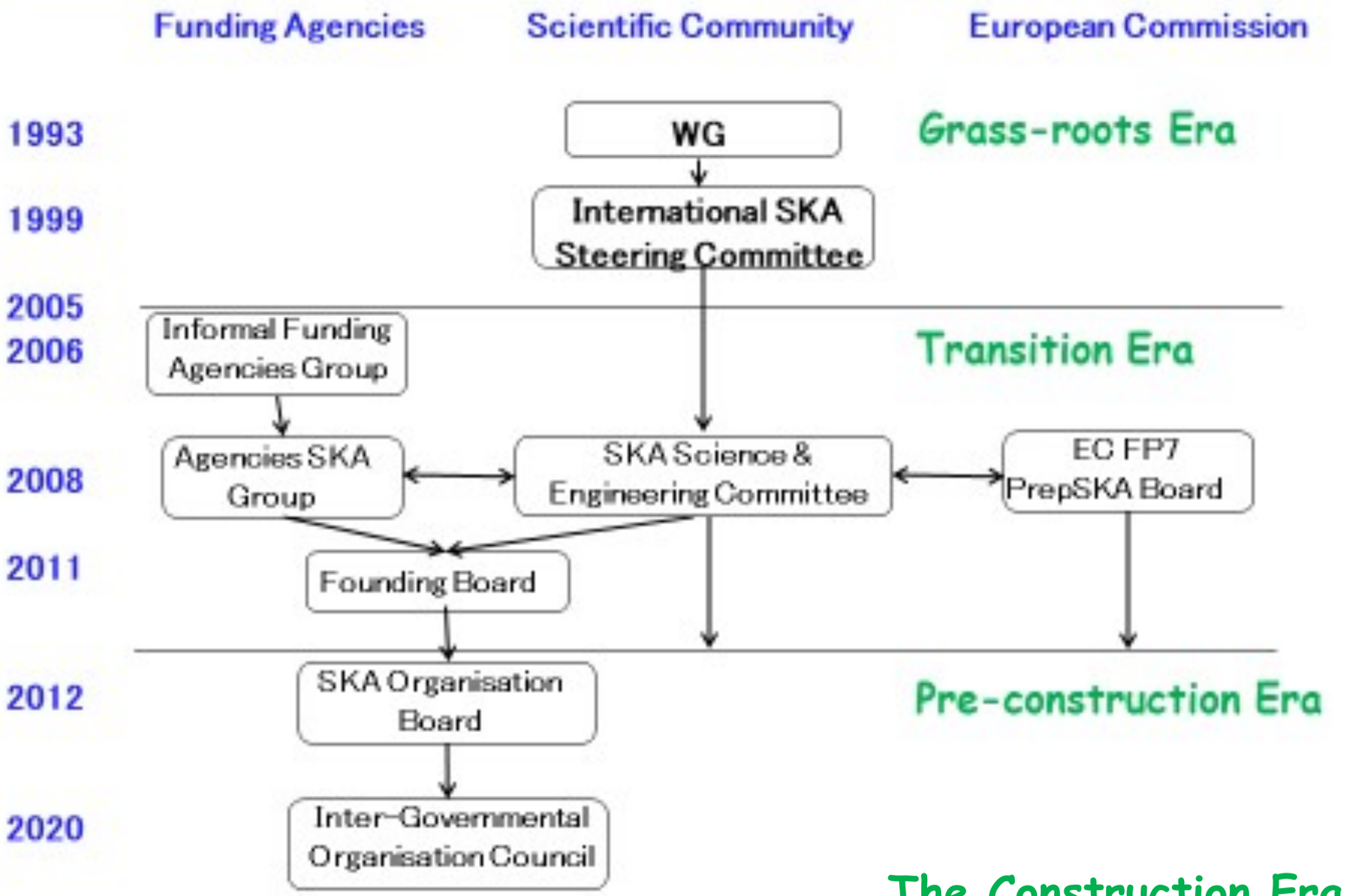
The Square Kilometre Array:

An Observatory for the 21st Century

Catherine Cesarsky
Chairperson, SKAO Council

Saclay, May 10 2023

Evolution of SKA Governance



Credit: R. Schilizzi

A short history of SKA (till 2021)

- A 30-year journey from early concepts
- 20 years of technology exploration
- 12 years since first, tentative steps towards an IGO
- 10 years since SKA Organisation established

3.1 The objects for which the SKA Organisation is established are:

3.1.1 to carry out the Business Plan;

3.1.2 to select a preferred site for the SKA Facility in accordance with these Articles;

3.1.3 to develop an organisational framework for the construction and operation of the SKA Facility; and

A short history of SKA (till 2021)

- A 30-year journey from early concepts
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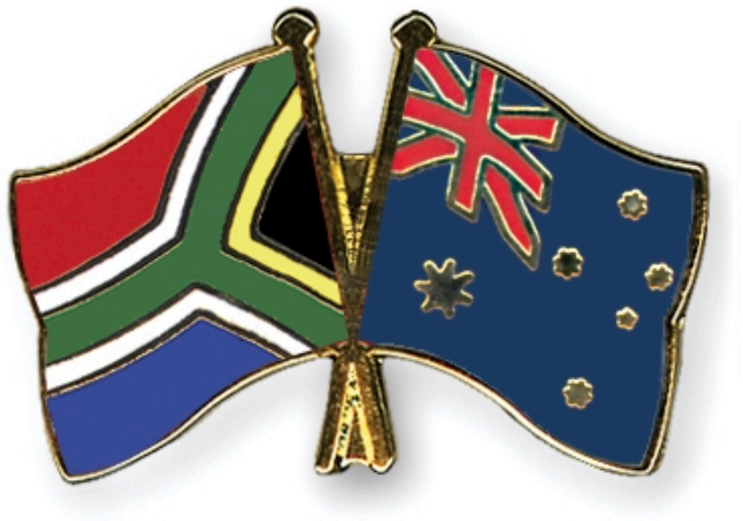
- 12 years since first, tentative steps towards an IGO
- 10 years since SKA Organisation established
- 9 years since the site decision

The two sites which will host the core of the SKA Telescope are Australia and South Africa, whilst the SKA Organisation Headquarters is in the UK.



This decision (Link to PDF) to co-locate the telescopes in two sites came after careful consideration of all of the science goals, industry goals and suitability in terms of location, sustainability, local considerations and factors relating to economics and the site infrastructure.

