



The Square Kilometre Array:

Dr. Althea Wilkinson
SKA Signal & Data Transport Consortium

DARA Nairobi
19th October 2018

What is the SKA?



- The Square Kilometre Array (SKA) is
 - Worldwide effort
 - to build **world's largest radio telescope**,
 - with square kilometre (one million square metres) collecting area (150 football pitches).
- Huge leap forward for radio astronomy
- One of largest scientific endeavours in history
- Detailed design well under way - critical design reviews due 2018-2019

No radio astronomy project has ever been conceived on this scale

- 
- Everything is required "en masse"
 - Remote environment
 - Very challenging performance goals
 - Very low cost per unit area?
 - Major ICT Project

SKA across the world



Members

Host Countries: Australia, South Africa, United Kingdom



African partner countries

The SKA Concept



- **A large radio telescope for transformational science:**
 - Up to 1 million m² antenna collecting area distributed over 3000+ km;
 - Operating from <50 MHz (wavelength > 3 m) to >14GHz (< 3 cm) - two or more detector technologies;
 - Connected to signal processor and high performance computing system by a **massive optical fibre network.**
- **Providing**
 - 50 x **sensitivity** of current world's best radio interferometers,
 - Up to 1 million x **survey speed**



Realising the Vision

Problem:

How to produce a telescope which is...

- Low-cost,
- Large Field of View,
- Wide frequency range,
- Reliable,
- Easy maintained

A massive inter-related R&D, detailed design and system engineering task !

The Consortia



SKA
SQUARE KILOMETRE ARRAY

SIGNAL AND DATA TRANSPORT



SKA
SQUARE KILOMETRE ARRAY

LOW-FREQUENCY APERTURE ARRAY



SKA
SQUARE KILOMETRE ARRAY

DISH



SKA
SQUARE KILOMETRE ARRAY

ASSEMBLY, INTEGRATION & VERIFICATION



SKA
SQUARE KILOMETRE ARRAY

SIGNAL AND DATA TRANSPORT



SKA
SQUARE KILOMETRE ARRAY

INFRASTRUCTURE AUSTRALIA



SKA
SQUARE KILOMETRE ARRAY

TELESCOPE MANAGER



SKA
SQUARE KILOMETRE ARRAY

SDP

SCIENCE DATA PROCESSOR



SKA
SQUARE KILOMETRE ARRAY

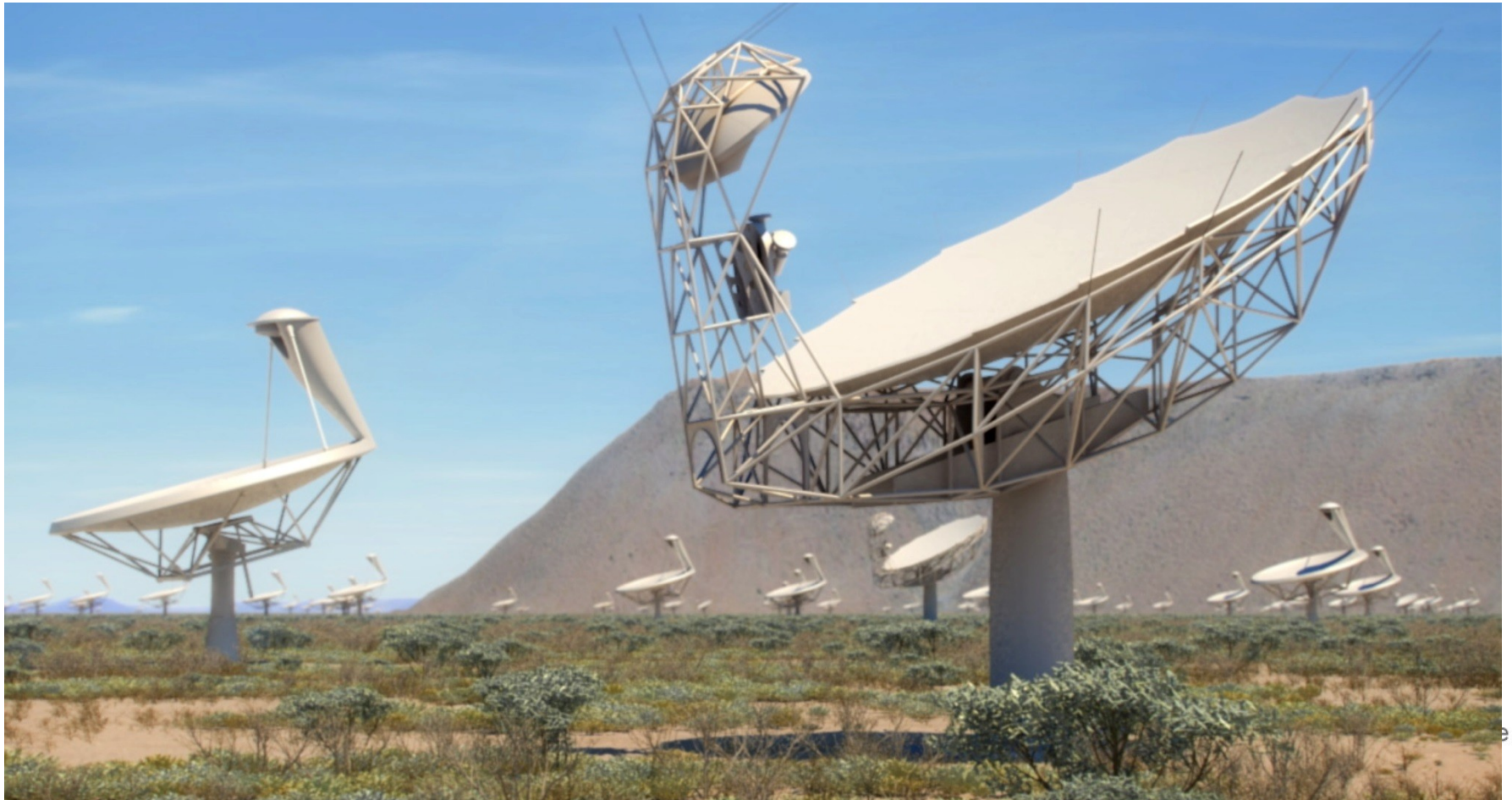
INFRASTRUCTURE SOUTH AFRICA

Correlator

Dishes



- SKA will build ~133 15m dishes in South Africa in Phase 1:
- Phase 2 will see 2500 dishes across Africa



SKA1 MID - the SKA's mid-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.



Location:
South Africa



Frequency range:
350 MHz to
14 GHz



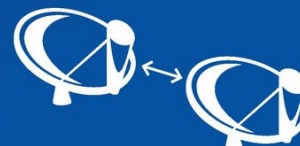
~200 dishes
(including 64 MeerKAT dishes)



Total
collecting
area:
33,000m²



or
**126
tennis
courts**



Maximum distance
between dishes:
150km



SKA1 MID

Total raw data output:
2 terabytes
per second

62 exabytes
per year



x340,000



Enough
to fill
340,000
average laptops with
content **every day**

Compared to the JVL, the current best
similar instrument in the world:

