SADT Technical Information Pack

Rev 2.0, January 2016

Content in this document is approved by SADT and subject to change

Signal and Data Transport Consortium

SIGNAL AND DATA TRANSPORT

Introducing SKA

SKA Phase 1 has Two Telescopes

South Africa

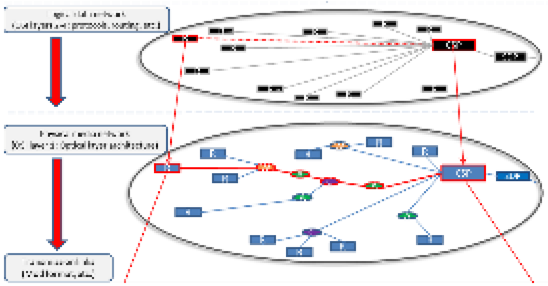
SKA1_Mid 350 MHz – 14 GHz
64 MeerKAT dishes
133 SKA1 dishes.

Australia

SKA1_Low 50 – 350 MHz
131,000 aperture array dipole
512 stations of 256 antennas

SKA Design Elements

Low frequency aperture array



Signal & Data Transport

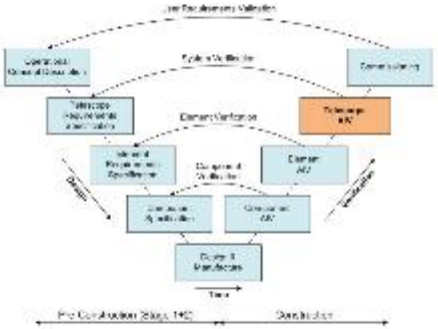
Central Signal Processor

Science Data Processor

Dish

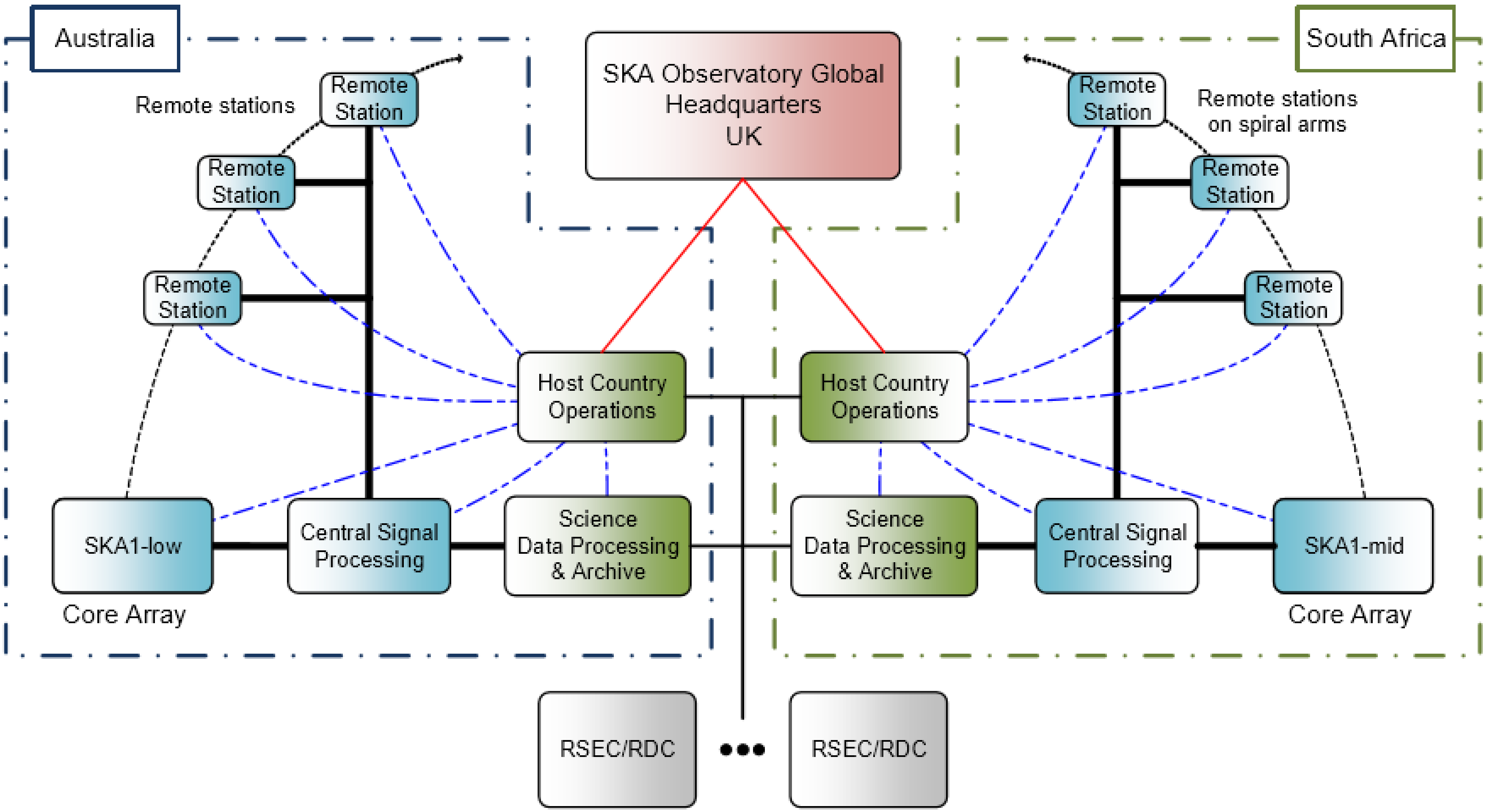
Infrastructure

Telescope Manager



Assembly, Integration Verification

SKA Observatory



SKA Uses 3 Network Types

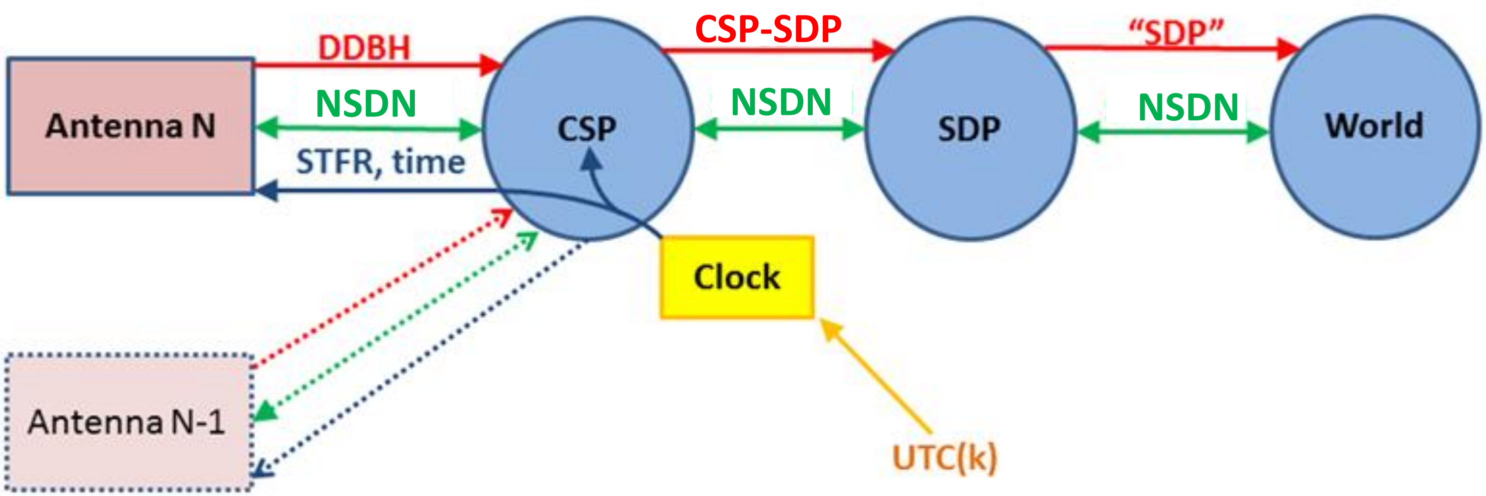
SKA SIGNAL AND DATA TRANSPORT

Science Data
- DDBH
- CSP-SDP
- *SDP to world*

Sync & Timing
- Clock ensemble
- Freq. & Phase
- UTC time

Non-Science Data
- Control & Monitor
- Alarms
- Internet, VoIP

"Spanning" Tasks: Network Architecture; Network Manager; Local Infrastructure



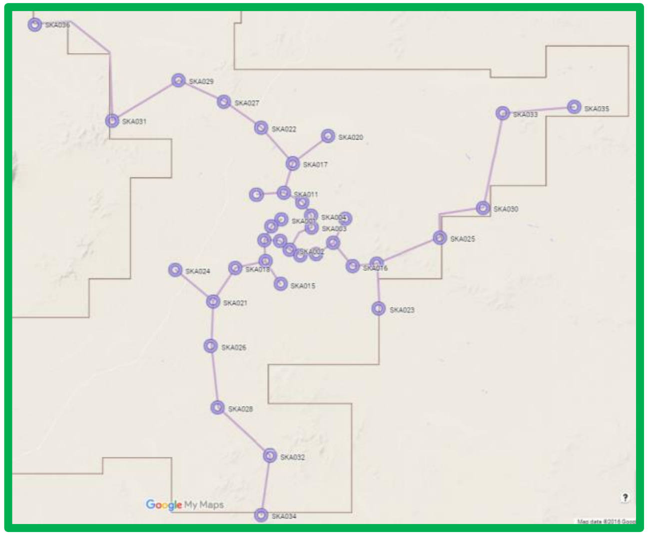
SKA Global Design Consortia

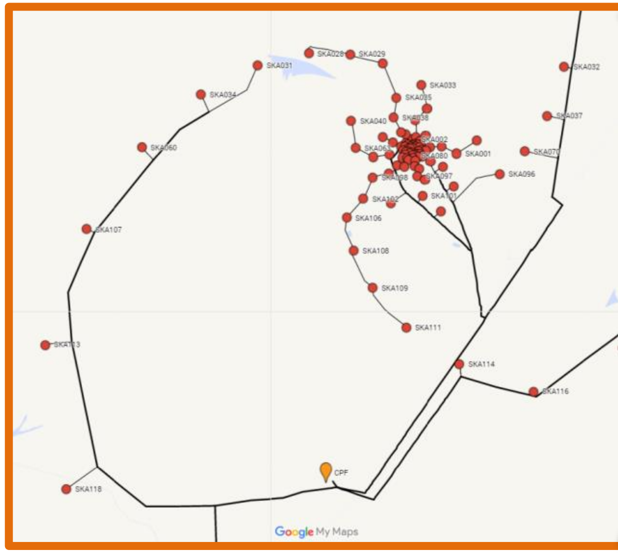
SKA Global Consortia

SKA Telescope Sites
Remote array stations and cable routing to CPF

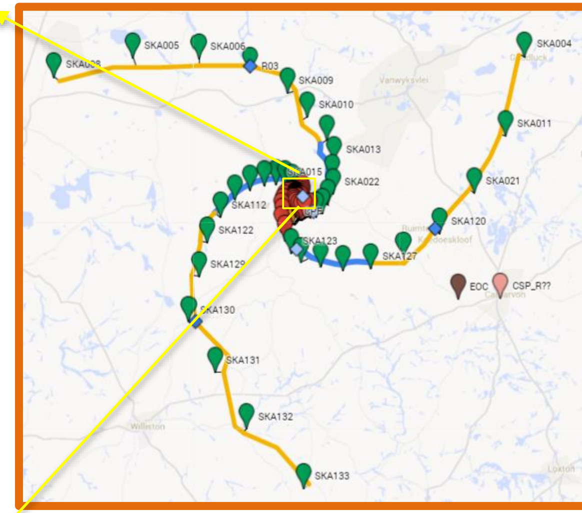
Australia
SKA1-Low Outer array

Cable distance optimised topology examples

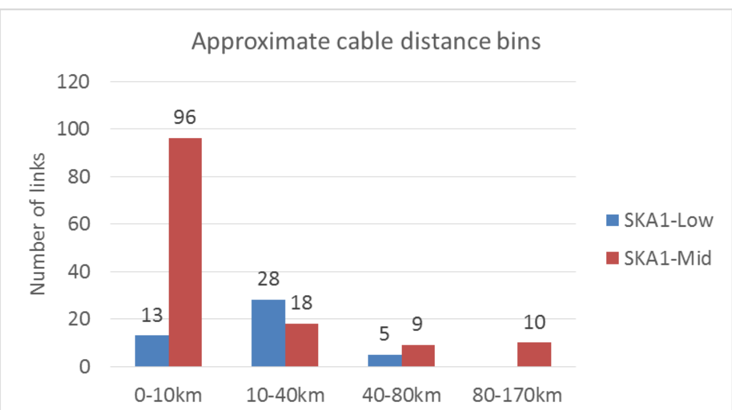




South Africa
SKA1-Mid Inner Array

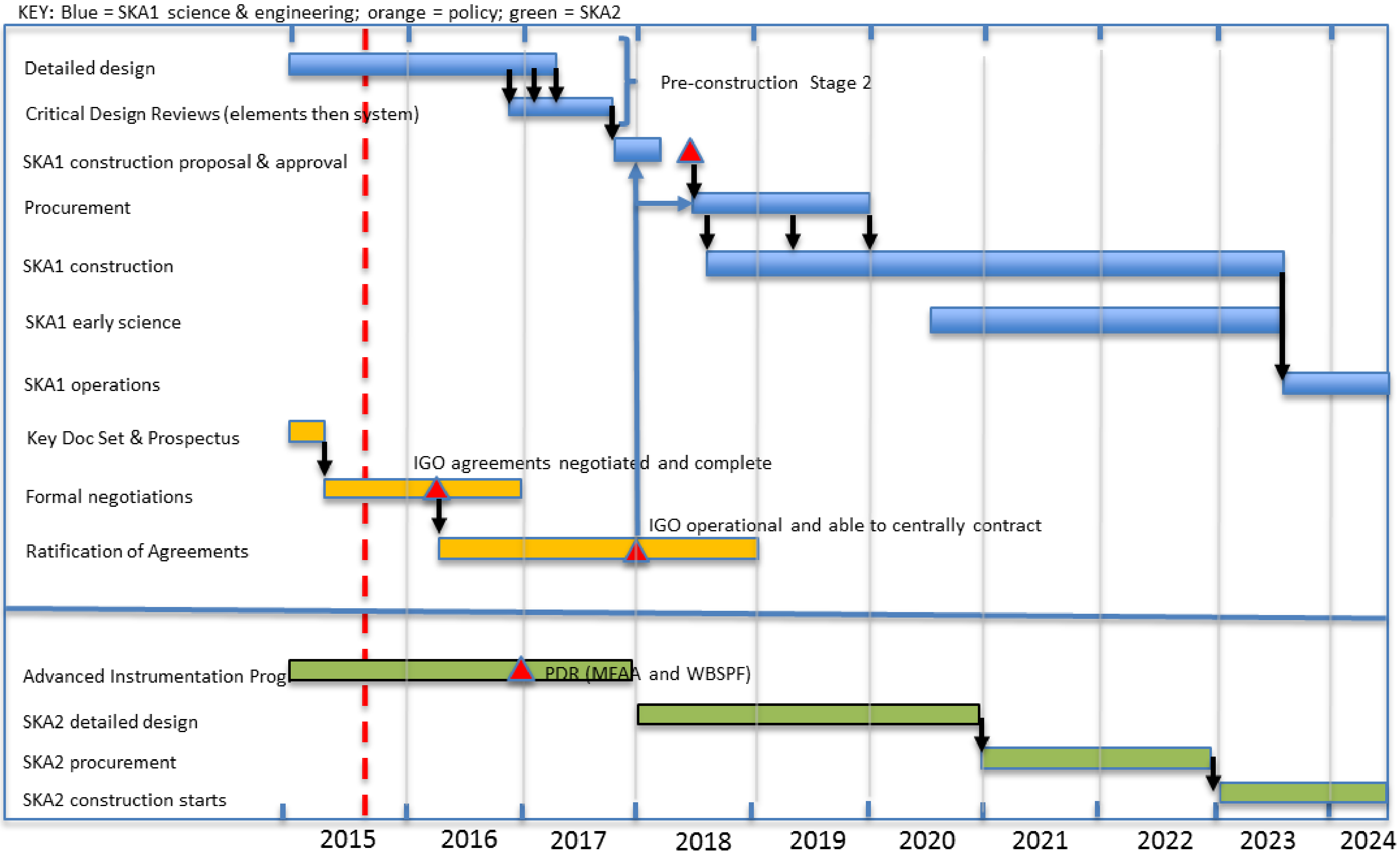


South Africa
SKA1-Mid Outer Array



Array layout config ref: https://www.skatelescope.org/wp-content/uploads/2014/03/SKA-TEL-SKO-0000308_SKA1_System_Baseline_v2_DescriptionRev01-part-1-signed.pdf, October 2015

High-level SKA Project Schedule

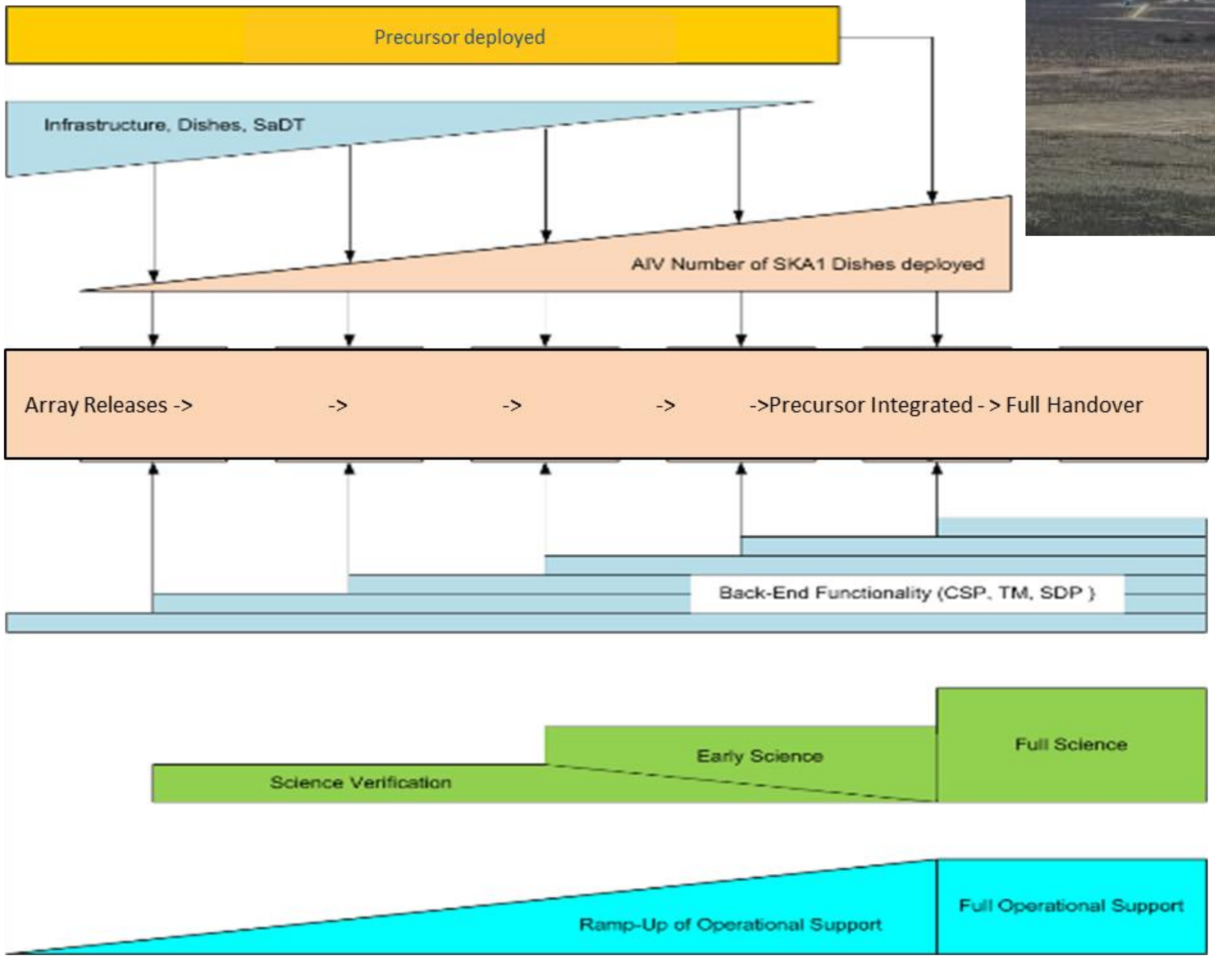


Andrea Casson, August 2015

SKA1 Telescope Roll-out Physical and Functional

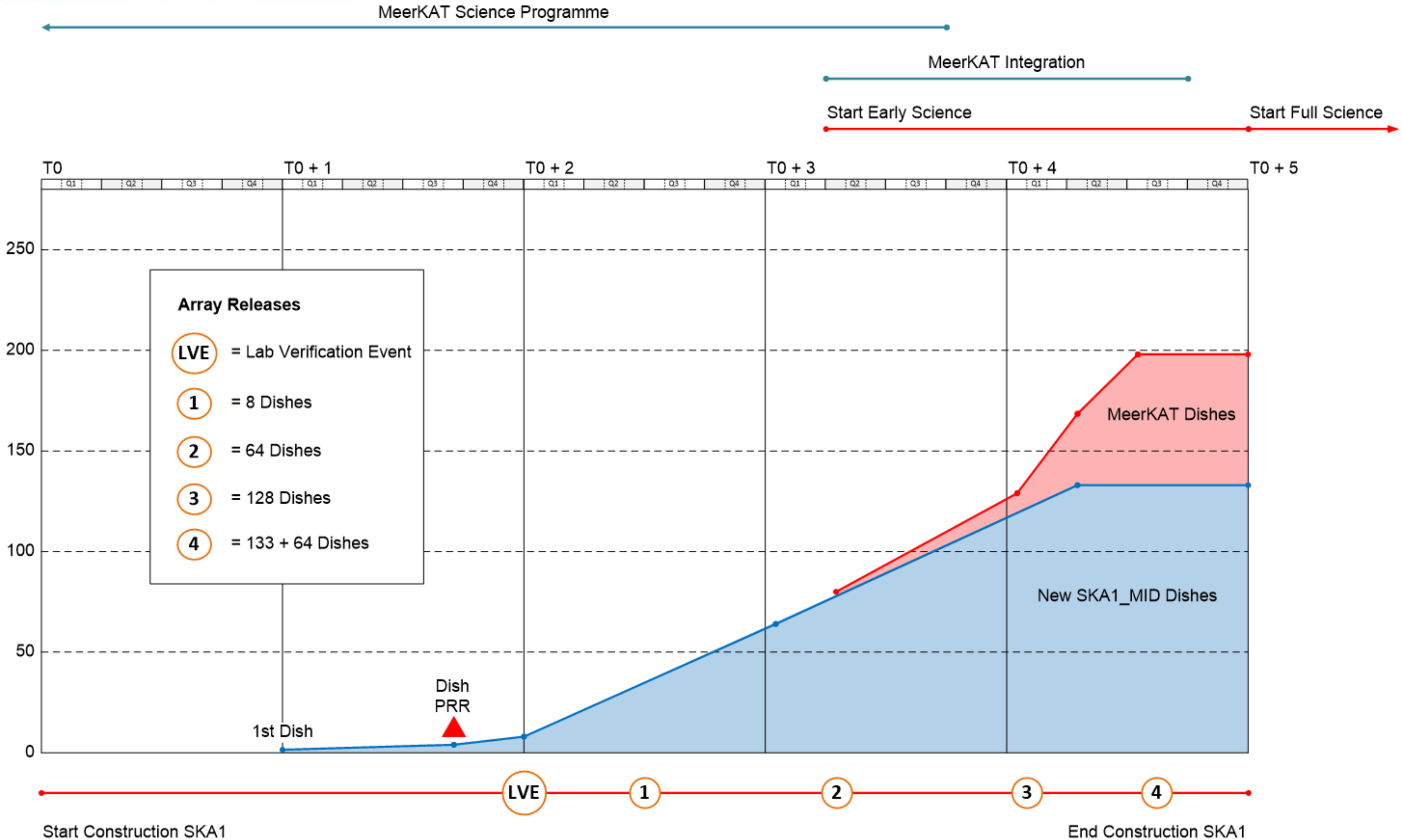
SKA SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

