SKA-France & Developments in Africa

Dr. Chiara Ferrari
(SKA-France Director, Chair of European SKA Forum, OCA)
SKA at a glance

• A global collaboration to design, build and operate the next generation radio astronomy observatory

• A new Inter-Governmental Organisation for astronomy and fundamental physics with 50+ year lifetime

• It will consist of:
  - An array of ~200 dishes in ZA
  - An array of ~131000 antennas in AU
  - A global HQ in UK
  - Two data computing centres in ZA & AU + A worldwide network of SKA regional centres (SRC)

• SKA is now:
  - Q4/2020: IGO exists
  - Q2/2021: construction activity begins

C. Ferrari - Radio Fra-Tun 09/02/21

Courtesy: SKAO, H2020 AENEAS
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  - February 3-4, 2021: First SKA Observatory Council
  - Q2/2021: construction activity begins

“This is the culmination of many years of work by hundreds of people, whose talents and dedication are the driving force behind the SKA. That collective effort, guided with skill and efficiency by the safe hands of the SKA Office, has brought us to this point.”

Dr. Catherine Cesarsky
Chair of the SKA Board of Directors

Courtesy: SKAO, H2020 AENEAS
Development of the SKA project
SKA Phase 1 (SKA1)

SKA1-LOW (AUS)
130,000 log periodic antennas

SKA1-MID (SA)
197 dishes (15m)

- 50 MHz — 350 MHz — 15 GHz
The graph on the right shows the expenditure over the 10-year period, outlining construction capital cost, construction support, operations and business enabling functions, and the Observatory Development Programme cost.

The construction of SKA1 is estimated to cost €1.282 billion (June 2020). A further €0.704 billion (June 2020) will support the first 10 years of SKA Observatory operations.

The formal end of construction will be signified by a successful Operations Readiness Review (ORR). This review 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. This process confirms compliance to Level 0 requirements and the ability to execute high-priority science cases.

However, handover of the commissioned and verified system for scheduled observing will be gradual. It is expected that specific modes will be released in sequence, starting with basic (and commonly used) modes, and allowing particularly difficult and more esoteric modes to be added over time.

**Baseline schedule**

<table>
<thead>
<tr>
<th>Key project milestones</th>
<th>SKA-Low</th>
<th>SKA-Mid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of construction (T0)</td>
<td>1st July 2021</td>
<td>1st July 2021</td>
</tr>
<tr>
<td>Earliest start of major contracts (C0)</td>
<td>August 2021</td>
<td>August 2021</td>
</tr>
<tr>
<td>Array Assembly 0.5 finish (AA0.5)</td>
<td>February 2024</td>
<td>March 2024</td>
</tr>
<tr>
<td>SKA-Low = 6-station array</td>
<td></td>
<td></td>
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<tr>
<td>SKA-Mid = 4 stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array Assembly 1 finish (AA1)</td>
<td>February 2025</td>
<td>February 2025</td>
</tr>
<tr>
<td>SKA-Low = 18-station array</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKA-Mid = 8 stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array Assembly 2 finish (AA2)</td>
<td>February 2026</td>
<td>December 2025</td>
</tr>
<tr>
<td>SKA-Low = 64 stations</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKA-Mid = 64 stations, baselines mostly &lt;20km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Array Assembly 3 finish (AA3)</td>
<td>January 2027</td>
<td>September 2026</td>
</tr>
<tr>
<td>SKA-Low = 256-station array, including long baselines</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKA-Mid = 128-station array, including long baselines</td>
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<td></td>
</tr>
<tr>
<td>Array Assembly 4 finish (AA4)</td>
<td>November 2027</td>
<td>June 2027</td>
</tr>
<tr>
<td>SKA-Low = full Low array</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKA-Mid = full Mid array, including MeerKAT dishes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Readiness Review (ORR)</td>
<td>January 2028</td>
<td>December 2027</td>
</tr>
<tr>
<td>End of construction</td>
<td>July 2029</td>
<td>July 2029</td>
</tr>
</tbody>
</table>

Construction of the SKA telescopes will take eight years (including 18 months contingency), planned to begin in July 2021 following approval by the SKAO Council.
Development of the SKA project
Development of the SKA project
A Golden Age for Radio Astronomy

Some of the SKA Pathfinders

- NenuFAR
  - France
  - 10-85 MHz

- LOFAR
  - Europe
  - 30-80 MHz + 110-240 MHz

- CHIME
  - Canada
  - 400-800 MHz

- APERTIF
  - The Netherlands
  - 1 - 1.750 GHz

- JVLA
  - US
  - 1- 50 GHz

SKA Precursors

- MWA
  - Australia
  - 80 - 300 MHz

- ASKAP
  - Australia
  - 700 - 1800 MHz

- HERA
  - South Africa
  - 50 - 250 MHz

- MeerKAT
  - South Africa
  - 0.580 – 14 GHz

SKA

- SKA1-LOW
  - Australia
  - 50 MHz - 350 MHz

- SKA1-MID
  - South Africa
  - 350 MHz – 15.4 GHz
Why building the SKA?
Why building the SKA?

