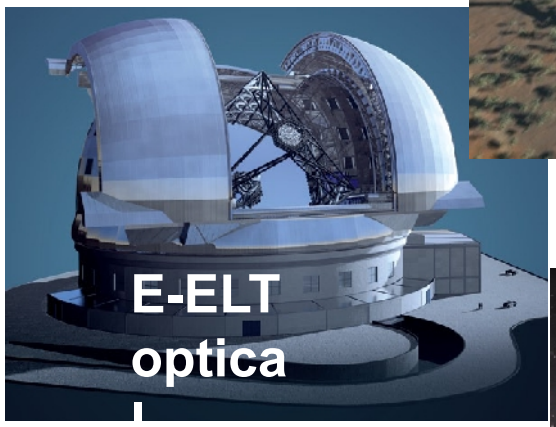
# SKA: Impact and Opportunities

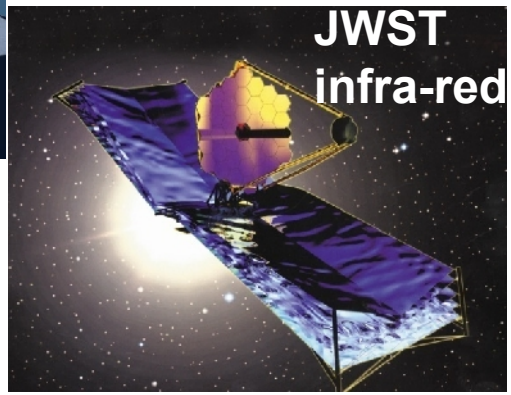
Philip Diamond
SKA Director General

Lisbon
Nov 30, 2012

# Great Observatories for the coming decades





# SKA Concept

- A large radio telescope for transformational science:
  - up to 1 million m2 antenna collecting area distributed over a distance of 3000+ km;
  - operating at frequencies from 70 MHz (wavelength = 3+m) to 10GHz (~3 cm) with two or more detector technologies;
  - connected to a signal processor and high performance computing system by a massive optical fibre network.
- Providing
  - 50 x sensitivity of current world's best radio interferometers, and
  - up to 1 million x survey speed
- Construction will proceed in two phases (SKA1 & SKA2)
- SKA1 cost ~350 M€
- SKA2 cost ~1.5 B€

# SKA2 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?
  How did galaxies evolve?
  Dark Energy, Dark Matter

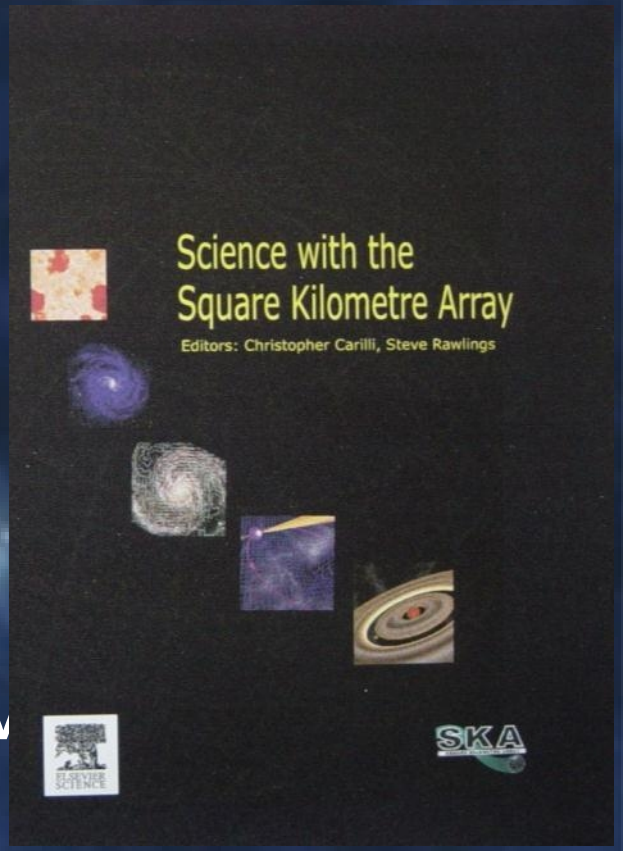
- **Astro-biology**

## FUNDAMENTAL FORCES

- **Pulsars, General Relativity & gravitational wav**

- **Origin & evolution of cosmic magnetism**

## TRANSIENTS (NEW PHENOMENA)




*Science with the Square Kilometre Array* (2004, eds. C. Carilli & S. Rawlings, *New Astron. Rev.*, **48**)