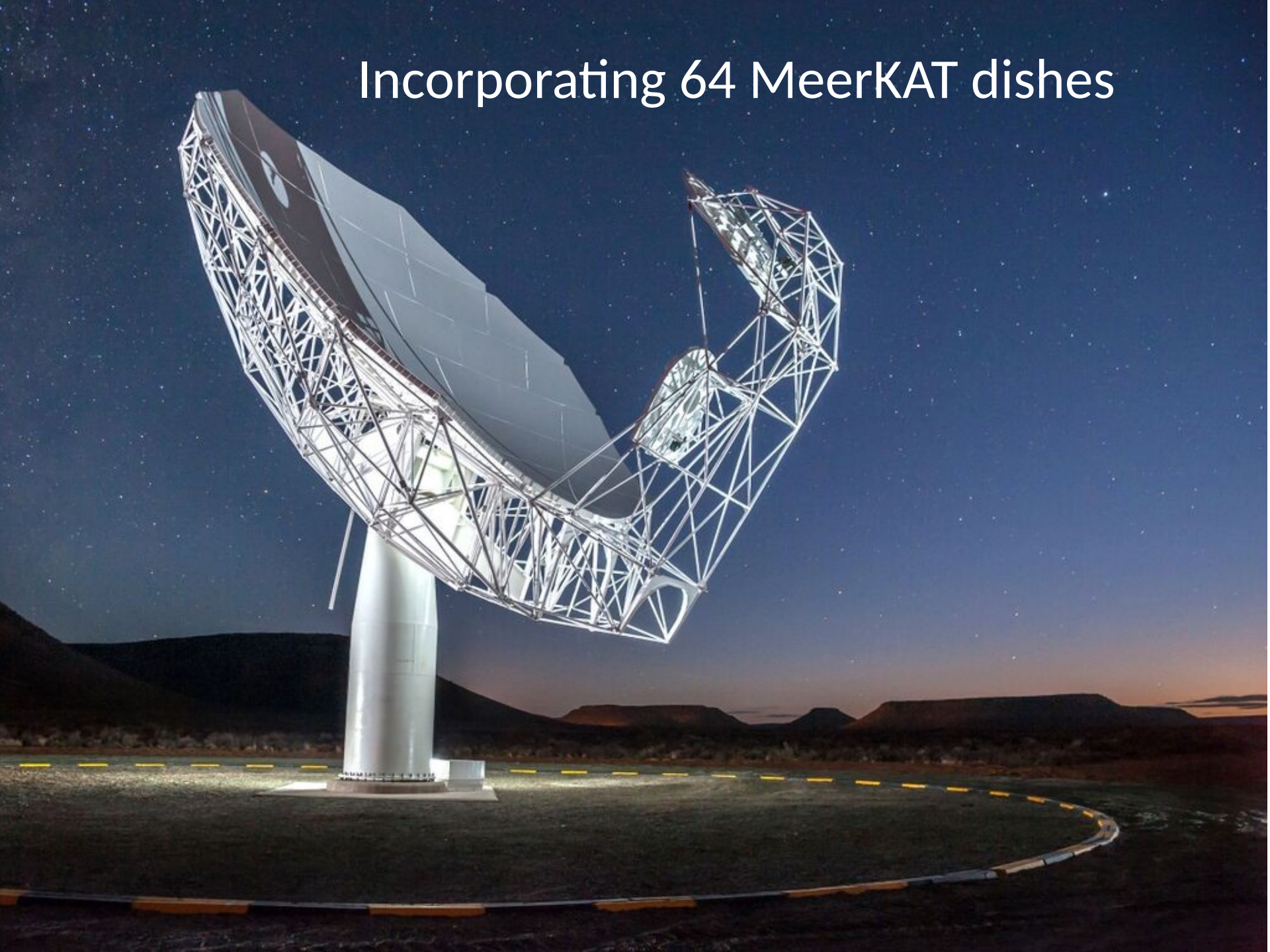


4x
the
resolution

5x
more
sensitive

60x
the survey
speed

Incorporating 64 MeerKAT dishes



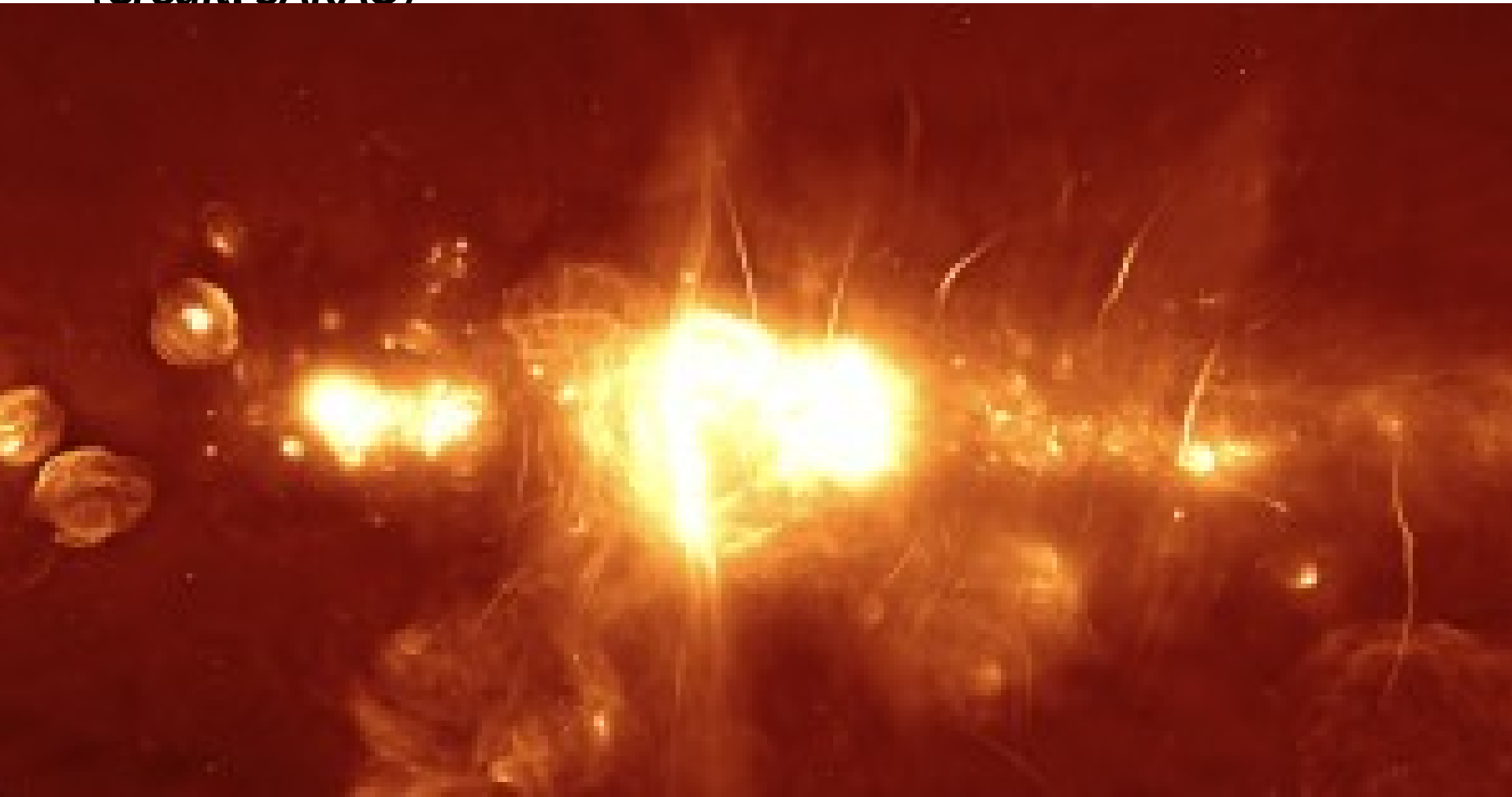
MeerKAT as it looks today



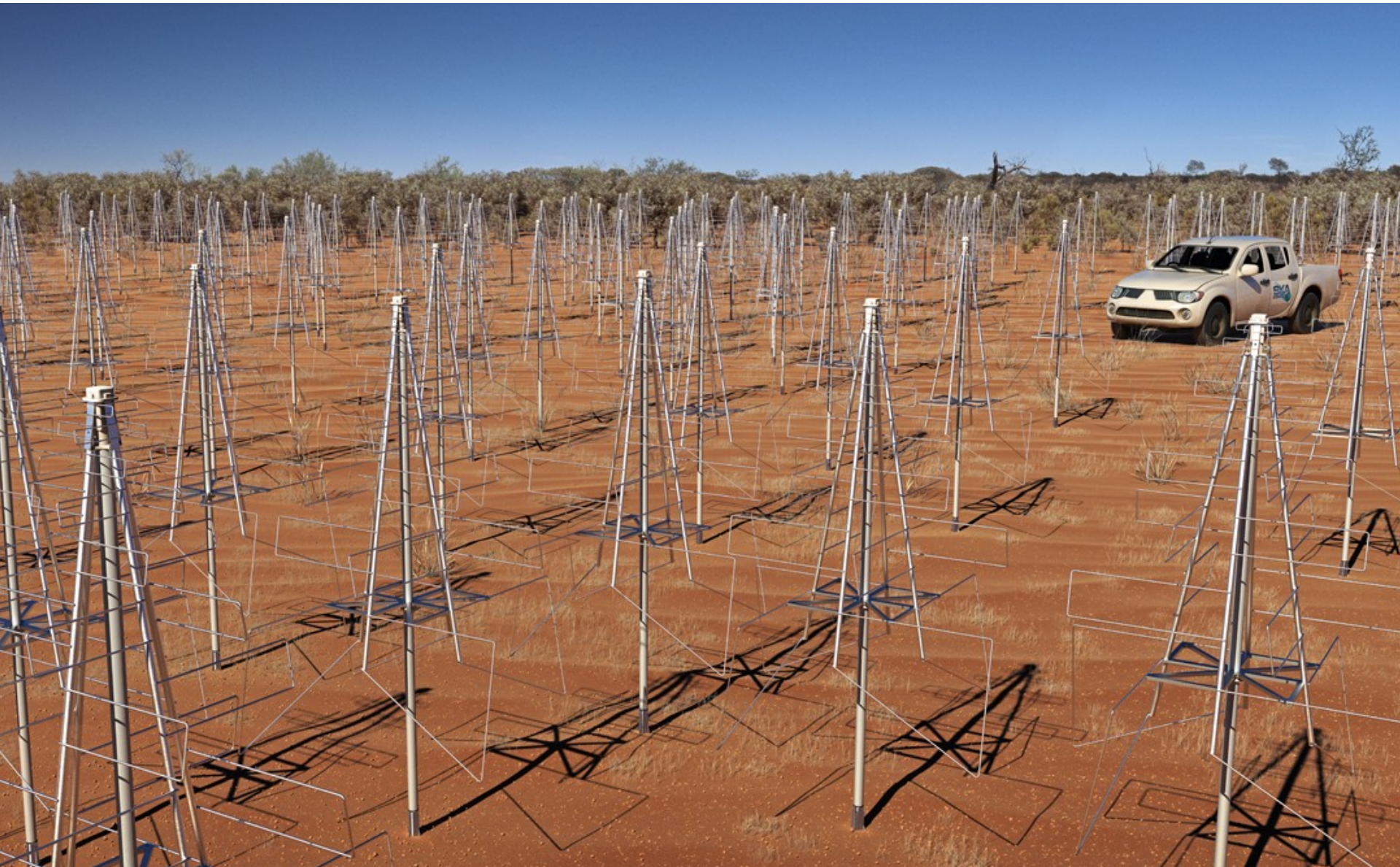
MeerKAT's first image

The central regions of our galaxy with a wealth of never before seen features, as well as a clearer view of previously known supernova remnants, star-forming regions, and radio filaments.

