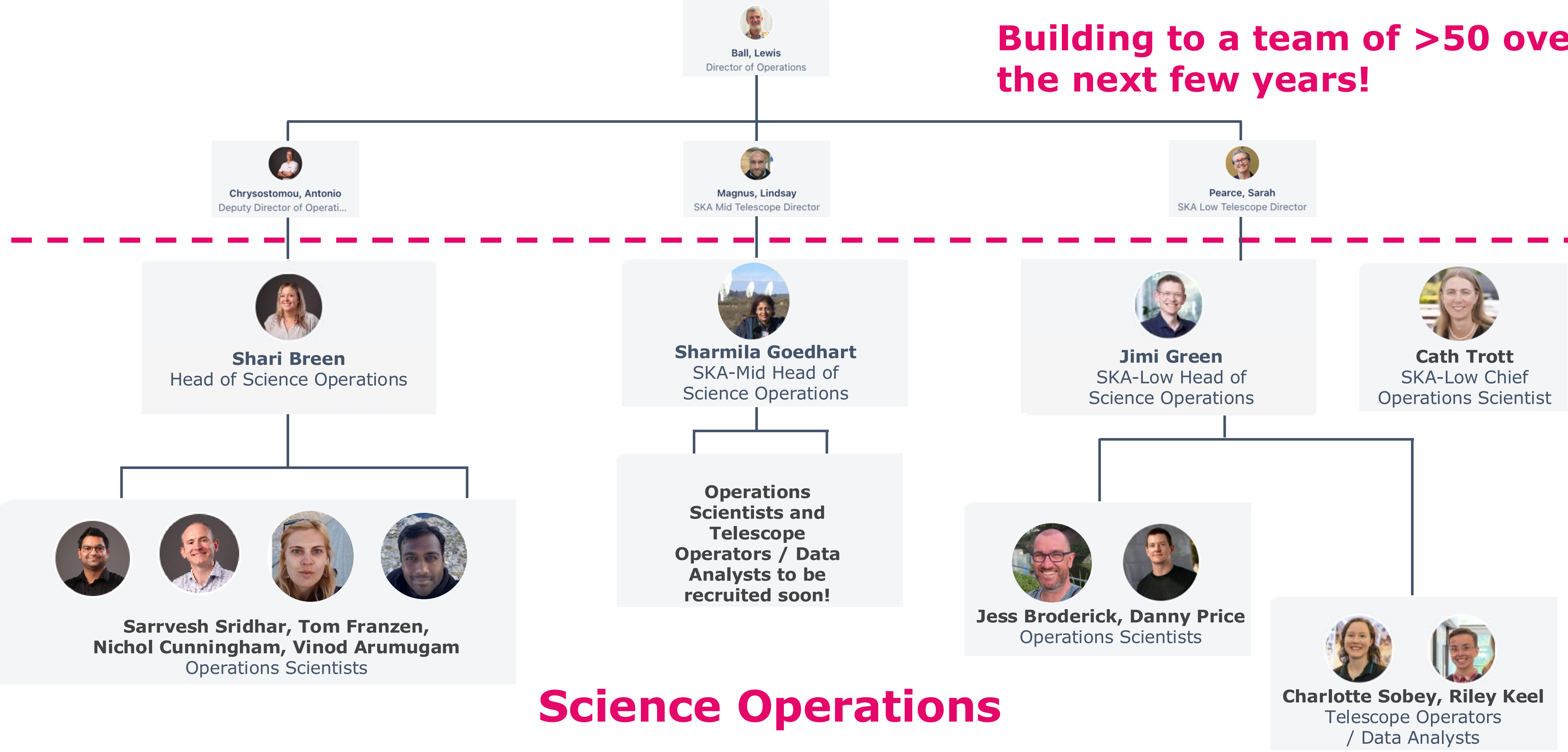
**Cycle 0 + (AA\*)**





# SKAO Science Operations: a team effort

Building to a team of >50 over the next few years!



## Science Operations





# SKAO Science Operations: a team effort




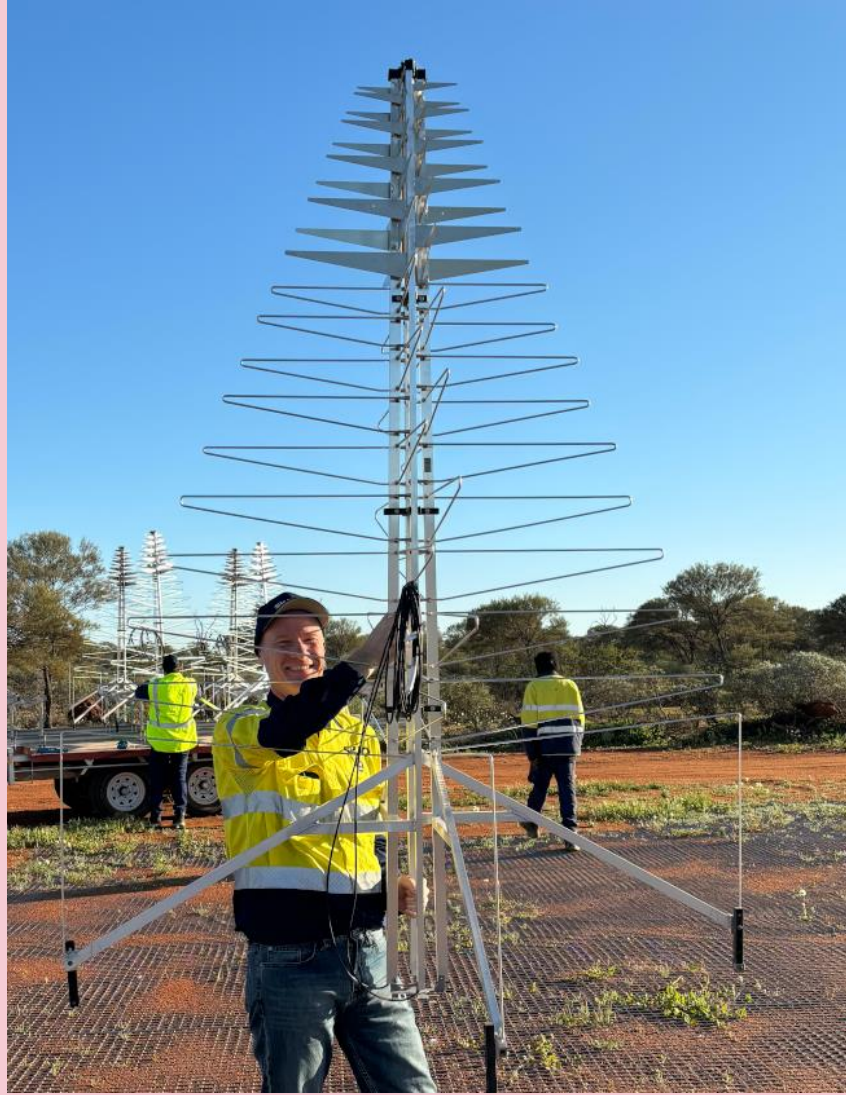


**Yearly team meeting + site visit; 2024 September**





# Working closely with the Science Commissioning team

- This team also growing; ultimately 7 members of the SKA-Low commissioning team in Perth.
- Science Operations will support AA0.5+ commissioning observations (e.g. bandpass stability, phase and amplitude closure, developing a commissioning calibrator database, etc.).