# SKA1 Key Science Drivers

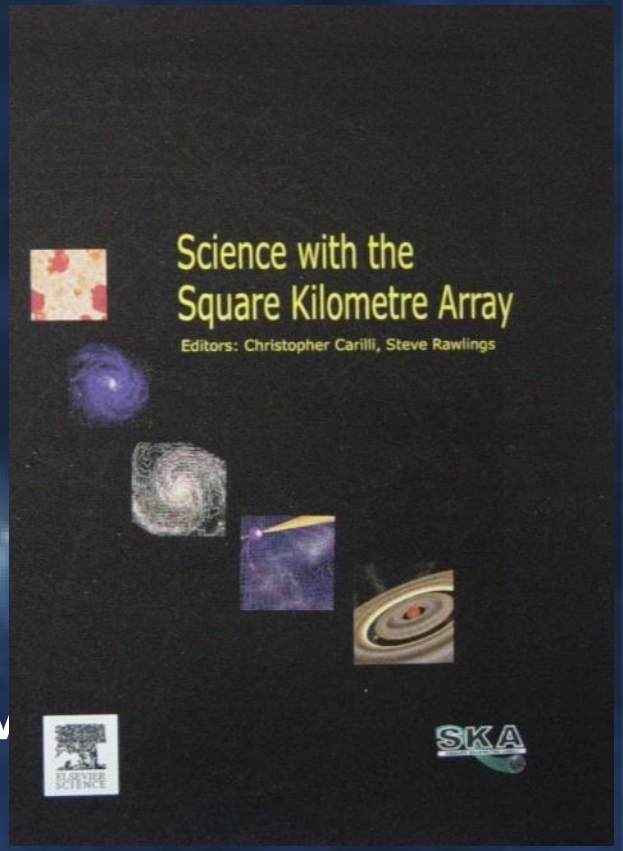
## ORIGINS

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

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

## FUNDAMENTAL FORCES

- **Pulsars, General Relativity & gravitational wav**




*Science with the Square Kilometre Array* (2004, eds. C. Carilli & S. Rawlings, *New Astron. Rev.*, **48**)

# The SKA Organisation

- SKA Organisation set up as “Company Limited by Guarantee” 14 December 2011
- Members:
  - Australia, Canada, China, Italy, Netherlands, New Zealand, South Africa, Sweden and United Kingdom
  - India is an Associate Member
  - Germany to join very shortly
- Governed by a Board of Directors.
- General meeting of the Members has ultimate authority.
- Board meets 3-4 times annually; next meeting 30-31 January 2013.

- The Members fund the SKA Office, and their governments provide funding for the design effort within their own countries.

