The Square Kilometre Array

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SKA Program Development Office

EVN Symposium, Manchester September 2010

Time line

1995-00	Preliminary R&D
2000-07	Initial Concept Stage
2008-12	System Design Stage
2013-23	Detailed design & construction
2020-50+	Operations

The SKA concept

- up to 1 million m^2 collecting area distributed over baselines of 3000+ km
  - 50% within 2.5 km, 75% within 180 km, 100% within 3000+km
- operating at frequencies from 70 MHz to 10 GHz (ΛΛ 4m-3cm) with two or more detector technologies
- connected to a data processor and high performance computing system by an optical fibre network

providing

- 40 x sensitivity of EVLA, and
- up to 10000 x survey speed

A survey instrument with unprecedented capability to follow up individual objects with high angular and time resolution

SKA Concept (2)

- Construction will proceed in two phases:
  SKA_1, SKA_2
  SKA_1 will be a subset (~10%) of **SKA_2**

- Major science observations already possible with SKA_1 in 2020

Project Status

ROADMAPS

Europe AstroNet
SKA and E-ELT equally high priority for ground-based large-scale projects

US Decadal Review
SKA represents the long-term future for radio astronomy. Mid-decade review opportunity for further funding

Australia Decadal Plan: Pathway to SKA remains #1 priority for radio astronomy in Australia. €200M in investment in radio astronomy infrastructure/capability.

African Union Heads of State acknowledge importance of SKA in the development of knowledge-based economies and driving HCD programs. South Africa is spending €200M on radio astronomy.

Status (2)

SKA project is evolving quickly

- significant investments in tech. verification programs, pathfinders & precursors
- government ministries & funding agencies are engaged

Key decisions coming up (2010-12)

- future organisation & governance for pre-construction phase (2012-15)
- pre-construction funding
- site decision

SKA Key Science Drivers

ORIGINS

- Neutral hydrogen in the universe from the Epoch of Re-ionisation to now

  When did the first stars and galaxies form?
  Properties of galaxies & how did they evolve?
  Dark Energy, Dark Matter

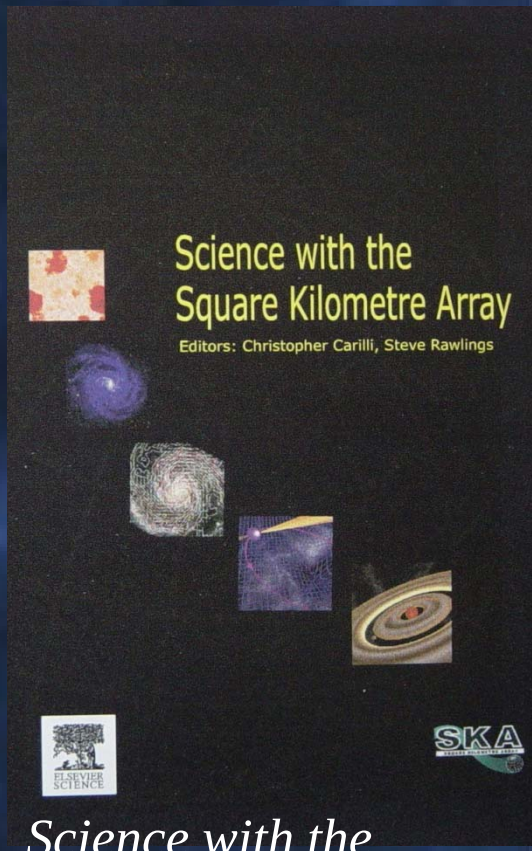
- Cradle of Life

FUNDAMENTAL FORCES

- Pulsars, General Relativity & gravitational waves

- Origin & evolution of cosmic magnetism

TRANSIENTS (NEW PHENOMENA)



Science with the Square Kilometre Array

(2004, eds. C. Carilli & S. Rawlings, *New Astron. Rev.*, **48**)

VLBI science and the SKA

Galaxy evolution: first galaxies and black holes

- Resolve AGN and star formation in weak objects
- Direct imaging of complex evolving structures associated with accretion disks and jets
- HI absorption systems, kinematics and distribution of gas close to AGN
- Water masers in accretion disks, H_0 and dark energy
- High resolution mapping of redshifted radio absorption lines, measurement of changes in fundamental constants with time

