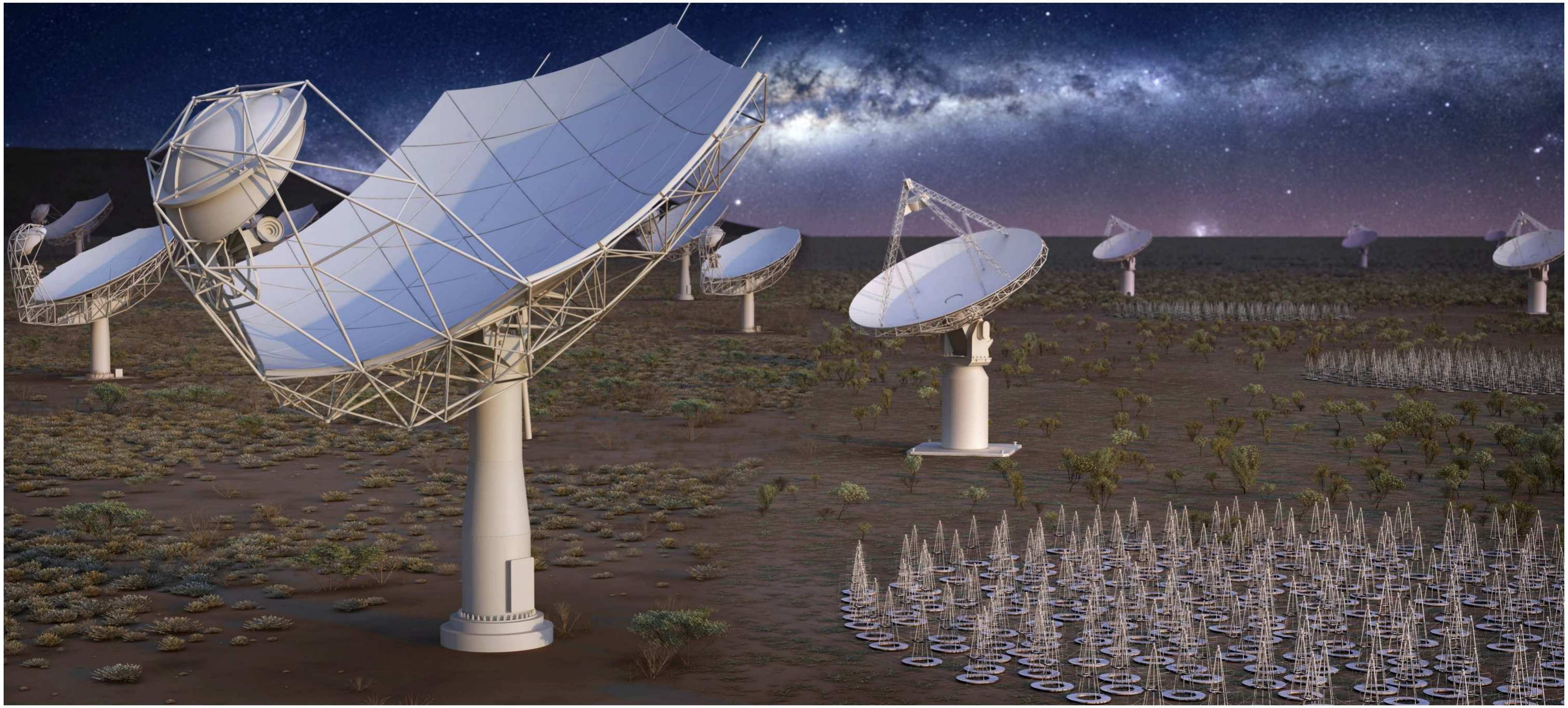
Technology Challenges on the Road to the SKA

