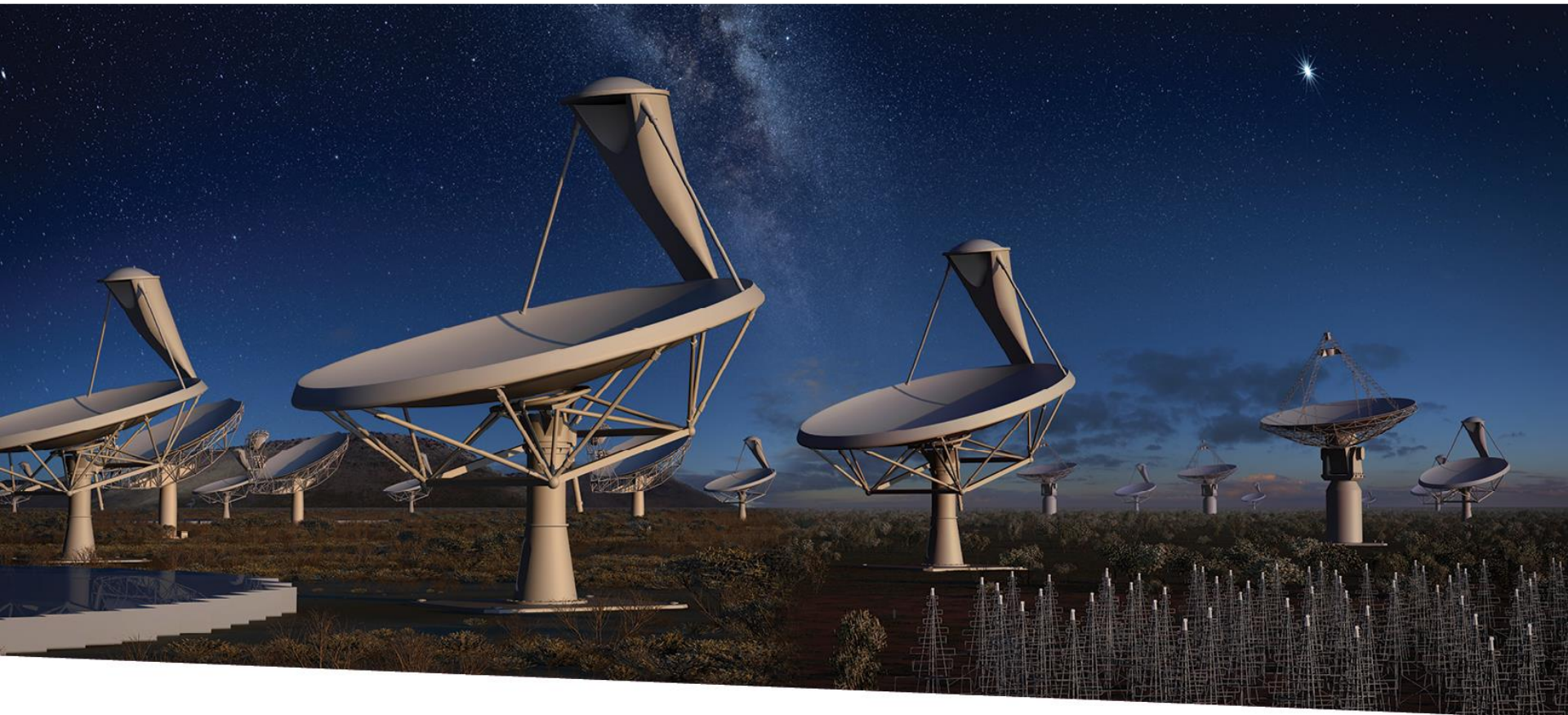


# Square Kilometre Array : The Radio Astronomy Mega-Project of the Future



**SQUARE KILOMETRE ARRAY**

Exploring the Universe with the world's largest radio telescope

**Y. Gupta & J.C. Guzman**  
(on behalf of the SKA Project)

ICALEPCS-2015, Melbourne, 21 Oct 2015

# Talk Outline



- Context
- Key science goals
- The SKA as an observatory
- Governance structure
- Current status and timelines
- Summary

