The Square Kilometre Array:
Concluding our past, realising our future

Philip Diamond, Director-General
25th November 2019
International effort to build the World’s largest radio telescope
Prime Motivation: Study the history of the Universe in Hydrogen
Will enable transformational science in many other areas
SKA—Key Science Drivers: The history of the Universe

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

Extremely broad range of science!
Science Drivers and Requirements

Cradle of Life
- Understand how rocky planets form
- Understand the origins of life
- Understand exoplanet characteristics

Cosmology and the Cosmic Dawn/EOR
- Understand the first 700 M years of the universe
- Understand when the first stars formed

Evolution of Galaxies
- Understand how galaxies replenish their gas
- Understand the relationship between HI and AGN

Strong-field tests of gravity; transient radio sky
- Understand gravity in extreme environments
- Understand multi-messenger astrophysics

Exploring the unknown
- Open new radio science windows
- Provide next generation radio telescope

High Spatial, Spectral & Temporal Resolution

Imaging Sensitivity, Speed

Polarimetry

Broad Frequency Coverage
SKA Phase 1

3 sites (AUS, RSA, UK-HQ)  2 telescopes (LOW, MID)  one Observatory (SKAO)
Construction: 2021-2027 (Science commissioning 2023+)

SKA1-Low: 512 x 256 low-freq dipoles, 50 - 350 MHz
65 km baselines (11" @ 110 MHz)
Murchison, Western Australia

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

MeerKAT
Precursor Telescopes

Operational

Operational

In construction

Operational

Exploring the Universe with the world's largest radio telescope
SKA HQ: Jodrell Bank, UK

€20M project: a UK contribution

A ‘nexus for radio astronomy’
SKA1 Anticipated Sensitivity

- Improved performance predictions now available at all frequencies
- Opportunity for seamless interface of SKA to ALMA capabilities
## SKA1 Design Baseline Cost

<table>
<thead>
<tr>
<th>Design Baseline</th>
<th>October 2019 snapshot</th>
<th>Provided through annual contributions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Value (€M) (Dec 2017 euros)</strong></td>
<td>Capital cost of construction (€M)</td>
<td>Construction Support Budget (€M)</td>
<td>Observatory Operations &amp; Business-Enabling Functions (€M)</td>
</tr>
<tr>
<td><strong>1697</strong></td>
<td><strong>(760 + 180) = 940</strong></td>
<td><strong>(140 + 26) = 166</strong></td>
<td><strong>591</strong></td>
</tr>
</tbody>
</table>
A little history
Previous meetings

- Oct 2013: Manchester, UK
- Sept/Oct 2014: Fremantle, AU
- Nov 2015: Penticton, CA
- Oct 2016: Stellenbosch, ZA
- June 2017, Rotterdam, NL
- Nov 2019, Shanghai, CN

- Jul 2013: Cost Cap
- Oct 2013: Consortia kick-off
- Q4 2014/Q1 2015: re-baselining
- PDRs
- Cost Control
- CDRs
- System CDR
Status
Treaty signing: Rome, 12 March 2019

19 August: NL ratified

14 October: AU Joint Standing Committee On Treaties discussing.

12 November: ZA National Assembly approves Convention.

Progressing well in other countries.

Expected Entry-into-force: May 2020.

Similar to ESO, CERN, ITER, ESA......
System Critical Design Review
System CDR

Events

- 13 September 2019:
  - Internal publication of CDR documentation

- 21 October 2019:
  - Publication of CDR documentation
  - Kick-off teleconference

- 19 November 2019
  - OAR status update/draft agenda

- 09-12 December 2019:
  - CDR Meeting

- March 2020: Target CDR closeout
Document Tree (CDR Reading Guide)

- 4 Overview documents under review
- 32 System Documents under review
- 90 System design reference documents
- 2000+ Underlying Element documents
Examples of System Artefacts

- Functional
- Networking
- Power
- Timing and frequency
- Verification
Many more…. 

Risk Management
Organisation
WBS and cost book
Systems Engineering
Schedule
# Construction Schedule

<table>
<thead>
<tr>
<th>Key project milestone</th>
<th>Designation</th>
<th>LOW Telescope</th>
<th>MID Telescope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of construction</td>
<td>T0</td>
<td>1st January 2021</td>
<td>1st January 2021</td>
</tr>
<tr>
<td>Earliest start of major contracts</td>
<td>C0</td>
<td>1st July 2021</td>
<td>1st July 2021</td>
</tr>
<tr>
<td>Integrated Test Facility Qualification Event finish</td>
<td>ITF-QE Fin</td>
<td>January 2024</td>
<td>December 2023</td>
</tr>
<tr>
<td>Array Assembly 1 finish</td>
<td>AA1</td>
<td>September 2024</td>
<td>December 2024</td>
</tr>
<tr>
<td>Array Assembly 2 finish</td>
<td>AA2</td>
<td>October 2025</td>
<td>January 2026</td>
</tr>
<tr>
<td>Array Assembly 3 finish</td>
<td>AA3</td>
<td>September 2026</td>
<td>October 2026</td>
</tr>
<tr>
<td>Array Assembly 4 finish</td>
<td>AA4</td>
<td>July 2027</td>
<td>July 2027</td>
</tr>
<tr>
<td>Operations Acceptance Review</td>
<td>OAR</td>
<td>September 2027</td>
<td>September 2027</td>
</tr>
<tr>
<td>End of Construction</td>
<td></td>
<td>September 2028</td>
<td>September 2028</td>
</tr>
</tbody>
</table>
Planning for Operations
Summary

