Global R&E Networks for the SKA Observatory

Richard Hughes-Jones

SA3CC Meeting at SLAC

30 April – 1 May 2024

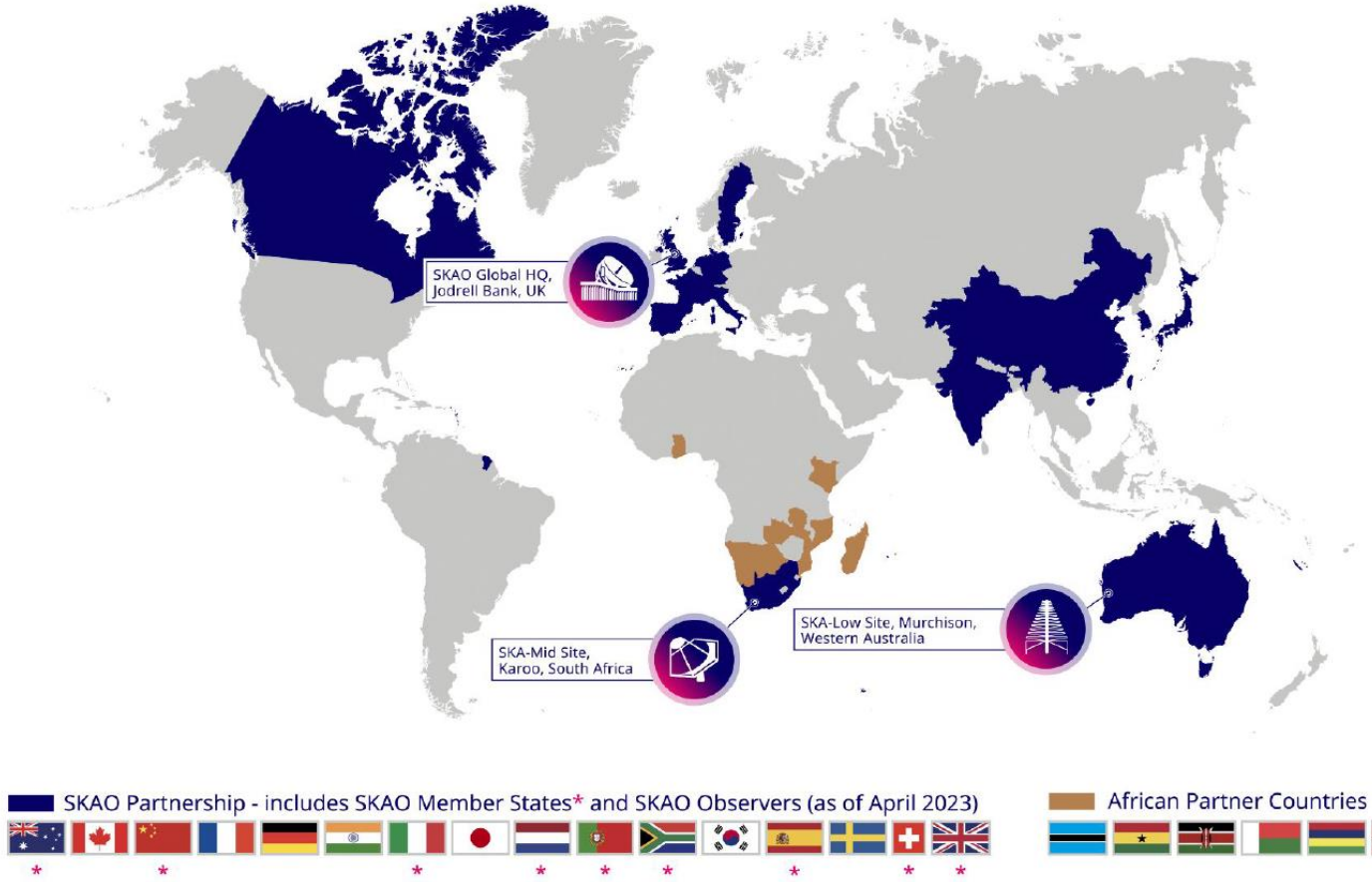
SKAO An Inter Governmental Organisation Since January 2021

Full members:
Australia, China, Italy, Netherlands, Portugal, South Africa, Spain, Switzerland, UK

Accession stage:
India, Canada, France, Germany

Awaiting government decision:
Sweden

Early stages:
South Korea, (Poland, Ireland Japan, Thailand)



SKA1-Mid: 350 MHz – 15 (24+) GHz
~200 15-m dishes across ~150 km

SKA1-LOW: 50 – 350 MHz
~130,000 antennas across 70km

SKA Low Construction Underway

TOP Left to Right: First RPF for AA0.5 Installed,

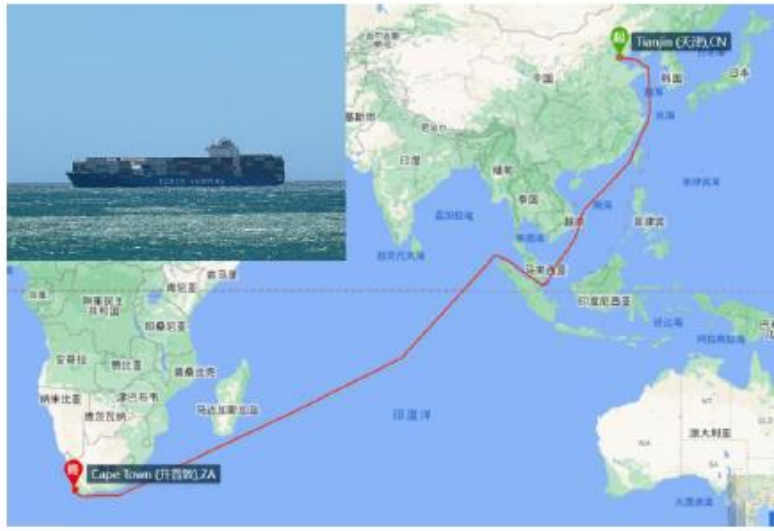
Clearing & Laydown of the mesh at Station S10,

