Square Kilometre Array:

Philip Diamond, Director-General

June 2019
21st Century Observatories

LIGO: operational

JWST: 2021

ALMA: operational

SKA: 2028

E-ELT: 2024

CTA: 2024

Radio waves  Microwaves  Infrared  Ultraviolet  X-rays  Gamma
SKA— Key Science Drivers: The history of the Universe

- Cosmic Dawn (First Stars and Galaxies)
- Galaxy Evolution (Normal Galaxies z~2-3)
- Cosmology (Dark Matter, Large Scale Structure)
- Cosmic Magnetism (Origin, Evolution)
- Cradle of Life (Planets, Molecules, SETI)
- Testing General Relativity (Strong Regime, Gravitational Waves)

Exploration of the Unknown

Brodest science range of any facility on or off the Earth.
The SKA Science Community

• ~900 researchers from around the world
SKA: A global Research Infrastructure

Potential Future Members

+.....

SKA Observatory will be established as an Intergovernmental Organisation in 2020, taking over from the SKA Organisation. It will undertake the construction and operation of the telescope.

As of March 2019, confirmed SKA Observatory members are

Exploring the Universe with the world’s largest radio telescope
Convention signing: 12 March, Rome
Establishing SKA Observatory, an IGO

Similar to ESO, CERN, ITER, ESA.....
Square Kilometre Array

3 sites; 2 telescopes + HQ
1 Observatory

Design Phase: ~ €200M; 600 scientists+engineers,
Now in final year

Phase 1
Construction: 2020 – 2027/8
MeerKat (South Africa) integrated
Cost cap: €691M (2017 Euros)

Phase 2
~2000 dishes across 3500km of Southern Africa
Major expansion of SKA1-Low across Western Australia
SKA: HQ in UK; telescopes in AUS & RSA

SKA1-LOW: 50 – 350 MHz
Phase 1: ~130,000 antennas across 65km

SKA1-Mid: 350 MHz – 24 GHz
Phase 1: 200 15-m dishes across 150 km
SKA1-Low: Array of Arrays

Antenna/Receptor

SKA1-Low "Station"

Antenna Beam

Station Beam

SKA1-Low "Array"

Correlation and Tied-array Beams
SKA1 – Low: Layout

- 512 aperture array stations
- Maximum baseline 65 km
- 3 modified spiral arms
SKA1 –Mid: Layout

- 133 SKA 15m dishes
- 64 MeerKAT 13.5m dishes
- Maximum baseline 150 km
- 3 logarithmic spiral arms
- ~ 50% within ~2 km randomly distributed
SKA1 Bands

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency Range</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>50 – 350 MHz</td>
<td>300 MHz</td>
</tr>
<tr>
<td>Mid Band 1</td>
<td>0.35 – 1.05 GHz</td>
<td>700 MHz</td>
</tr>
<tr>
<td>Mid Band 2</td>
<td>0.95 – 1.76 GHz</td>
<td>810 MHz</td>
</tr>
<tr>
<td>Mid Band 3</td>
<td>1.65 – 3.05 GHz</td>
<td>1.4 GHz</td>
</tr>
<tr>
<td>Mid Band 4</td>
<td>2.80 – 5.18 GHz</td>
<td>2.4 GHz</td>
</tr>
<tr>
<td>Mid Band 5a</td>
<td>4.6 – 8.5 GHz</td>
<td>3.9 GHz</td>
</tr>
<tr>
<td>Mid Band 5b</td>
<td>8.3 – 15.3 GHz</td>
<td>2 x 2.5 GHz</td>
</tr>
</tbody>
</table>

65,536 channels maximum across any band, zoom windows possible

Possible Wide-Band and/or High Frequency upgrade paths

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency Range</th>
<th>Bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mid Band A</td>
<td>1.6 – 5.2 GHz</td>
<td>2 x 2 GHz</td>
</tr>
<tr>
<td>Mid Band B</td>
<td>4.6 – 24 GHz</td>
<td>2 x 2.5 GHz</td>
</tr>
<tr>
<td>Mid Band 6</td>
<td>15 – 24 GHz</td>
<td>2 x 2.5 GHz</td>
</tr>
</tbody>
</table>
SKA HQ: Jodrell Bank, UK

€20M project; UK contribution

A ‘nexus for radio astronomy’
Precursor: MeerKAT in the Karoo: 64 dishes. Conducting early science
Precursor: Australian SKA Pathfinder; operational

MWA Phase 2: operational
Precursor: Australian SKA Pathfinder; operational

MWA Phase 2: operational

1.6MW solar/battery power station: operational
Hardware in South Africa

SKA-P2: Karoo (China/Germany/Italy), 24 April 2019
Hardware in Australia

AAVS1: AU/IT/NL/UK/CN
Computing Challenges (SKA1)

SKA-LOW

~2 Pb/s
7.2 Tb/s
8.8 Tb/s

SKA-MID

Global Traffic in 2020 ~500 Tb/s
~50 PFlops
~5 Tb/s (over 600 km)
@Perth
~250 PFlops
@Cape Town
~600 PB/yr

AWS, IBM, Google, Nvidia, SGI, Intel, ...