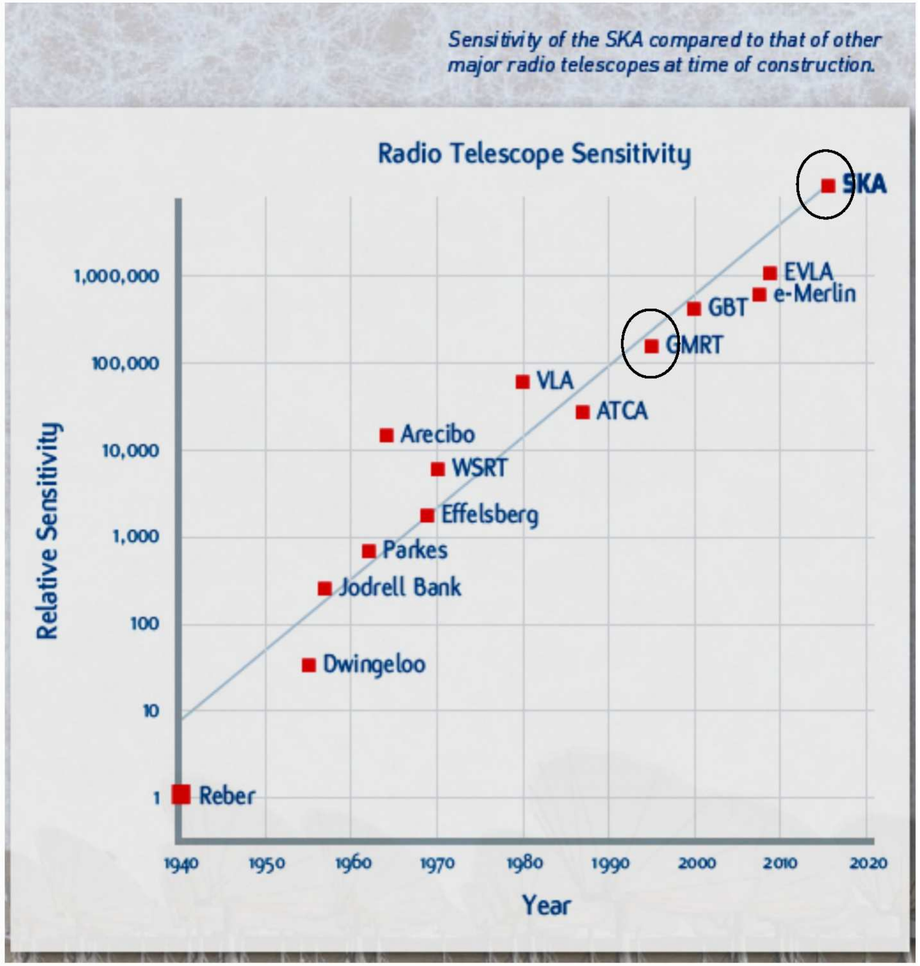


Yashwant Gupta

National Centre for Radio Astrophysics, Pune

SKA : overview

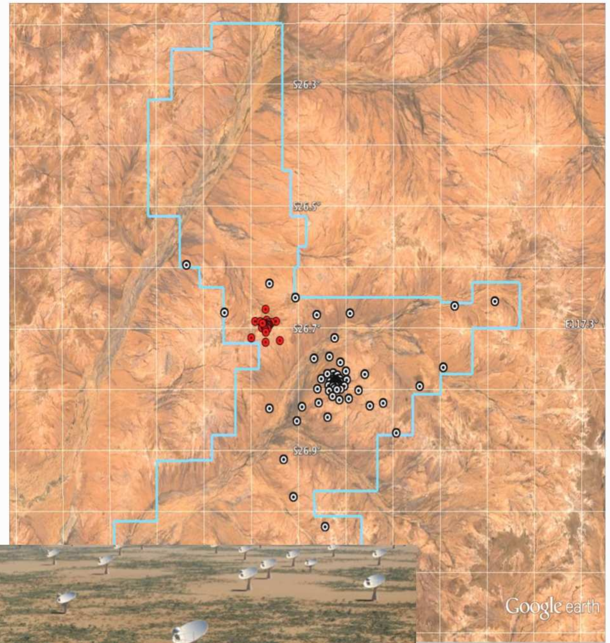
- The SKA is the most ambitious Radio Astronomy project ever attempted
- 1 square km (1,000,000 sq m) collecting area (~ 30 x GMRT !) ➔ ~ 3000 small sized antennas, with larger field of view
- High resolution ➔ antennas spread out over distances up to 3000 km, but connected in real-time (by optical fibre)
- Wide frequency range: 50 MHz - 15 GHz
- Location : Australia AND South Africa (radio quiet regions, far away from human habitat)
- Cutting edge science in all frontline areas
- Currently completing design for SKA Phase-I; construction : 2020 - 2027



Radio telescope sensitivities over the years
SKA will be 50x better than today's best !

SKA Design & Technologies

- Receptor stations spread out over a region of 3000 km ; highly compact & dense central core region
- Multiple detector technologies to cover the large frequency range : dishes (high frequency), sparse & dense aperture arrays (low & mid frequencies)
- Extensive optical fibre network (petabits/sec) : > total internet traffic)
- State of the art low noise electronics & real-time signal processing
- Supercomputing capability (petaflops) for post processing requirements
- Complex telescope management structure




Main technology challenges towards the SKA

- Antennas and electronics : wideband feeds, low noise electronics
- Data transport from antennas to central signal processor
- Real-time signal processing
- Science data processing
- Storage / archival of the science data processor output
- Dissemination of data to region data centres
- Observatory-wide management system : algorithms + software
- Managing the power requirement challenge
- Large volume (industry scale) production of items
- Reliability and availability, especially in the harsh environment
- ...