(Credit: SARA0)



Low frequency Array:
131,000 log periodic antennas in Australia in
Phase 1. 1,000,000 in Phase 2.



SKA1 LOW - the SKA's low-frequency instrument

The Square Kilometre Array (SKA) will be the world's largest radio telescope, revolutionising our understanding of the Universe. The SKA will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - SKA1 MID and SKA1 LOW - observing the Universe at different frequencies.



Location: Australia



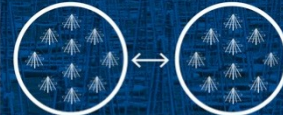
Frequency range:

50 MHz to
350 MHz



~130,000
antennas spread between
500 stations

Total collecting area:
0.4km²



Maximum distance between stations:

65km



SKA1 LOW

Total raw data output:

157 terabytes
per second

4.9 zettabytes
per year



Enough to fill up
35,000 DVDs
every second

5x

the estimated
global internet
traffic in 2015
(source: Cisco)



Compared to LOFAR Netherlands, the current best similar instrument in the world

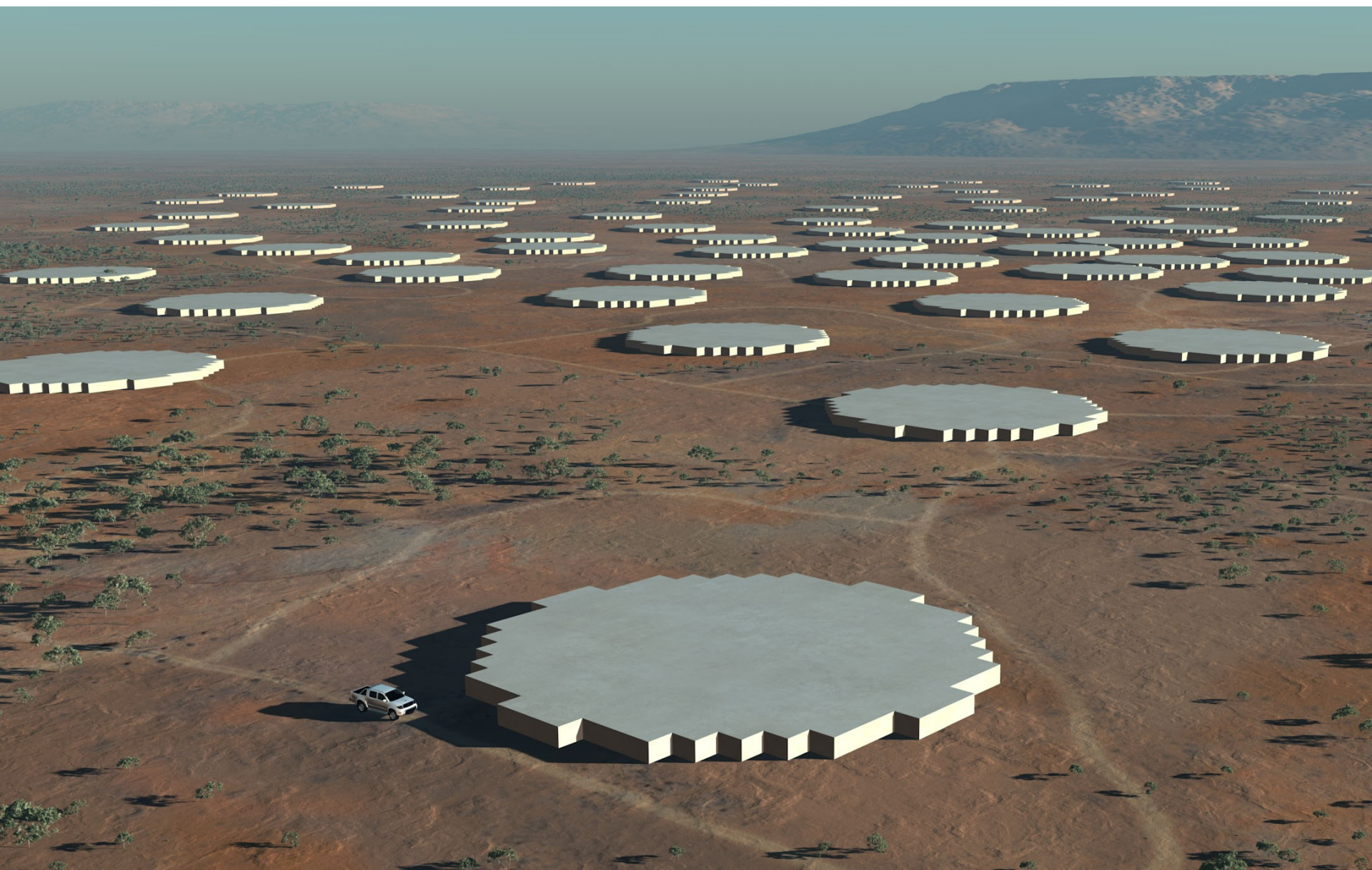


25%
better
resolution

8x
more
sensitive

135x
the survey
speed

Dense Aperture arrays: In South Africa in Phase 2d



SKA HQ: Jodrell Bank



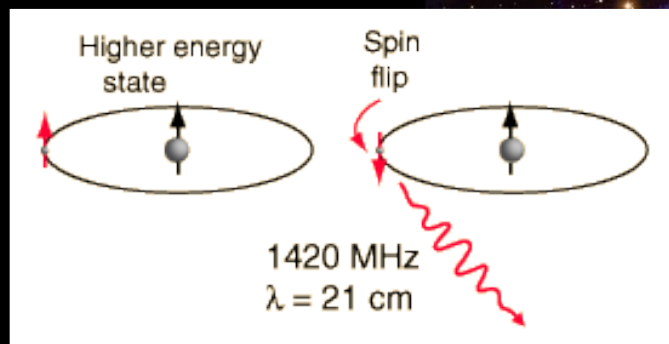
New SKAO Headquarters




International Design team

- Project Management and System Engineering Team at Jodrell Bank Observatory, Manchester, UK
- ~400 engineers (institutes and industry) in 12 Member countries
- 10 International design consortia
- €120M committed for 5-year design programme; underway right now.
- €650M+inflation for 10% Stage 1 (SKA1)
- SKA will be built by industry
- Too large for universities and research institutes.

How did we choose the sites? Consider the expanding universe...



