The Square Kilometre Array:
Timeline to SKA Phase 1, Key Science Projects, and UK involvement

An overview talk prepared by the UKSKASC
May 2015
The Square Kilometre Array (SKA)

The SKA is a next-generation radio interferometer:

• 3 telescopes, on 2 sites
• Collecting area > 5 km² on baselines up to 3000 km
• Frequency range 50MHz - 14GHz
• Expected cost: >1.5 billion Euros

Compared to current instruments, SKA will be:

• ~100x more sensitive
• ~10⁶x faster surveying the sky

SKA uses innovative technologies
• Major ICT project...

SKA-Mid: ~ 2500 15m dishes, South Africa
SKA-Low: 2-3 million low-freq. antennas: Australia
Mid-freq. aperture array: ~ 250 60m arrays, South Africa
SKA Phase 1

SKA Phase-1 is the first phase of the SKA project:

- builds on technologies of “precursors”, ASKAP, MeerKAT & MWA, along with “pathfinders” such as LOFAR, eMERLIN, eEVN

SKA Phase 1 has an agreed budget cap of €650 million

- UK contribution: £100M. UK role ~18-19%

Original baseline design didn’t fit within the budget cap

- a ‘re-baselining’ process went on during 2014/15
  - Science Working Groups developed high-priority science cases
  - SKA project office + Science Review Panel (SRP) rated these
  - SKA project office costed various new baseline options
  - SRP assessed impact of each of these on high-priority science
  - Science & Engineering Advisory Panel assessed project risks
  - SKA Board considered advice and approved new baseline design
New baseline SKA Phase 1

SKA Phase 1 baseline design:

- **SKA1-Mid (South Africa)**
  - 200 15m dishes (inc. 64 MeerKAT dishes)
  - Three frequency bands:
    - Band 1: 350-1050 MHz
    - Band 2: 950-1760 MHz
    - Band 5: 4600-13800 MHz
  - Maximum baseline ~150 km

- **SKA1-Low (Australia)**
  - 130,000 low-frequency antennas
  - 50MHz – 350 MHz
  - Max. baseline 65km

- **Construction 2018-2022**
- **Early science from ~2020**
SKA Sensitivity

SKA1 raw sensitivity ($A_{\text{eff}}/T_{\text{sys}}$):

- At low frequency
  - SKA1-Low: ~8 x LOFAR
- At high frequency
  - SKA1-Mid: ~5 x JVLA

SKA1 survey speed:

- At low frequency
  - SKA1-Low: ~135 x LOFAR
- At high frequency
  - SKA1-Mid: ~60 x JVLA

SKA Phase 2 will be 1-3 orders of magnitude higher still.
SKA Timeline

Critical steps on the timeline to SKA are:

• 2012: Site decision made
• 2013-2016: Pre-construction: detailed design
  – 11 technical work packages
  – Worked on by project office and international consortia
• March 2015: SKA Phase 1 baseline design finalised
• 2015-2018: Establishment of Key Science Projects
• 2016-2017: Ratification of agreements
• 2018-2022: SKA Phase 1 construction
  – early science exploitation from ~2020
• 2022-2028 SKA Phase 2 (full SKA) construction
SKA Science

SKA will tackle an exceptionally wide range of science:

- Neutral hydrogen in the universe from cosmic dawn until now
- Evolution of galaxies; AGN; dark matter; dark energy
- Star formation and the cradle of life
- Fundamental forces: pulsars, general relativity, gravitational waves
- Origin and evolution of cosmic magnetism
- Transients: new phenomena

There are currently 10 Science Working Groups (SWGs) within SKA with one further SWGs in the process of being set up.

- see following slides for a summary of each, and UK contacts
- these are not closed shops: anyone can request to join
  - members are actively involved in developing and shaping SKA1
- these are not (proto) key science projects
- Scope for lots more science that falls outside these SWGs
Science Working Groups

Epoch of Reionisation / Cosmic Dawn
- Key Science Goal: map neutral hydrogen in intergalactic medium at z=6-27 (Universe 100Myr-1Gyr old)
  - UK contact: Jonathan Pritchard (Imperial; SWG Chair)

Fundamental Physics with Pulsars
- Key Science Goals: identify and use pulsars for strong-field tests of gravity, and gravitational wave detection
  - UK contact: Ben Stappers (Manchester; SWG Co-Chair)

HI and Galaxy Evolution
- Key Science Goals: resolved studies of HI emission in and around galaxies out to z~1 (lookback time ~8Gyr)
  - UK contact: Steve Eales (Cardiff)
Science Working Groups

Cradle of Life
• Key Science Goal: How do planets like Earth form and nurture life?
  – UK contact: Melvin Hoare (Leeds; previous SWG Chair)