AIV roll-out features including consortia input, science experiments, and an operation support



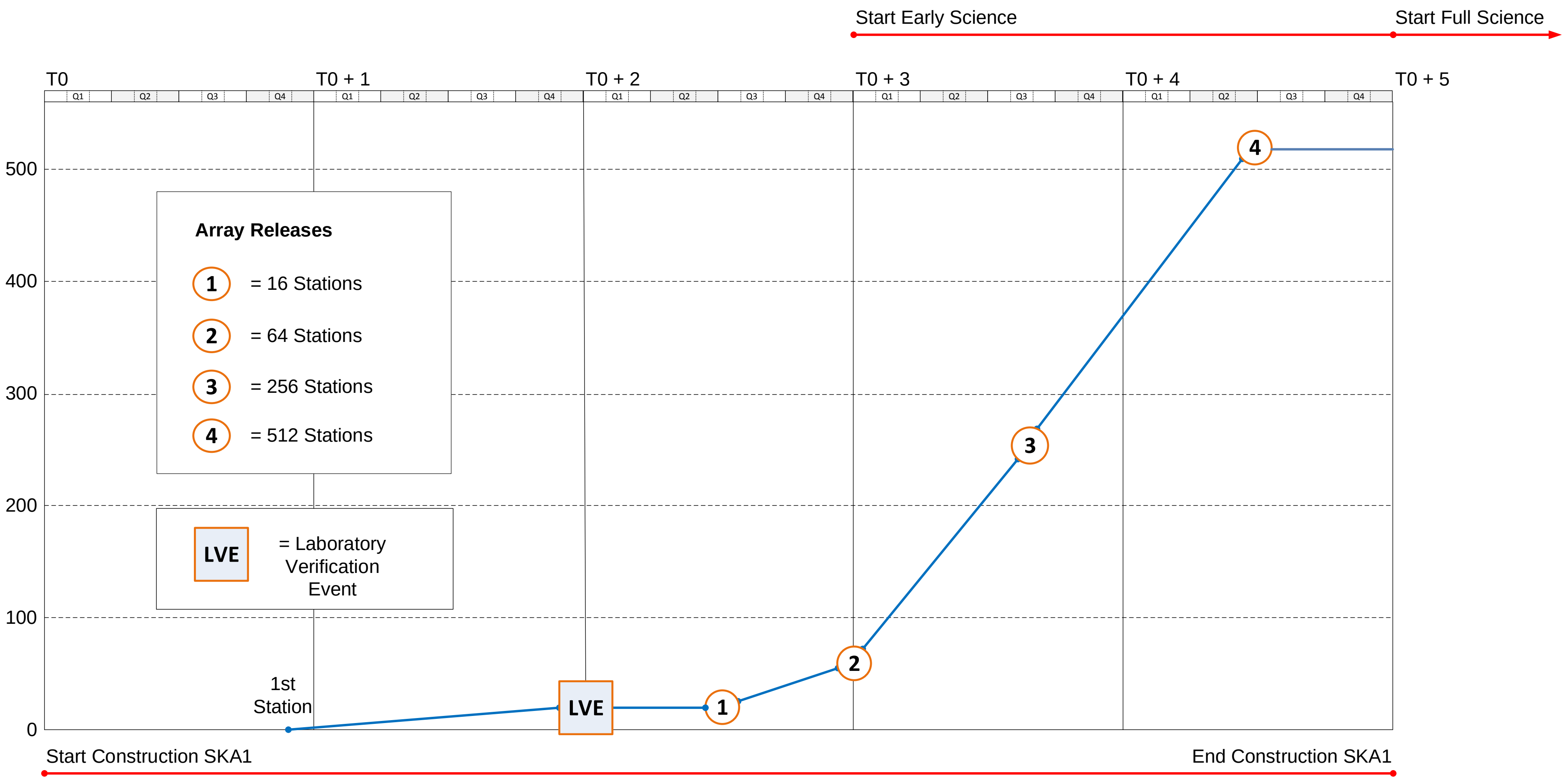
South African core array site with MeerKAT dishes, September 2015

SKA1-MID Dish Roll-Out



Richard Lord, AIV Consortium, 11 November 2015

SKA1-LOW Station Roll-Out



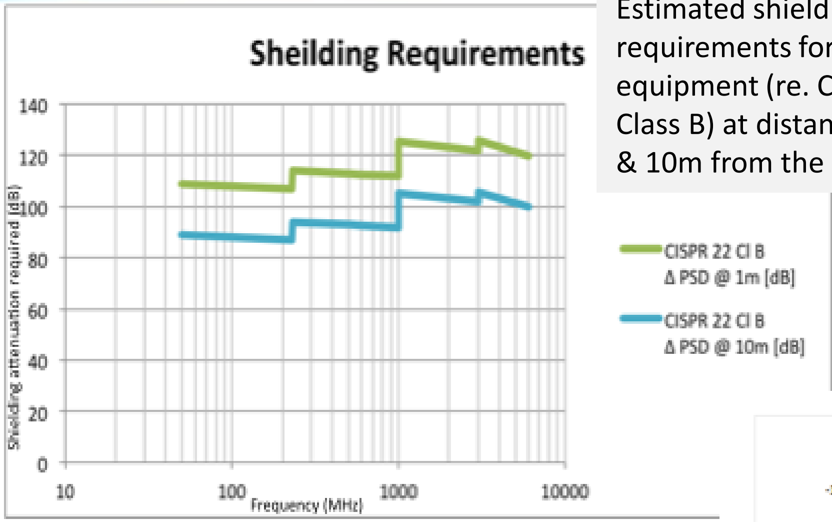
Richard Lord, AIV Consortium, 11 November 2015

Current Telescope Level Requirements & Estimated Design Constraints

- Capital Cost Ceiling, both telescopes: 650M Euro (SADT ~30M Euro per telescope)
- Deployment Period: Years 2018 to 2022
- Power Consumption Cap, SADT Array site equipment: Mid 111kW, Low 51 kW
- Annual Availability
  - Operationally "Available" for 95% of the time
  - Operationally "Degraded" for 50% to 95% of the time
- Environmental - Dish & Remote beamforming Station Environmental
  - Outside open air operating temperature -5 C to +50 C
  - Outside open air non-operating temperature -15 C to +60 C
  - Dish pedestal forced air flow, but not air conditioned
  - Operating humidity 40 - 60%
  - Storage & transport humidity 40 - 95%
- Max Receptor Baselines – Mid 150 km, Low 80 km
  - Approx. max cabled routed distances - Mid 160 km, Low 80 km
- Array Synchronisation – Clock phase 1ps, Time stamp 10ns

Stringent RFI Shielding Requirements

SIGNAL AND DATA TRANSPORT



Estimated shielding requirements for COTS equipment (re. CISPR 22 Class B) at distances of 1m & 10m from the RFI culprit

- Approx 100dB of shielding requirement to use standard COTS equipment in dish pedestals

Ref: SKA EMI/EMC STANDARDS AND PROCEDURES
SKA-TEL-SKO-0000202, Rev 01

MeerKAT Dish, Feed, & pedestal enclosure

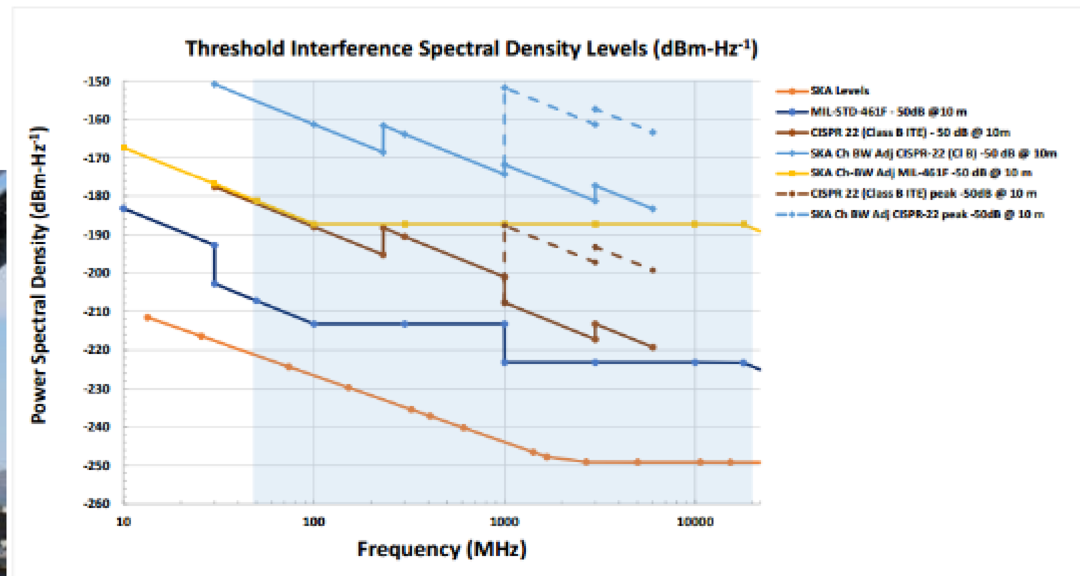


Figure 6: Power spectral density of relevant standards and other documents (dBm-Hz^{-1}). From top to bottom: CISPR-22 levels reduced by 50 dB, adjusted for minimum SKA channel bandwidth; MIL-STD-461F reduced by 50 dB, adjusted for minimum SKA channel bandwidth; CISPR-22 levels reduced by 50 dB; MIL-STD-461F reduced by 50 dB; EMI levels applicable to the SKA standard. CISPR-22 levels are quasi-peak below 1 GHz; average (solid) or peak (dashed) above 1 GHz. The shading indicates the SKA range of frequencies.

Client side Science Observation Data Capacity

SIGNAL AND DATA TRANSPORT

- Current client side Ethernet interface estimates, per location and experiment

Data Source Location	Experiment	SKA1-Low	SKA1-Mid
Remote Array Station Egress	All	3 x 40GE**	1 x 100 GE
Central Processing Facility Ingress	All	108 x 40GE	133 x 100GE
Central Processing Facility Egress	Visibilites	48 x 100GE	64 x 100GE
Central Processing Facility Egress	Pulsar Search	8 x 100GE	8 x 100GE
Central Processing Facility Egress	Pulsar Timing	2 x 10GE	2 x 10GE
Central Processing Facility Egress	NSDN	2 x 10GE	2 x 10GE
Science Processing Facilty Egress*	All	1 x 100GE	1 x 100GE

**Network connectivity for science data transport to world-wide regional centres currently out of scope for SKA1*

***6 beamformed stations per super-station, calibration beam data also included in client capacity*

SIGNAL AND DATA TRANSPORT

Introduction to the SaDT

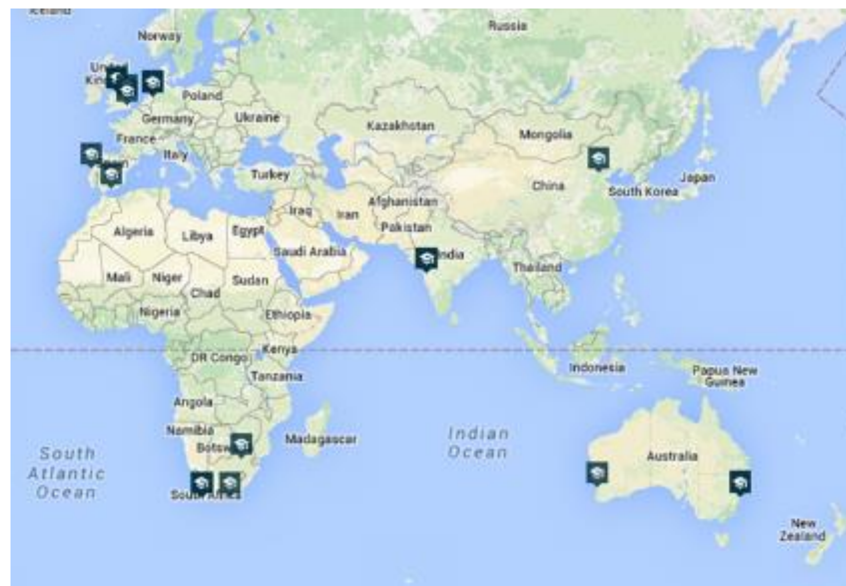
The Signal and Data Transport Consortium

Signal and Data Transport (SADT) Consortium

- Consortium Board, chair: Huib-Jan van Langevelde
- 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, India
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 Work Packages and Leaders

- SKA.TEL.SADT.MGT, Project management – Jill Hammond, Uman
- SKA.TEL.SADT.SE, System engineering – Rob Gabrielczyk, Uman
- SKA.TEL.SADT.SAT.CLOCKS, SAT Clock Design – David Hindley, NPL
- SKA.TEL.SADT.SAT.LMC, SAT Local Monitoring and Control - Rajesh Warange, NCRA
- SKA.TEL.SADT.SAT.STFR, Distribution of UTC and Frequency – Paul Boven, JIVE Netherlands
- SKA.TEL.SADT.NWA Network architecture – Richard Oberland, Uman
- SKA.TEL.SADT.NMGR Network manager – Yashwant Gupta, NCRA
- SKA.TEL.SADT.NSDN Non Science Data Network- Shaun Amy, CSIRO
- SKA.TEL.SADT.DDBH Digital data back haul – Richard Oberland, Uman
- SKA.TEL.SADT.CSP-SDP CSP to SDP Data Transmission – Richard Hughes-Jones, GÉANT
- SKA.TEL.SADT.SDP-Deliv SDP Interfaces & Data Transmission – Richard Hughes-Jones, GÉANT
- SKA.TEL.SADT.LINFRA Local infrastructure – Jaco Muller, SKA Africa

SKA
SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

DDBH

Digital Data Back Haul

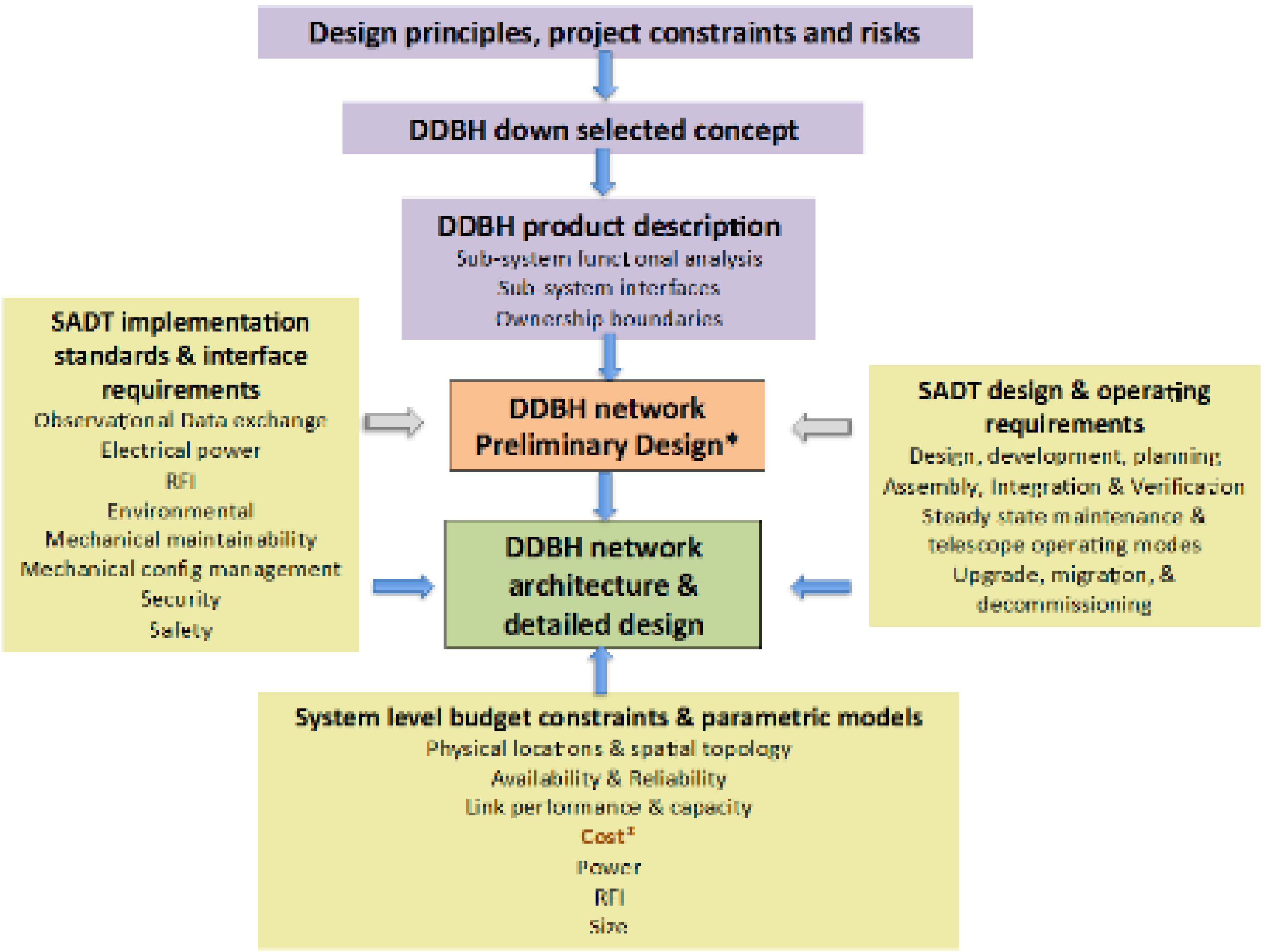
SADT.DDBH Digital Data Back-Haul

SIGNAL AND DATA TRANSPORT

The digital data backhaul networks of the telescope are responsible for transporting digitized science data from the receptor stations to the central processing facility (CPF). Both the SKA1-Low and SKA1-Mid telescopes require their own DDBH node termination equipment and optical fibre infrastructure.

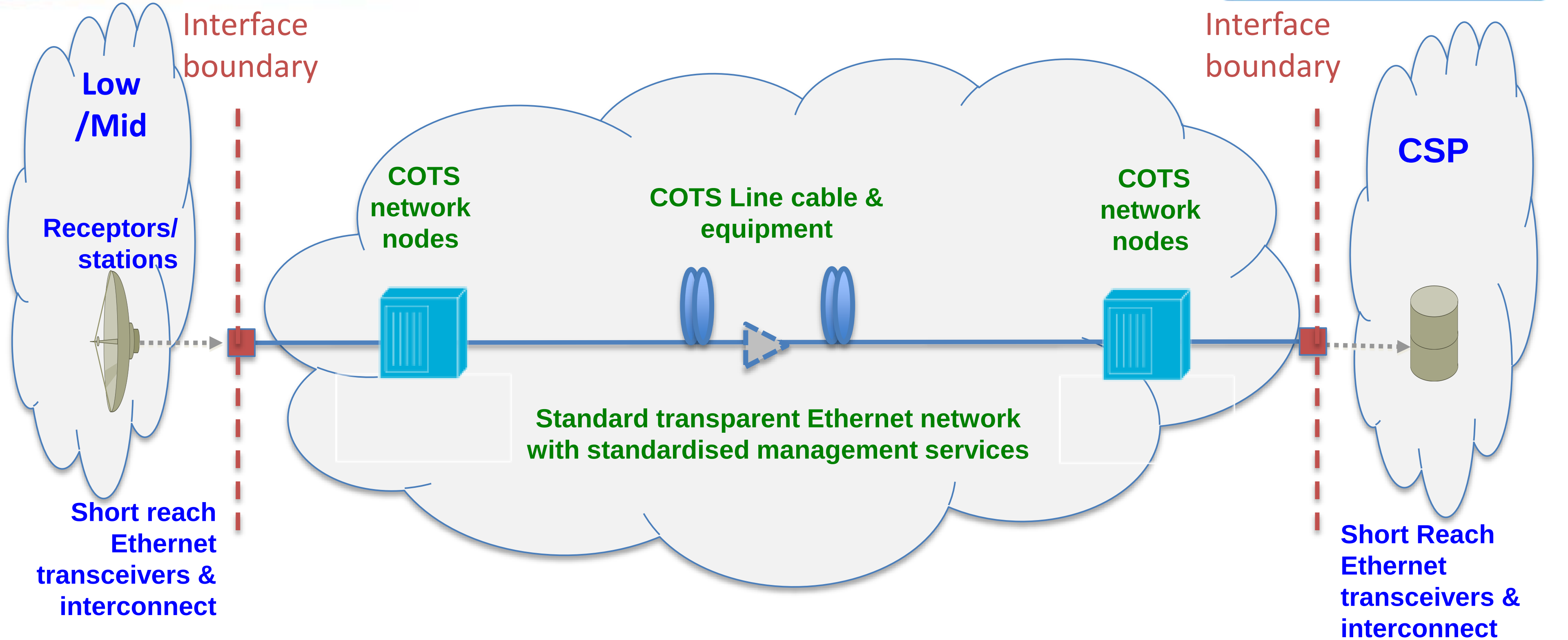
The DDBH will be implemented using Commercial Off The Shelf (COTS) equipment. This approach carries low technical risk, since it builds on the considerable industry experience, however the unique telescope environment requirements must be met.