# Office of the SKA Organisation

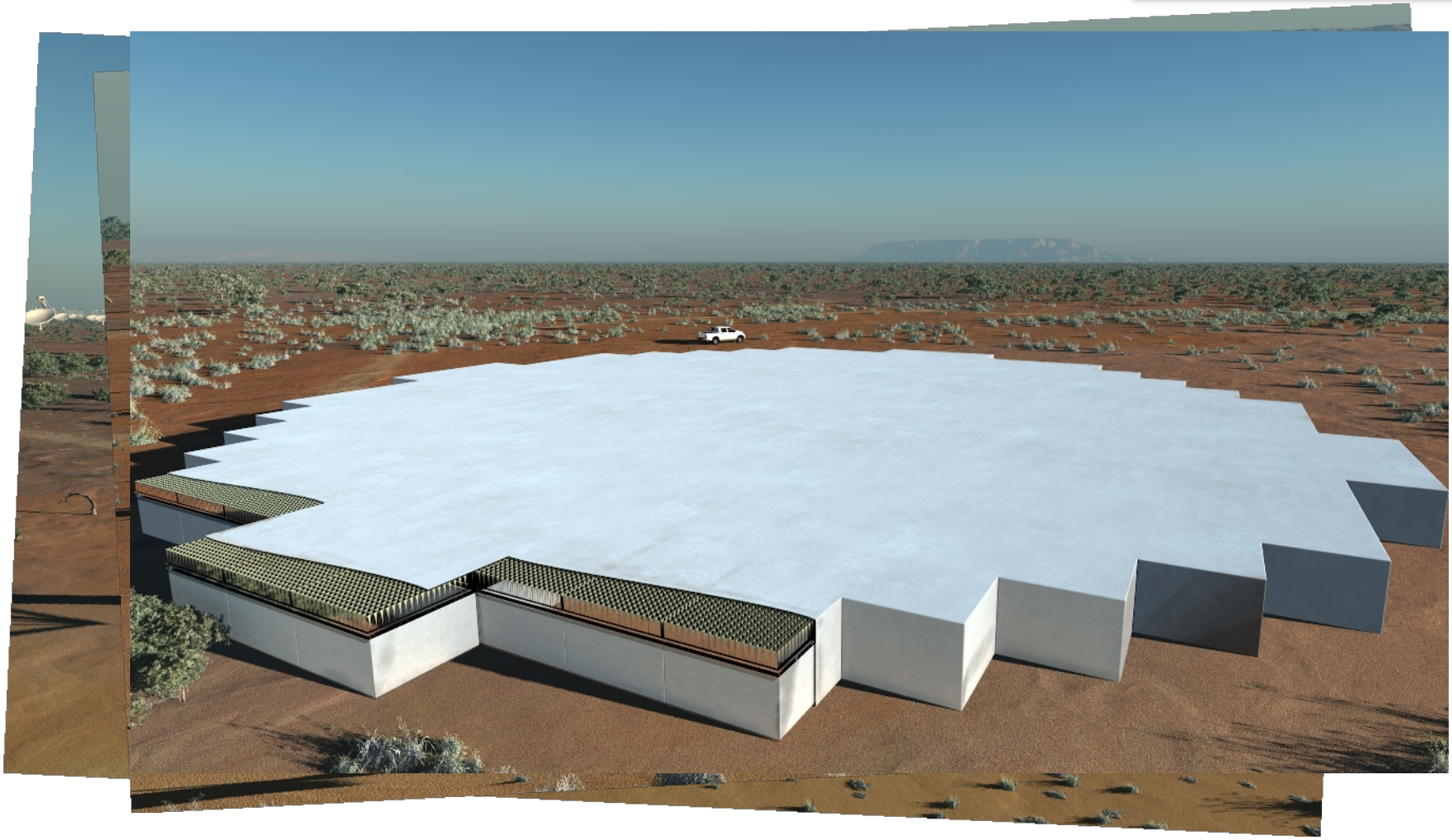
- Operational arm of the SKA Organisation
- Based at Jodrell Bank Observatory, UK
- Funding for 2012-2015 approved
- Director-General + SKA System Engineering team (20 staff now, growing to >50 by 2014)
- Coordinating design effort around the world: undertaking system engineering, defining standards, defining policies.
- SKA Design Authority rests with the SKA Office.
- Design to be undertaken by Consortia
  - Composed of Research Organisations, Universities and Industry
  - Request for Proposals to engage in design work to be issued on 15th February 2013.
  - Agreements to be signed by June/July 2013.
- Work with the SKA Board to identify funding for SKA Phase 1 construction

# Work Packages

- Led by SKA Office
  - Management
  - Science
  - System Design and system engineering
  - Maintenance & Support and Operations
- Carried out by Work Package Consortia
  - Site and Infrastructure (originally Site Engineering)
  - Dish Array
  - Aperture Arrays
  - Signal and Data Transport
  - Clock and Timing Distribution
  - Central Signal Process
  - Science Data Processor
  - Telescope Manager
  - Power
- Advanced Instrumentation Programmes (to be integrated with Dish & AA WPs)
  - Mid Frequency Aperture Array
  - Phased Array Feeds
  - Wide Band Single Pixel Feeds

