The SKA - Challenges, Opportunities, and Industry Involvement

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The SKA – “will be the largest scientific instrument on the planet”

- A ‘next generation’ global radio astronomy facility
- To be built in either Southern Africa, or Australia
- Will operate between around 70 MHz to 25 GHz
- **50 times** the sensitivity and **8000 times** the survey speed of current instruments
- a collecting area of around **1 million square meters** over a vast unpopulated area
- a combination of **3000-5000 dishes** and wide FoV antennas
- will employ beam forming technology on a scale **not previously explored**
- Needs data transport system and computing power beyond that available today
- Will address **fundamental questions** about the universe
SKA Key Science Questions

• When & how were the first stars and galaxies formed?

• What is the large scale structure of the universe? ‘Dark Energy’ ‘Dark Matter”

• What is the origin and evolution of cosmic magnetic fields?

• Was Einstein right? Can we detect gravitational waves?

• Planet formation and the ‘Cradle of Life’ Will we find ET?

• EXPLORATION OF THE UNKNOWN
The SKA timeline & estimated project costs

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

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

Over 100 Organisations
8 SKA Consortia

SKA Program Development Office

- Based at University of Manchester, UK
- Group of domain specialists
- Mission – to deliver a costed design by 2012
SKA Movie – 3 minutes
The Challenges of Radio Astronomy

- The signals are extremely weak.
  - We need huge antennas to capture them
  - They need to be in special places

- Astronomers ‘compete’ with noise
  - From radio, TV, phones, machines, etc
  - From the equipment itself, amplifiers etc

- Signals are buried in the noise
  - Need smart techniques to ‘resolve’
  - This means huge computing power

- Large amounts of data to handle
  - Pushing boundaries in capacity, speed and storage
But better instruments needed to answer the key science questions
SKA System Diagram on a Page

Diagram by Andrew Faulkner
SKA as e-science

Antenna Array → DSP ("correlator") → Post-processing HPC ("imaging")

Tier 0 (SKA)
Tier 1 (National)
Tier 2 (Regional)
Tier 3 (Institute)
Tier 4 (Researcher)

E-science:
Global collaboration in key areas of science, and the next generation of infrastructure that will enable it. More data, more computation, faster networks, more collaboration, exploration of data and models – in silico discovery, floods of public data, GRID computing, ..

Pb/s
0.1 – 1 Tb/s
Gb/s
• Each pair of antennas is called a baseline
• The more different baselines there are, the more detailed the astronomical image.
• Short baselines - antennas are close to each other - provide coarse structure.
• Long baselines provide the fine detail, the longer, the finer the detail.
SKA is an “aperture synthesis” telescope

A large aperture telescope is ‘synthesized’ by sampling the wave-front in the aperture plane.
Possible Site Schematic

- Comms links
- Central Processing Facility
- Dishes spread along spiral
- Station
- Max. Distance for Dense AAs
- Max. Distance for Central Power Dist’n

- Dishes
- Dense AA
- Sparse AA
- Numbers of dishes (2000-3000) depends on whether Phased Array Feeds and/or Aperture Arrays are used in the SKA.
- Each technology is characterized by a frequency range and field of view.
Aperture Array Technology
Production Thinking

ASTRON Prototype – The Netherlands

Electronic Sensor

Courtesy ASTRON, OPAR
Phased Array Feed Prototype

One of three prototypes under development.
Multi-pixel phased array feeds

from Dave Deboer
Dishes + Single Pixel Feeds

USA
Allen Telescope Array 42x6m hydroformed dishes

Canada
Prototype 10 m composite dish

South Africa
Prototype 15 m composite dish
Composite Dish Manufacturing (Canada)

Final Mould Alignment

Removing from Mould Mounted on Drive
Metal Dish Manufacturing

Novel Sheet Metal Structure

12m antenna

stretch-formed panels

Patriot Systems
Wide field-of-view

Base model·SKA

Allen Telescope Array

Parkes
Correlators – Ultimately Built in Industry
Electrical power – not solved yet

• Solar potential is high on both sites.
  • 24-hour coverage is needed.
    • Requires storage or alternative night-time power source.
• Cost likely to be an issue if not subsidized.
• 30-50MW required for full SKA
• Role for small scale (~100 kW) systems if they exist.
Other Power Issues

- Systems must withstand occasional flooding.
- Priority power not needed for SKA but power-outage notice might be needed.
- Safety grounding issues in desert areas.
- Lightning protection required
- Equipment subject to unusually high temperatures and large diurnal swings.
- Power for redundant communication needed for emergency shut-down
- Staggered antenna slewing is standard practice for arrays.
- Some equipment will require local UPS systems that may need remote control.
The Pre-Cursor Projects
South Africa + 7 countries
Australia
Spectrum Measurements: 80 MHz – 1.6 GHz