Installation of the first antenna with the Wajarri Yamaji people

Left: The Construction Camp

Right: Ploughing in power and Fibre cables

SKA Mid Construction Underway

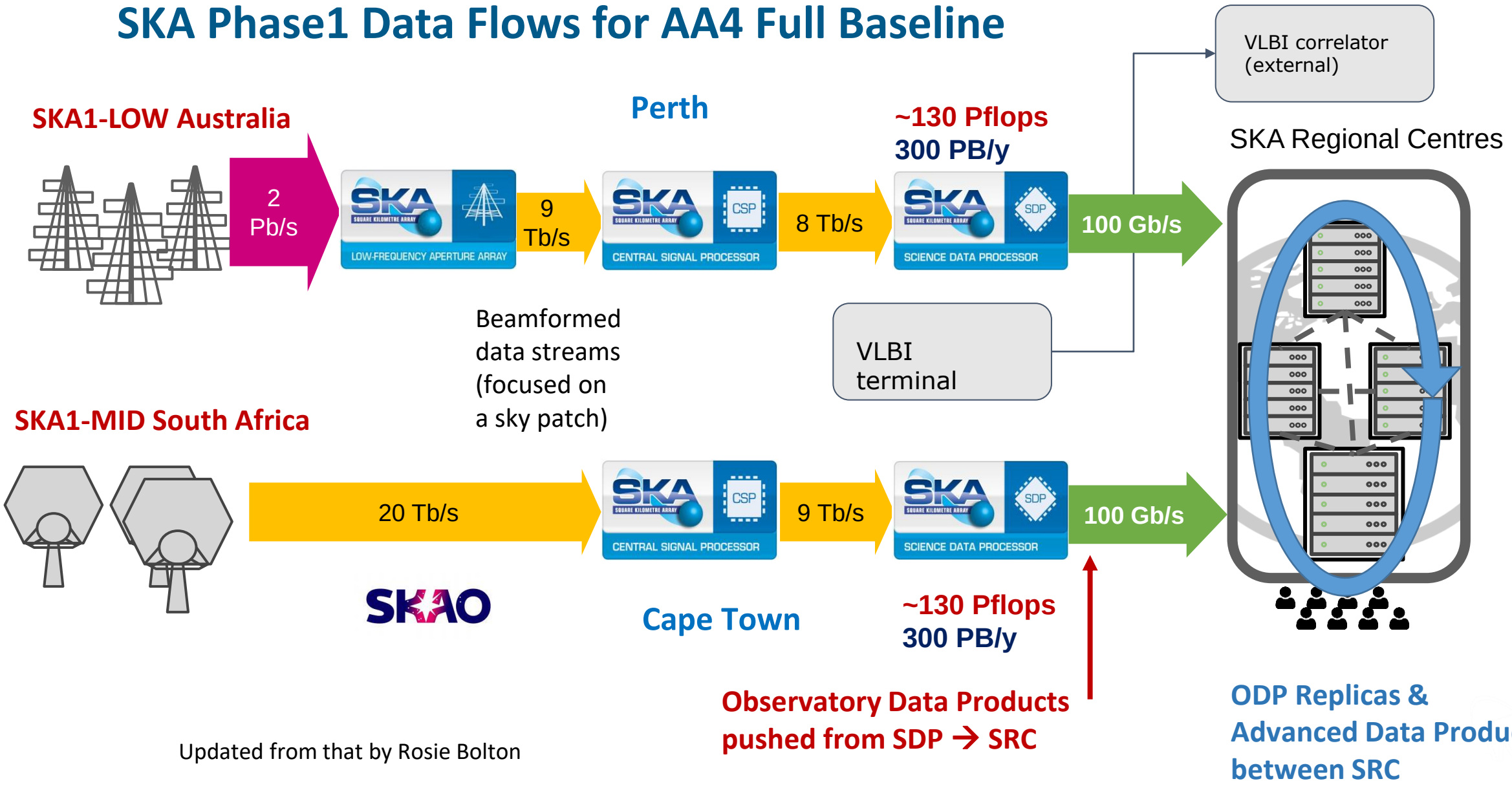


TOP Left to Right: First SKA Mid Dish lowered in place,
First SKA Mid Dish shipped from China to South Africa late in Nov 23
Ship docked Jan24 due to delay at Cape Town harbour

Left: New roads in the SKA core.

Mid: Successful installation & configuration of the AA0.5 servers in the Karoo Array Processor Building

SKA Phase1 Data Flows for AA4 Full Baseline



Updated from that by Rosie Bolton

SKA Regional Centre Capabilities

Science Enabling Applications
Analysis Tools, Notebooks, Workflows execution Machine Learning, etc

Distributed Data Processing
Computing capabilities provided by the SRCNet to allow data processing

Data Discovery
Discovery of SKA data from the SRCNet, local or remote, transparently to the user

Visualization
Advanced visualizers for SKA data and data from other observatories

Support to Science Community
Support community on SKA data use, SRC services use, Training, Project Impact Dissemination

Interoperability
Heterogeneous SKA data from different SRCs and other observatories

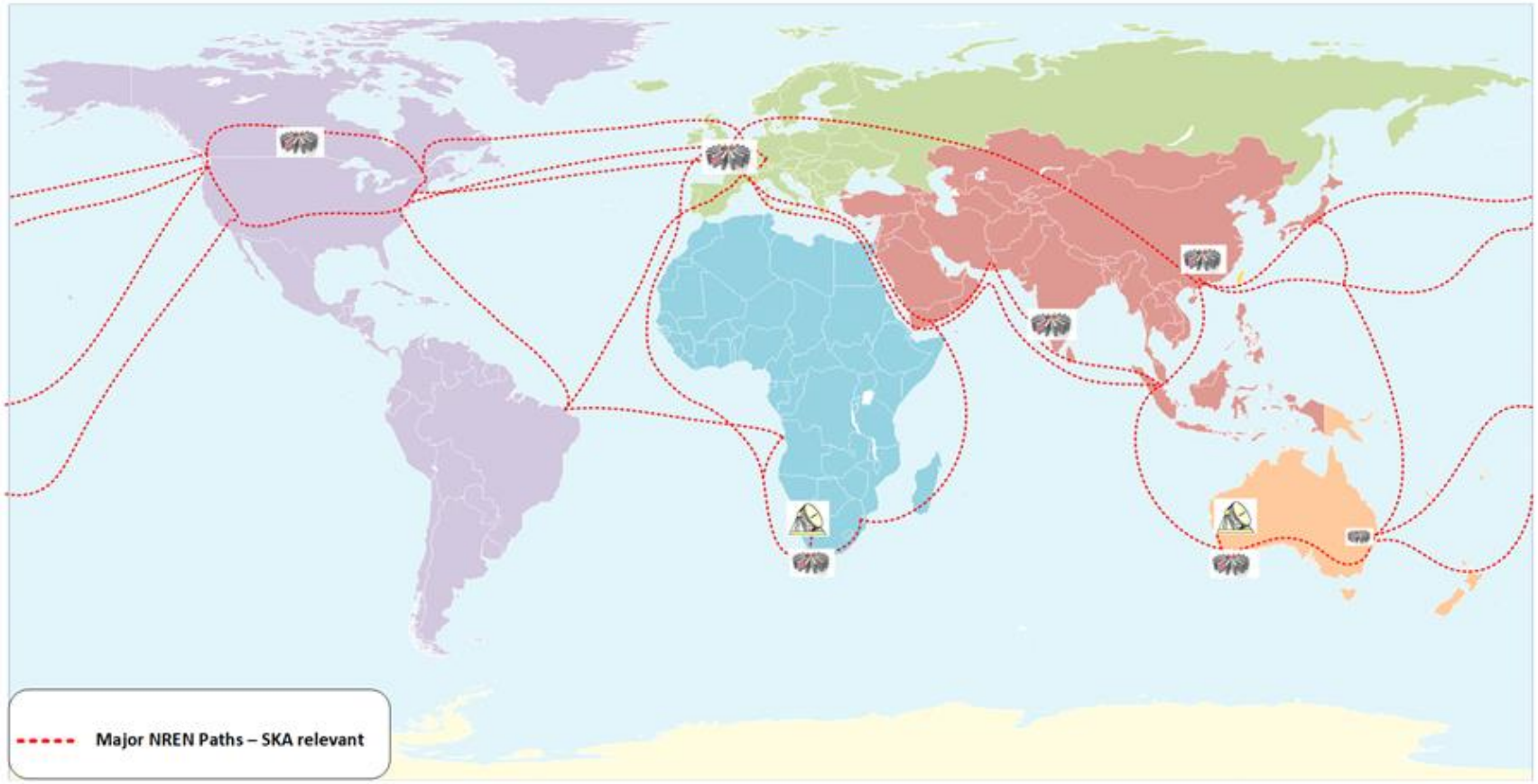
Data Management
Dissemination of Data to SRCs and Distributed Data Storage