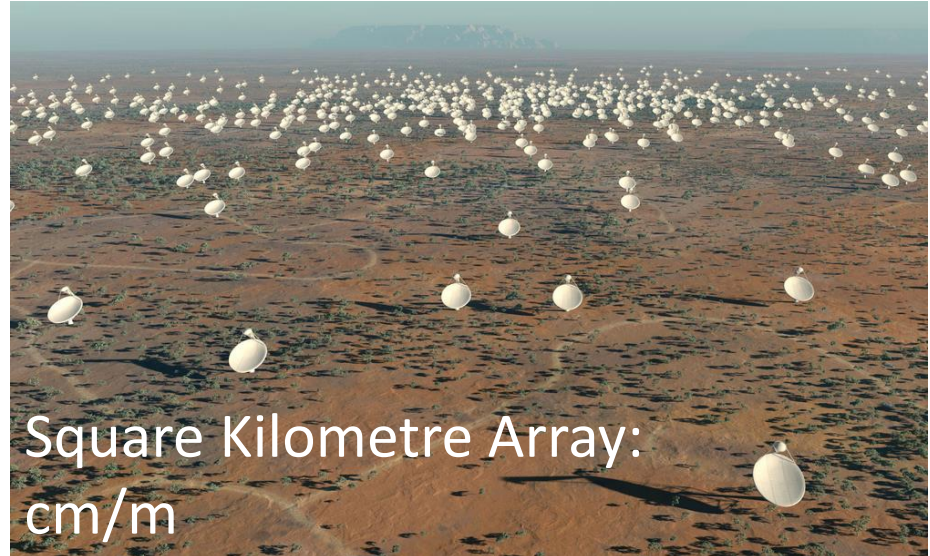




# The SKA will be one of Great Multi-wavelength Observatories of the future decades

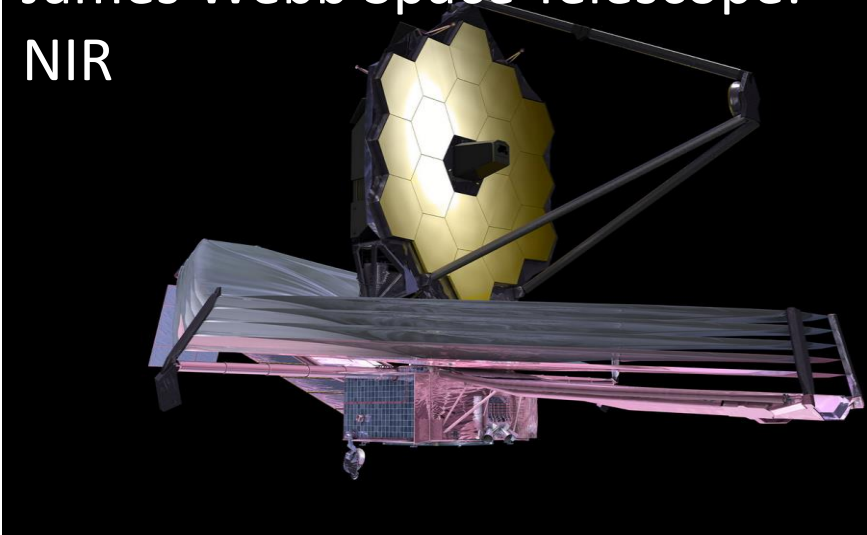


E-ELT/TMT/GMT: optical/IR



Square Kilometre Array:  
cm/m

James Webb Space Telescope:  
NIR



Atacama Large Millimetre Array  
(ALMA): mm/submm



# Radio telescope sensitivities over the years

The SKA will be **50x** better than today's best !





# SKA : A broad overview



- The SKA is the most ambitious Radio Astronomy project ever attempted
- 1 square km (1,000,000 sq m) collecting area ( $\sim 30 \times$  GMRT !)  
e.g.  $\sim 3000$  small sized antennas, with larger field of view
- High resolution : receptors spread out over distances up to 3000 km, but connected in real-time (by optical fibre)
- Wide frequency range : 70 MHz - 10 GHz
- Location : Australia & South Africa (radio quiet regions, far away from human habitat)
- Broader science range than any other science facility on the Earth
- Total estimated costs for the SKA :
  - Phase I : 650 M Euros
  - Total :  $\sim 1.5$  billion Euros (?)