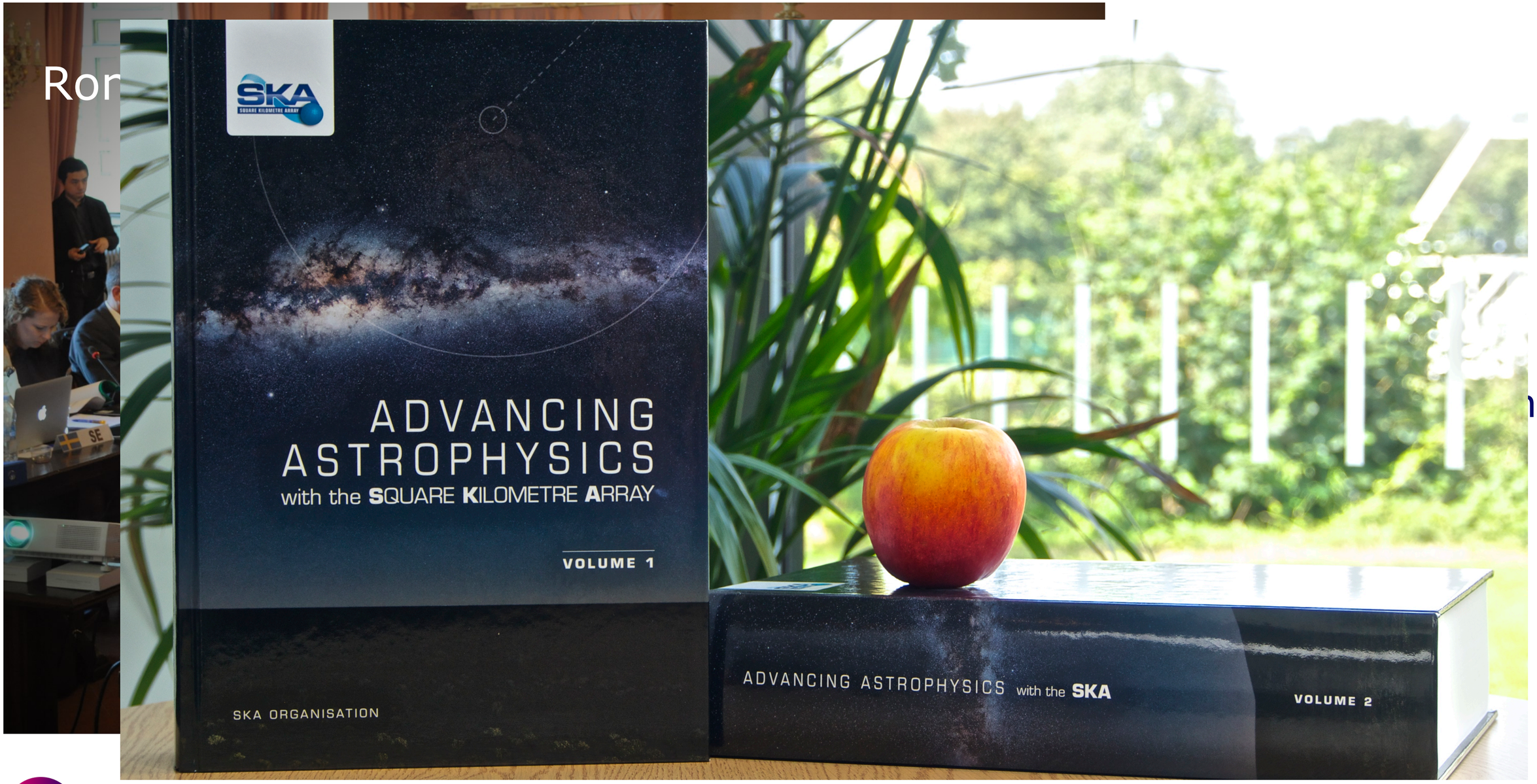
View the members' statement on the teleconference of 14th November 2012.

View the members' statement on the meeting of 25th May 2012.

Creating the SKAO

- SKA Organisation member governments agreed to develop an Intergovernmental Organisation in 2014-2015
- Rationale:
  - Appropriate for a genuinely global research infrastructure of SKA's scale
  - Government commitment: political stability, funding stability
  - A level of independence in structure
  - 'Freedom to operate', specifically through procurement process, employment rules etc
- Building an organisation based on successful IGOs such as ESO, EMBL, CERN

A short history of SKA



A short history of SKA (till 2021)

- A 30-year journey from early concepts
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- 12 years since first, tentative steps towards an I
- 10 years since SKA Organisation established
- 9 years since the site decision
- 8 years since detailed design process began

2015 - 2016 Element Preliminary Design Reviews

Consortia presented detailed proposals for assessment by an expert panel from the SKA and external organisations.

2016 System Preliminary Design Review

External experts assessed the SKA's system design, ensuring it was mature enough to enable the start of detailed design work.

2018 - 2019 Element Critical Design Reviews

The proposed design for each element was assessed against the project's tough engineering requirements.

France in the ‘pre-SKA Observatory’ SKA….

- July 2018 – Cape Town
- Maison SKA-France joins the SKA Organisation
- …becomes the 12th Member of SKA Org

December 2019 System Critical Design Review

An independent panel of external reviewers endorsed the SKA's overall design, including how all parts of the SKA will work and interact with one another.

Early 2020 Independent Cost Review

An independent review by consulting firm Arup concluded that the schedule and approach to construction follows logic and evidences good practice across both SKA-Low and SKA-Mid.

Mid 2020 Operations Reviews

Independent reviews of both the array operations and the business-enabling functions were successfully concluded in the first half of 2020.

Convention

- Negotiations on a Convention/ Treaty began 2015
- Establishing SKAO as an international organization for astronomy comprising States working together
- Convention defines:
  - Members (States)
  - Associate Members (States)
  - Cooperating Partners (States, institutions, others…)

International negotiations

- 4 plenary meetings between 2015 and 2016 – all in Rome, led by the Italian government
- Specialist working groups in financial and policy areas
- ‘Convention Task Force’ active 2017 and into 2018
- Finalisation of detailed policies and support for Initialling 2018 into 2019

Seven countries signed the treaty, including Australia, China, Italy, The Netherlands, Portugal, South Africa and the United Kingdom. India and Sweden, who also took part in the multilateral negotiations to set up the SKA Observatory IGO, are following further internal processes before signing the treaty. The entry into force of the convention took place in February 2021.

2021-2022: France

- May 2021: Confirmation of intent to join SKAO by President Macron
- Decision by SKAO Council to approve membership of France
- 7th March 2022: signature of cooperation agreement with CNRS
- Permits participation in SKAO while ratification of Convention takes place