**Portugese Interest**

# Antenna Types



Artist renditions from Swinburne Astronomy Productions

# Site Selection

- Site agreement – May 2012
- Ratified – 14 November 2012

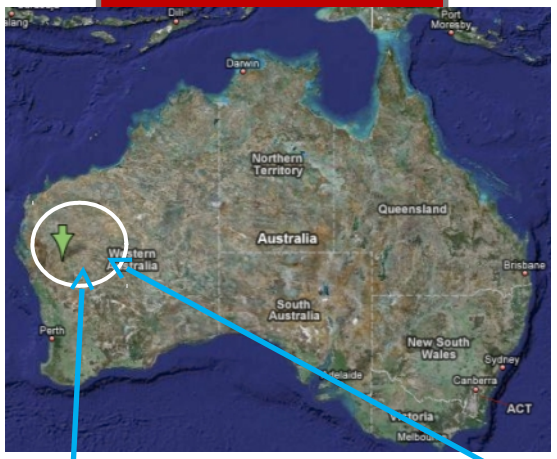
| SKA1 | | SKA2 | |
|---|---|---|---|
| SKA1_AA_low (Low Frequency Aperture Array) | Australia/New Zealand | SKA2_AA_low | Australia/New Zealand |
| SKA1_dish_mid (Mid Frequency Dish Array) | South Africa | SKA2_dish_mid | South Africa |
| SKA1_dish_survey (Mid Frequency Dish Array with Phased Array Feeds) | Australia/New Zealand | | |
| | | SKA2_AA_mid (Mid Frequency Aperture Array) | South Africa |

# SKA Phase 1 (SKA1)

**Southern**


**SKA1_MID**
**254 Dishes including:**
**64 x MeerKAT dishes**
**190 x SKA dishes**

**Australia**




**SKA1_LOW**
**50 x Low Frequency Aperture Array Stations**

**SKA1_SURVEY**
**96 Dishes including:**
**36 x ASKAP**
**60 x SKA dishes**

Exploring the Universe with the world's largest radio telescope

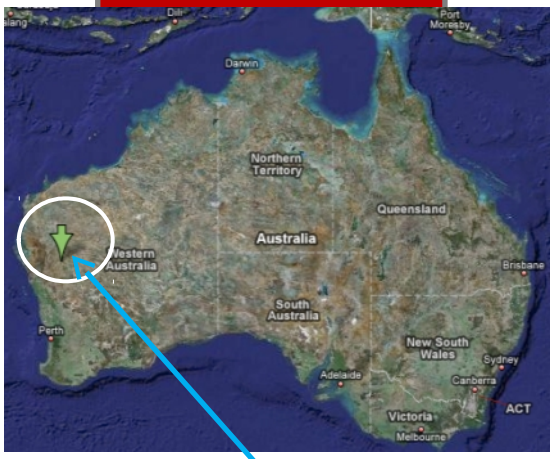
# SKA Phase 2 (SKA2)

**Southern**


**SKA2_MID**
**2500 Dishes**

**SKA2_AA**
**250 x Mid Frequency Aperture Array Stations**

**Australia**




**SKA2_LOW**
**250 x Low Frequency Aperture Array Stations**

Exploring the Universe with the world's largest radio telescope

# Top Level Schedule

**Technical**

- 2008 - 12 Preparatory Phase (PrepSKA)
- 2012 - 15 Pre-construction phase
- 2016 - 19 SKA1 construction
- 2016 Advanced Instrumentation Program decision
- 2018 - 23 SKA2 construction
- 2020 → Full science operations with Phase 1
- 2024 → Full science operations with Phase 2