Figure 1:
Top Panels: SKA1 reference surveys in comparison with existing surveys and/or surveys planned for the next future with SKA pathfinders and precursors. LOFAR, VLASS and SKA1 reference surveys are highlighted in blue, orange and red respectively. Different symbols refer to different survey coverage: all-sky (filled circles); wide tiers (filled triangles); deep tiers (asterisks); ultra deep tiers (starred symbols).

Left: Depth (5σ flux limit) vs. frequency. Band 1 and/or 2 SKA surveys are all shown at a reference frequency of 1.4 GHz. The red and blue dashed lines indicate a slope of $\propto n^{-1}$ for different 1.4 GHz flux normalizations.

Right: Depth (5σ flux limit) vs. angular resolution. The black and brown lines represent approximate estimates of the confusion limit at 120 MHz and 1 GHz respectively (see Appendix for more details).

Bottom panel: SKA1 reference surveys in comparison with existing or planned surveys. Only surveys with observing frequencies in the range 1-3 GHz are shown. Area coverage vs depth (5σ flux limit); for 3 GHz VLA surveys the flux limit has been rescaled to 1.4 GHz.
Exploring the cosmos with the SKA

Cosmic dawn & Epoch of Reionisation
Cosmology
Galaxy evolution
Cosmic magnetism
Fundamental physics
Transient sky
Cradle of life
Solar, Heliospheric and Ionospheric Physics

Braun et al. 2015
With the JVLA on a 0.25 deg$^2$ field

With SKA1
- 400 deg$^2$
- 20 deg$^2$
- 1 deg$^2$

Staveley-Smith & Oosterloo 2015
Epoch of Reionisation and Cosmic Dawn

Courtesy: B. Semelin

Koopmans+ 15
Cosmic magnetism

Total intensity and polarisation of synchrotron radiation

Faraday Rotation

Faraday Tomography

Credit: Marijke Haerkorn
Pulsars

- Strongly self-gravitating compact bodies
- Very stable clocks

Test of gravitation theories

Astrophysics

Emission physics

Extreme magnetic fields

Binary & stellar evolution

Gravity

Supernova explosions

Super-dense matter

Figure 2: Artistic impression demonstrating the wide range of physics and astrophysics that finds its application when studying pulsars.
Synergies

- Epoch of Reionisation
- Star & Planet Formation
- Galaxy evolution as a function of redshift and environment
- The transient sky
- Gravitational wave Science
- Cosmology
The richest synergy chapter ever published about SKA vs. other projects, including:

- instruments covering the whole electromagnetic spectrum
- gravitational wave detectors

178 co-authors from
- 40 research institutes
- 6 private companies
SKA-France milestones

First SKA-France Day

October 16, 2017

SKA-France Coordination

July 1st, 2016
SKA-France milestones

February 1st, 2018

Kick-off meeting of Maison SKA-France
Mai 17, 2018

MESRI publishes the French Large Research Infrastructure Roadmap
CNRS approved as new member of SKAO by the SKA Board of Directors
November 15, 2019

Two new academic partners of Maison SKA-France
The French Ministry of Higher Education, Research and Innovation has announced that France is now engaged in the process of applying for membership in SKA Observatory.
Technology

8.8 Tb/s

7.2 Tb/s

~2 Pb/s

Beam-forming

Pulsar search & Correlation

50 PFLOPS

2 x 5 Tb/s

250 PFLOPS

Imaging & Science

350 PB/telescope/yr (could be a lot, lot, lot more)

SKA1-MID

SKA1-LOW

Callisto

CNIM

THALES

Air liquide

KALRAY

Bull

Inria
SKA contribution to a knowledge society

• SKA offers challenge and opportunities in terms of energy needs:
  o Reduction of the environmental impact associated with energy consumption of computing centre
  o Broader driver for the collaboration between Africa and Europe in the development of carbon-free energy system

• One of the “big science” Big Data projects driving the development of:
  o Open Science practices with much wider impact
  o Artificial Intelligence / Machine Learning-optimized exascale platforms
  o Networking and communication

• A lively collaboration between academia, society, research infrastructures and industry:
  o Acquired expertise in critical elements of the innovation sector (electricity supply, connectivity, IT, …)
  o Adaptability and capacity to produce novel solutions in emerging challenges
SKA contribution to a knowledge society

Open Science

Human capital development

Courtesy: MPIfR/Gundolf Wieching
Initial signatories of the SKA Observatory Convention

Human Capital Programmes