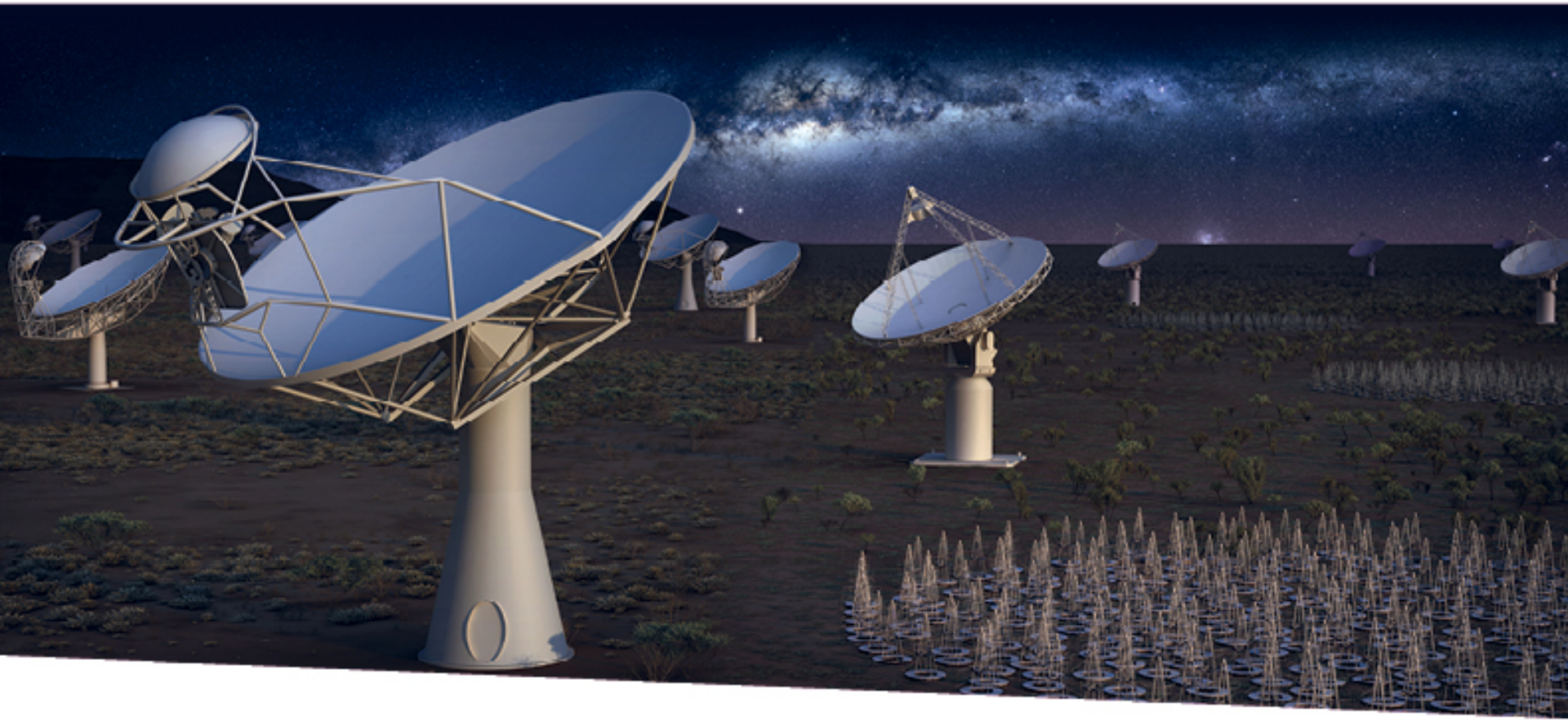
Status of Design – Planning for Construction