Strong field tests of gravity using pulsars

- Astrometry → model independent distances to pulsars

Strong gravitational lensing

- 10^5 lensed systems out to z~1, evolution of the luminous and dark matter distribution of galaxies and clusters

VLBI science and the SKA(2)

Astrometry

- distance determination of 1000s of pulsars, trace ISM density, temperature and turbulence
- mass function of many binary systems
- absolute astrometry and geodesy to determine the inertial reference frame to <10 μarcsec

Astrobiology at Long Wavelengths

- proto-planetary disks, pebble-sized rocks

Other science

- resolving stellar flares and stellar winds
- direct imaging and tracing evolution of jets in galactic X-ray binary systems
- new types of transient objects

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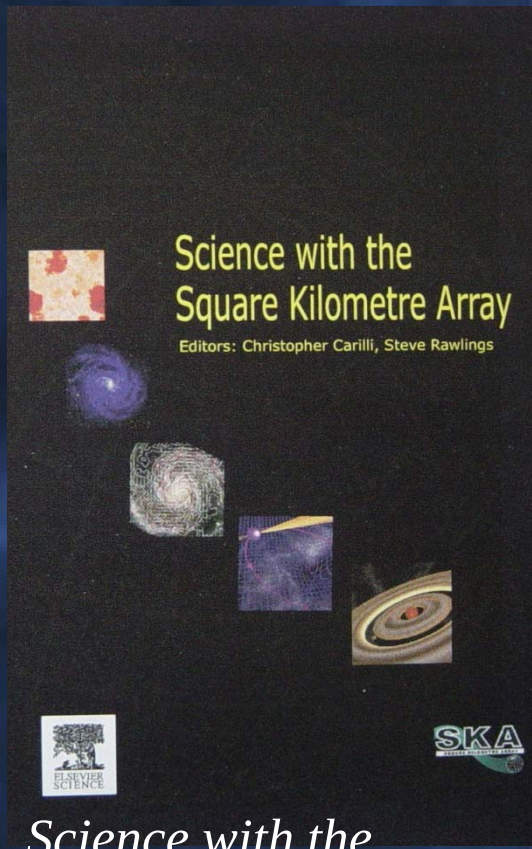

Science with the Square Kilometre Array

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Square Kilometre Array Technical Requirement Snapshot

Wavelength (Frequency)	1 cm–4 m (0.07–25+ GHz)
Sensitivity	A_{eff}/T_{sys} ~ 10000 (10 nJy, 1000 h)
Field of view	1 deg^2 or larger (@ 1 GHz)
Survey speed	~ 10^{10} deg^2 m^4 K^{-2} (100 Gpc^3 survey of H I to $z > 1.5$)

Key Science for Phase 1 (SKA_1)

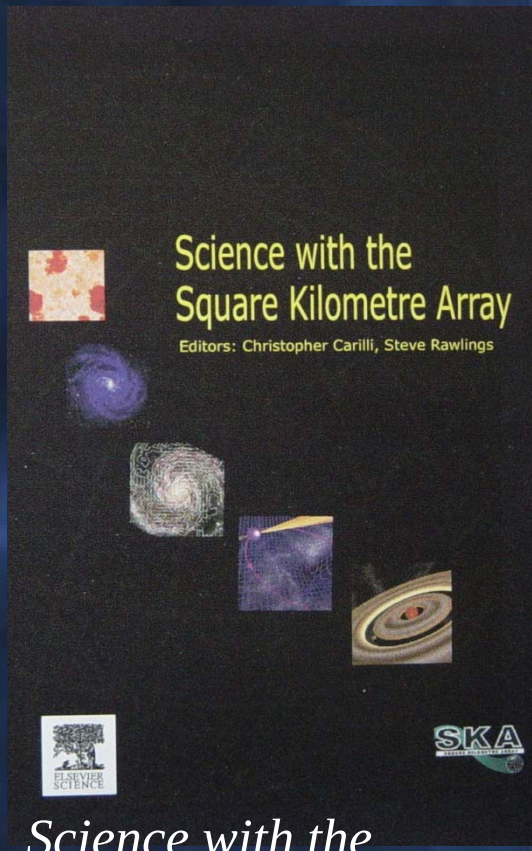
ORIGINS

- Neutral hydrogen in the universe from the Epoch of Re-ionisation to now

When did the first stars and galaxies form?
How did galaxies evolve?
Dark Energy, dark matter