Mobile Phone



Aircraft



Digital TV

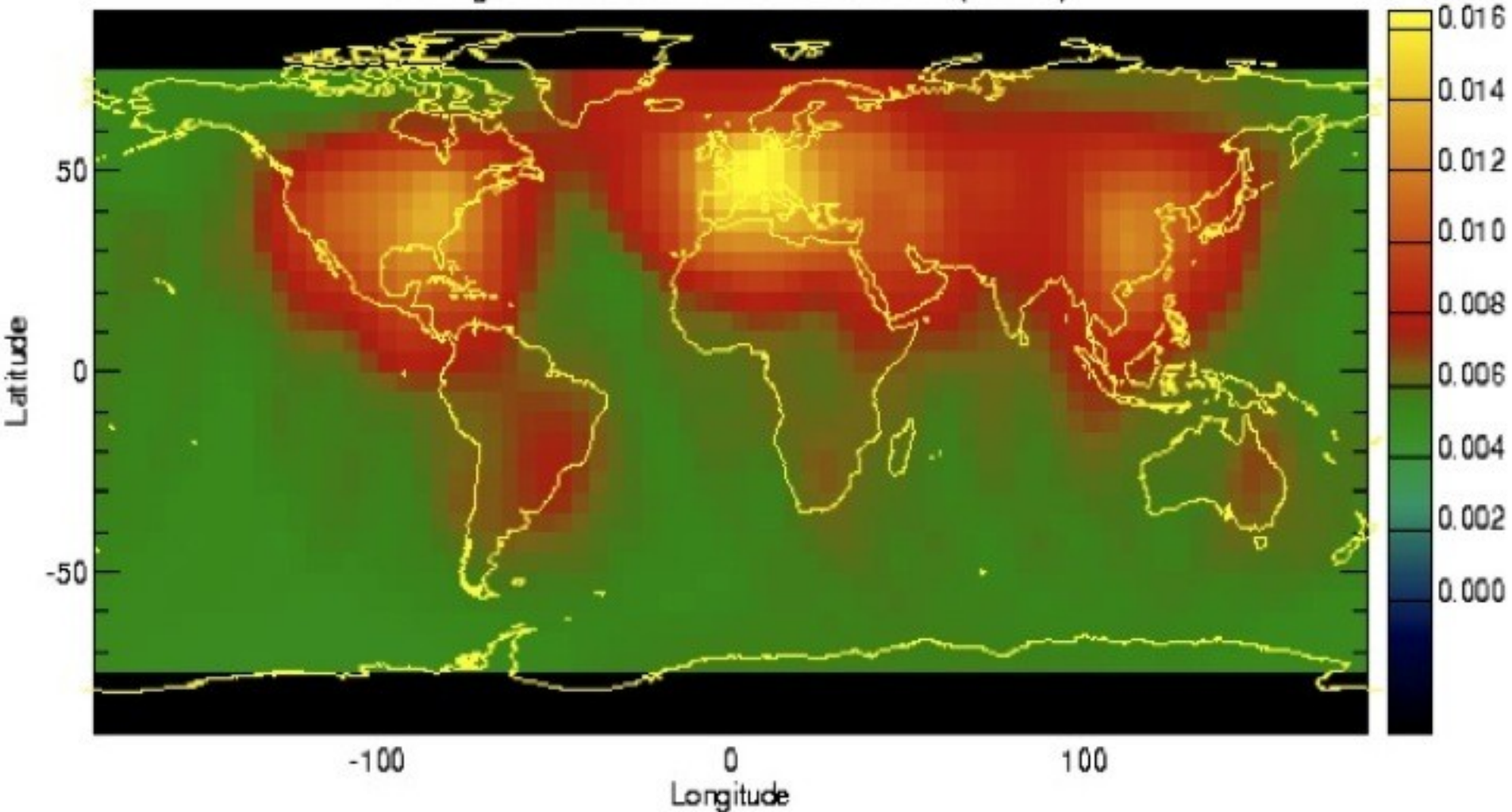


FM

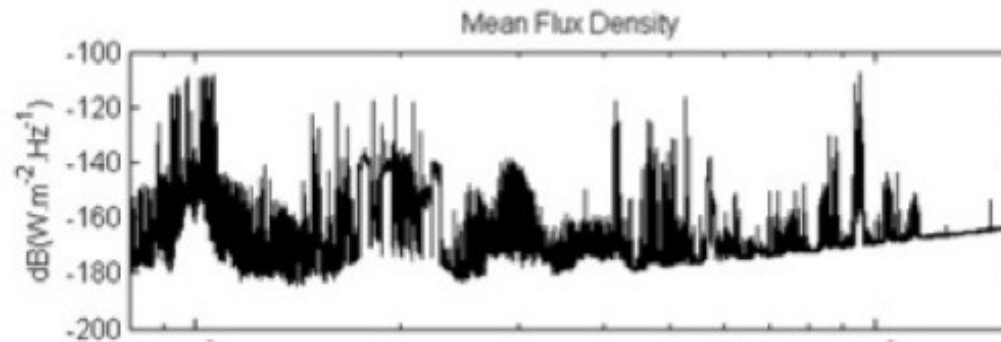
How did we choose the site?



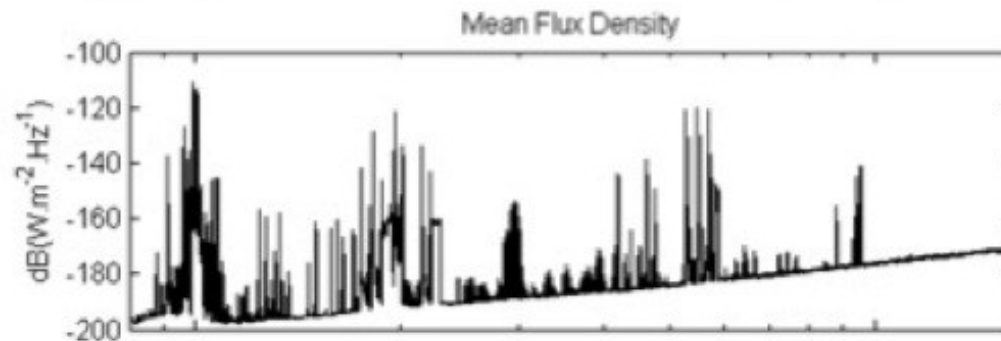
Background Radiation at 131.0 MHz (mV/m)



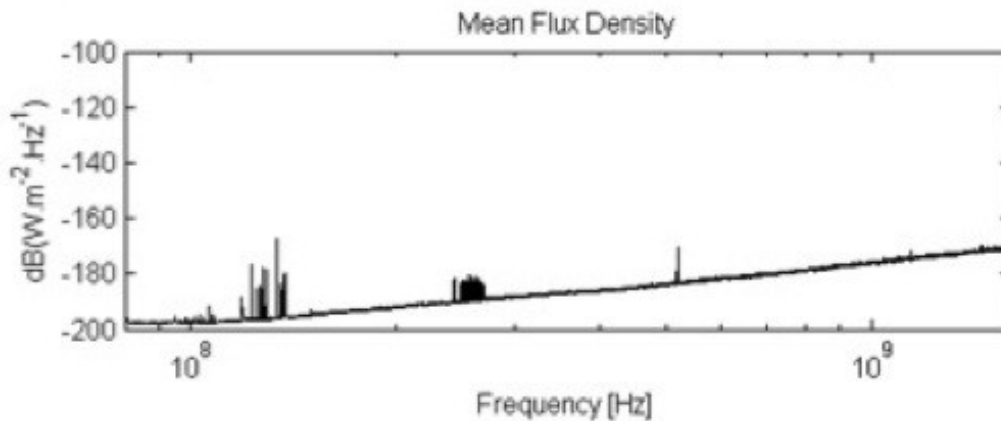
How did we choose the site?