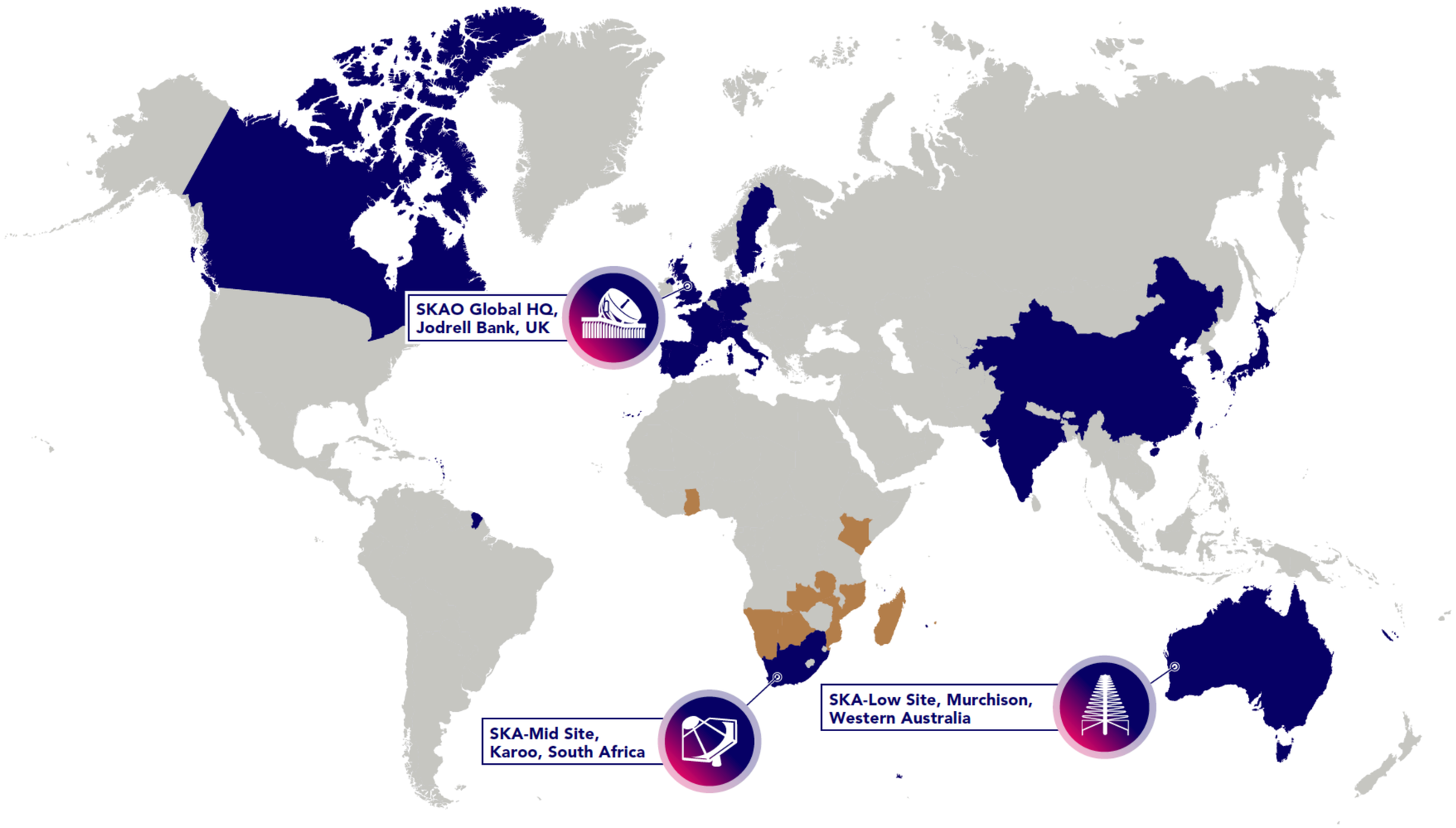

SKAO

Who are we?

The Square Kilometre Array Observatory (SKAO)

An inter-governmental organization, governed by a treaty. SKAO was born in January 2021.

Members	Australia, China, Italy, Netherlands, Portugal, South Africa, Switzerland, UK
Accession stage	France, Spain, Germany
Membership negotiations	Canada
Interim agreements	India, Sweden
Early stages	Japan, South Korea



SKAO Partnership - includes SKAO Member States* and SKAO Observers (as of June 2022)

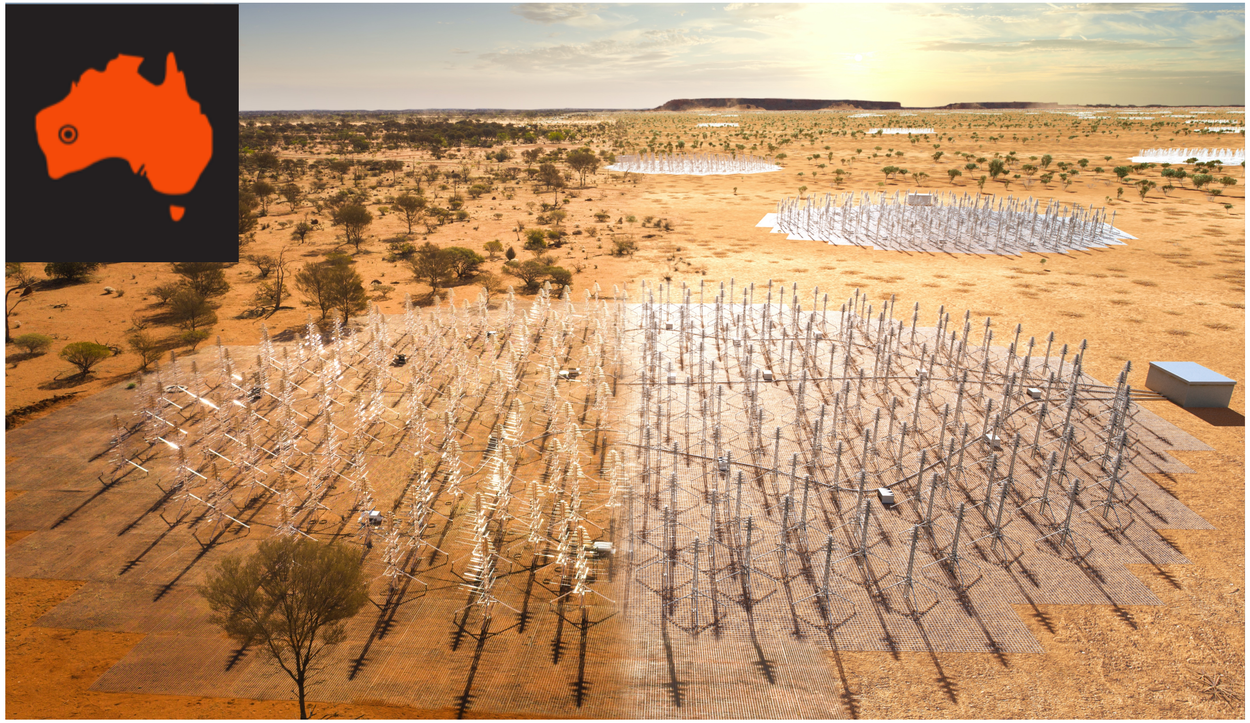
African Partner Countries

What are we building?
One Observatory, Two Telescopes, Three Sites

SKA1-Low: 131,072 low-freq antennas
(512 stations each with 256 dipoles)
50 – 350 MHz
65 km baselines (11” @ 110 MHz)
Murchison, **Western Australia**

SKA1-Mid: 197 dishes
(133 x 15m + 64 x 13.5m dishes)
0.35 – 15.4 GHz
150 km baselines
(0.22” @ 1.7 GHz; 34 mas @ 15 GHz)
Karoo, **South Africa**

MeerKAT



Phase 2 (aspiration): > 2000 dishes across Africa; > 500,000 dipoles across Australia