FUNDAMENTAL FORCES

- Pulsars, General Relativity & gravitational waves



Science with the Square Kilometre Array

(2004, eds. C. Carilli & S. Rawlings, *New Astron. Rev.*, **48**)

Baseline design for SKA_1

1) Low frequency array for 70 - 450 MHz
for measurements of Epoch of Re-ionisation and hydrogen in the distant universe

2) Dish array with single pixel feeds for 450 MHz to 3 GHz

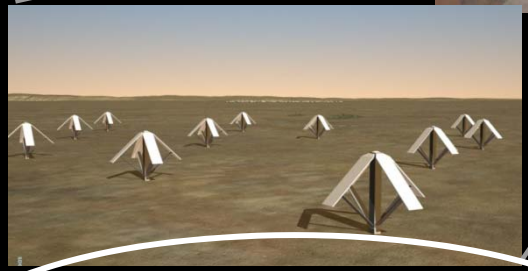
for pulsar timing → tests of strong gravity and gravitational waves, and hydrogen in the nearby universe

Baseline lengths up to 100km

SKA_1 baseline design

200 Dishes

Central Region



50 Sparse Aperture Arrays

Single pixel feed

Artist renditions from Swinburne Astronomy Productions

Advanced Instrumentation Program

- Further development of innovative wide-field **"radio camera"** technologies **at mid-frequencies**
- potential for enhancing SKA_1 and be a major part of **SKA_2**

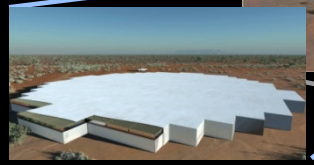
dense aperture array
(FoV ~ 200 deg^2)

phased array feeds (PAFs) on the dishes
(FoV ~ 30 deg^2)

- Decision in 2016

SKA_2 including AIP technologies

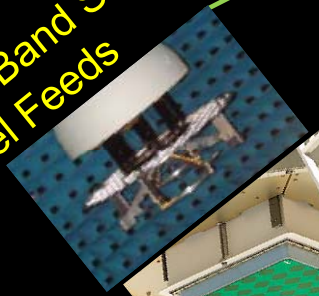
250 Dense Aperture Arrays



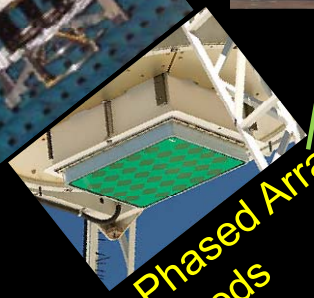
3-Core Central Region

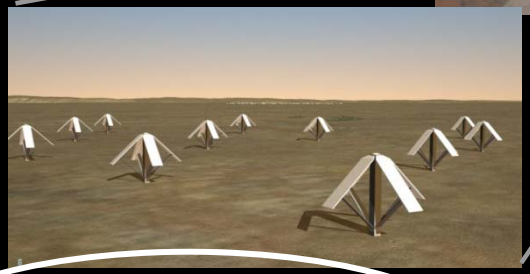
3000 Dishes

Wide Band Single Pixel Feeds



Phased Array Feeds





250 Sparse Aperture Arrays

Artist renditions from Swinburne Astronomy Productions

SKA is driving development of new science & technical solutions

Dishes, feeds, receivers (N=3000)
Aperture arrays (N=250)
Signal transport (800 Tbit/s)
Signal processing (exa-MACs)

