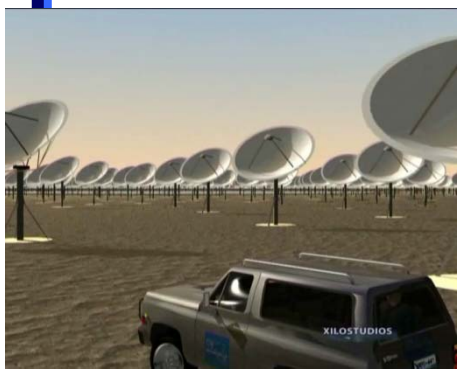
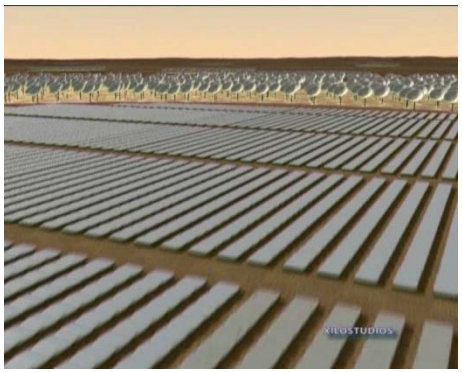
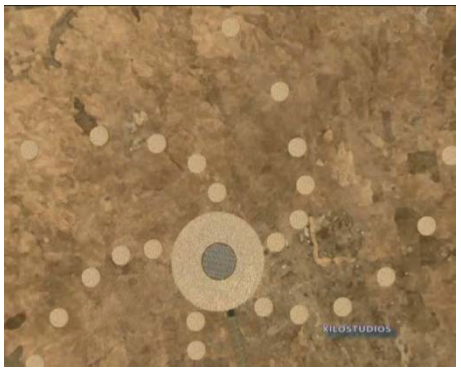
The SKA - Challenges, Opportunities, and Industry Involvement

Phil Crosby
SKA Program Development Office





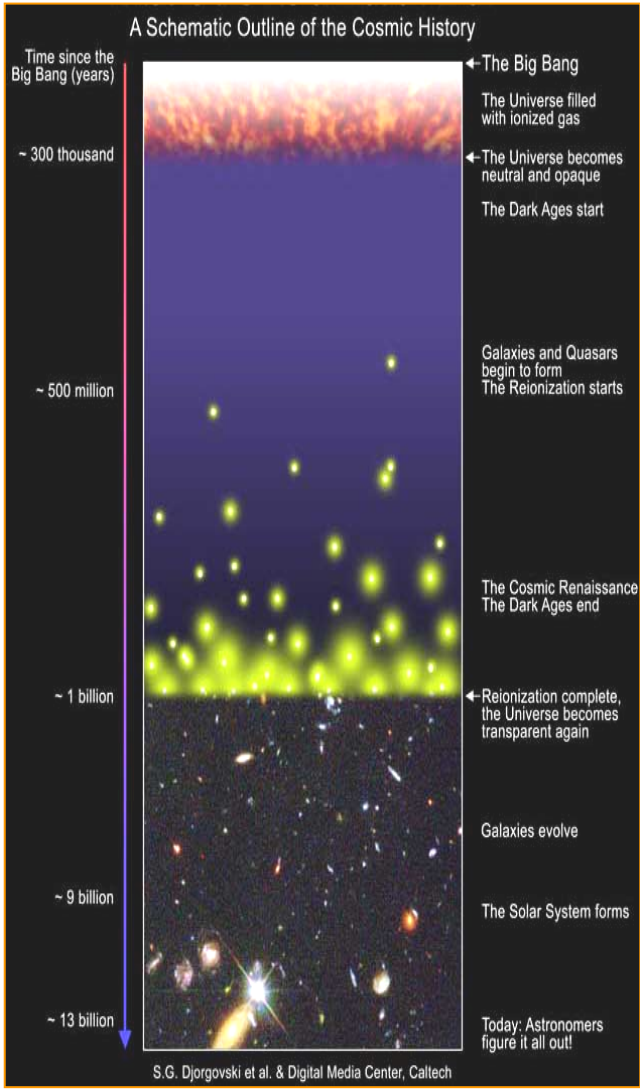


The SKA – "will be the largest scientific *instrument* on the planet"

- 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

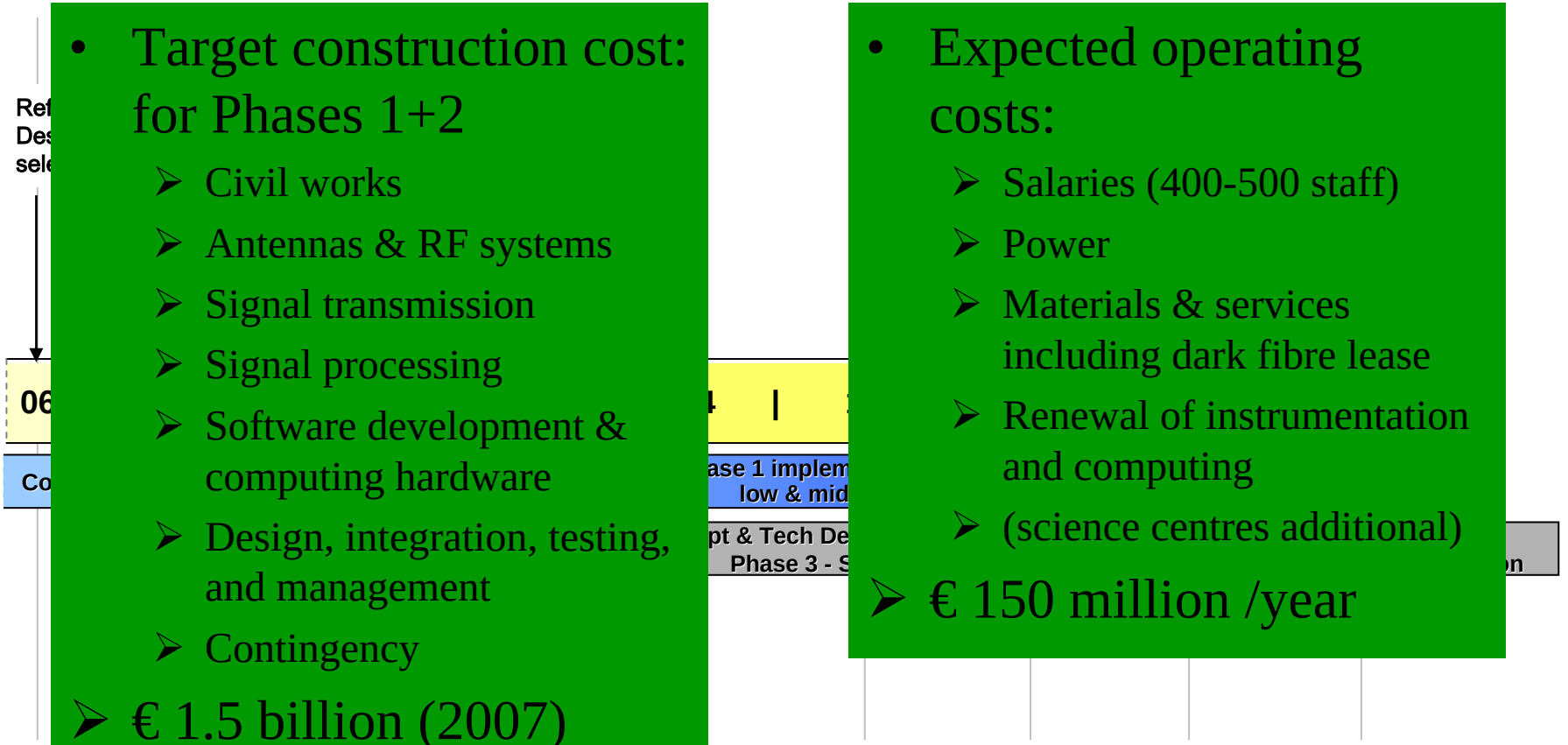
- When & how were the first stars and galaxies formed?
- What is the large scale structure of the universe? ‘Dark Energy’ ‘Dark Matter”
- What is the origin and evolution of cosmic magnetic fields?
- Was Einstein right? Can we detect gravitational waves?
- Planet formation and the ‘Cradle of Life’
  Will we find ET?
- EXPLORATION OF THE UNKNOWN



The SKA timeline & estimated project costs

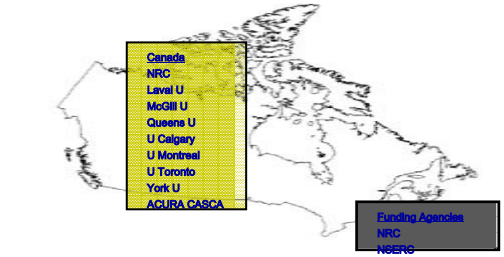
- Target construction cost: for Phases 1+2
  - Civil works
  - Antennas & RF systems
  - Signal transmission
  - Signal processing
  - Software development & computing hardware
  - Design, integration, testing, and management
  - Contingency
- € 1.5 billion (2007)

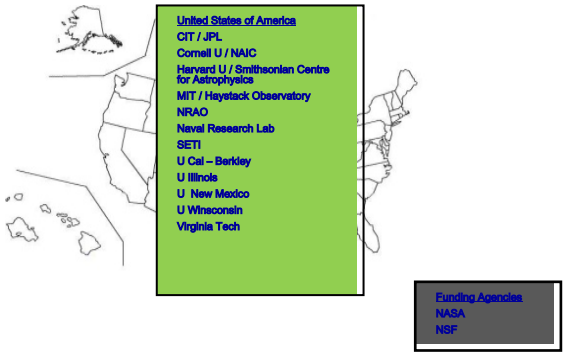
- Expected operating costs:
  - Salaries (400-500 staff)
  - Power
  - Materials & services including dark fibre lease
  - Renewal of instrumentation and computing
  - (science centres additional)
- € 150 million /year