SADT.DDBH Digital Data Back-Haul
DDBH work package design process



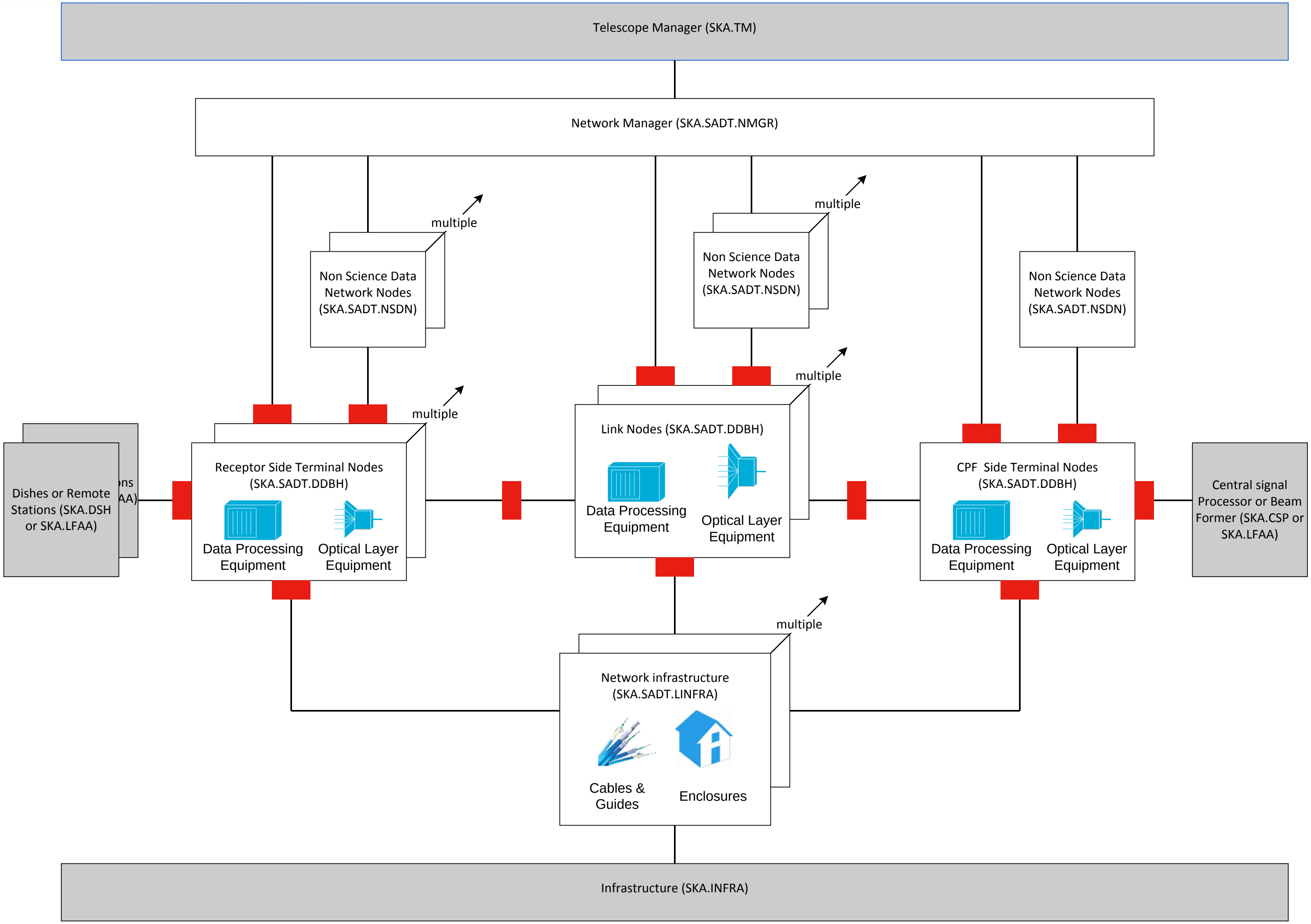
SADT.DDBH Digital Data Back-Haul

DDBH network current design concept



- 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; 36 remote beam formed super-stations, 2 x 100GE transport lanes (3x 40GE clients)
  - Passive spans with DWDM optics

SADT.DDBH Digital Data Back-Haul
DDBH network products and interfaces



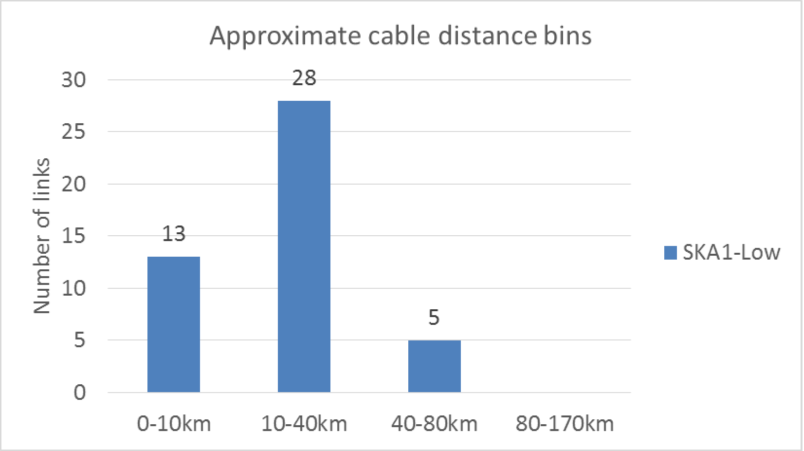
SADT.DDBH Digital Data Back-Haul
COTS cost estimation & market forecasting

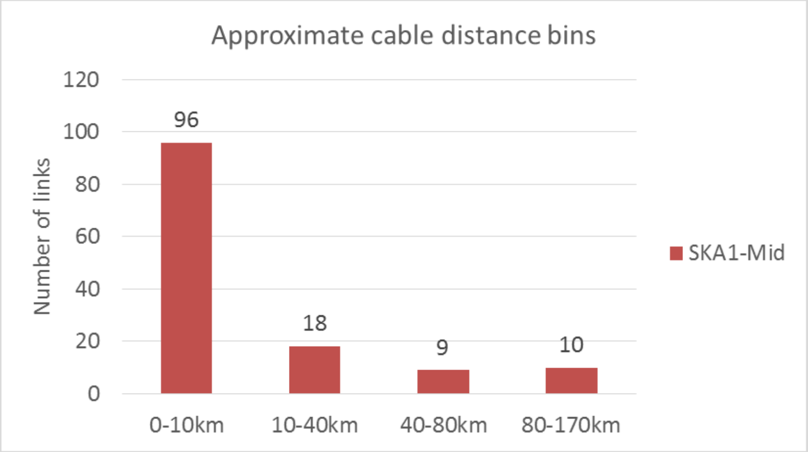
SKA SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

Estimated fractional selling price drop per annum

- Cost and power consumption a function of
  - Year deployed (roll-out)
  - Data capacity
  - Cable distance

Estimated cable routed distance bins





Array layout config ref: *https://www.skatelescope.org/wp-content/uploads/2014/03/SKA-TEL-SKO-0000308_SKA1_System_Baseline_v2_DescriptionRev01-part-1-signed.pdf, October 2015*

CSP-SDP

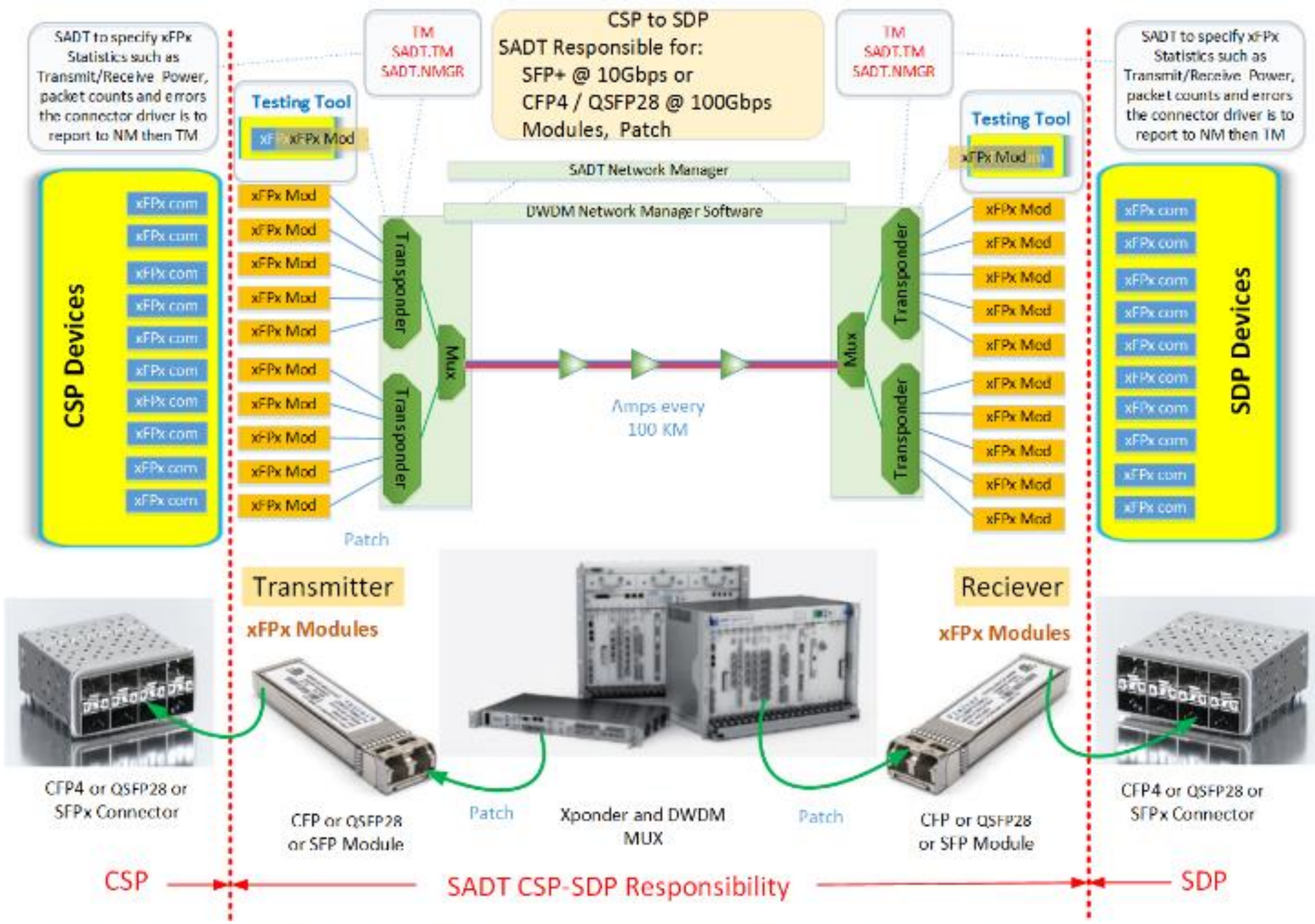
Data Transport from Central Signal Processing to Science Data Processing Facilities

SKA.TEL.SADT.CSP-SDP CSP to SDP transmission

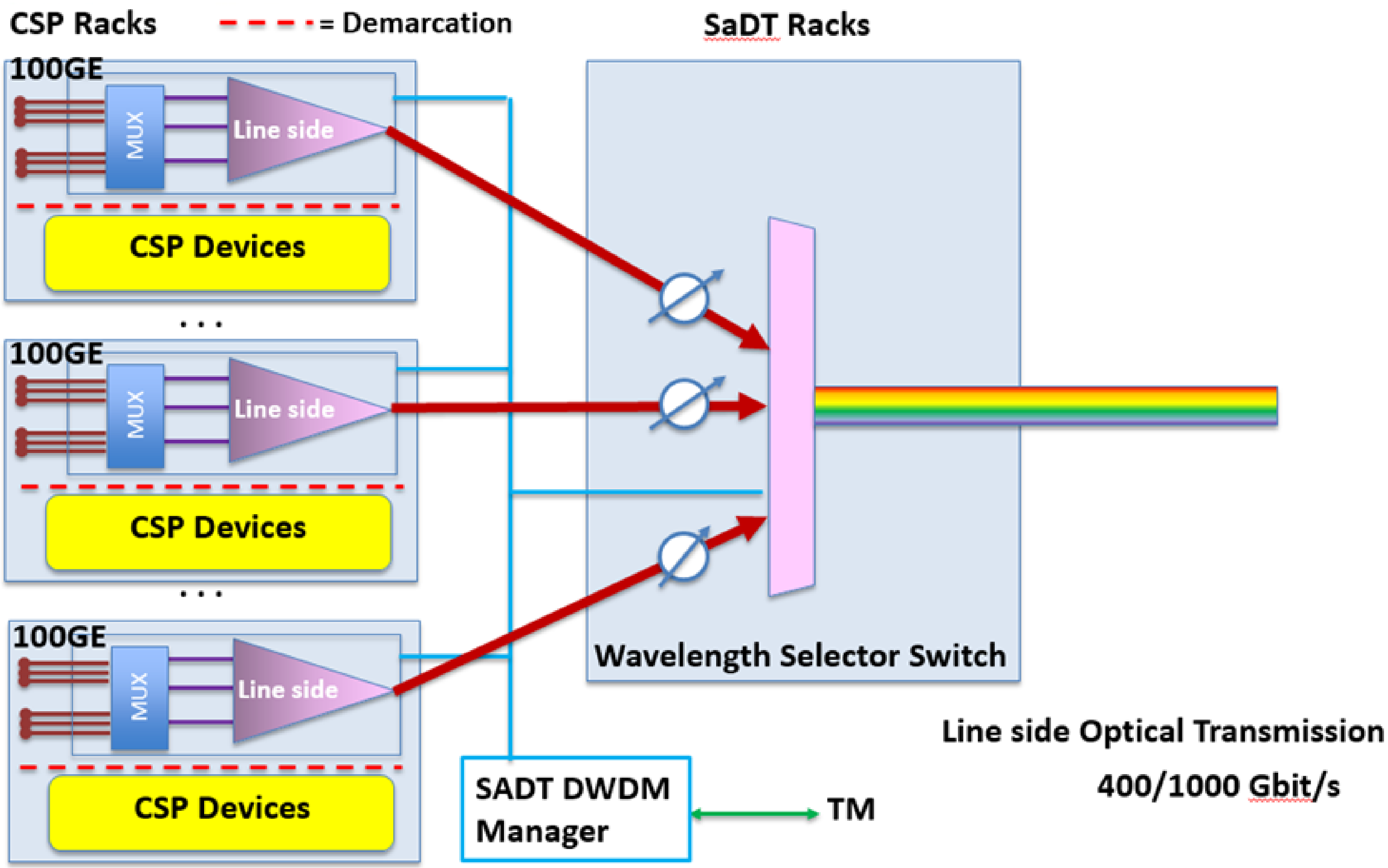
- The SKA 1 CSP-SDP Network provides long distance high bandwidth connectivity between the Central Signal Processor (CSP) locations, and the Science Data Processor (SDP) complex for each of the two observatories. It will carry the science data traffic, and non-science data such as monitoring and control from TM, IP phones, internet access and other auxiliary site traffic

SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
CSP-SDP Network Overview

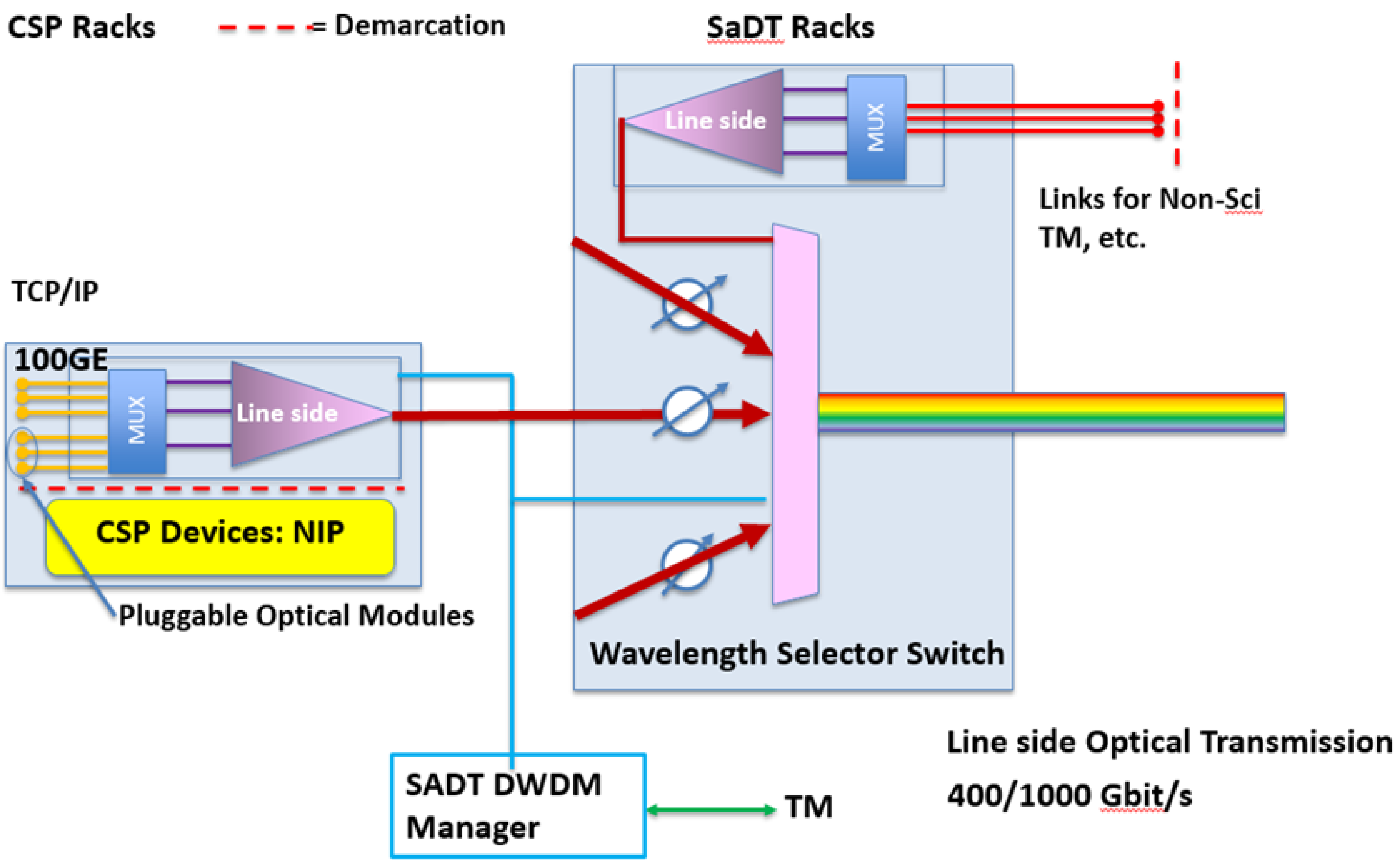
- Provides a high bandwidth path from the Correlator to the HPC.
- Carries the following on 100 Gigabit Ethernet channels:
  - Visibility
  - Pulsar
  - VLBI
  - NSDN



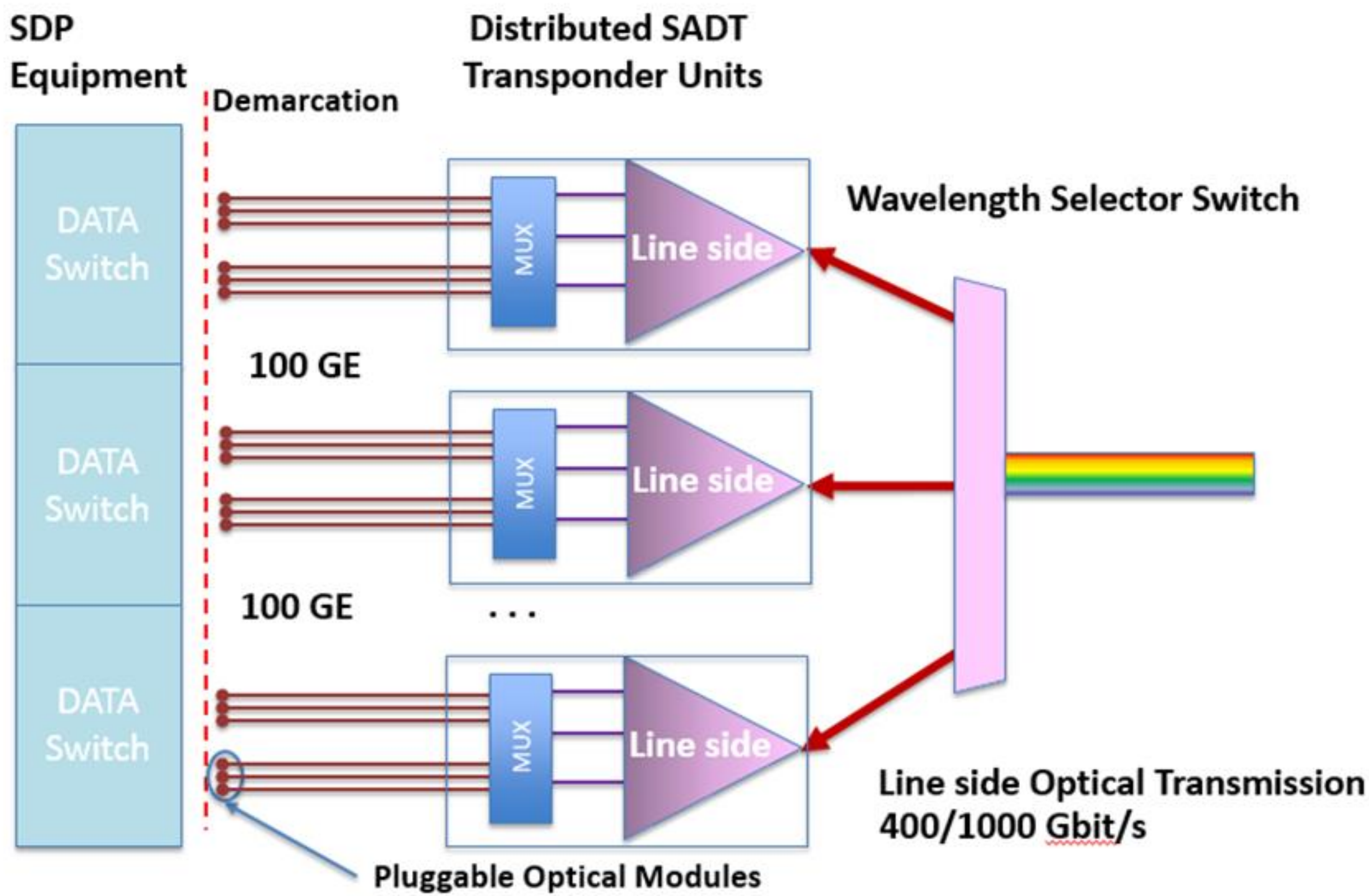
SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
CSP Egress: Visibility Data transport concept