Cosmology
• Key Science Goal: high precision tests of cosmological models
  – UK contact: Filipe Abdalla (UCL) (+ others)

Radio Transients
• Key Science Goals: Extreme astrophysics: stellar explosions, black holes and neutron stars.
  – UK contact: Rob Fender (Oxford; previous SWG Chair)
Science Working Groups

Cosmic Magnetism

- Key Science Goal: Understand the origin, evolution and influence of cosmic magnetic fields
  - UK contact: Anna Scaife (Manchester)

Continuum Surveys

- Key Science Goals: Cosmic history of star formation & black hole accretion
  - UK contact: Matt Jarvis (Oxford) (+ others)

Extragalactic Spectral Line

- Key Science Goals: (non-HI) extragalactic spectral line studies
  - UK contact: Rob Beswick (Manchester; SWG coordinator)
Science Working Groups

The Milky Way Galaxy

- Key Science Goals: studies of Milky Way ISM and molecular clouds; nearby clusters; star-forming regions;
  - UK contact: Mark Thompson (Hertfordshire; SWG Co-chair)

There is one other proto-science working group in the process of being formalised

- Solar Physics

Other science working groups may be established in the future, e.g. particle ray astrophysics.

For more information on SKA Science Working Groups see https://www.skatelescope.org/swg-terms-of-reference/
Key Science Projects

The SKA Board has approved the development of Key Science Projects for SKA Phase 1

• In total, between 50 and 70% of the observing time on SKA-1 over a 5-yr period is expected to dedicated to KSPs

Key Science Projects should satisfy one or more of:

• substantially address key science objectives identified for SKA-1
• require large allocations (>1000 hr) over 1-5 years
• require substantial dedicated or customised observatory resources

Current plan is that observatory will define a list of notional KSPs, but prospective KSP teams will self-organise and propose specific projects, and these proposals will be reviewed.

• KSP PIs and membership are expected to be balanced across member states in accordance with member contributions
“SKA Phase 1 Key Science Goals”

As part of the “re-baselining” procedure to finalise the Phase 1 SKA design, 13 key science goals were identified by the Science Review Panel, in combination with the SWGs.

- This is effectively a first-draft list of the “notional KSPs”

<table>
<thead>
<tr>
<th>Science Goal</th>
<th>SWG</th>
<th>Objective</th>
<th>SWG Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CD/EoR</td>
<td>Physics of the early universe IGM - I. Imaging</td>
<td>1/3</td>
</tr>
<tr>
<td>2</td>
<td>CD/EoR</td>
<td>Physics of the early universe IGM - II. Power spectrum</td>
<td>2/3</td>
</tr>
<tr>
<td>4</td>
<td>Pulsars</td>
<td>Reveal pulsar population and MSPs for gravity tests and Gravitational Wave detection</td>
<td>1/3</td>
</tr>
<tr>
<td>5</td>
<td>Pulsars</td>
<td>High precision timing for testing gravity and GW detection</td>
<td>1/3</td>
</tr>
<tr>
<td>13</td>
<td>HI</td>
<td>Resolved HI kinematics and morphology of $\sim10^{10} \text{M}_{\odot}$ mass galaxies out to $z\sim0.8$</td>
<td>1/3</td>
</tr>
<tr>
<td>14</td>
<td>HI</td>
<td>High spatial resolution studies of the ISM in the nearby Universe.</td>
<td>2/5</td>
</tr>
<tr>
<td>15</td>
<td>HI</td>
<td>Multi-resolution mapping studies of the ISM in our Galaxy</td>
<td>3/5</td>
</tr>
<tr>
<td>18</td>
<td>Transients</td>
<td>Solve missing baryon problem at $z\sim2$ and determine the Dark Energy Equation of State</td>
<td>=1/4</td>
</tr>
<tr>
<td>22</td>
<td>Cradle of Life</td>
<td>Map dust grain growth in the terrestrial planet forming zones at a distance of 100 pc</td>
<td>1/5</td>
</tr>
<tr>
<td>27</td>
<td>Magnetism</td>
<td>The resolved all-Sky characterisation of the interstellar and intergalactic magnetic fields</td>
<td>1/5</td>
</tr>
<tr>
<td>32</td>
<td>Cosmology</td>
<td>Constraints on primordial non-Gaussianity and tests of gravity on super-horizon scales</td>
<td>1/5</td>
</tr>
<tr>
<td>33</td>
<td>Cosmology</td>
<td>Angular correlation functions to probe non-Gaussianity and the matter dipole</td>
<td>2/5</td>
</tr>
<tr>
<td>37 + 38</td>
<td>Continuum</td>
<td>Star formation history of the Universe (SFHU) – I+II. Non-thermal &amp; Thermal processes</td>
<td>1+2/8</td>
</tr>
</tbody>
</table>

Table 2. List of highest priority SKA1 science objectives, grouped by SWG, but otherwise in arbitrary order.
Key Science Projects

The details of KSPs will be established over a series of meetings from 2015-2017, beginning at:

• Stockholm meeting, 24-27 Aug 2015

The aims of these meetings are to:

• Further develop KSP concepts, and review the first-draft notional KSP list developed in the re-baselining process.