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Alistair McPherson

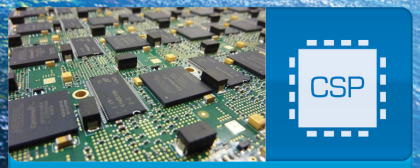
18 May 2016

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


WIDE BAND SINGLE PIXEL FEEDS


TELESCOPE MANAGER



CENTRAL SIGNAL PROCESSOR


SIGNAL AND DATA TRANSPORT

SCIENCE DATA PROCESSOR


DISH


MID-FREQUENCY APERTURE ARRAY


LOW-FREQUENCY APERTURE ARRAY


ASSEMBLY, INTEGRATION & VERIFICATION


INFRASTRUCTURE AUSTRALIA

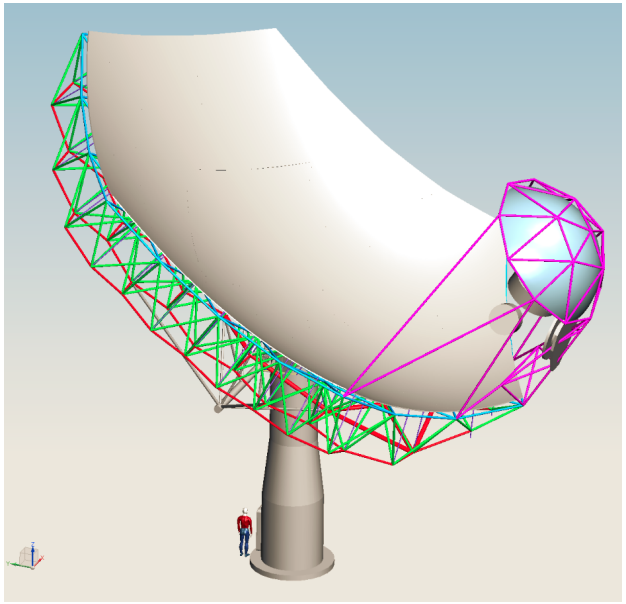

INFRASTRUCTURE SOUTH AFRICA

>€150M design effort – fully funded

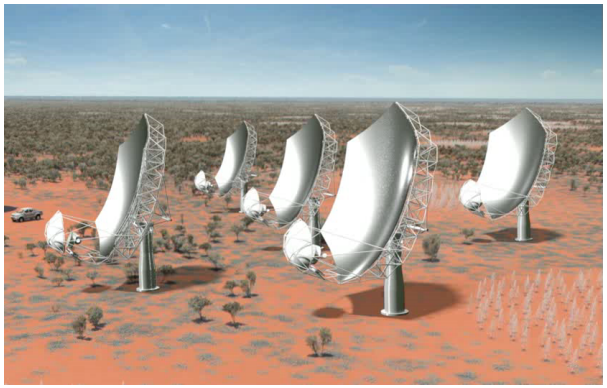
Status of Design activities

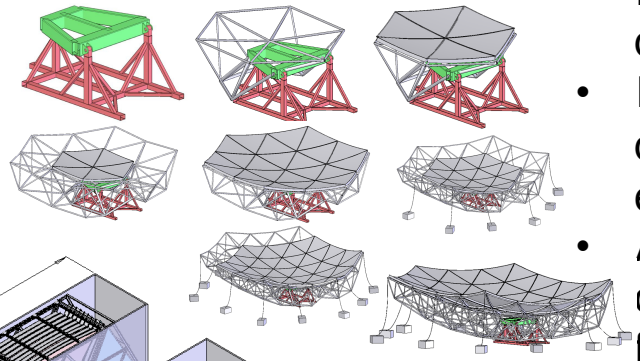
- 9 consortia have completed Preliminary Design Reviews
  - Massive effort – 100s documents
  - Some issues, as expected, but closing off now
  - Detailed design moving to Stage 2;
- Operations Concepts Review: Report Received
- System Review: Report Received
- Engineering Meeting, Stellenbosch, SA Oct 1-5, 2016.
- Critical Design Reviews planned in Q3/Q4 2017

Dish Consortium



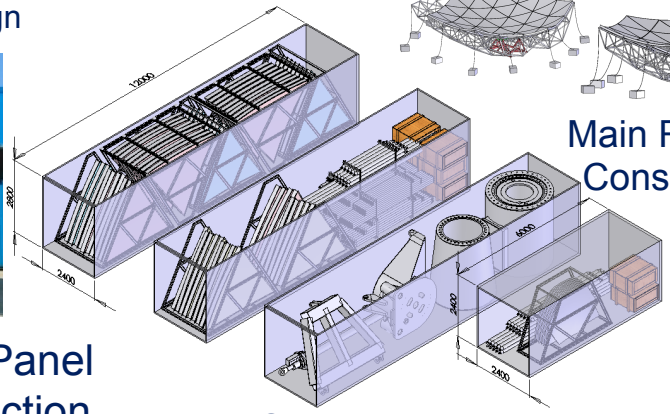
SKA-P Prototype Dish
Modular component design





Main Reflector Construction

Al Test Panel construction

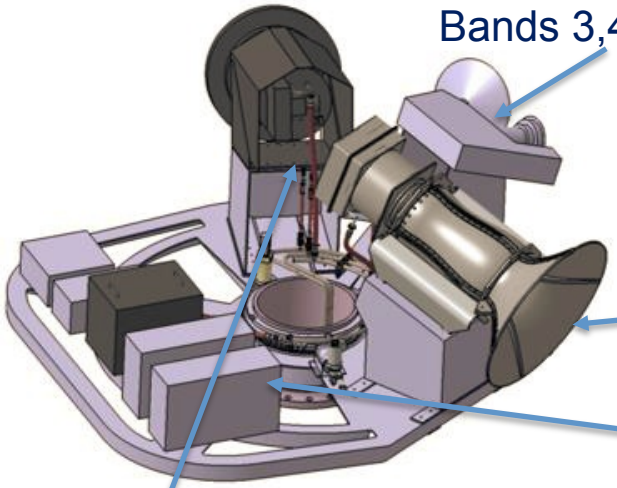


Dish Shipment
4 containers per dish x 133

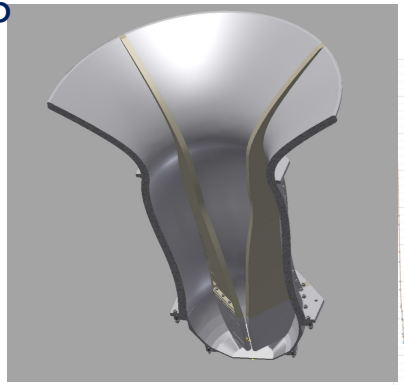
Consortium Progress

- Main reflector down selection complete – CETC54/MTM design Al multi panel reflector.
- PDR reviews successful and detail design planned.
- Internal ICD's well developed portioning sub elements
- Antenna/foundation ICD defined for prototype foundation is SA.
- Band 1 Feed selection completed – Ambient Feed selected providing Ops savings. Prototype under construction.
- Band 2 SPF tested on DVA1 demonstrating excellent on sky performance

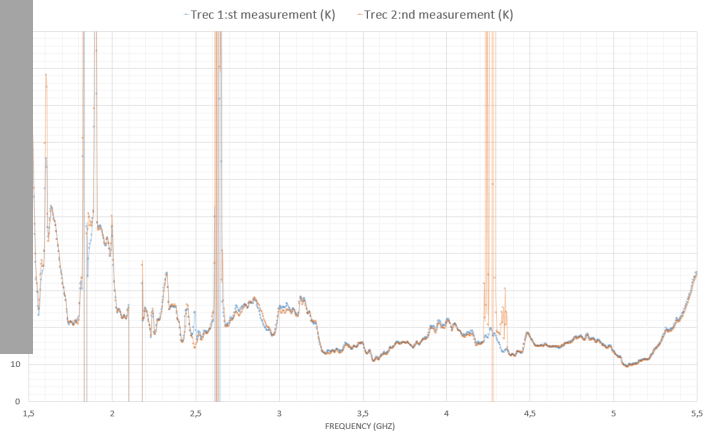
Feeds and Receivers



Bands 3,4 & 5



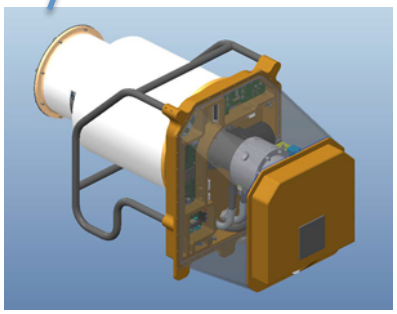
SPF Band 1



SPF Feeds and Antenna indexer

Band 1	0.35-1.05 (GHz)	28K
Band 2	0.95 -1.76	20K
Band 3	1.65-3.05	20K
Band 4	2.8-5.18	22K
Band 5	4.6-13.8	25K

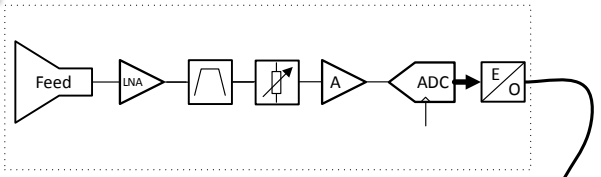
Single Pixel Feed observing frequency and sensitivity