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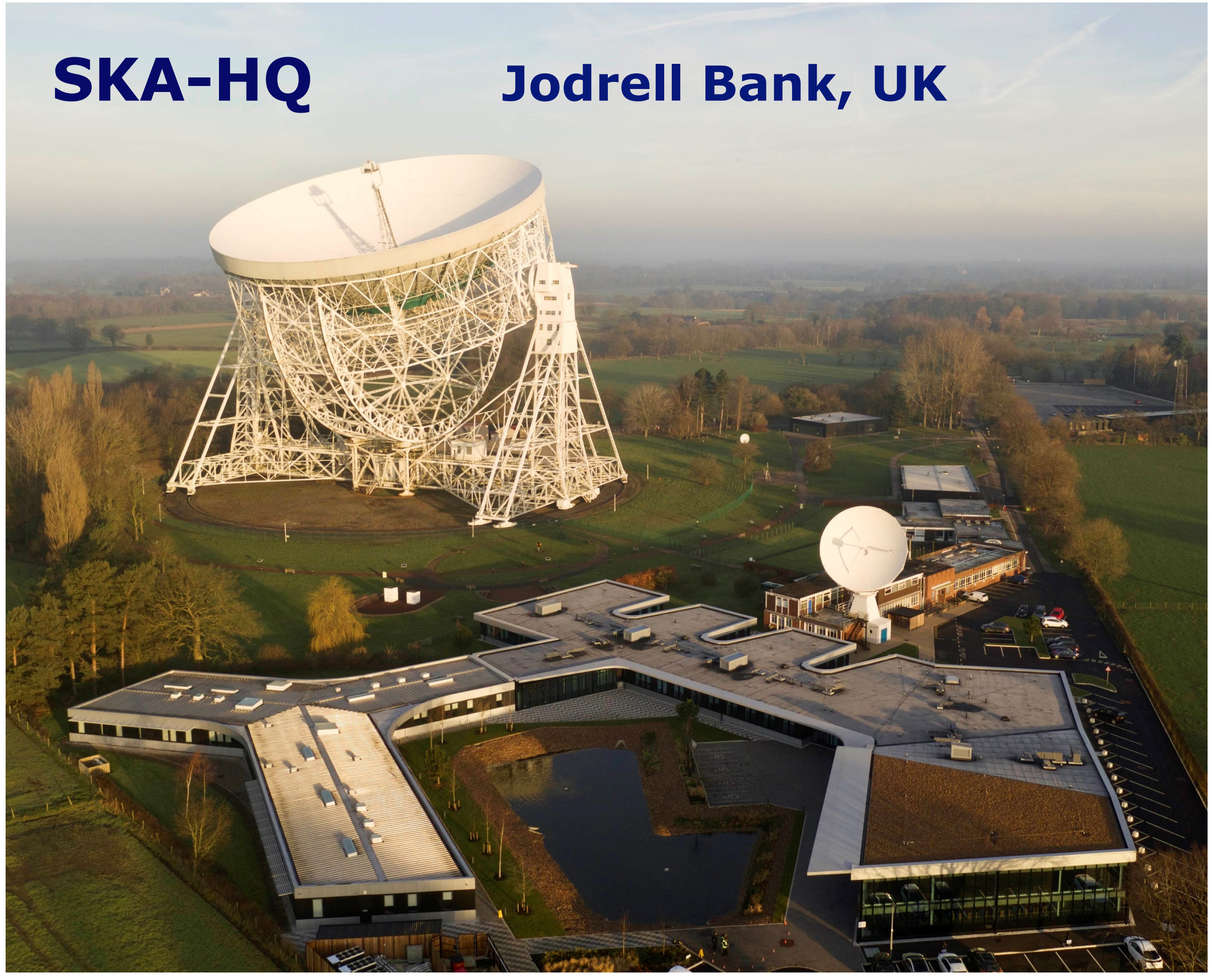
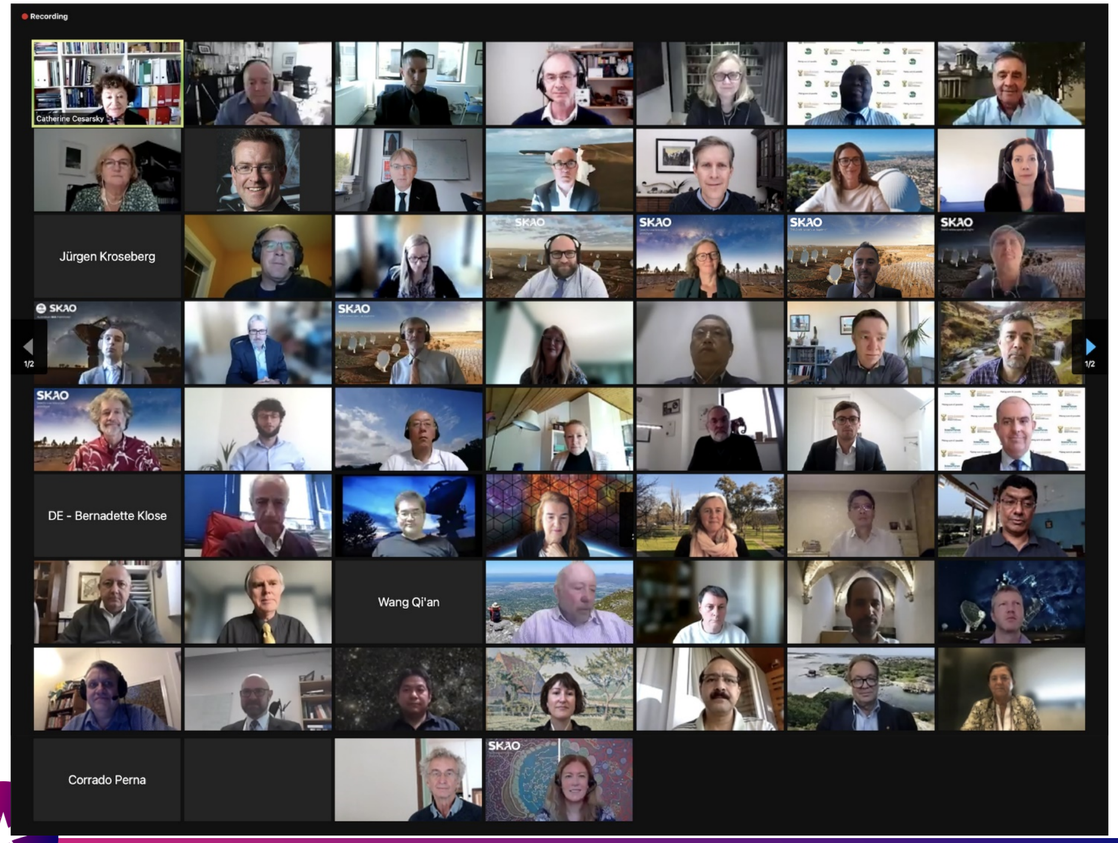


- Telescope sites selected for their radio quietness → low population density
- Total project cost: ~€2.1B;
- early science 2026/27;
- operational in 2029/2030
- Long term aspiration:
  SKA Phase 2, ~10 times larger

SKAO is being built by radio astronomers for all astronomers

SKA Observatory

- At Council meeting n°3, decision for commencement of construction.Eight Council meetings so far.



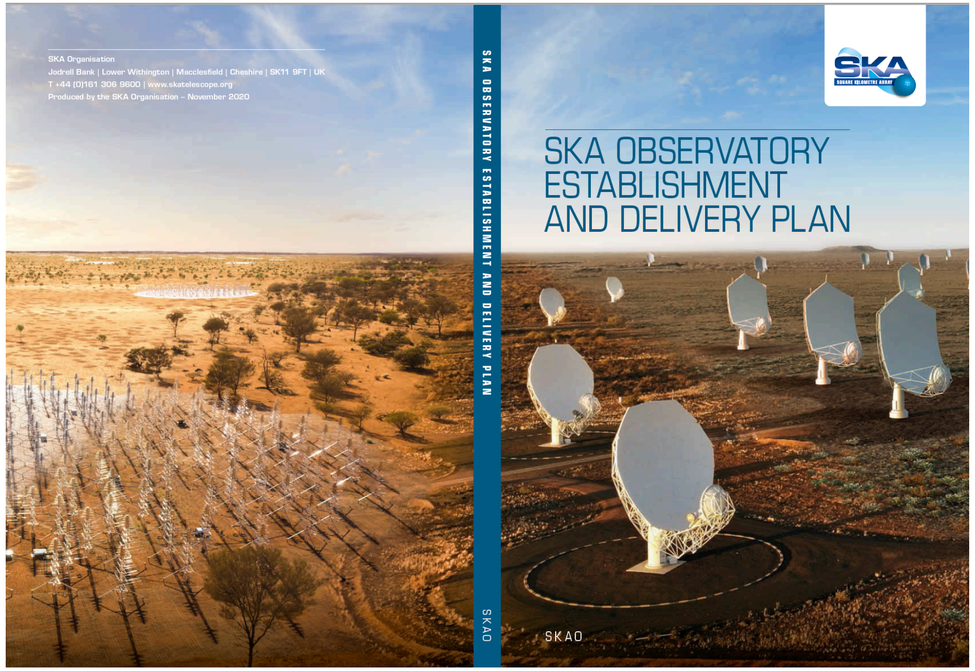
Delivering SKA Observatory

January 2021: SKAO born

June 2021: SKAO Council approved the Construction Proposal and the SKAO Establishment and Delivery Plan

July 2021: Construction activities began

March 2023: 48 contracts awarded, totalling ~€475M; more major contracts being prepared