Data Challenge

Main technology challenges towards the SKA

Key items	SKA1	SKA2
Dishes, feeds, receivers	133	2000-2500
Low and mid aperture array antennas	130,000	500k – 1000k
Signal transport	2 Pb/s short-range 8 Tb/s long-range	20 Pb/s short-range 100 Tb/s long-range
Signal processing	Exa-MACs	Exa-Macs
Software engineering and algorithm development	modest to significant challenge	very significant challenge
High-perfroamnce computing	50-270 Pflops	Exa-Flops
Data storage	ExaByte	Multi-ExaByte
Distributed power requirements	~10 MW	50 MW

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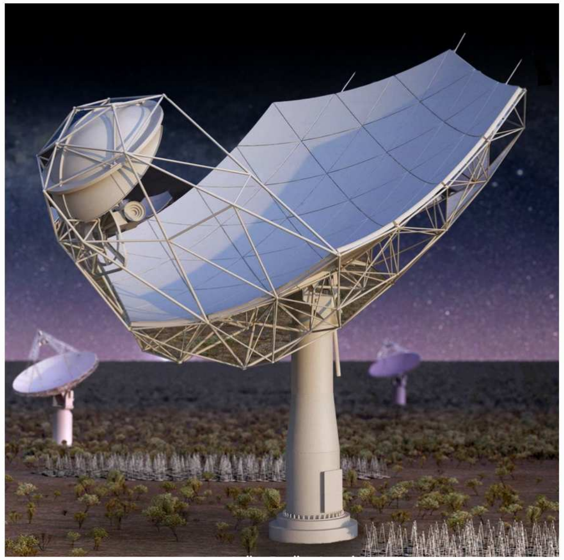
Data Challenge

Challenges : Antennas & electronics

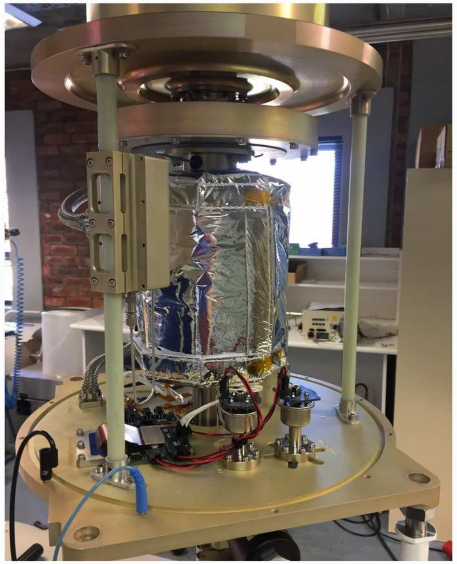
- Large range of frequencies, wide bandwidths :
  - SKA-Low : dipole with matched pattern over wide frequency range
  - SKA-mid : multiple, large bandwidth feeds

- Low noise electronics :
  - Room temperature devices for SKA-Low
  - Cryogenic cooled receivers for SKA-Mid

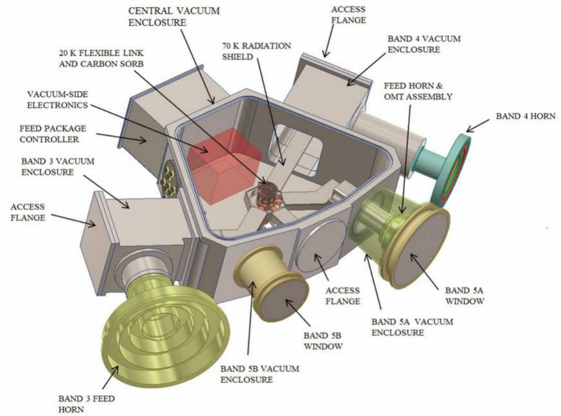


Band	Frequency Range	Bandwidth
Low	50 – 350 MHz	300 MHz
Mid Band 1	0.35 – 1.05 GHz	1 GHz
Mid Band 2	0.95 – 1.76 GHz	1 GHz
Mid Band 3	1.65 – 3.05 GHz	1 GHz
Mid Band 4	2.80 – 5.18 GHz	2.5 GHz
Mid Band 5a	4.6 – 8.5 GHz	2.5 GHz
Mid Band 5b	8.3 – 15.3 GHz	2 x 2.5 GHz