} ongoing verification programs

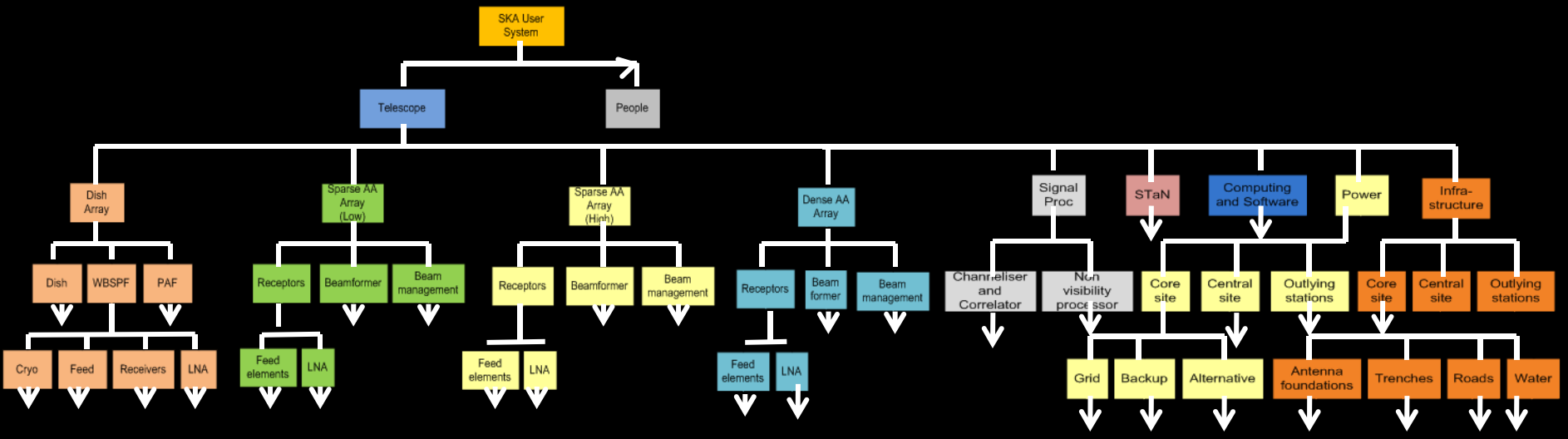
Software engineering and algorithm development
High performance computing (exa-flop capability)
Data storage (exa-byte capacity)
(Distributed) power requirements (50 -100 MW)

INDUSTRY ENGAGEMENT IS CENTRAL TO THE SKA

SKA System Design (2007-2012)

Contributing programs (70 fte/yr)

- EC FP6 SKA Design Study (SKADS)
- EC FP7 Preparatory Phase (PrepSKA)
- US Technology Development Program
- "Precursor" telescopes on the candidate sites (ASKAP (AU), MeerKAT (SA))
- "Pathfinder" telescopes like e-EVN, e-MERLIN



Baseline design component:

Sparse aperture arrays for the lowest frequencies

LOFAR (Netherlands et al)

MWA (USA, Australia)

Baseline design component:

Dishes + single pixel feeds

ATA (USA)

42x6m
hydroform
dishes

MeerKAT (South Africa)

80x12m composite dishes

ASKA

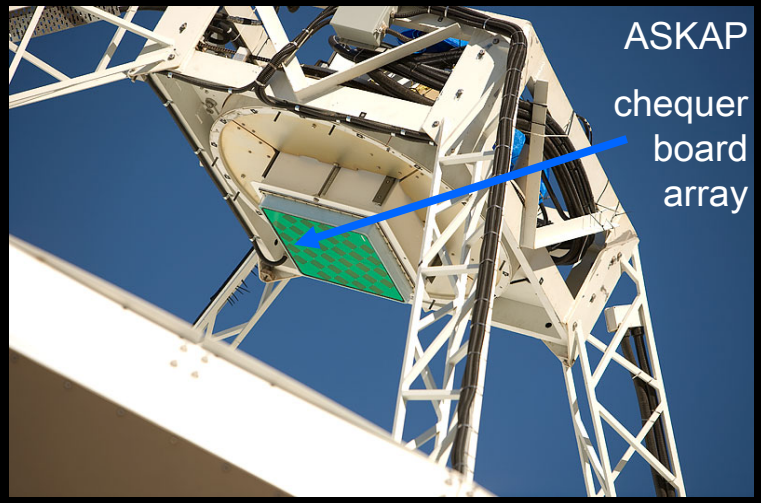
36x12

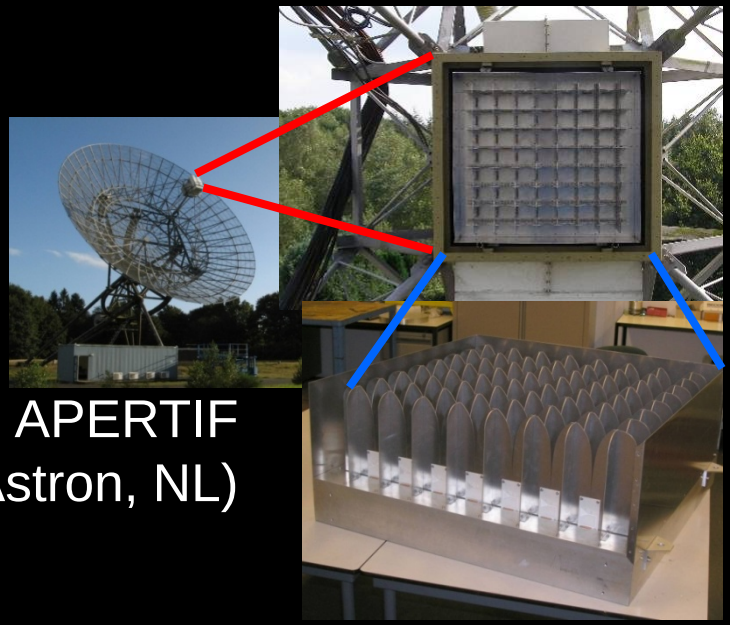
RT

ada)

