SKA & MeerKAT System Overview

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Context

Radar guy:

"*A radio telescope is half a radar (receive-only), on a stable ground-based platform, observing stationary targets*"

So what are the major challenges?

- Sensitivity — 1Jy = 10^{-26} W/m^2/Hz
- RF interference — >100dB shielding levels
- Data rates — 2Tbps into processor
- Processing speed — PetaFlop (10^{15}) processor (for SKA1)
- Imaging dynamic range — 10^6 :1

→ RF gain & phase stability
Pointing stability
Rotational stability

Overview

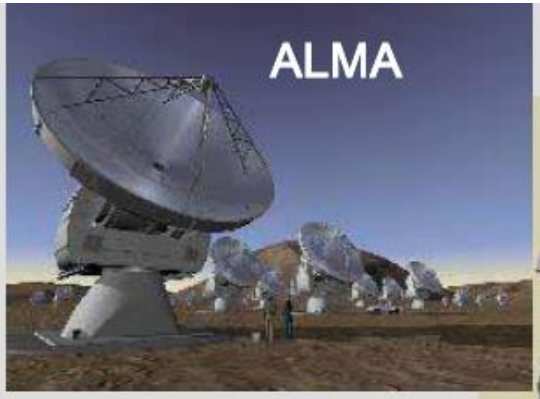
1. What is SKA & MeerKAT?
2. Project timeline
3. MeerKAT System
   - Overview
   - System components
   - Key performance areas

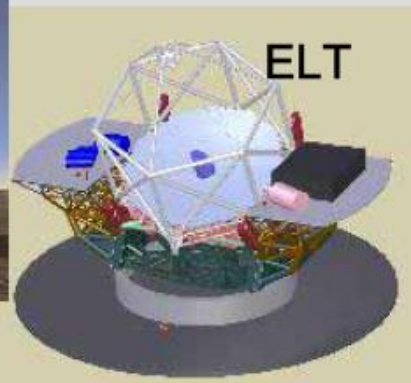
Overview

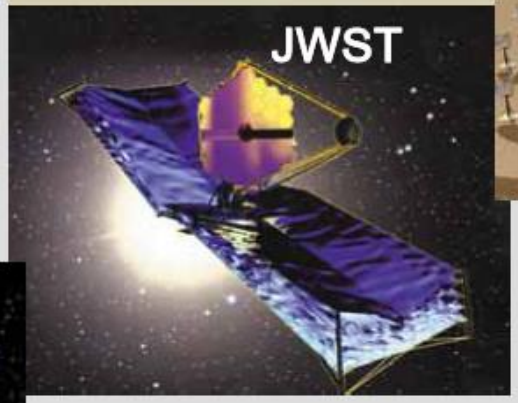
1. What is SKA & MeerKAT?

What is the Square Kilometre Array (SKA)?

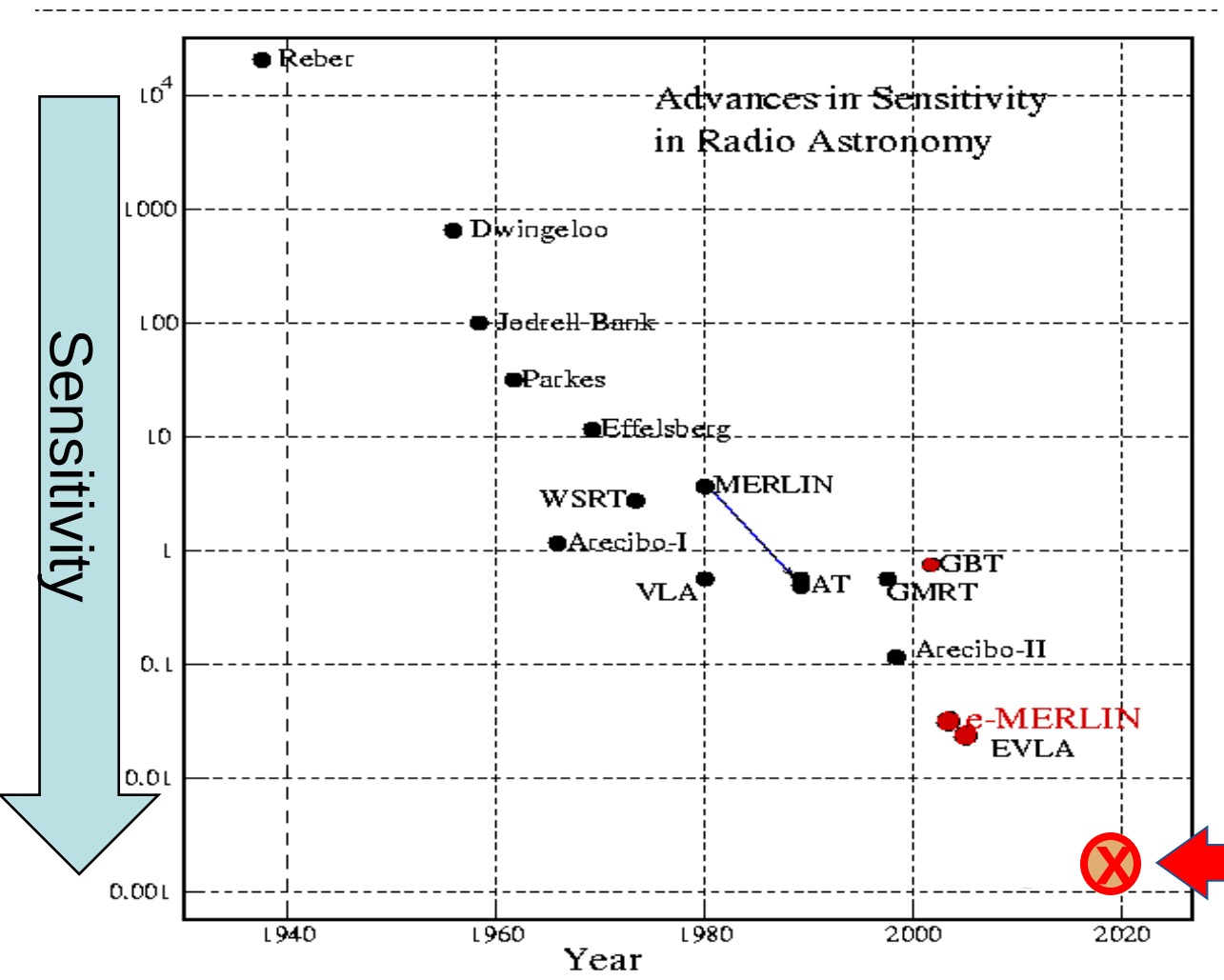
Next generation of astronomy instruments:







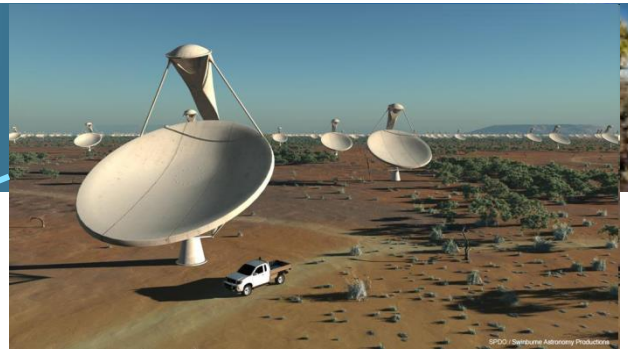
What is the Square Kilometre Array (SKA)?