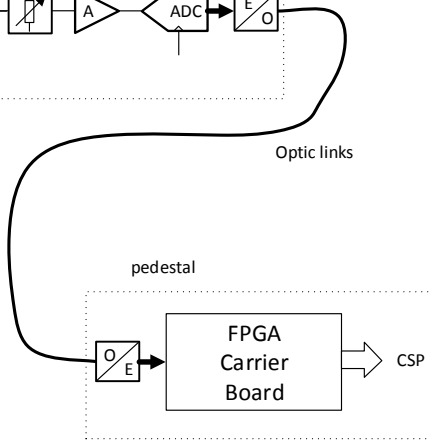
SPF Band 2

LNA wafer and device development

Feed indexer



RF Signal Digitization



Low Frequency Aperture Array (LFAA)

- Overview
  - Consists of the ‘array’ of antennas, Low Noise Amplifiers, Analogue to Digital transport, Signal Processing.
  - Signal Processing, Beam-forms the antenna signals into 512 stations.
  - To be built in Australia (MRO).
  - Covers lowest frequency band for SKA1, 50MHz – 350MHz.
  - Approximately 131000 antenna make up the ‘array’.

- Challenges
  - The sheer scale of the array.
    - Communications and processing across the array.
    - Testing.
  - Be able to deliver the maximum Science possible within the Cost Cap.
  - Remotely located with aggressive Power limitations.
  - Aggressive Development Timelines.

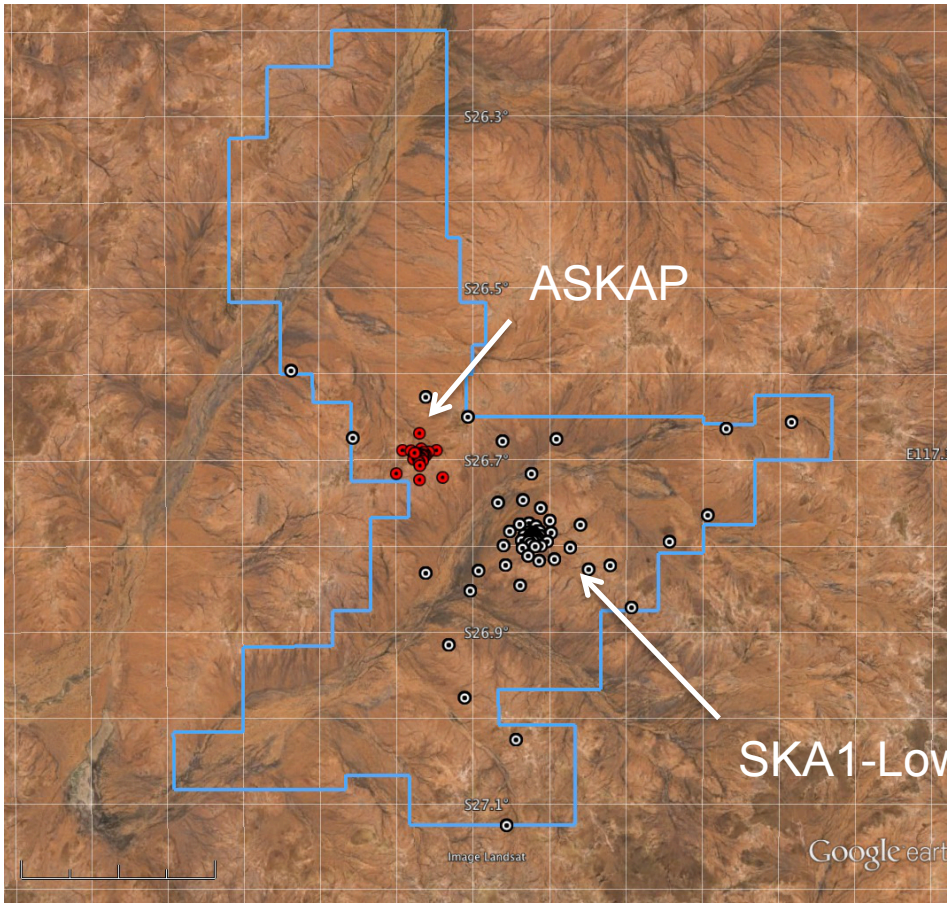
LFAA – (Low) Configuration

- SKA1 Configurations
- Baseline max ~ 156km

  - Consortium led by ASTRON (Netherlands).

  - Consortium made up of 10 global institutions.

  - Additional Institutions:
    - ICRAR, KLASA, INAF
    - STFC, University of Malta
    - JIVE, University of Cambridge
    - University of Manchester, Oxford University



Central Signal Processor (CSP)

- Overview
  - CSP is the ‘brain’ of the Square Kilometre Array (SKA).
  - Converts Digitized astronomical signals detected by the Receivers into formats required for Data Processing.
  - CSP includes design of Hardware and Firmware/Software
- Challenges
  - Has to process enormous amounts of Data in real time, hence generates enormous amounts of Data for Science Data Processor.
    - In real numbers for Frequency Band 1 of the MID telescope this means 64Gbits / second into the Correlator & 33Tbits / second output to the Science Data Processor.
  - Be able to deliver the maximum Science possible within the Cost Cap.
  - Remotely located with aggressive Power limitations.
  - Aggressive Development Timelines.

Central Signal Processor (CSP)

Geographical distribution of the CSP consortium members

- MID Correlator Beamformer lead by NRC of Canada
- LOW Correlator Beamfomer lead by CSIRO of Australia
- Pulsar Search lead by Manchester University
- Pulsar Timing lead by Swinburne University
- Additional Institutions:
  - ASTRON, AUT, CISCO, CITA, Compucon NZ
  - Curtin University/ICRAR, INAF, JIVE, SELEX
  - MDA Systems, Open Parallel, STFC, MPIfRA
  - NLeSC, NVIDIA, Massey University, Oxford University
  - Auckland University, Nyriad, NCRA, UPMadrid, JPL, IBM