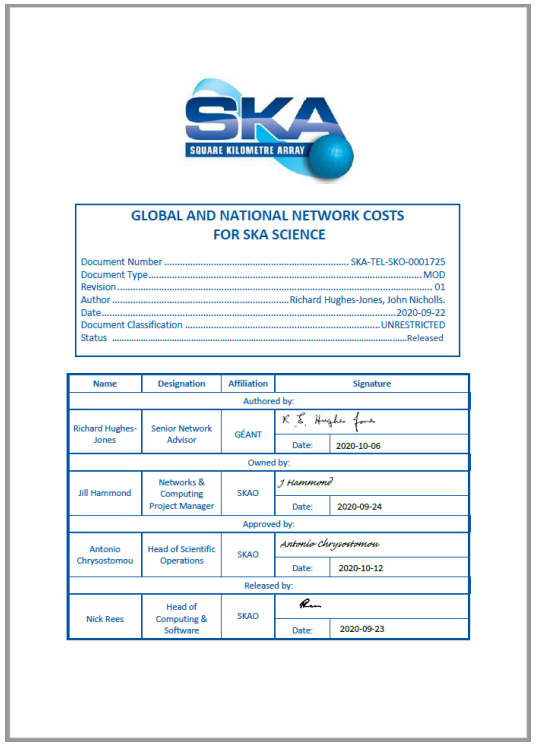
Delivering SKA data products to scientists, storing SKA data for future use, computer facilities to undertake scientific analysis and local user support all fall outside of the construction budget

With thanks to Rosie Bolton & Shari Breen

Fibre and Cable Systems and major NREN paths

- The 2020 intercontinental fibre cable systems used by the international research and education community.
- Document produced for the SKA Regional Centres Coordination Group
  John Nicholls (AARNet) & Richard Hughes-Jones (GÉANT)





GLOBAL AND NATIONAL NETWORK COSTS FOR SKA SCIENCE

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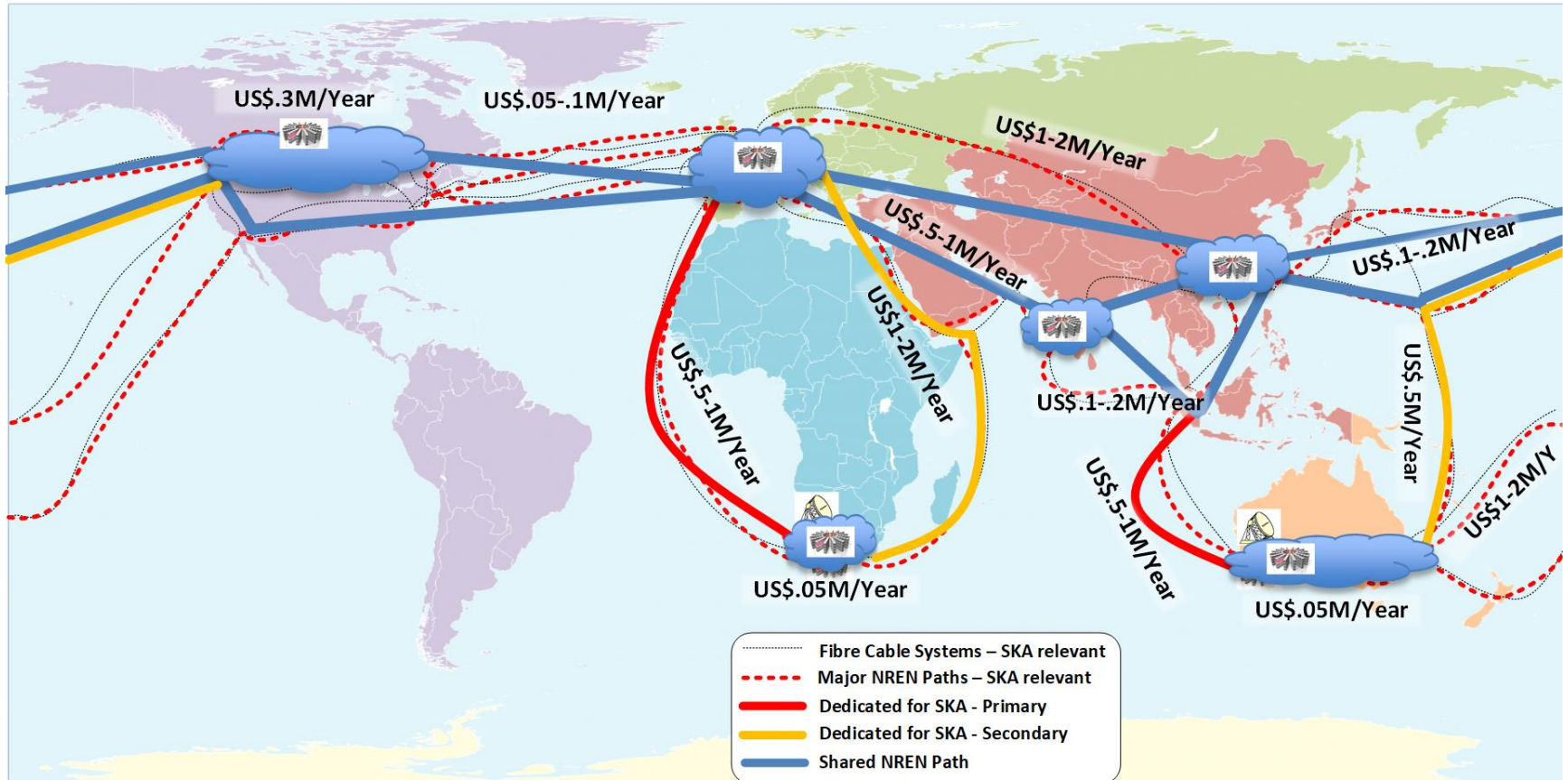
Global Network & Paths of Interest to SKA

- Dedicated 100 Gigabit Primary paths (**red lines**) & Backup paths (**yellow lines**) from both telescopes
- Use of the shared academic network (**blue lines**).
- 1 PetaByte/day pushed by SDP from each Telescope → 100 Gigabit/s for the Full Design
- Costs based on 10 to 15 year IRU per 100 Gbit circuit projected to 2025 prices



- Primary 100G bandwidth USD 1.7 – 2.3 M per year.
- Backup 100G bandwidth USD 2.3 – 3.3 M per year When required.
- SKAO agreed to funding the operational costs of these paths.
- Funding for the shared network infrastructure follows that for other science communities.

Main Flows of Data

- From the Telescopes to the SRCs for the 1st replica of Observatory Data Products (ODP).
- Between SRCs to create the 2nd replica of the ODPs
- Between SRCs to create a 2nd replica of the Advanced Data Products (ADP).

- In terms of storage there will also be an archive copy of the ODPs and ADPs stored at the SRCs.