<b>George Heald</b> <i>SKA-Low Lead Commissioning Scientist</i>	<b>Randall Wayth</b> <i>SKA-Low Senior Commissioning Scientist</i>	<b>Shivani Bhandari</b> <i>SKA-Low Commissioning Scientist</i>	<b>Giulia Macario</b> <i>SKA-Low Commissioning Scientist</i>
			

**3x SKA-Low Commissioning Scientists**  
Recruitment commencing soon





# Tools for the community

SKAO OBSERVATORY

ABOUT US CAREERS SEARCH

SKAO

Explore Opportunities Resources Partners News & Events Science Users

Home > Science Users > SKA tools

## SKA tools

This page provides a list of tools that SKAO has made available to the user community.

- Sensitivity calculators
- Staged delivery, array assemblies and subarrays
- SKA subarray templates library

Feedback to SKAO  
Science  
Operations:  
[sciops@skao.int](mailto:sciops@skao.int)

SKAO Sensitivity Calculator

MID LOW

Subarray Configuration \* AA\* Number of Stations 307

Degrees Right Ascension \* 00:00:00.0 Declination \* -25:42:15.0 Minimum Elevation \* 45 deg

### Continuum

Integration Time \* 1 hours

Central Frequency \* 200 MHz

Continuum Bandwidth \* 300 MHz

Number of sub-bands \* 1

Spectral Resolution 5.43 kHz (8.1 km/s)

Spectral Averaging \* 1 Effective resolution 5.43 kHz (8.1 km/s)

Image Weighting \* Briggs Robust Value 0

### Results

- Weighted continuum sensitivity 9.53 uJy/beam (1.32)†
- Continuum confusion noise 7.85 uJy/beam
- Total continuum sensitivity 12.35 uJy/beam
- Continuum synthesized beam-size 7.8" x 7.4"
- Continuum surface-brightness sensitivity 6.58 K
- Weighted spectral sensitivity 1.62 mJy/beam (1.39)‡
- Spectral confusion noise 8.12 uJy/beam
- Total spectral sensitivity 1.62 mJy/beam
- Spectral synthesized beam-size 7.8" x 7.6"
- Spectral surface-brightness sensitivity 838.48 K
- FWHM of the RMSF 0.1 rad/m<sup>2</sup>
- Maximum Faraday depth extent 4.3 rad/m<sup>2</sup>
- Maximum Faraday depth 222.0 rad/m<sup>2</sup>

Warning: You are approaching the confusion limit given the synthesized beam-size and frequency.

† Weighting correction factor (30% bandwidth)  
‡ Weighting correction factor (single channel)

Zoom Window

Pulsar Search (PSS)

CALCULATE RESET


Note: The theoretical sensitivity is computed using direction, frequency, and LST-dependent SEFD values following the procedure described in Sokolowski et al. (2022).

© SKAO 2024 | Version 1.4.2

<https://www.skao.int/en/science-users/ska-tools>



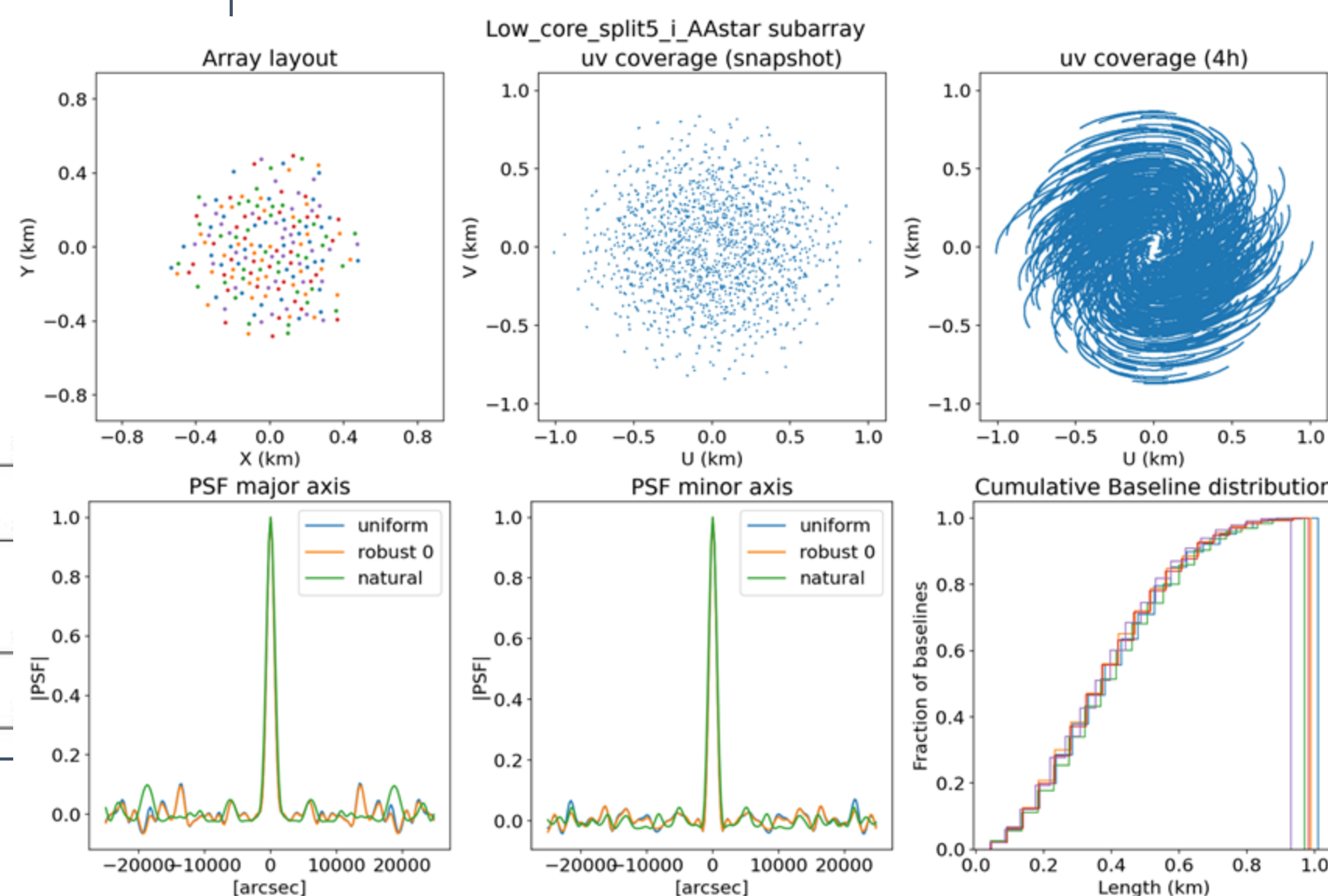
# Tools for the community



## SKA Low and Mid Subarray Templates

SKAO-TEL-0002380      Revision 01  
 Classification:      UNRESTRICTED  
 Document type:      REP  
 Date:      2024-06-12  
 Status:      Released