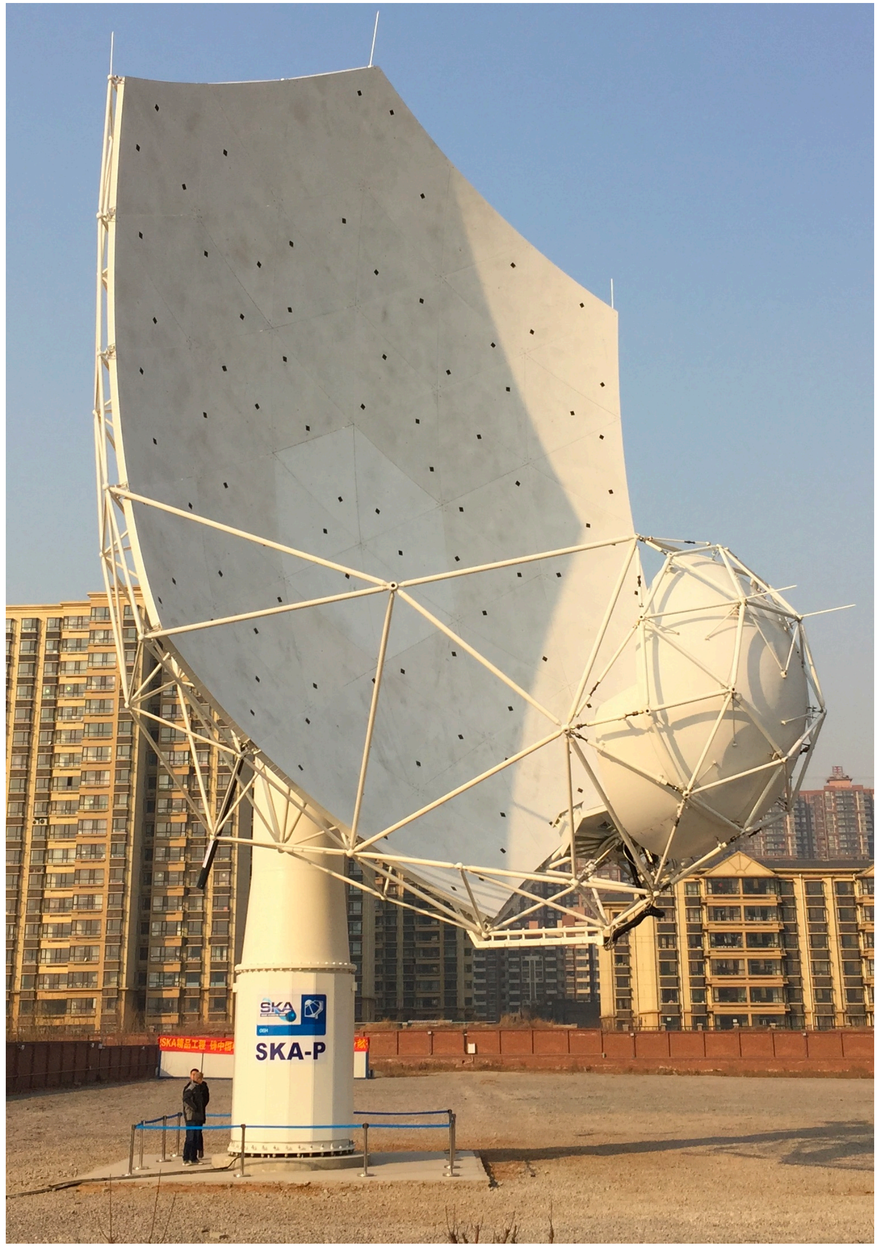
First and Future Generation Feeds/Receivers

Band	Frequency Range	Bandwidth
Low	**50 – 350 MHz**	**2 x 150 MHz**
Mid Band 1	**0.35 – 1.05 GHz**	**700 MHz**
Mid Band 2	**0.95 – 1.76 GHz**	**810 MHz**
Mid Band 3	1.65 – 3.05 GHz	1.4 GHz
Mid Band 4	2.80 – 5.18 GHz	2.4 GHz
Mid Band 5a	**4.6 – 8.5 GHz**	**3.9 GHz**
Mid Band 5b	**8.3 – 15.3 GHz**	**2 x 2.5 GHz**

65k channels maximum across any band, zoom windows possible with 16k channels

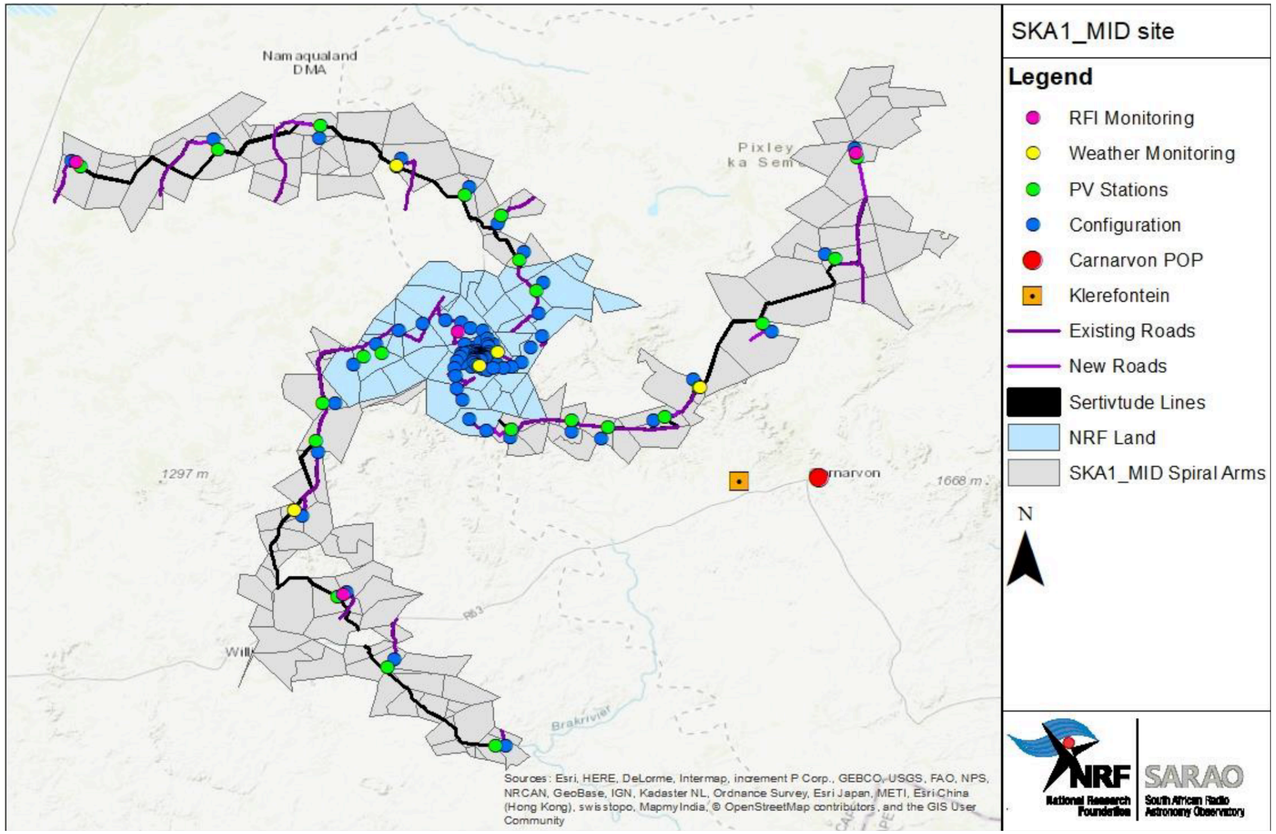
Future upgrades? (Observatory Development Programme)			
Mid Band “A”	1.6 – 5.2 GHz	2 x 2 GHz	Bands 3+4
Mid Band “B”	4.6 – 24 GHz	(2 x 2.5 GHz)	Bands 5+6
Mid Band 6	15 – (28) GHz	(2 x 2.5 GHz)	Band 7 27-50 GHz?