Signal and Data Transport (SADT) Consortium

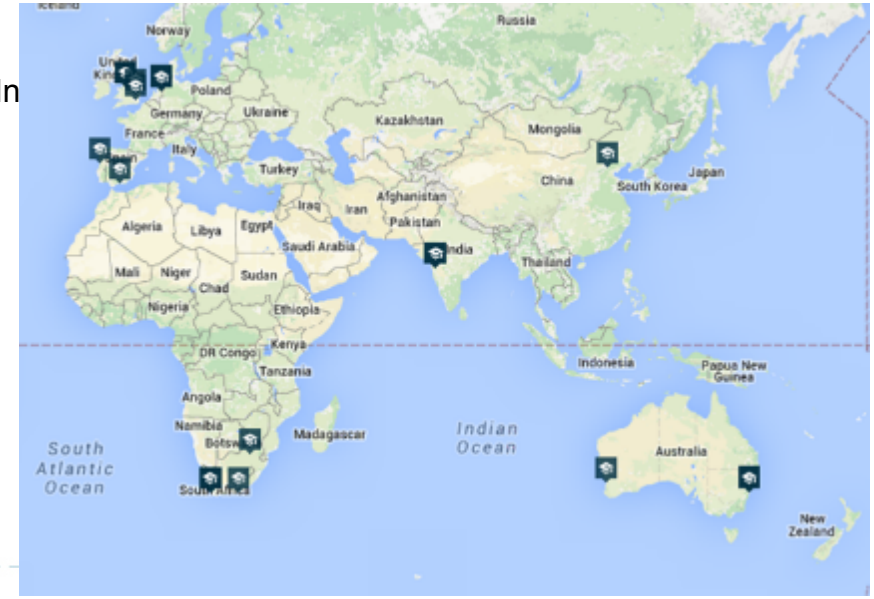
Lead institute: University of Manchester

- Leader: Keith Grainge
- Project Manager: Jill Hammond
- System Engineer: Rob Gabrielczyk
- Project Engineer: Richard Oberland

SADT Consortium

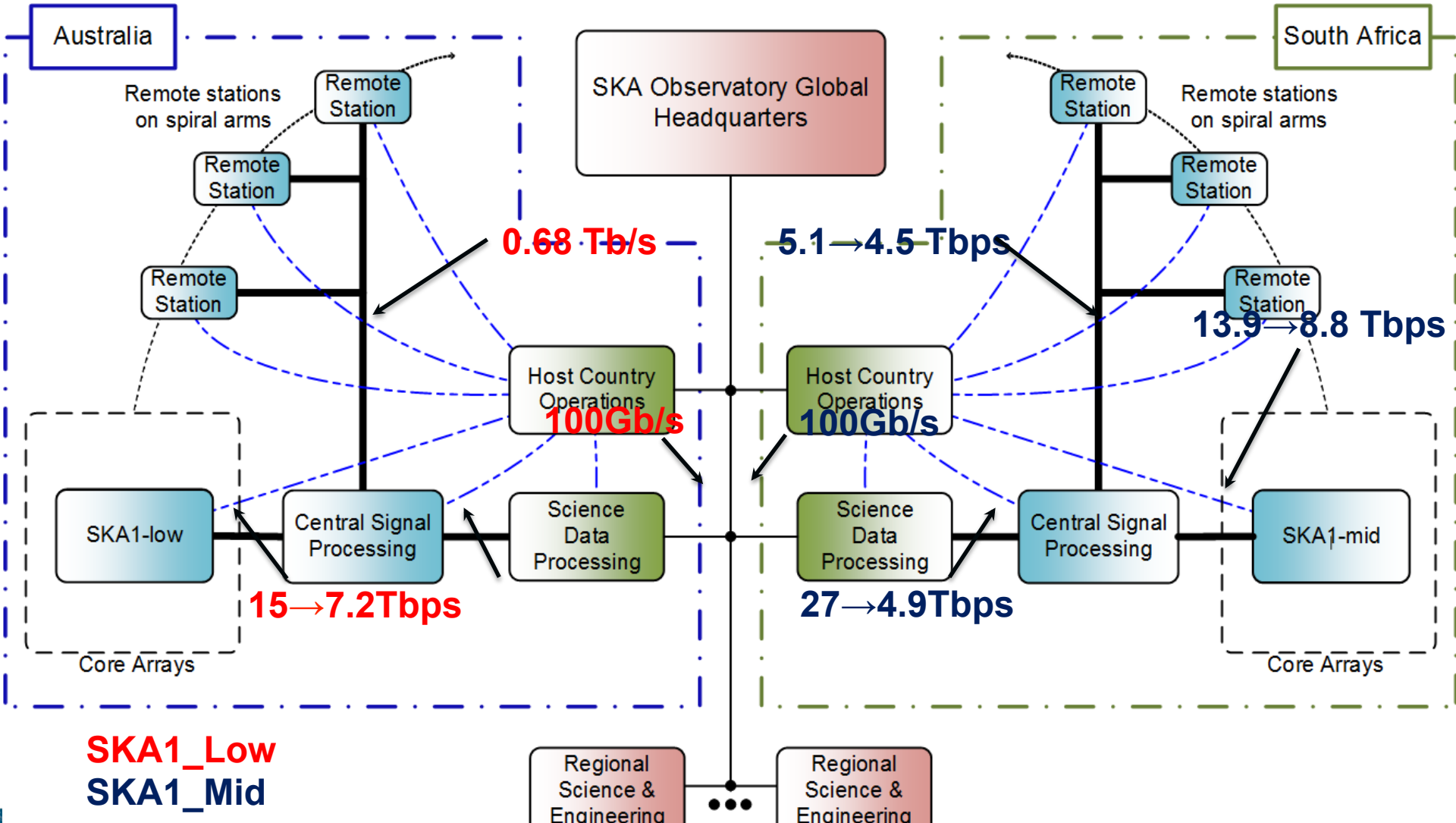
Institutions involved in the Signal and Data Transport consortium include :-

Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
Australia Academic and Research Network (AARNet), Australia
University of Western Australia, Australia
Tsinghua University/ Peking University, China
National Centre for Radio Astrophysics (NCRA) / Tata Consulting, In
Persistent Systems, India
Joint Institute for VLBI in Europe (JIVE), The Netherlands
Instituto de Telecomunicações (IT), Portugal
SKA South Africa
Nelson Mandela Metropolitan University (NMMU), South Africa
Meraka Institute, CSIR, South Africa
EM Software and Systems (EMSS), South Africa
University of Granada, Spain
University of Manchester, UK
National Physical Laboratory (NPL), UK
GÉANT, UK