Sydney:
population 4 million

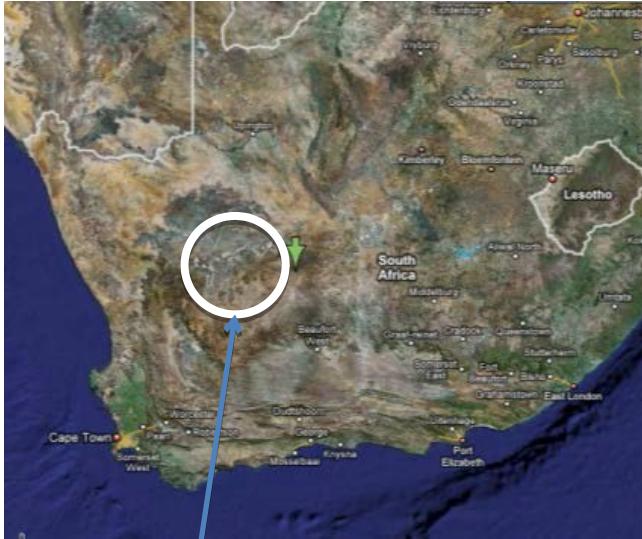


Narrabri:
population 4000

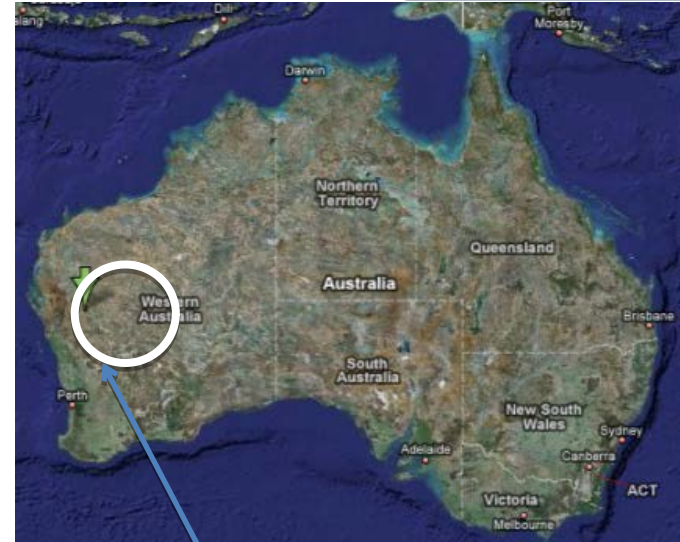


Mileura:
population 4

SKA Phase 1

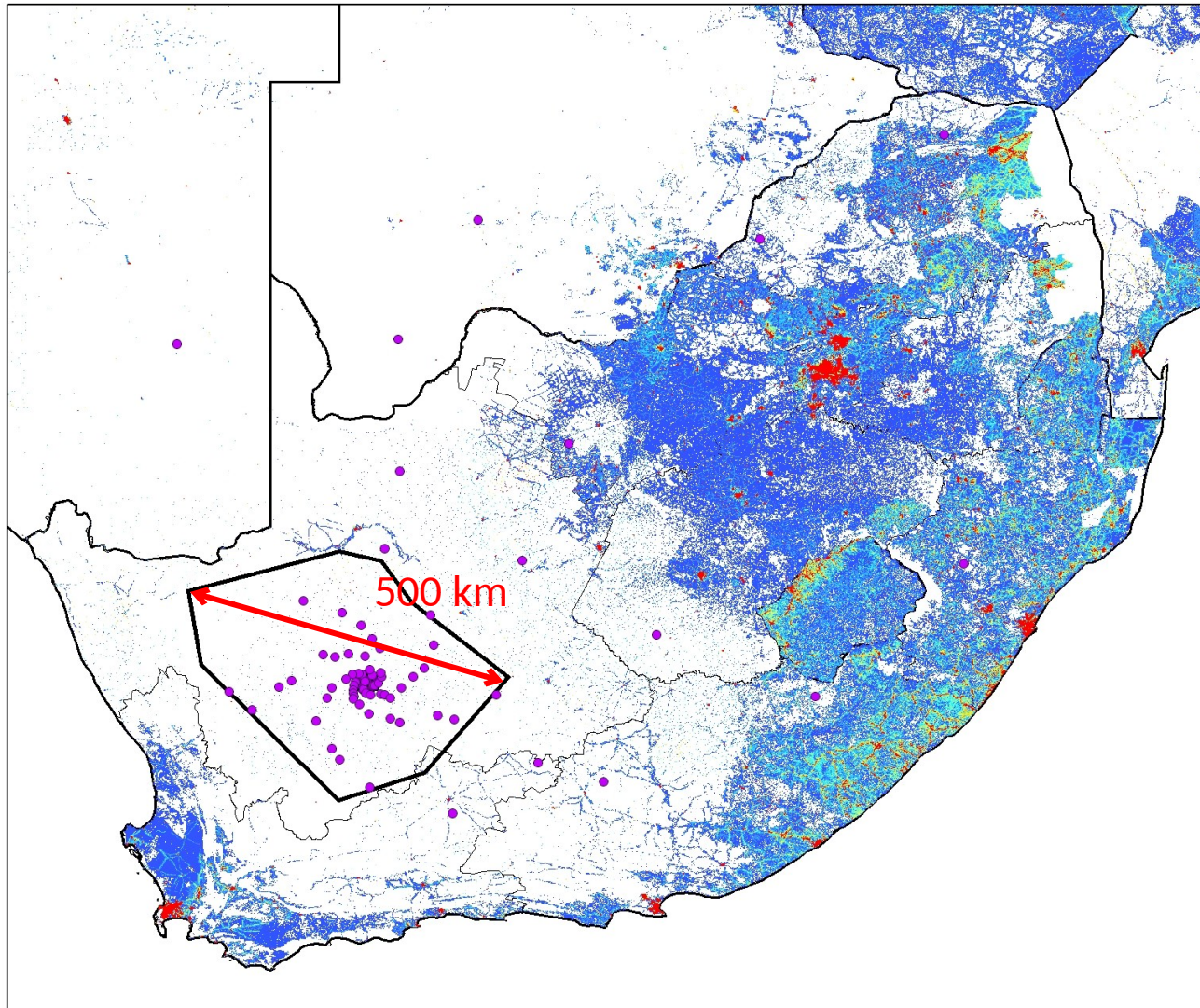


SKA-Mid
~200 dishes
Incorporating MeerKAT



SKA-Low
131,000 element AA

Karoo Radio Astronomy Reserve



Legend

- SKA_Configuration_SPDO_Dish_Full
- AA1_SPDO_Version1
- AA2_SPDO_Version2
- KCAA1

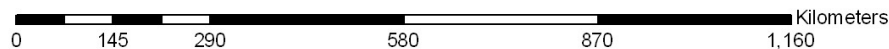
Population (per sq km)

Value

- | |
|--------------------|
| 0 - 4 |
| 4.00000001 - 14 |
| 14.00000001 - 29 |
| 29.00000001 - 47 |
| 47.00000001 - 68 |
| 68.00000001 - 91 |
| 91.00000001 - 116 |
| 116.00000001 - 142 |
| 142.00000001 - 169 |
| 169.00000001 - 197 |
| 197.00000001 - 225 |
| 225.00000001 - 255 |



Contact:
Dr. Adrian Tiplady
SKA South Africa
17 Baker Street
Rosebank
2196
South Africa
Tel: +27 11 442 2434
Fax: +27 11 442 2454
Email: atiplady@ska.ac.za

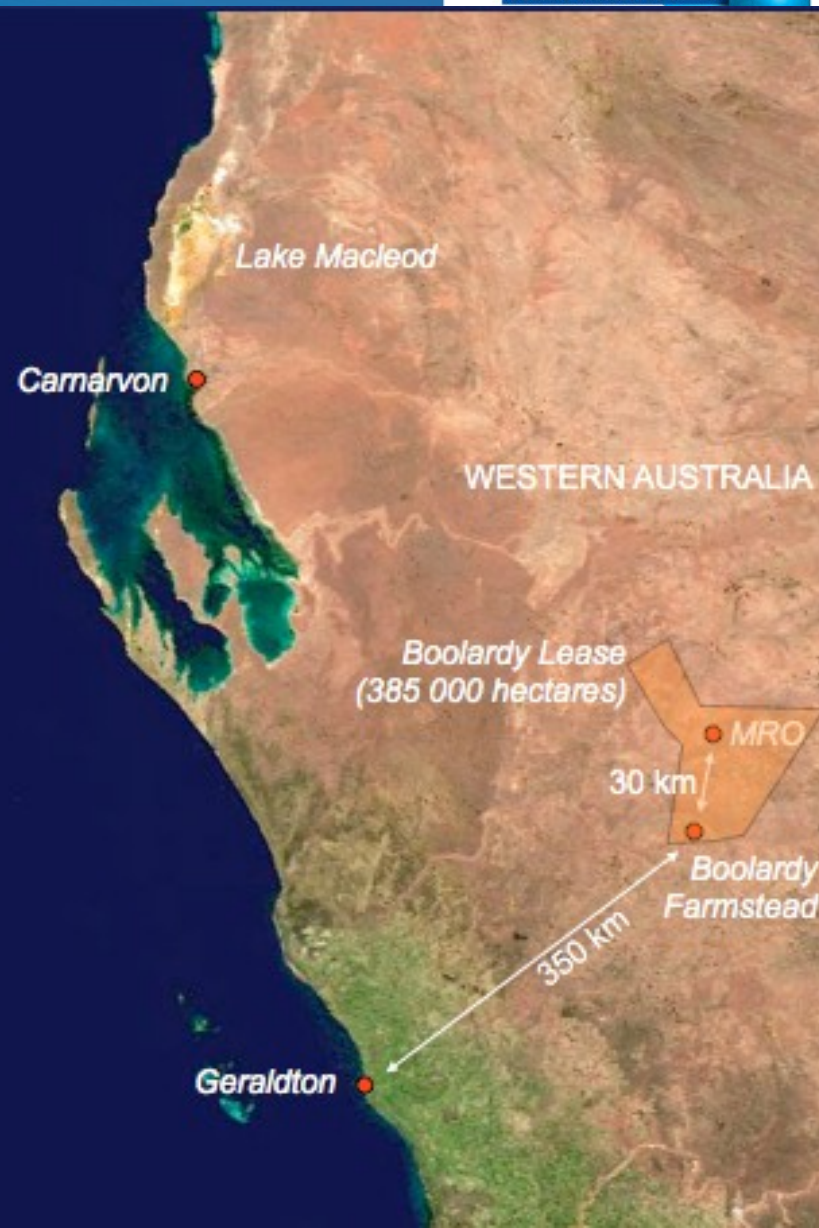


Murchison Radio Astronomy Observatory



Shire of Murchison:

- 50,000 km² ; size of the Netherlands
- 0 gazetted towns
- 29 sheep/cattle stations
- 110 population => 0.002 km⁻²



Signal & Data Transfer Consortium



Get the timing signals to the receptors (very accurately)