Challenges : Antennas & electronics



Band 2 :   0.95 – 1.76 GHz



Band 5 :
5a: 4.6 – 8.5 GHz
5b: 8.3 – 15.3 Ghz

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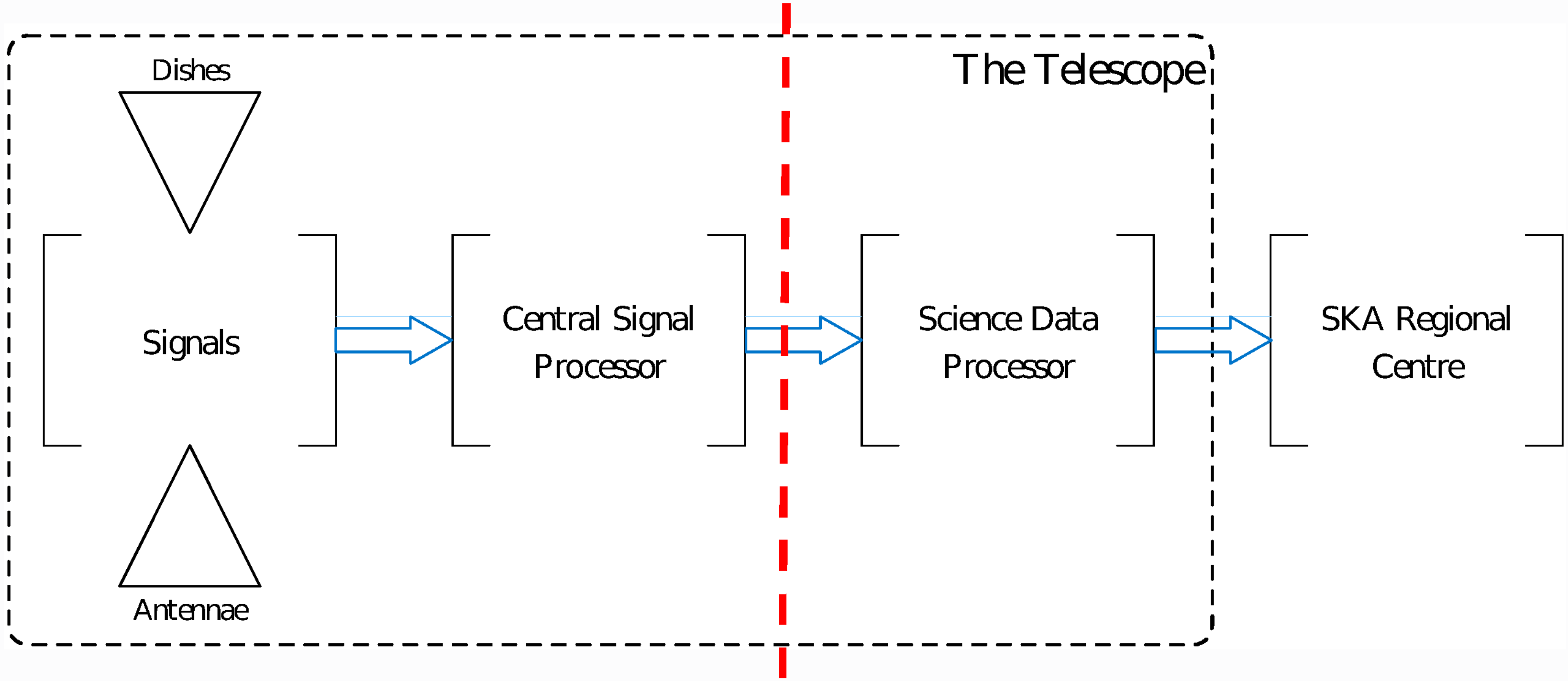
Data Challenge

Data Challenges for the SKA

- Data flow :
  from Antennas ➡ Central Signal Processor ➡ Science Data Processor ➡ Archiving system / Specialised Pipeline Processor
- Data rates are very large; processing capabilities are challenging