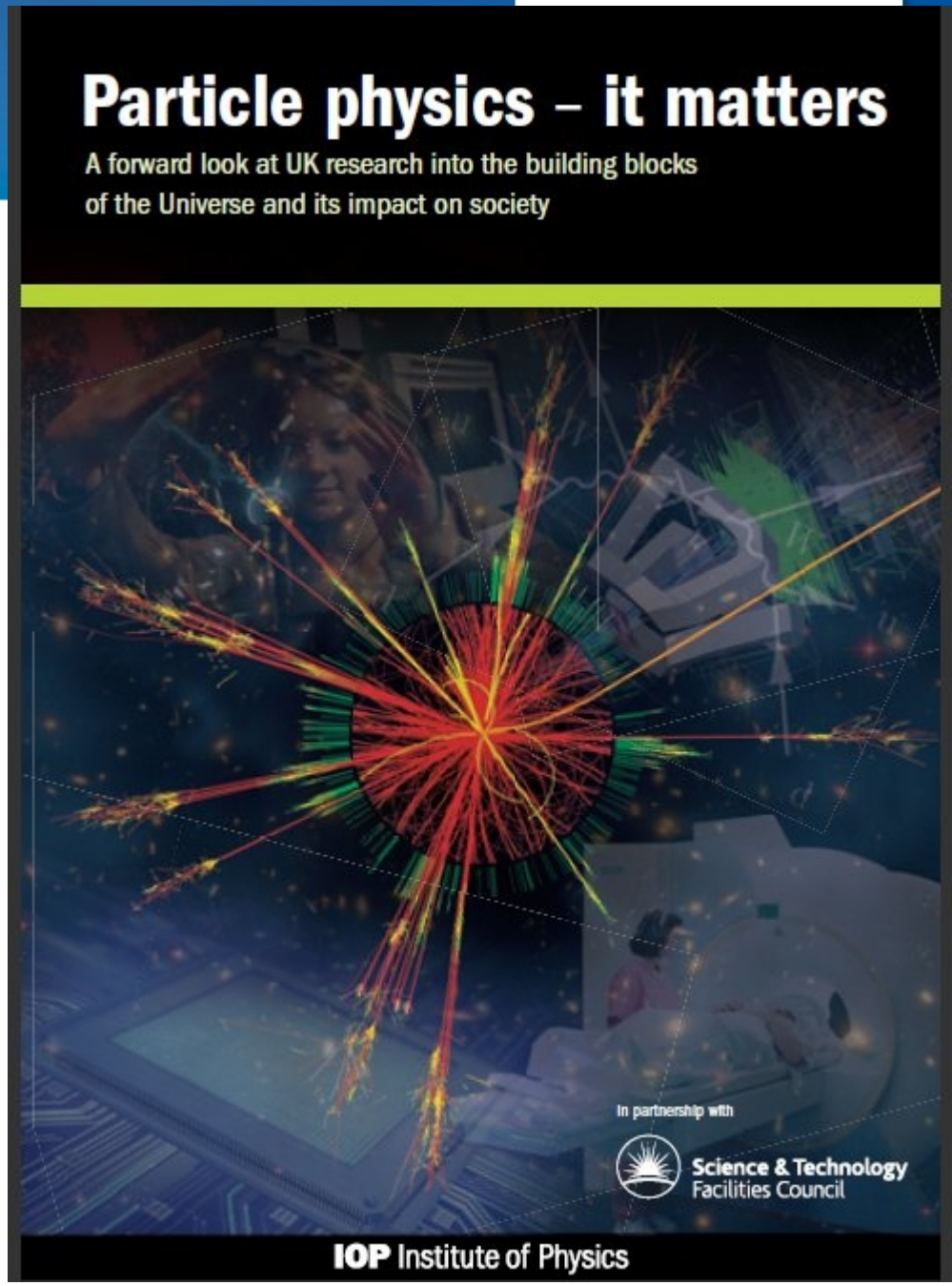
**Programmatic**

- 2011
  - Approve funding for pre-construction phase
  - Establish SKA Organisation as a legal entity
  - Select location for the office of the SKA Organisation
- 2012
  - Site selection
  - Appoint Director-General
- 2014 Approve construction funding for SKA1
- 2018 Approve construction funding for SKA2