Dish and antenna designs

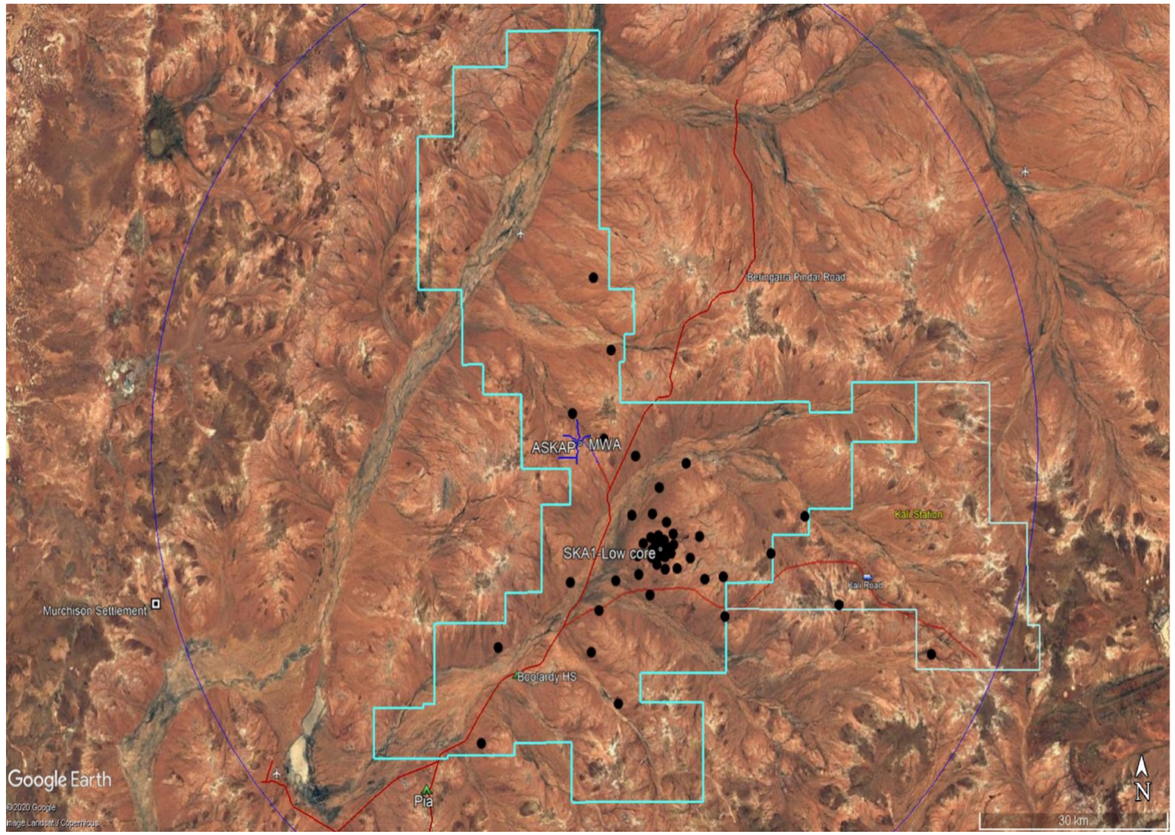


Array configurations in South Africa and Australia

SKA-Mid
150 km extent



SKA-Low
74 km extent



Construction Strategy

- Target: build the SKA Baseline Design (197 Mid dishes; 512 Low stations: AA4)
- Not all funding yet secured, therefore following Staged Delivery Plan (AA*)
- Develop the earliest possible working demonstration of the architecture and supply chain (AA0.5).
- Then maintain a continuously working and expanding facility that demonstrates the full performance capabilities of the SKA Design.

Milestone Event (earliest)		SKA-Mid (end date)	SKA-Low (end date)
AA0.5	4 dishes 6 stations	2024 Dec	2024 Aug
AA1	8 dishes 18 stations	2025 Nov	2025 Oct
AA2	64 dishes 64 stations	2026 Oct	2026 Sep
AA*	144 dishes 307 stations	2027 Aug	2028 Jan
Operations Readiness Review		2027 Nov	2028 Apr
End of Construction		2028 Jul	2028 Jul

- **Best argument for further investment is a working system!**

First science expected in 2026/27

Establishing SKAO in Australia and South Africa

- Staff in Australia: currently ~35, eventually ~150.
- Staff in South Africa: currently ~35, eventually ~150
- [Staff in UK: currently ~165, eventually ~175]

- Facilities in host countries:
  - Science Operations Centres (Perth, Cape Town)
  - Engineering Operations Centre (Geraldton, Klerefontein)
  - Australia only: Boolardy Accommodation Facility

Interim EOC Geraldton

- iEOC is a joint Construction and Operations supported facility
- Need to supplement initial facility
  - Lab, workshop, RFI meas. focused
  - Seeking 2nd office facility Q3 2023

Interim Engineering Operations Centre, Karoo

Construction Commencement Ceremony (05 Dec 22)

Telescope Access, based on contribution level

Key Science Projects (KSPs)

- Large programs (>500 h ?) performed over multiple cycles
- PI & leadership team from SKA-member countries; co-Is from any country (latter may be limited)