Key science:

- Dark energy, Dark matter
- Origin of magnetism
- Cradle of life
- Evolution of galaxies
- The dark ages
- Tests of gravity

SKA overview



Sites:

- -South Africa
  - -~2000 dish array
  - -Mid frequency aperture array
- -Australia
  - -Low frequency aperture array

Global: 55 institutes, 20 countries involved.

- 12 paid-up member countries.

Budget: ~ € 1.5 Billion (for phases 1 & 2)

Timescale:

- -Site decision → 2012
- -Phase 1 (10% scale) → 2021
- -Phase 2 (full scale, low & mid frequencies) → 2025?

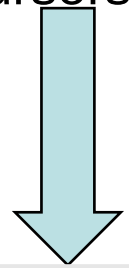
South Africa's role in SKA

South Africa's role in the SKA and build-up of the project:

a) SA is the preferred site, and will host the majority of the instrument.

b) Technology development: Prototypes & Precursors.

c) Take part in the SKA System development.



MeerKAT:

- 3% SKA
- SA funded
- World-class telescope (most sensitive in its frequency range)

Overview

1. What is SKA & MeerKAT?
2. Project timeline

Overview

XDM: Build | Operate

1 dish

Overview

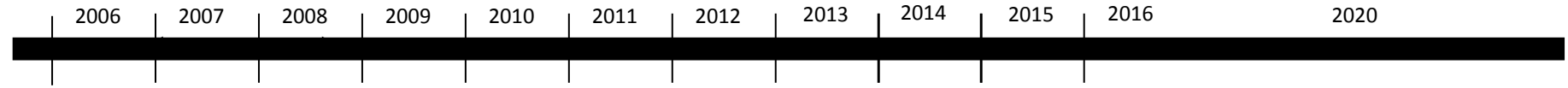
XDM: Build | Operate

KAT-7: Design | Build | Operate

7-dish array

Basic site infrastructure

Overview



XDM: Build | Operate

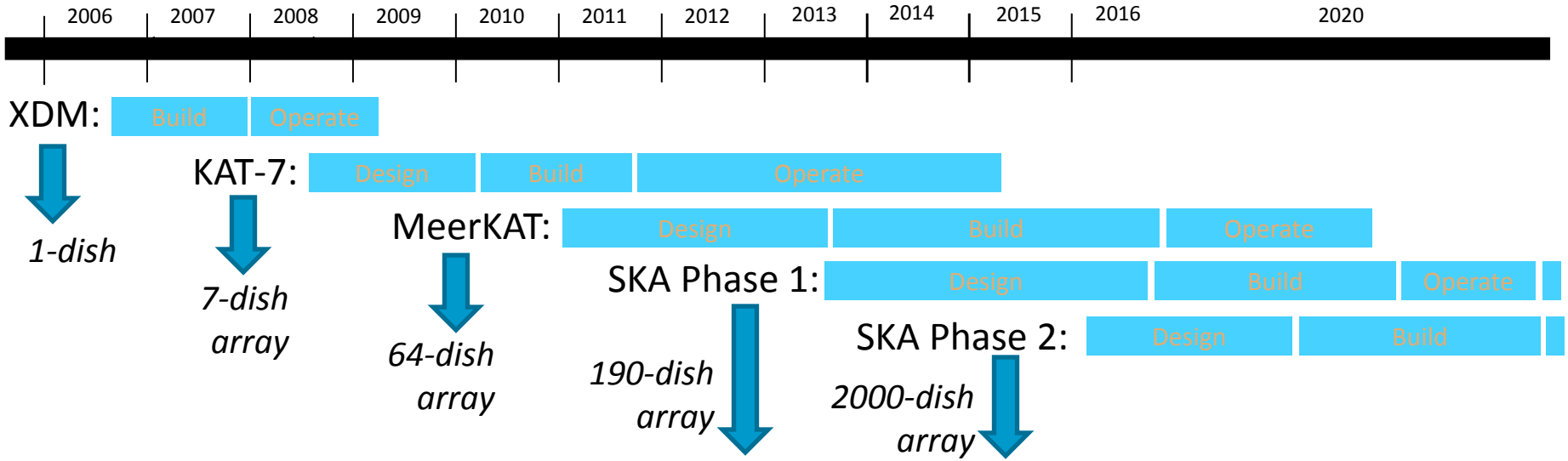
KAT-7: Design | Build | Operate

MeerKAT: Design | Build | Operate

64-dish array

Data processing facility

Overview


2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2020
XDM:
Build
Operate
1-dish
KAT-7:
Design
Build
Operate
7-dish array
MeerKAT:
Design
Build
Operate
64-dish array
SKA Phase 1:
Design
Build
Operate
190-dish array
SKA Phase 2:
Design
Build
2000-dish array