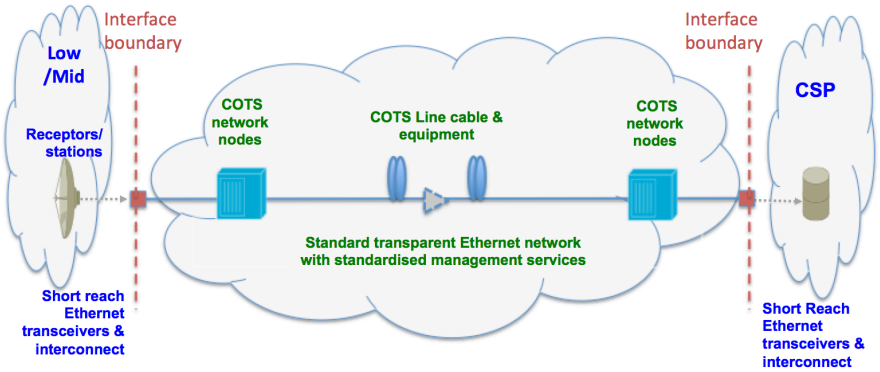


- Various industry sub-contractors

SaDT Architecture



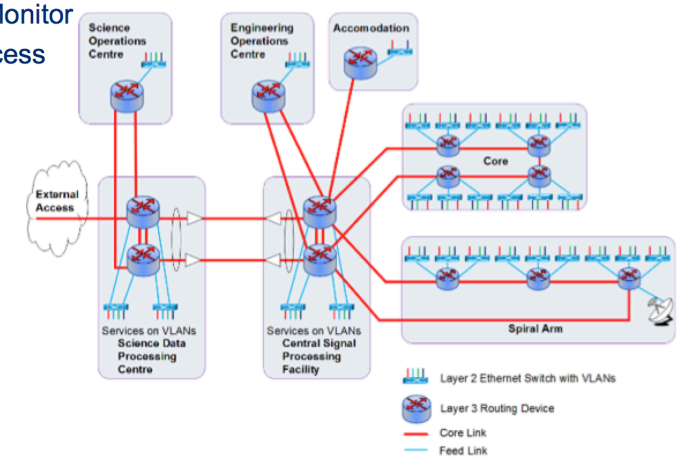
DDBH Network (COTS equipment)



- Fully managed COTS solution – vendor agnostic design
- SKA-Mid; 133 dish antennas, 1x100GE transport lanes
  - Passive spans with LR4/ER4 grey optics or amplified/regen spans with DD/Coherent DWDM
- SKA-Low; 45 remote beam formed stations, 2 x 20GE transport lanes
  - Passive spans with LR/ER/ZR grey optics

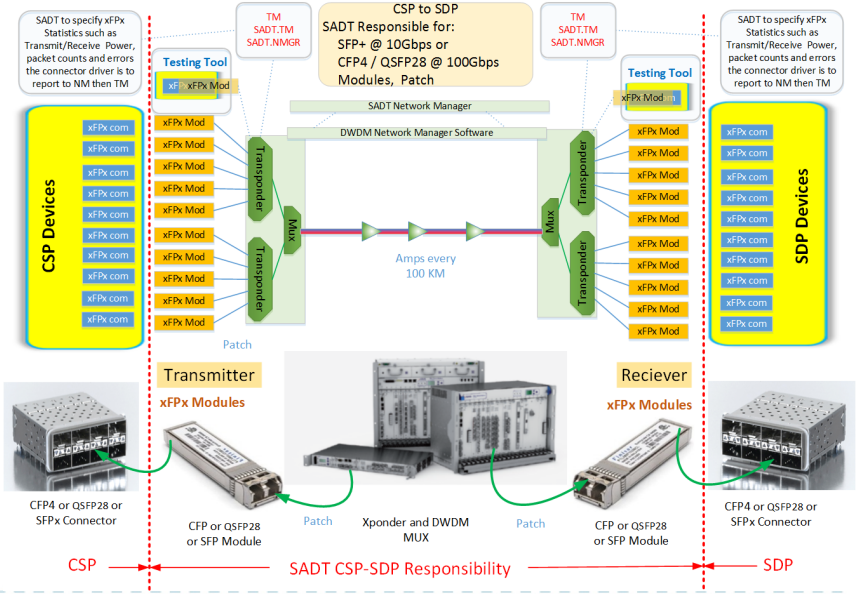
NSDN Network

- A network infrastructure with resilience – given the topology.
- The set of services include:
  - Control & Monitor
  - Internet access
  - IP phones
  - Security



SaDT Networks

CSP-DSP Network



Clocks Timing & Frequency Distribution

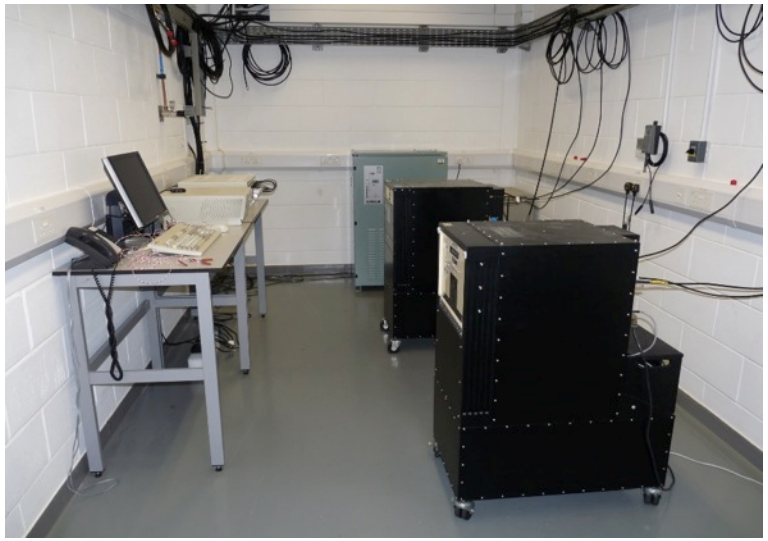
Requirements:

- Phase coherence of array

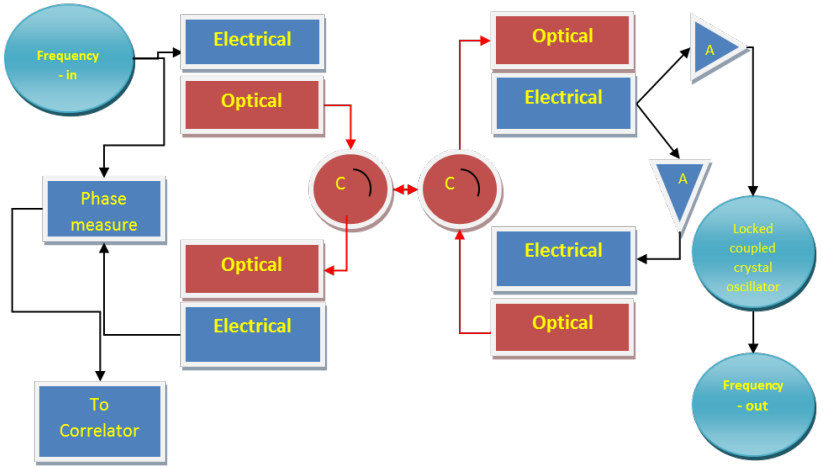
→ accuracy = 0.000 000 000 001s

- Long-term timing for pulsars

→ 0.000 000 001 over 10 years

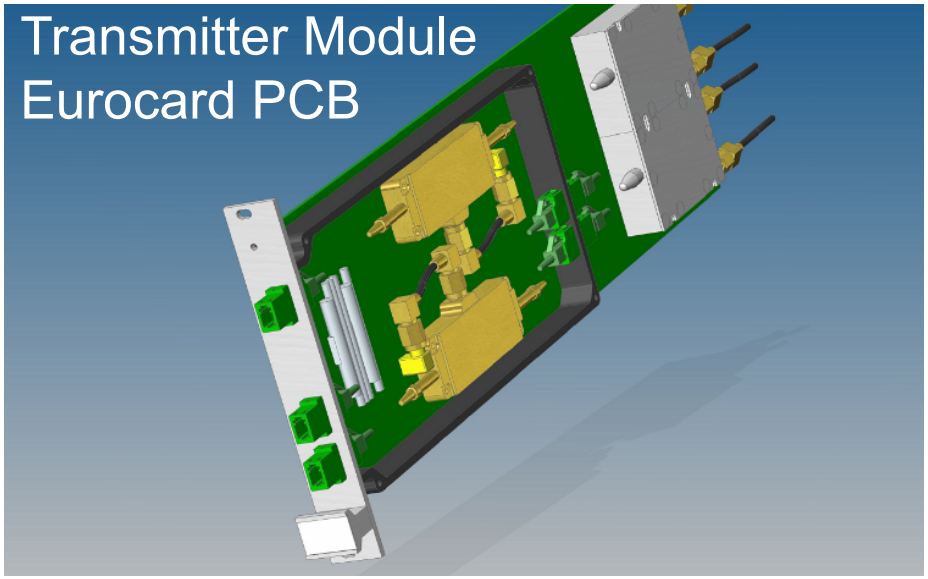


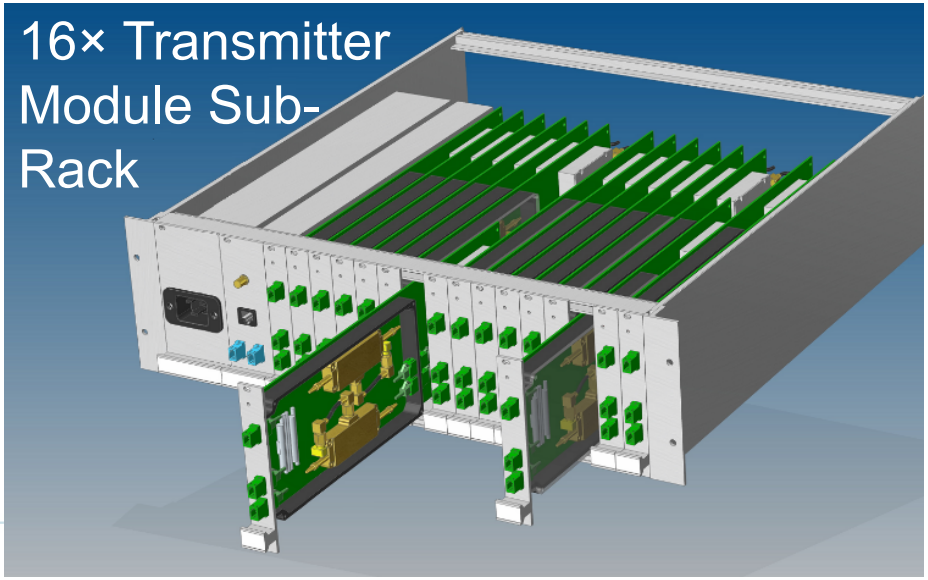
- Collaboration between:
  - JIVE, the Netherlands
  - University of Manchester, NPL
  - Tsinghua and Peking Universities
  - University of Western Australia
  - NMMU, South Africa



Clocks Timing & Frequency Distribution

Hydrogen Maser clock example ,at NPL UK





- Absolute time at antennas and RPFs
- Selected the 'White Rabbit' standard for distribution of absolute time
  - Open Hardware design
  - Mostly off-the-shelf hardware
  - Single fibre round-trip measurement and compensation
  - Sub-ns accuracy