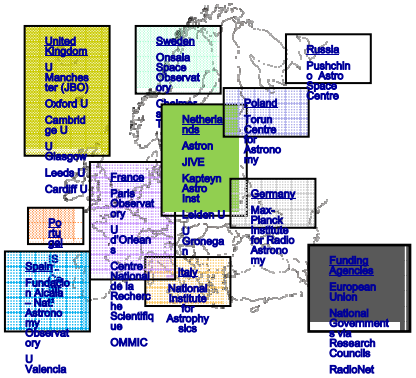


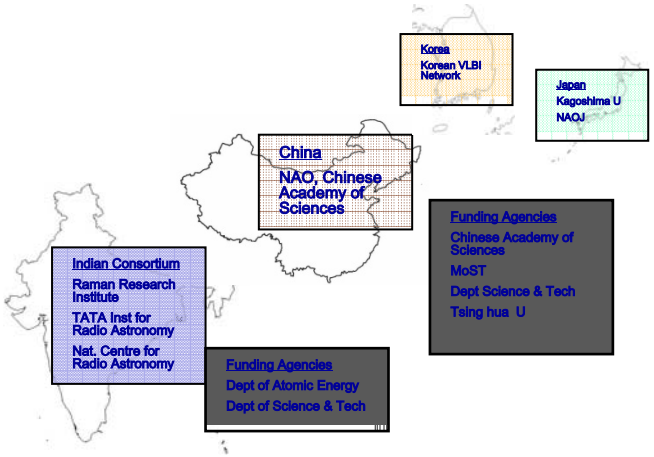
The SKA Global Network

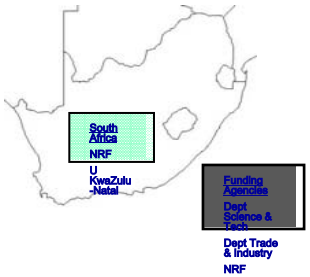
Over 100 Organisations
8 SKA Consortia

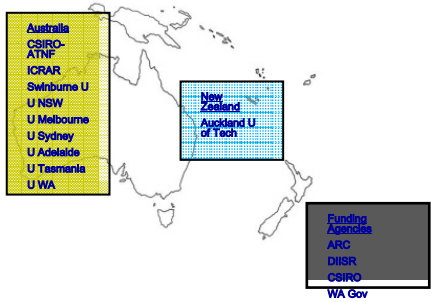












SKA Program Development Office

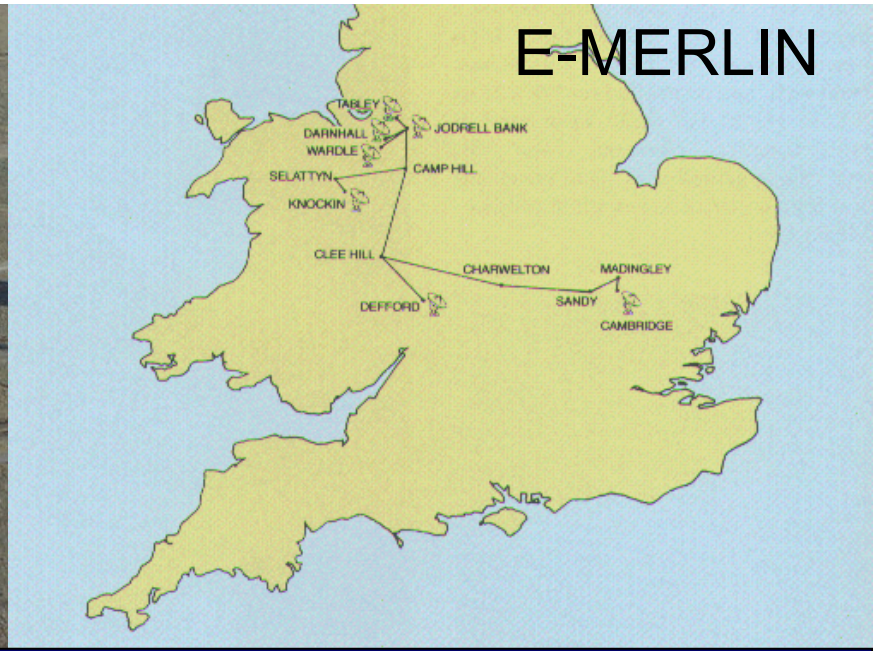
- Based at University of Manchester, UK
- Group of domain specialists
- Mission – to deliver a costed design by 2012

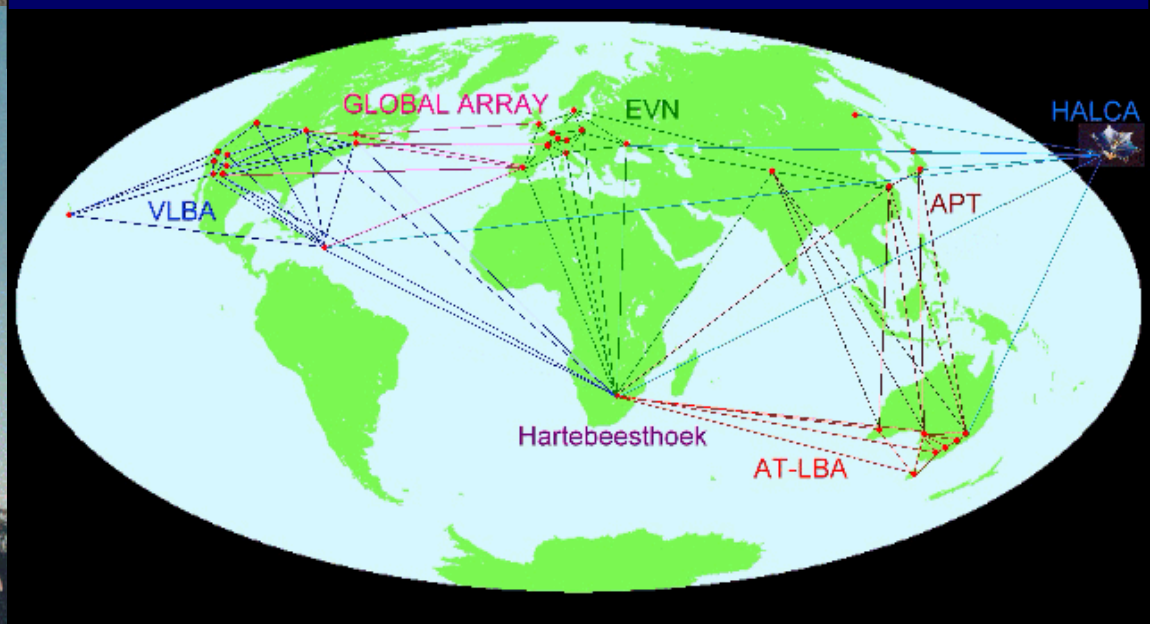
SKA Movie – 3 minutes

The Challenges of Radio Astronomy

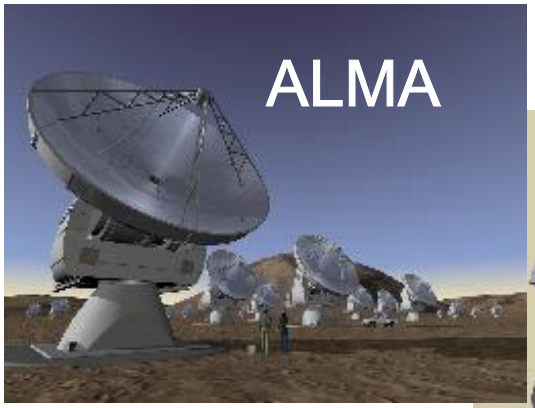
- The signals are extremely weak.
  - We need huge antennas to capture them
  - They need to be in special places
- Astronomers ‘compete’ with noise
  - From radio, TV, phones, machines, etc
  - From the equipment itself, amplifiers etc
- Signals are buried in the noise
  - Need smart techniques to ‘resolve’
  - This means huge computing power
- Large amounts of data to handle
  - Pushing boundaries in capacity, speed and storage

Array Telescopes





But better instruments needed to answer the key science questions



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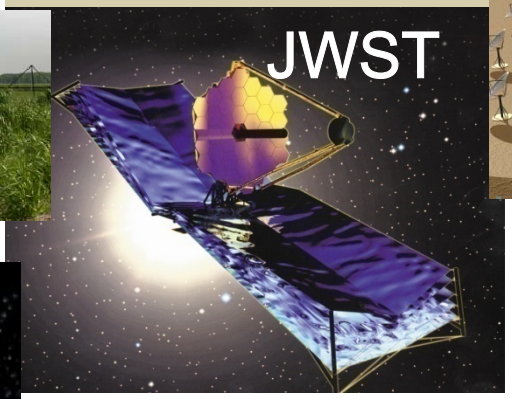
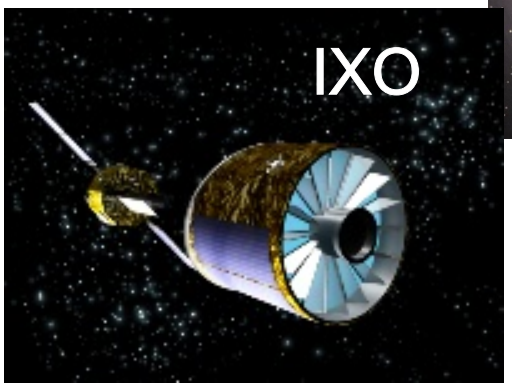
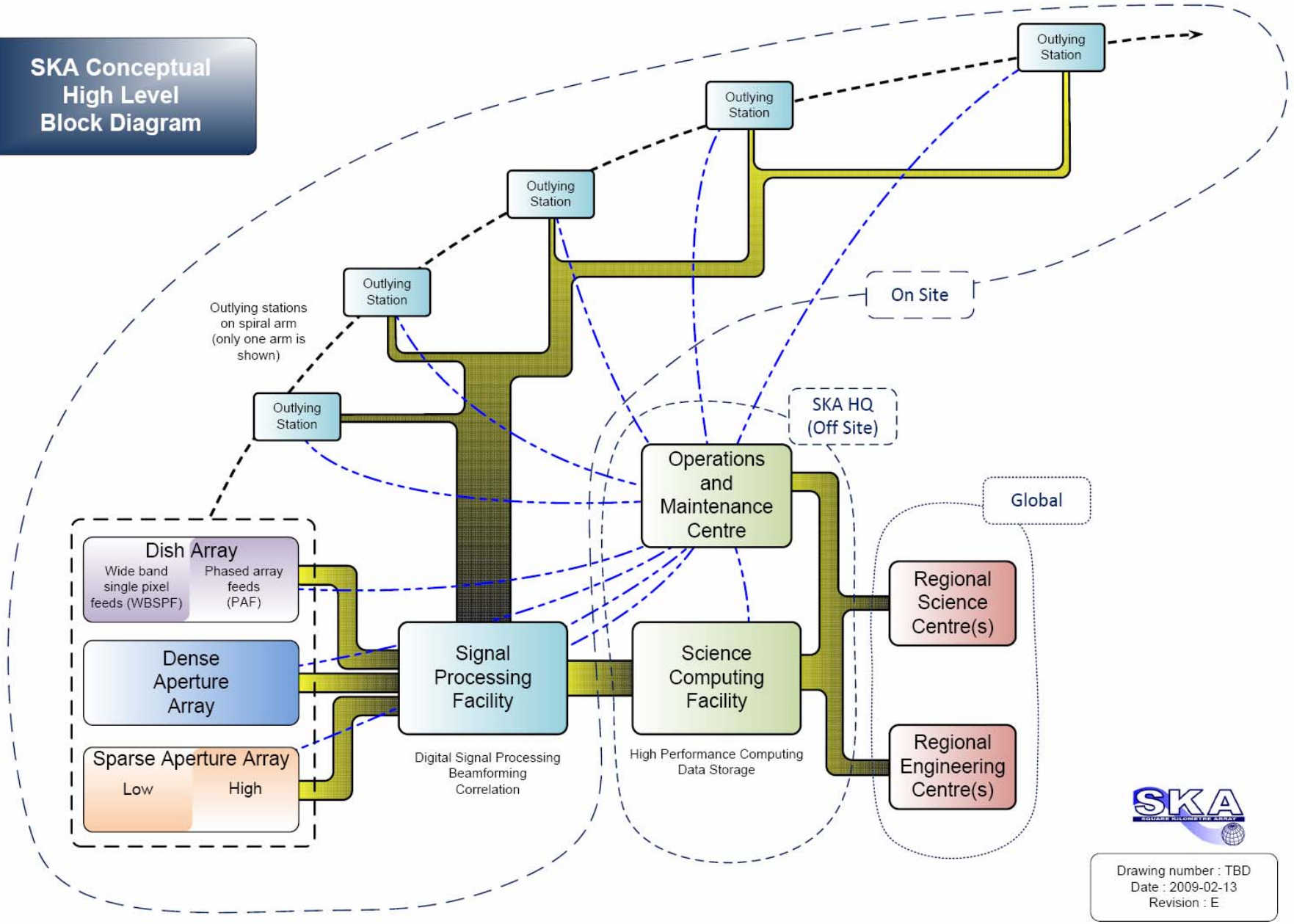