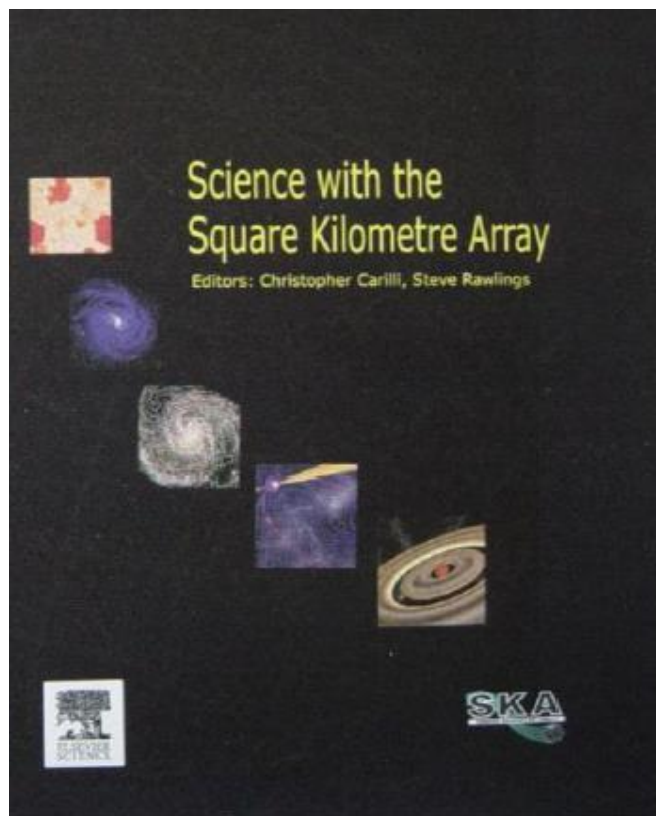


# SKA Key Science Areas



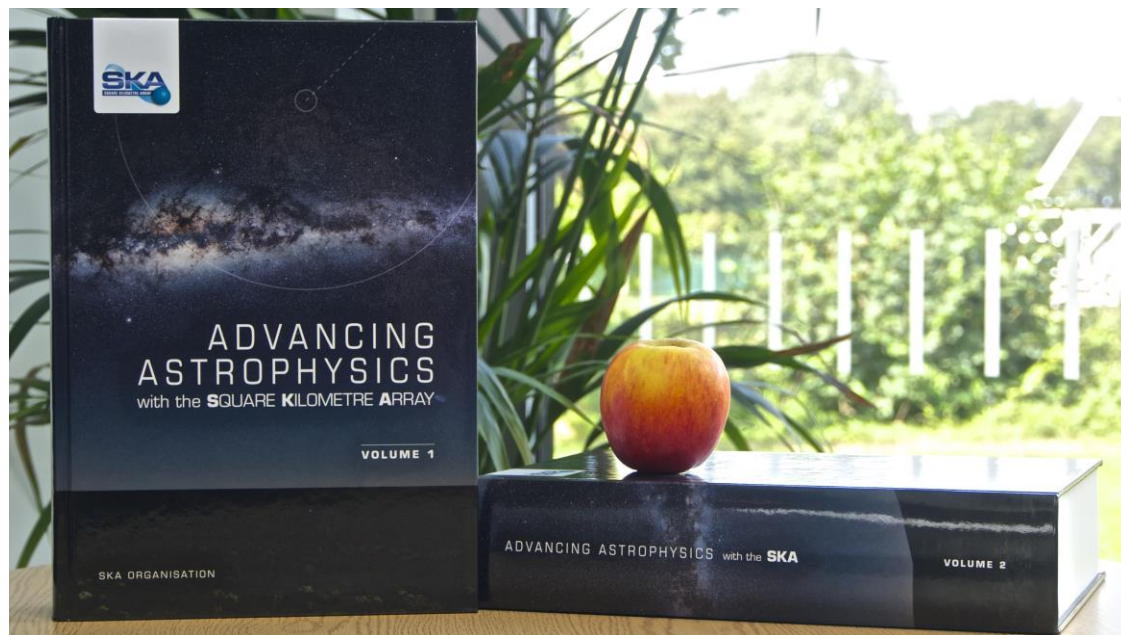


# Science with the SKA : evolving over the years



## *Science with the Square Kilometre Array*

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

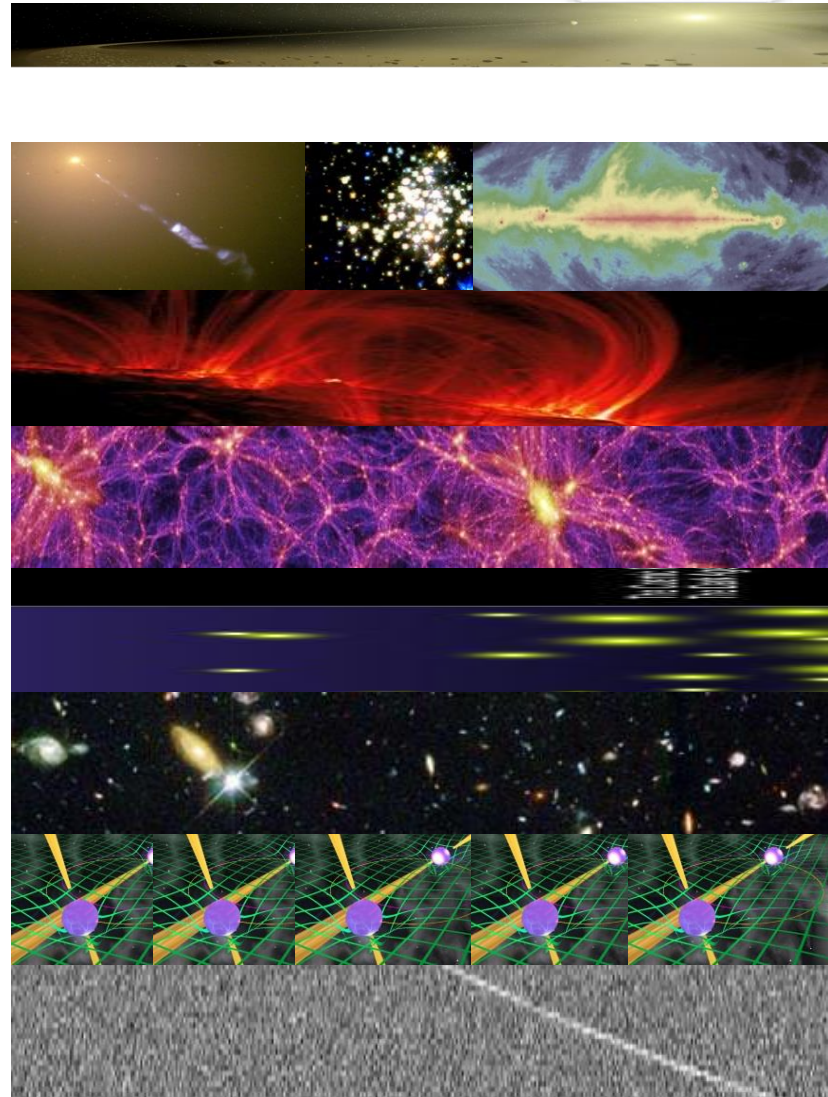


Updated Science Case (2015) :  
2 volumes, 135 chapters, 9 kg (!)

# SKA : Key Science Areas



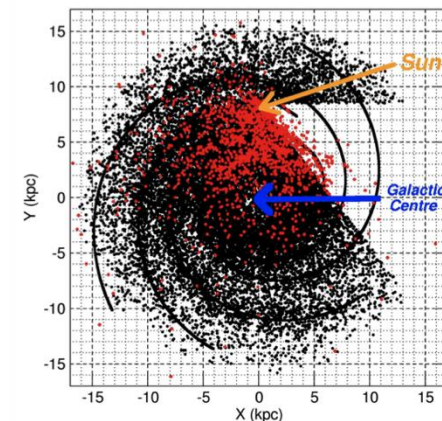
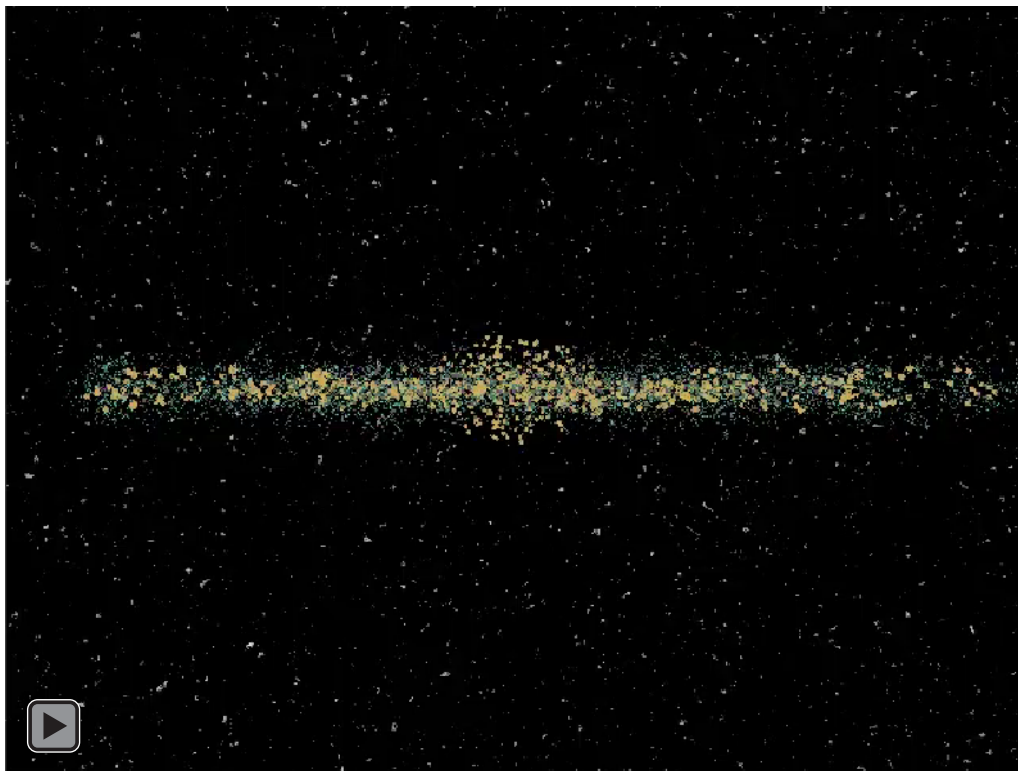
- **Epoch of Reionisation / Cosmic Dawn**
  - The first stars & galaxies in the Universe
- **Cosmology**
  - The grand design of the Universe
- **Galaxy Evolution / Continuum**
  - Star formation in galaxies over time
- **Galaxy Evolution / Neutral Hydrogen**
  - Gas content in galaxies over time
- **Cosmic Magnetism**
  - What generates magnetic fields in space
- **Transients**
  - Bursts of emission from special objects
- **Pulsars / Strong field tests of gravity**
  - Gravity waves and fundamental physics
- **Astrobiology / Cradle of Life**
  - Looking for the building blocks of life
- **Serendipity : new, unexpected discoveries !**





# Finding all the pulsars in the Milky Way...

(Cordes et al. 2004, Kramer et al. 2004, Smits et al. 2008)