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Driving Requirements

Use cases

- Imaging
- Pulsar timing
- Transients

Requirements

Survey speed

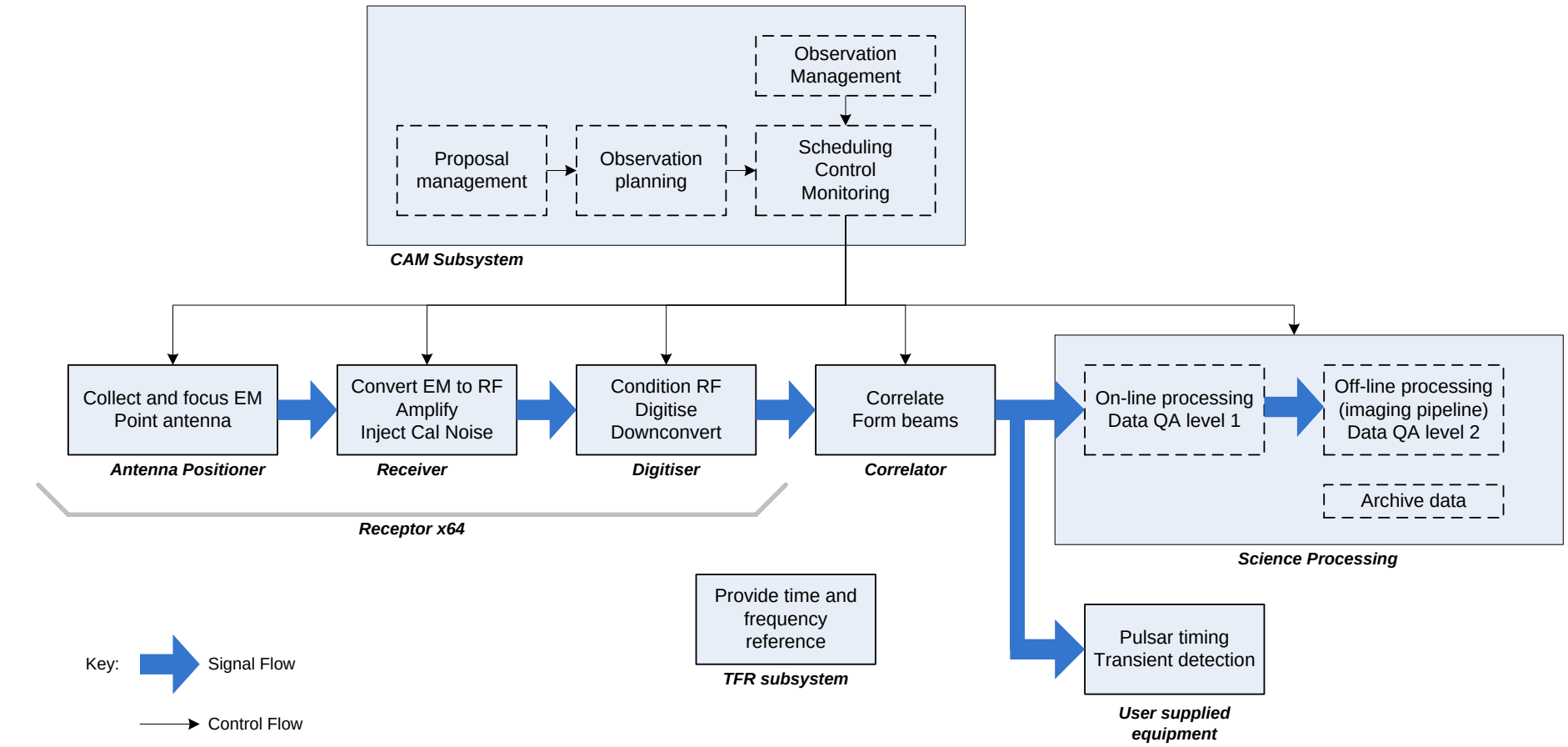
- Sensitivity (compact structures)
- Sensitivity (extended structures)
- Field of view
- Imaging dynamic range
- Bandwidth
- Slew speed
- Concurrent observation modes

Budget

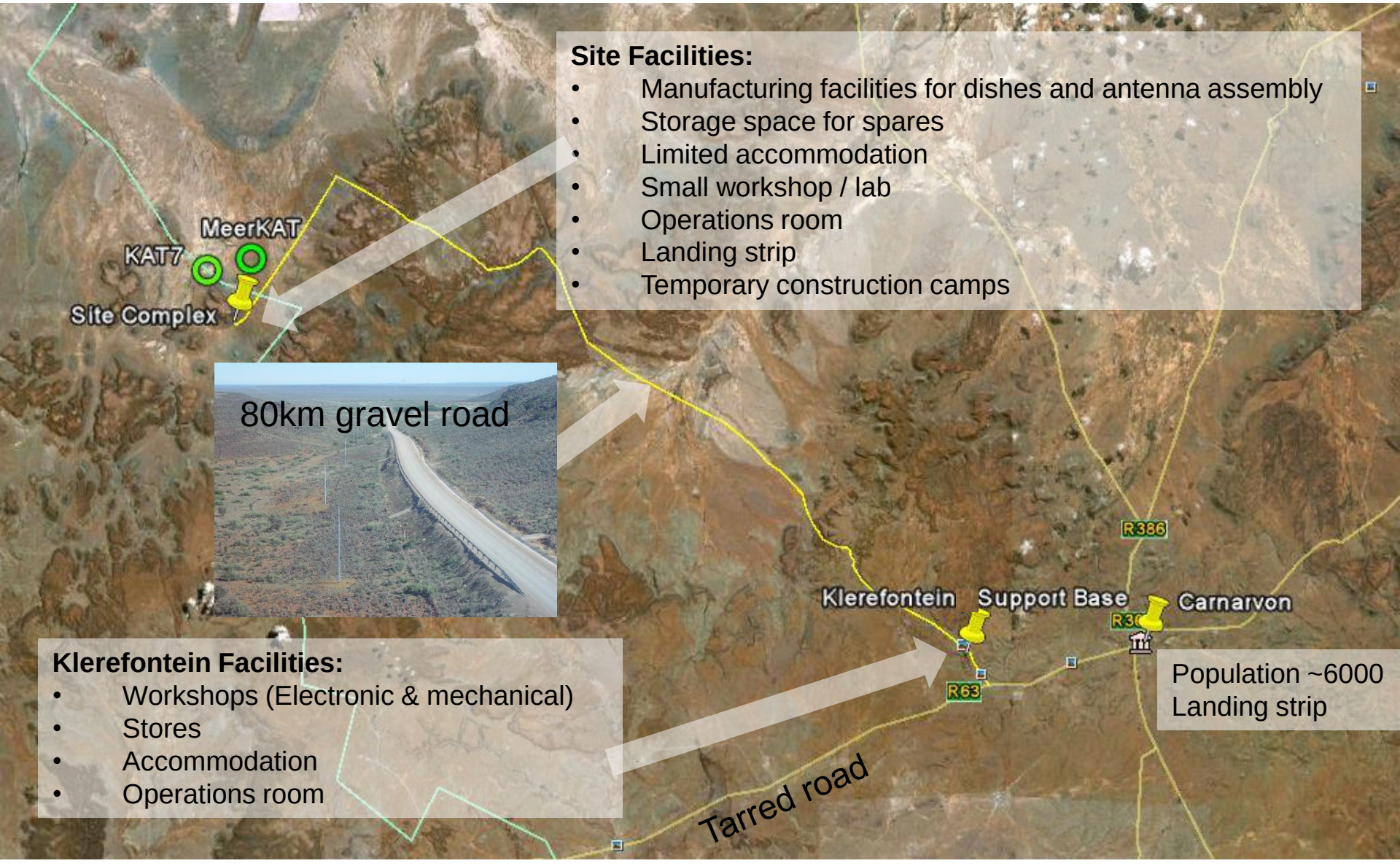
Solution

- Small-ish dishes
- Sensitive receivers
- Array configuration
- Wideband back-end
- Concurrent modes