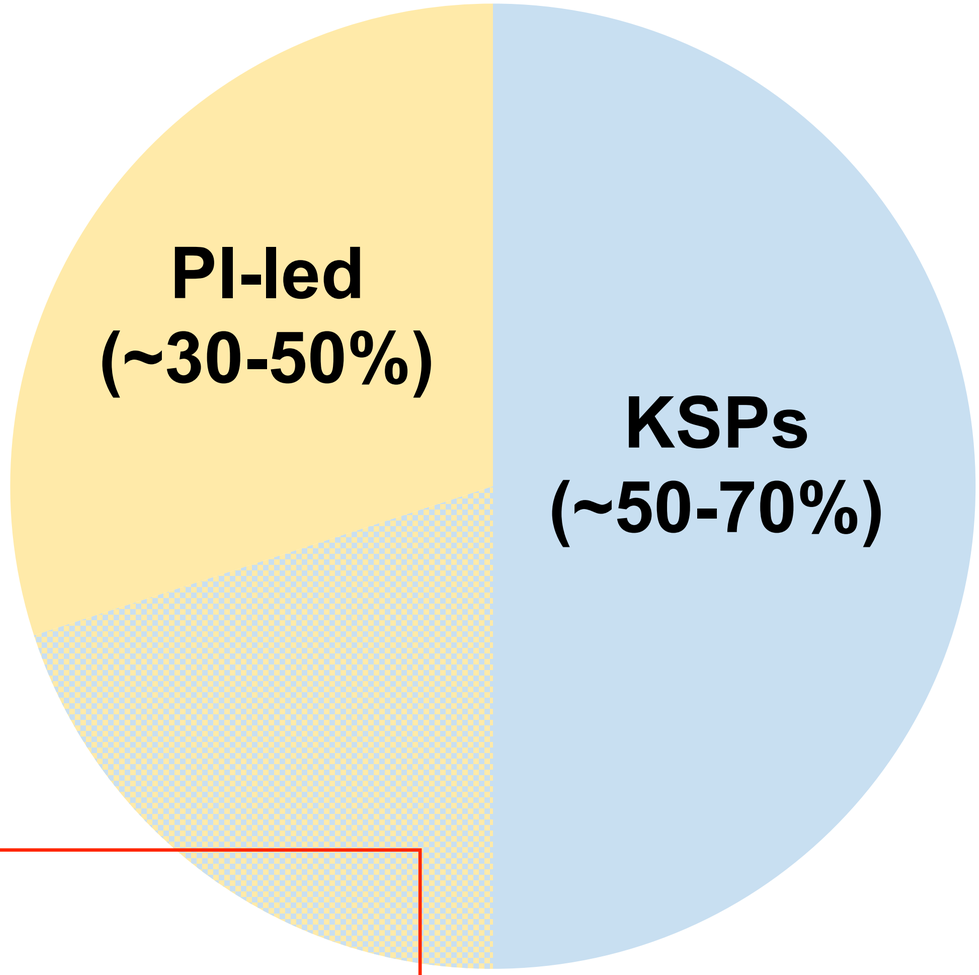
Principal Investigator (PI) Projects

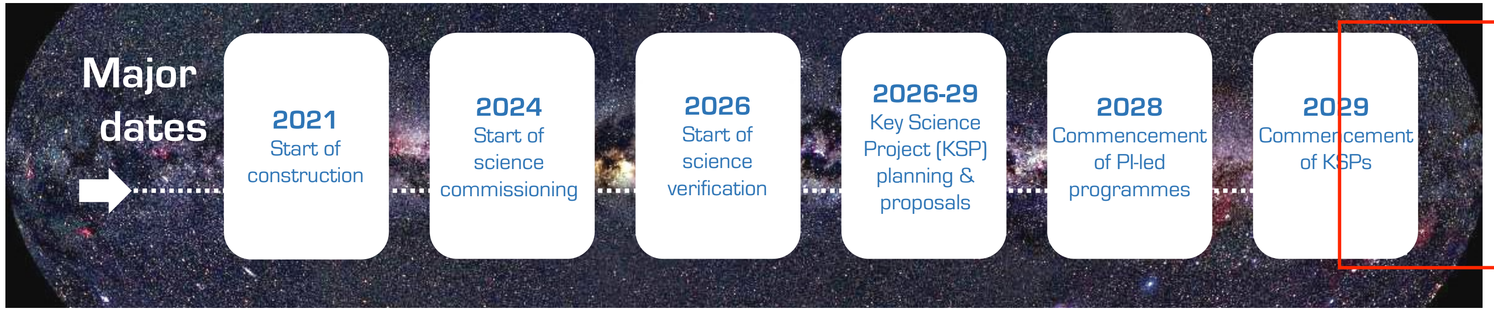
- Small programs (<500 h ?) performed within a single cycle

Director-General's Discretionary Time

- Time allocated by the D-G outside of the normal TAC process

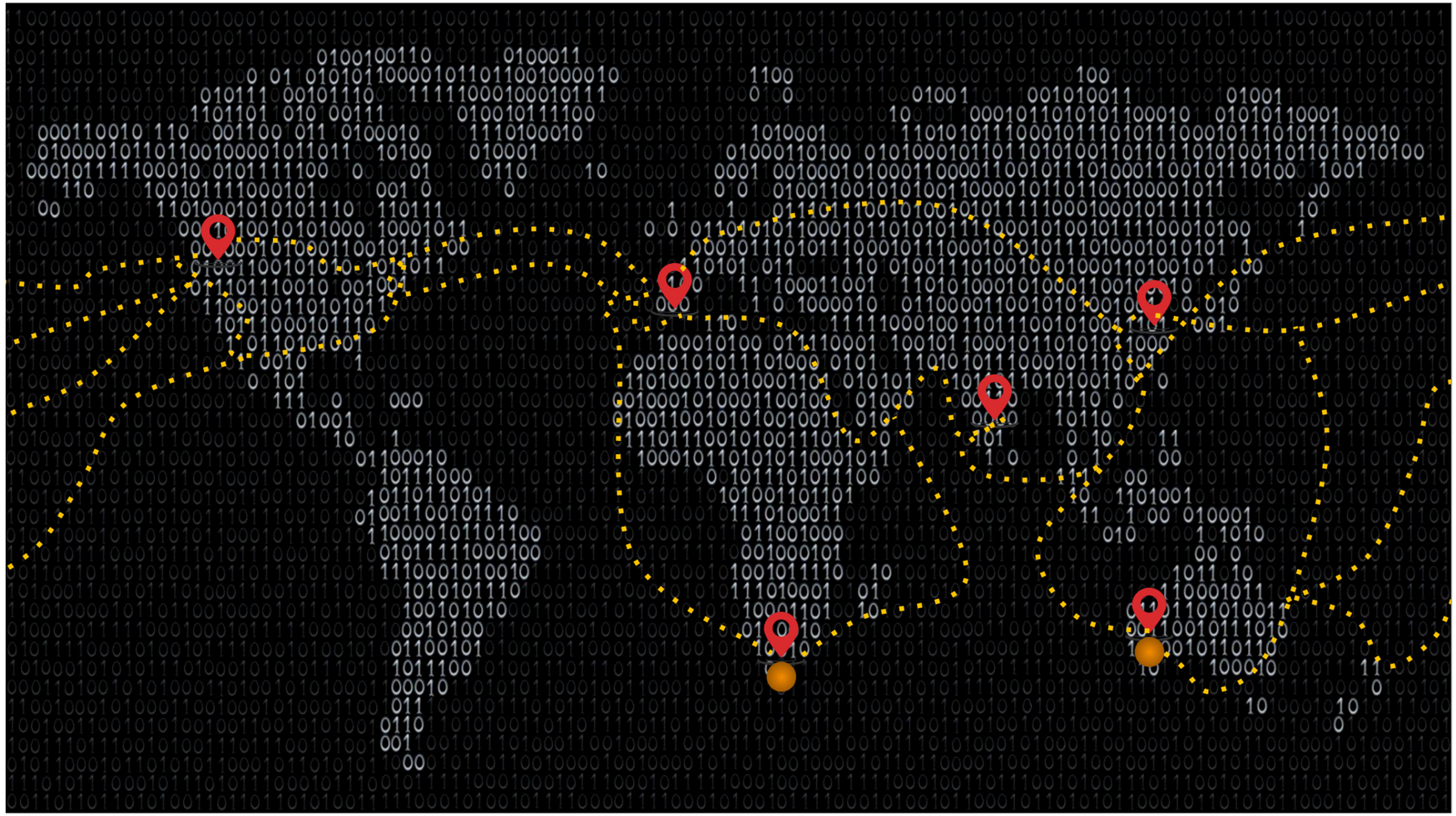
International time – fraction not yet determined