10 m composite prototype

Advanced Instrumentation Program: dishes+multi-pixel feeds





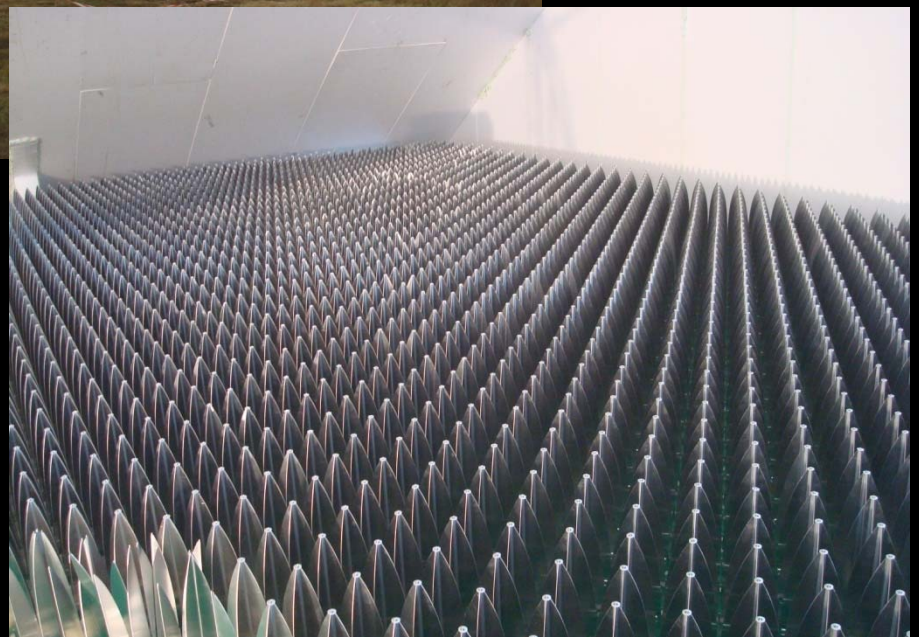
APERTIF
(Astron, NL)

DRAO
Canada

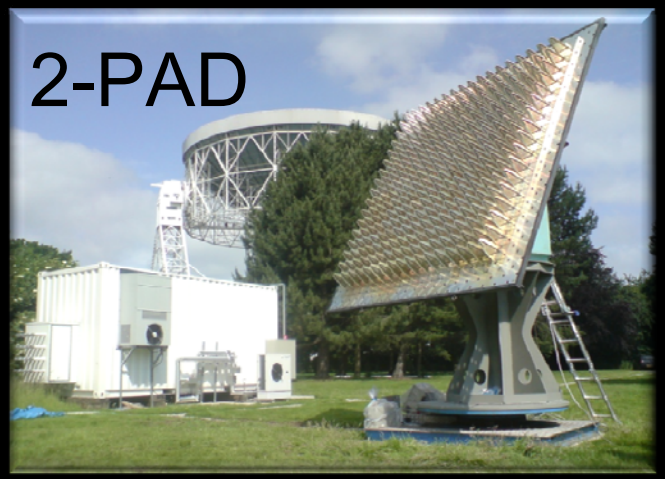
Advanced Instrumentation Program: dense aperture array