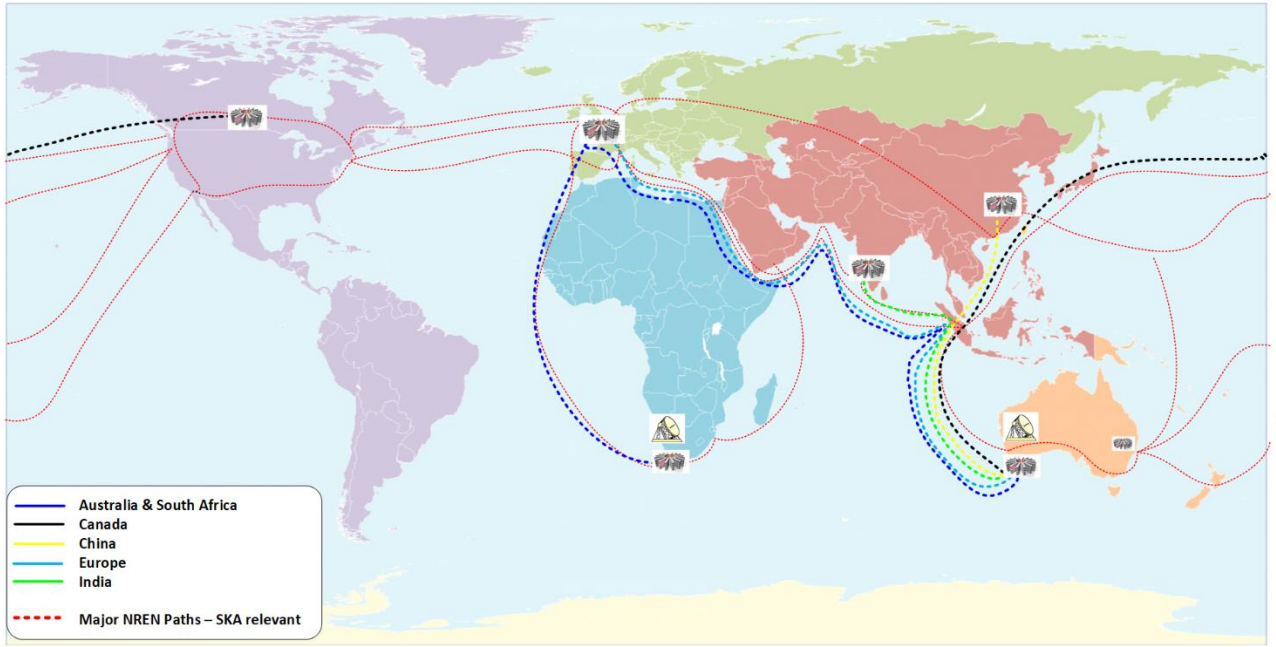
- Need to access data from other telescopes for the physics analysis.

Global Paths of the Data Flows Pushed to the SRC for the 1st Replica

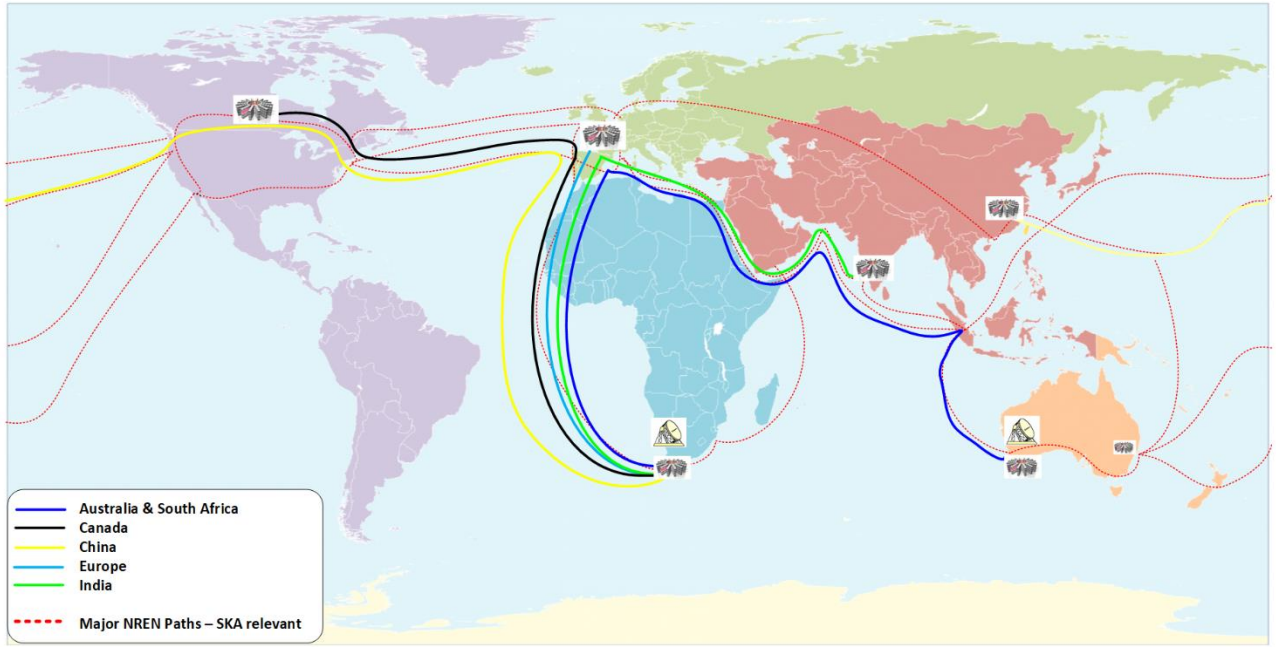
- Five flows on the submarine cable from Perth to Singapore .
- Then join the general purpose routed IP academic network.
- Single flows on the routes to Canada, China and India, Australia is local, and
  two 20 Gbit/s flows would be carried to London to reach SRCs in Europe and South Africa.

- Five flows on the submarine cable from Cape Town to London.
- Then join the general purpose routed IP academic network.
- Different submarine cables used to reach India and Australia, Europe is local, and
  two 20 Gbit/s flows cross the Atlantic to SRC in Canada and China.