SKA Regional Centre Network

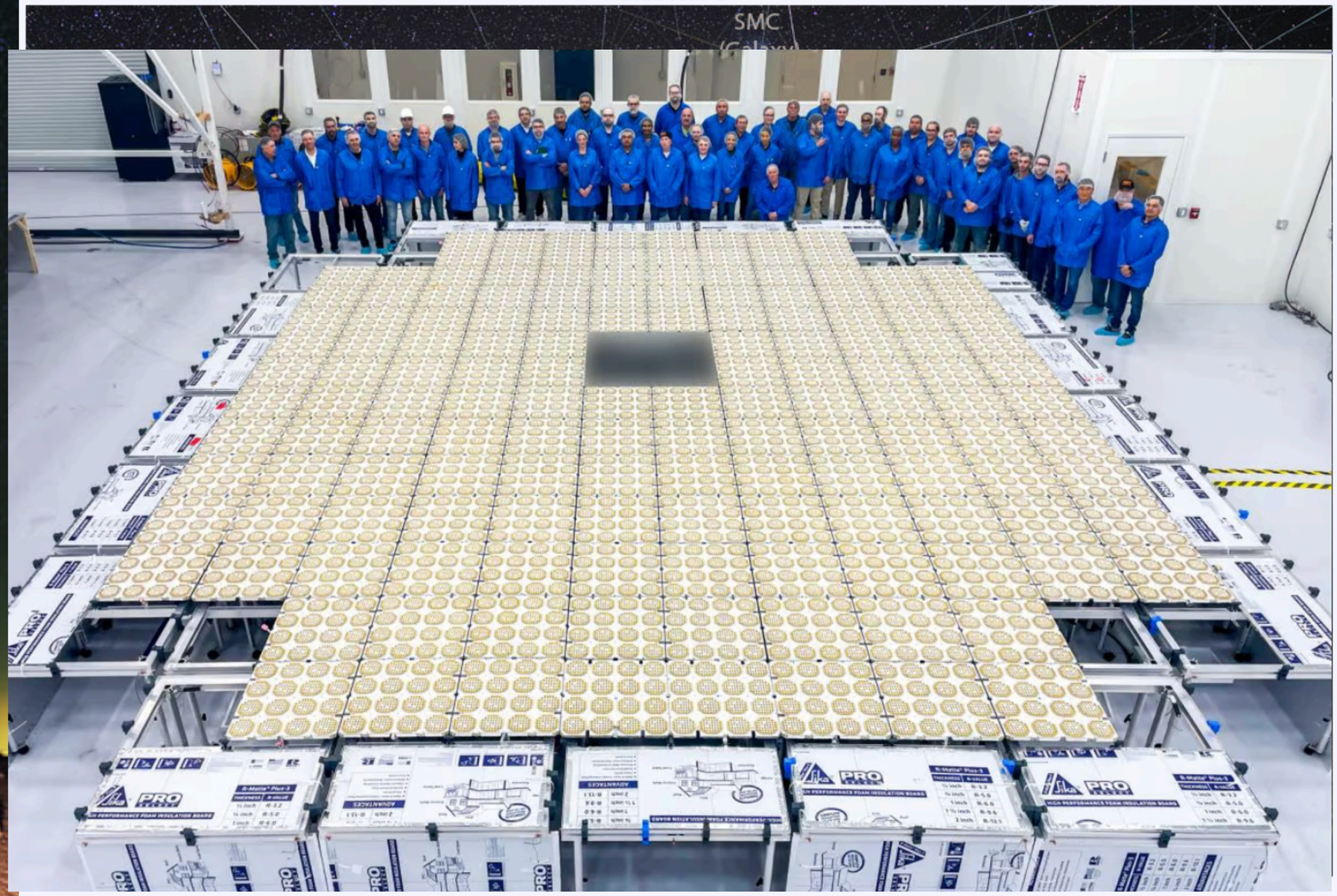
“To ensure that scientists can access SKA data products and use them to make discoveries"



Current key challenges

- Impact of external factors (inflation, labour shortages, supply chains) on construction costs and schedules: working with Council and member states to mitigate
- Pace of engagement in some of aspiring Member governments, potential for mis-alignment with the construction schedule.
- Spectrum management issues, especially those related to low-earth orbit mega-constellations.

2022 June 14



Satellites Behind Pinnacles
Image Credit & Copyright: Joshua Rozells

Address through:

- Work with satellite companies
- SKAO is a Sector Member of ITU
- SKAO is a permanent Observer in UN COPUOUS

- SKAO and US NOIRlab formed Centre for the Protection of Dark & Quiet Skies

Photo by: Trevor

Summary

- Level of risk for the project has increased due to the global situation; however, mitigations are planned and a clear strategy is in place;
- Construction activities are proceeding at pace;
- SKAO presence in the site host countries is a major positive milestone;
- SKAO science is now clearly on the horizon


NEW EYES
ON THE
UNIVERSE
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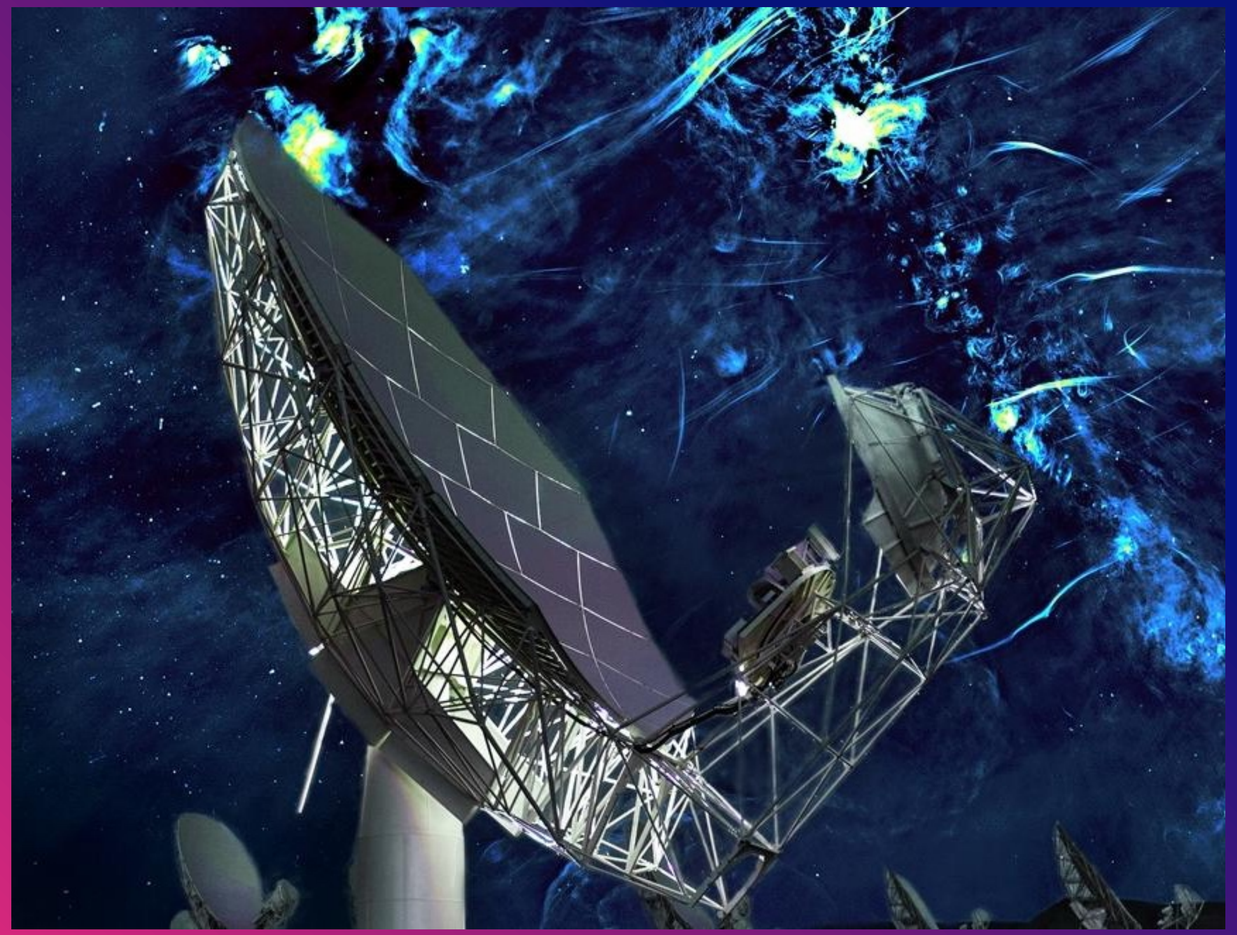
SKAO
ngvla
Next Generation Very Large Array



SKAO

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

www.skao.int