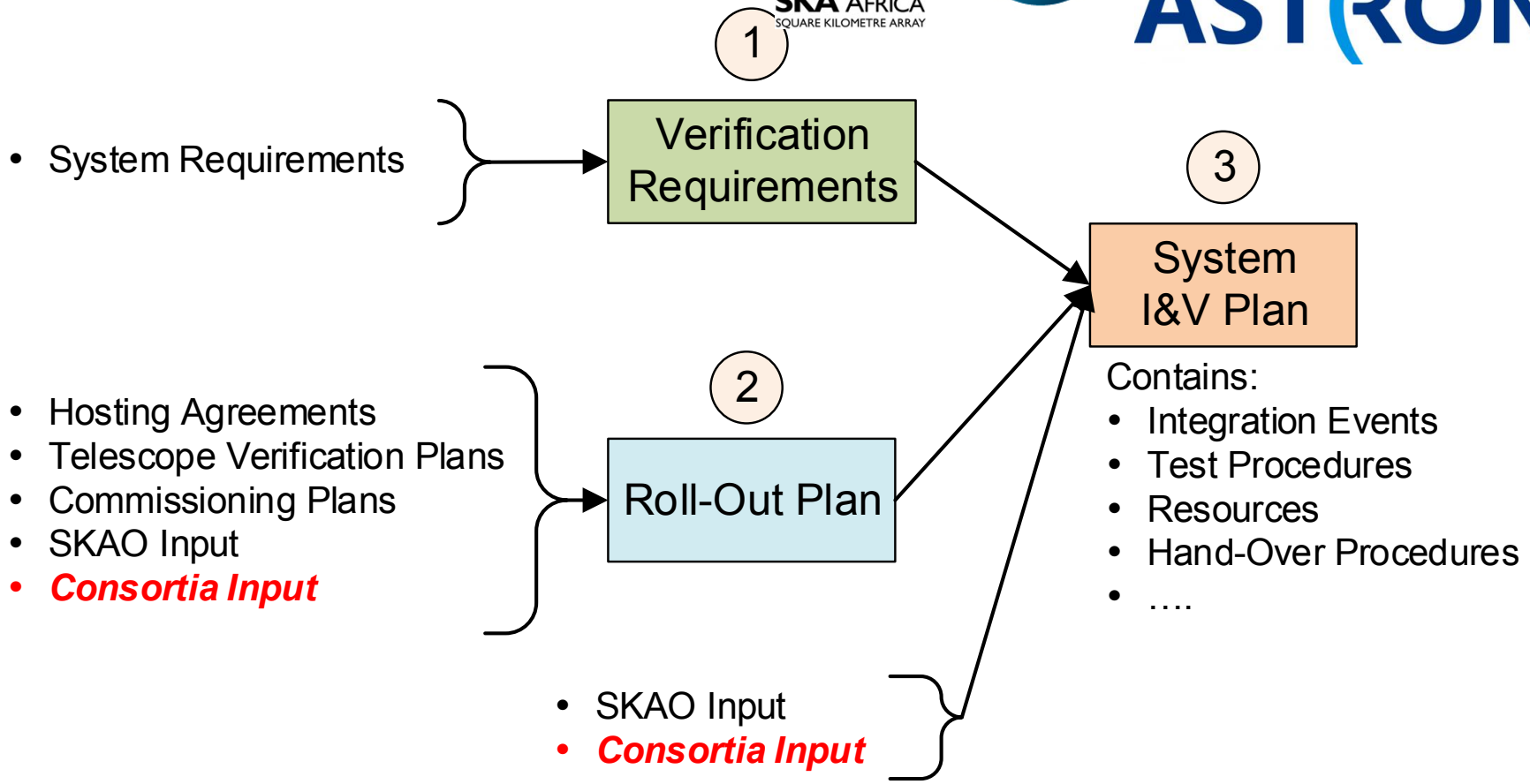
SDP

- Scope of the work package
  - To design the algorithms, software and hardware required to reduce the data from the correlators and beamformers into science products ready for distribution to a worldwide network of regional centres for further analysis
  - This will require two supercomputers – one in RSA, one in WA - with a total of several hundred petaflops of performance (peak)
    - And require storage of several hundreds of petabytes
    - Widely seen as a defining big data project for the next decade
  - Some requirements are unique
    - Unlike a typical supercomputer, these systems will be an integral part of the telescope and will have to do real time as well as batch computation
- Consortium headed by Cambridge University with contributions from nearly all member countries, India not involved

TM

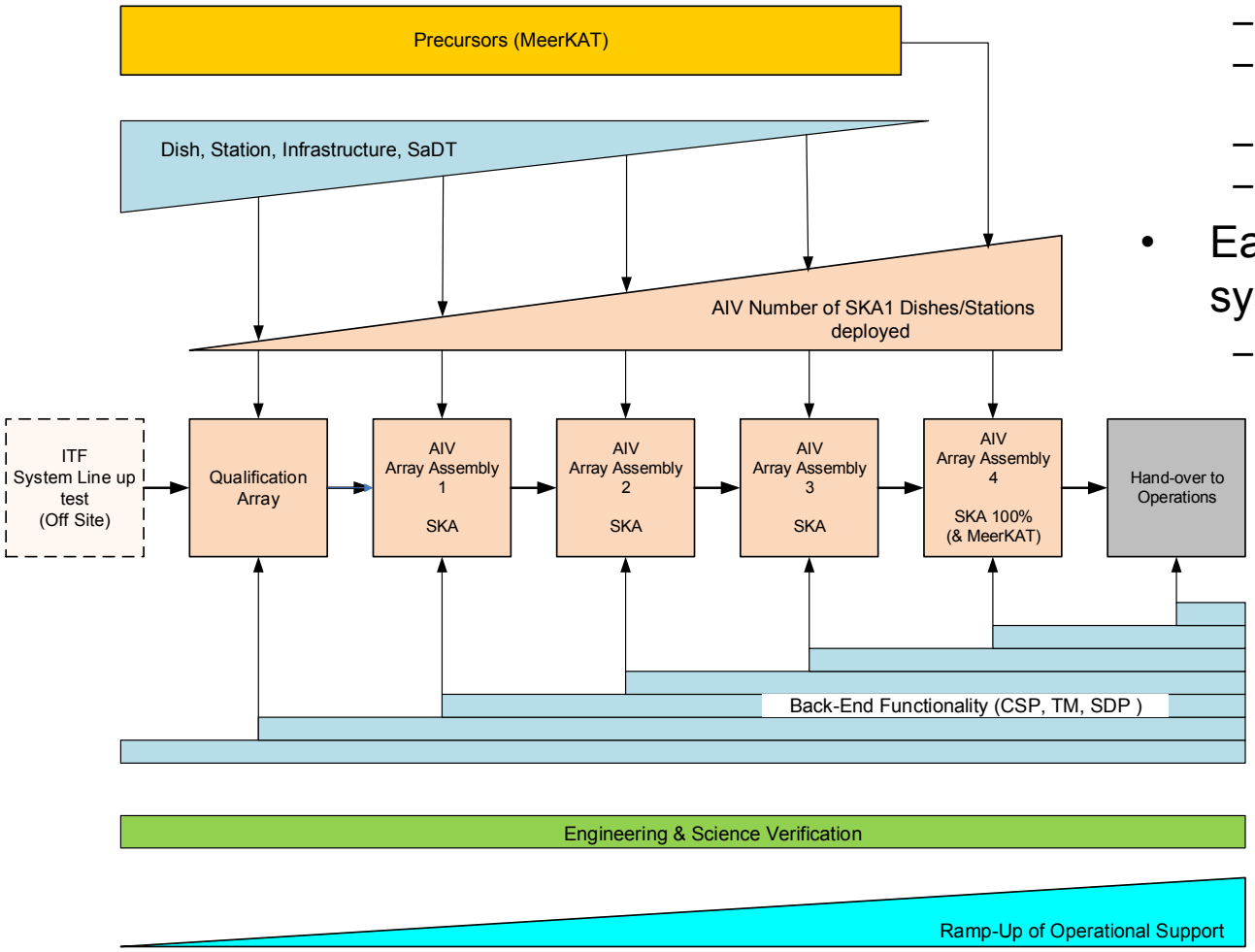
- Scope
  - Produce the software to
    - manage the SKA's observing programmes
    - Command and control the two telescopes
  - Hardware requirements considerably smaller than SDP – commodity-based private cloud (e.g. OpenStack) is envisaged
  - The Telescope Manager is the "central nervous system" of the SKA
  - Consortium lead by India – NCRA and the Tata Institute for Fundamental Research
    - Tata Consulting Services involvement too
    - Other contributions from UK, Italy, South Africa, Australia and Portugal