SKA Conceptual High Level Block Diagram



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Date : 2009-02-13
Revision : E

SKA System Diagram on a Page

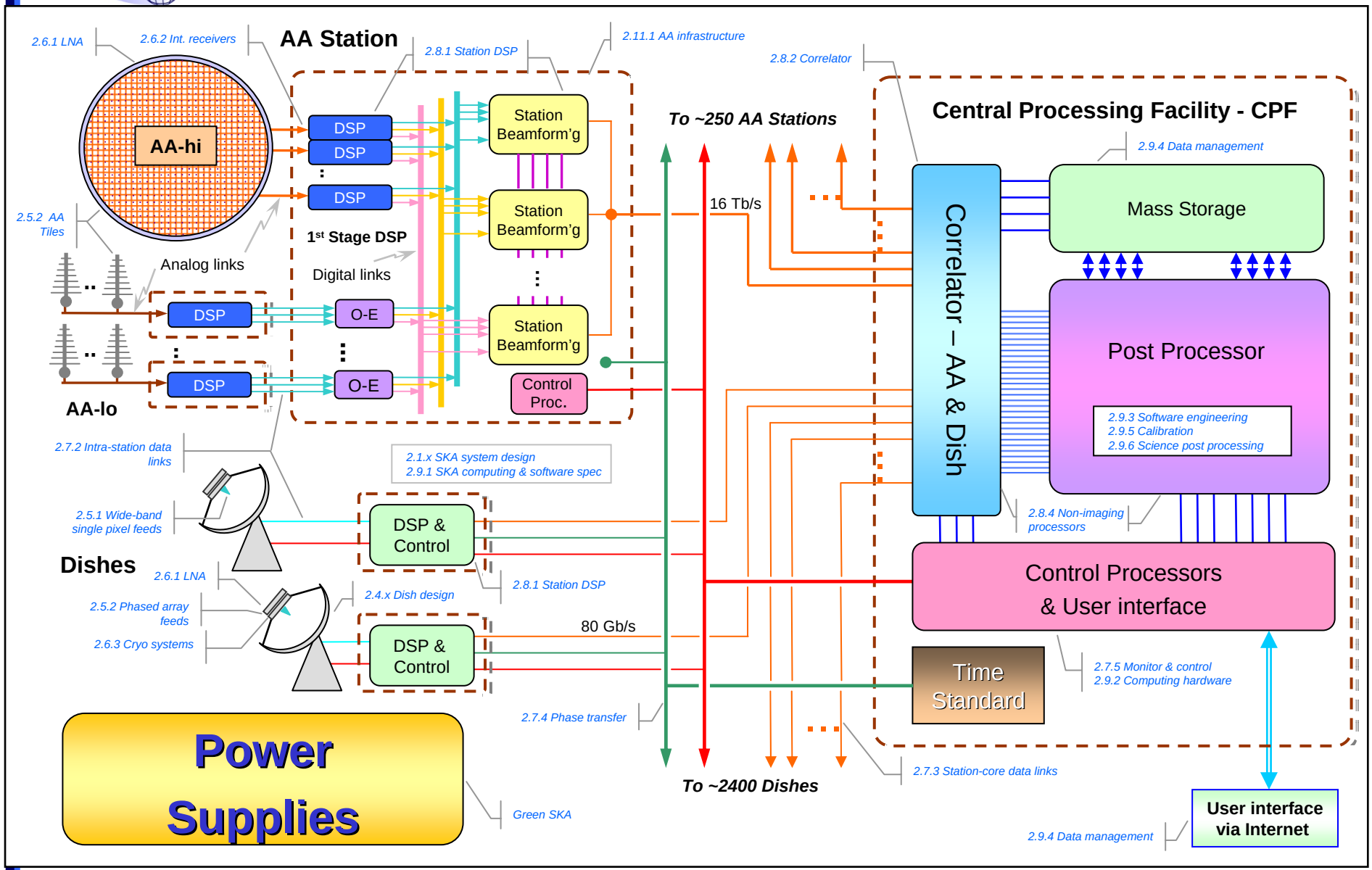
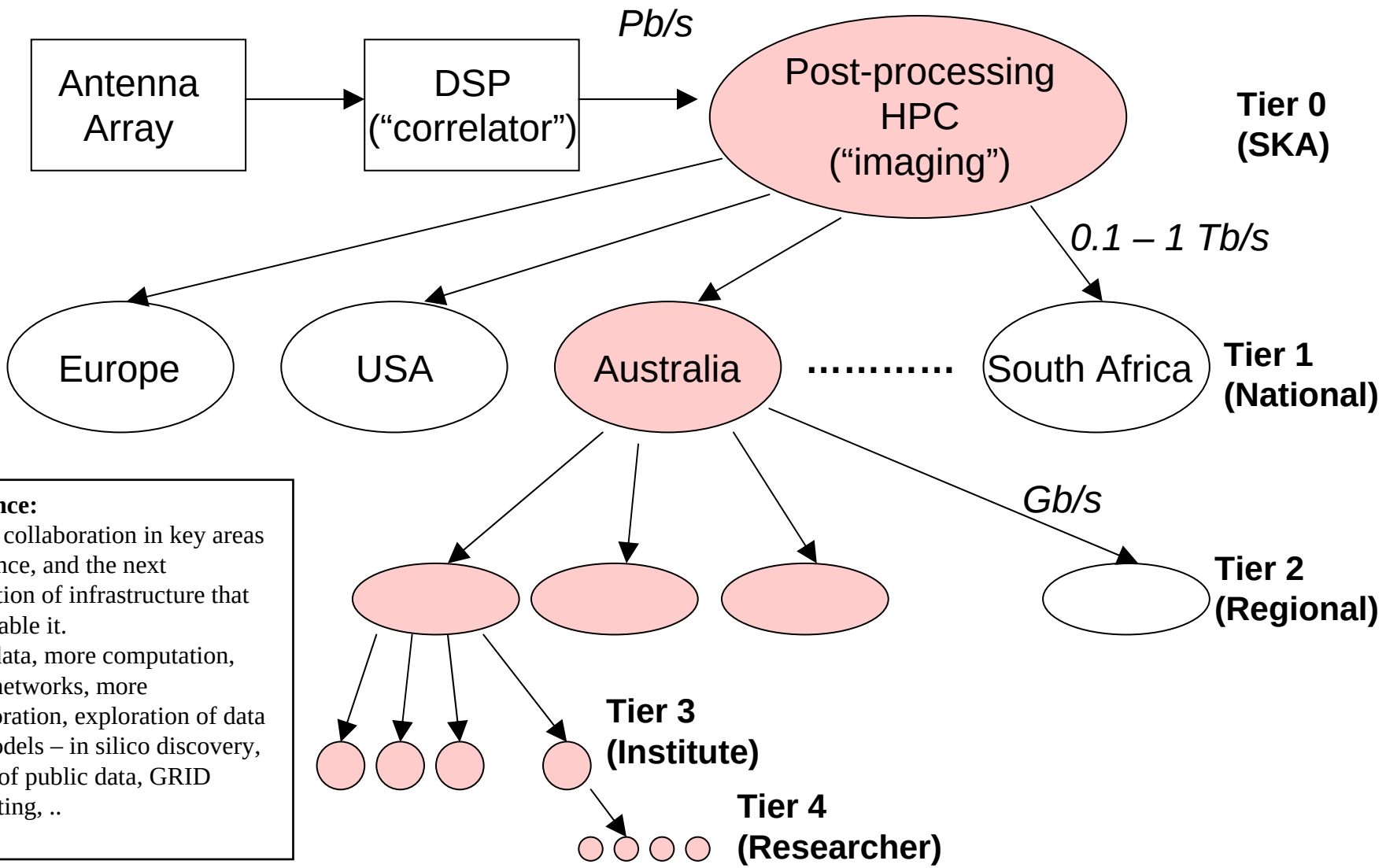


Diagram by Andrew Faulkner

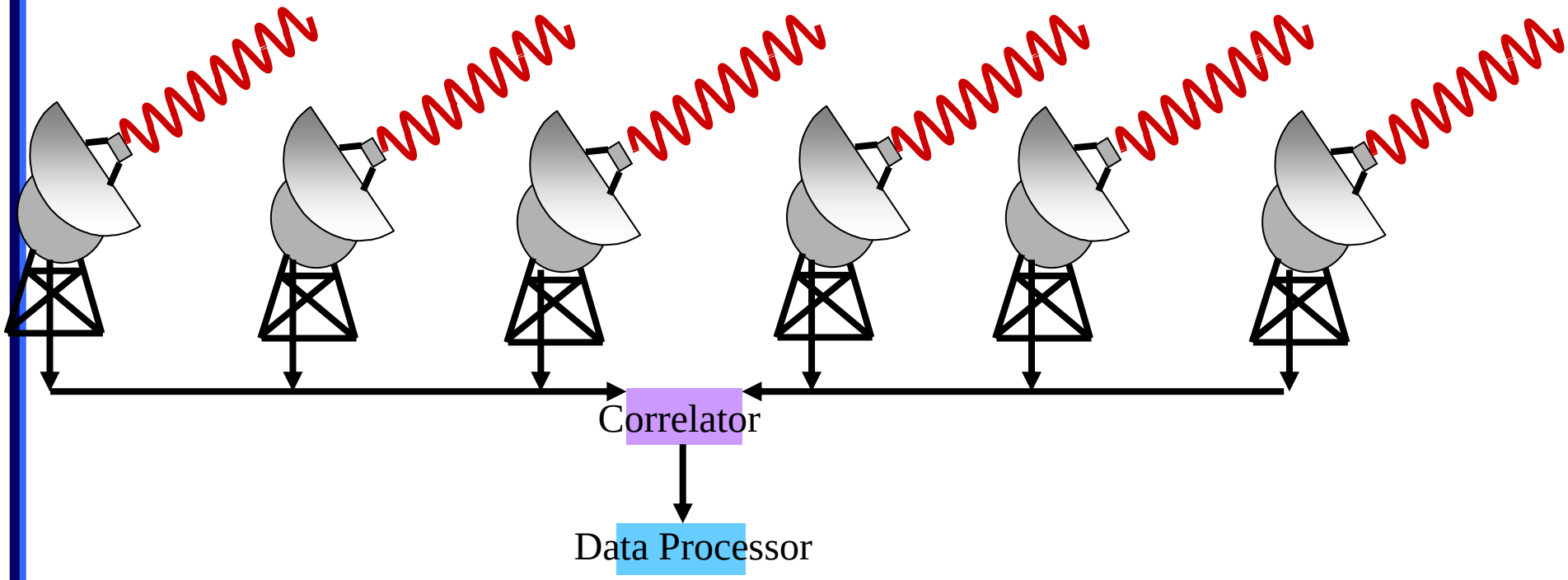
SKA as e-science



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, ..