Sydney
Pop. 4 million

Narrabri
Pop. 6,000

Boolardy
Industry Opportunities

Summary of Opportunities in the SKA Signal Path

- Antenna
  - Concentrator Feed Support
- Feed Hardware
  - Feeds Cryogenics Enclosures
- RF Electronics
  - LNA Down-conversion LO Beamforming
- Short-haul Links
  - Fibre Opto-electronics
- Station Electronics
  - Filterbanks Beamformer Stn Correlator
- Long-haul Links
  - Fibre Opto-electronics Optical Amplifiers
- Central DSP
  - Filterbanks Beamformers Correlator
- Computing
  - Hardware [Software]
- Archive, Distribution

From P. Hall
The SKA – “will be the largest scientific collaboration on the planet”

- To meet the SKA timelines, a very high level of industry involvement will be needed, especially R & D, and economical mass production and deployment.

- **Benefits** to industry include opportunities to:
  - Grow and hone the creative energies of the best professionals
  - Perfect leading-edge techniques and products in a very demanding application,
  - Generate and share information in a benign and commercially non-threatening environment
  - Raise company profile/visibility by association with an innovative, high profile, international mega-science project
  - Gain early involvement and favourable positioning in a € 1.5 billion (2007) project spanning a wide range of engineering and computing disciplines.
**Industry Opportunities and the SKA**

### Site works and Infrastructure

- Site studies, and infrastructure engineering
- Site works for design & construction of antennas, support buildings (offices, equipment, accommodation, etc), cable roll-out, and repeaters
- Electrical supply to chosen site, in order of 50 MW (with a proportion of ‘green’ energy (TBD))
- High-speed (Tb/s) digital fibre optic links for distance regimes extending from 100 m to 3000 km
SKA Project Support, Tools, Operations & Maintenance

- Outreach and public education
- Project management, site supervision (works management), and Systems engineering support
- Radio-frequency interference mitigation using coherent and incoherent techniques
- High dynamic range (>60 dB) image formation using sparsely-sampled Fourier plane data
- SKA scheduling, operations and maintenance models
High volume production & deployment

- Low-cost manufacturing of small to medium diameter dishes
- Advanced mechatronic systems for feed positioning and antenna control
- Decade bandwidth feed antennas for dish flux concentrators
- Broadband, active, phased arrays for aperture and focal plane applications
- Low noise wideband RF amplifiers for both cryogenic and uncooled applications
- Low-noise, highly integrated, receivers for both cryogenic and uncooled applications
- Low-cost, high-speed (Gs/s) analog to digital converters
Low-medium volume production & deployment

- High-speed digital signal processing engines (correlator) at 24 peta-flops/sec
- Ultra-fast supercomputing at 200 peta-ops/sec
- High speed data transmission at 160 Gb/sec
- Software engineering for robust, intelligent, array control and data processing
- Master oscillator time standards, and distribution
What kinds of firms should consider participating in the SKA?

- **Information & Communication Technology (ICT)** - hardware, software, digital fibre systems, data management, high-speed / high-volume data processing, control systems, modelling and simulation systems, networked enabled system deployment & management, integrated circuit design, fabrication, and test, telecoms systems.

- **Engineering Construction & Maintenance (ECM)** – building construction, electrical and mechanical services, R & D services, environmental services, fibre optic, power, civil engineering, land access consultants, remote infrastructure operations and maintenance, site management & planning, surveying services.

- **Advanced Aerospace & Radar Technology and Equipment** – antenna design and manufacture, image processing, radio astronomy, receiver feed systems, wideband phased arrays, RF devices, RFI mitigation.

- **Advanced Materials and Manufacturing** - advanced materials, composites, sheet metal fabrication.

- **Systems Integration & Maintenance** – project design, execution, interface management, risk management, scheduling, operations and maintenance of complex distributed systems.

- **Transport, Training, and Other Goods & Services** – regional support, recruitment and training, transport and logistics, community consultation and studies, regulatory monitoring.
Intellectual Property

• SKA has developed a Statement of Intent on IP.
  – Signed by organizations participating in the SKA.
  – Establishes ground rules on protection, licensing, and donation of foreground and background IP for the SKA project.

• An IP strategy will be developed, with registered ownership
  – Negotiations in the spirit of scientific cooperation.
  – Signed by legal entities, when that becomes possible.

• SKA must have access to IP developed in the national & regional projects:
  – Some of this will be generated in industry.
  – Where possible, IP licensed early for the SKA, so that it can be used in open bidding, rather than giving advantage to a particular supplier.
To Summarise...

- The SKA is an ‘icon’ project – a BIG leap.
- Answers to key science questions
- Global collaboration institutes & industry
- Challenges yet to be solved
- Potential for industry ‘spin-off’ products & IP
Thank You

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