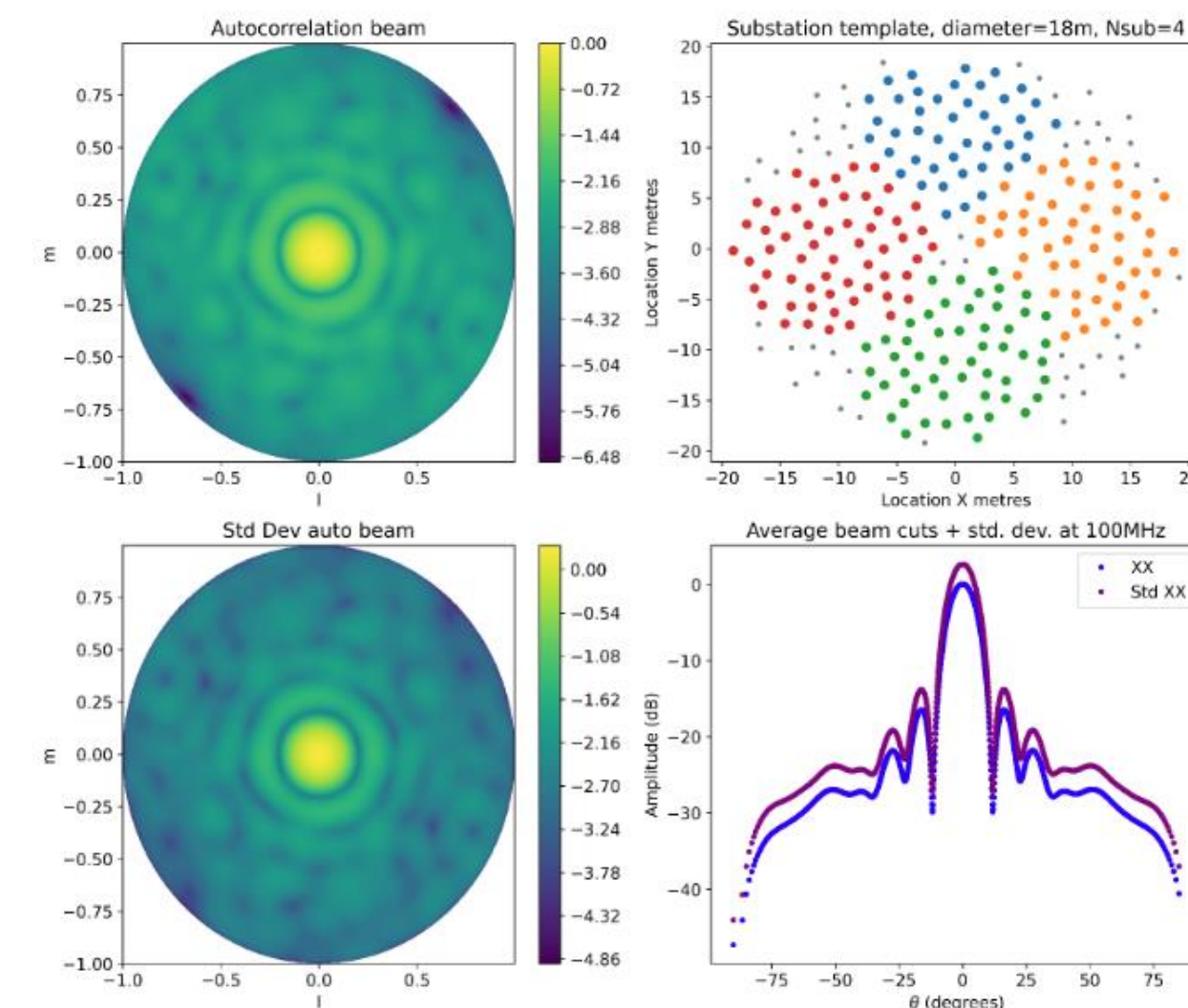
Role	Name	Designation	Affiliation	Signature
Author	Sarrvesh Sridhar	Operations Scientist	SKAO	
Author	Wendy Williams	Scientist	SKAO	
Author	Shari Breen	Head of Science Operations	SKAO	
Approver	Shari Breen	Head of Science Operations	SKAO	
Released by	Lewis Ball	Director of Operations	SKAO	




## SKA-Low Substation Templates

SKAO-TEL-0002390      Revision 01  
 Classification:      UNRESTRICTED  
 Document type:      REP  
 Date:      2024-08-20  
 Status:      DRAFT

Role	Name	Designation	Affiliation	Signature	Date
Author	Cathryn Trott	SKA-Low Chief Operations Scientist	SKAO		2024-08-20
Owner	Shari Breen	Head of Science Operations	SKAO		2024-08-20
Approver	Jimi Green	SKA-Low Head of Science Operations	SKAO		2024-08-20
Released by	Sarah Pearce	SKA-Low Telescope Director	SKAO		2024-08-20



- Collaborated with the SKA science working groups to define this first set of templates: 32 for SKA-Mid; 27 for SKA-Low.
- Document released for feedback (questionnaire with six open-ended questions) and refinement.
- Python simulation tool also available.

- Like subarrays, users will be able to select from a series of SKA-Low substation templates.
- Document includes 18, 12, 9 and 6m diameter examples. 18 and 12m for cross-correlation; 9 and 6m for fly's eye mode.





# Staged delivery memo and software package

- Memo (v. 3): <https://www.skao.int/en/science-users/ska-tools/494/ska-staged-delivery-array-assemblies-and-subarrays>
- Software interface to the antenna coordinates.
- SKAO repository: <https://gitlab.com/ska-telescope/ost/ska-ost-array-config>
- Detailed documentation in a Jupyter notebook.
- Allows you to
  - Configure a custom subarray.
  - Simulate interferometric observations.
  - Plot array layout and *uv* coverage.
  - Export the layout to CASA for more comprehensive simulations.
- Figure on the right plots baseline distribution and *uv* coverage of two Mid subarrays.



## SKAO staged delivery, array assemblies and layouts

SKAO-TEL-0002299      Revision 03  
Classification:      UNRESTRICTED  
Document type:      REP  
Date:      2024-10-03  
Status:      RELEASED