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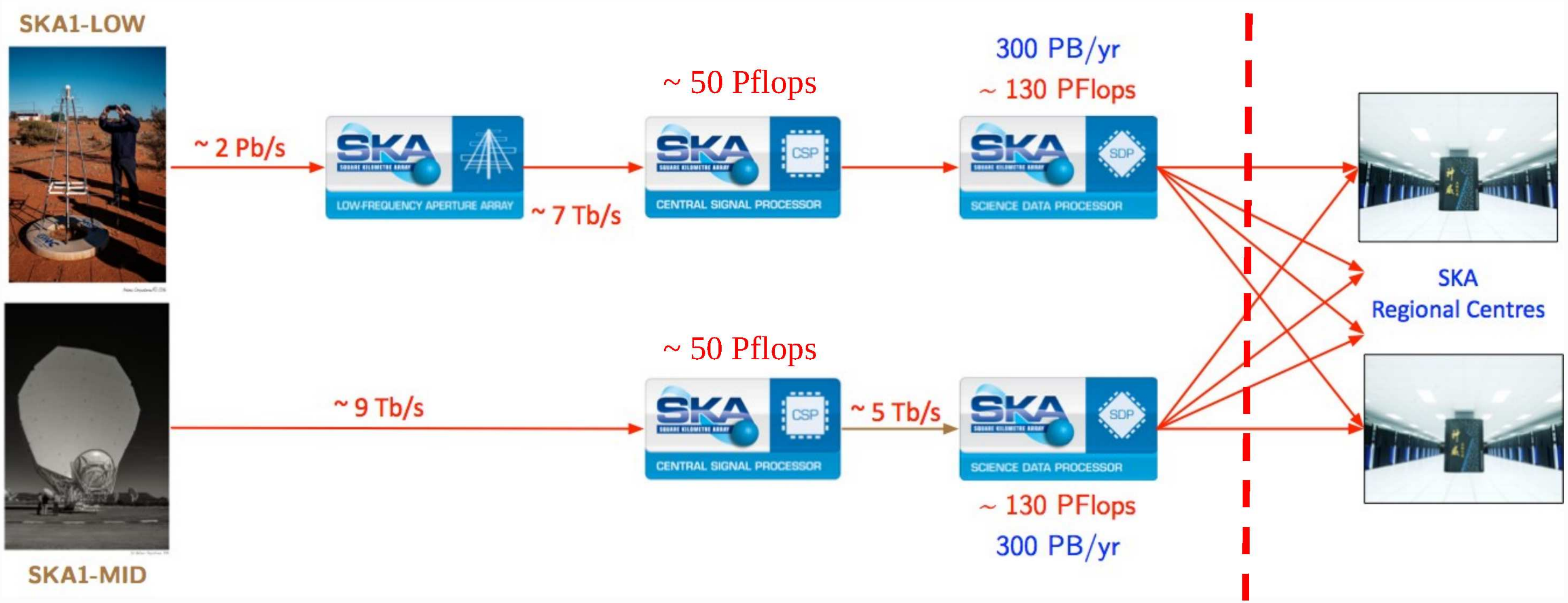
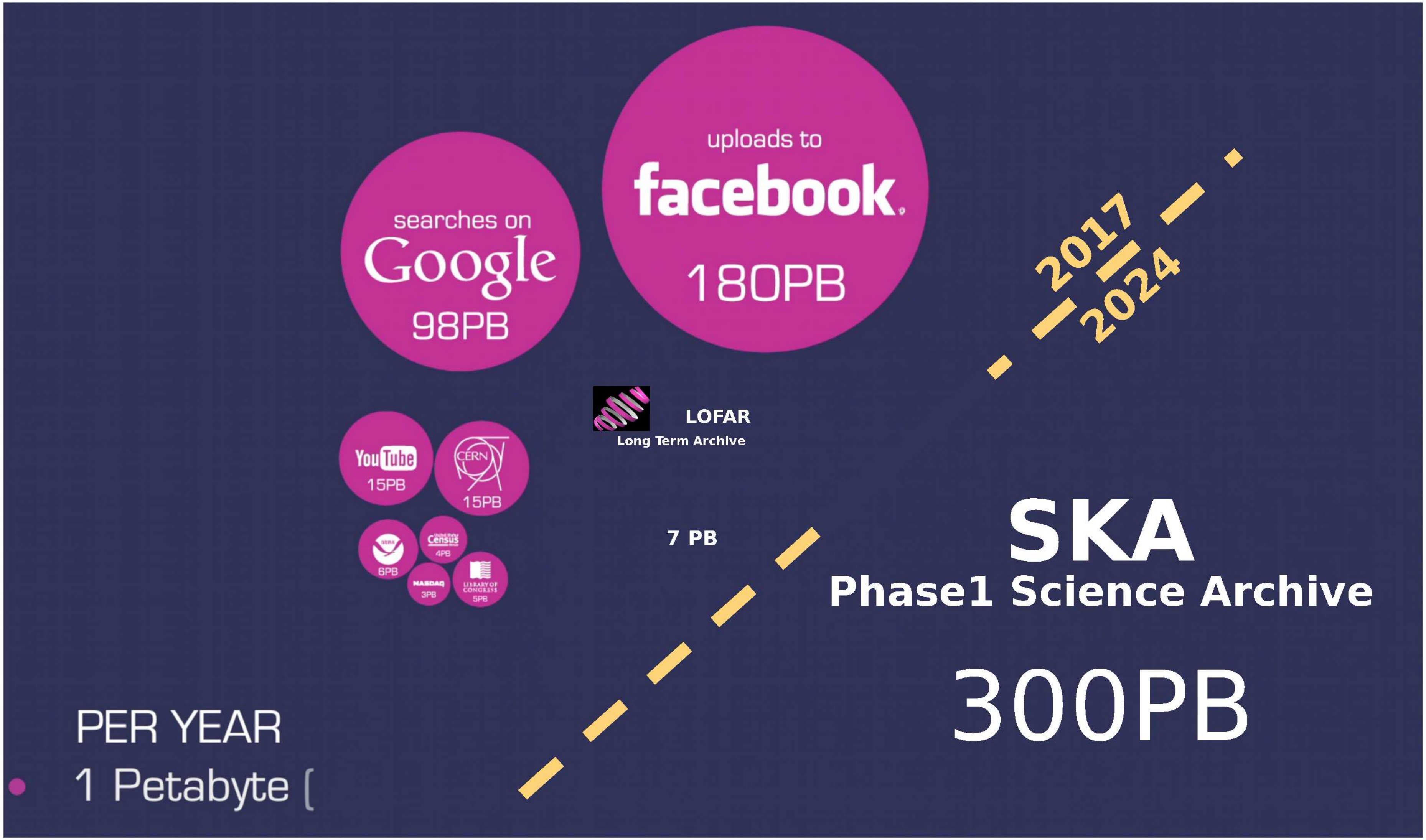