System functional overview



Geographical layout



Site Facilities:

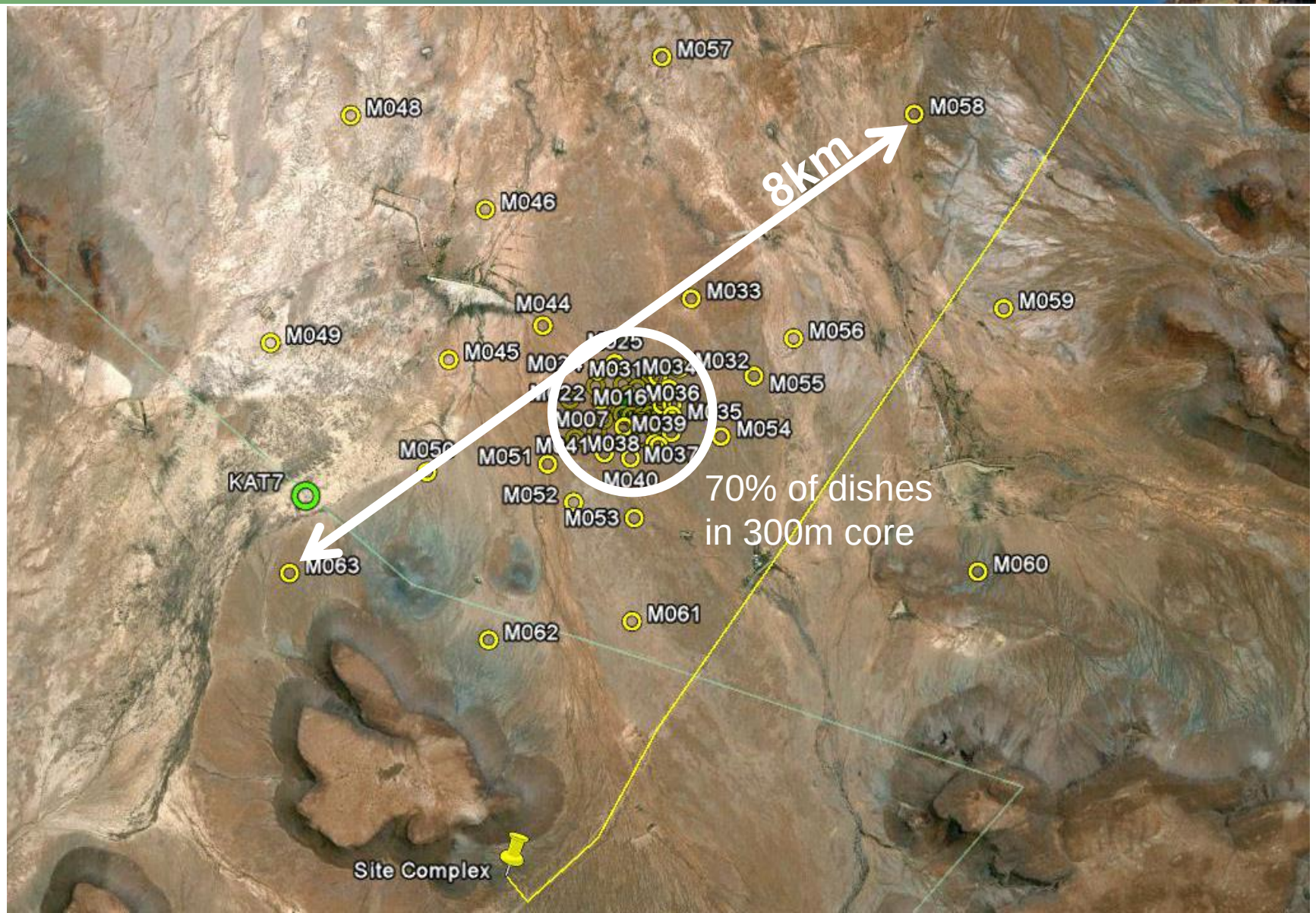
- Manufacturing facilities for dishes and antenna assembly
- Storage space for spares
- Limited accommodation
- Small workshop / lab
- Operations room
- Landing strip
- Temporary construction camps

Klerefontein Facilities:

- Workshops (Electronic & mechanical)
- Stores
- Accommodation
- Operations room

Population ~6000
Landing strip

Array layout



Receptor (antenna)