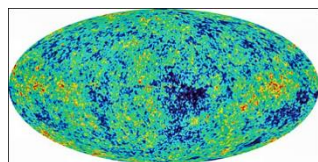


- ~40,000 normal pulsars
- ~2,000 millisecond psrs
- ~100 relativistic binaries
- first pulsars in Galactic Centre
- first extragalactic pulsars

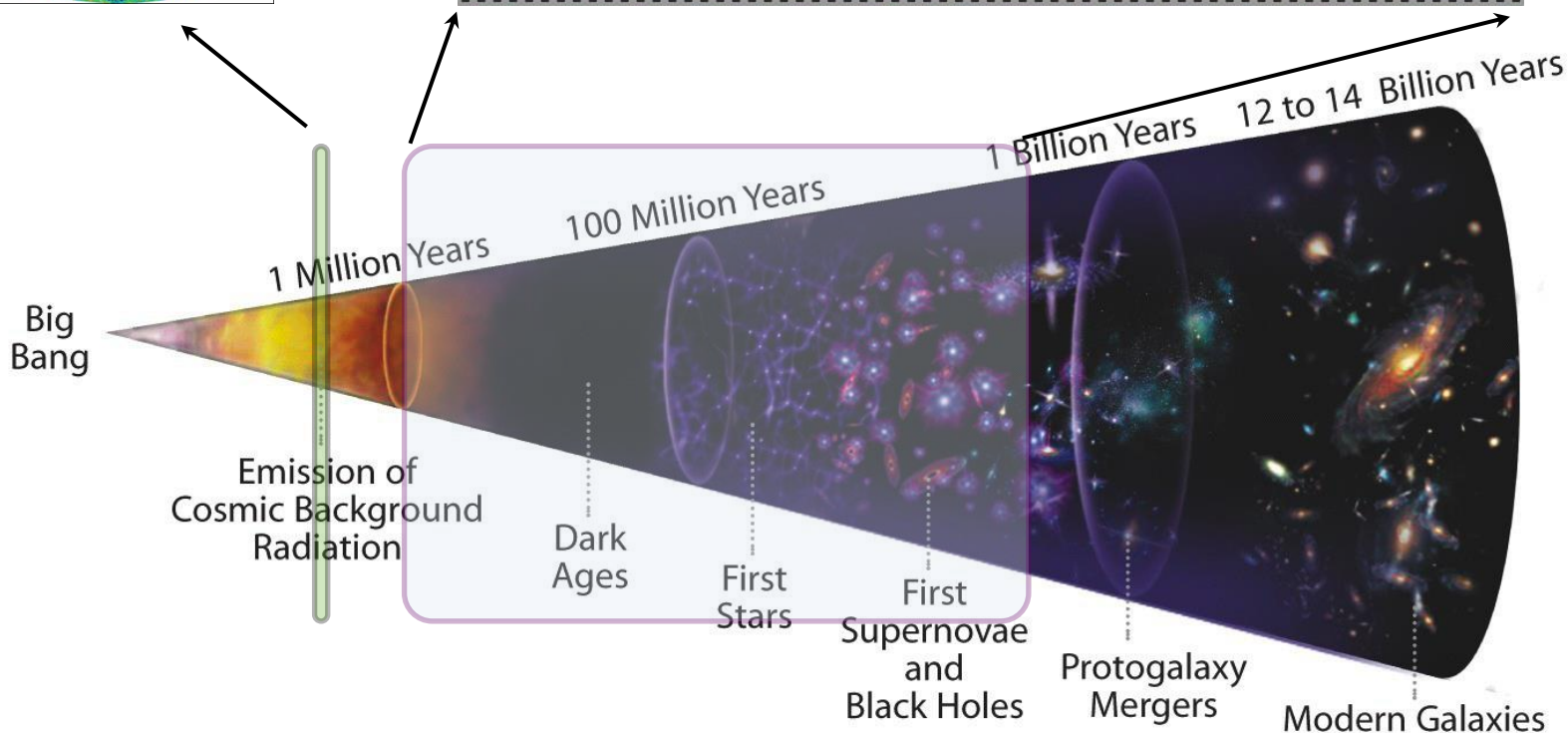
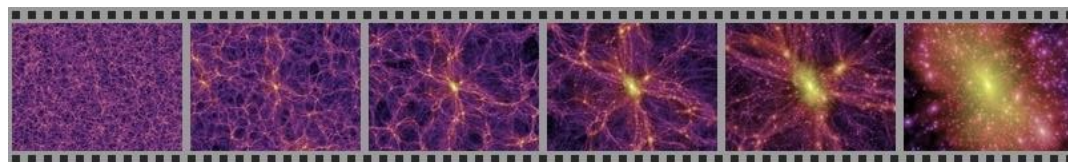
- Timing precision is expected to increase by factor  $\sim 100$
- Rare and exotic pulsars and binary systems: including PSR-BH systems!
- Testing cosmic censorship and no-hair theorem
- **Current estimates are ~50% of population with SKA1, 100% with SKA2**

# HI surveys of the EoR, Cosmic-Dawn & Dark Ages

CMB displays a single moment of the Universe. Its initial conditions at  $\sim 400,000$  yrs



HI emission from the Dark Ages, Cosmic Dawn & EoR traces an evolving “movie” of baryonic and DM structure formation at  $t_{\text{univ}} < 10^9$  years.





# The SKA Observatory



# The SKA (as of March 2015)

## SKA Observatory

3 sites : 2 telescopes; 1 HQ

### Phase 1

Construction : 2018 – 2023

Construction cost : € 650 M

Operations cost : ~ € 75 M/yr, TBD

MeerKat integrated

ASKAP incorporated, subject to negotiation

Advanced Instrumentation Programme



# SKA-MID : Karoo, South Africa



**Phase 1:** 200 15m dishes spread over 150 km (2018 – 2023)

**Phase 2:** 2500 dishes spread over 3500 km (2025 – 2033)



## The Karoo

- 800 km north of Cape Town
- Radio quiet protected by Astronomy Advantage Act
- Building on MeerKAT



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# SKA-LOW : Murchison, Australia



**Phase 1:** 130,000 dipole antennas over 80 km (2018 – 2023)

**Phase 2:** 500,000 dipoles over 250 km (2025 – 2033)



## Murchison Desert

- 800 km north of Perth
- Very low popn density
- Radio quiet zone protected by ACMA
- ASKAP & MWA precursors