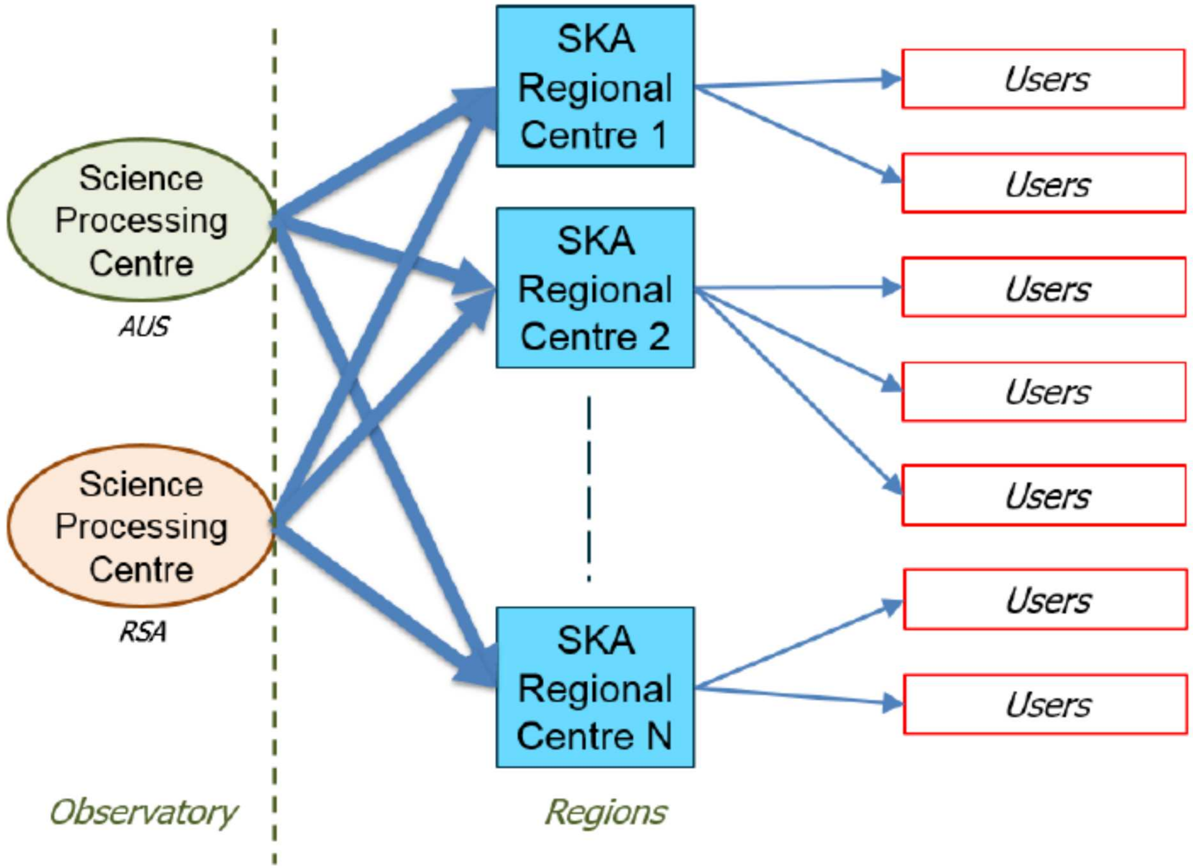
Data Challenges for the SKA

- Science Data Archive for SKA vis-a-vis other data archives we know about : clearly, SKA data archive dominates !



Data Challenges for the SKA

- SKA global data flow model :