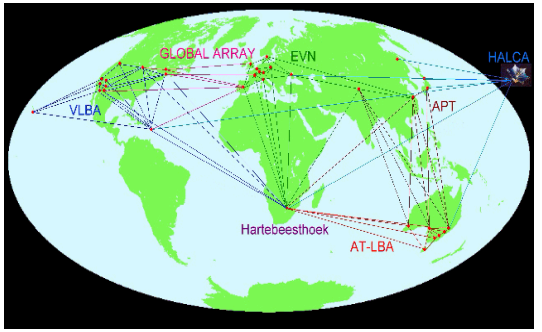
Interferometry using arrays

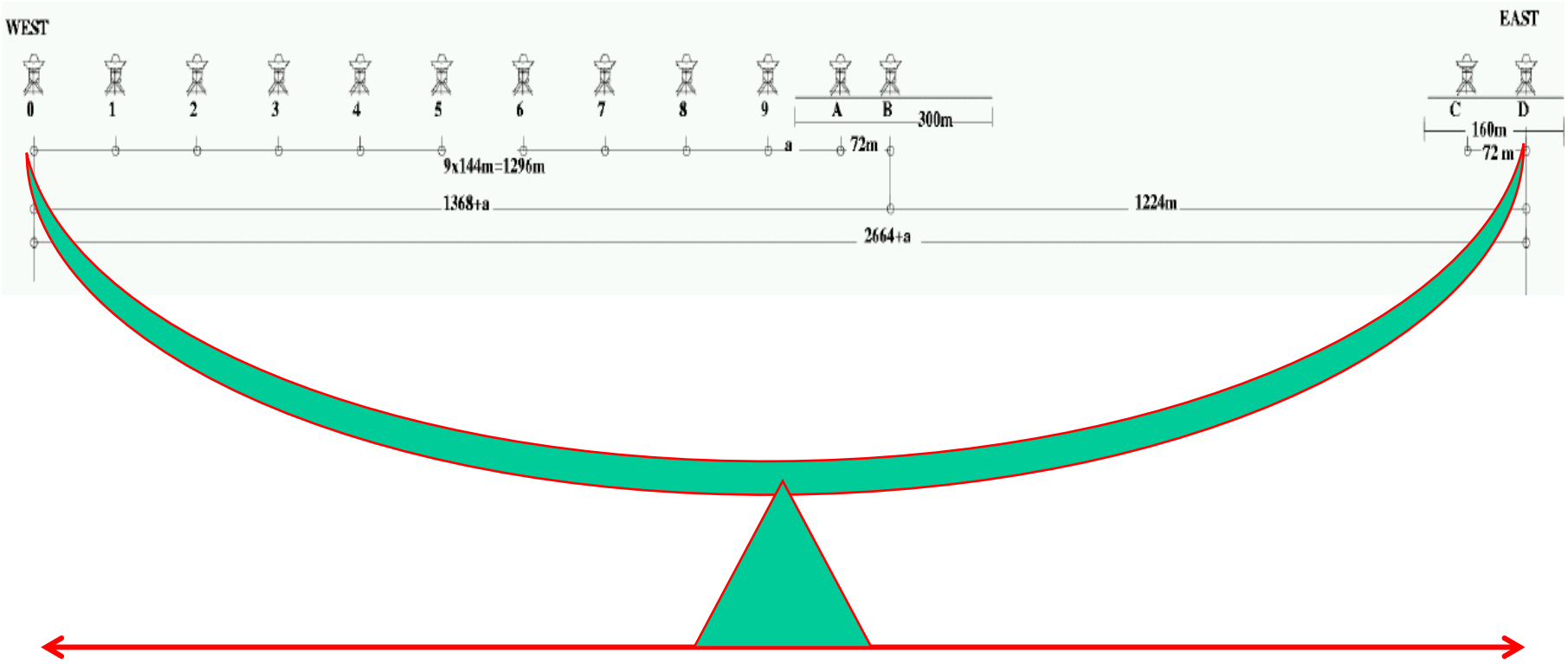
- Each pair of antennas is called a baseline
- The more different baselines there are, the more detailed the astronomical image.
- Short baselines - antennas are close to each other - provide coarse structure.
- Long baselines provide the fine detail, the longer, the finer the detail.



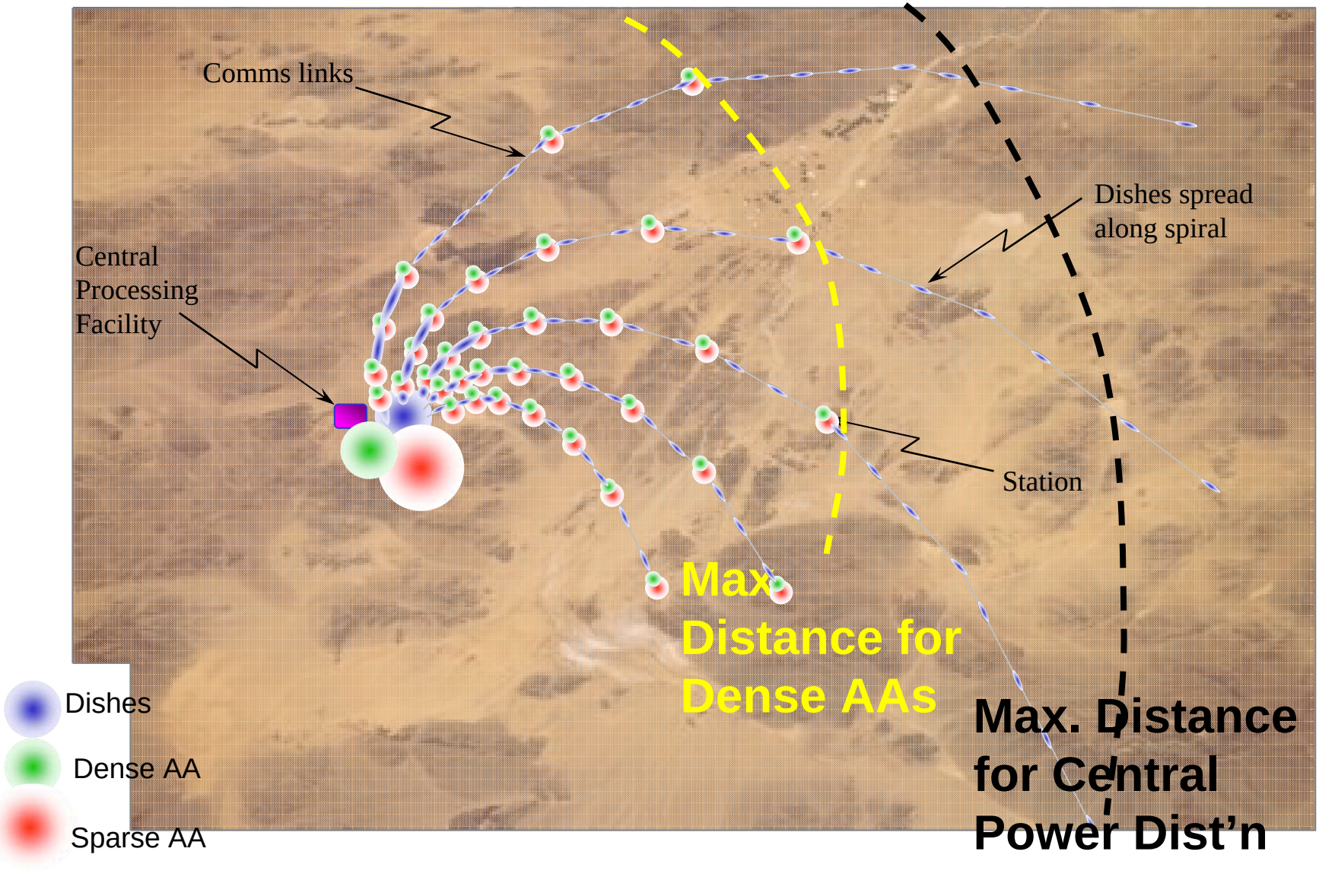
SKA is an “aperture synthesis” telescope