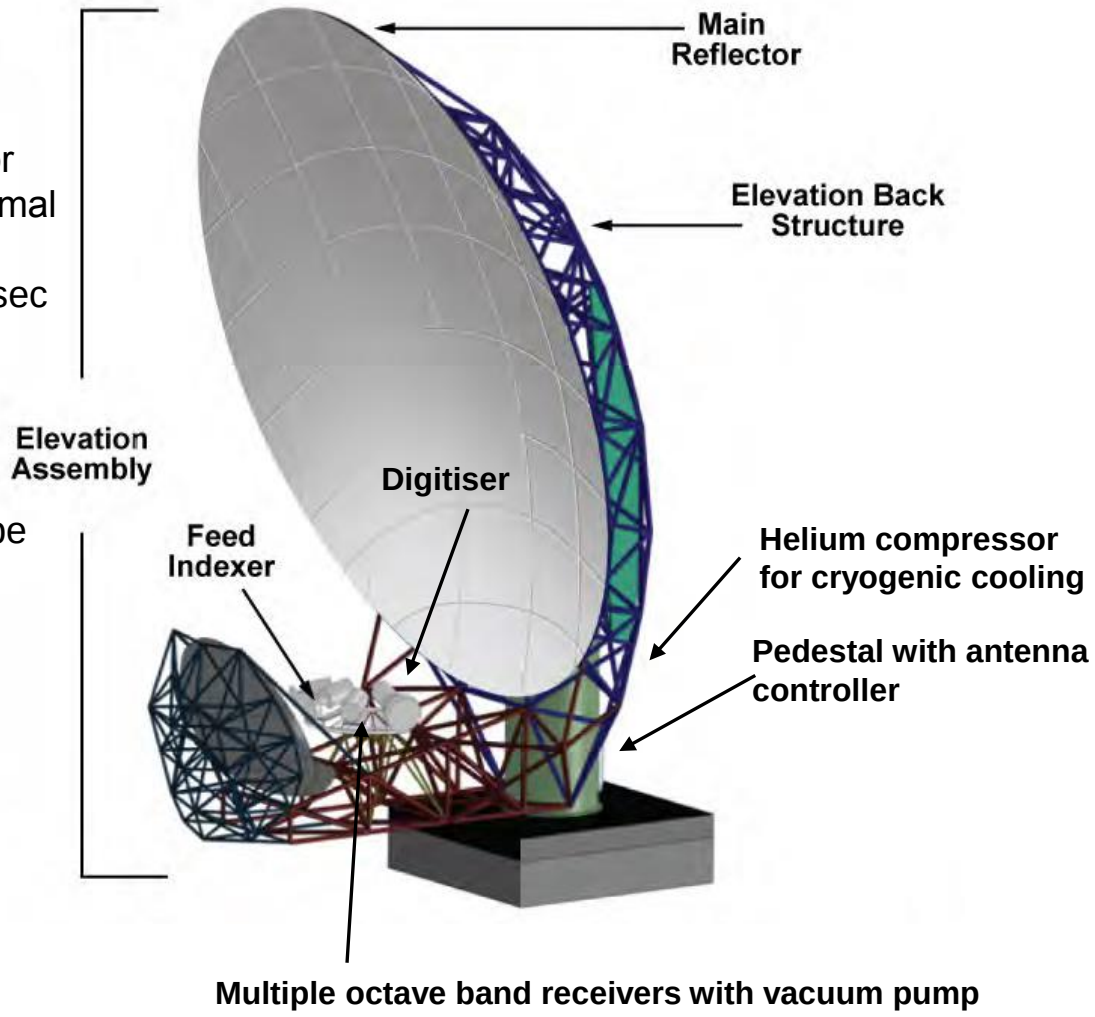
- Gregorian offset antenna
- Multiple cryo-cooled, octave band single pixel receivers.
- Direct Digitisation at the receiver
- High Pointing Accuracy (5” over 20min for good conditions, 25” over 4 hours for normal operational conditions)
- “Fast” slew speeds (2deg/sec Az, 1deg/sec El)

<u>Key performance</u>:

- Sensitivity (Ae/Tsys)
- Rotationally symmetric beam and sidelobe pattern
- Gain & phase stability

Ae/Tsys (sqm/K)	Spec	Achieved
1 Dish	3.4	6
64 Dishes	220	380

(L-band)

