SKA Developments

Richard Schilizzi
SPDO

SKADS Conference, 4 November 2009
The SKA

- The SKA is a large radio interferometer with 5 key science drivers and a very wide range of science impact

- It comprises
  - a number of sensor types spread over 1000s of km
  - covering the frequency range from 70 MHz to at least 25 GHz
  - connected to a signal processor and high performance computing system by an optical fibre network

- It is a global program involving more than 50 institutes in 20 countries
  coordinated by the SKA Science and Engineering Committee (SSEC) and the SKA Program Development Office (SPDO)
### SKA: prime characteristics

1. **very large collecting area (km$^2$)** → sensitivity to detect and image hydrogen in the early universe
   - *sensitivity* ~ $50 \times$ EVLA, LOFAR

2. **very large field of view** → fast surveying capability over the whole sky
   - *survey speed*, up to one million times faster than EVLA

3. **wide frequency range required for the key science projects**
   - SKA-low: 70-300 MHz
   - SKA-mid: 300 MHz-10 GHz
   - SKA-high: 10-25+ GHz

4. **large physical extent (3000+ km)** → capability for detailed imaging of compact objects, and astrometry with sub milli-arcsec angular resolution
Possible telescope configuration

Central Processing Facility

Communications links + power

Receptors in stations along spiral arms

Dense aperture arrays

Remote stations to >3000 km

1500 dishes (15m diameter) in central ~5 km

+1500 from 5 km to 3000+ km

Sparse aperture arrays

AA-hi Station

AA-lo Station
SKA Key Science Drivers

ORIGINS
- Probing the Dark Ages
  When & how were the first stars formed?
- Cosmology and Galaxy Evolution
  Galaxies, Dark Energy and Dark Matter
- Atrobiology
  What are the conditions for life and where can it be found?

FUNDAMENTAL FORCES
- Strong-field tests of General Relativity
  Was Einstein correct?
- Origin & Evolution of Cosmic Magnetism
  Where does magnetism come from?

plus The Exploration of the Unknown
(Special Session 5)

Science with the Square Kilometre Array
<table>
<thead>
<tr>
<th>Year</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007-12</td>
<td>telescope design and cost</td>
</tr>
<tr>
<td>end-2012</td>
<td>site selection + initial (10% SKA, Phase 1) construction funding approved</td>
</tr>
<tr>
<td>2012-13</td>
<td>establish SKA organisation</td>
</tr>
<tr>
<td>2013-18</td>
<td>detailed design &amp; construction of Phase 1 at low and mid frequencies</td>
</tr>
<tr>
<td>end-2016</td>
<td>construction funding approved for 100% SKA at mid and low frequencies</td>
</tr>
<tr>
<td>2017-22</td>
<td>finish construction at low and mid-frequencies</td>
</tr>
<tr>
<td>2019→</td>
<td>science operations with Phase 1</td>
</tr>
<tr>
<td>2023→</td>
<td>full operations at low and mid frequencies</td>
</tr>
<tr>
<td>2013-22</td>
<td>high frequency technology development</td>
</tr>
<tr>
<td>2023→</td>
<td>start of construction of SKA at high frequencies</td>
</tr>
</tbody>
</table>

- **SKADS** EC FP6 SKA Design Study
- **PrepSKA** EC FP7 Preparatory Phase
  - SPDO engineering team for system design
  - “Policy work packages”
  - EC funding 2008-2011 (€ 5.5M)
  - Supplemented by national funding
- **US Technology Development Program (TDP)**
  - Goals aligned with PrepSKA
- **Precursors on the candidate sites**
  - MeerKAT (South Africa)
  - ASKAP (Australia)
- **Pathfinders** (LOFAR, Apertif, ATA, MWA, LWA, EVLA, eMERLIN, eEVN)
PrepSKA: 7 work packages

WP1 PrepSKA management
WP2 Costed telescope design
WP3 Further site characterization in Australasia and Southern Africa
WP4 Governance
WP5 Procurement and involvement of industry
WP6 Options for funding
WP7 Impact on broad government priorities

WPs 4-6 led by the Funding Agencies in NL, IT, UK resp.
WP2: Telescope design + cost

- Dishes, feeds, receivers
- Aperture arrays
- Signal transport
- Signal processing
- Software engineering and algorithm development
- High performance computing
- Data storage
- Power requirements

**Missing**: continuation of SKADS science simulations

Verification programs
Optimisation of technology boundaries will take place based on science performance and cost.

Time axis not shown.
PrepSKA WP2 progress

Concept delineation

- Draft Design Reference Mission v0.4 released
- System Engineering Management Plan released
- Dish Verification Program underway
  - Dish, feed, LNA prototypes under development and deployment
- Aperture Array Verification Program
  - AA-low: verification underway through LOFAR, MWA, LWA
  - AA-high: EMBRACE, draft AAVP DoW under review, funding being sought in NL, UK, Portugal, France, Italy
- Signal transport/LO distribution, SKADS, PrepSKA WP2 WBS
- Signal processing, new ideas under development
- Software and computing, top level issues identified
- Costing tool, SKADS/ICRAR
**Dishes**

**ATA**
42x6m hydroformed dishes

**ASKAP**
36x12m panel dishes

**KAT-7/MeerKAT**
80x12m composite dishes

**CART**
10 m composite prototype
Single pixel wide band feeds

Quad ridge Lindgren horn

Quasi Self Complementary feed

From German Cortes

ATA feed

Chalmers “Eleven” feed

Inverted conical sinuous feed
PrepSKA WP2 progress

Concept delineation

- Draft Design Reference Mission v0.4 released
- System Engineering Management Plan released
- Dish Verification Program underway
  - Dish, feed, LNA prototypes under development and deployment
- Aperture Array Verification Program
  - AA-low: verification underway through LOFAR, MWA, LWA
  - AA-high: EMBRACE, draft AAVP DoW under review, funding being sought in NL, UK, Portugal, France, Italy