SKA Regional Centres
SKA Regional Centres (c.f. CERN Computing Grid)

Observatory Data Products flow from the Science Data Processors in Perth and Cape Town to SRCs around the globe
<table>
<thead>
<tr>
<th>Element</th>
<th>RRN Submission</th>
<th>CDR Submission</th>
<th>CDR Meeting</th>
<th>CDR Close</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM</td>
<td>29 January 2018</td>
<td>28 Feb 2018</td>
<td>17-20 Apr</td>
<td>14 Jul 2018</td>
</tr>
<tr>
<td>INAU</td>
<td>19 March 2018</td>
<td>30 April 2018</td>
<td>27-29 June 2018</td>
<td>Dec 2018</td>
</tr>
<tr>
<td>INSA</td>
<td>19 March 2018</td>
<td>30 April 2018</td>
<td>2-4 July 2018</td>
<td>Feb 2019</td>
</tr>
<tr>
<td>- PSS Element CDR</td>
<td></td>
<td>(includes LMC sub-element)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- PST Element CDR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CBF Low</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- CBF Mid</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MeerKAT Integration</td>
<td></td>
<td>22 Oct 2018</td>
<td></td>
<td>29 May 2019</td>
</tr>
<tr>
<td>SDP Pre-CDR SDP CDR</td>
<td>09 Mar 2018</td>
<td>25 Apr 2018</td>
<td>20-22 Jun 2018</td>
<td>02 May 2019</td>
</tr>
<tr>
<td></td>
<td>17 Sep 2018</td>
<td>31 Oct 2018</td>
<td>15-18 Jan 2019</td>
<td></td>
</tr>
<tr>
<td>LFAA re-planned</td>
<td>15 Oct 2018</td>
<td>05 Nov 2018</td>
<td>11-13 Dec 2018</td>
<td>30 Jun 2019</td>
</tr>
<tr>
<td>DSH Pre-CDR DSH CDR</td>
<td>17 Sep 2018</td>
<td>28 Sep 2018</td>
<td>26-27 Nov 2018</td>
<td>30 Jun 2019 (Pre)</td>
</tr>
<tr>
<td></td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
<td>TBD</td>
</tr>
<tr>
<td>System CDR</td>
<td></td>
<td>13 Sept 2019 (Internal)</td>
<td>9-12 Dec 2019</td>
<td>March 2020</td>
</tr>
</tbody>
</table>
SKA Science Advisory Groups

Science Working Groups (SWGs)

- Cradle of Life
- Cosmic Magnetism
- Cosmology
- Epoch of Reionisation & the Cosmic Dawn
- Extragalactic Continuum (+ Surveys)
- Extragalactic Spectral Line
- Gravitational Waves
- HI Galaxies
- Our Galaxy
- Pulsars
- Solar and Heliospheric Physics
- Transients (Exploration of the Unknown)
- (Gravitational Waves – currently forming)

Focus Groups

- High Energy Cosmic Particles
- VLBI [https://astronomers.skatelescope.org/science-working-groups/]
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Membership to SWGs is open to any actively publishing researcher with a science interest in SKA and willingness to contribute an appropriate level of effort toward SKA science needs as described below.

- open to researchers affiliated with both SKA-member and non-member nations.

Researchers can nominate themselves for membership by contacting the relevant SWG Chair or office project scientist. Each Science Working Group consists of two tiers of membership: Core members and Associate members.
SKA1 Science Milestones (Doc. 822)

- Science Commissioning: mid 2023
- Science Verification: 2026
- Shared Risk PI Observations: 2027
- PI Observations: 2028
- KSP Observations: 2029

Timeline:
- 2019
- 2020
- 2021
- 2022
- 2023
- 2024
- 2025
- 2026
- 2027
- 2028
- 2029
SKA1 Procurement

- Procurement model being decided **now**
  - Updated Work Breakdown Structure (WBS) and Cost Book under development
  - Work-packages will be identified as suitable for in-kind contribution
  - Model will be a hybrid of in-kind + cash procurement
  - All contributors can expect ~70% Fair Work Return

- Country needs to be a Member of SKA Observatory to gain maximum benefit as SKA Observatory issues Call for Tender and, in some cases, allocates work.
Timeline

- **2018**: Design Phase
- **2019**: System CDR
- **2020**: Construction Proposal to Council
- **2021**: SKA Observatory Operational
- **2022**: Procurement phase
- **2023**: Construction SKA1

- **Convention Signing (7 States)**
- **Original signatories ratify**
- **SKA Observatory Council 1st Meeting**
- **New Members/AM’s join and ratify**
- **SKA Observatory IGO**
Leveraging international conferences...

• EWASS 2019 (Lyon, France):
  • Jean-Paul Kneib as invited speaker for SKA session
  • SKA booth: Visit us and make it your home!

• WCSJ 2019 (Lausanne):
  • 100s of sci. journos from around the world!
  • Presence of key stakeholders from EC (sponsor), int’l RIs, Swiss gvt, etc.: high-level event in Switzerland
  • SKA booth: great opportunity to feature Swiss involvement in SKA! Feel free to join us! (contact DirCom)