AIV Work Package



AIV Consortia is responsible for the Planning, there are no Products developed

Array Assemblies (with ITF)



- Described by:
  - Assembly Date
  - Number of Dishes / Stations
  - Array Capability → Determines back-end Element functionality
  - Key Engineering Goals
  - Science Capability
- Each Array Release is a system in its own right
  - Array seize and added functionality grows with each Array Assembly

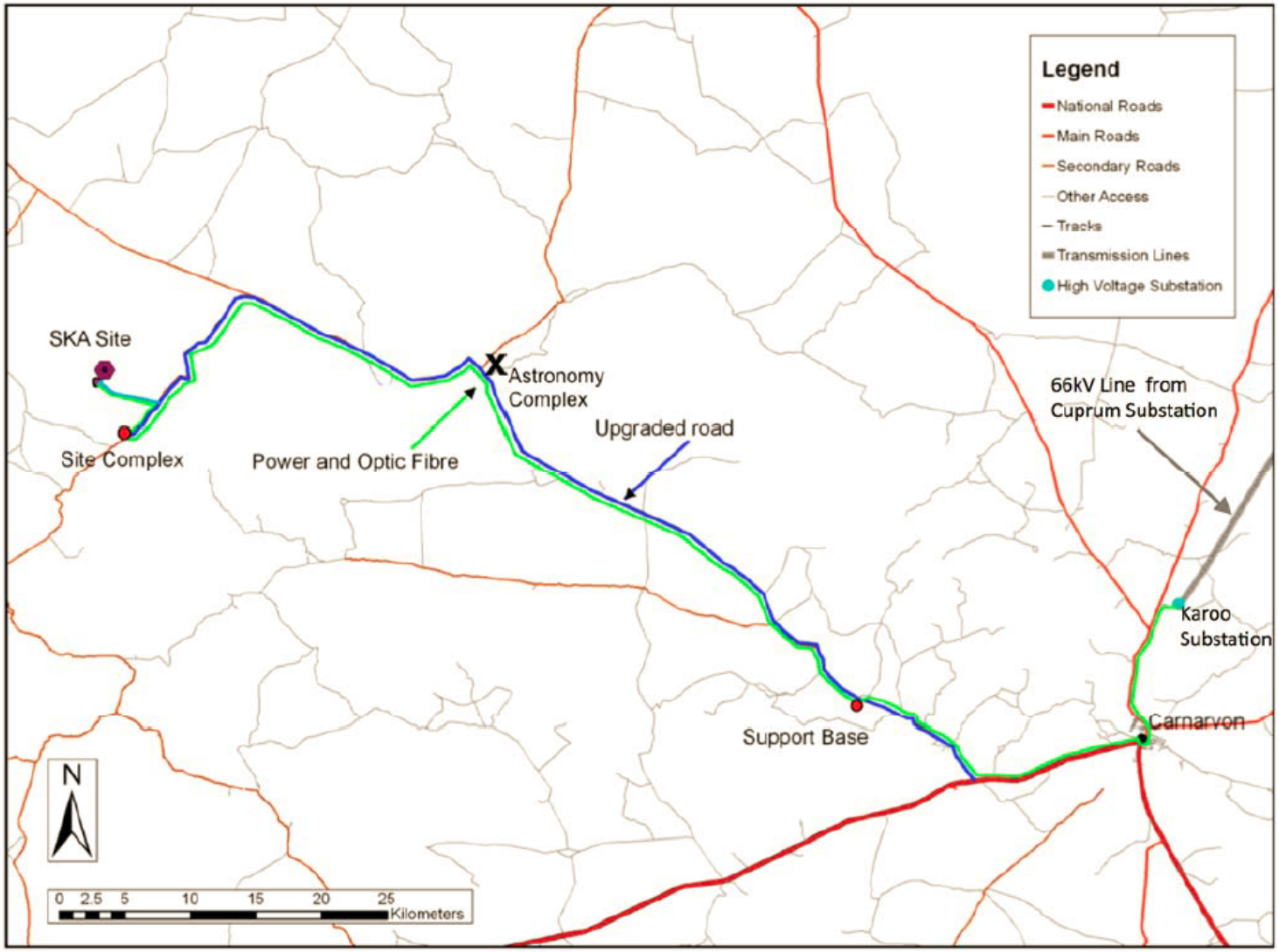
MeerKAT Precursor Integration into SKA1 Mid

The 64 MeerKAT Dishes are integrated, NOT any of the backend MeerKAT Correlator / Beamformer, Science Processor or Telescope Manager systems.

Power Supply: South Africa

- Existing Grid Connection
  - Feeder from ESKOM (national utility) Grid
    - 66kV Radial feeder (100km to Carnarvon)
    - 40-year old transmission line
    - Limited to 6.5 MVA for SKA
  - Feeder to SKA Site
    - 33kV Transmission Line (105 km from Carnarvon)
    - Limited to 5.2 MVA (not sufficient)
    - High (25%) Line Losses

Power Supply: South Africa



Power Supply: Australia

- Reticulated power not feasible
  - Grid: 270km away
  - Natural Gas: 140km away
- Likely fully islanded power solution
  - Abundant solar resource
  - Diesel for reliability
  - Storage extend solar

Power Supply Investigations

- Power Supply Options Workgroup (PSOW)
  - Investigate alternative supply solutions
  - Focus on renewables & storage
  - Interact with industry through country liaisons
  - South Africa Specifications: Released May 2016
  - Australia Specifications: Released June 2016

Construction Planning

Construction Phases

- Contract Preparation
- Contract Award
- Construction/Manufacturing Design
- Factory Build
- Factory Test/Verification
- Delivery to Site
- Contractors Site Assembly/Construction and Verification
- SKA Assembly Integration and Verification

Procurement Process

- Direct Procurement
  - Contract
- In Kind Contribution
  - Memorandum of Understanding or similar

- Specification
- Statement of Work
- Supporting Documents

Call for Expressions of Interest

- Cost Book
  - Based on Work Breakdown Structure
  - Valued to Cost Cap
- Non-Binding
- In-Kind or Cash
- Discussion & Development

Management Options

- Directly contracted by SKA Office
- Agreement with Member for ‘In-Kind’ Contribution
- Contracted through Member’s resources
- Supported by SKA DCs
- Software procurement

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Exploring the Universe with the world's largest radio telescope