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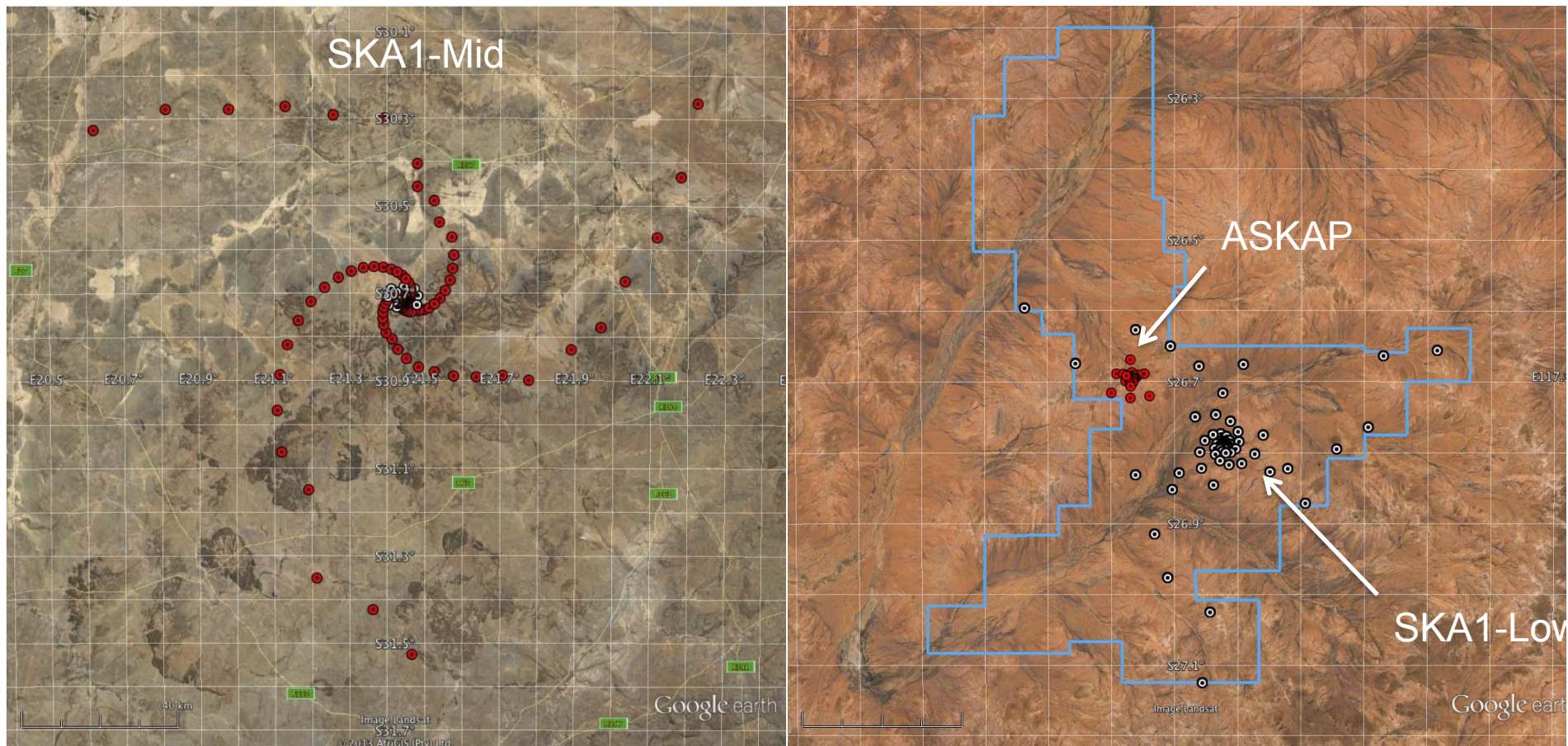
## Murchison Desert

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# SKA1 Configurations for Mid & Low



- SKA1 max baselines = 156 km (Mid), 65 km (Low)



# Key events in the last 12 months

- Sep 2014: SKA rated as top priority new project in French 5-year astronomy infrastructure planning
- Dec 2014: Portugal releases its national research infrastructure roadmap: SKA included
- Dec 2014: Italian government passes legislation, includes 30 Meuros for industrial astronomy – SKA/CTA
- Dec 2014: UK releases its 10-year Science and Technology strategy – SKA prominent (UK construction funding 100 Mpounds for SKA1 construction already committed in March 2014)
- March 2015: SKA1 re-baselining
- April 2015: SKA HQ decision
- Sep 2015: India officially joined as full member of SKA



# SKA HQ: Jodrell Bank, UK



# Delivering science

- SKA Observatory will deliver quality-controlled, calibrated, science quality data to archives in Perth and/or Cape Town.
- It will not provide added-value software, pipelines etc which will be required to extract maximal science.
- Teams awarded Key Science time will be expected to find resources to develop additional tools
- Discussions on-going for nations to establish Regional Data Centres/Regional Science & Engineering Centres to help support SKA science and development engineering.