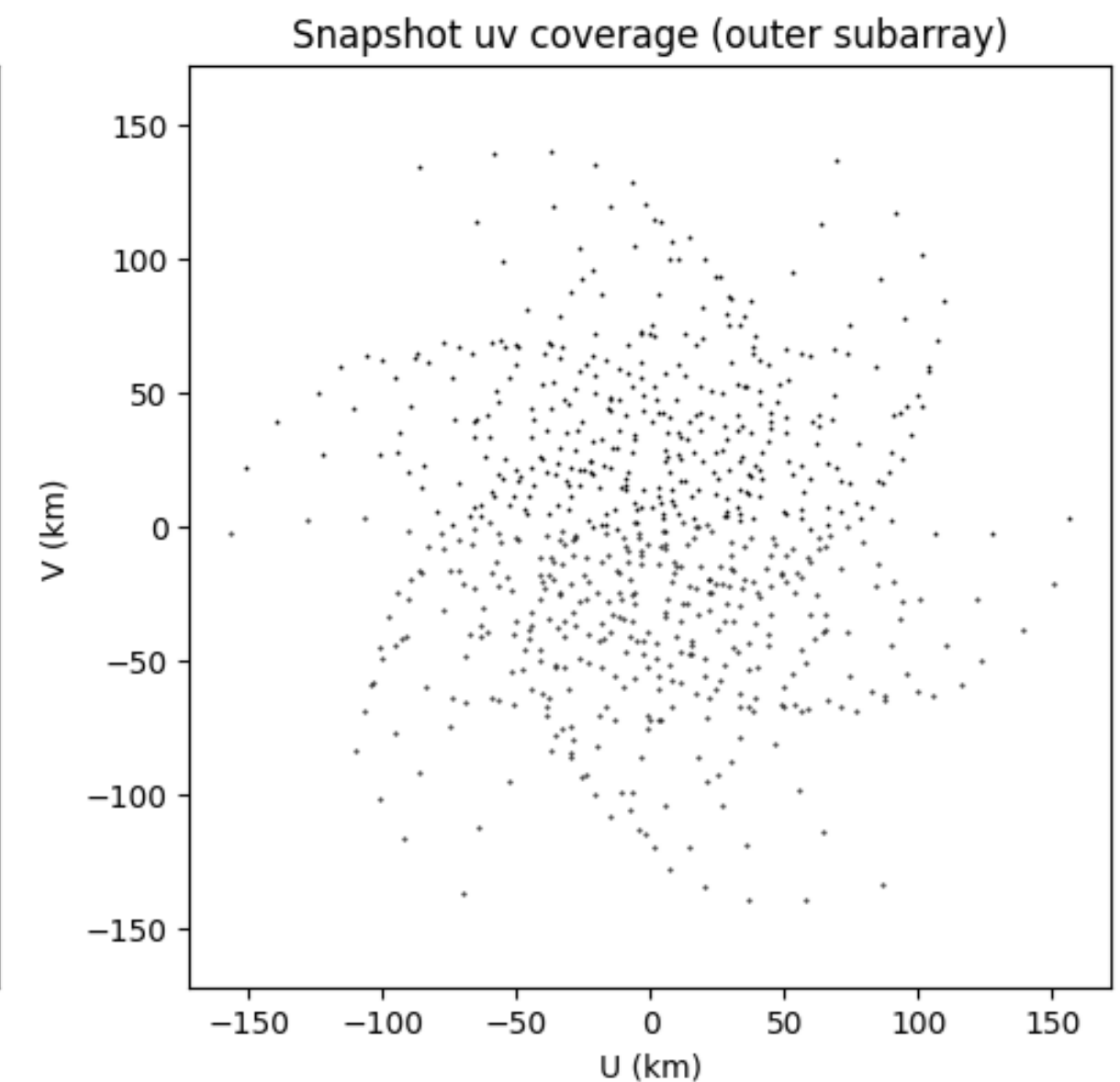
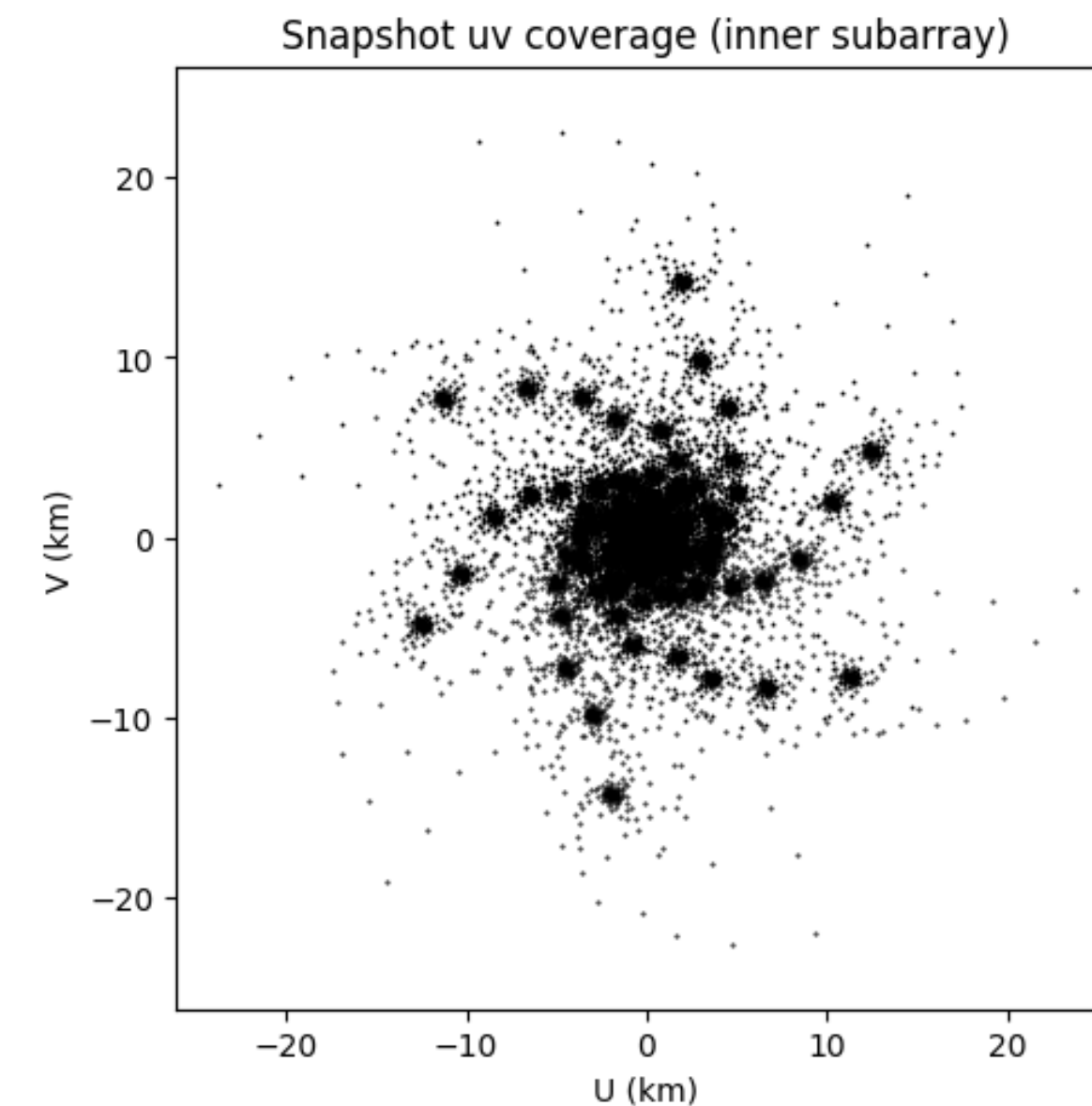
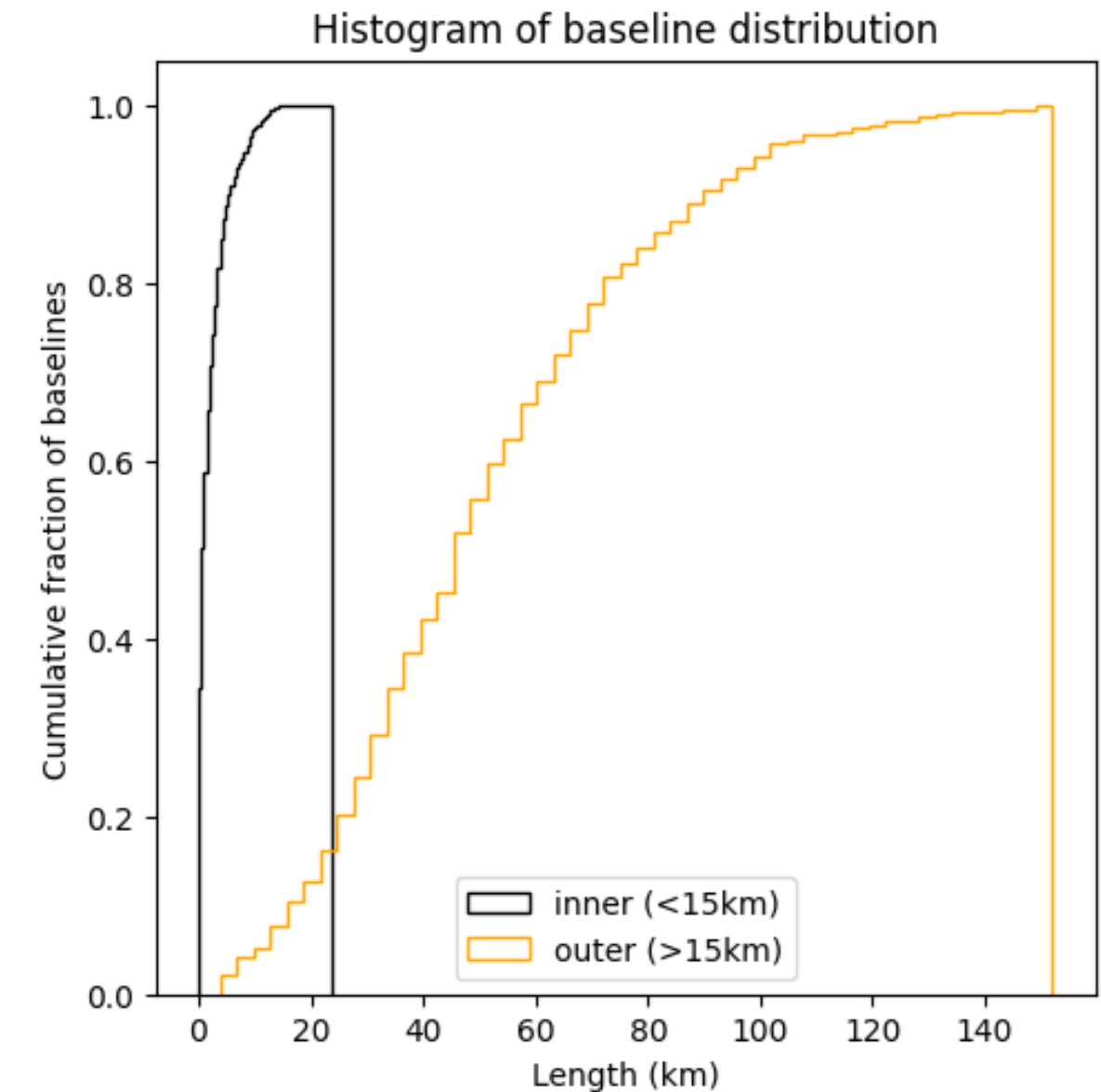
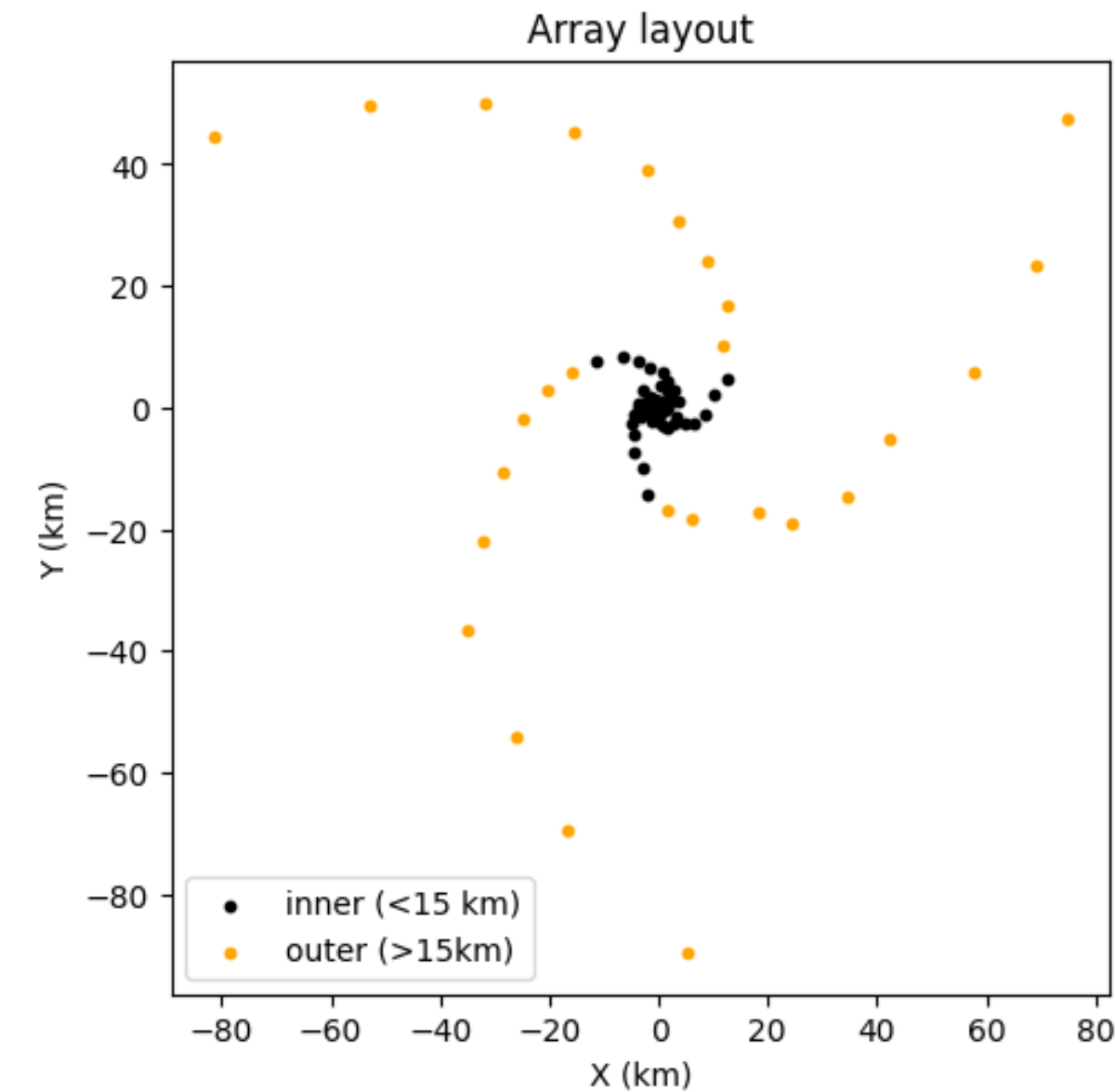
Role	Name	Designation	Affiliation	Signature	Date
Author	Sarrvesh Sridhar and Science Operations	Operations Scientist	SKAO	<hr/>	
Owner	Shari Breen	Head of Science Operations	SKAO	<hr/>	
Approver	Luca Stringhetti	Acting Director of Programmes	SKAO	<hr/>	
Released by	Lewis Ball	Director of Operations	SKAO	<hr/>	