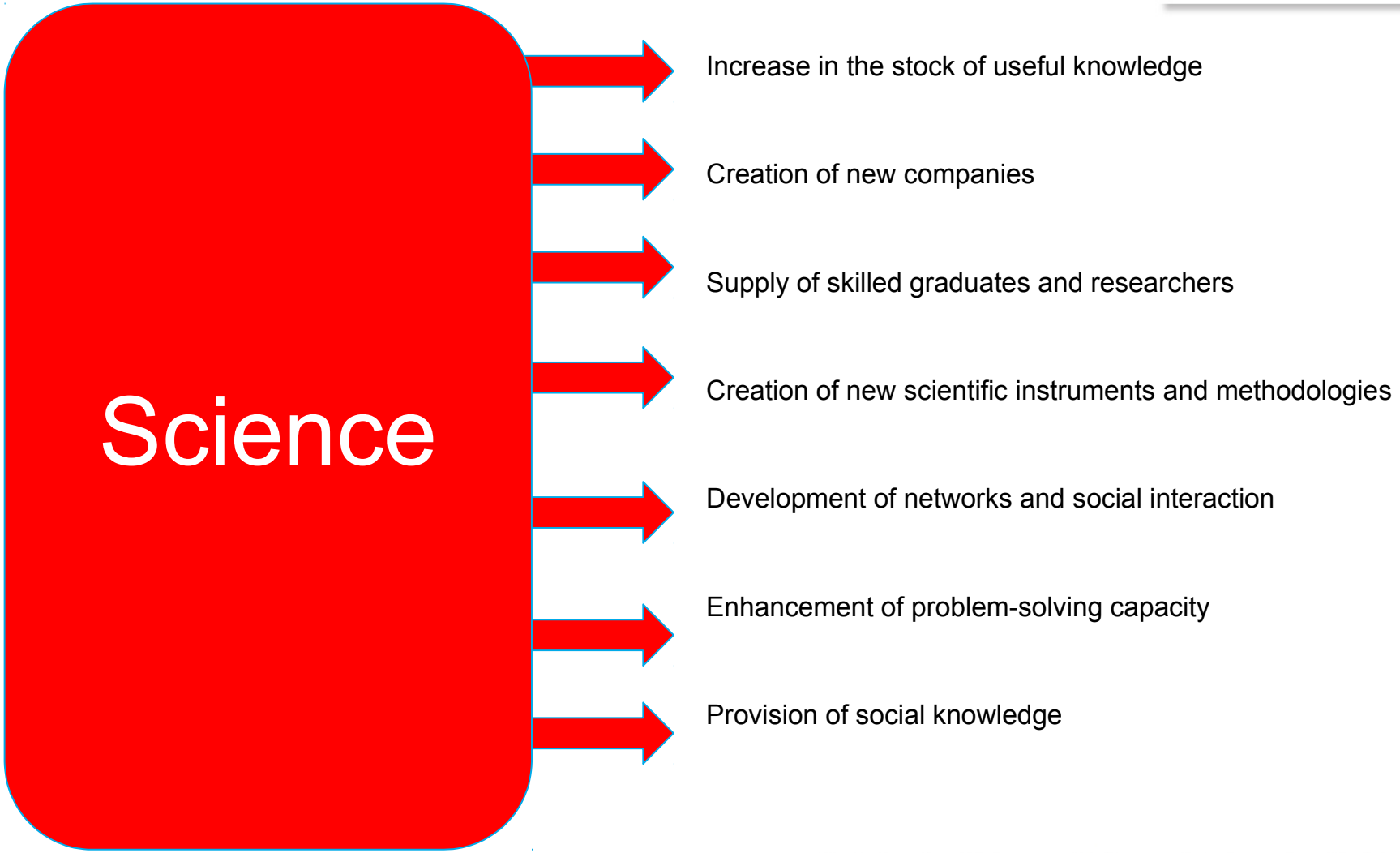
# Impact of the SKA?

- STFC Vision document: A new vision for new times

- ***"We believe that 'impact' takes many forms, from short term to long term, covering economic, social and environmental benefits, and physical and psychological well-being."***



# Royal Society: the Scientific Century



# What's the return from investment in SKA?

- Some questions to be answered
- Science
  - 'Open skies' or restricted?
  - Regional support centres?
- Industrial return
  - In-kind contributions?
  - Geo-return to industry?
  - Depends on technology choices?
- As a tool for innovation and societal development?
- Never forget the 'wow' factor . Astronomy is the undoubted world-leader in exciting the next-generation of scientists and engineers and their parents – the taxpayers……

# Impact of Radio Astronomy: specific examples

- Development of cheap low-noise-amplifiers of benefit for telecommunications industry.
- Radio imaging algorithms had strong influence on medical tomography, NMR imaging, finger-print detection, speed cameras!
- Development of intensity interferometry by Hanbury-Brown and Twiss at Jodrell Bank in 1950s led to quantum cryptography
- Very Long Baseline Interferometry measures rotational parameters of Earth, directly useful to GPS and navigation: civil and military applications.
- Need to locate mobile antennas in France led to founding of Cambridge Positioning Systems Ltd, techniques used by GPS and Galileo
- NEOs: using radar astronomy to determine orbits of NEOs

# Story of IEEE 802.11: wifi

- John O'Sullivan and collaborators build a special instrument to look for the exploding black holes using the Dutch radio telescopes

# Story of IEEE 802.11: wifi

- 1970s: John O'Sullivan searches for Exploding Black Holes – '*There has to be a better way*'
- 1980s: perfected Fourier Transform on a chip
- 1996: CSIRO obtains US patent 5487069
- 2001: Skellern develops a wireless chip meeting IEEE standards
- > 1 billion devices sold using this chip
- CSIRO has received > $450m income from its patent.