SKA1-LOW Australia

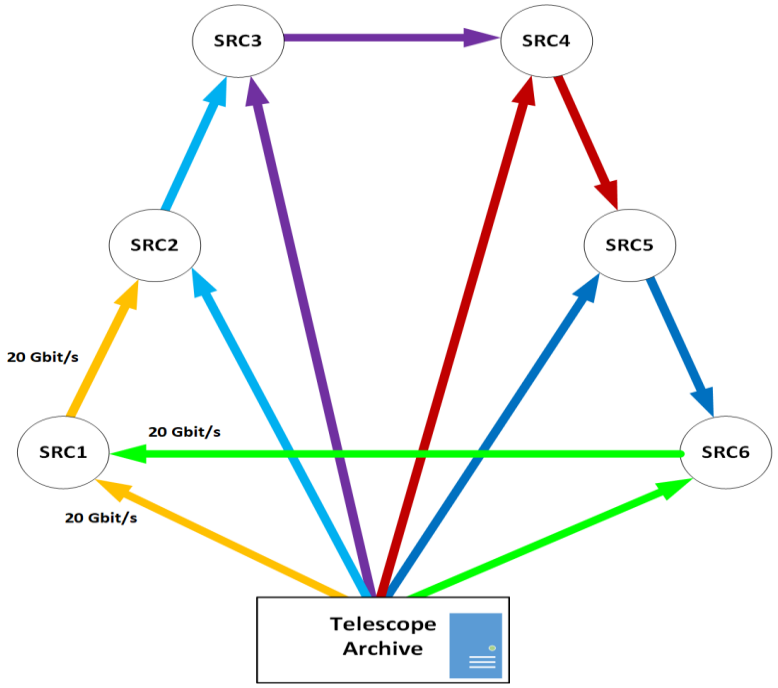


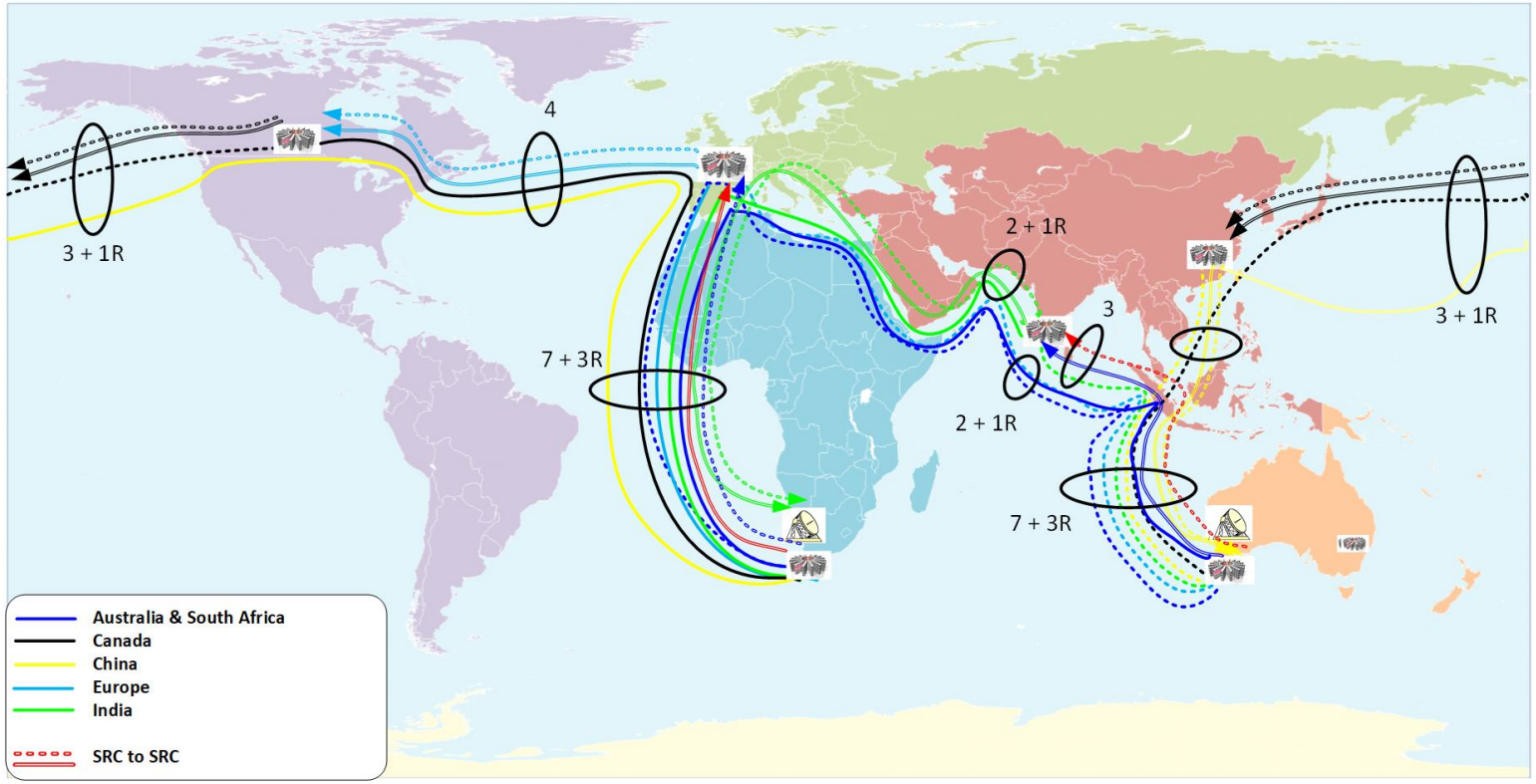
SKA1-MID South Africa



Global Data Flows if the SRC Re-distribute data 2nd Replica

- Each SRC accepts its fraction of the Observatory Data Products and re-distributes to another SRC.
- SRC has 20 Gbit/s flow from the telescope & a second continuous 20 Gbit/s flow from another SRC.
- Each SRC sends out a 20 Gbit/s flow.
- Makes substantial use of the shared academic network.





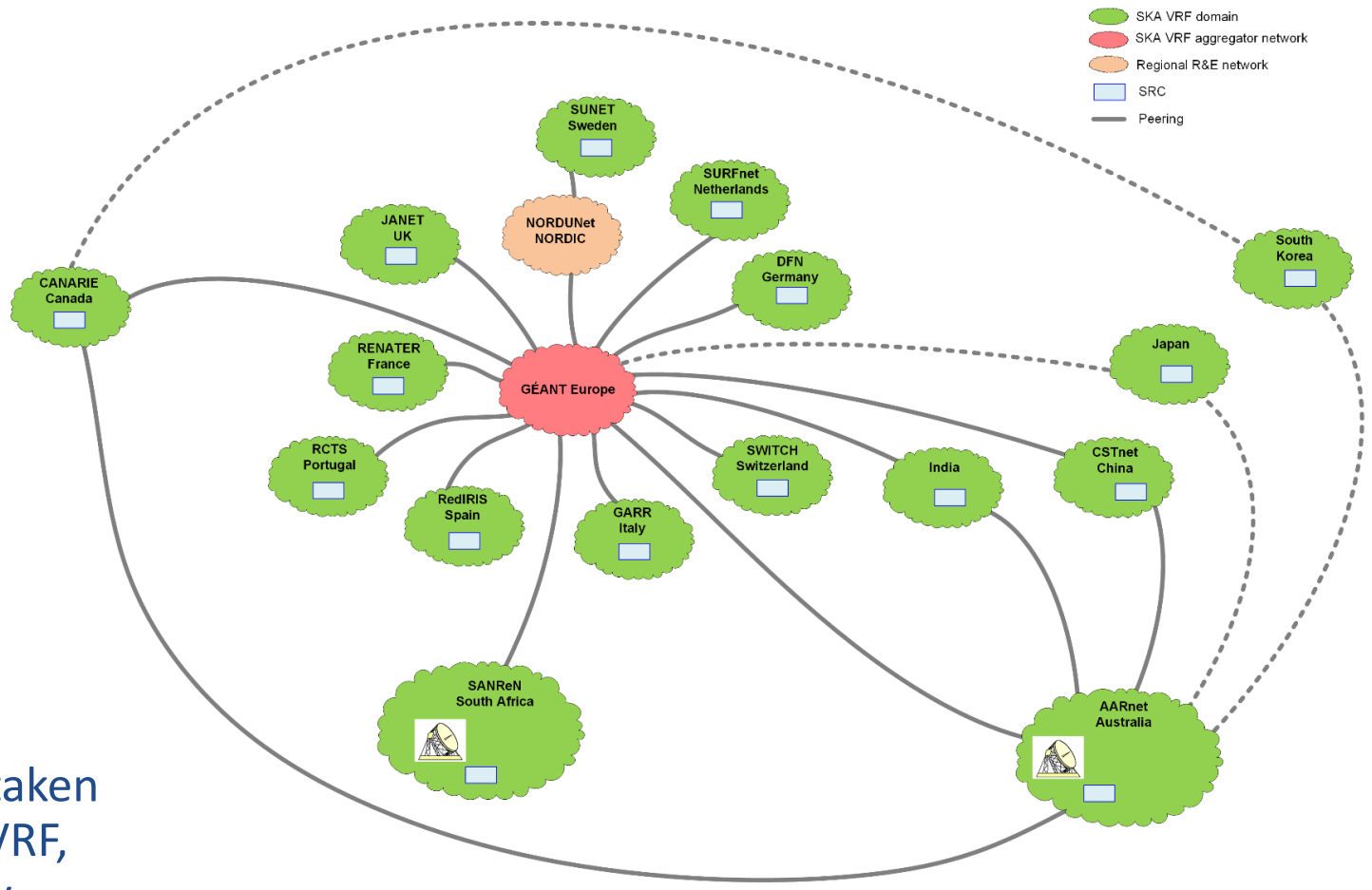
SKA-NREN Forum Technical Working Group
Global Network Connectivity & Architecture for SKA