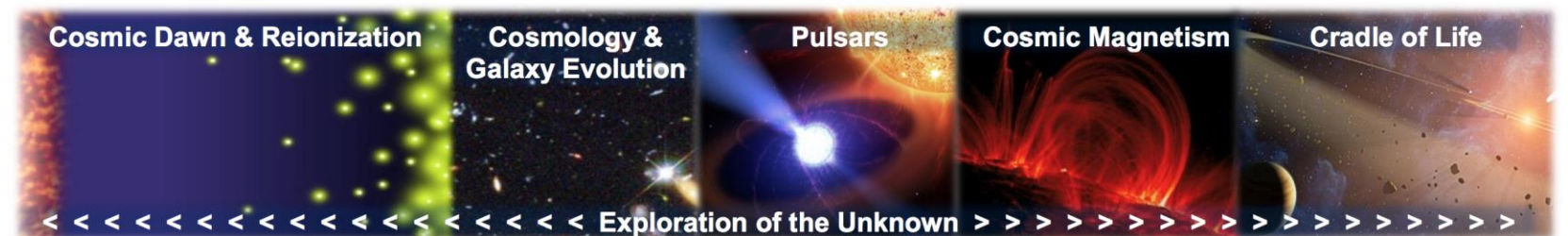
# Phase I



# Phase II



# Science



50 MHz

100 MHz

1 GHz

10 GHz



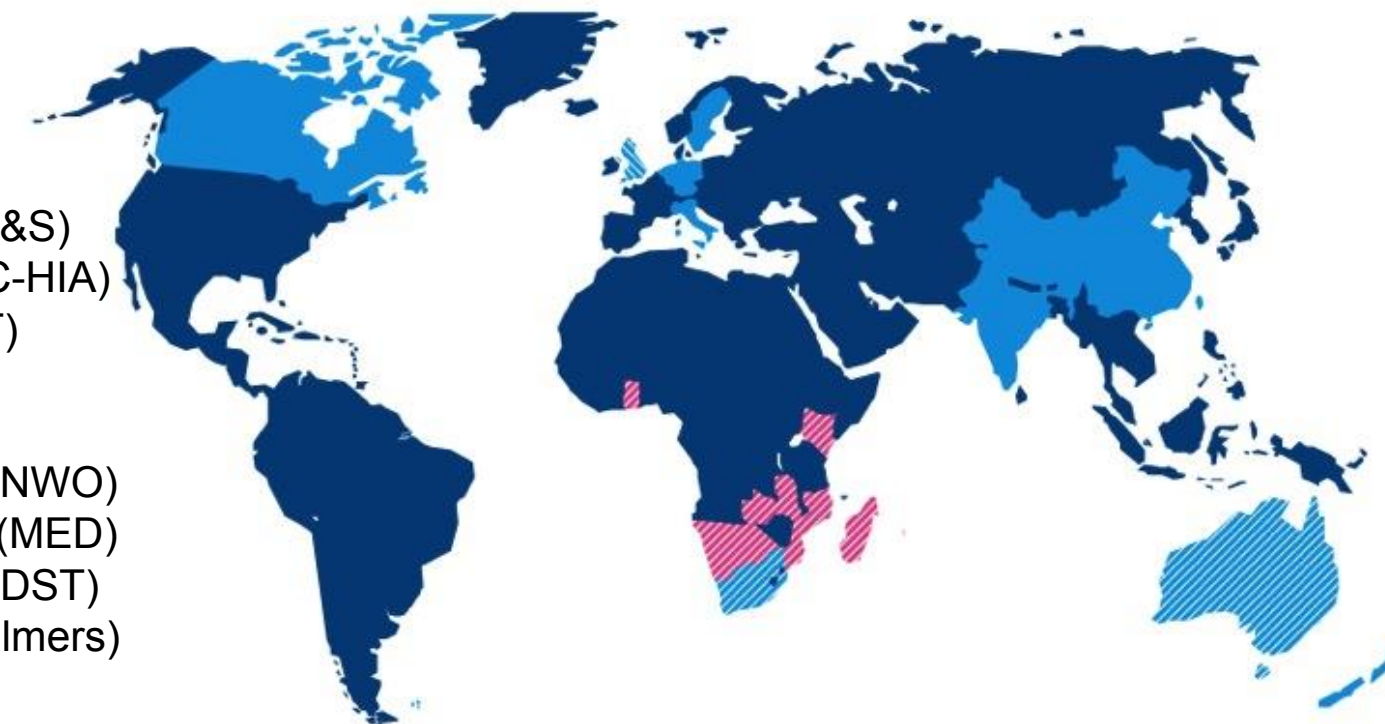
# SKA Governance



# SKA Organisation: 10 countries, more to join

## Members:

- \* Australia (Dol&S)
- \* Canada (NRC-HIA)
- \* China (MOST)
- \* India (DAE)
- \* Italy (INAF)
- \* Netherlands (NWO)
- \* New Zealand (MED)
- \* South Africa (DST)
- \* Sweden (Chalmers)
- \* UK (STFC)



● Full members

▨ SKA Headquarters host country

▨ SKA Phase 1 and Phase 2 host countries



▨ African partner countries  
(non-member SKA Phase 2 host countries)

This map is intended for reference only and is not meant to represent legal borders

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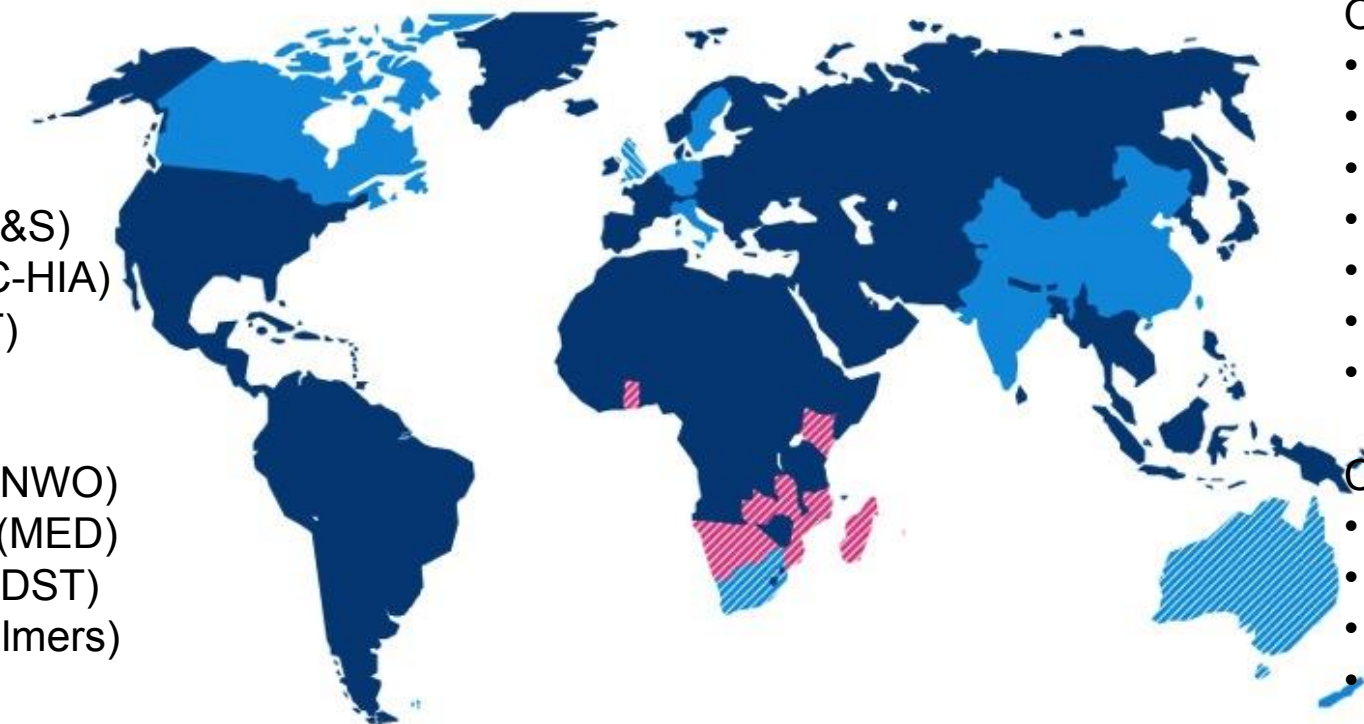
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- \* South Africa (DST)
- \* Sweden (Chalmers)
- \* UK (STFC)