- Staffing profile projected for 10-year period from 2021-2030 from Construction and into the Operations phase

<table>
<thead>
<tr>
<th>Location</th>
<th>CONSTRUCTION PHASE</th>
<th>OPERATIONS PHASE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2021</td>
<td>2022</td>
</tr>
<tr>
<td>GHQ</td>
<td>141.1</td>
<td>145.6</td>
</tr>
<tr>
<td>AUS</td>
<td>21</td>
<td>35</td>
</tr>
<tr>
<td>RSA</td>
<td>20.5</td>
<td>39.5</td>
</tr>
<tr>
<td>TOTAL</td>
<td>182.6</td>
<td>220.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Item</th>
<th>Total (€M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOW Power</td>
<td>11.8</td>
</tr>
<tr>
<td>MID Power</td>
<td>6.3</td>
</tr>
<tr>
<td>Data Transport</td>
<td>6.2</td>
</tr>
<tr>
<td>Mid O&amp;M</td>
<td>6.1</td>
</tr>
<tr>
<td>LOW O&amp;M</td>
<td>6.0</td>
</tr>
<tr>
<td>Staff travel</td>
<td>4.2</td>
</tr>
<tr>
<td>DG Contingency</td>
<td>2.5</td>
</tr>
<tr>
<td>MID Running</td>
<td>2.5</td>
</tr>
<tr>
<td>LOW Running</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Review process

• Review timetable for further revisions of the Operations Plan

<table>
<thead>
<tr>
<th>2019</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q1</td>
</tr>
<tr>
<td>Q2</td>
<td>Q2</td>
</tr>
<tr>
<td>Q3</td>
<td>Q3</td>
</tr>
<tr>
<td>Q4</td>
<td>Q4</td>
</tr>
<tr>
<td>BD-30</td>
<td></td>
</tr>
</tbody>
</table>

- System CDR
- IGO
- OP Rev04 Submission to Observatory Council
- OP Rev03 External Review
- OP Rev02 Review by SEAC
- OP Rev01 BD-29

• External review panel:
  • Andreas Kaufer (ESO, Chair)
  • Stuartt Corder (ALMA)
  • Claire Chandler (NRAO)
  • Doug Simons (CFHT)
SKA Data
SKA Data Flow Challenge

Low Central Signal Processor

~7 Tb/s

Few km

800 km

Perth Supercomputer

~5 Tb/s

Mid Central Signal Processor

~8 Tb/s

Few km

~5 Tb/s

Cape Town Supercomputer

600 km

130 Pflops

600 PB/yr

130 Pflops

Exploring the Universe with the world’s largest radio telescope

Colloquium - December 2018
SKA Data Flow Challenge: SKA Regional Centres

600 PB/yr

LOFAR
23PB

Uploads to Google
100PB

Uploads to Facebook
180PB

SKA Phase1 Science Archive
600PB
Deployment Baseline Definition

Current cost estimate: €940M

Cost cap: €691M

Funding available: under discussion
Process of Definition

- Build on 2017 community endorsed Cost Control Process
- Now: updating cost estimates for elements in ‘descope ladder’
- Now: explore other options for potential savings
  - (e.g. SKALA4.1 antennas 20% better than requirement; explore consortia cost-saving ideas; further explore phasing options, ….)
- Dec/Jan: engagement with SWGs
- February: Board meeting to establish single cost goal for deployment baseline and ‘appetite for risk’
- April: definition of deployment baseline, communication with Board
- Late April: three Information sessions with science community
- May: Gateway Cost Audit using engineering consultants
- May: Advanced drafts of construction proposal, operations plan etc shared with the Board (BD-32)
Next Science Meeting

- 2020 SKA Science Meeting and KSP Workshop, 7 – 11 September
  - Stellenbosch University
  - Up to 350 participants
  - Title: “The Precursor View of the SKA Sky”

Photo Credit: Jefri Tamba 2018
Timeline

• Q1 2019: Treaty signing

• Q4 2019: System CDR (Dec 9-12)

• Q2 2020: SKA Observatory exists, post ratification
  • 1st SKA Observatory Council Meeting (23-24 June 2020)

• Q3 2020: Construction and operations proposal submitted to SKAO Council, after approval by the SKA Board

• November 2020: SKA Observatory Council to approve start of construction
• December 2020: formal transition of staff from SKA Org to SKA Obs

• Q1 2021: Construction activity begins

• Q3 2024/5: Science Commissioning starts, community involved

• 2027/8: SKA1 construction complete
This meeting

• Presenting SKA System Design
• First community view on SKA Operations, Commissioning Plan and SKA Regional Centres
  • Seeking your input on how we can improve our plans
  • Seeking your input on how the community will be access SKA data through the SRCs

• Momentum in SKA excellent
• Schedule has accelerated
• Excellent mood emerging from Board/CPTF meetings last week
SKA shakes hands with SUMMIT (200 Pflops)

• The largest workflow of the SKA, even astronomy, successfully executed on the fastest supercomputer SUMMIT, simulating the EoR using the SKA1-low configuration

• The peak ingest data rate 400Gbps is on the same scale of the SDP, which will have a peak of 5 Tbps
  • This is a single observation of 6 hours; compared with multiple tasks streaming into the SDP

• A maximum of 4560 compute nodes (98% of SUMMIT) was used – SKA big data challenge!

• This experiment shows astronomers can handle SKA data processing (see demonstration in the afternoon coffee time)
Keynote speech at Huawei Connect Sept 2019

Showed movie from SHAO of Atlas900 256Pflop distributed computer analyzing MWA GLEAM survey in 10.02 seconds