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

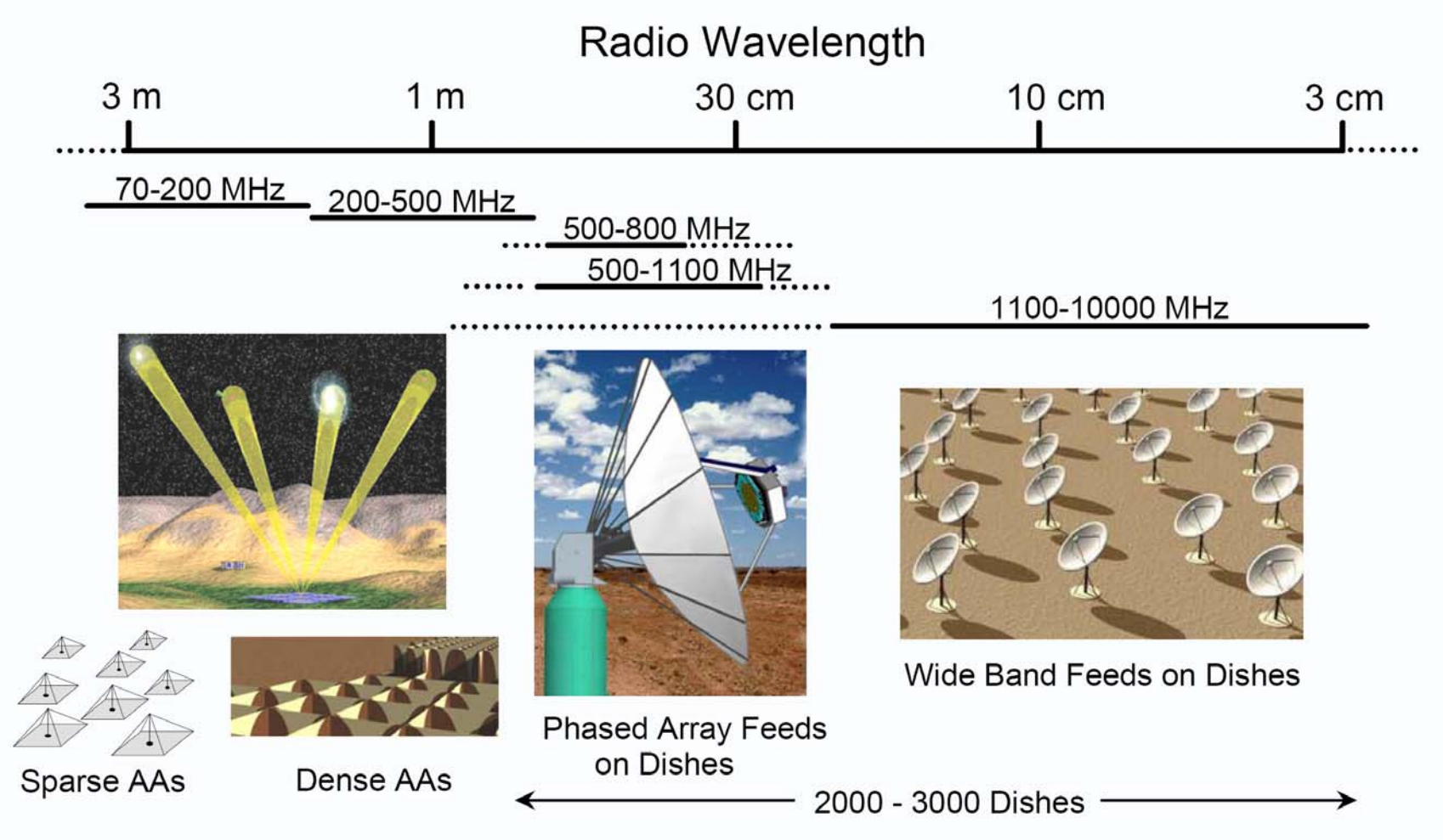




Possible Site Schematic

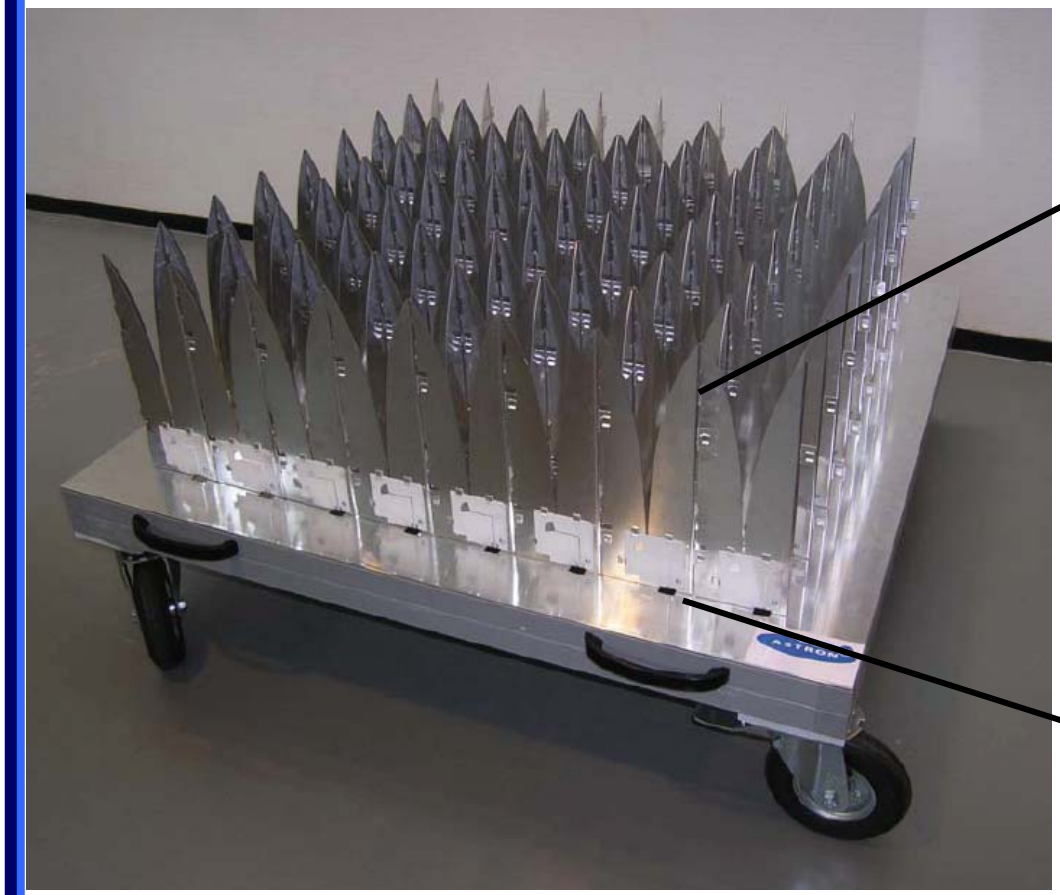


Concise Picture of Technology Options



- 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

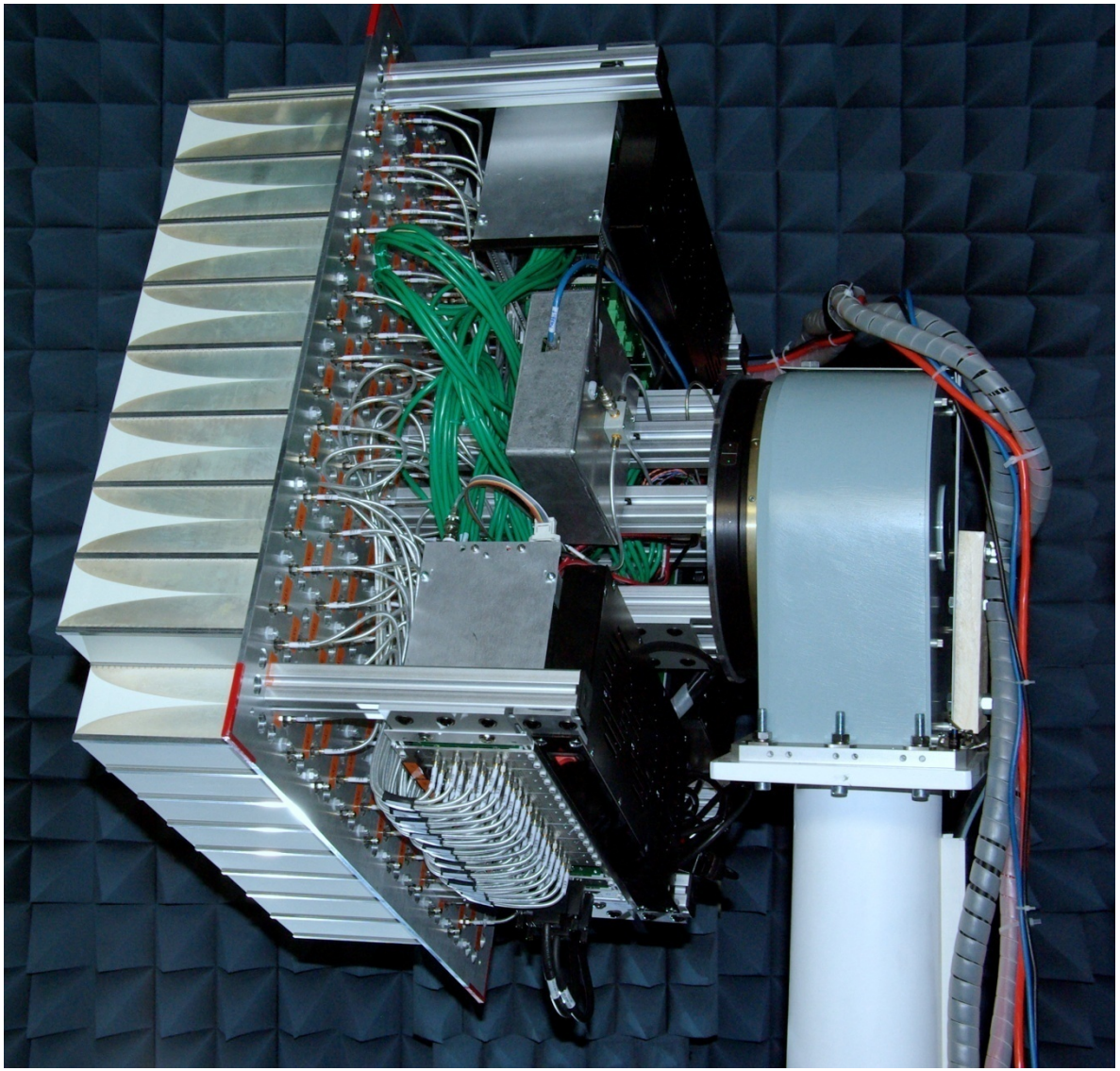


ASTRON Prototype – The Netherlands

Electronic Sensor

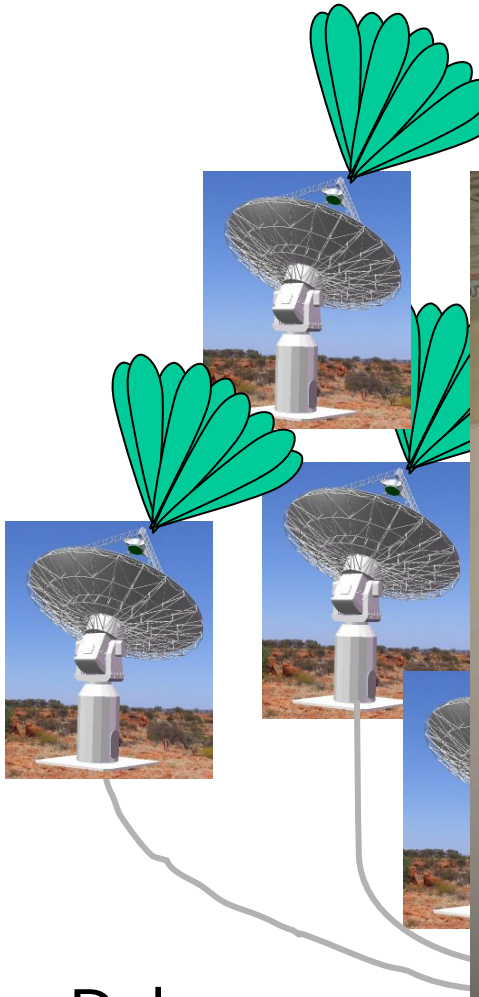
Courtesy ASTRON, OPAR

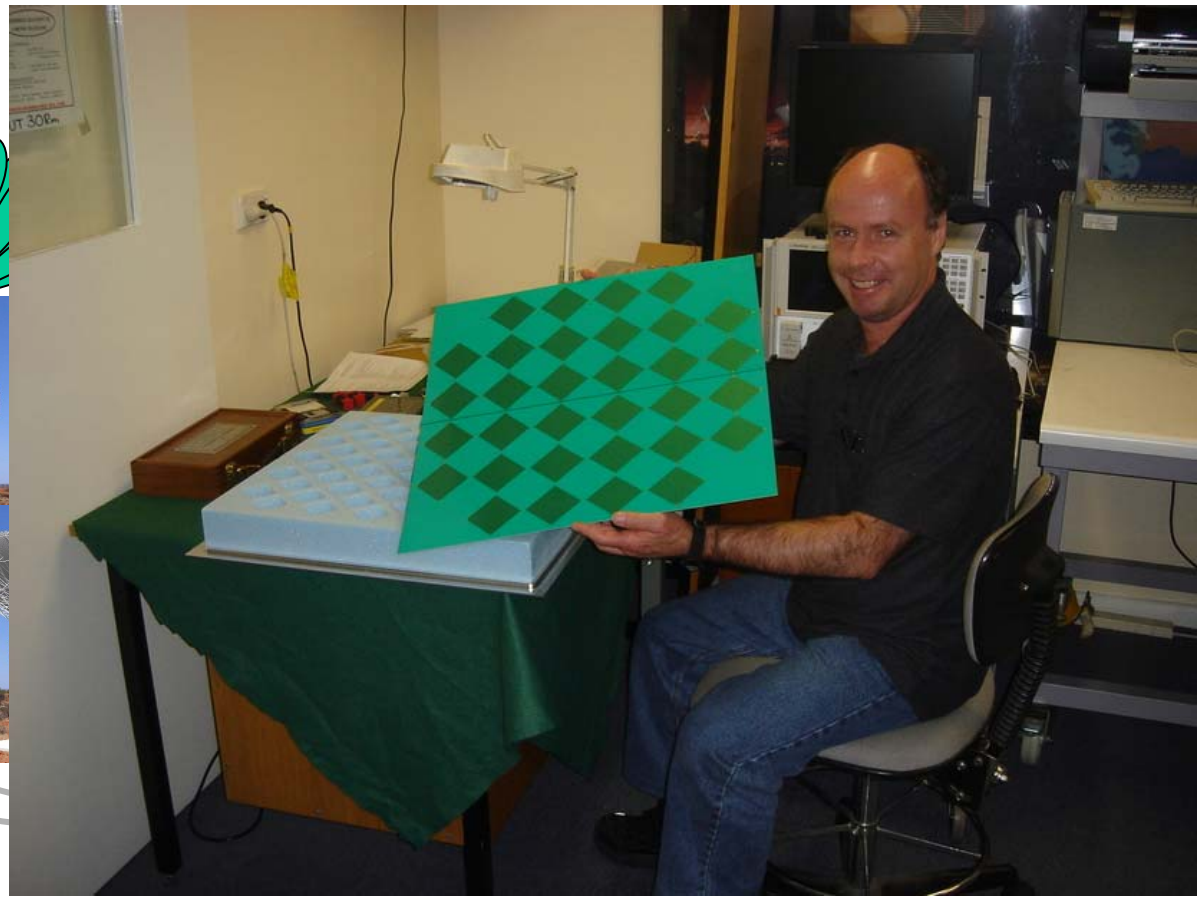
Phased Array Feed Prototype



One of three prototypes under development.