## Observers:

- France
- Germany
- Japan
- Malta
- Portugal
- Spain
- USA

## Contacts:

- Brazil
- Ireland
- Korea
- Russia
- Switzerland



● Full members

▨ SKA Headquarters host country

▨ SKA Phase 1 and Phase 2 host countries



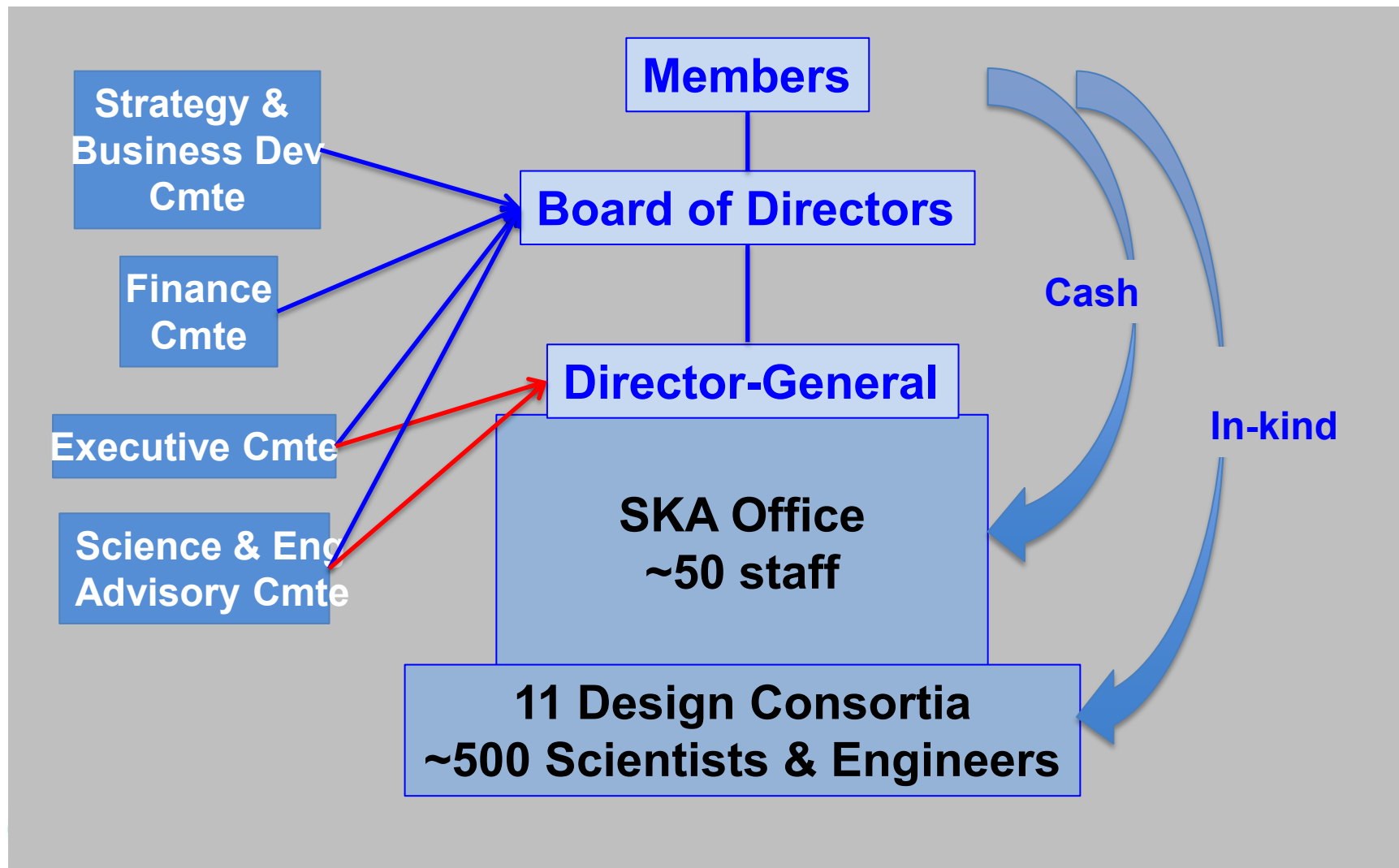
▨ African partner countries  
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# SKA Governance + current funding:

## UK not-for-profit company.



# SKA Governance in the long run :

## Evolve to Inter-governmental Organisation



- SKA Member governments will negotiate the establishment of an intergovernmental organisation (IGO), similar to ESO/CERN/ITER/ESA.
- Will provide:
  - Long-term government commitment and funding stability
  - Availability of Privileges and Immunities from members
  - ‘Freedom to operate’, specifically through procurement process
- First formal negotiation meeting: 14-16 October, Rome.
  - Draft treaty text exists
  - Draft procurement policy, draft financial protocol + more, all exist

# SKA Design status



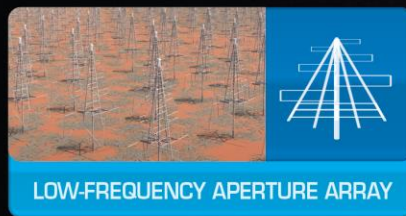
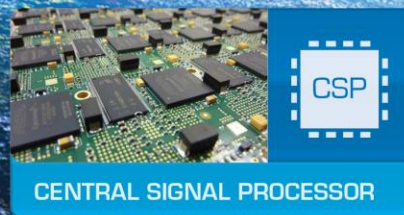
# SKA-I Design : Work Packages



- Following are led by SKA Office :
  - Management
  - Science
  - System Design and system engineering
  - Maintenance & Support and Operations
- Following are carried out by Work Package Consortia :
  - Dish Array
  - Aperture Arrays
  - Signal and Data Transport (including synchronisation and timing)
  - Central Signal Processor
  - Science Data Processor
  - Telescope Manager
  - Infrastructure, including power
  - Assembly, Integration and Verification
- Additional packages on Advanced Instrumentation Programmes (to be integrated with Dish & AA WPs) by WP Consortia :
  - Mid Frequency Aperture Array
  - Wide Band Single Pixel Feeds