- Signal transport/LO distribution, SKADS, PrepSKA WP2 WBS
- Signal processing, new ideas under development
- Software and computing, top level issues identified
- Costing tool, SKADS/ICRAR
Sparse aperture arrays for the lowest frequencies

LOFAR (Netherlands et al)

LWA (USA)

MWA (USA, Australia)
Multi-pixels at mid frequencies with dishes + phased array feeds

ASKAP chequer board array

APERTIF (Astron, NL)

Vivaldi arrays

DRAO Canada
Multi-pixels at mid-frequencies with a dense aperture array

EMBRACE

SKADAS

2-PAD
Signal transport networks

European VLBI Network (1 Gbit/s)
LBA in Australia (1 Gbit/s)

SKA data rates (8 GHz BW/pol max)

160 Gbit/s/beam/dish (<200km)
160 Gbit/s/station (>200km)
Signal processing

HPC ~100 Pflops, 0.1-1 exabyte archive
Software

- Observation preparation
- Telescope operations
- Monitor & control
- Data handling, storage and distribution
- Calibration & imaging
- Special data processing (eg pulsar data)
- Visualisation
WP3: Site characterisation

- Deep RFI measurements
- Establish Radio Quiet Zones
- Array configuration
- Infrastructure deployment and operations costs and timescales
- Impact of site physical characteristics on design
- Characterise ionospheric turbulence
- Characterise tropospheric water vapour turbulence
- Detailed risk analysis of science environment
WP3 progress

Current focus on
1) generating array configurations in Australasia and Southern Africa
2) preparation for the RFI monitoring campaign

Activities starting on
1) Preparation for tropospheric phase fluctuation measurement
2) Mandate for external consultant on infrastructure capital and operations expenditure for AU and RSA
3) Mandate for external consultant on the long term RFI environment in Australia and Southern Africa
South Africa + 7 countries
Southern Africa

Dish construction building

First KAT7 antenna

Support base
Funding agencies and governments from 12 countries agreed in February 2009 to form the ASG under the leadership of the UK Science and Technical Facilities Council.

Aim is to:
- deliver a non-binding Joint Agreement on the Implementation of the SKA in 2011/12;
- Achieve sufficient consensus and make decisions on key policy areas of the SKA Project, and
- Prepare the groundwork for the subsequent establishment of a formally-constituted SKA Steering Group.

Meets twice per year.
ASG: Work Streams

- **Schedule**
  - funding
  - Technical – concern about absence of “The SKA Design”
  - site selection and development
  - implementation of governance structures
  - pre-construction administrative lead-time

Schedule Tiger Team to report to ASG by June 2010

- **Construction Readiness (post-PrepSKA) funding and Interim Governance**
  - Joint Implementation Agreement
  - Decision-making body
  - Science case for Phase 1

- **Site selection process** Joint ASG-SSEC Working Group
  + PrepSKA policy WPs
WP4: governance

NWO lead

- Long term governance options under study
  - International organisation (ITER)
  - National legal entity (ESRF)
  - MoU-based (LHC-ATLAS)
  - Treaty (ESO, CERN)

- Interim governance 2011-2014
  - Simplify current tri-partite governance
  - Establish an SKA Corporate Entity
  - New MoU
  - (Extend current International SKA Collaboration and SPDO MoAs)
WP5: Procurement & Industry participation

INAF lead
- Top-level procurement issues paper released
- Global procurement options paper in preparation

- Industry relationships and relevant government policies from Precursors/Pathfinders/Design Studies
- Map and verify potential global industry players
- Investigate current ‘best practice’ models for industry participation
- Harmonise approach of ‘regions’ to development and networking of industry capability for the SKA
- Design and create industry database
- Develop IP strategy for the SKA project
STFC lead

- **Business case/Proposal per country**
  - Science case
  - Industrial return
    - Tool for innovation and societal benefit
- **Cost-capped Phase 1 (300 M€, 2007)**
- **Draft spend profile from 2011 to 2023 including operations from 2016**
Costs

- **Target construction cost:** 1.5 billion € (2007) for Phases 1+2
  - Civil works
  - Antennas & RF systems
  - Signal transmission
  - Signal processing
  - Software development & computing hardware
  - Design, integration, testing, and management
  - Contingency

- **Expected operating costs:** 150 million €/year
  - Salaries (400-500 staff)
  - Power
  - Materials & services including dark fibre lease
  - Renewal of instrumentation and computing
  - (science centres additional)
WP2

- Release of v1.0 Design Reference Mission
- Conceptual Design Reviews for
  - System engineering
  - Reflector antennas
  - Aperture Array antennas
  - Signal transport
  - Signal processing

WP3

- Configurations
- External consultancies for infrastructure costs, long term radio quietness
- Tropospheric phase stability
WP4-7, governance, procurement, funding, implementation plan will produce position papers

SSEC
- Science/technology/cost tradeoff analysis
- Phase 1 options

Agencies SKA Group
- Post-PrepSKA funding
- SKA Schedule/Timeline
- Site selection process
Major meetings

- SKA2010
- SKA-ELT meeting
- International SKA Forum 2010
- Annual WP2 meeting,
Further information

www.skatelescope.org