Multi-pixel phased array feeds





from Dave Deboer

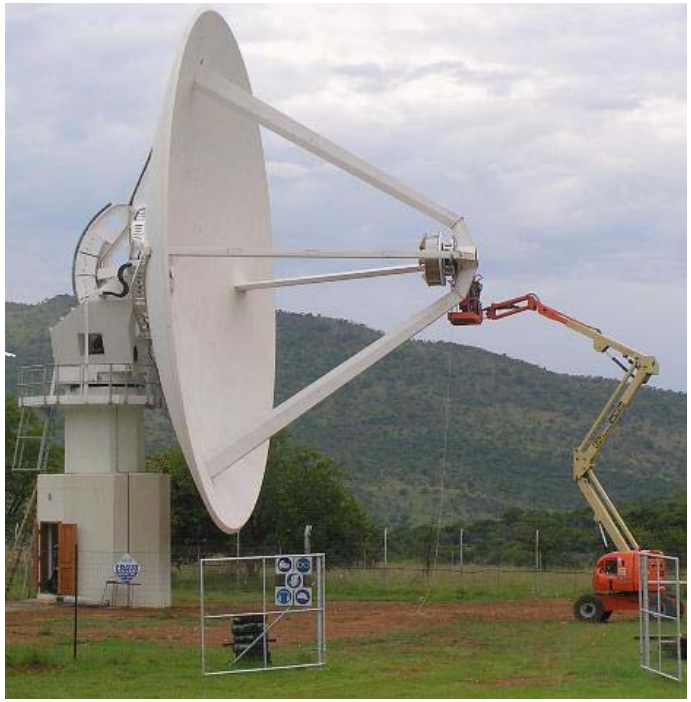
Dishes+Single Pixel Feeds

USA

Allen Telescope Array 42x6m hydroformed dishes

Canada

prototype 10 m composite dish

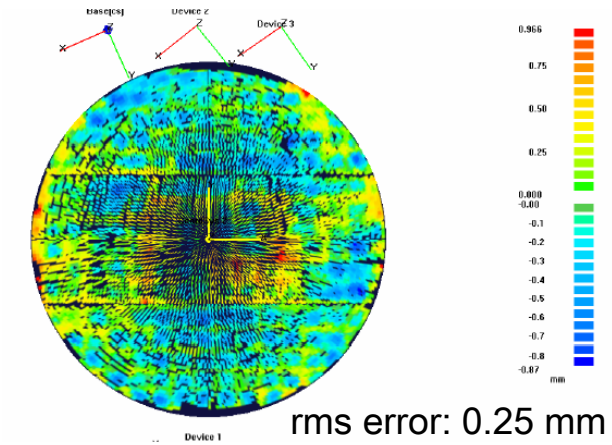


South Africa

Prototype 15 m composite dish

Composite Dish Manufacturing

(Canada)