Get the data from the receptors to the computers

Karoo Array Processor building



KAPB



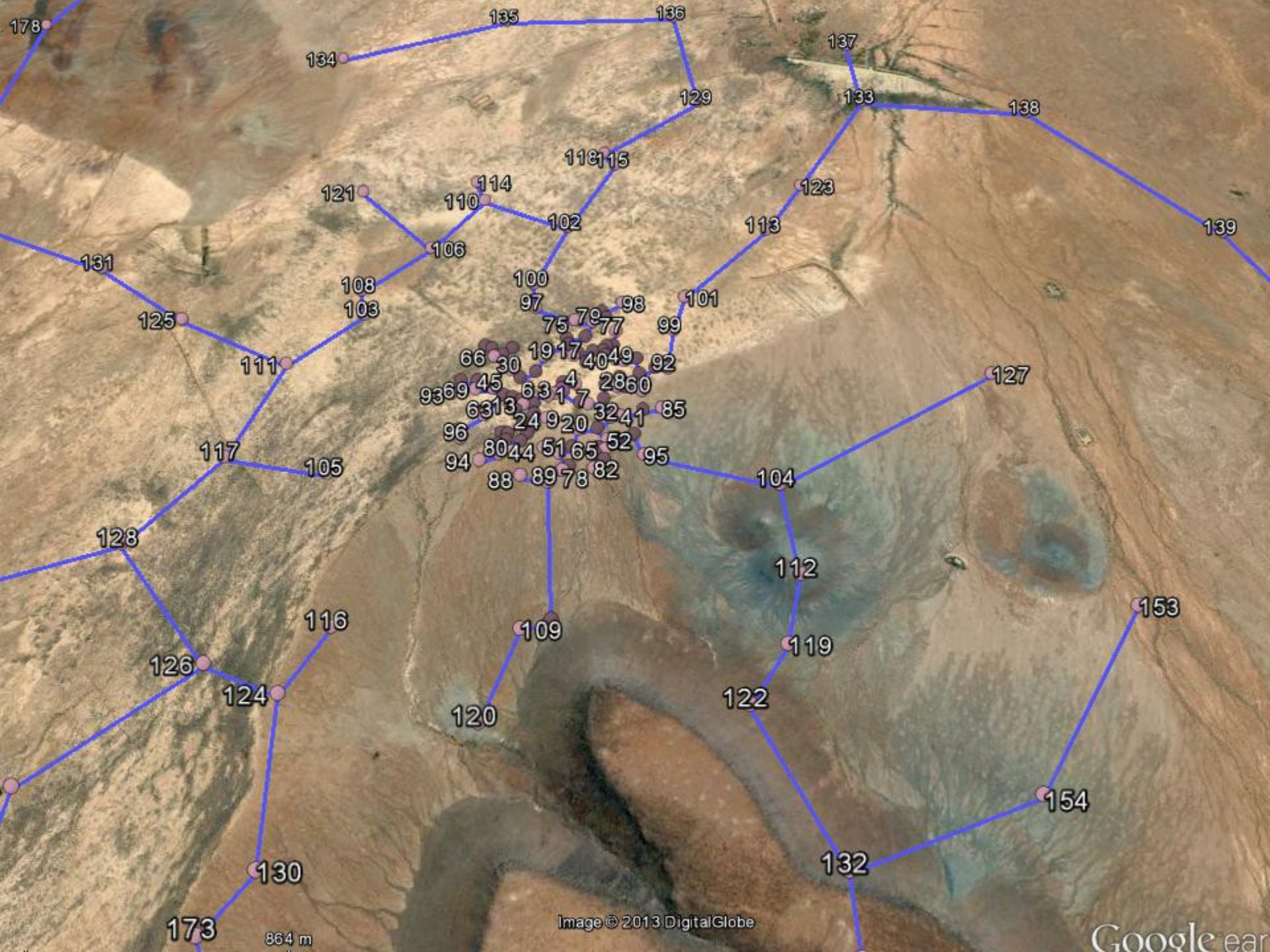
SK1-MID in South Africa



Image Landsat

47 km

Google earth







22/10/2013

O

Is to be
a) perfect
b) low cost
c) totally
transparent!





22/10/2013

SKA IN AFRICA

The Department of Science and Technology welcomes you to
CARNARVON, home of the Square Kilometre Array

www.dst.gov.za

www.nrf.ac.za

www.ska.ac.za

www.skatelescope.org



science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



National
Research
Foundation



Northern Cape Government



Pixley Ka Seme District Municipality



Kareeberg Municipality

22/10/2013

BERINGARRA PINDAR RD



Tallering Station	14
Yuin Station	63
Murgoo Station	150
Pia Wadjarri Community	178
Boolarady Station	197
Nookawarra Station	291
Beringarra Station	326

Warning: No Fuel or Service on this Road

25/11/2013





26/11/2013



How will SKA1 be better than today's best radio telescopes?

Astronomers assess a telescope's performance by looking at three factors - **resolution**, **sensitivity**, and **survey speed**. With its sheer size and large number of antennas, the SKA will provide a giant leap in all three compared to existing radio telescopes, enabling it to revolutionise our understanding of the Universe.



WITH THE SKA

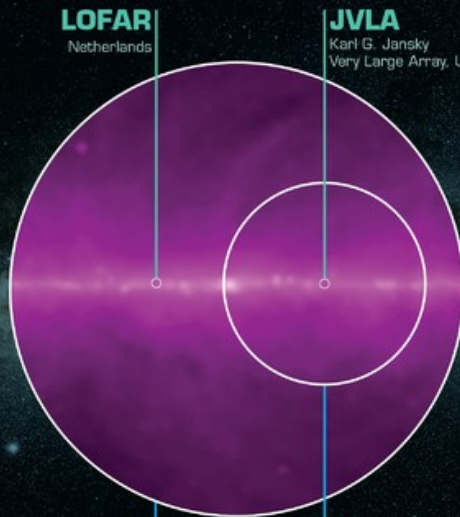
WITH CURRENT RADIO TELESCOPES

SKA1 LOW x1.2 LOFAR NL

SKA1 MID x4 JVLA

RESOLUTION

Thanks to its size, the SKA will see smaller details, making radio images less blurry, like reading glasses help distinguish smaller letters.



SKA1 LOW
Australia

SKA1 MID
South Africa

SKA1 LOW x135 LOFAR NL

SKA1 MID x60 JVLA

SURVEY SPEED

Thanks to its sensitivity and ability to see a larger area of the sky at once, the SKA will be able to observe more of the sky in a given time and so map the sky faster.

The **Square Kilometre Array** (SKA) will be the world's largest radio telescope. It will be built in two phases - SKA1 and SKA2 - starting in 2018, with SKA1 representing a fraction of the full SKA. SKA1 will include two instruments - **SKA1 MID** and **SKA1 LOW** - observing the Universe at different frequencies.



WITH THE SKA

WITH CURRENT RADIO TELESCOPES

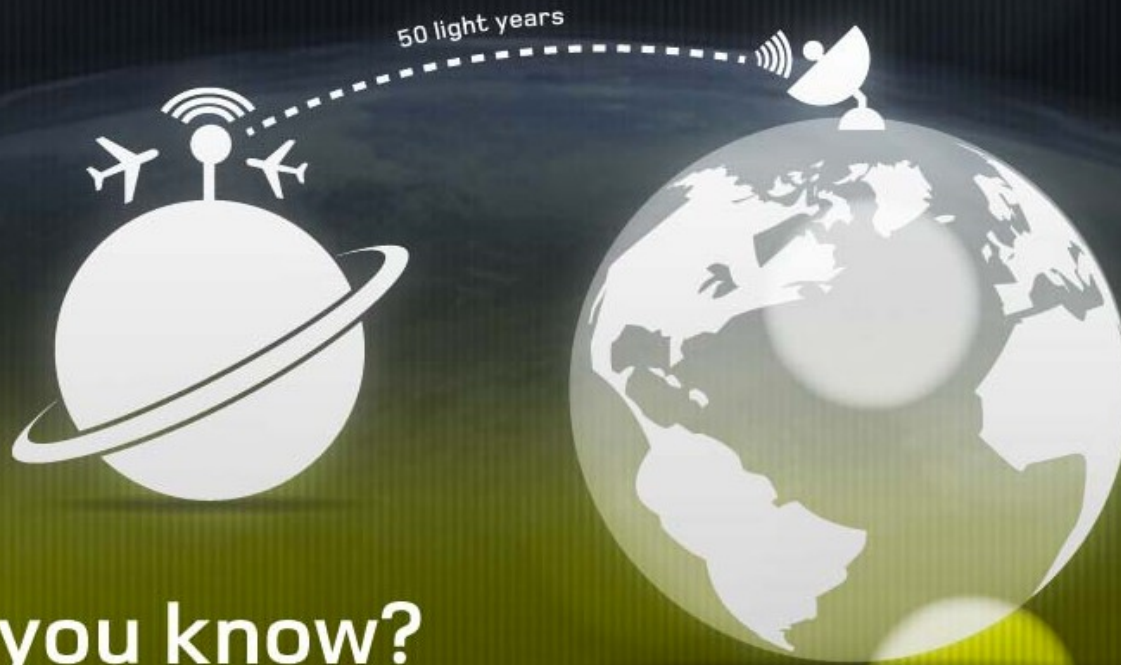
SKA1 LOW x8 LOFAR NL

SKA1 MID x5 JVLA

SENSITIVITY

Thanks to its many antennas, the SKA will see fainter details, like a long-exposure photograph at night reveals details the eye can't see.