***Impact!***

# SKA pushing the envelope

- Low-cost antennas
- Low-cost, high-performance receiving systems
- Non-cryogenic cooling
- > 1Pb/s data transport (> 10x internet traffic of the Earth)
- Low-power signal processing
- Distribution of time at pico-second level over thousands of kilometres
- Exascale computing
- Data mining algorithms
- Sustainable power in remote regions

# People: astronomy attracts the best

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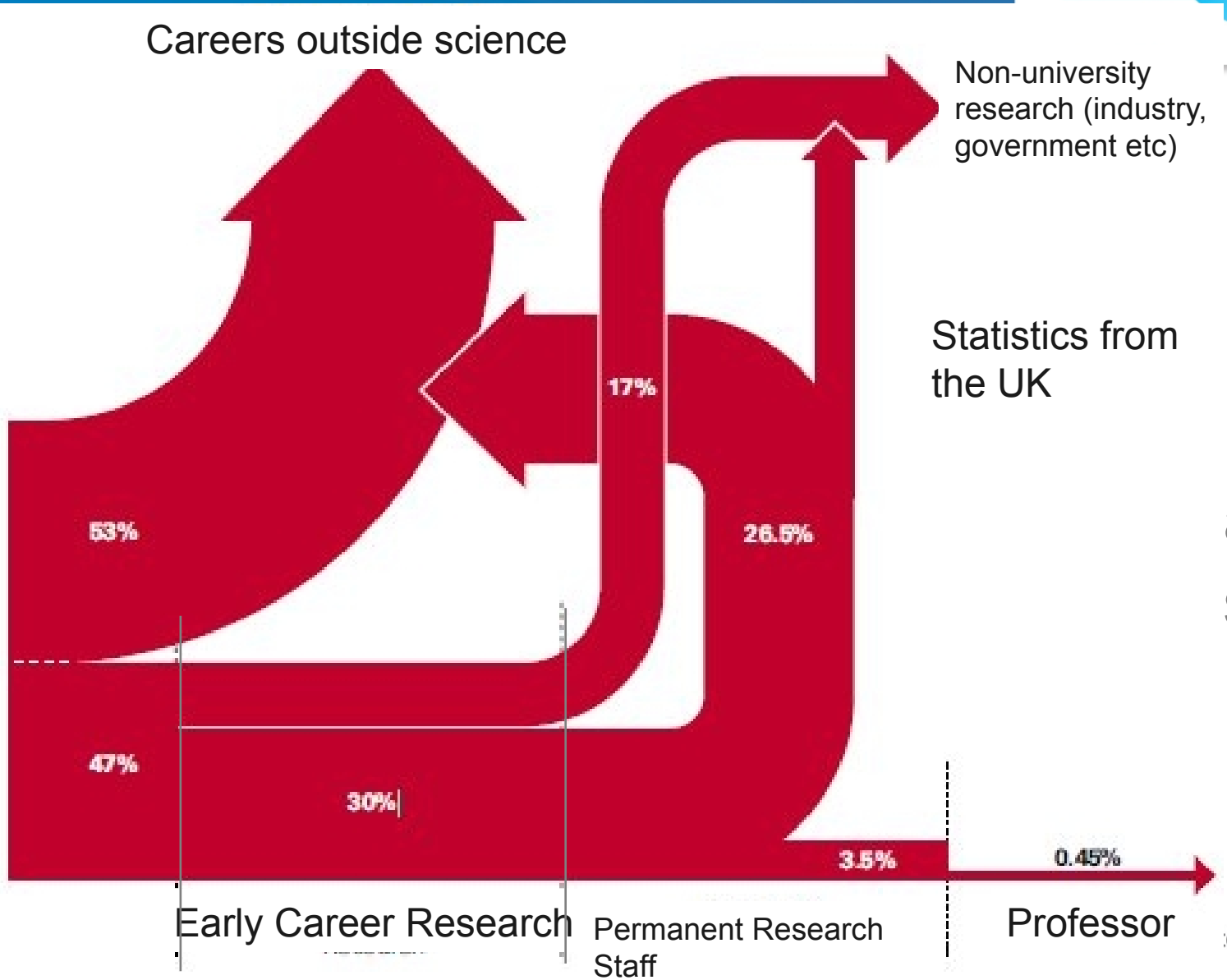