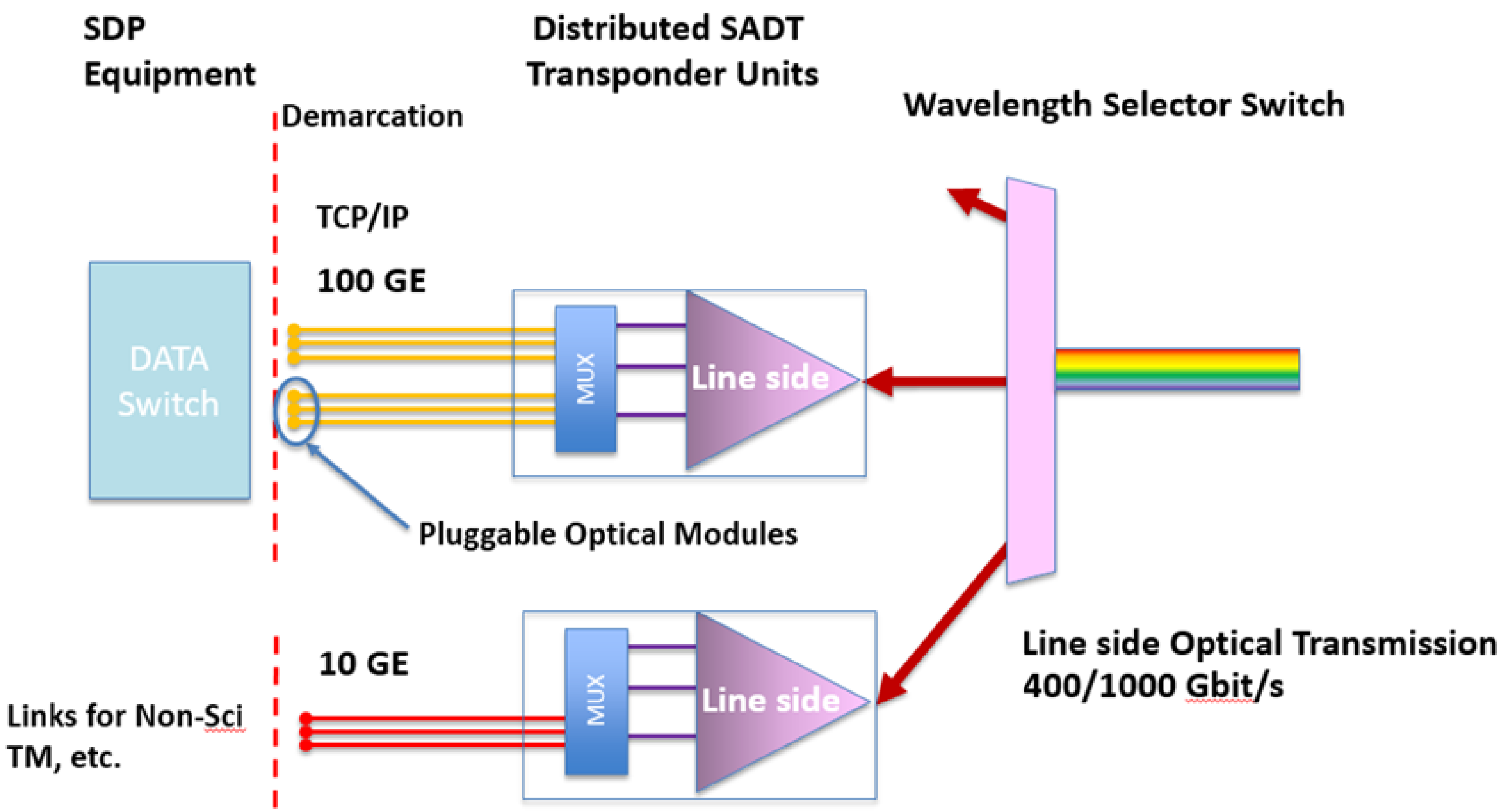
SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
CSP Egress: Pulsar & NSDN transport concept



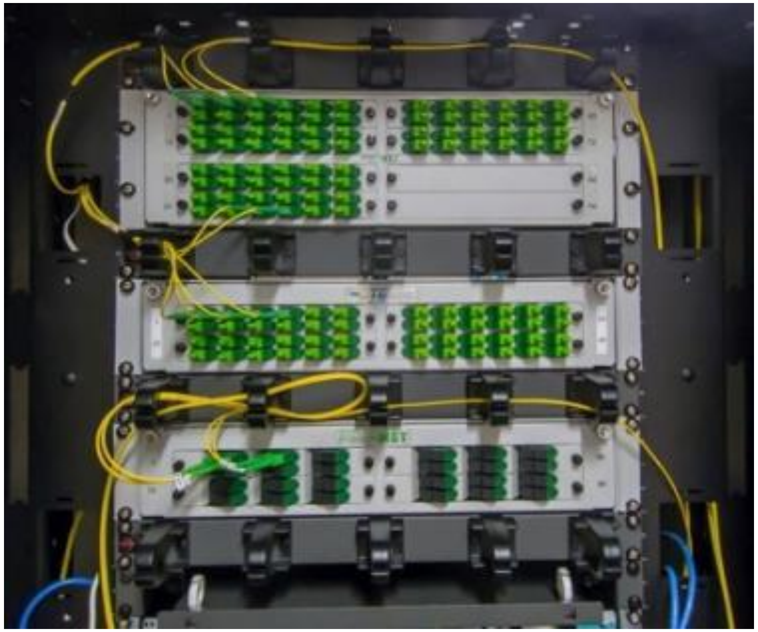
SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
SDP Ingress: Visibility data transport concept



SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
SDP Ingress: Pulsar & NSDN transport concept



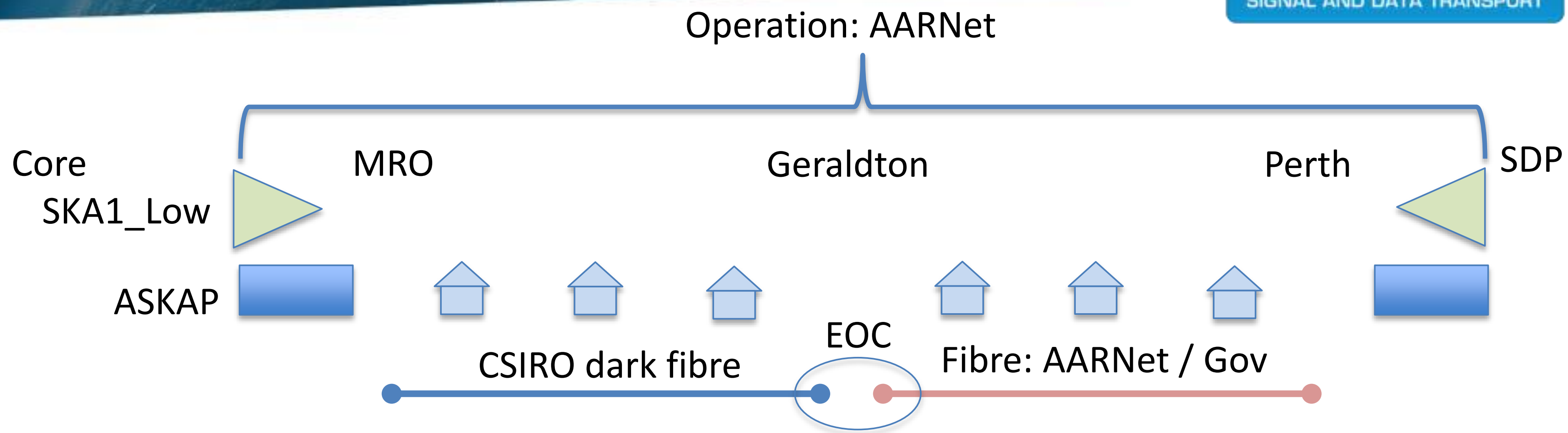
SKA.TEL.SADT.CSP-SDP CSP to SDP transmission Existing MRO to Perth link amplifier huts



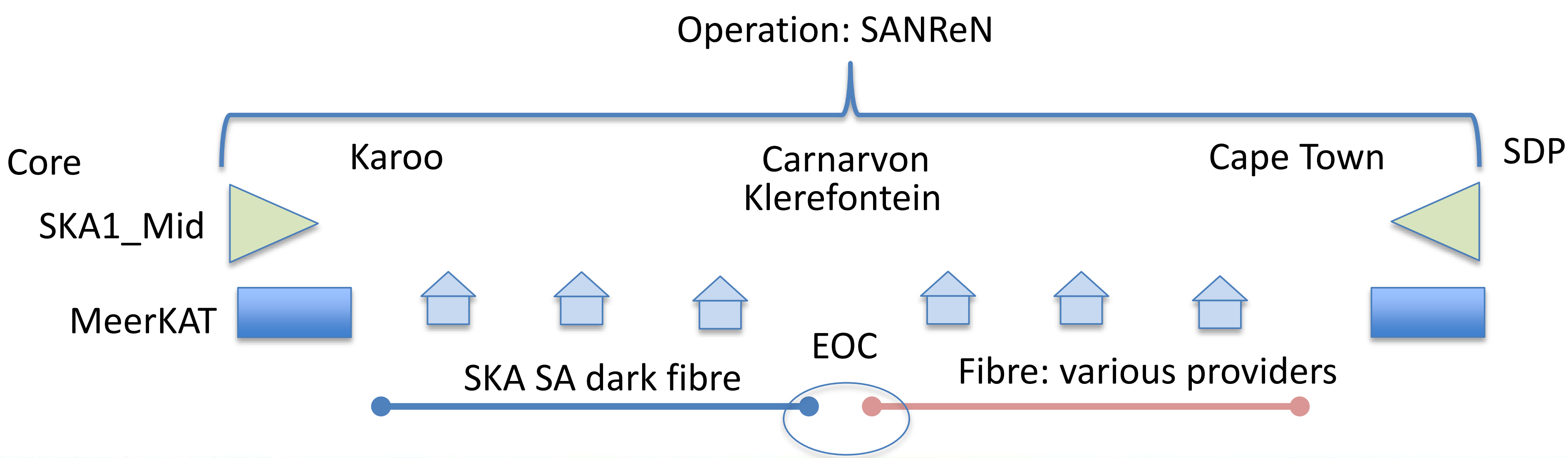
Solar powered CEV picture (left) and communications rack (right) installed at Geraldton (WA) (courtesy of S. Amy, CSIRO)

- No regeneration required for 820/900 km
- Do need amplifier huts every ~100 km

SKA.TEL.SADT.CSP-SDP CSP to SDP transmission
CSP-SDP link operations concept



- ASKAP & CSIRO ask AARNET to manage the core-HPC network
- MeerKAT have a similar approach with SANReN



SIGNAL AND DATA TRANSPORT

SDP-Deliv

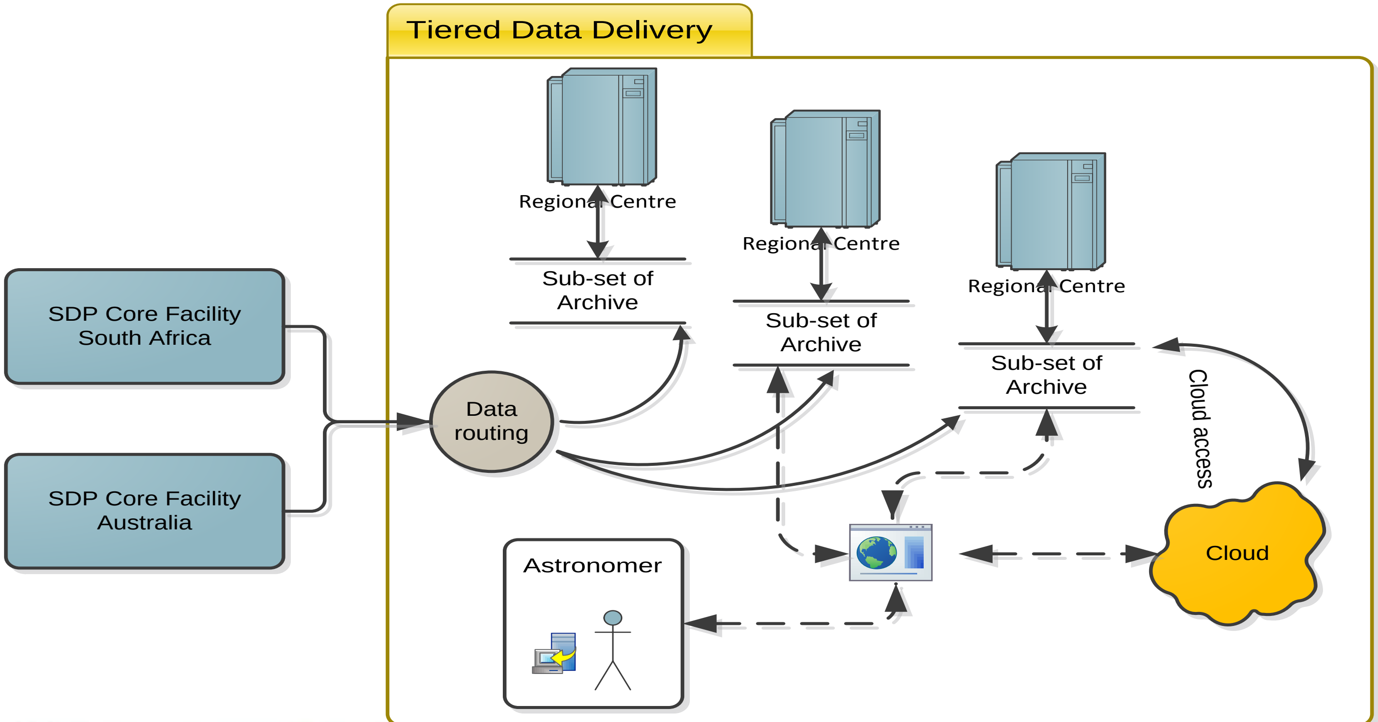
Connecting the Observatory to the Astronomy Community

SKA.TEL.SADT.SDP-Deliv
SDP Interfaces and Data Transmission

This work package is responsible for the definition of an interface description between the output of the SDP and the Outside World. SADT and SDP consortia propose that this work be extended to include consideration of the full data delivery to the radio astronomy community..

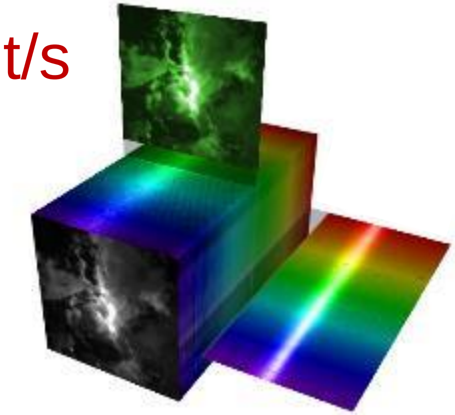
SKA.TEL.SADT.SDP-Deliv
SDP Interfaces & Transmission - Delivering Data

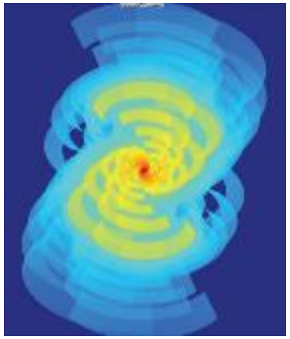
- SDP HPC processing places the SKA data in local archives.
- Model to provide access to the astronomy community:
  - Having a replica is a basic requirement.
  - Only move the data once.
  - Protocols must be suitable for high bandwidth and real-time transfers.

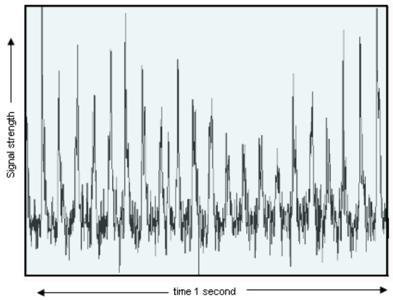


SKA.TEL.SADT.SDP-Deliv
Data Products from SDP

- Image cubes of sky maps 18PB n*/year ~30Gbit/s
  - SDP Fourier transform of CSP time series
  - Moderate external compute and model fitting
- Epoch of Re-ionisation 1.6PB/ 6 Hr ~600 Gbit/s
  - Uses calibrated aperture plane
  - Enormous compute of power spectra
- Relativity Gravitational lensing 70PB/2500Hr 60Gbit/s
  - Uses further processed aperture plane data
  - Considerable compute of galaxy elipsciity
- Pulsars 4-5 PBytes/y ≤10Gbits
  - Discovery and in depth study; timing 10 ns in 10 years
  - Large physics compute
- VLBI we do 4 Gbit/s now !
  - Data direct from the correlator ~ 10 Gbit/s UDP



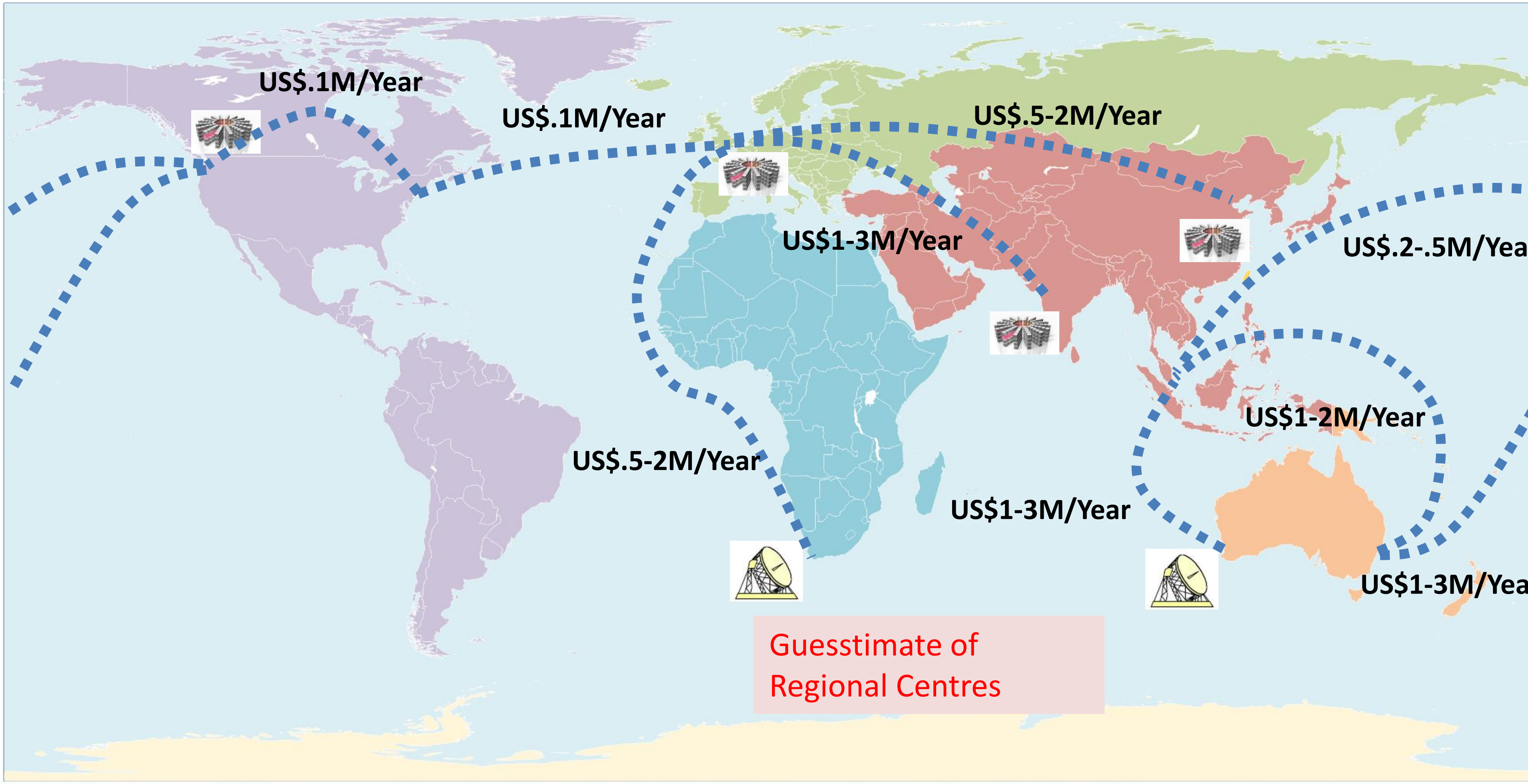




Bottom Line: Lots of data, work in progress to constrain it – what about 100 Gbit/s

SKA.TEL.SADT.SDP-Deliv
Estimated SDP to world costs

- 10 year IRU per 100Gbit circuit 2020-2030
- Guesstimate of Regional Centres locations

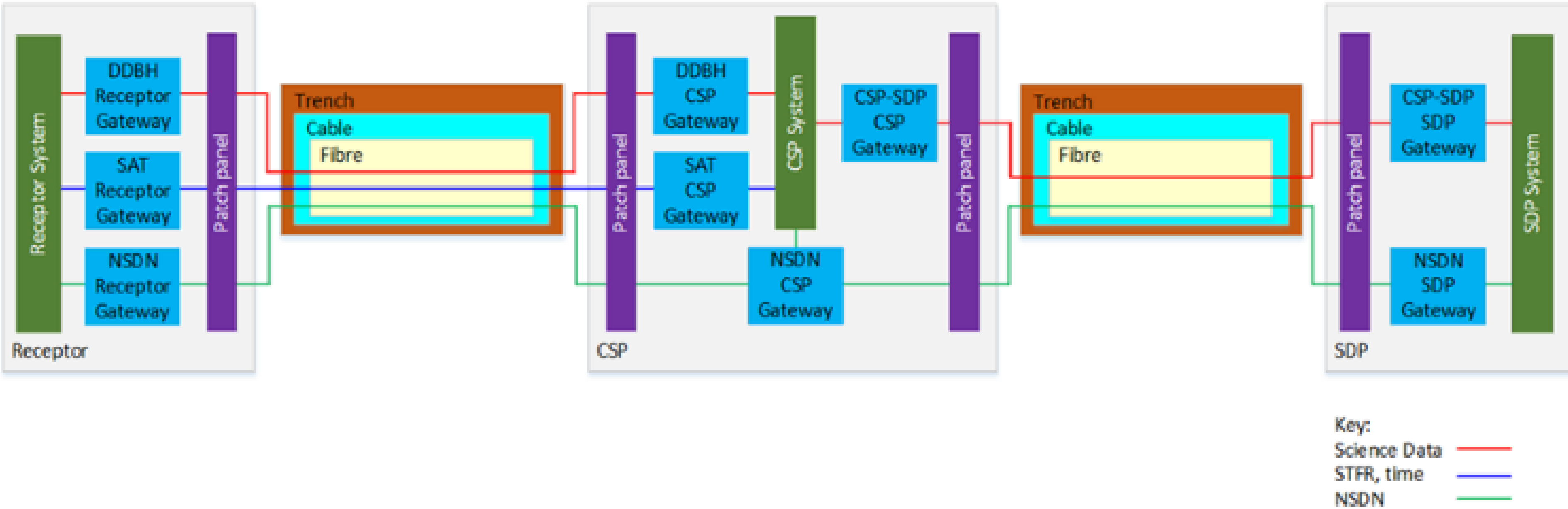


NWA

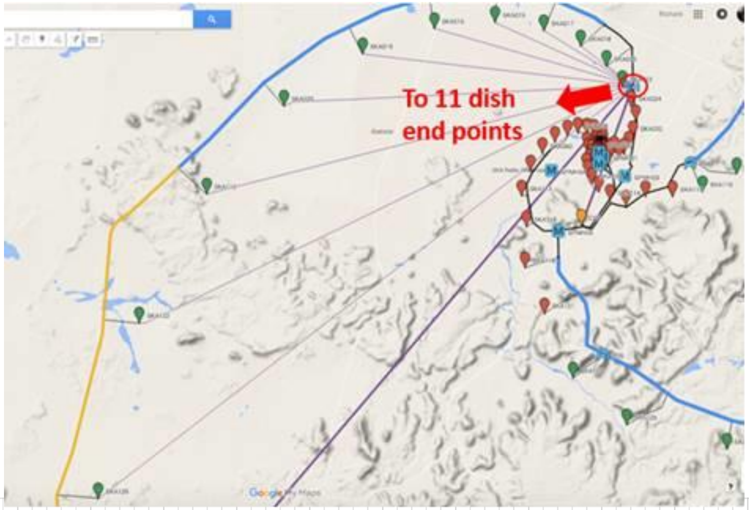
SaDT Network Architecture

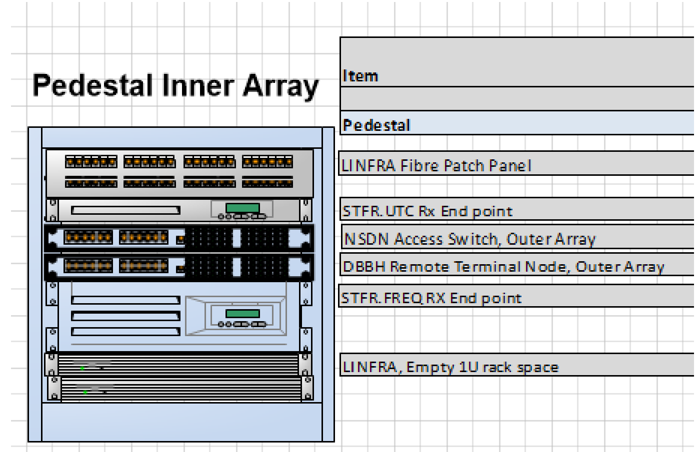
SADT.NWA Network Architecture

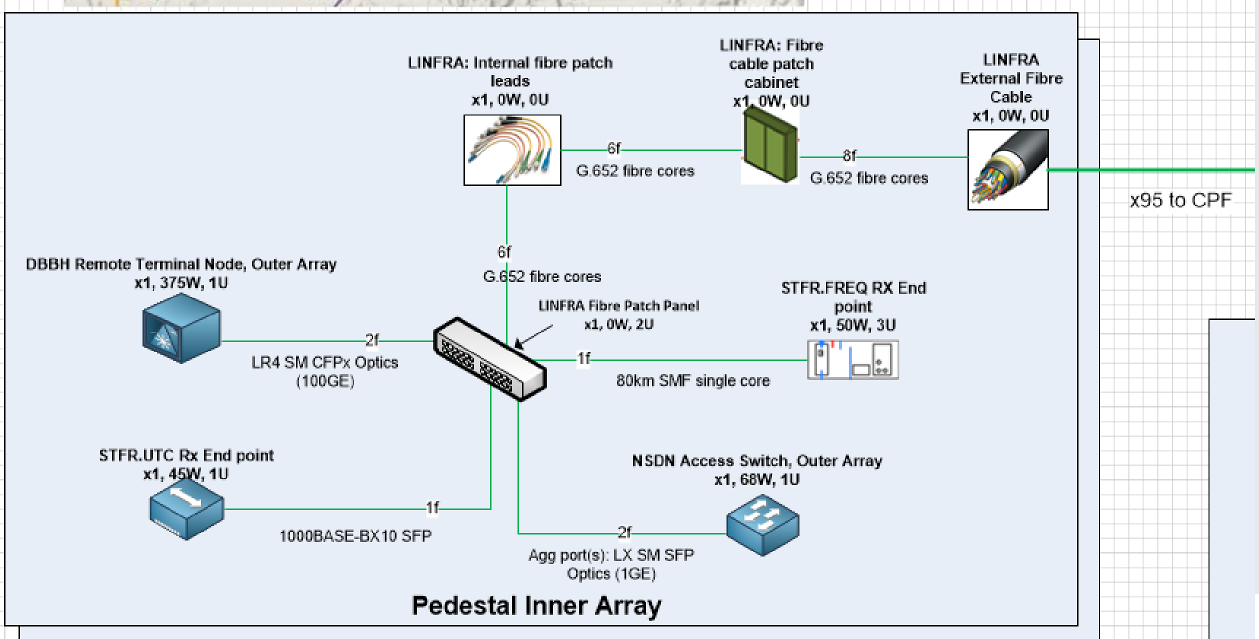
- The signal and data transport network architecture defines the top level physical and functional aspects of the network capable of carrying all the network services required by the telescope.