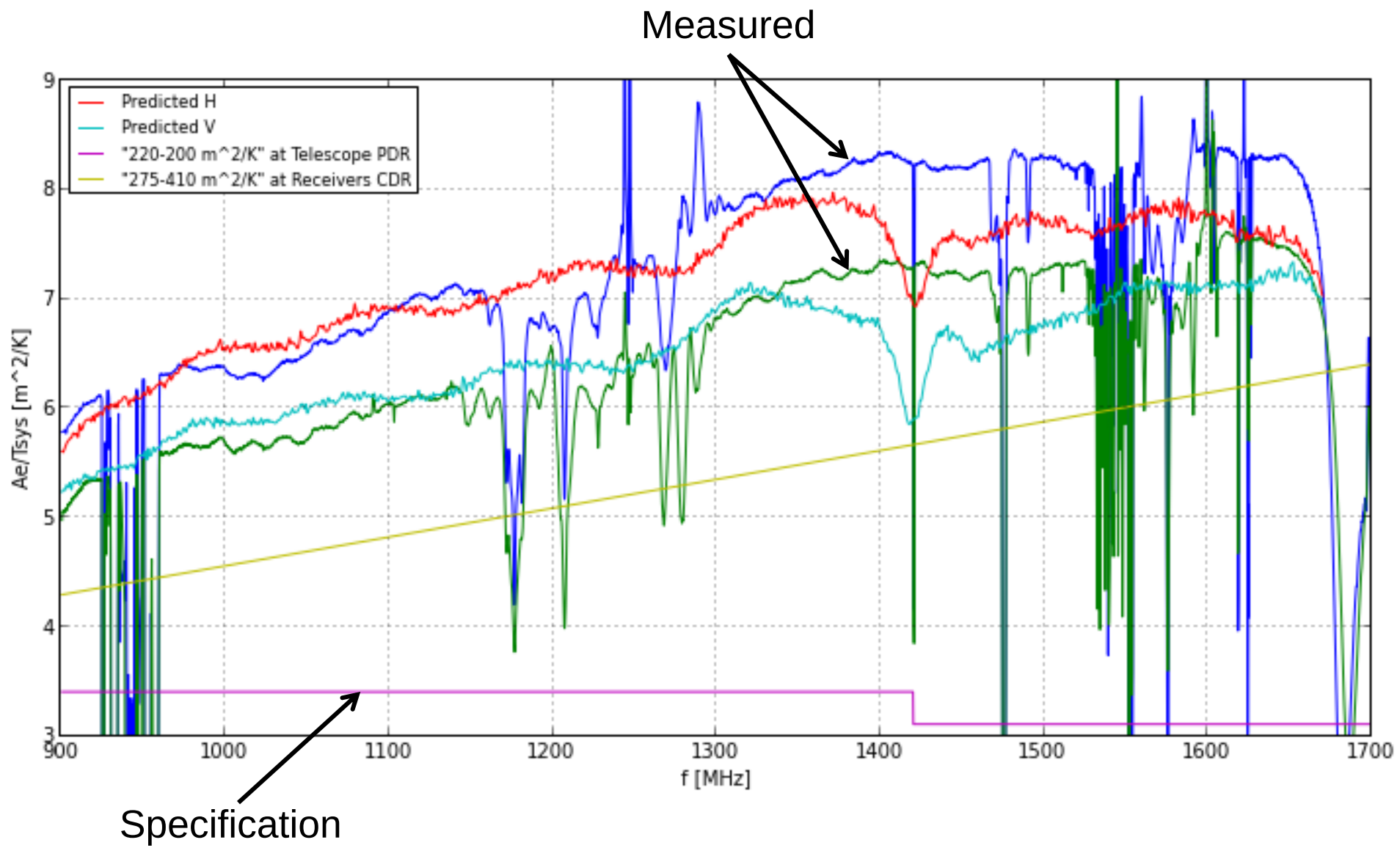


Frequency Bands

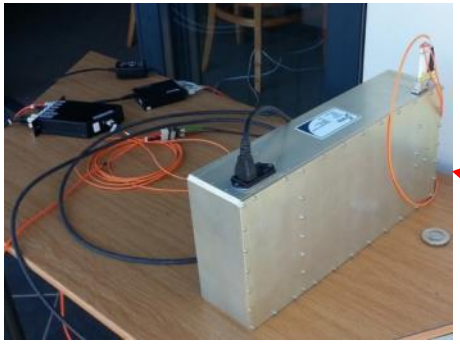
	Freq	Sampling rate (MSps)	Bits	Processed BW (MHz)	Project Stage
UHF-band	0.58 – 1.015	1088*	10	435	1
L-Band	0.9 – 1.67	1712	10	770	1
S-Band	*	*	*	*	2
X-band	8 – 14.5		3*	2000	3

* *TBD/TBC*

Receptor Performance – Ae/Tsys (L-band)



Receivers

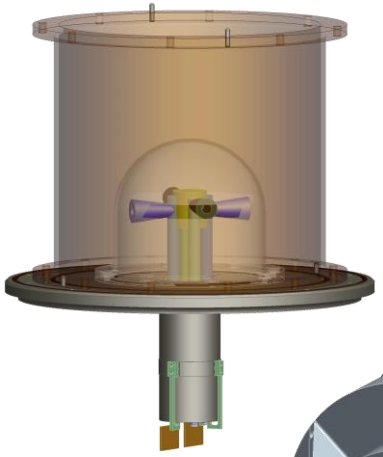


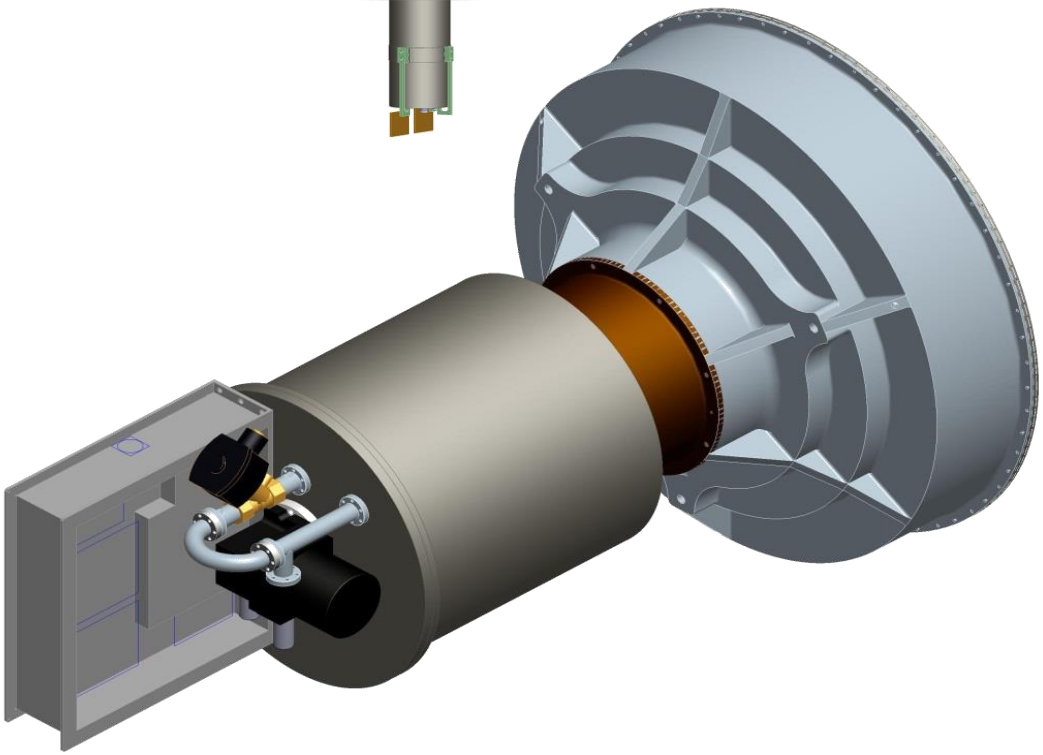
Receivers

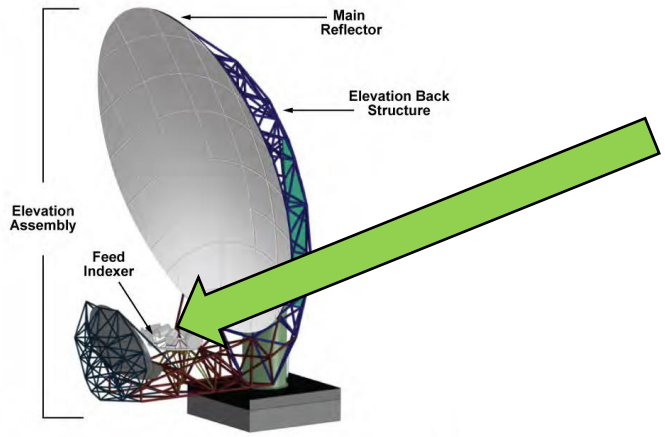
Receivers:

- UHF-band (580 – 1015MHz)
- L-band (900 – 1670MHz)
- X-band (8 – 14.5GHz)