• Support development of potential KSP collaborations

• Maximise potential for commensality of observations
  – to achieve all key science in a 5-yr period, the same observations will need to serve multiple KSP groups, each with limited data rights for specific science objectives.

Attendance of this, or any other, KSP workshop is not a pre-requisite for KSP participation or leadership.
Input to Stockholm Meeting

Registration for the Stockholm meeting is now closed, but if you wish to input views you can pass them to any attendee:

- Participants listed online:

- In particular, 4 members of UK SKA Science Committee will be attending and are happy to pass on views of UK interest
  - Mark Birkinshaw (Bristol)
  - Jonathan Pritchard (Imperial)
  - Anna Scaife (Manchester)
  - Mark Thompson (Hertfordshire)
Global SKA Structures

Current country members:
- Australia
- Canada
- China
- Germany (until 06/15)
- India
- Italy
- Netherlands
- New Zealand
- South Africa
- Sweden
- UK
- Others joining soon…
# Pre-construction Work Packages

1. System
2. Science
3. Maintenance and support /Operations Plan
4. Site preparation
5. Dishes

<table>
<thead>
<tr>
<th>6. Aperture arrays</th>
<th>ASTRON (lead), UK, Itals, ICRAR (Aus)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Signal transport</td>
<td>UK (lead)</td>
</tr>
<tr>
<td>8. Data networks</td>
<td>UK (lead)</td>
</tr>
<tr>
<td>9. Signal processing</td>
<td>Canada (lead) UK</td>
</tr>
<tr>
<td>10. Science Data Processor</td>
<td>UK (lead), AU (CSIRO ), NL (ASTRON ) South Africa SKA, Industry (Intel, IBM )</td>
</tr>
<tr>
<td>11. Monitor and Control</td>
<td></td>
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<tr>
<td>12. Power</td>
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</table>
SKA Headquarters

SKA Headquarters have been located at Jodrell Bank during the development phase. Recent board decision is that they will remain there during the operational phase:

• Secures UK involvement
• UK will lead inter-governmental negotiations
• UK SKA efforts coordinated by (UK) SKA Programme Board
  - aligned with stakeholders: BIS, SKA Board, University of Manchester.
UK SKA Structures

UK SKA Board Members
John Womersley (STFC)
Paul Alexander (Cambridge)

UK SKA Programme Board
(BIS, UK PIs, Univ. Manc, Board Members, Committee Chairs)

UK SKA Industrial Committee
UK Industry Community

UK SKA Oversight Committee
5 Universities + National labs

UK SKA Science Committee
UK Science Community
UKSKASC

The UK SKA Science Committee has been established to:

• engage the UK science community
• provide a platform for discussion and dissemination of critical SKA science issues
• collate, summarise and present the views of the UK Science Community to the UK SKA board members

See our webpage at:

• http://www.stfc.ac.uk/ukskasc
  – contains useful science links to SKA documents & descriptions
  – contains list of UKSKASC members

Next community meeting:

• Manchester, on 4th November 2015
  – more details and registration form on UKSKASC webpage soon
How to get involved / Having a voice

You can get involved in SKA now, and input your views:

• Through the Science Working Groups:

• By getting involved in the development of Key Science Projects
  – too late now for the August Stockholm meeting, but this is only the first of several planned meetings so keep an eye open for more

• By passing your views through your the SKA contact person at your institute, or any member of the UKSKASC
  – UKSKASC chair is Philip Best (Edinburgh); pnb@roe.ac.uk

• By coming along to UK SKA Community Meetings
  – next one in Manchester on 4th November 2015
  – see www.stfc.ac.uk/ukskasc for more info & to register
Summary

• The SKA will be an extremely powerful facility for an exceptionally broad-range of science.

• SKA Phase 1 will be built on a timescale of 2018-2022

• The first stages of designing Key Science Projects are just beginning: these will be widely open, so please get involved

• You can find out more, and input your views, by coming along to the forthcoming UK SKA Community Meeting
  – Manchester, 4/11/2015
  – see www.stfc.ac.uk/ukskasc for more information / registration