- It is planned to have SKA Regional Centre in India

Data Challenges for the SKA

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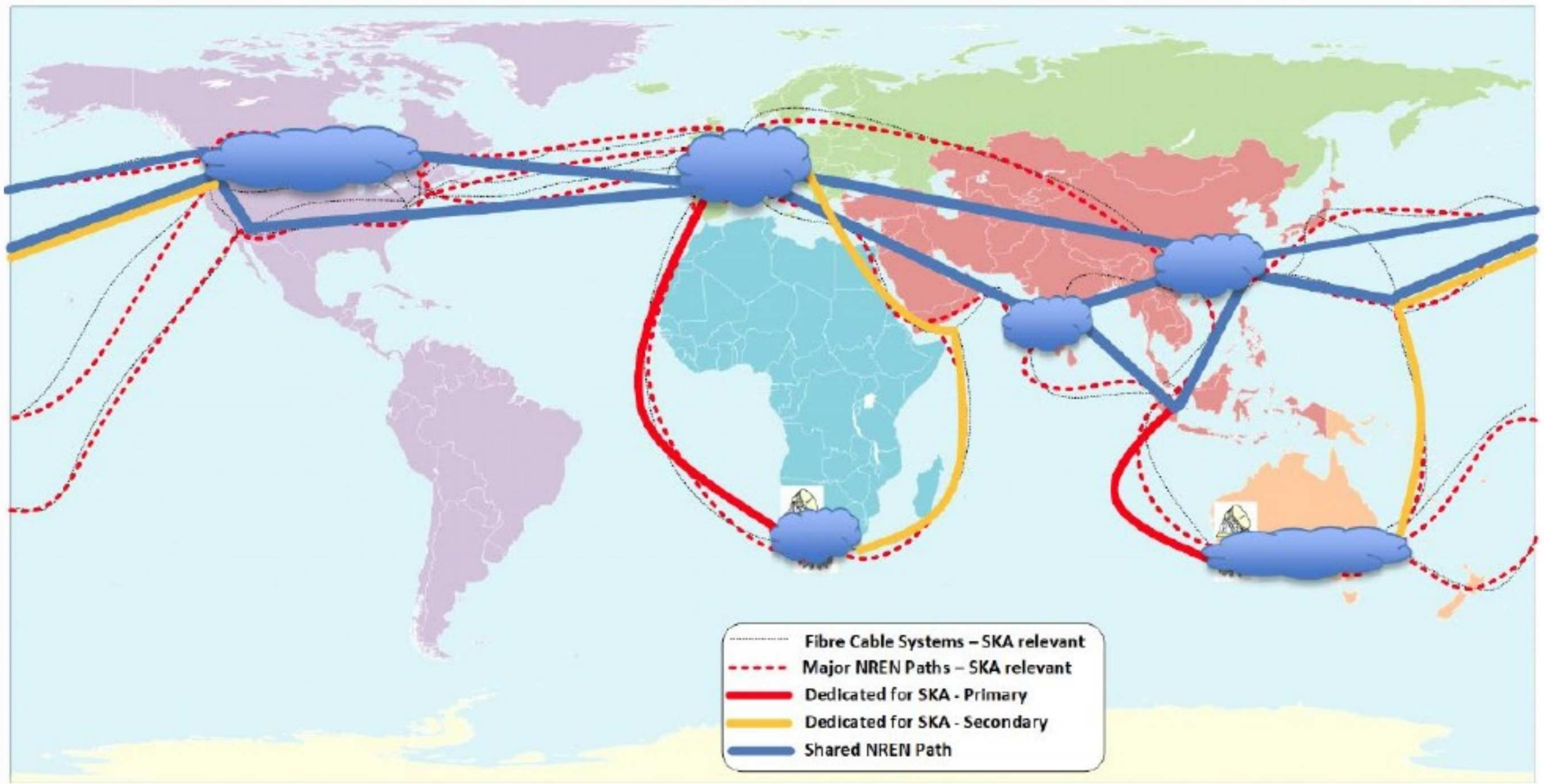

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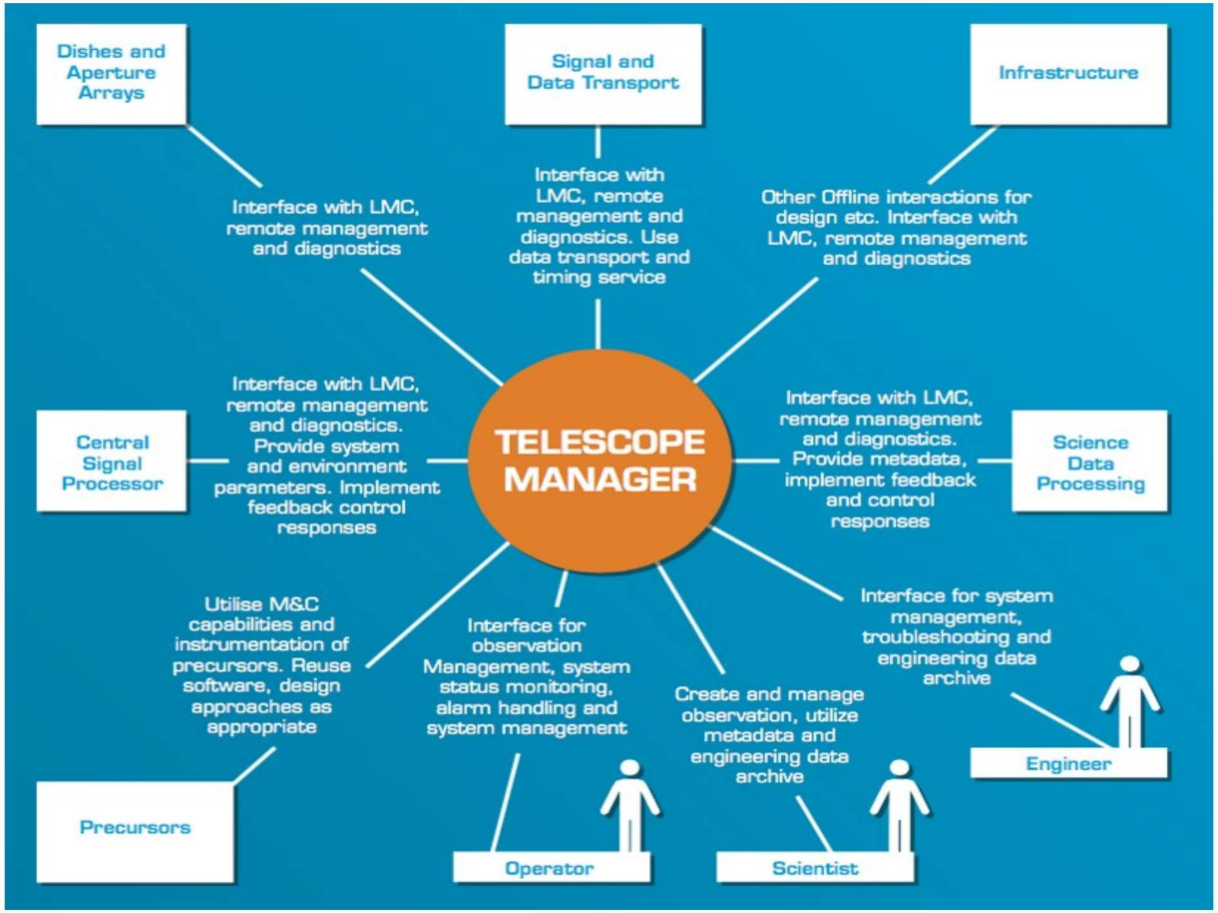
Data Challenge