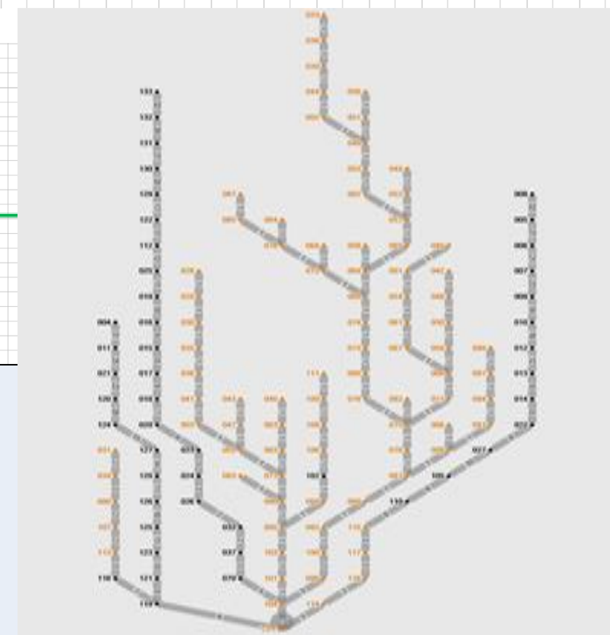


SADT.NWA Network Architecture
Rack configuration and spatial modelling









SADT.NWA Network Architecture
Blackbox specifications & allocations

Blackbox Product Types

LINFRA External Cable fibre cores
LINFRA Power strip
LINFRA Fibre Patch Panel
STFR.UTC Tx End point, CPF
STFR.UTC Repeater
STFR.UTC Rx End point
STFR.FREQ RX
STFR.FREQ RX & Amplifier
STFR.FREQ TX, CPF
NSDN Access Switch, Outer Array
NSDN Access Switch, Inner Array
NSDN Distribution switch, Outer Array
NSDN Distribution switch, Inner Array
NSDN Regeneration/Repeater, Outer Array
NSDN Core switch, CPF
DBBH Receptor Node, L1 Transponder (up to 300km)
DBBH Receptor Node, L1 Transponder (up to 10km)
DBBH Receptor Node, L2 Switch (up to 10km)
DDBH Link Node (EDFA Amplifier Pair)
DDBH Link Node (Optical Coupler/WDM))
DBBH CPF Node, L1 Transponder (up to 300km)
DBBH CPF Node, L1 Transponder (up to 10km)
DBBH CPF Node, L2 Switch (up to 10km)
CLKS Clock System
CLKS, NTP Server
NMGR M&C System
SAT.LMC PC Central Controller
SAT.LMC PC104 CLOCKS Controller
SAT.LMC PC104 UTC Controller
SAT.LMC PC104 FRQ Controller

Blackbox Product Specs

Total service throughput per optical channel, Gbit/s
WDM channels aggregated per fibre
Max number of external nodes served, >300m
External cable interfacing fibre cores
Fibre Type
Power consumption, W
Rack footprint, U
External cable facing port reach, km
Quantity of black boxes per rack config (e.g. CPF, Inner array stations)

Location dependent SADT Specifications

Loc ID
Config ID
Lat
Long
Direct distance to CPF supplied
Nearest node distance supplied
Nearest distance node ID
Power Demanded (W)
Rack Space Demanded (U)
Total LINFRA ext cable fibres supplied

SIGNAL AND DATA TRANSPORT

LINFRA

Local Infrastructure for SaDT

SKA.TEL.SADT.LINFRA Local Infrastructure

The fibre optic network is the physical layer across which all of the SKA1 telescope networks operate – Science Data, Telescope Manager, Synchronisation and Timing, Non Science Data network, plus a number of auxiliary networks such as the Building Management System

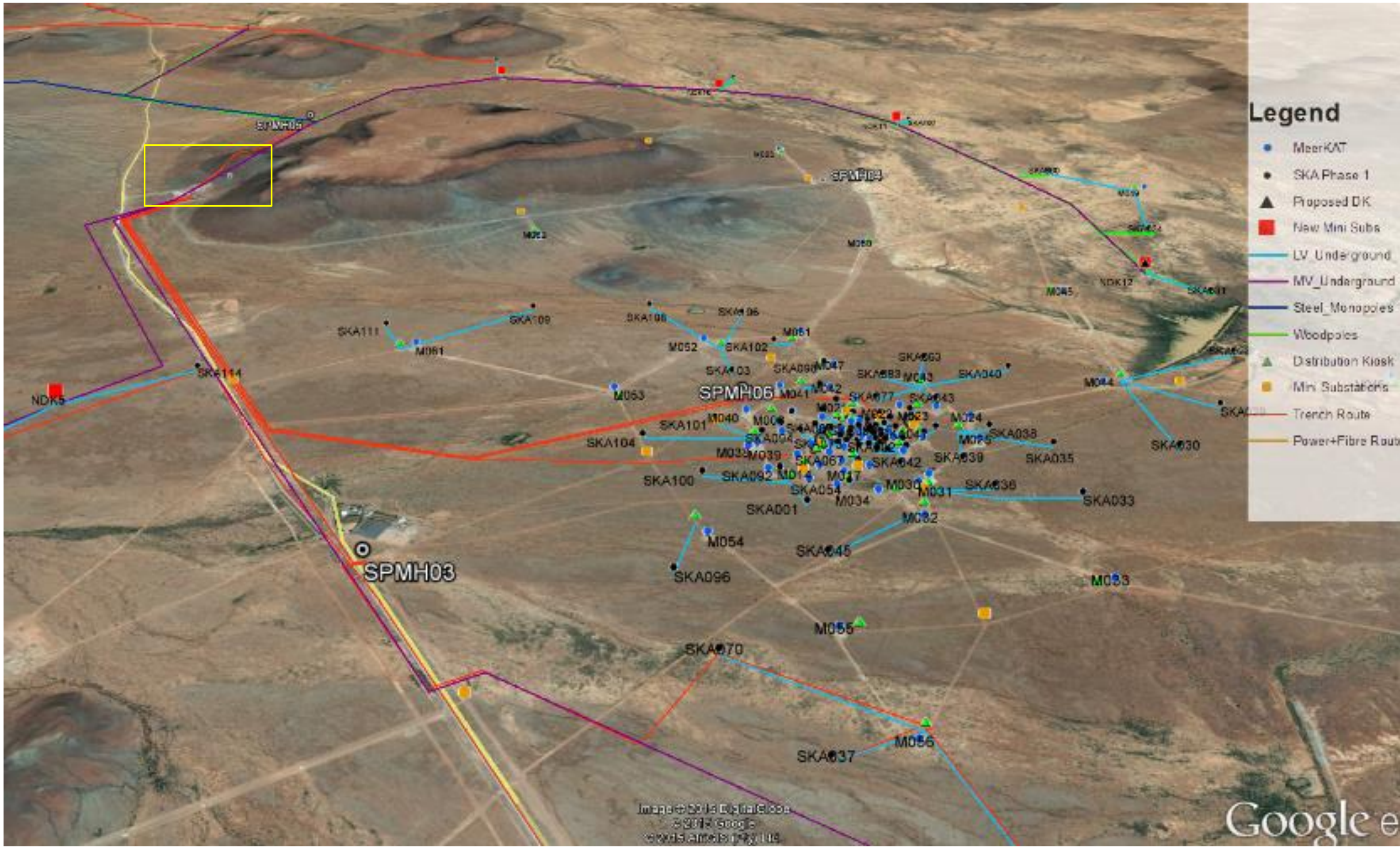
SKA.TEL.SADT.LINFRA Local Infrastructure

Installation of optic fibre during construction of the ASKAP antennas and associated infrastructure in 2011.
Image courtesy Shaun Amy/CSIRO

Karoo Array Processing Building and associated assembly infrastructure in 2015.
Image courtesy Richard Oberland/Uman

SKA.TEL.SADT.LINFRA Local Infrastructure
SKA1-Mid Core array reticulation concepts

SIGNAL AND DATA TRANSPORT



- Fibre cable; power cable; trenching; manholes; ducts; drawpits
- In-house and off-the-shelf spatial modelling tools for spatial optimisation
- Obvious saving – combine fibre with power reticulation

SKA.TEL.SADT.LINFRA Local Infrastructure Rack mounted Equipment Specs

- CONFIG NUMBER
- DESCRIPTION
- TRAY HEIGHT (INCL CLEARANCE) REQUIREMENT (U)
- TRAY DEPTH (INCL CLEARANCE) REQUIREMENT (mm)
- MASS (kg)
- EMI Standard
- POWER CONSUMPTION (W)
- THERMAL DISIPATION
- POWER SOCKET TYPE
- FUSE RATING REQUIREMENT (A)
- AIRFLOW DIRECTION REQUIREMENT (COLD TO HOT)
- FIBRE CONNECTORS LOCATION
- POWER CONNECTOR LOCATION
- EARTH STRAP LOCATION
- PRODUCT LABEL LOCATION
- STATUS INDICATORS LOCATION
- MOUNTING DIRECTION (INSERT)
- MOUNTING SUPPORT
- MOUNTING METHOD

SIGNAL AND DATA TRANSPORT

NSDN

Non-Science Data Network

SADT. NSDN Non-Science Data Network

The purpose of the Non-Science Data Network (NSDN) is to transmit and receive throughout the system the monitoring and control information from the Telescope Manager (TM) element, and the general communications (Auxiliary Network, AUX) traffic. The NSDN is an observatory- site wide infrastructure that carries a number three sets of services to the various locations required to operate and maintain the telescopes and observatory. These services carry ‘live’ observation critical data; testing, diagnostic and commissioning data; all other monitor and control information, and the general purpose communications traffic (e.g. IP telephony).

SADT.NSDN Non-Science Data Network
Architecture drivers

- Deliberately location agnostic:
  - clearly there will be some implementation differences but where possible strive to implement the same design in both Australia and South Africa.
- Utilise in-depth knowledge of the existing precursor networks.
- Core, Distribution (where applicable), Access
- MPLS Core/Backbone:
  - standard industry practice (e.g. campus/enterprise/ISPs)
  - VPNs (layer 2 and layer 3)
- Avoiding “specials”:
  - e.g. every pedestal is the same

SADT.NSDN Non-Science Data Network Operational factors

- Have taken a Total Cost of Ownership view.
- Industrial Ethernet switches – system trade-off required.
- Operational Model needed to consider maintenance (and what level) and self-sparing
- Network operations overhead with multiple vendors. Need to minimise!
- Security:
  - pragmatic view
  - “use” cases
- Learn from the precursors

SADT.NSDN Non-Science Data Network
Service and location Matrix

SKA SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

	Site Monitor locations	Power system locations	Water & sanitation locations	SADT intermediate network locations	Dish / LFAA Remote Station Locations	Site Processor Facility	Trusted Offices	Science Proc Centre	Science Ops Centre	Eng Ops Centre	Accomodation	Contractor Accomodation	Admin Buildings
TM Related Flows													
System Configuration data	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
States & Modes	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Light grey	Dark grey	Light grey
Alarm Signals	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Calibration Data	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Execution Status	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Light grey
Schedule	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Light grey
MeerKAT Proxy data	Green	Green	Green	Green	Dark grey	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Science calculation / data													
Calibration Transforms	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Data Products	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Pipeline	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Dark grey
Administration													
Security signals	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Light grey	Light grey	Light grey
safety signals	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Light grey	Light grey	Light grey
QA	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Light grey
Asset Information	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Light grey
Internet / Enterprise													
External Input	Dark grey	Dark grey	Dark grey	Green	Green	Green	Green	Green	Green	Orange	Dark grey	Dark grey	Light grey
Guest services (hard & soft)	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Light grey	Light grey	Light grey	Light grey	Light grey	Dark grey	Dark grey	Light grey
Enterprise services	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Dark grey	Light grey
Videoconferencing	Dark grey	Dark grey	Dark grey	Dark grey	Dark grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Dark grey	Light grey
Voice	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Dark grey	Light grey
Internet services	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Light grey	Dark grey	Light grey

- Dark grey: No data flow required
- Light grey: General data communication services
- Green: Production and Engineering Service Data Flows
- Orange: Engineering Service Data Flow only

SADT.NSDN Non-Science Data Network Services, Characteristics, Locations

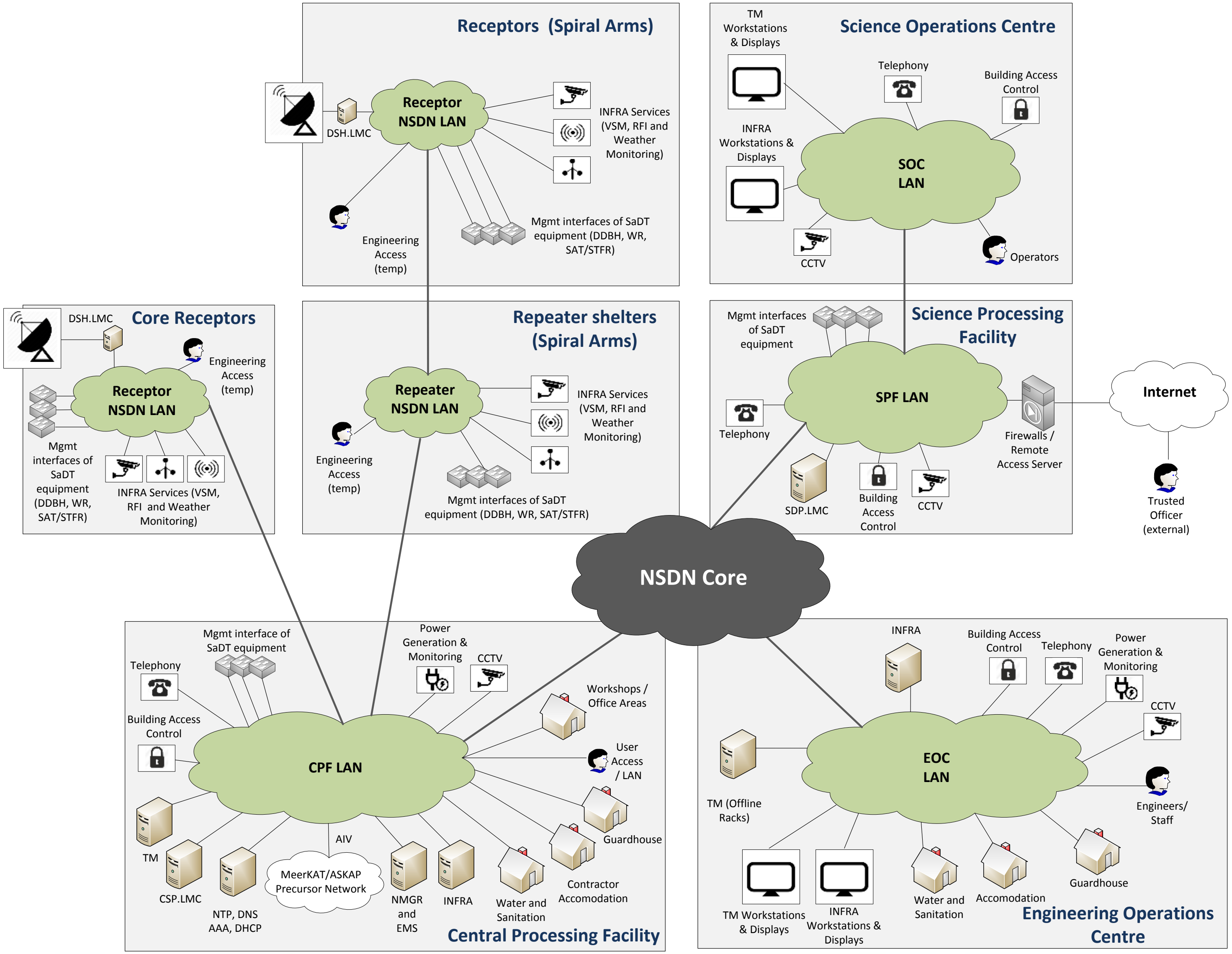
SIGNAL AND DATA TRANSPORT

Network Locations
Power system locations
Water & sanitation locations
SADT intermediate network locations
Dish / LFAA Remote Station Locations
Site Processor Facility
Trusted Offices
Science Proc Centre
Science Ops Centre
Eng Ops Centre
Accomodation
Contractor Accomodation
Admin Buildings
Site Monitor locations

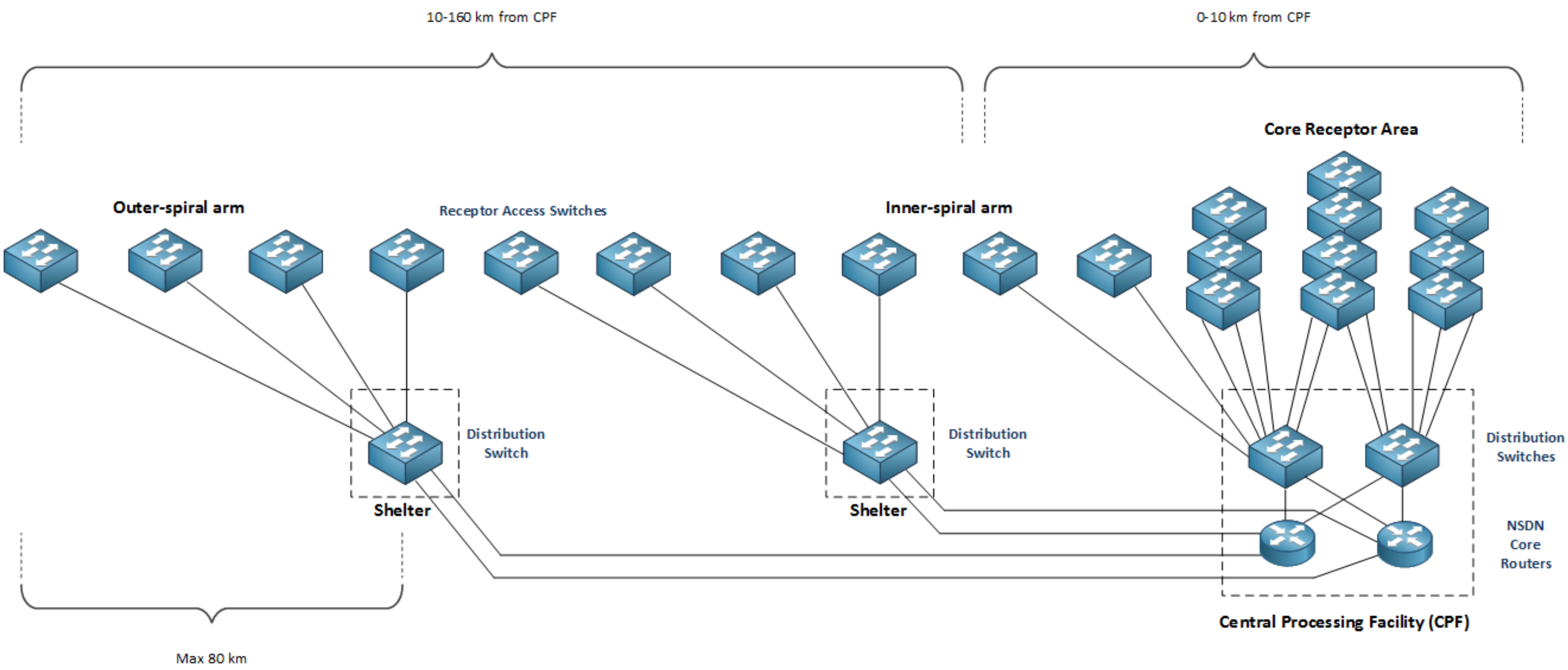
Service Characteristics
Service Name
Service End points
Service Description
Does the service have any critical redundancy requirements
What time to repair does the service require
What is the average service bandwidth requirement
What is the peak service bandwidth
Physical Port Speed required
Number of Ports
Is VLAN trunking required to the service end point
Number of Vlan per port - if required
Port Type
Transceiver package
cable connector
Distance to Local Element
Multicast required
Power over Ethernet (POE)
IP Version
IP Addressing
Protocol
QOS - What Packet Loss can the service tolerate
What is the end to end latency requirement
Port Security requirements
What is the maximum packet payload the network needs to support

Service	Description
System Configuration data	Monitor and control transactions with specific associated values.
Asset Information	Quasi-static data associated with Observatory assets. This will also include serial numbers.
Safety signals	Commands and associated values that directly affect or influence safety.
States & Modes	Monitor and Control information altering the state or observing mode of the instrument.
Alarm Signals	Alarm data is a warning signal indicating abnormal conditions exist in the system.
Security signals	Physical security monitoring and control. E,g, Building security door monitors
MeerKAT Proxy	All data associated with the MeerKAT precursor telescope handed to SKA Telescope systems via defined interfaces.
Calibration Data	The process whereby the output of a measurement is related back to the value of the measure and, in order that absolute measurements are possible.
Calibration Transforms	
Execution Status Schedule	Defined observing times and objects
QA	Quality Assurance
Data Products	A dataset, which when combined with other datasets providing spectrally, temporally and/or spatially resolved measurements of phenomena of astronomical interest or of sectors of the celestial sphere
External Input	Data entering the SKA System from trusted external sources.
Pipeline	Pipeline code for the processing of astronomy data.
Guest Services	Data associated with guest services provided by the obsertvatory. These include both services associated with custom experiments and visitors to Observatory sites.
Enterprise Services	Observatory central functions that apply across the telescope and host country facilities.
Video Conferencing	Packet based Enterprise Video & Audio conferencing capabilities and facilities
Voice	Voice data and signalling carried over a packetised network. Commonly referred to as VoIP.
Internet Services	External data accessed from the global network.