# Staged delivery memo and software package

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- Software interface to the antenna coordinates.
- SKAO repository: <https://gitlab.com/ska-telescope/ost/ska-ost-array-config>
- Detailed documentation in a Jupyter notebook.
- Allows you to
  - Configure a custom subarray.
  - Simulate interferometric observations.
  - Plot array layout and  $uv$  coverage.
  - Export the layout to CASA for more comprehensive simulations.
- Figure on the right plots baseline distribution and  $uv$  coverage of two Mid subarrays.







**SKAO construction activities are proceeding at pace; SKAO science is now clearly on the horizon. It is therefore time for detailed operational planning provided by 'year in the life'!**





# The SKA is a flexible science machine



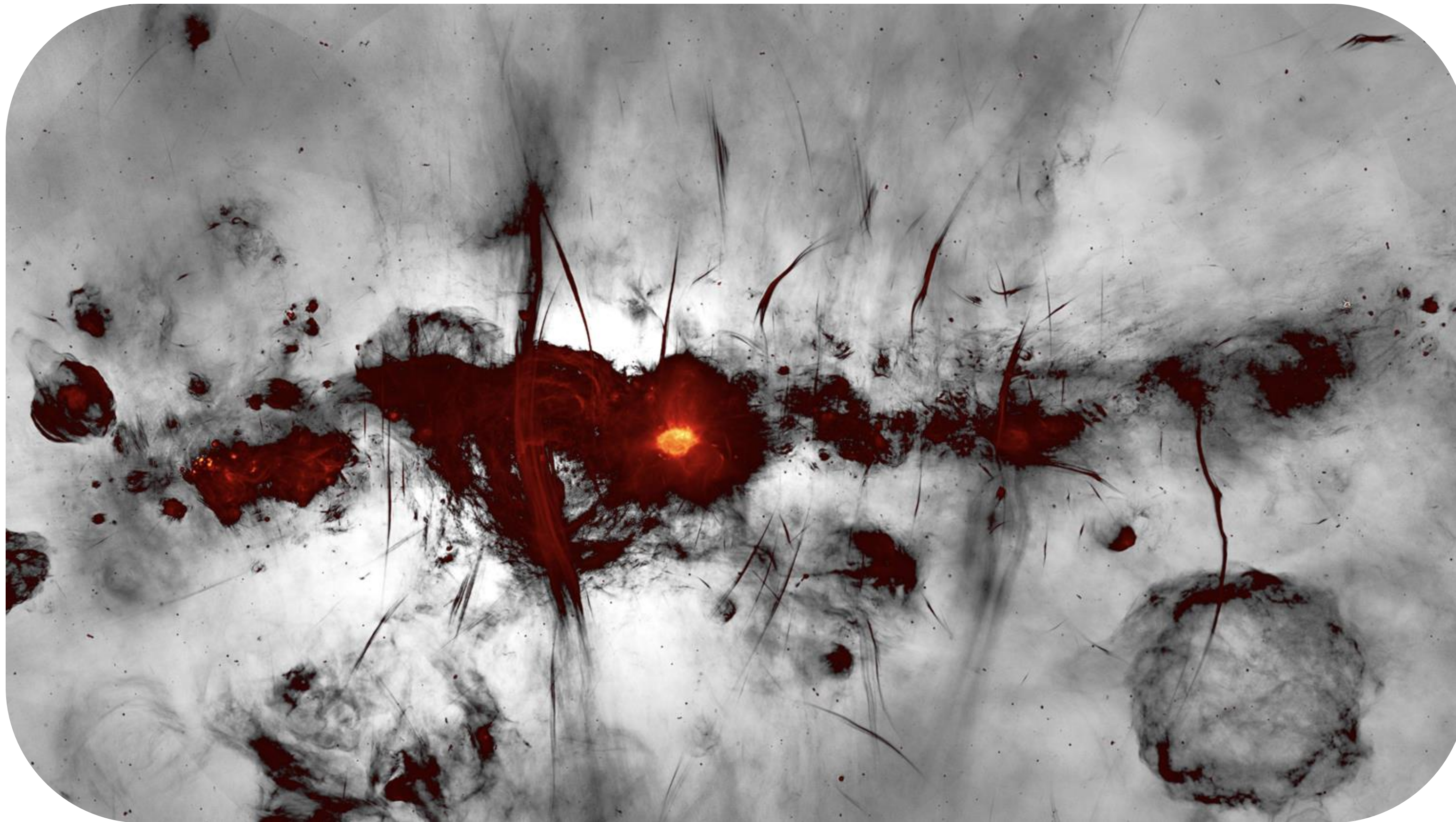
- SKA systems are hugely flexible!
- Two telescopes to cover a frequency range between 50 MHz and 15.4 GHz.
- Each supports up to 16 subarrays (splitting the 307 stations and 144 dishes into smaller arrays).
- Very flexible Correlator Beamformers (CBFs), but ultimately resource limited.
- Both imaging and non-imaging modes: broadband continuum, spectral/zoom modes, pulsar and fast transient search (PSS), pulsar timing (PST), dynamic spectrum, flowthrough, VLBI.
- Commensality supported (data, observing, multiplexed).

→ **Numerous operational challenges**





# We will deliver data products



Credit: I. Heywood, SRAO (2022, ApJ, 925, 165)  
MeerKAT 1.28-GHz Galactic Centre mosaic

- Our data are **BIG**; expecting to deliver **~700 PB/year of data products**.
- Don't need to be a radio expert to access the SKA!
- Transformational science increasingly relies on multiwavelength data; everyone is welcome!
- Data products delivered to users by SRCNet (e.g. AusSRC: <https://aussrc.org/>).