End-to-End management of the observatory

- SKA observatory will be a vast, distributed system requiring sophisticated end-to-end management system
- Telescope Manager : brain and nervous system of the observatory
- Design phase work (2014 – 2018) led by India (NCRA + industry partners)



TM Consortium : Partners & Roles

LMC (INAF, Italy)

Observation Management (UKATC , UK)

Telescope Management (NCRA , India)

Infrastructure (Engage SKA Consortium , Portugal)

Project Management (NCRA, India)

System Engineering (SKA SA, South Africa)

Prototyping (NCRA , India)

Review, support (CSIRO , Australia ; NRC-HIA, Canada)

The Telescope Manager Consortium was led by the Indian team (NCRA + partners from research institutes & industry) and included members from 7 other countries. Each member played a specific role in the consortium, contributing to one or more of the major activities.

TM design completed by India led team

SKA INDIA

SKA SQUARE KILOMETRE ARRAY

Indian-Led Telescope Manager Consortium Concludes Design Work On SKA

Members of the Telescope Manager consortium gathered at SKA Global Headquarters in the UK for the Critical Design Review in April. Credit: SKAO

SKA Global Headquarters, 6 August 2018 – After four and a half years, the international Telesc (TM) consortium has formally concluded its work on the architectural design of a fundamental par for the Square Kilometre Array: the nervous system of the Observatory, which is called the Telesc

WWW.INDIANEXPRESS.COM
THE SUNDAY EXPRESS, AUGUST 5, 2018

Team led by Pune institute designs 'nervous system' of largest radio telescope

12 countries working together to build telescope that will provide closer look at 'one million square metres of sky'

ANJALI MARAR
PUNE, AUGUST 4

A TEAM of international scientists, led by Pune-based TIFR-National Centre for Radio Astrophysics (NCRA), has become the first among 12 other design teams to successfully develop a control system for the Square Kilometre Array (SKA), the world's largest radio telescope that is currently in the design and planning stage.

The NCRA team has developed, designed and received approval for the the Telescope Manager (TM), the key software and control system, or the 'nervous system', of the SKA. The TM

The international consortia has allocated a budget of 700 million euros for the first phase of the SKA. The Indian government has, so far, contributed Rs 30 crore for the first phase of the telescope's development.

To develop the TM's design, Indian scientists and their industry partners, TCS Research and Innovation, teamed up with experts from six countries - Commonwealth Scientific and Industrial Research Council (CSIRO), Australia, National Research Council of Canada (NRC), National Institute for Astrophysics (INAF), Italy, Instituto de Telecomunicacoes (IT) and School of Science of Porto University from

currently operational.

This highly complex engineering facility, with thousands of dish antennas, will offer researchers greater insight into one million square metres of the sky and faster surveying ability in a shorter span of time, to improve the overall understanding about the universe and to track some of the earliest star formations, among other functions.

The world's largest radio telescope is expected to generate astronomical data to the tune of 3 lakh terabytes annually. To draw a comparison, the NCRA-operated upgraded Giant Metrewave Radio Telescope (GMRT), located in Khodad near Pune, generates data ranging

Strong appreciation for Indian leadership and capability in TM design work !

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Data Challenge

The power supply challenge

- For SKA Phase-1, both SKA-Low and SKA-Mid will have a power requirement ~ 5 MW (~ 50 MW for the full SKA) – significant challenge (and cost)
- Serious push to green energy sources will be needed – already being tried out at the Australia site.

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- Observatory-wide management system : algorithms + software
- Managing the power requirement challenge
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Mass production and related challenges

- Large volumes / quantities of items will need to be produced with uniform quality
- Rugged and reliable quality to (a) withstand harsh environment and (b) meet the low maintenance requirement of distributed elements
- The SKA project looks to industry to provide large volumes with the above qualities

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- **Significant opportunity for industry participation and contribution**