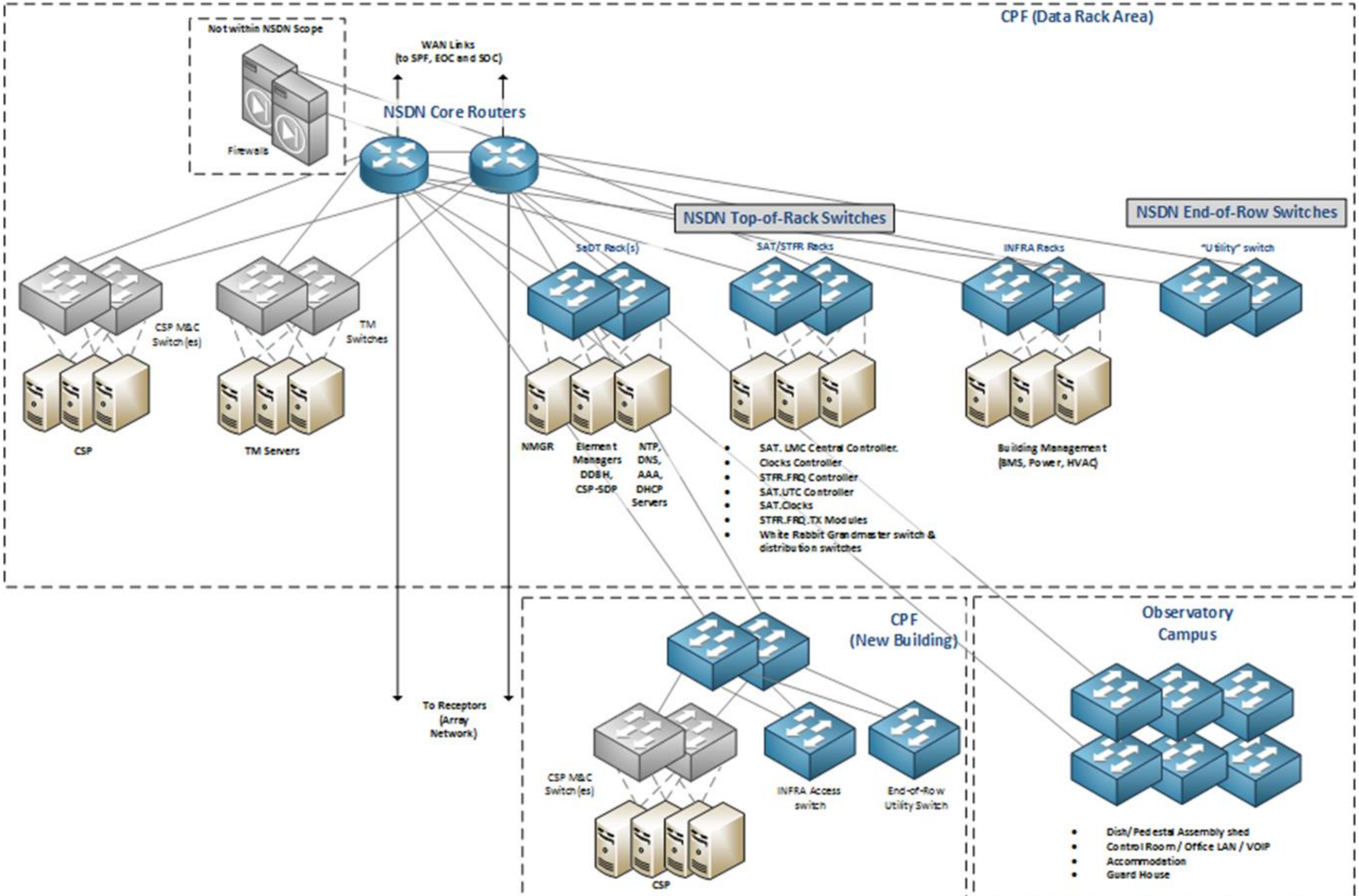
SADT.NSDN Non-Science Data Network
NSDN Spatial Network Distribution



SADT.NSDN Non-Science Data Network
Array Architecture concept

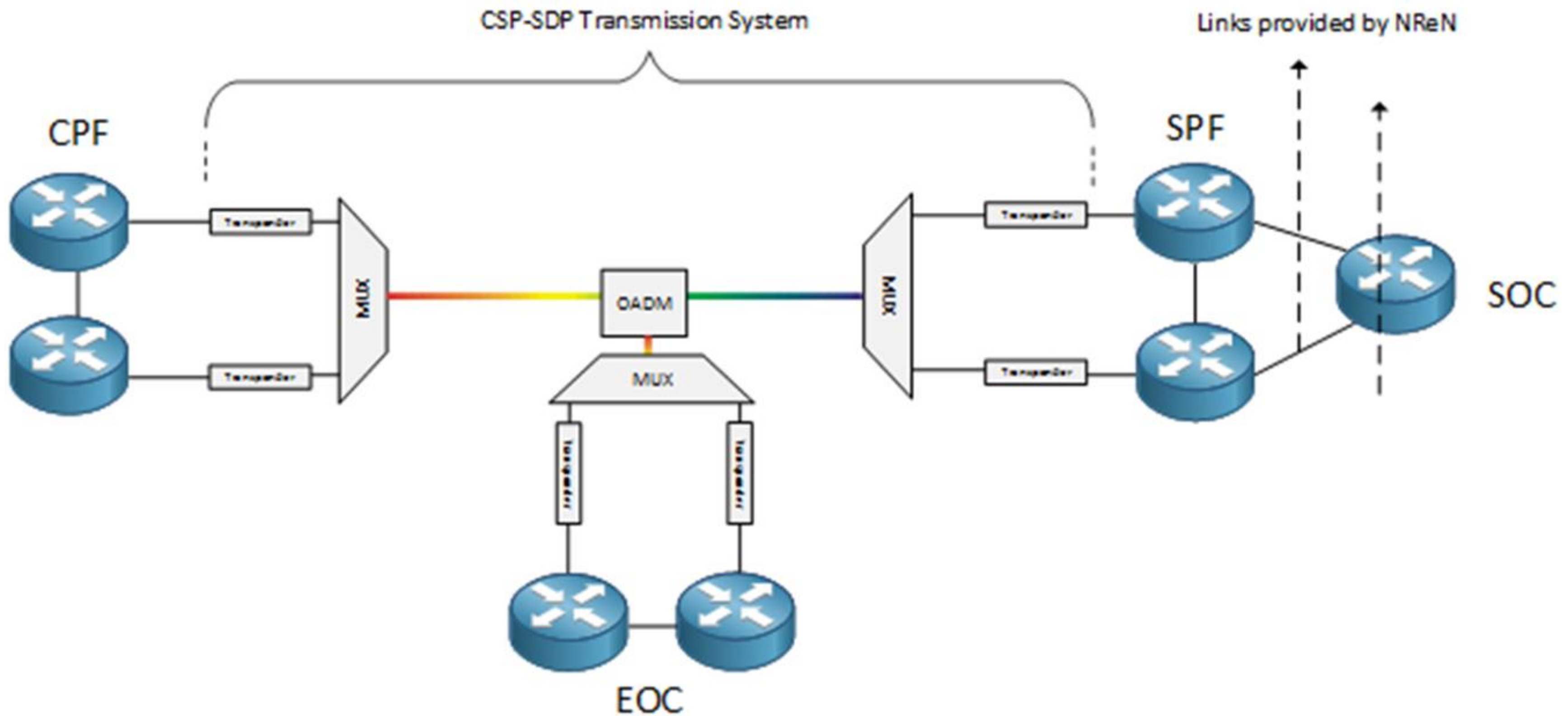


SADT.NSDN Non-Science Data Network
Preliminary Detailed Design concept at CPF



SADT.NSDN Non-Science Data Network
NSDN WAN Transmission across CSP-SDP

- Similar approach for Australia and South Africa



Geraldton/
Klerefontein

Perth/
Cape Town

NMGR

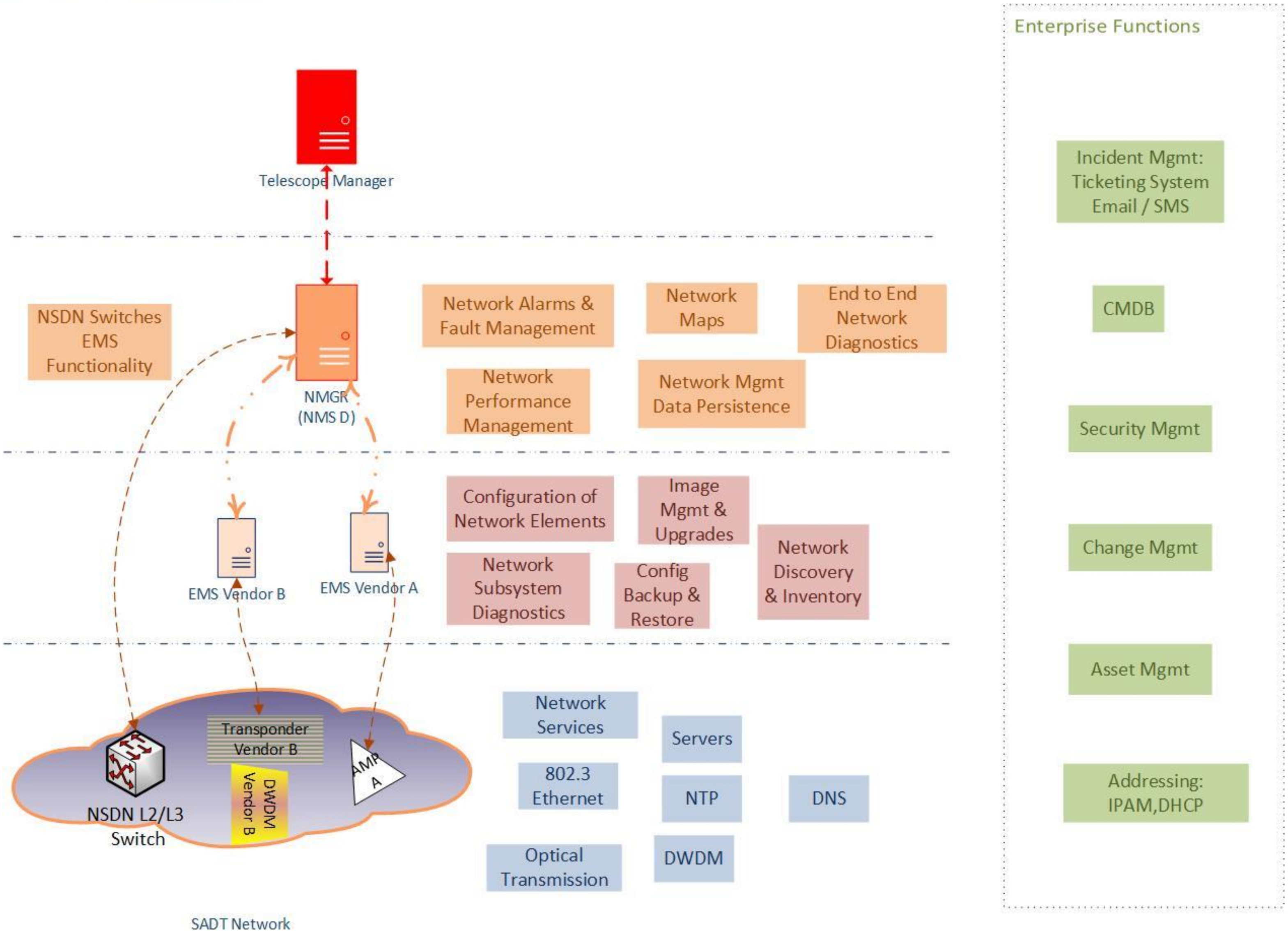
SADT Network Manager

SKA.TEL.SADT.NMGR Network Manager

The SADT.NMGR sub element is responsible for monitoring and controlling the DDBH, NSDN, CSP-SDP networks and their associated infrastructure at the receptor array, CPF, EOC, SOC and SDP.

The role of network management includes the configuration and setup of all the equipment (including hardware and software elements), monitoring health and performance parameters, optimizing the behaviour of the network and detecting and responding to adverse situations. Network monitoring and control interfaces are provided to operators and engineers, as well as to the Telescope Manager element. Engineers are provided with additional interfaces to facilitate troubleshooting, reconfiguration and upgrades.

SKA.TEL.SADT.NMGR Network Manager Management Layers



SADT.NMGR Network manager
Functionality In Scope for SADT NMGR

- **Fault Management**
  - Reception and processing of SNMP traps, Syslog messages, ICMP pings, etc.
  - Performing diagnostics
  - Performing monitoring for network devices, servers and applications.
- **Performance Management**
  - Polling regularly by SNMP (or other standard protocol) for performance counters.
  - Rolling up counters at predefined intervals
  - Storage of performance counters
- **Configuration Management**
  - Inventory management
  - Network maps
  - Configuration backup and restore
  - Configuration audits & compliance reports
  - Configuration templates & bulk configuration
  - Change automation
  - Change notifications
  - Scheduled tasks
  - Power cycle network element
  - Startup / shutdown card / port
  - Image file management
  - Software / firmware upgrade
- **Other Requirements for NMGR**
- Interfacing between SADT network and Telescope Manager in accordance with the SADT TM ICD & the LMC Common Interface Guidelines
- Performance requirement as per the L1 alarm latency requirement
- L1 availability requirement for SADT and the Telescope

SQUARE KILOMETRE ARRAY

SIGNAL AND DATA TRANSPORT

SAT.CLOCKS

Synchronisation & Timing: Clock Design

SKA.TEL.SADT.SAT.CLOCKS Clock Design

This work-package covers provision of the SKA reference timescale . There will be two similar realisations of the SKA reference timescale, one in South Africa and one in Australia.
A robust design is proposed for each timescale, based on the use of three active hydrogen masers as the reference clocks.

SKA.TEL.SADT.CLOCKS Clocks design
Clock System overview

Hydrogen Maser clock example ,at NPL UK

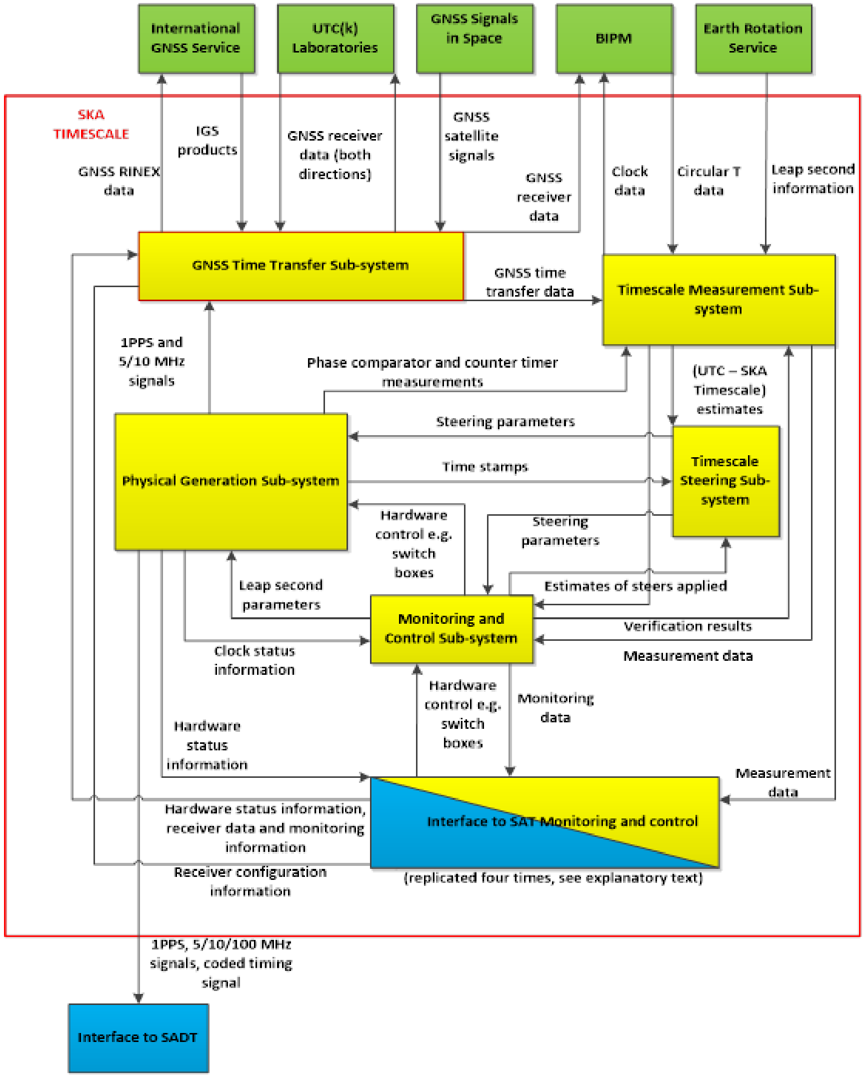
- Requirements:
  - Phase coherence of array
    → accuracy = 1ps
  - Long-term timing for pulsars
    → 10ns over 10 years
- “3 cornered hat” H-masers
- GNSS link to UTC

→ SKA time

- Baseline: 3 instances
- Stringent environmental requirements
- Incorporate existing site masers (TBC)

SKA.TEL.SADT.CLOCKS Clocks design
SKA Timescale block diagram

SKA TIMESCALE: BROKEN DOWN INTO SUB-SYSTEMS



SAT.STFR

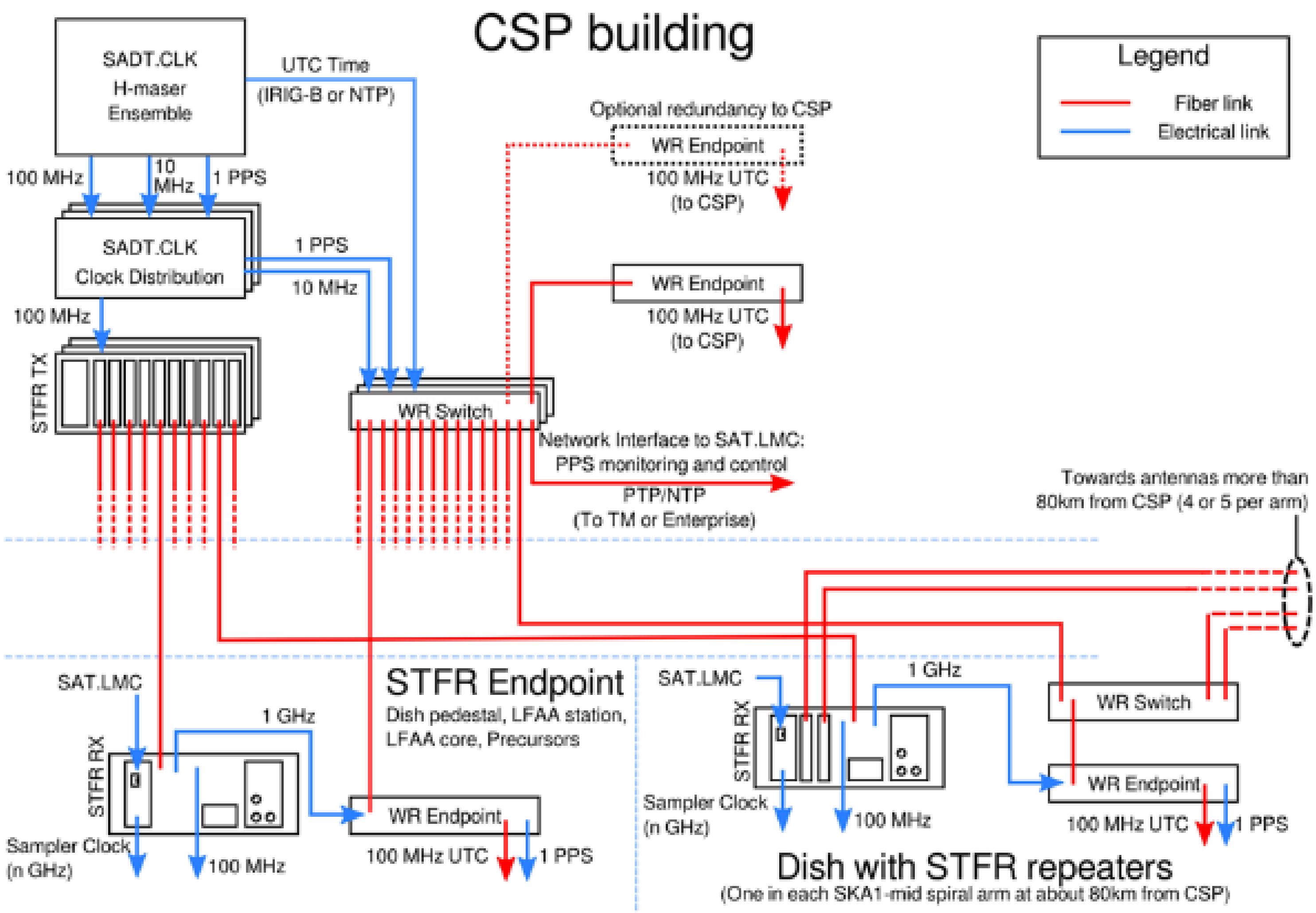
Synchronisation & Timing : Station Time and Frequency Reference

SADT.SAT.STFR Station Time & Freq Reference

The SAT.STFR (Synchronisation and Timing – Station Time and Frequency Reference) carries out the function of delivering standard frequency references and timing signals derived from the SKA frequency and timescale reference (SAT.CLOCKS) to the receptors and other locations. The reference signals must be delivered with sufficient precision to enable each of the telescopes

i. to be phase-coherent
ii. to support the demanding requirements on absolute time for scientific observations such as pulsar timing on timescales of decades
iii. to distribute absolute time for system management, antenna pointing, beam steering, time stamping of data and producing regular timing ticks
iv. to provide frequency standards for digitizer clocks
v. To provide time and frequency accurate enough for VLBI observations.