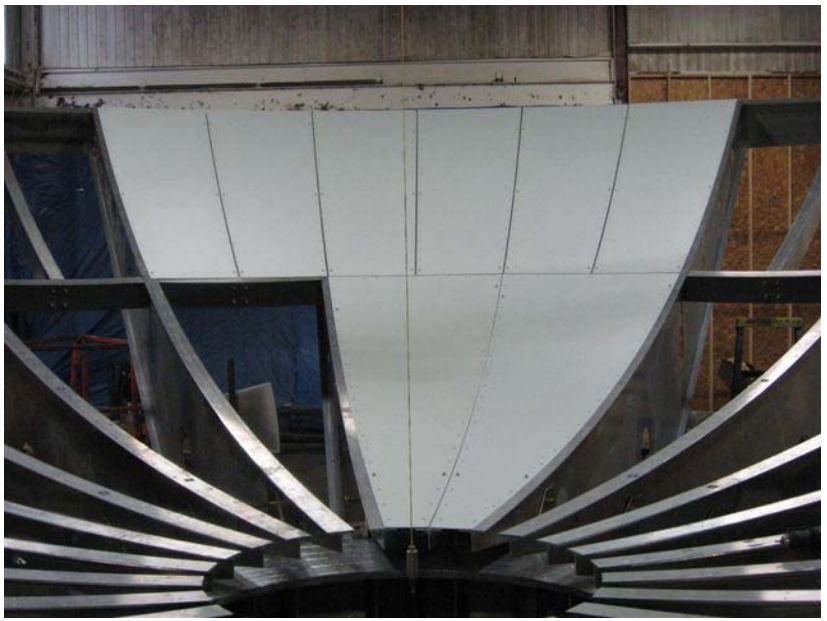


rms error: 0.25 mm

Metal Dish Manufacturing

Novel Sheet Metal Structure

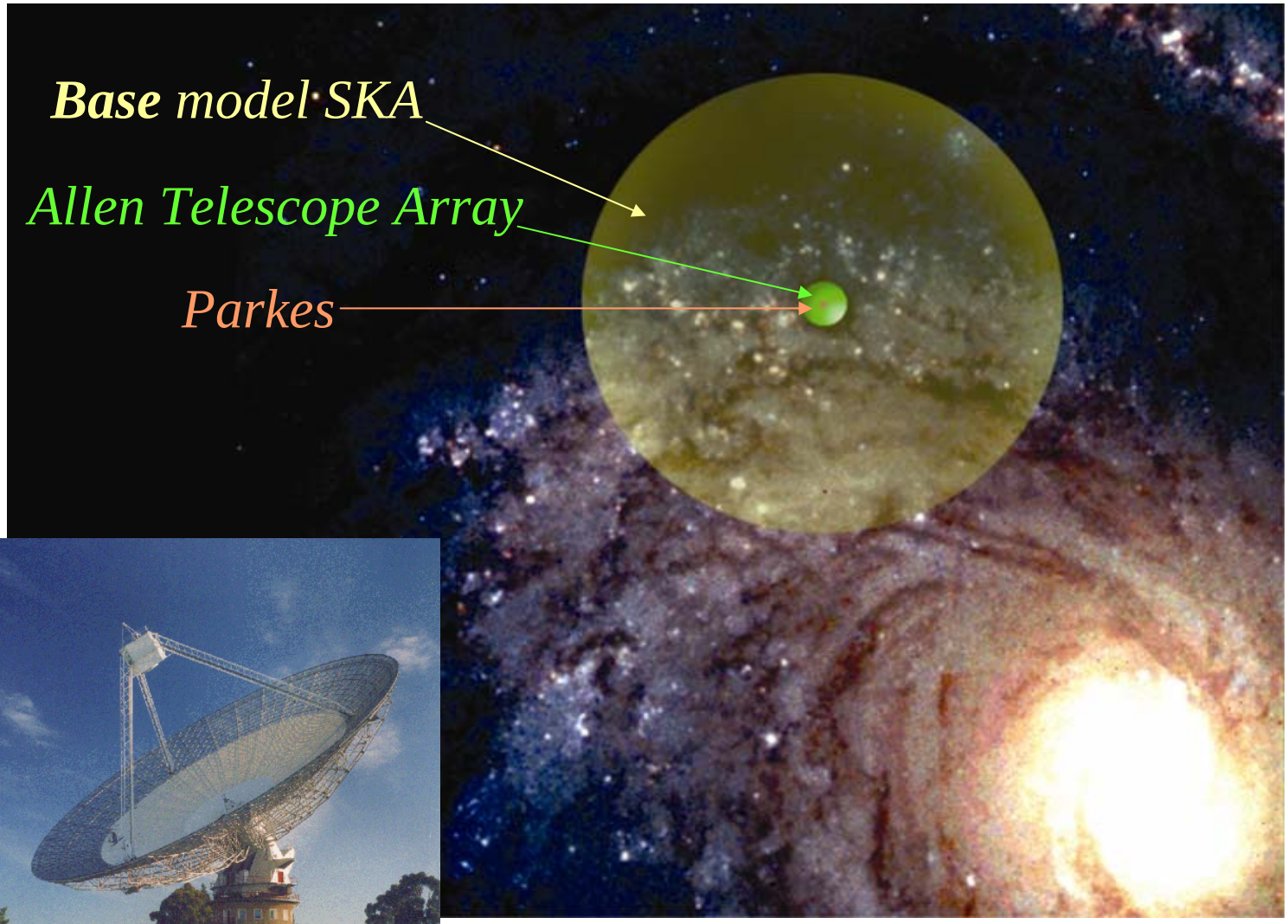
12m antenna



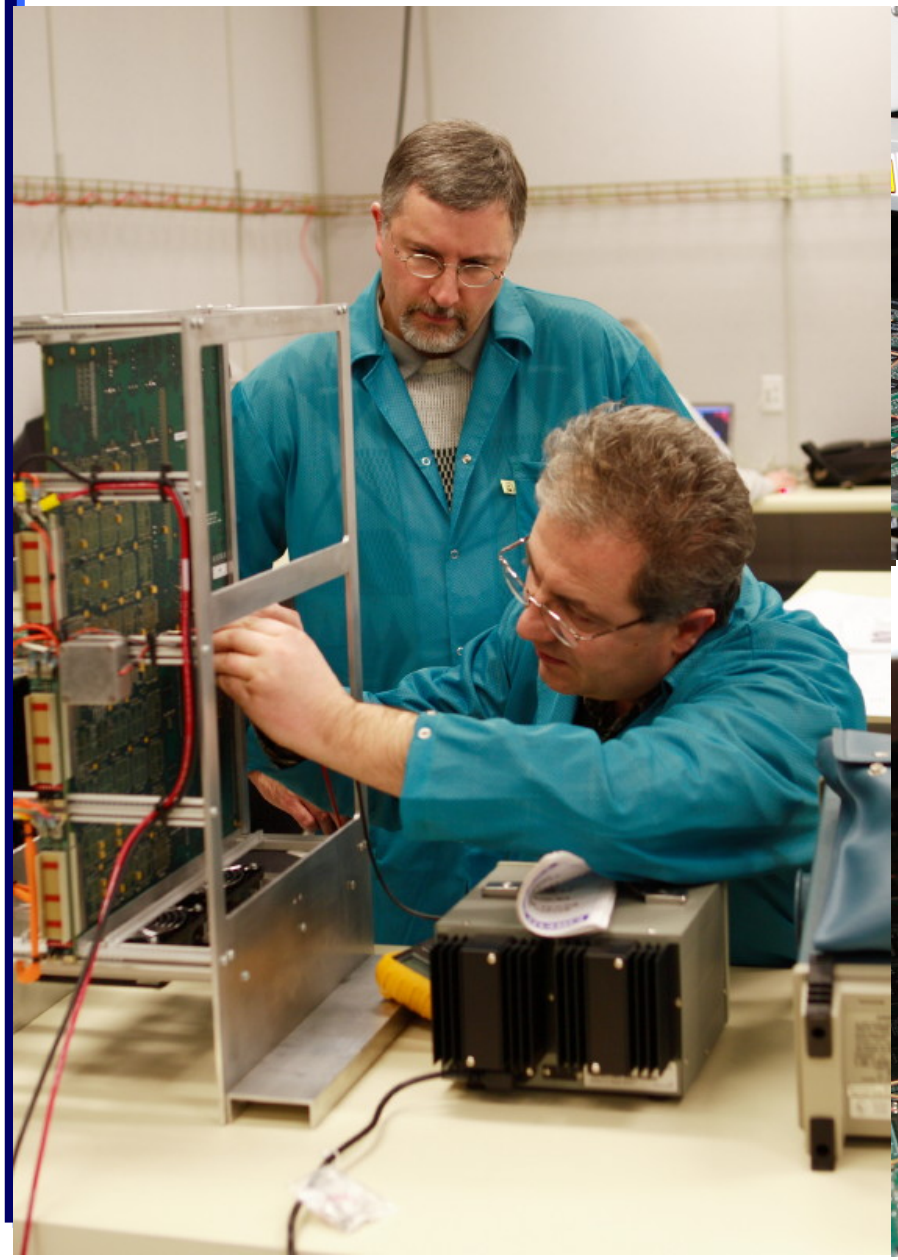
stretch-formed panels

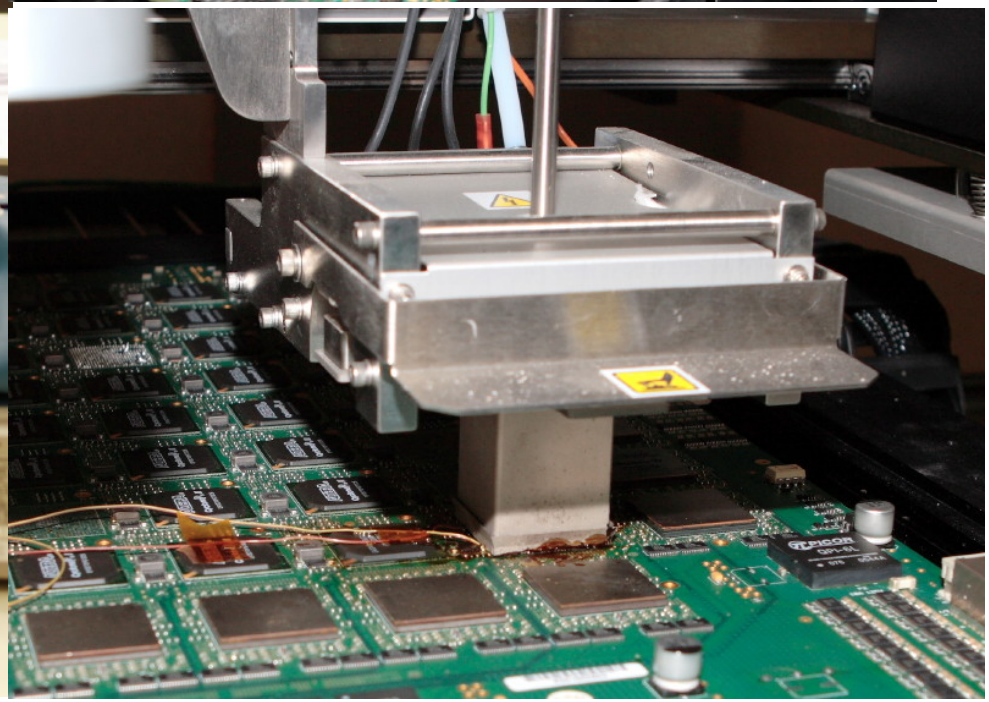
Patriot Systems

Wide field-of-view



Correlators – Ultimately Built in Industry





Electrical power – not solved yet

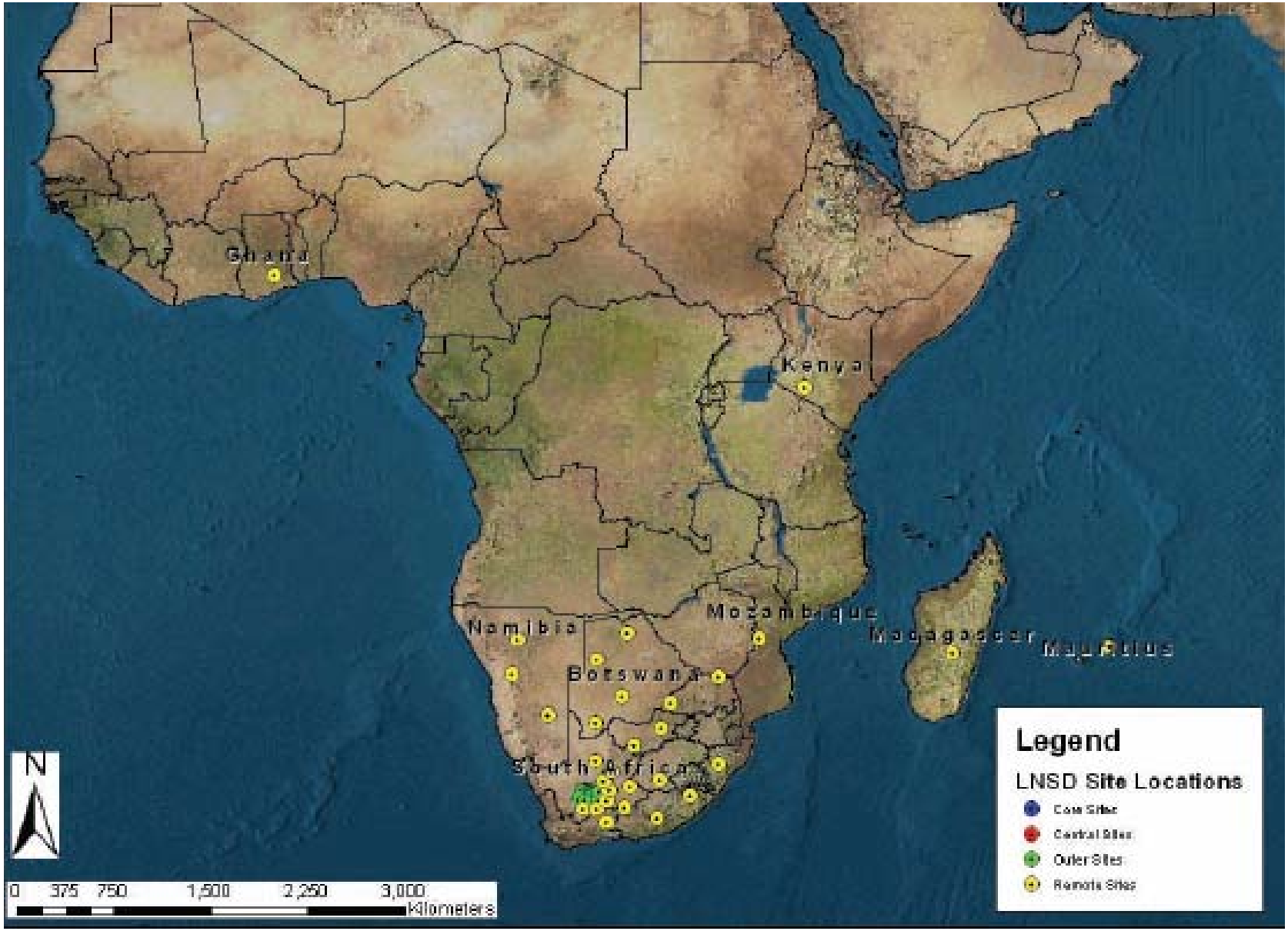
- **Solar potential is high on both sites.**
  - **24-hour coverage is needed.**
    - **requires storage or alternative night-time power source.**
  - **Cost likely to be an issue if not subsidized.**
  - **30-50MW required for full SKA**
  - **Role for small scale (~100 kW) systems if they exist.**

Other Power Issues

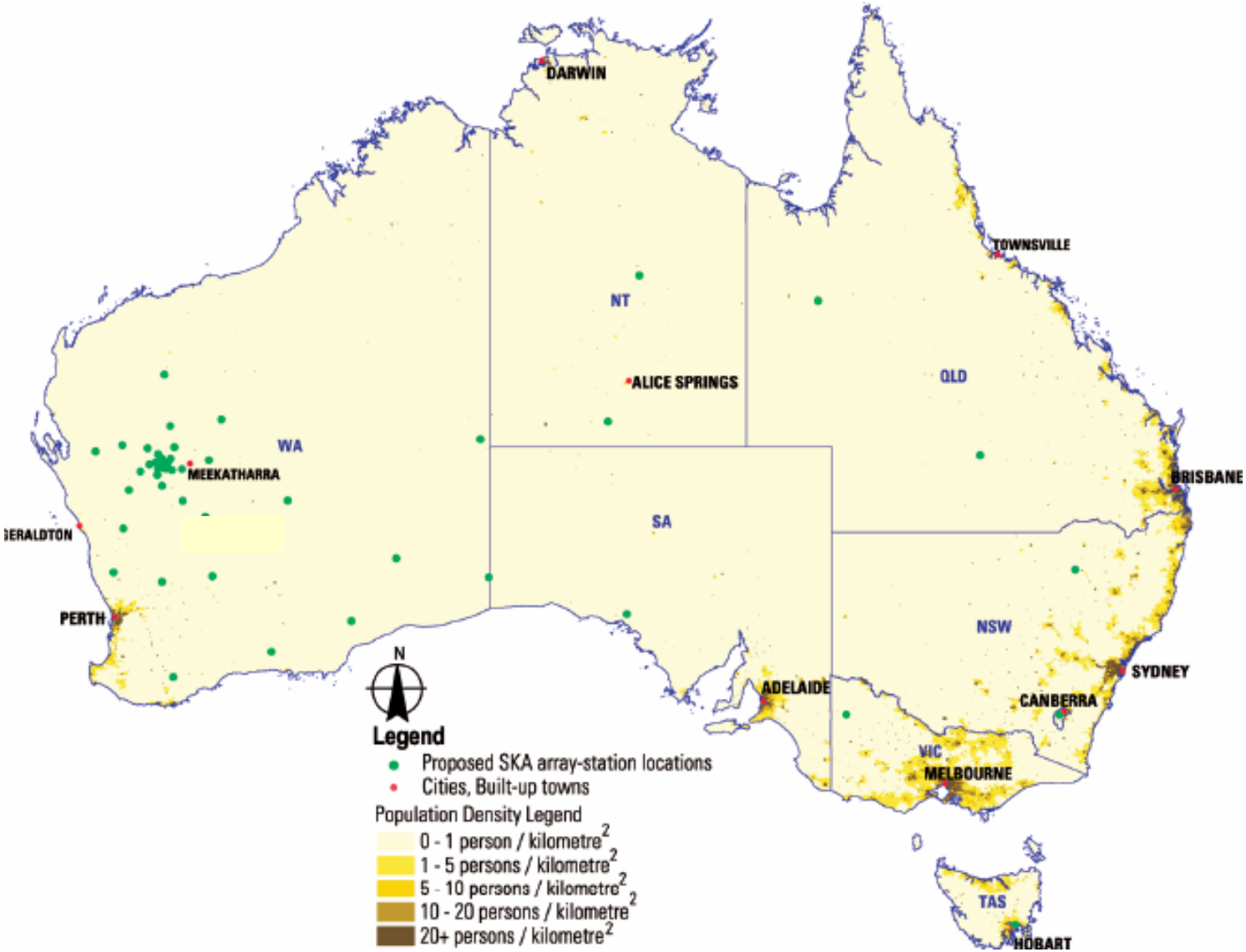
- Systems must withstand occasional flooding.
- Priority power not needed for SKA but power-outage notice might be needed.
- Safety grounding issues in desert areas.
- Lightning protection required
- Equipment subject to unusually high temperatures and large diurnal swings.
- Power for redundant communication 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