# International Design Teams

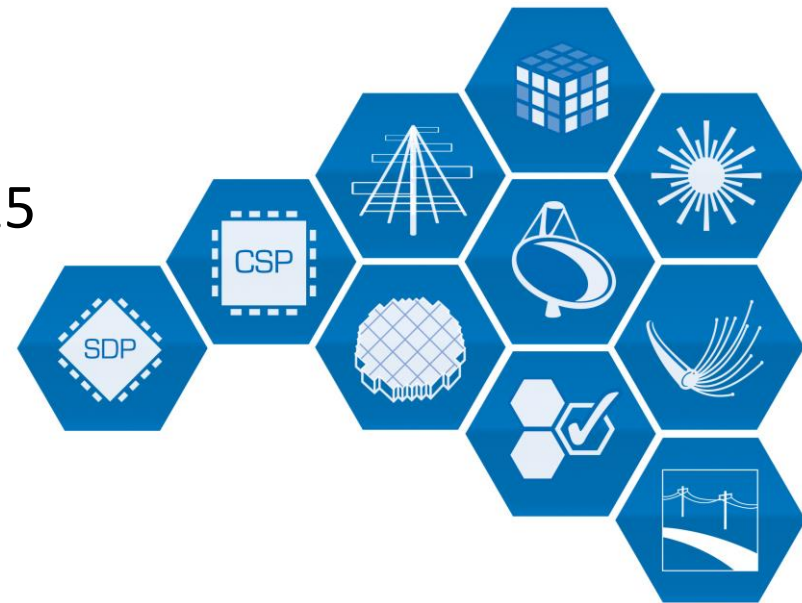
- Project Management and System Engineering based at Jodrell Bank, Manchester, UK
- ~500 scientists & engineers in institutes and industry in 11 Member countries of the SKA



**>€150M design effort – fully funded**

## Status of Design activities

- All 9 consortia have completed Preliminary Design Reviews
  - Massive effort – 100s documents
  - Some issues, as expected, but closing off now
  - Detailed design moving to Stage 2;
- Operations Concepts Review: Q3 2015
- Engineering Meeting, Penticton, Canada, Nov 9-13.
- System Review Q1 2016
- Critical Design Reviews planned in August/September 2017

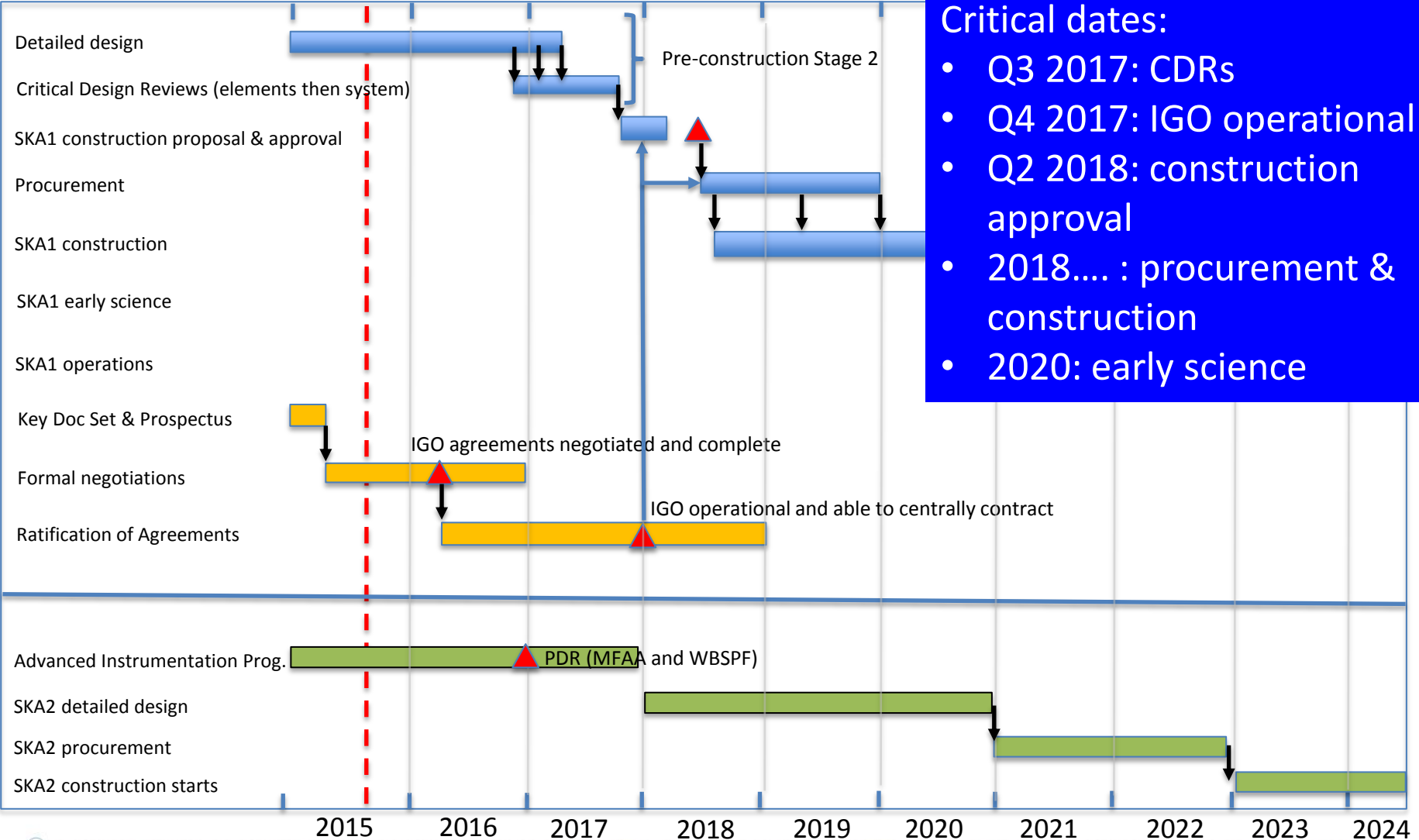




# High-level SKA Schedule



KEY: Blue = SKA1 science & engineering; orange = policy; green = SKA2



# SKA: Driving Innovation



Element	SKA 1	SKA 2
Dishes, feeds, receivers	~ 200	~ 2,500
Aperture arrays	~130,000	~ 1,000,000
Signal transport	~ 1 Pb/s	~ 10 Pb/s
Signal processing	~ exa-MACs	~ exa-MACs
High Performance Computing	~ 100s Teraflops	~ exa-flops
Data storage	Exa-byte	Exa-byte
Power requirements	~ 10 MW	~ 50 MW

**Key innovation: Software engineering and algorithm development**

**Exa =  $10^{18}$  or 1 followed by 18 zeroes;  
Increase in compute capability by factor 1000**



# Summary

- The SKA is the future of Radio Astronomy : a global cooperative effort to build the most sensitive facility.
- At 50x the best existing facility today, the full SKA will produce truly revolutionary new science; even SKA-1 (at 10%) will be a powerful new facility.
- Will be co-located in Australia (SKA-mid) & South Africa (SKA-low); HQ in UK; 10 member countries at present.
- Detailed design phase is proceeding well, construction expected to start in 2018, with early science in 2021.
- Many cutting-edge technologies required and being explored / developed for the SKA.



# SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope



[www.skatelescope.org](http://www.skatelescope.org)