Statistics from the UK

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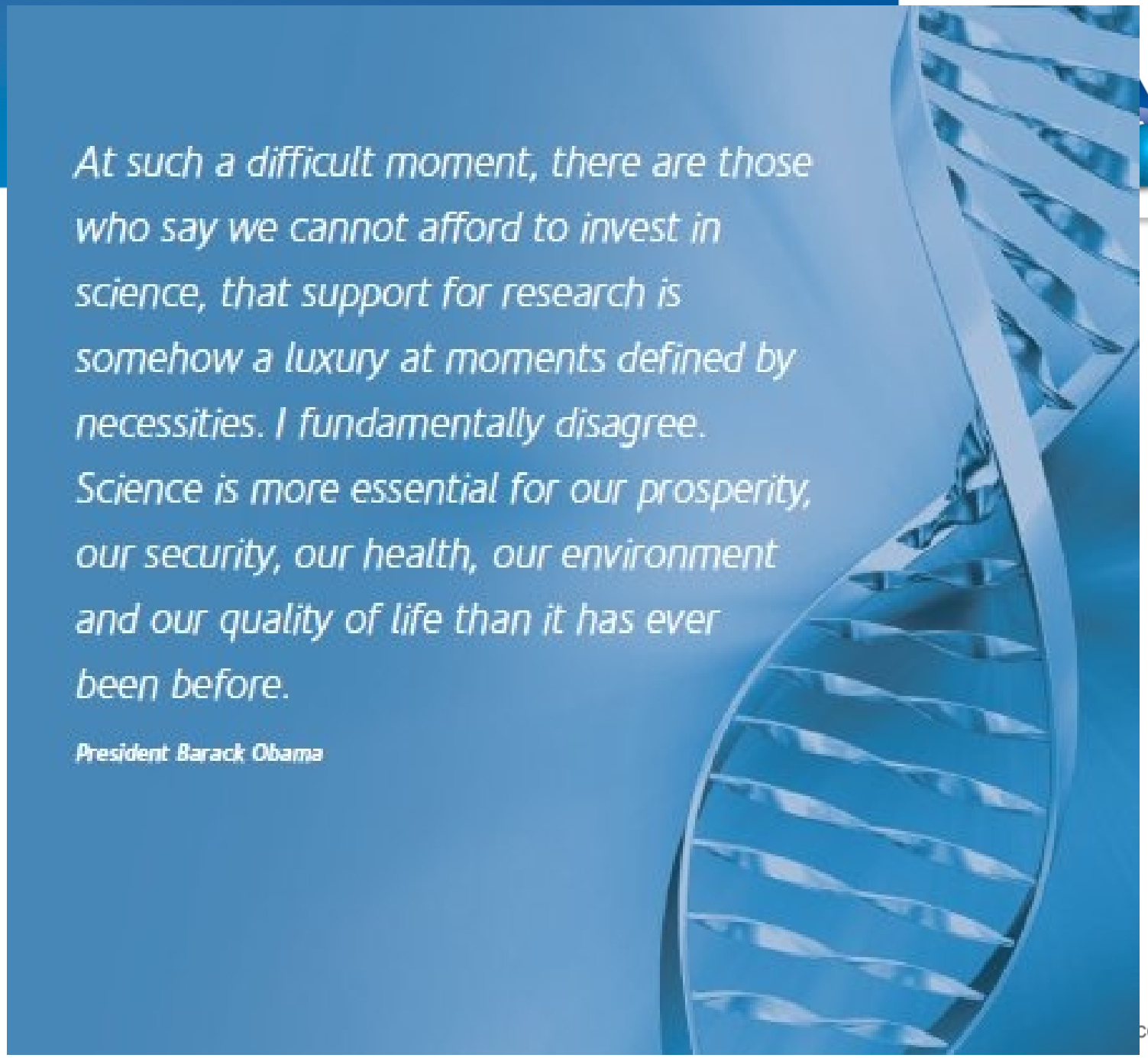
At such a difficult moment, there are those who say we cannot afford to invest in science, that support for research is somehow a luxury at moments defined by necessities. I fundamentally disagree. Science is more essential for our prosperity, our security, our health, our environment and our quality of life than it has ever been before.
President Barack Obama

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The Square Kilometre Array
www.skatelescope.org