Fun facts about the SKA



> Did you know?

- + The SKA will be so sensitive that it will be able to detect an airport radar on a planet 50 light years away.

<https://skatelescope.org/>



Interesting facts

- The dishes of the SKA will produce *10 times* the global internet traffic.
- SKA central computer will have processing power of *~ one hundred million PCs*.
- Data collected by SKA in a single day would take nearly *two million years* to playback on an ipod.
- The SKA will use enough optical fibre to wrap *twice around the Earth!*

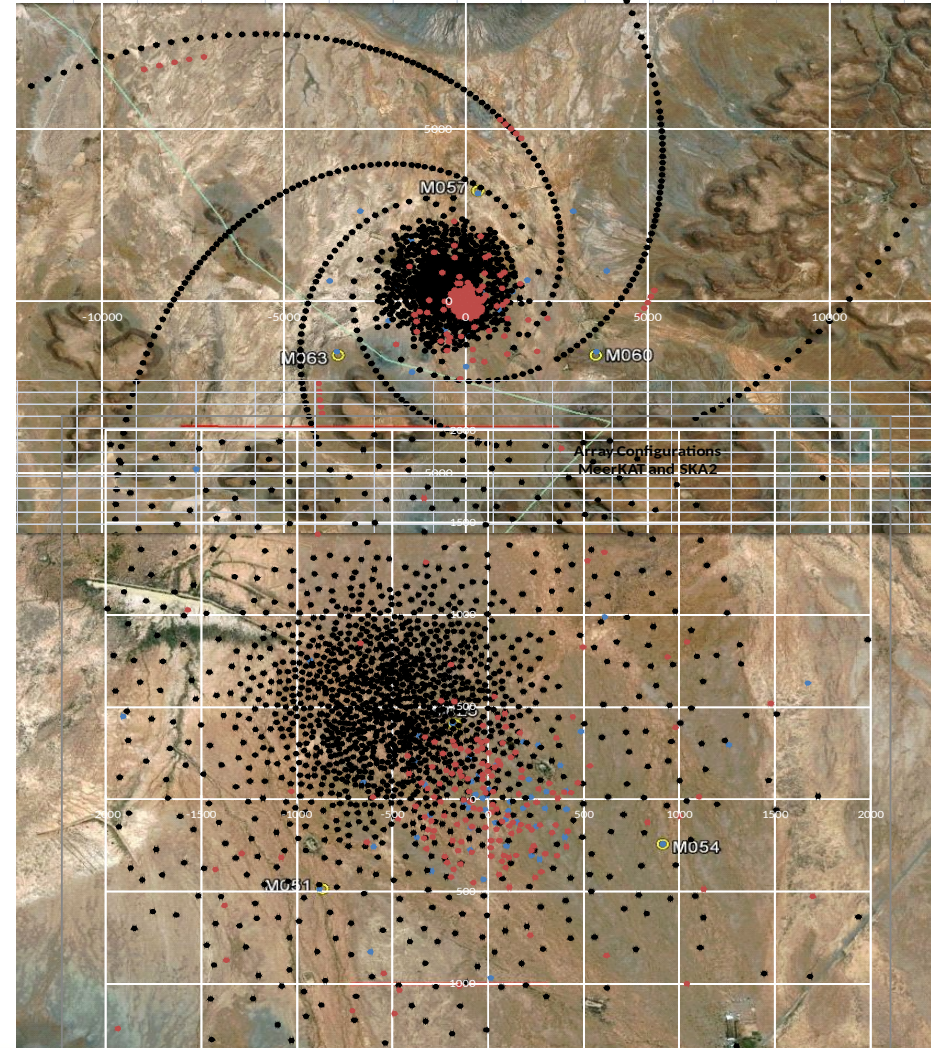
Network upgrade challenges

SKA Phase 2



- 10x number of antennas/stations
- At least 10x data rates
- Installing Phase 2 infrastructure over Phase 1?
- Long distances (~3000 km)

South Africa site illustration



Timeline



- 2005-2009 Technology research
- 2006 Short listing of sites(Australia OR South Africa)
- 2008-2012 Technology development
- 2011 Site selection (South Africa AND Australia)
- 2013 - 2016: Pre-construction, detailed design
- 2014 - 2016: Partners seek SKA1 funding
- 2016-2019: Construction approved
- 2019-2022: Issue construction contracts
- 2022-2027: Construction of SKA1
- 2024/2025: Early science begins
- 2019-2027: Design of full SKA
- 2027-2032: Construction of full SKA?

- SKA operational for 50 years.

The End



A white Toyota Land Cruiser is parked on a dirt road in front of two large radio telescope dishes. The dishes are mounted on white cylindrical bases and are supported by a complex metal structure. The background shows a dry, scrubby landscape under a clear blue sky. The text "ASKAP: Australian SKA Pathfinder" is overlaid in yellow on the image.

ASKAP:
Australian SKA Pathfinder

SKA stages - precursor - Phase 1 and Phase 2



KAT7





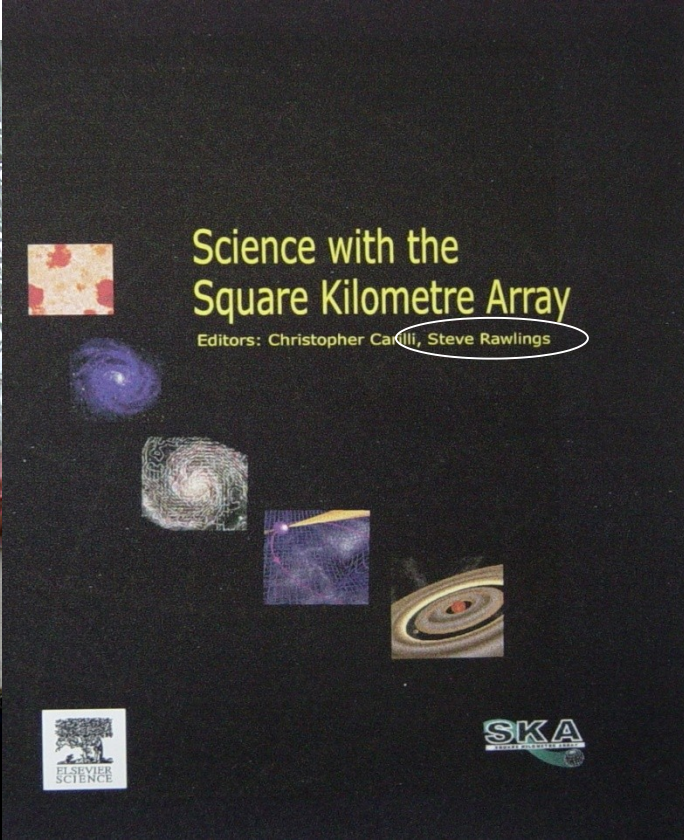
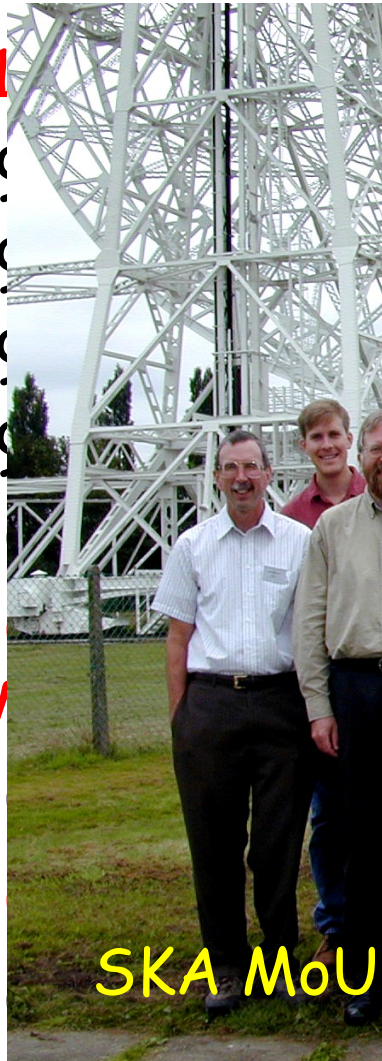
- First MeerKAT dish



MeerKAT
South African SKA Precursor

Visionary projects take a long time....