DARWIN
TOWNSVILLE
NT
ALICE SPRINGS
QLD
WA
MEEKATHARRA
BRISBANE
SA
GERALDTON
PERTH
NSW
SYDNEY
N
ADELAIDE
CANBERRA
VIC
MELBOURNE
TAS
HOBART
Legend
Proposed SKA array-station locations
Cities, Built-up towns
Population Density Legend
0 - 1 person / kilometre2
1 - 5 persons / kilometre2
5 - 10 persons / kilometre2
10 - 20 persons / kilometre2
20+ persons / kilometre2

Spectrum Measurements: 80 MHz – 1.6 GHz

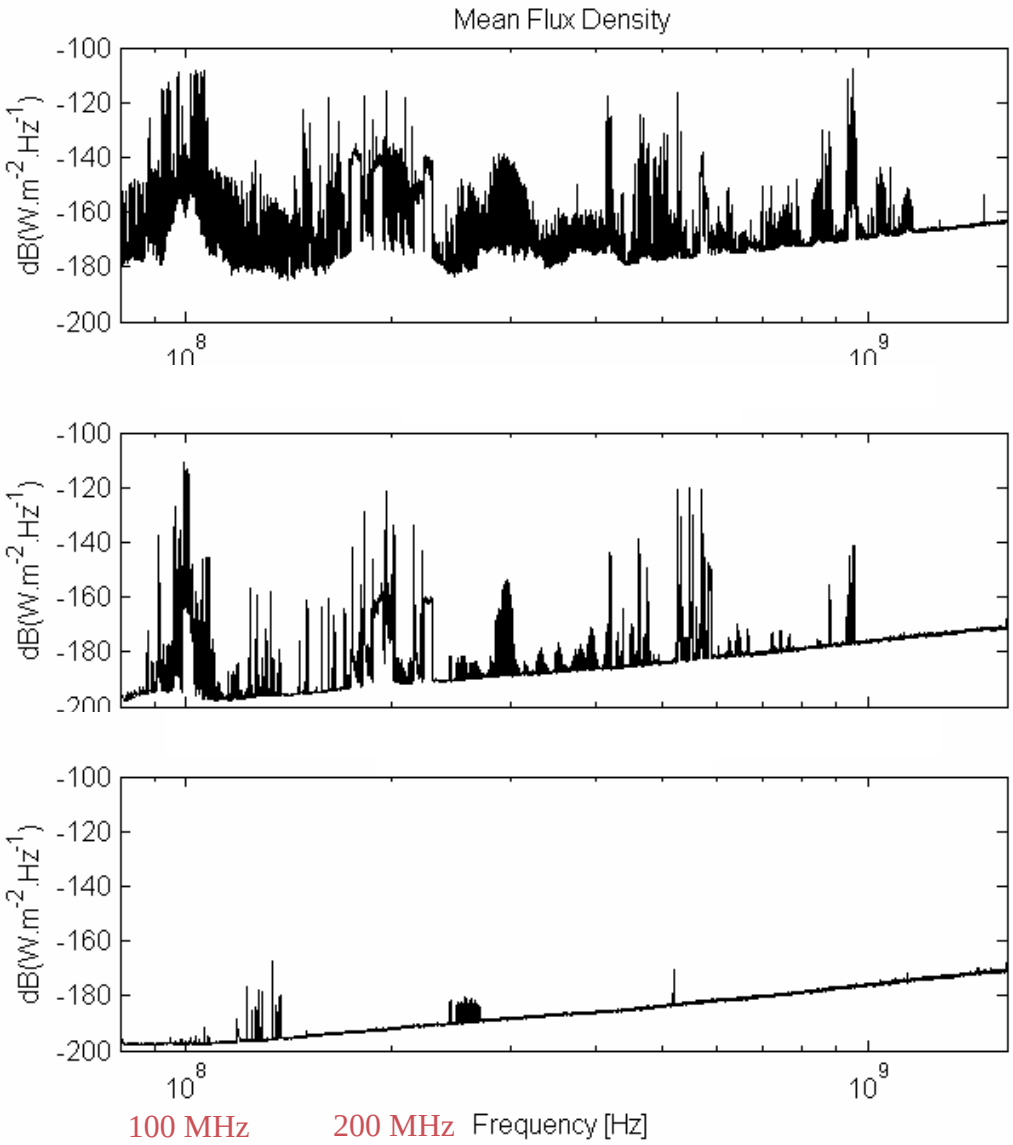
Sydney

Pop. 4 million

Narrabri

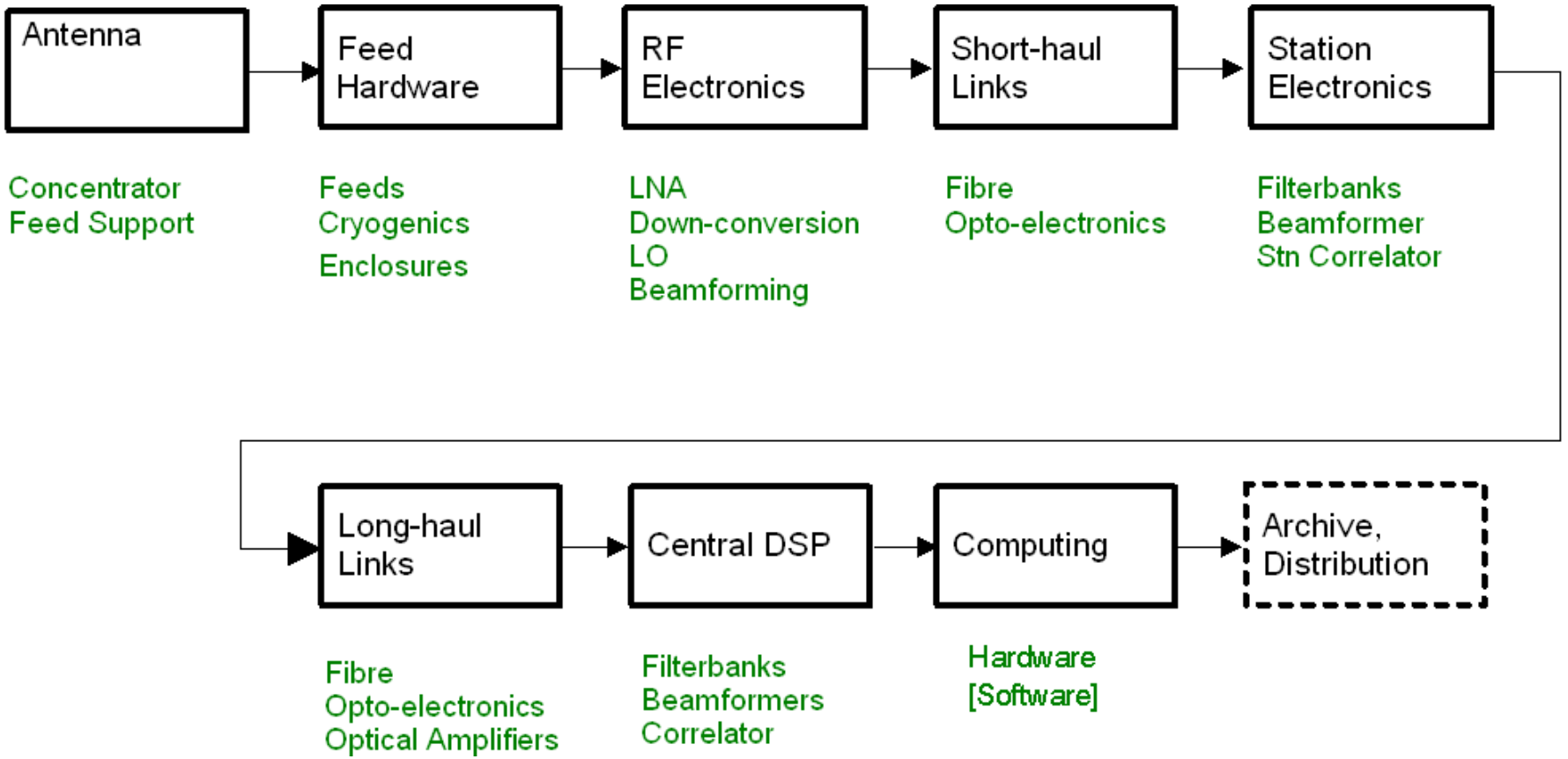
Pop. 6,000

Boolardy



Industry Opportunities

Summary of Opportunities in the SKA Signal Path



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.

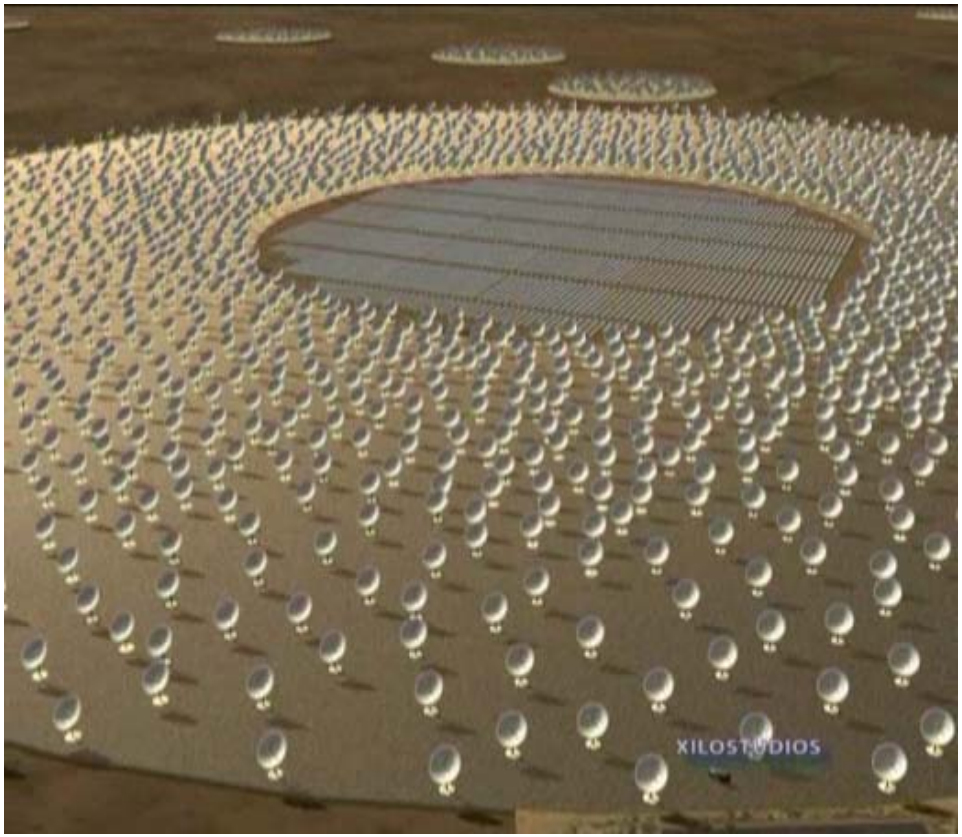
- Transport, Training, and Other Goods & Services – regional support, recruitment and training, transport and logistics, community consultation and studies, regulatory monitoring.

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

Phil Crosby
SKA Program Development Office