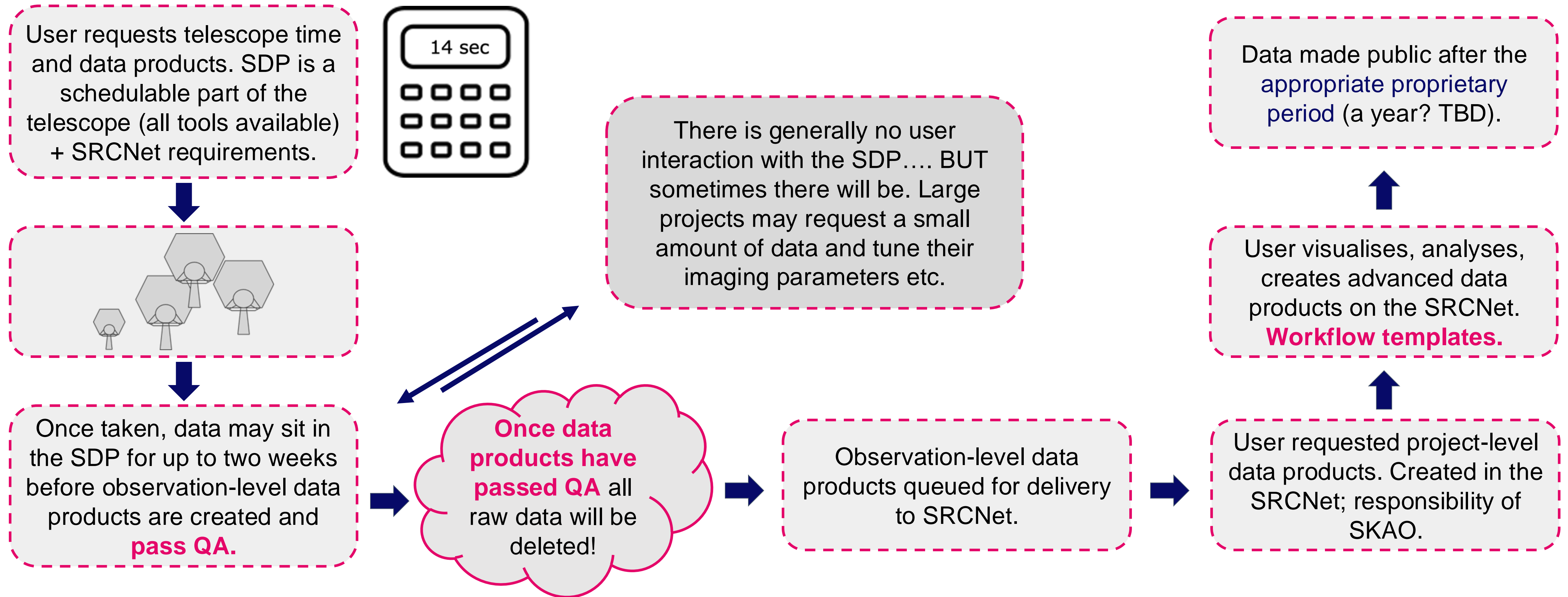
→ **Even more operational challenges**





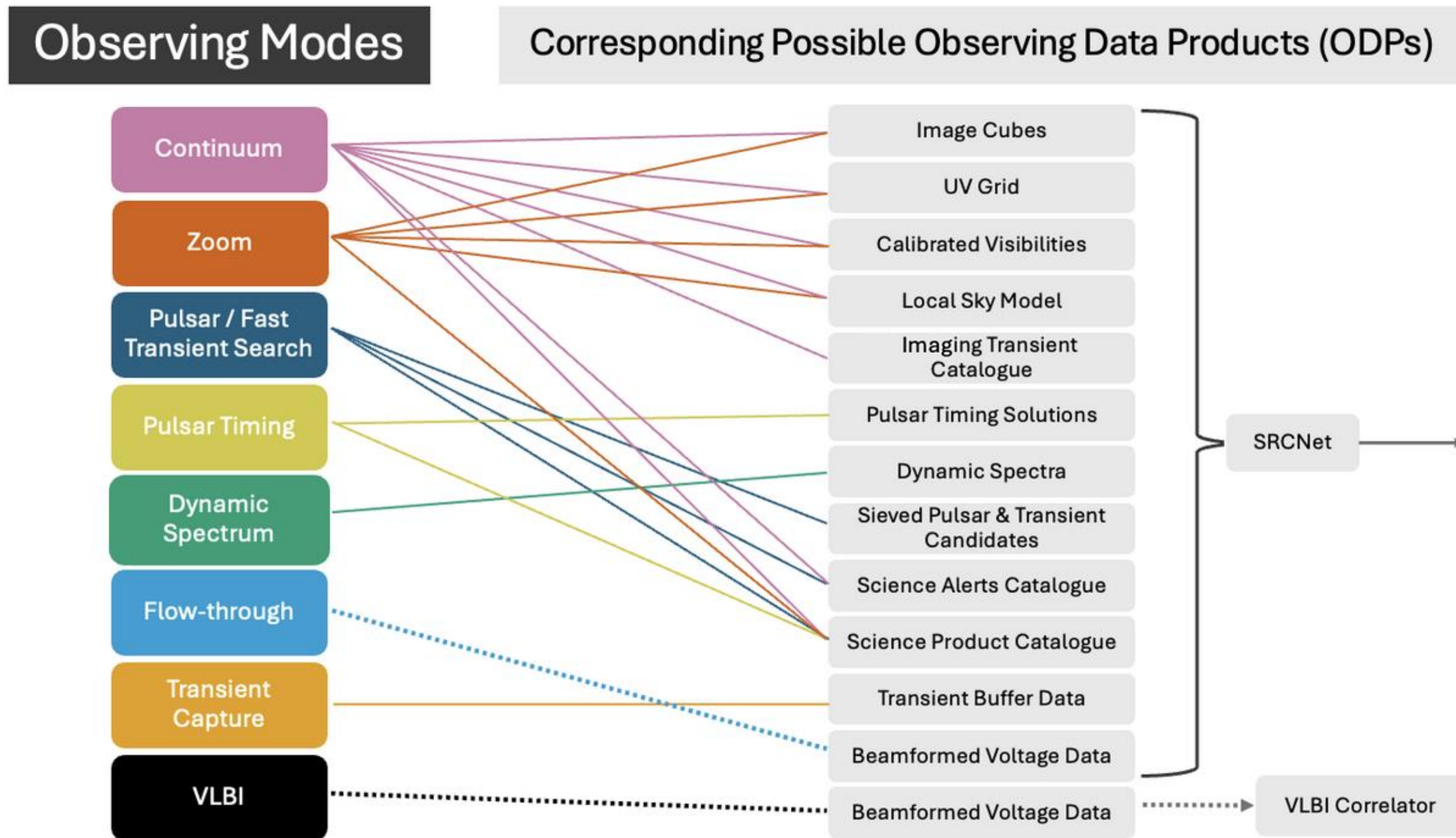
# SKAO Operational model (brief summary)

- **Details in the Observatory Establishment and Delivery Plan:** <https://www.skao.int/en/resources/402/key-documents>
- **SKAO science data products:** A summary document lists many of the kinds of data products we are expecting (details of data formats aren't yet available).





# Relationship between observing modes and data products





# Year in the life of SKA-Low and SKA-Mid



- **What does a year of Operations look like ('standard' year – e.g. Cycle 2)?**
- Covers as much of the system as we can reasonably include.
- How much user support do we expect in a year?
- How many proposals?
- What types of science projects (utilising extensive existing material as a starting point)?
- What is the telescope mode usage?
- What opportunities are there for commensality?
- What are the calibration requirements?
- What kinds of science data products do we expect to deliver and in what proportion?
- What would the load on our Science Data Processor (SDP) be?
- What resources are needed in SRCNet?
- Availability for science? Weather, RFI, maintenance.
- Power considerations, e.g. how much time does Mid spend slewing, tracking and scanning?
- **Aiming to be representative, not perfect. Can improve as developments occur + feedback from the community.**

## SKA1 Scientific Use Cases

SKA-TEL-SKO-0000015

Classification:

Document type:

Date:

Status:

Revision 04

UNRESTRICTED

GDL

2021-12-07

RELEASED





# What we are finding so far

- This is a substantial amount of work.
- Lots of preparatory work has to be done to enable year in the life planning.
- We are spending significant time talking to each other and people in other areas. Aligning visions/plans/understanding!
- **Enormously valuable!**



## Year in the Life of the SKA: Project Schedule

SKAO-TEL-0000000	Revision 01
Classification:	UNRESTRICTED
Document type:	NOT
Date:	2024-08-29
Status:	DRAFT

Documentation in prep.





# Science verification

- Final step in the broader delivery of the system (assembly, integration, verification, commissioning, science commissioning, science verification).
- **Full end-to-end test 'dress rehearsal', starting with a submitted idea, observation, data product creation, quality assurance and data delivery.**

- 1 Call(s) issued to the community for verification ideas to test specific modes and capabilities, supported by workshops.
- 2 Short description of the idea submitted by astronomers.
- 3 Light-touch assessment: does the idea provide the tests that we need? Do they use the correct modes? Appropriate comparison data? -> **Pool of prioritised ideas.**
- 4 Observations carried out. Data products (e.g. image cubes) created using the Science Data Processor (SDP), including a QA assessment.
- 5 Data products **delivered publicly** via the SRCNet following an announcement. Some SRCNet resources may be made available for analysis.
- 6 Report generated to assess the status of the associated observing mode, supported by community assessment.





# Expected mode availability for early science verification

## AA2 mode prioritisation:

1. Continuum
2. Pulsar timing (PST)
3. Pulsar and transient search

Zoom (maybe), VLBI (maybe-ish)  
Transient buffer (unlikely)