- Build on the experience with LHCONE and the AENEAS project.
- All Telescope to SRC and SRC to SRC data transfer traffic to operate on VRF peered over the shared academic network.
- For high performance data transfers the data transfer node servers (DTN's) should be located in a site "Science DMZ" with ACLs for site policy.
- The DTN nodes should be tuned for high RTT latency data transfers
  - kernel parameters defining maximum TCP buffer size
  - Queueing discipline
  - NIC ring buffer size
- All SRCnet data transfer traffic, at least, to use IPv6 only.
- Use larger MTU sizes. Specifically: 9000 byte Jumbo frames.
- For network monitoring SRCnet deploy a mesh of "perfSONAR" nodes with at least one perfSonar system per SRC site. (https://www.perfsonar.net)

Global Network Connectivity for SKA

- Global VRF based overlay with peering linked over the shared academic network.

- Isolation of SKA traffic from other users
- Easier for NRENs to implement the routing, policies and monitoring
- SKA traffic can be engineered
  - Use specific paths & routes
- Layer 3 routing provides isolation
  - any network configuration issues
  - strictly limits broadcast storms
- Layer 3 will re-route traffic as long as there is an alternative network path
- Configuration actions have to be undertaken by the NREN and a Site to join the SKA VRF, which provides an extra layer of security.



Data Distribution Across Countries Based on a Fair-share Model

- Allocate data to the SKA countries in proportion to their funding for SKA construction.

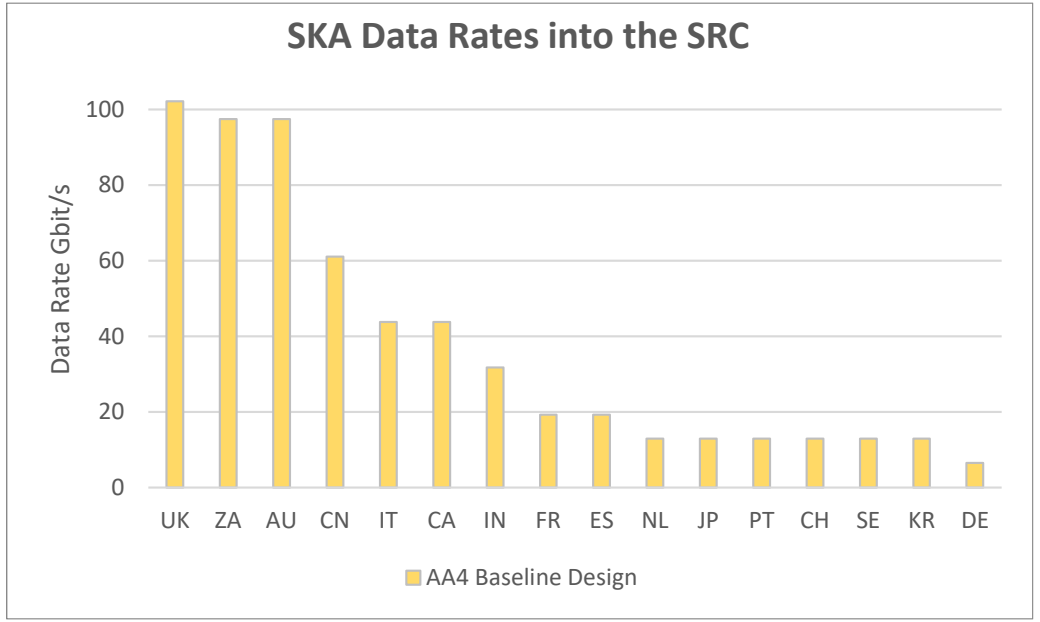
- Data flows included:
  - Movement of ODPs from telescope to SRC for the 1st replica
  - Movement of ODPs between SRCs for the 2nd replica
  - Movement of ADPs between SRCs to create the 2nd replica

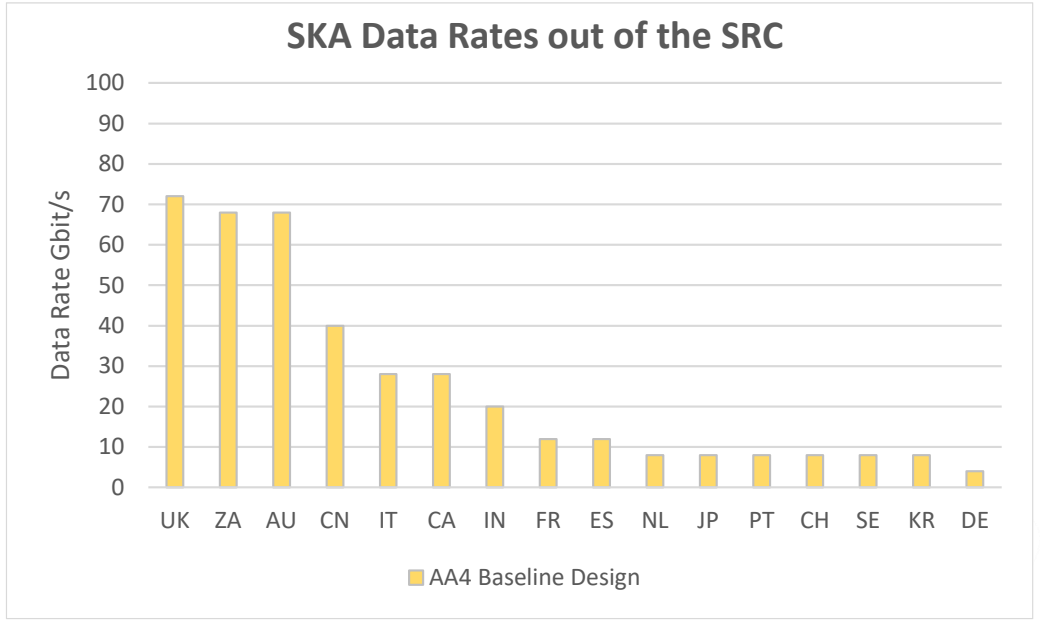
- Does not consider :
  - If compute architecture at a site matches the data product requirement.
  - A data cube will need to be at one location.
  - Amount of storage available at a site.