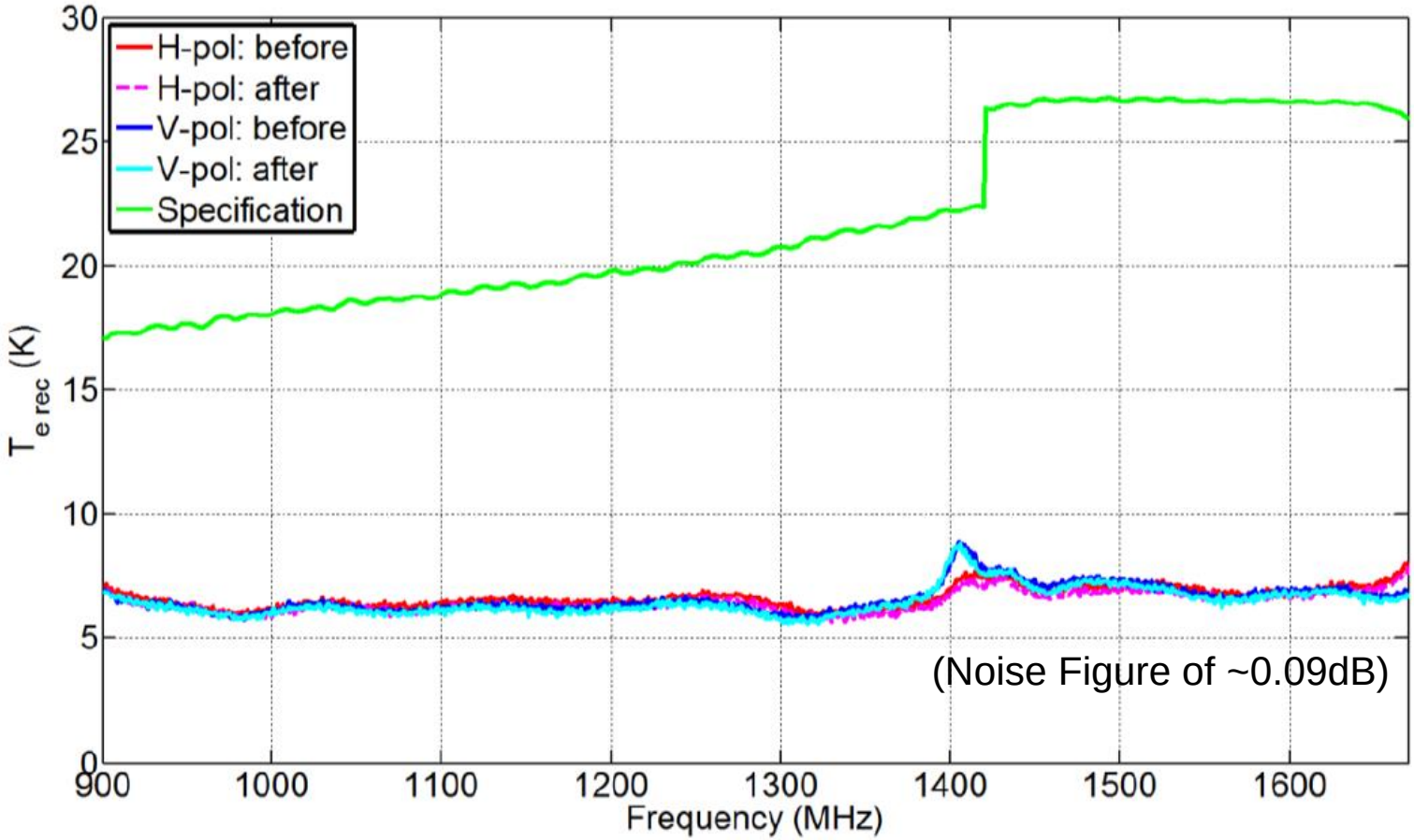
- Low receiver noise: GM cryogenic cooling with Novel OMT design
  - ($T_{Receiver}$ ~6K for L-band & UHF-band)
- High gain stability (0.7% over 20min)
- Polarisation Purity
- Stable calibration source
- Self-generated RFI was a big challenge