**Continuum:** 16k channels, 800 MHz  
(4 x 200 MHz) BW

**PST:**  $\geq 6$  beams (steerable) with de-dispersion, 800 MHz BW

**PSS:**  $\geq 16$  beams (steerable), not fully pipelined, non real-time operation, full BW



## AA2 mode prioritisation:

1. Continuum
2. Pulsar timing (PST)
3. Zoom
4. Pulsar and transient search

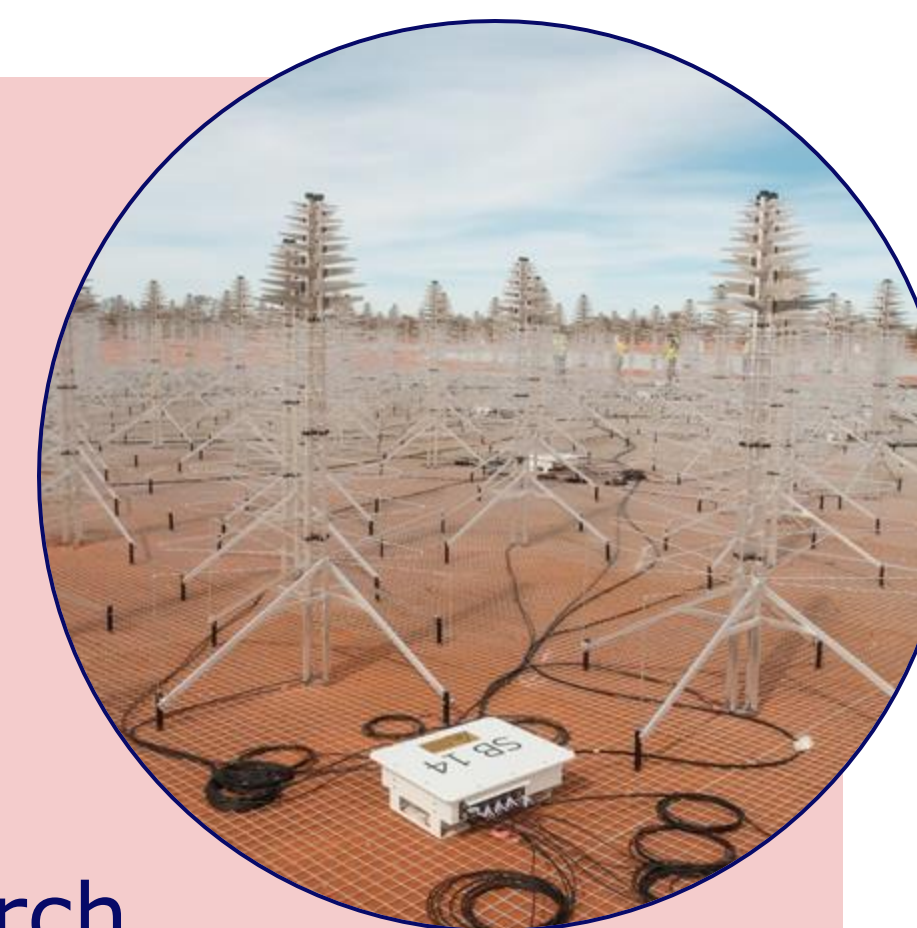
Transient buffer (unlikely), VLBI (unlikely)

**Continuum:** 27k channels, 150 MHz BW

**Zoom:** Up to 16 zoom windows (lowest resolution: 3.12 MHz BW, 1808 Hz resolution, 1728 channels)

**PST:**  $\geq 4$  beams

**PSS:**  $\geq 30$  beams



- Modes only available for science verification once they have successfully passed science commissioning. Continuum and PST likely to be the early focus (AA2).

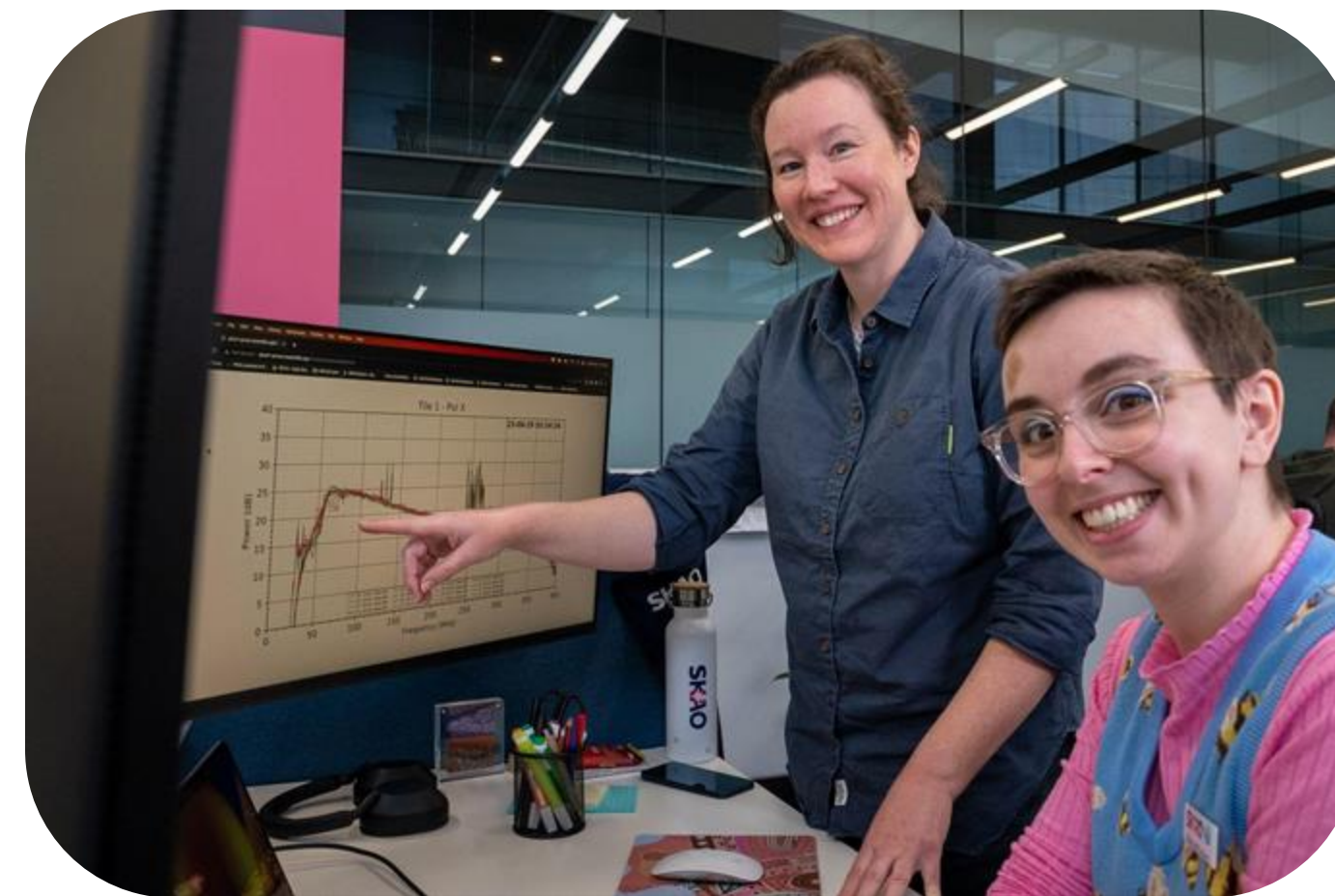




# Preparing for science verification

- Building up complexity of modes/capabilities/data products as we progress from AA2 → AA\*.
- Expecting to deliver visibilities alongside continuum/spectral data products during science verification.
  - Verification of pipelines.
  - Important for building trust.
- Verification periodically as modes/array mature/grow (even into Cycle 0).
- Released following announcements (observed in 'trickle' + dedicated blocks).

- Supported by community workshops.
- Mode availability, tool usage, SKA Regional Centre Network availability and usage.
- Intend to have a memo series, so that e.g. early career researchers can receive technical credit, especially if a dataset doesn't result in publication.



## SKAO

### Memo

Document Number SKAO-GOV-0000000  
Classification: UNRESTRICTED  
Document type: POL  
Revision: 01  
Date: 2021-05-20  
Status: Released

Author	Name	Designation	Affiliation	Signature	Date
	Astronomer	Policy & P&I Coordinator	SKAO		





Thank you for listening!

Jess.Broderick@skao.int

<https://recruitment.skao.int/vacancies.html>

<https://www.csiro.au/en/careers/career-opportunities/skao>

*We recognise and acknowledge the  
Indigenous peoples and cultures that have  
traditionally lived on the lands on which  
our facilities are located.*

**SKAO**

[www.skao.int](http://www.skao.int)