SADT.SAT.STFR Station Time & Freq Reference
Frequency & time distribution overview



SAT.STFR
Synchronisation & Timing : STFR.FRQ
Frequency Distribution

SADT.SAT.STFR.FRQ Frequency Distribution Concept A: System diagram & performance

SIGNAL AND DATA TRANSPORT

System schematic

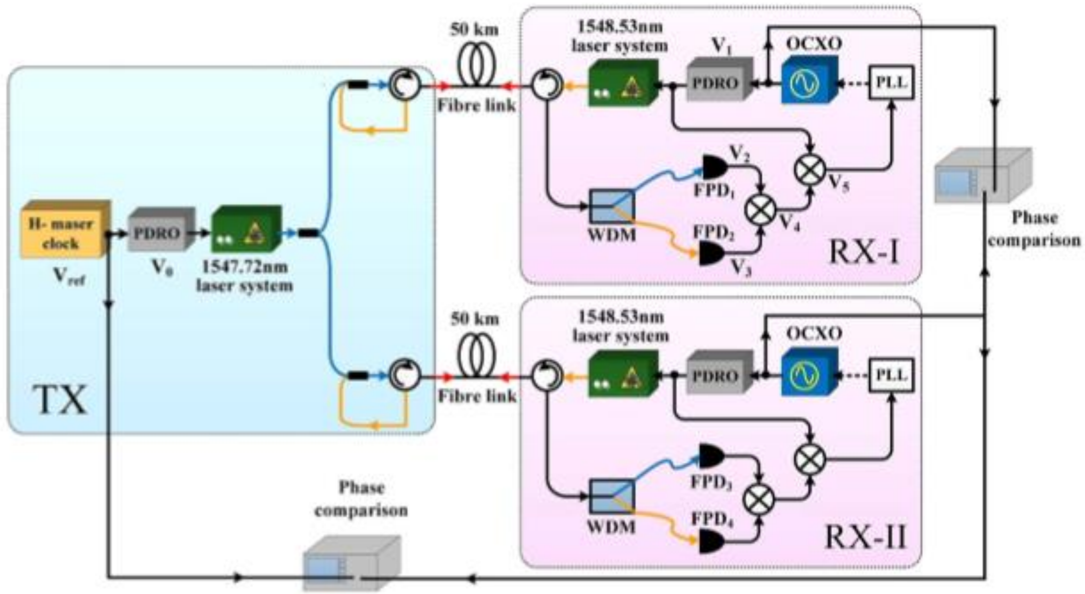


Figure 1. Schematic diagram of the client-side, 1f-2f actively compensated frequency dissemination system. PDRO: phase-locked dielectric resonant oscillator. OCXO: oven-controlled crystal oscillator. WDM: wavelength-division multiplexer. FPD: fast photodiode.

Performance

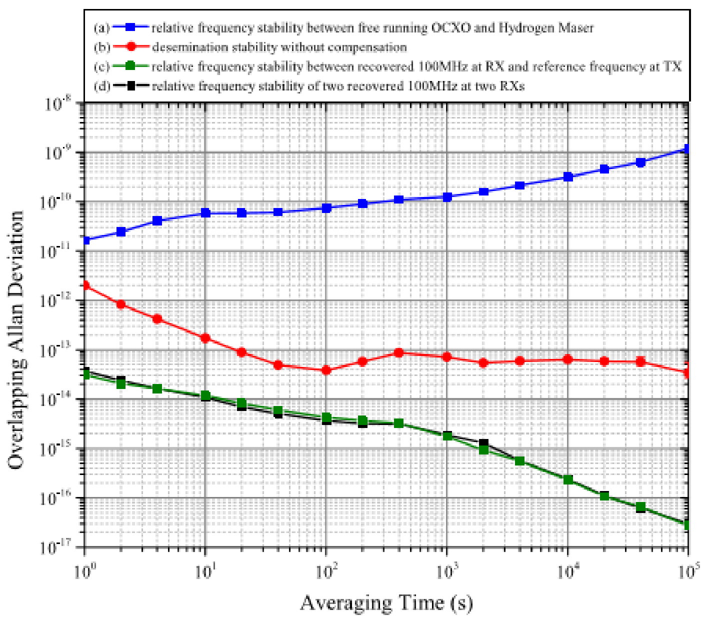
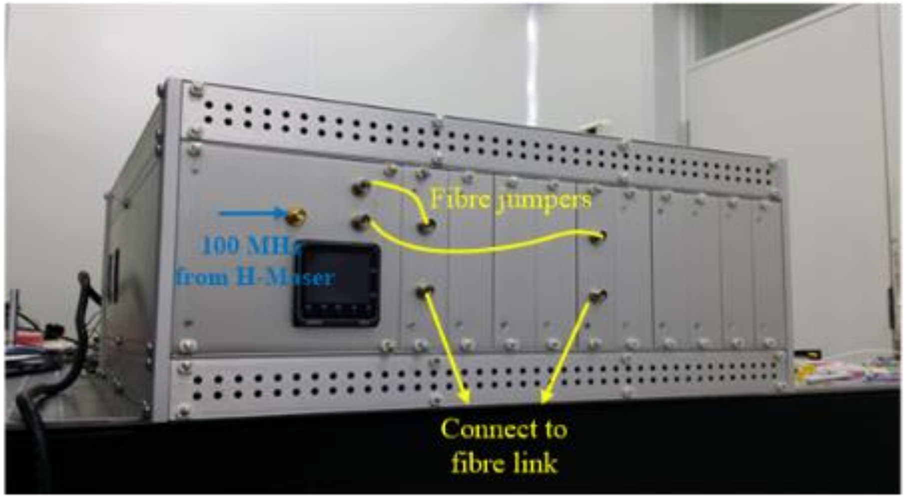


Figure 2. Results of relative frequency stability measurements. **(a)** Relative frequency stability between the free-running OCXO and H-maser clock. **(b)** Measured frequency stability of the dissemination system without compensation. **(c)** Relative frequency stability between the recovered 100-MHz signal at RX and V_{ref} at TX with the PLL closed. **(d)** Relative frequency stability of the two recovered 100-MHz signals at the two RX sites with both PLLs closed. Curves **(c,d)** were measured simultaneously.

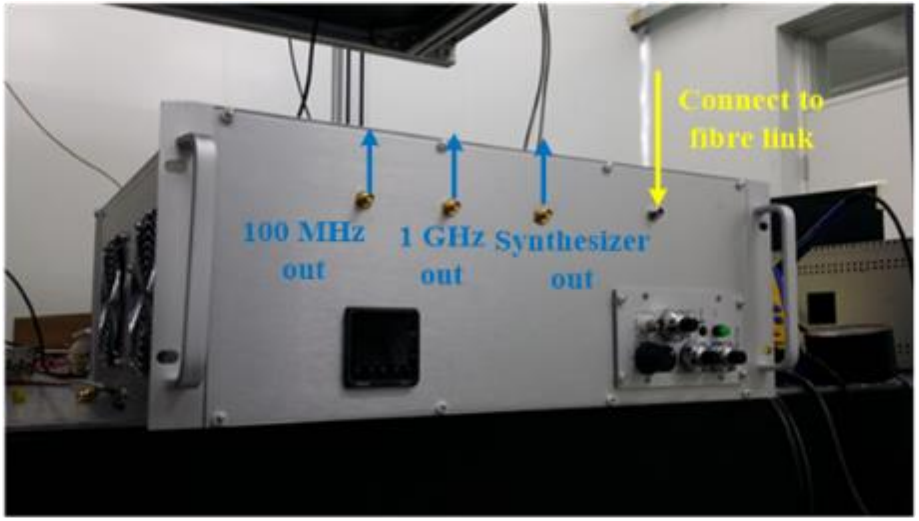
Ref: "Square Kilometre Array Telescope—Precision Reference Frequency Synchronisation via 1f-2f Dissemination", 2015, www.nature.com/scientificreports/

SADT.SAT.STFR.FRQ Frequency Distribution
Concept A: STFR Prototypes for field testing

Concept Prototype Transmitting Module



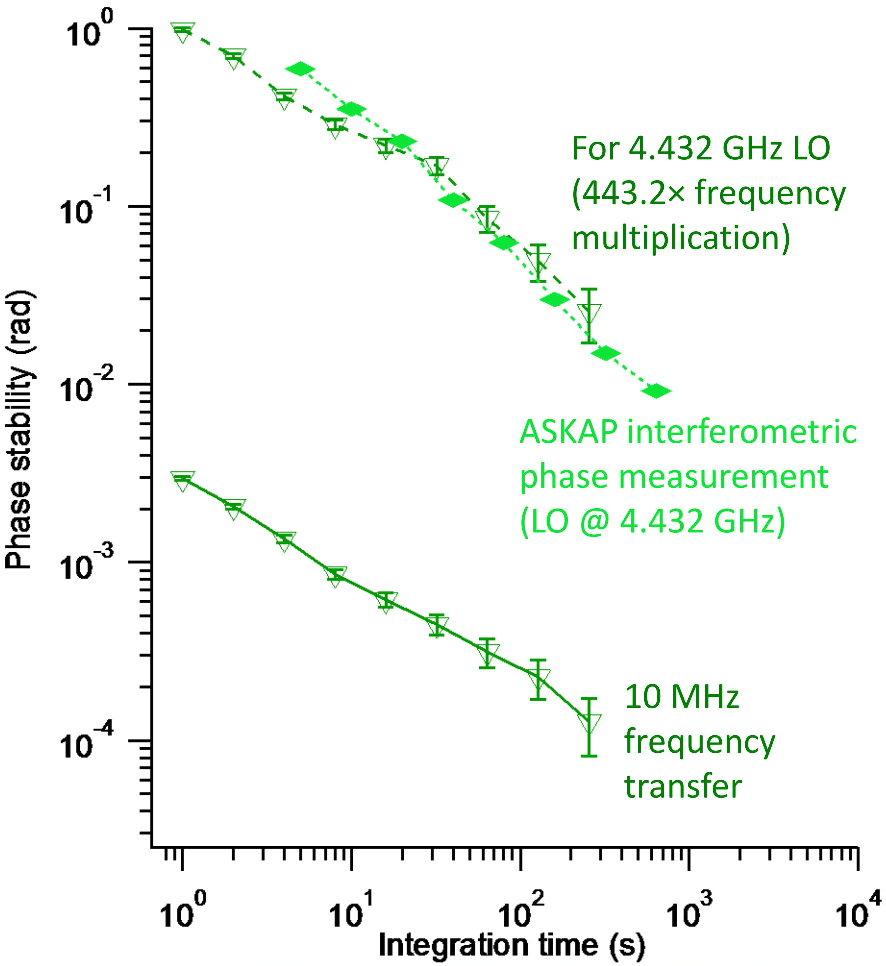
Concept Prototype Receiving Module

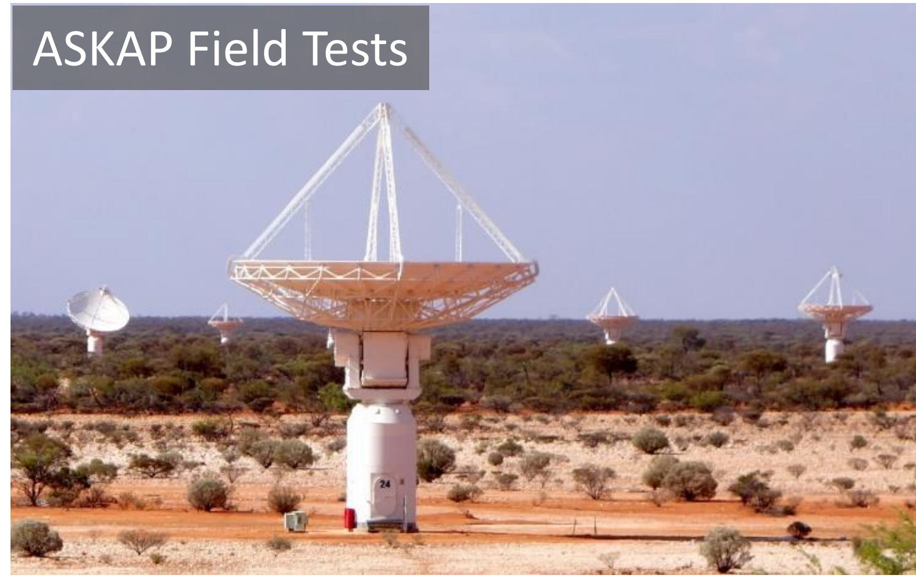


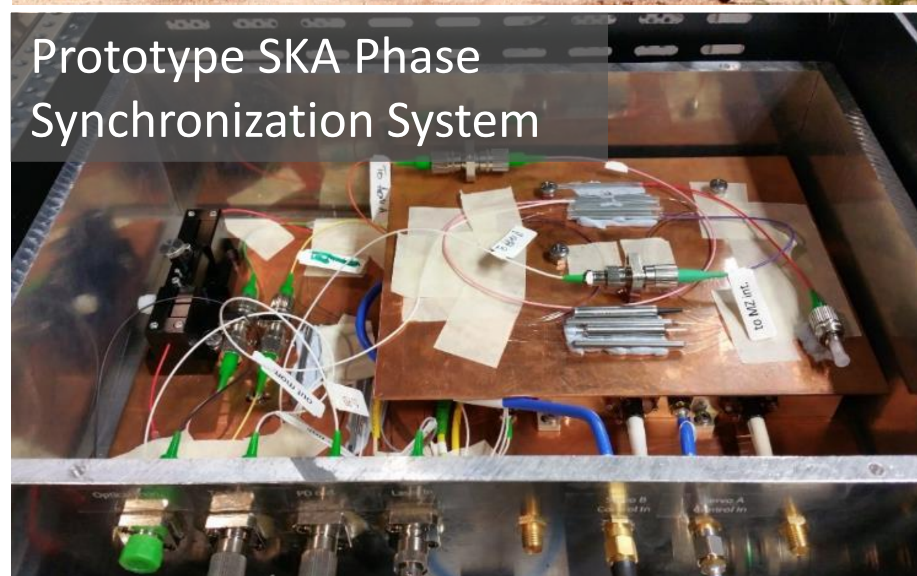
SADT.SAT.STFR.FRQ Frequency Distribution
Concept B: Astronomical Verification with ASKAP

Measured SKA phase synchronization system optical fibre transfer stability

- Astronomical verification of stability



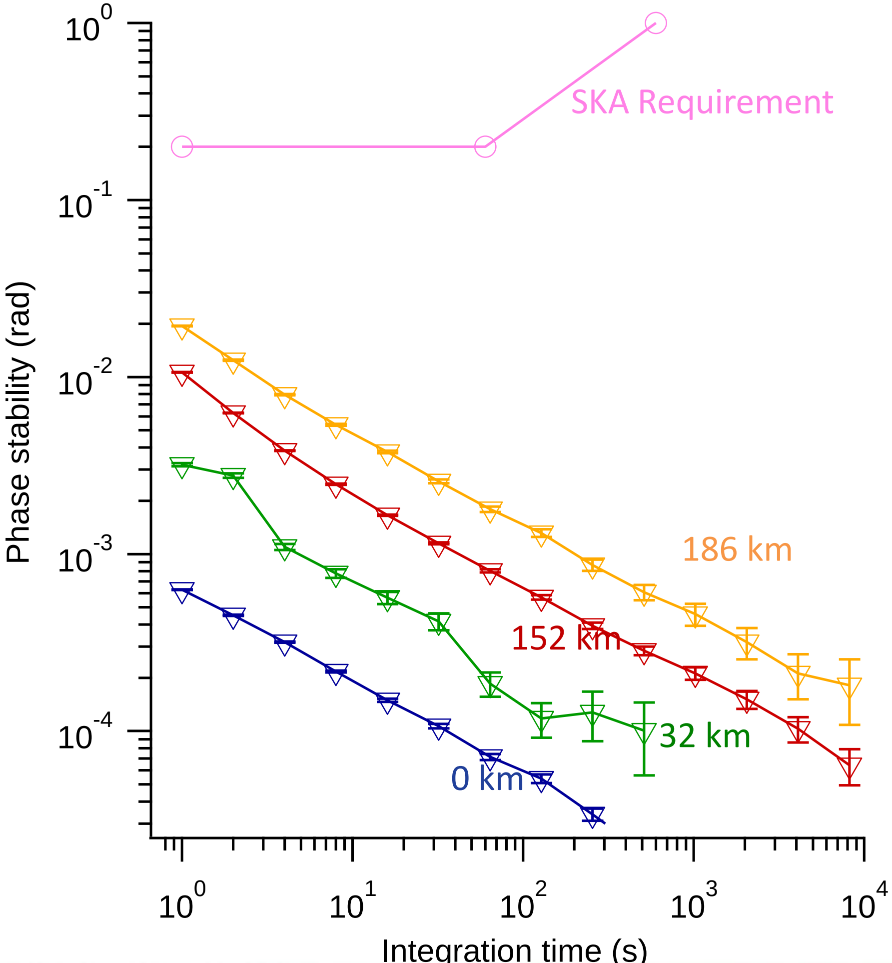




SADT.SAT.STFR.FRQ Frequency Distribution Concept B: South Africa Overhead Fibre Tests

Measured SKA phase synchronization system optical fibre transfer stability

- On overhead optical fibre links



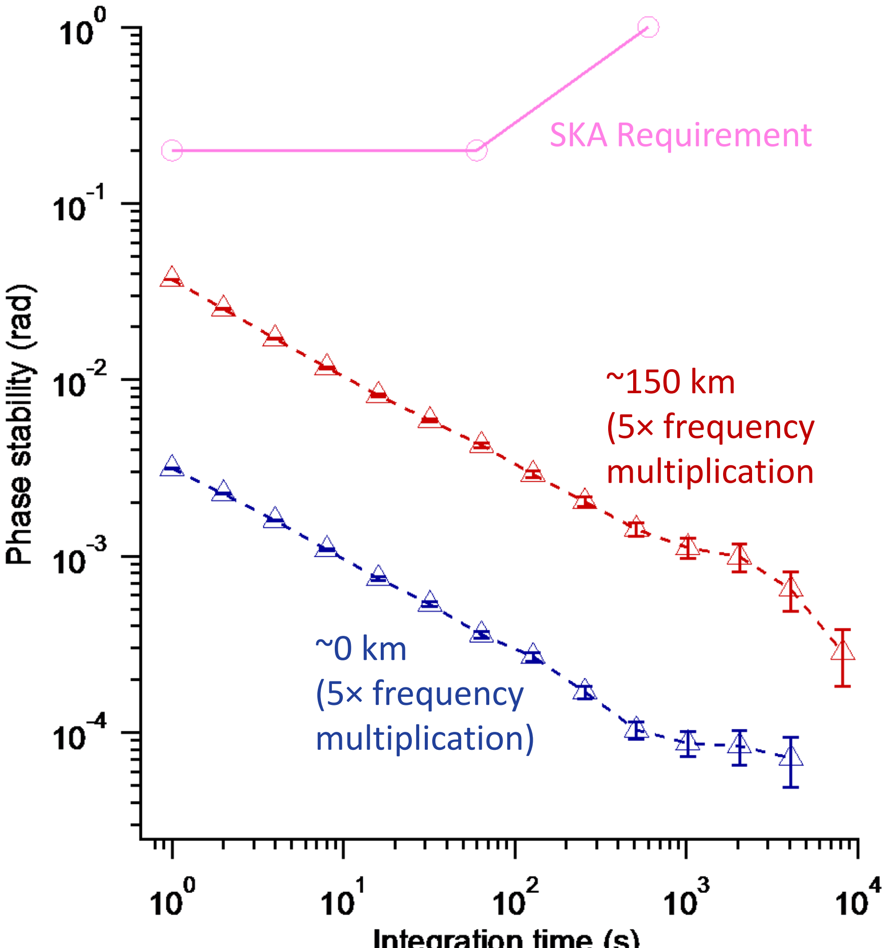
South African SKA Site Overhead Fibre

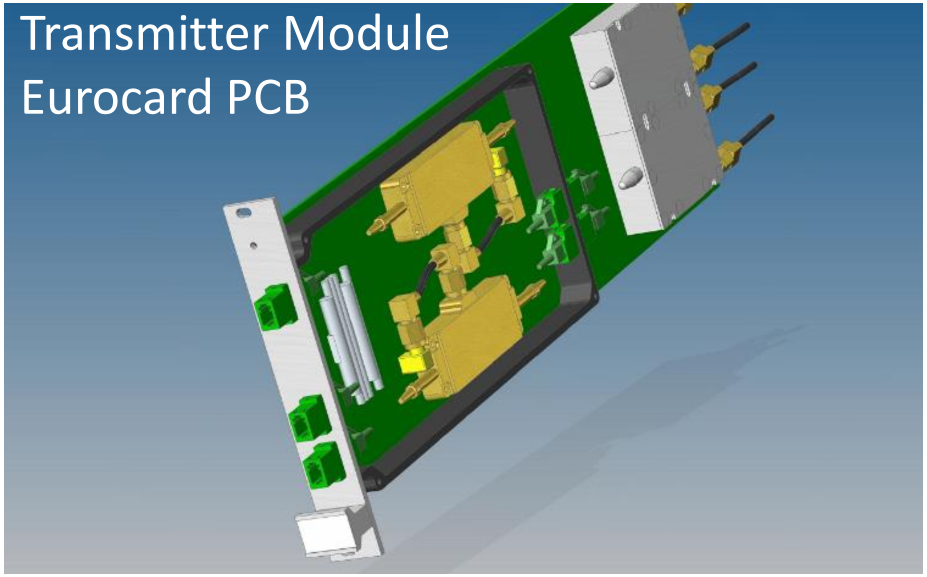
Prototype SKA Phase Synchronization System

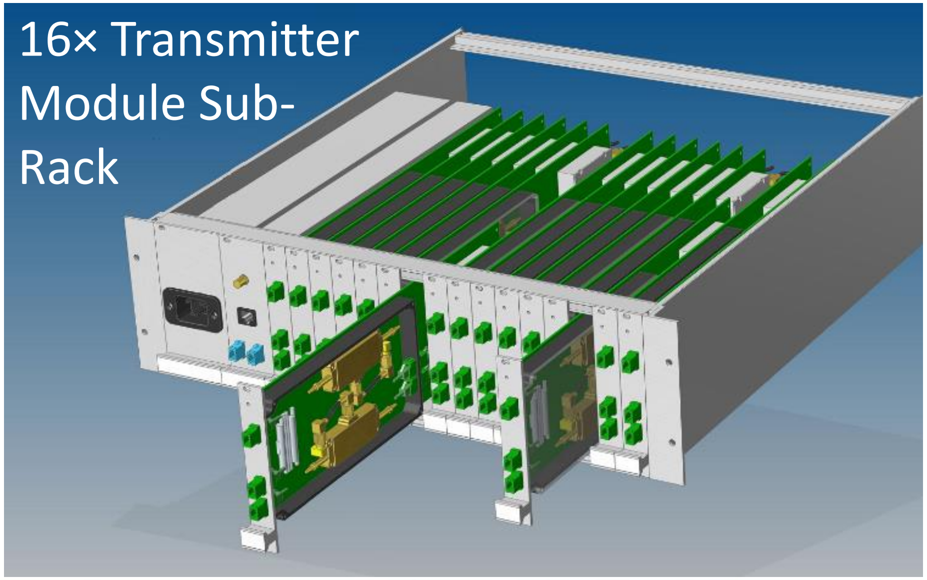
SADT.SAT.STFR.FRQ Frequency Distribution
Concept B: Design to Manufacture Development