EMBRACE

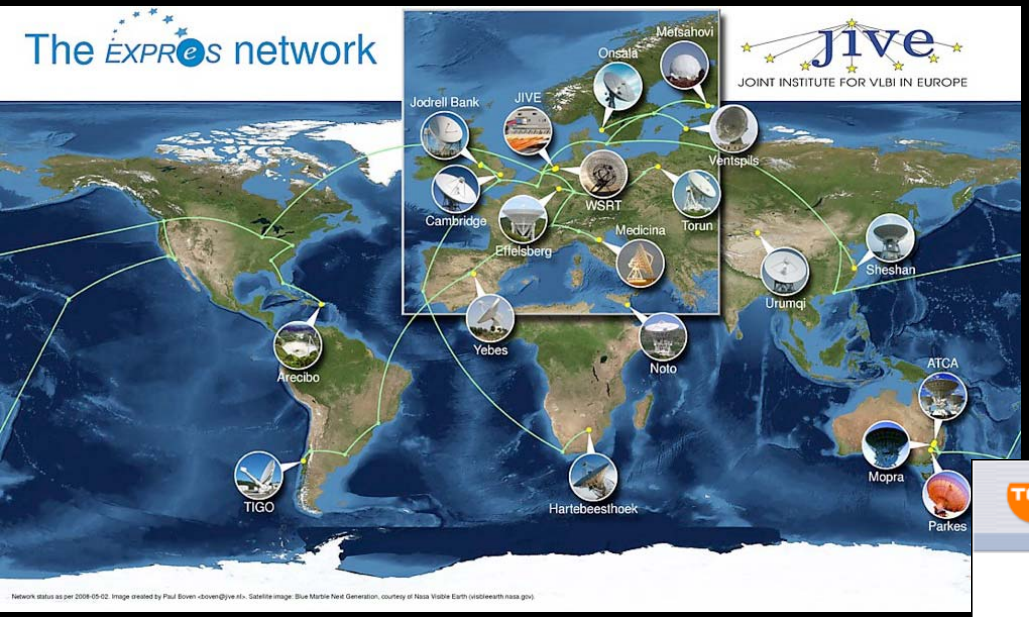
FP6-SKADS

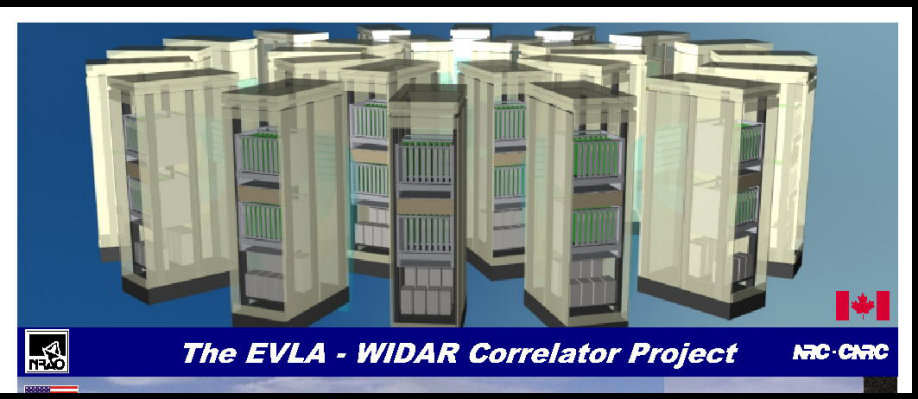


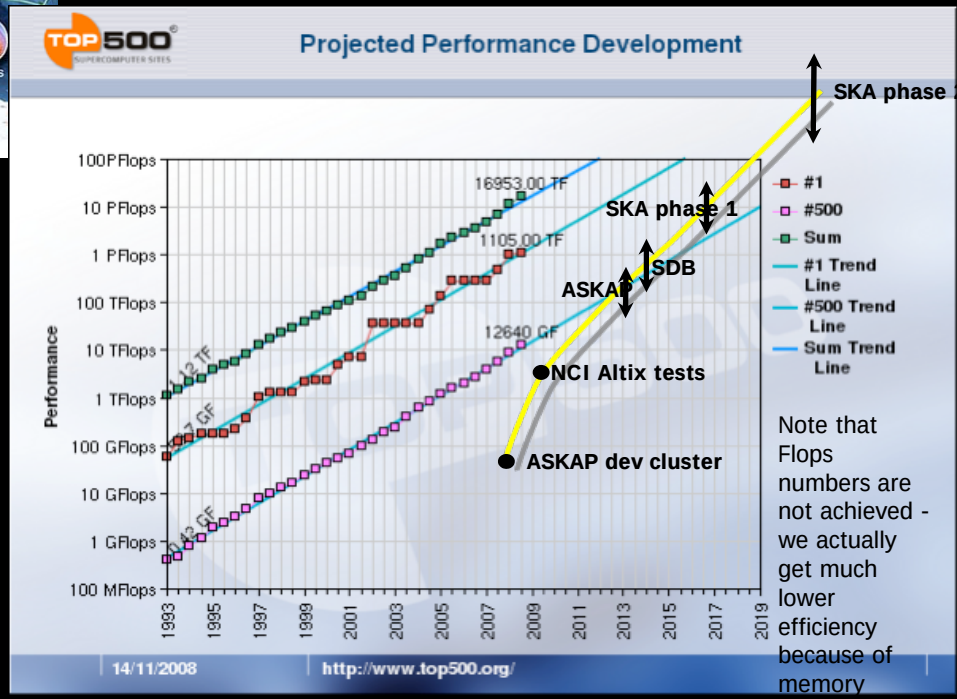
2-PAD



Signal transport, signal processing







Note that Flops numbers are not achieved - we actually get much lower efficiency because of memory

SKA Site

- **Physical requirements**
  - Extremely radio quiet environment
  - At least 3000 km in extent
  - Low ionospheric turbulence
  - Low tropospheric turbulence
- **Two candidates short-listed in 2006**
- **Site selection process**

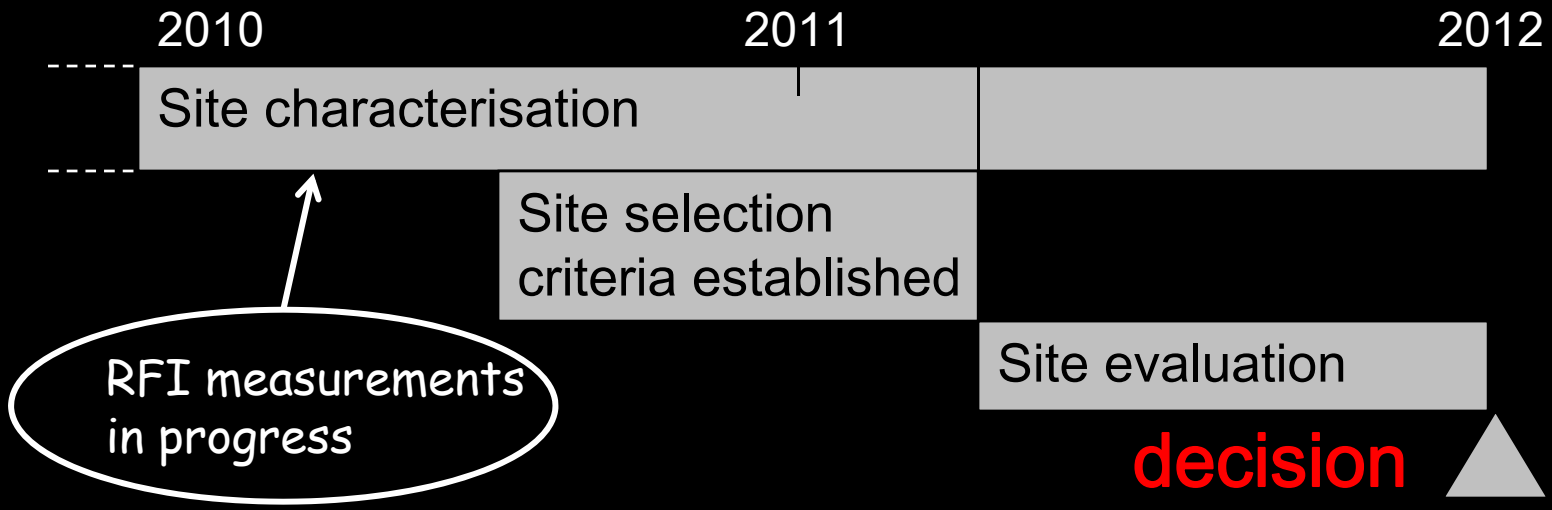



Image © 2007 TerraMetrics
Image NASA
Google

South Africa + 7 countries

Top level schedule for the SKA

Technical

2008-12	telescope system design and cost
2013-15	detailed design & pre-construction phase
2016-19	Phase 1 construction
2016	Advanced Instrumentation Program decision
2018-23	Phase 2 construction
2020→	full science operations with Phase 1
2024→	full science operations with Phase 2

Programmatic

2011	establish SKA organisation as a legal entity
2012	site selection
2014	construction funding approved for Phase 1 (350 M€, 2007)
2017	construction funding approved for Phase 2 (1.2 B€, 2007)

Further information
www.skatelescope.org