SRC Data Rates For AA4 Baseline Design

- AA4 (Low 100 Gbit/s Mid 100 Gbit/s)
  - Almost 100 Gbit/s into UK ZA AU
  - **Average Rates** into many countries 10 – 20 Gbit/s.

- Model only gives an indication.
  - Likely that SRCs will need at least 20 Gbit/s for SKA data.
  - Tuned Long-haul disk-to-disk transfers ~5-6 Gbit/s
  - Plan for multiple concurrent file transfers.
  - Consider the time that would be acceptable to move the datasets.

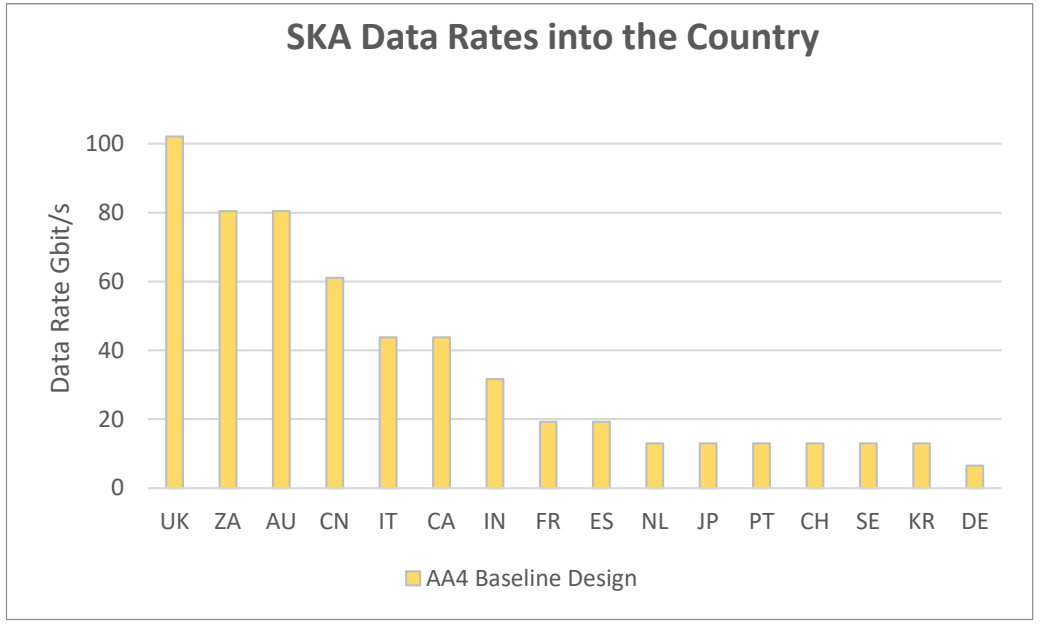


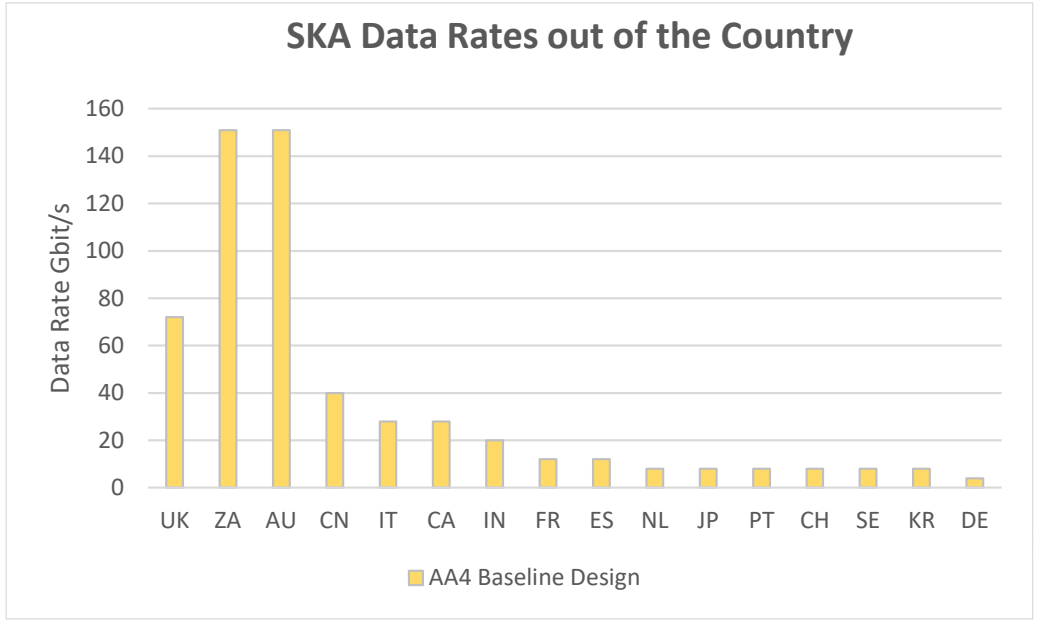


Country Data Rates For AA4 Baseline Design

- AA4 (Low 100 Gbit/s Mid 100 Gbit/s)
  - Almost 100 Gbit/s into UK
  - Telescopes to SRC in a host countries on local NREN.
  - The ~150 Gbit/s out of the host countries includes ODPs from the telescopes.
    Average Rates into many countries 10 – 20 Gbit/s.

- Model only gives an indication.
  - A data cube will need to be at one location.
  - ODPs to Europe ~40% (19% to the UK)
  - Expect significant traffic between AU & ZA





Data Rates for Array Configurations for AA2, AA*, AA4 (Design baseline)

- Based on data from
  “SKAO staged delivery, array assemblies and layouts” SKAO-TEL-0002299 dated Nov 2023

- Considered a plausible scenario using the following types of observations:

Low

- Image cube. Size dependent on the max. baseline length and the sensitivity on number of stations
  - AA* and AA4 baselines similar, sensitivity denominates
- Calibrated smoothed visibility data (EoR). Size is dependent on the number of baselines

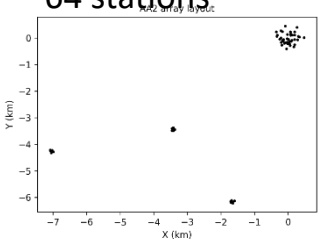
Mid

- Image cube. Size dependent on the max. baseline length and the sensitivity on number dishes

A Plausible Scenario for Data Rates from the Telescopes

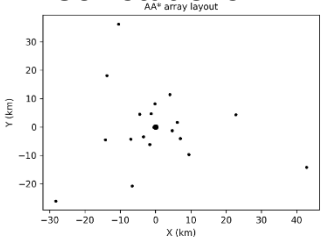
Low

AA2
64 stations



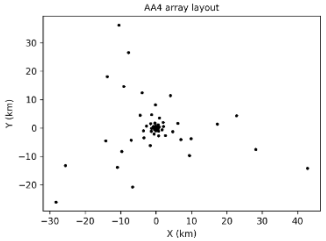
8 km baseline
Baseline ratio 0.11
Station ratio 0.125