- 1
- 19
- 19
- 19
- 19
- 19
- 2
- 2
- 2
- 2
- 2
- 2
- 2
- 2
- 2



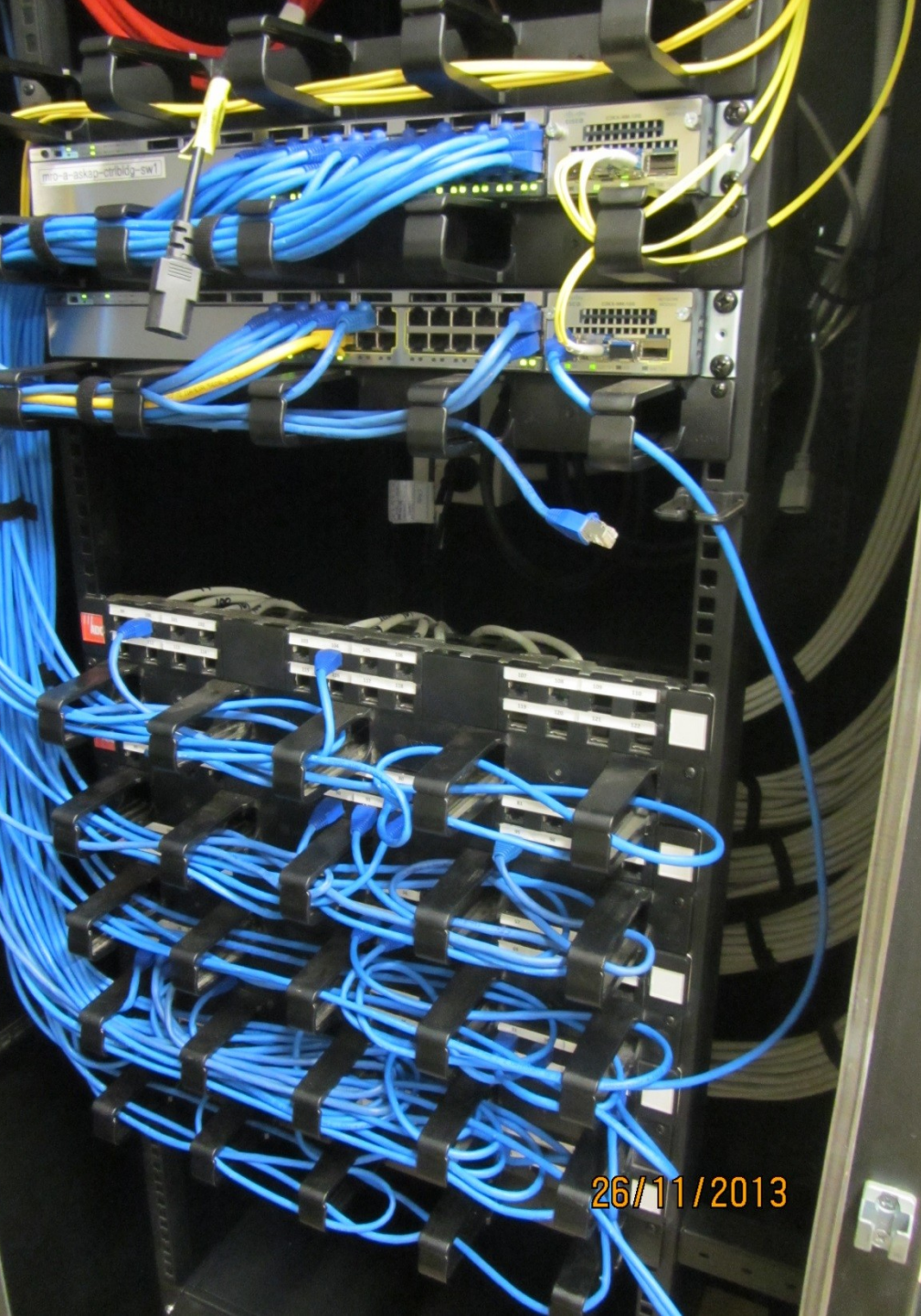
SKA MoU signed IAU Manchester 2000

formed

tee

zi)

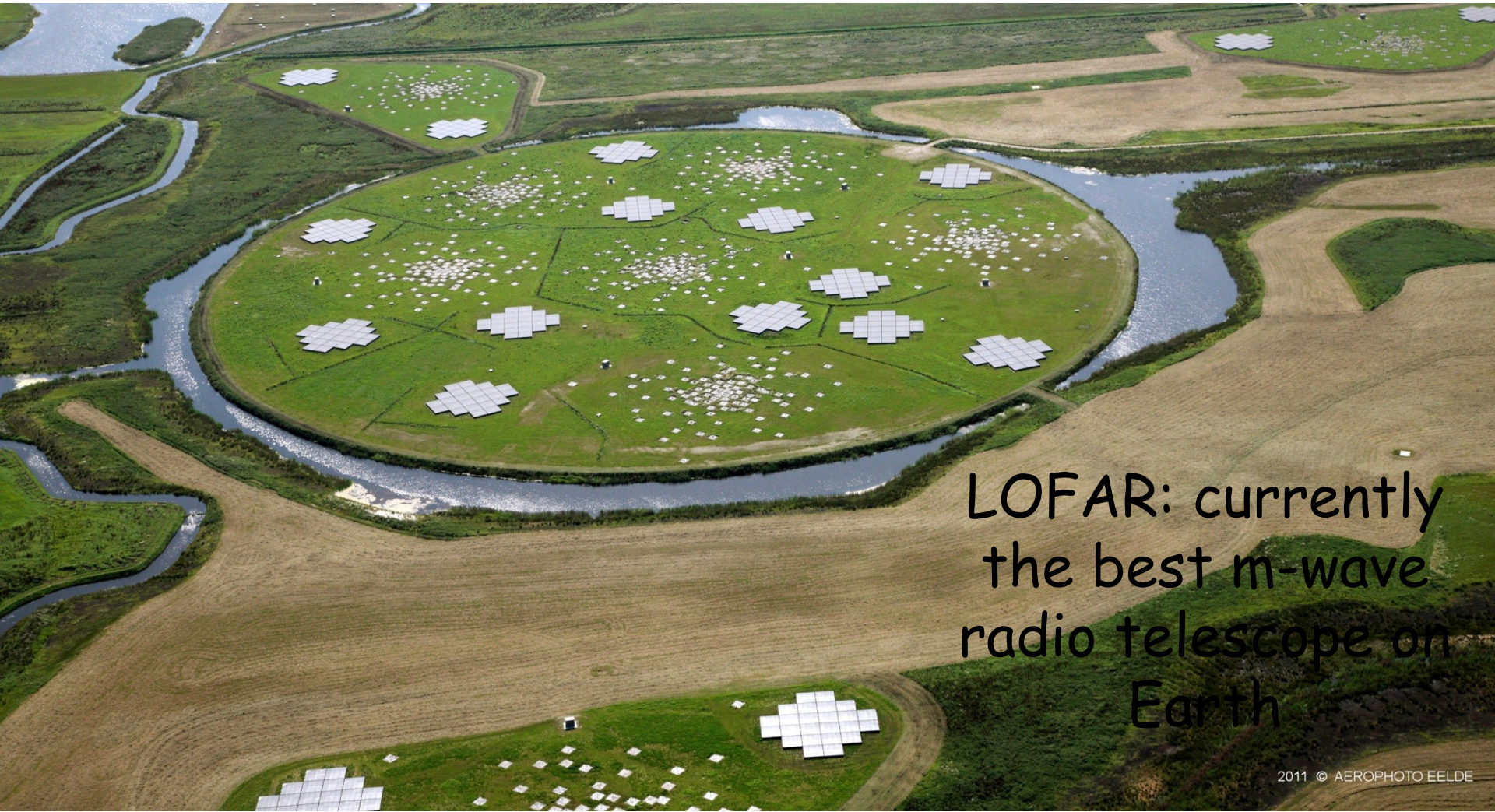
1
CADS



26/11/2013



23/10/2013



LOFAR: currently
the best m-wave
radio telescope on
Earth

2011 © AEROPHOTO EELDE

LOFAR, The Netherlands

"A volume of the 'Encyclopaedia of the Universe' is written in 21 cm typescript. Unfortunately the printing is rather faint and we need a large 'lens' to read the text! **Wilkinson 1991:**

Radio Interferometry: Theory, Techniques and Applications
IAU Coll. 131, ASP Conference Series, Vol. 19, 1991
T.J. Cornwell and R.A. Perley (eds.)

THE HYDROGEN ARRAY

P. N. WILKINSON

University of Manchester, Nuffield Radio Astronomy Laboratories, Jodrell Bank,
Macclesfield, Cheshire SK11 9DL, United Kingdom

ABSTRACT The time is ripe for planning an array with a collecting area of 1 km² (14 times larger than Arecibo and 75 times larger than the VLA). In view of its major astronomical target I have dubbed this concept 'The Hydrogen Array', although 1 μJy continuum sources will also be reliably detected. I present some initial thoughts about the issues involved.



26/11/2013



Why is astronomy in the radio band important?