Expected SKA phase synchronization system optical fibre transfer stability

- Short and long link examples







SAT.STFR

Synchronisation & Timing : STFR.UTC

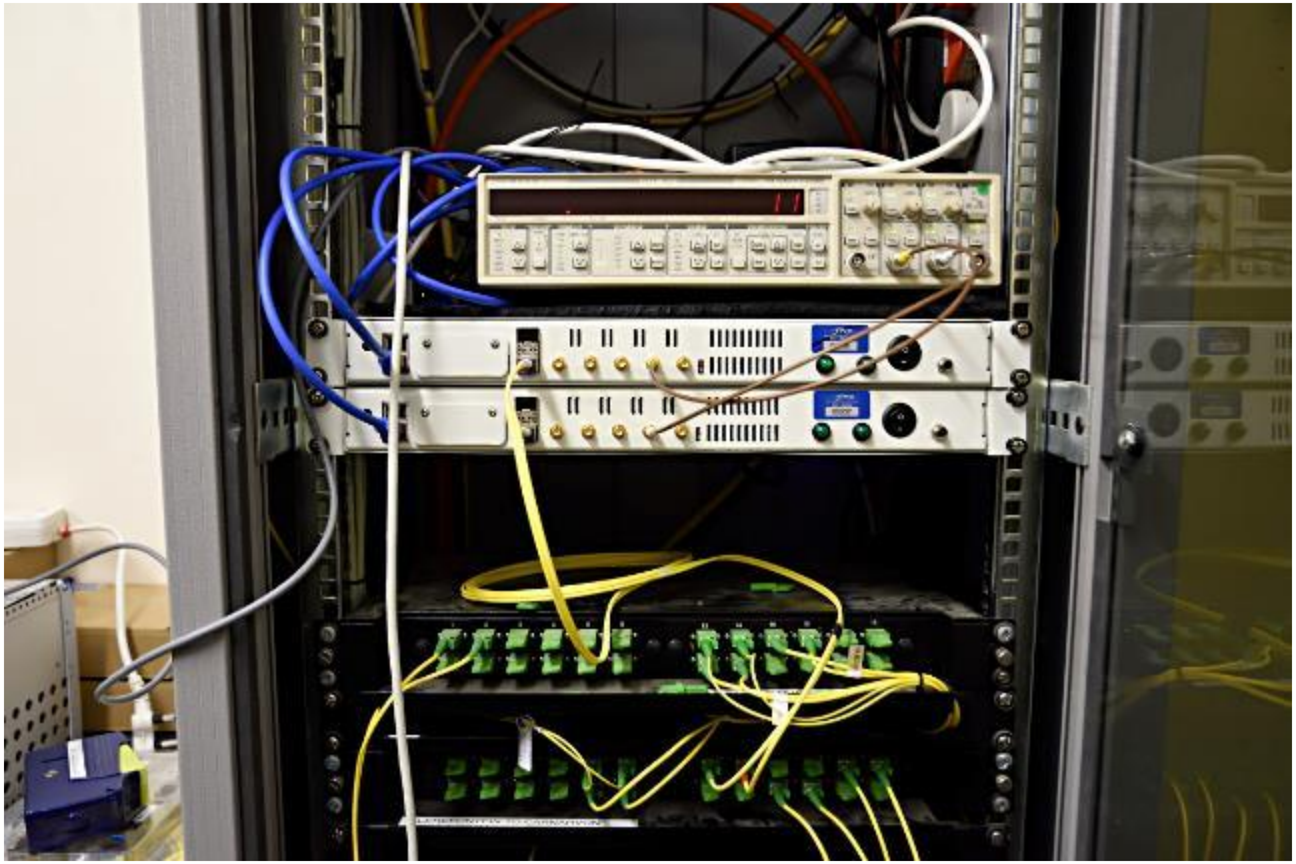
Time Distribution

SADT.SAT.STFR.UTC Time Distribution

- 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

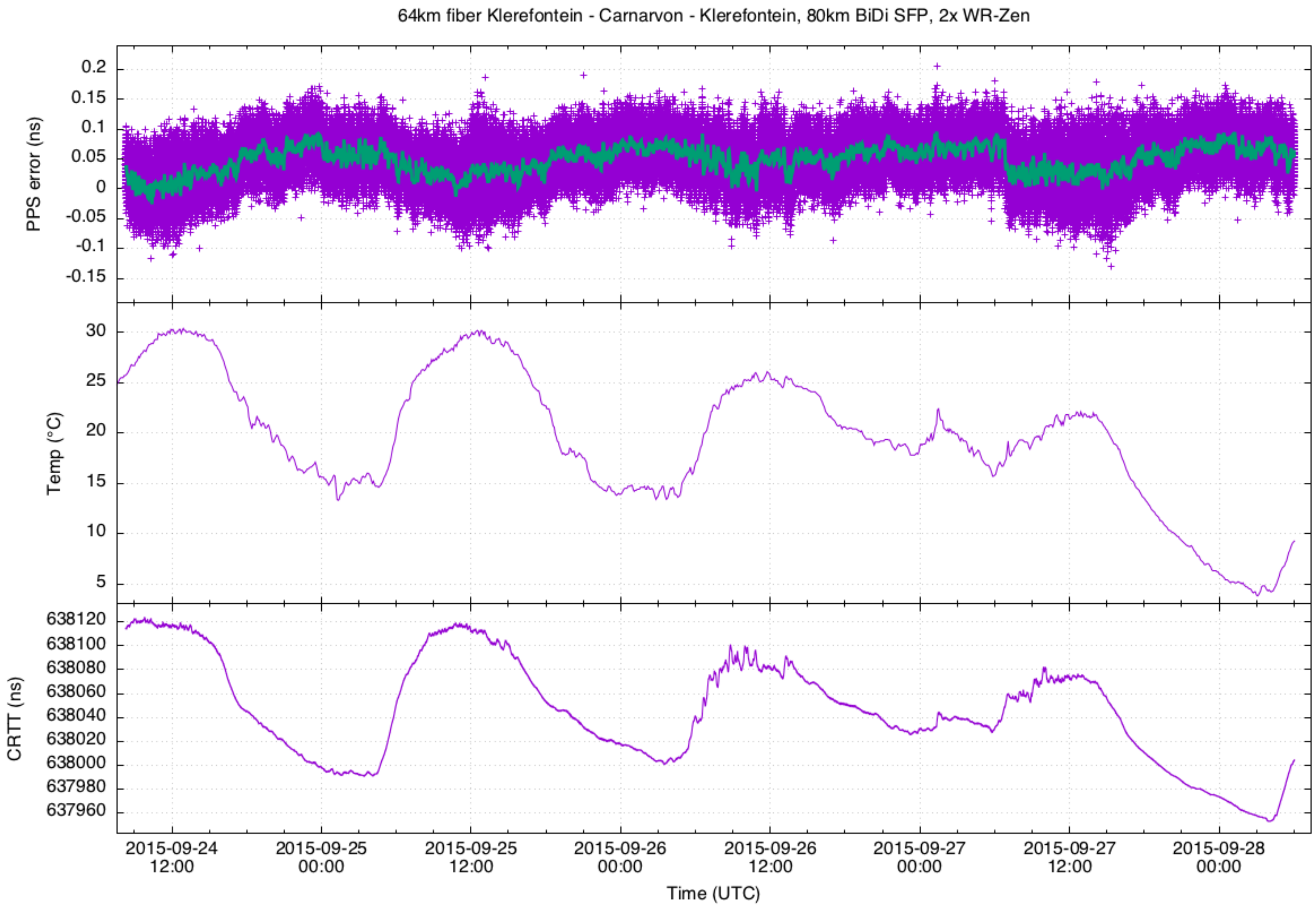
- Sub-ns accuracy demonstrated to hold even on overhead fibre in South Africa
- Can meet SKA timing requirement even at the most remote dishes.

SADT.SAT.STFR.UTC Time Distribution
Prototype equipment for field testing



- Time distribution prototypes (White Rabbit equipment) used for overhead cable field testing in South Africa

SADT.SAT.STFR.UTC Time Distribution
Time distribution field test results



- Performance logged over several days. 64km overhead cable
  - Compensated PPS variations are well below 1ns
  - Correlation between uncompensated Round Trip Time (CRTT) and outside temperature

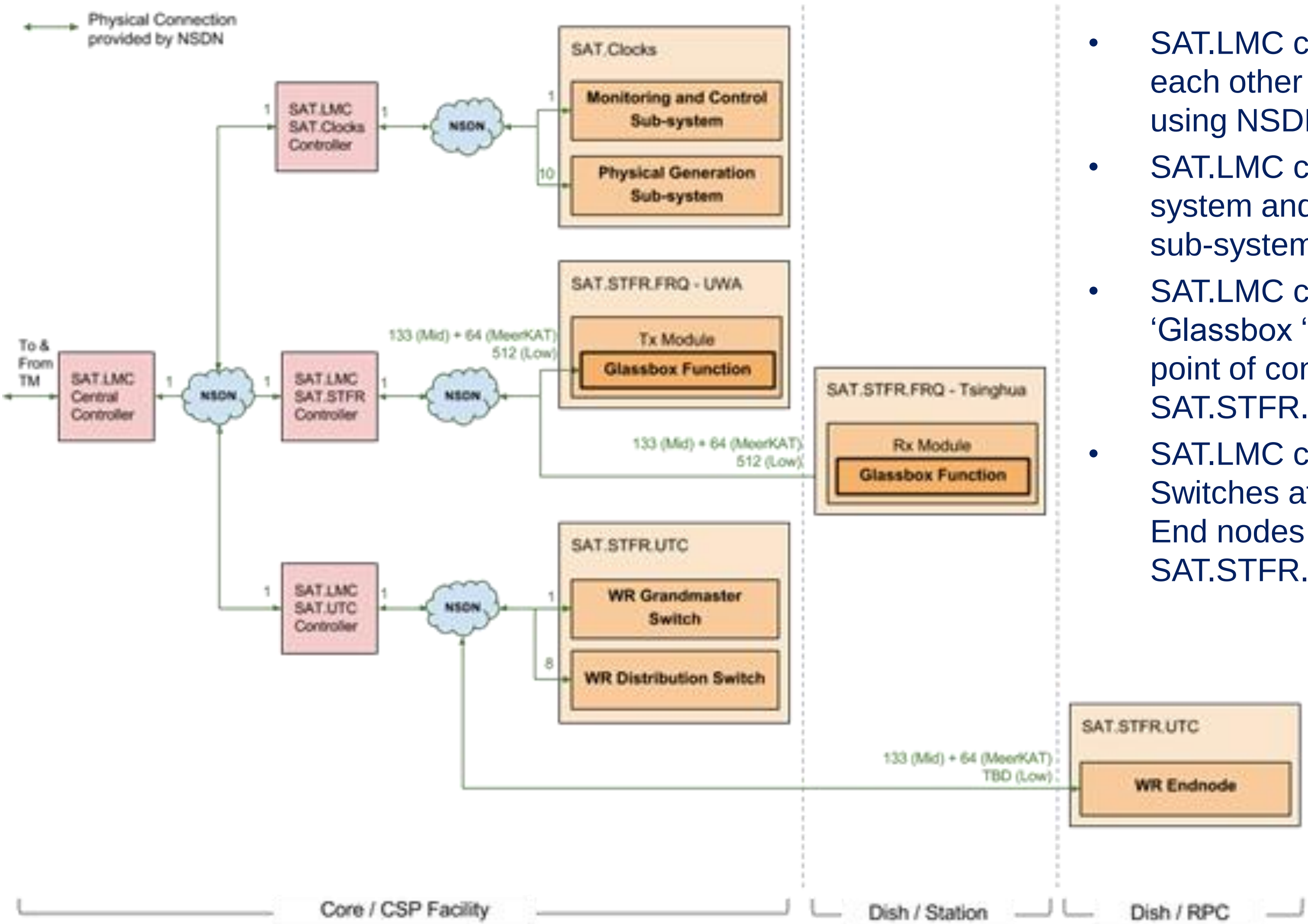
SAT.LMC

Synchronisation & Timing : Local Monitoring & Control

SADT.SAT.LMC
Local Monitoring & Control

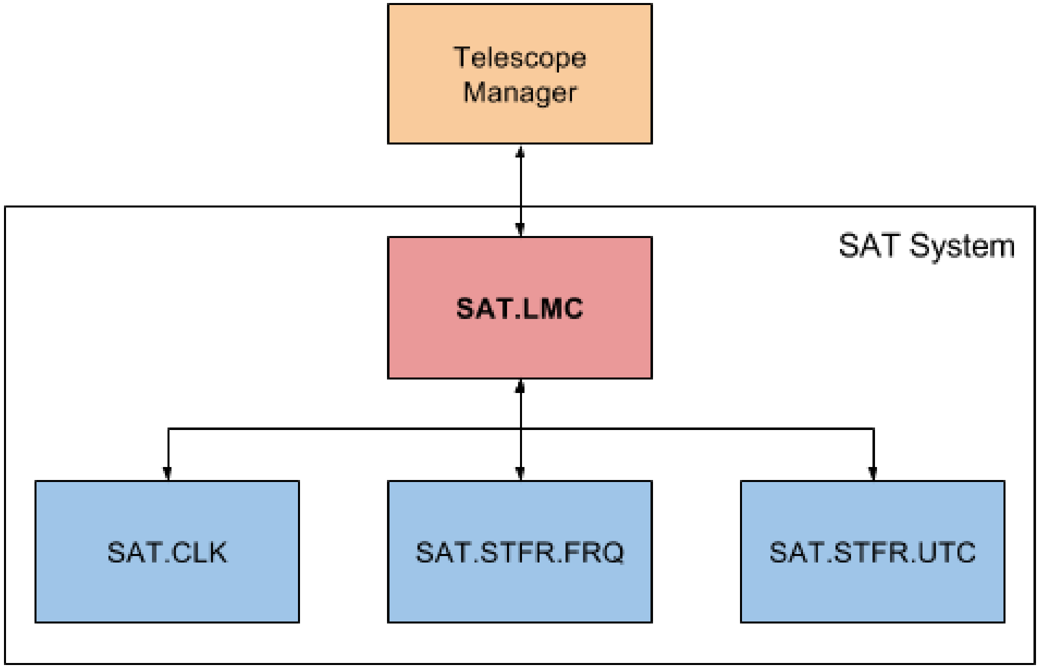
- The SAT.LMC will provide monitor and control functionality to the SAT.CLOCKS, SAT.STFR.FRQ and SAT.STFR.UTC sub-systems of the SAT system. This includes the configuration and setup of all the equipment (including hardware and software components), monitoring health and performance parameters, and detecting and responding to adverse situations.

SADT.SAT.LMC SAT Local Monitoring & Control Overview



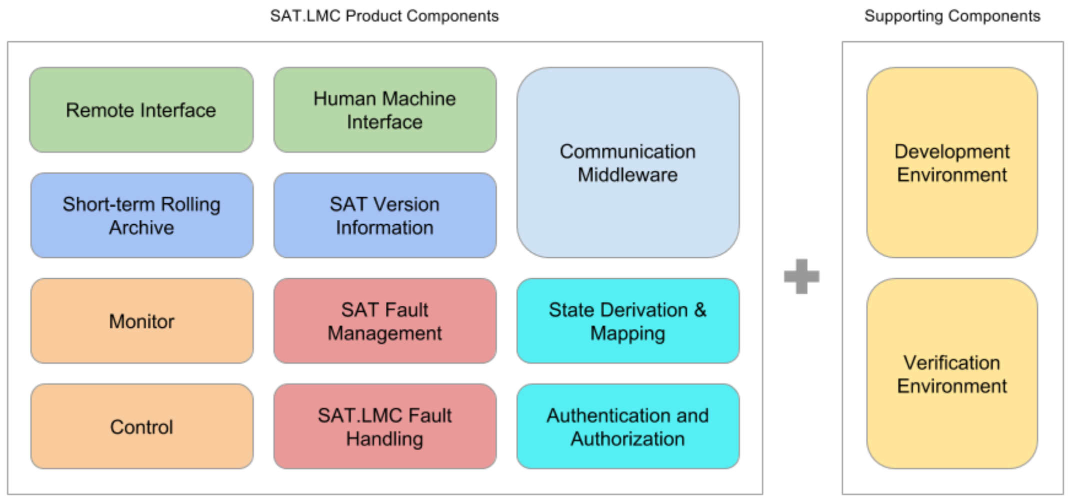
- SAT.LMC components connect to each other and SAT sub-systems using NSDN switches
- SAT.LMC connects to M&C sub-system and Physical Generation sub-system of SAT.CLOCKS
- SAT.LMC connects to the 'Glassbox 'Function as a single point of contact for SAT.STFR.FRQ sub-system.
- SAT.LMC connects with the WR Switches at the core and WR End nodes at the Dish / RPC of SAT.STFR.UTC sub-system

SADT.SAT.LMC
North & south bound interfaces



- Monitors and Controls SAT sub-systems (SAT.CLOCKS, SAT.STFR.FRQ and SAT.STFR.UTC)
- Receives command requests and sends monitoring data to TM
- Derives SAT operating state and translates to states understood by TM
- Hierarchical monitoring and control structure
- Coordinates alarm handling across SAT sub-systems
- Uses modular and compact PC104 industrial PCs as SAT sub-system controllers
- Software a major component and not hardware

SADT.SAT.LMC
Product component breakdown



- Monitor : Receive and send monitor data
- Control : Receive control commands from TM and send to SAT sub-systems
- Remote Interface : Interface to log into the SAT.LMC controllers from TM
- Human Machine Interface : Interface for the operator to login to the SAT.LMC controller
- Short-term Rolling Archive : Stores logs for the last 24 hours
- SAT Version Information : Stores information on the versions of S/W, H/W and F/W for SAT sub-systems
- SAT Fault Management : Handles faults across SAT sub-systems.
- SAT.LMC Fault Handling : Handles faults generated by SAT.LMC
- State Derivation & Mapping : Derives SAT state from SAT sub-systems and translates to TM state
- Authentication & Authorization : Authorizes and authenticates users for SAT.LMC

- Development Environment : Contains tools to develop SAT.LMC
- Verification Environment : Contains tools, scripts etc. to verify SAT.LMC

SKA
SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

Other Information

Re-Baselining & Past/Future events

Re-Baselining Statement (RBS), March 2015
Impacts on SADT

SKA SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT

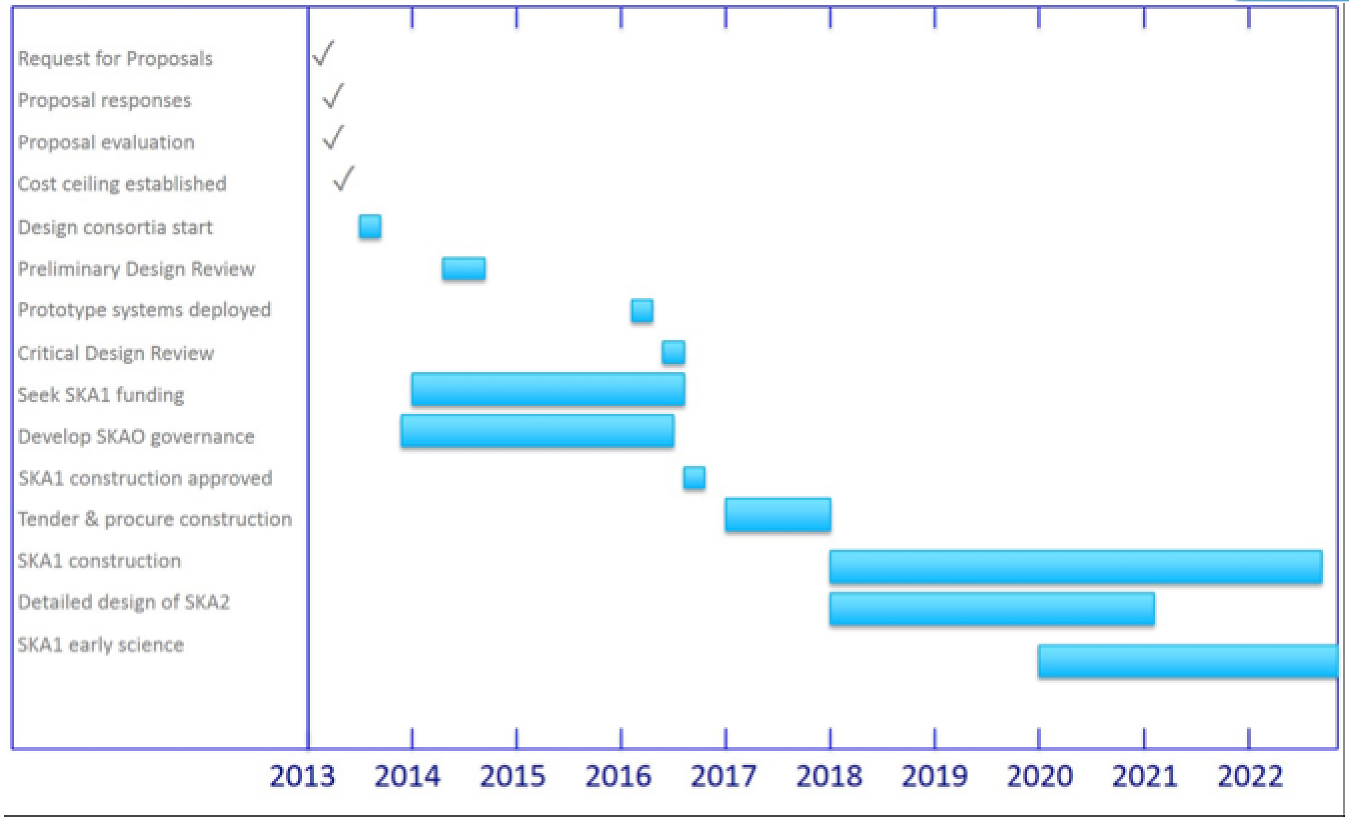
Item	SKA1 Mid		Item	SKA1-Low	
	BD V1 →	BD V2		BD V1 →	BD V2
Number of dishes	190	133	Number of dipoles	262144	131072
			Number of stations	1024	512
			Antennas per station	256	256
Receiver bands	1,2,3,4,5	2,5,1			
Frequency range	0.35-13.8 GHz	0.35-13.8 GHz		50-350 MHz	50-350 MHz
Baseline lengths	150km	150 (120) km	Baseline lengths	80km (70 TBC)	80 km (70 TBC)
			Remote stations built first to demonstrate calibration		
			Remote Station distribution	spiral	More uniform (random?)
Spectral channels		65536	Spectral channels		65536

Impacts from RBS

- Deferring SKA1_Survey
- Reducing the number of stations and dishes
- Reducing the number of frequency bands
- CSP-SDP required metadata now included in Re-Baselining
- Pulsar beams in SKA1_Low & SKA1_Mid

SKA1 Schedule and Recent Events - original

SKA SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT



- Completed Preliminary Design and Costing
  - Elements had external reviews end of 2014
- SKAO made a re-baselining exercise to fit the € 650 M cost cap.
  - SKA Board approval 9th March 2015
- Critical Design Reviews to commence late 2016

SKA
SQUARE KILOMETRE ARRAY
SIGNAL AND DATA TRANSPORT