AA*
307 stations



70 km baseline
Baseline ratio 1
Station ratio 0.6

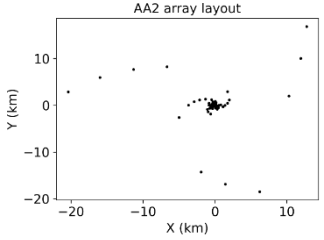
AA4 Design baseline
512 stations



70 km baseline
Baseline ratio 1
Station ratio 1

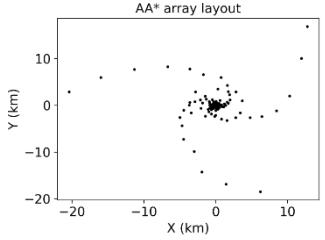
Mid

AA2
64 dishes



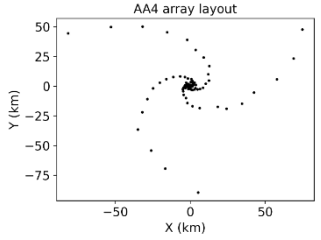
35 km baseline
Baseline ratio 0.23
Dish ratio 0.32

AA*
144 dishes



35 km baseline
Baseline ratio 0.23
Dish ratio 0.73

AA4 Design baseline
197 dishes



150 km baseline
Baseline ratio 1
Dish ratio 1

	AA2	AA*	AA4 (Design baseline)
Timescale Low	Oct 2026	Jan 2028	After 2030?
Low data rate Gbit/s	2-5	50	100
Timescale Mid	Mar 2027	Dec 2027	After 2030?
Mid data rate Gbit/	10	10	100

These numbers are indicative but not endorsed by SKAO.
A document with more robust estimation of rates
Expected Summer 2024

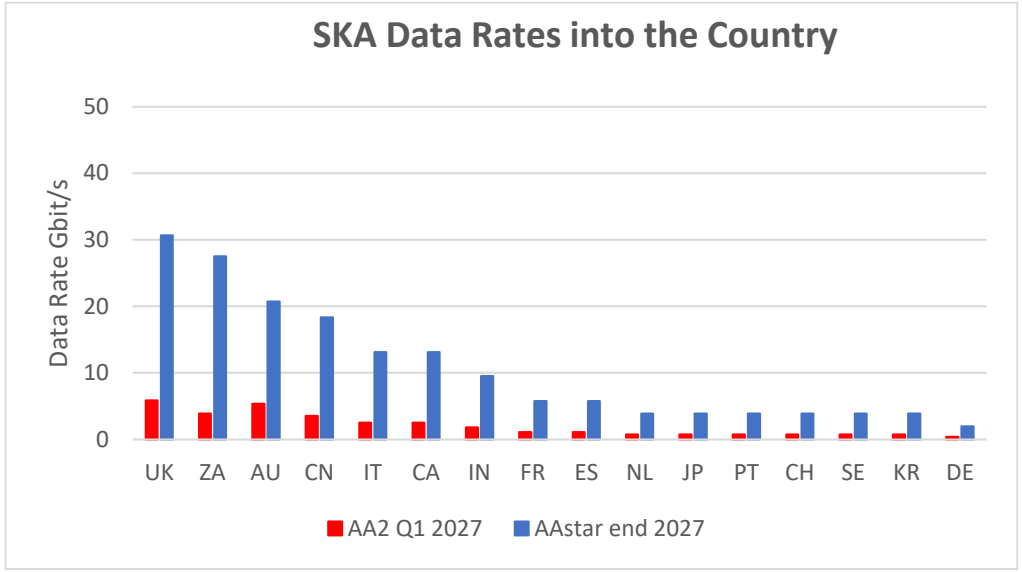
Country Data Rates

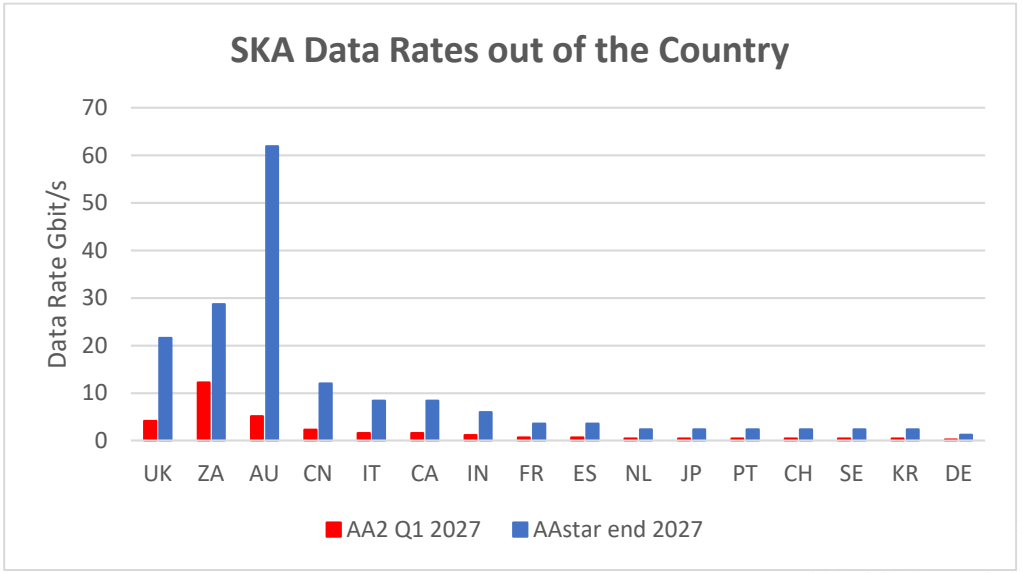
- Used the estimated bandwidth requirements for the different AAs.

- AA2 (Low 1.5 Gbit/s Mid 10 Gbit/s)
  - All countries have low rates.
  - Best to plan for disk-to-disk site transfers with each flow 5 – 10 Gbit/s.

- AA* (Low 50 Gbit/s Mid 10 Gbit/s)
  - 30 Gbit/s into the SRCs of UK ZA AU.
  - Rates into many countries 5-20 Gbit/s.
  - Data rate out of AU ~60 Gbit/s (inter-continental).

- Model gives an indication.
  - Tuned Long-haul disk-to-disk transfers ~5-6 Gbit/s
  - Plan for multiple concurrent file transfers.
  - Likely that SRCs will need ~ 10-20 Gbit/s for SKA data.
  - ODPs to Europe ~40% (19% to the UK)
  - Expect significant traffic between AU & ZA





Summary from SKA-NREN Forum Technical Working Group Global Network Connectivity & Architecture for SKA

- All Telescope to SRC and SRC to SRC data transfer traffic to operate on peered VRFs.
- NRENs, and the sites, design the network implementations.
- For high performance data transfers the data transfer node servers (DTN's) should be located in a site "Science DMZ".
- The DTN nodes should be tuned for high RTT latency data transfers.
- All SRCnet data transfer traffic, at least, to use IPv6 only.
- Use larger MTU sizes. Specifically: 9000 byte Jumbo frames.
- Monitor the network with a mesh of "perfSONAR" nodes for SRCnet.

Implement for SRCnet 0.1. Avoid disruption. Provide the infrastructure for smooth growth.

Questions ?