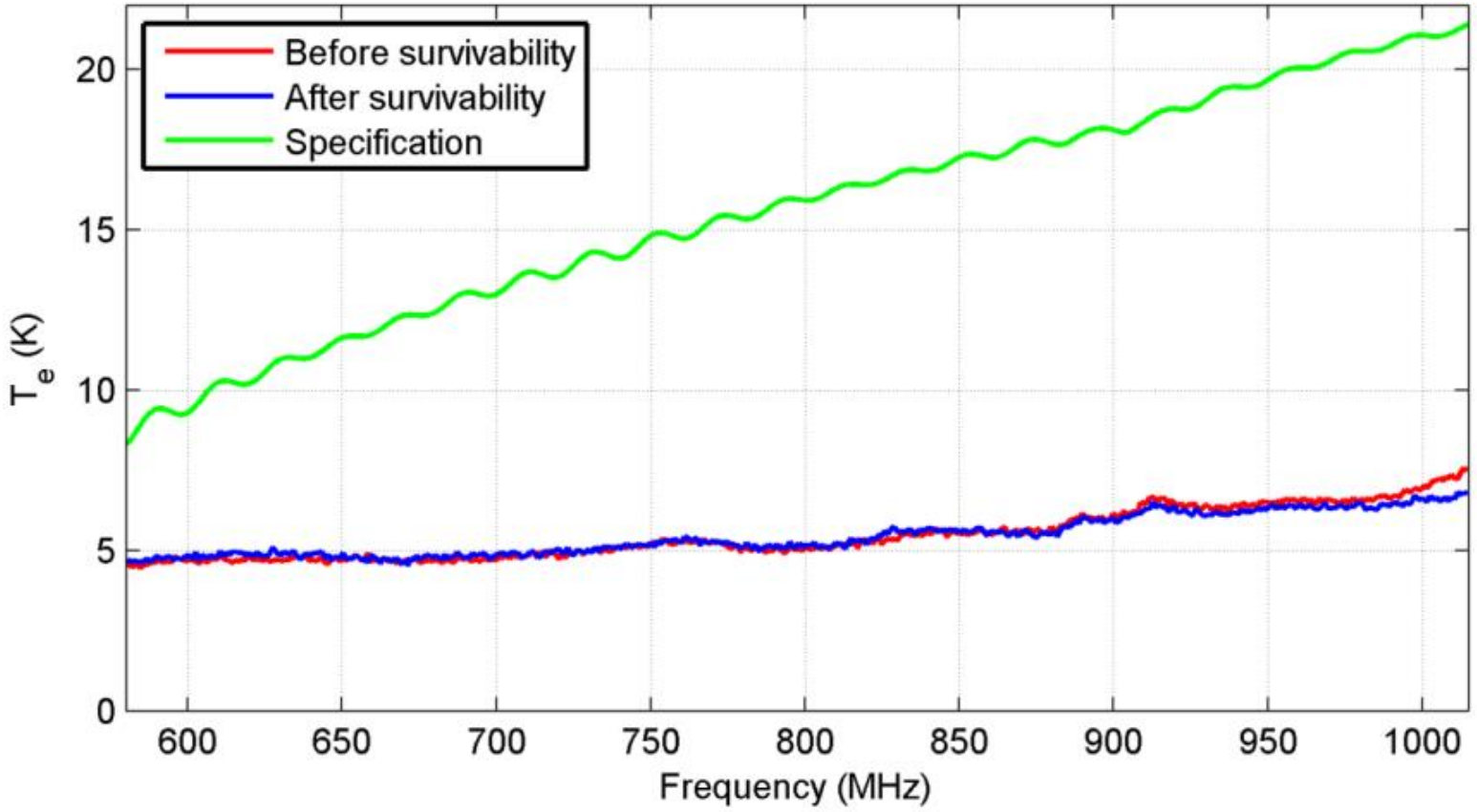




L-band Receiver Noise Temperature



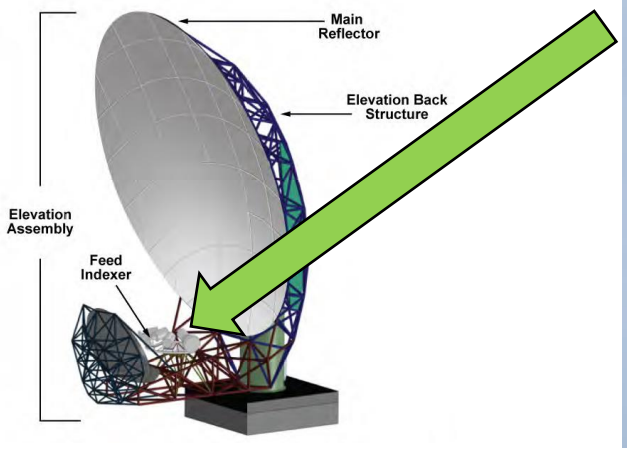
UHF-band Receiver Noise Temperature



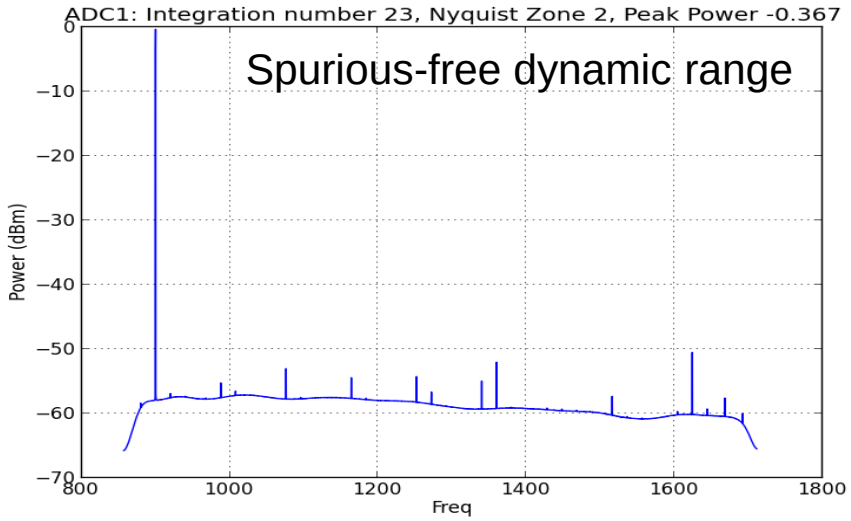
Digitiser

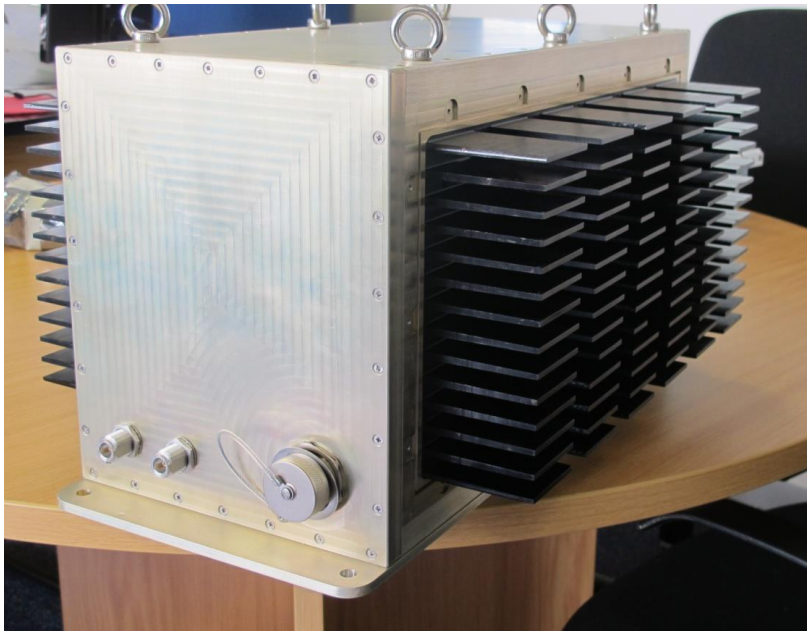
Digitiser:

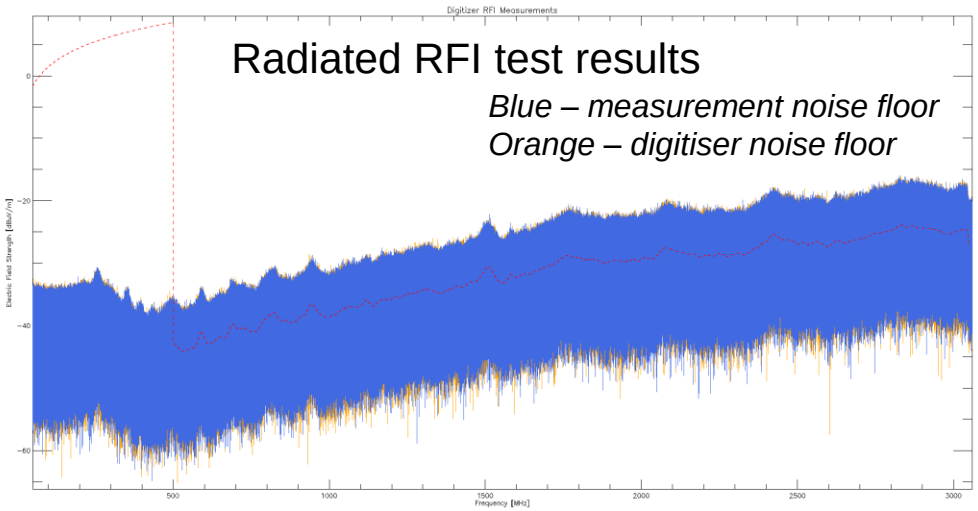
- Bandwidth (1.7GS/s for L-band sampling)
- Dynamic range /headroom for RFI → 10- bit sampling in L-band
- Gain & phase stability
- RFI is a big challenge



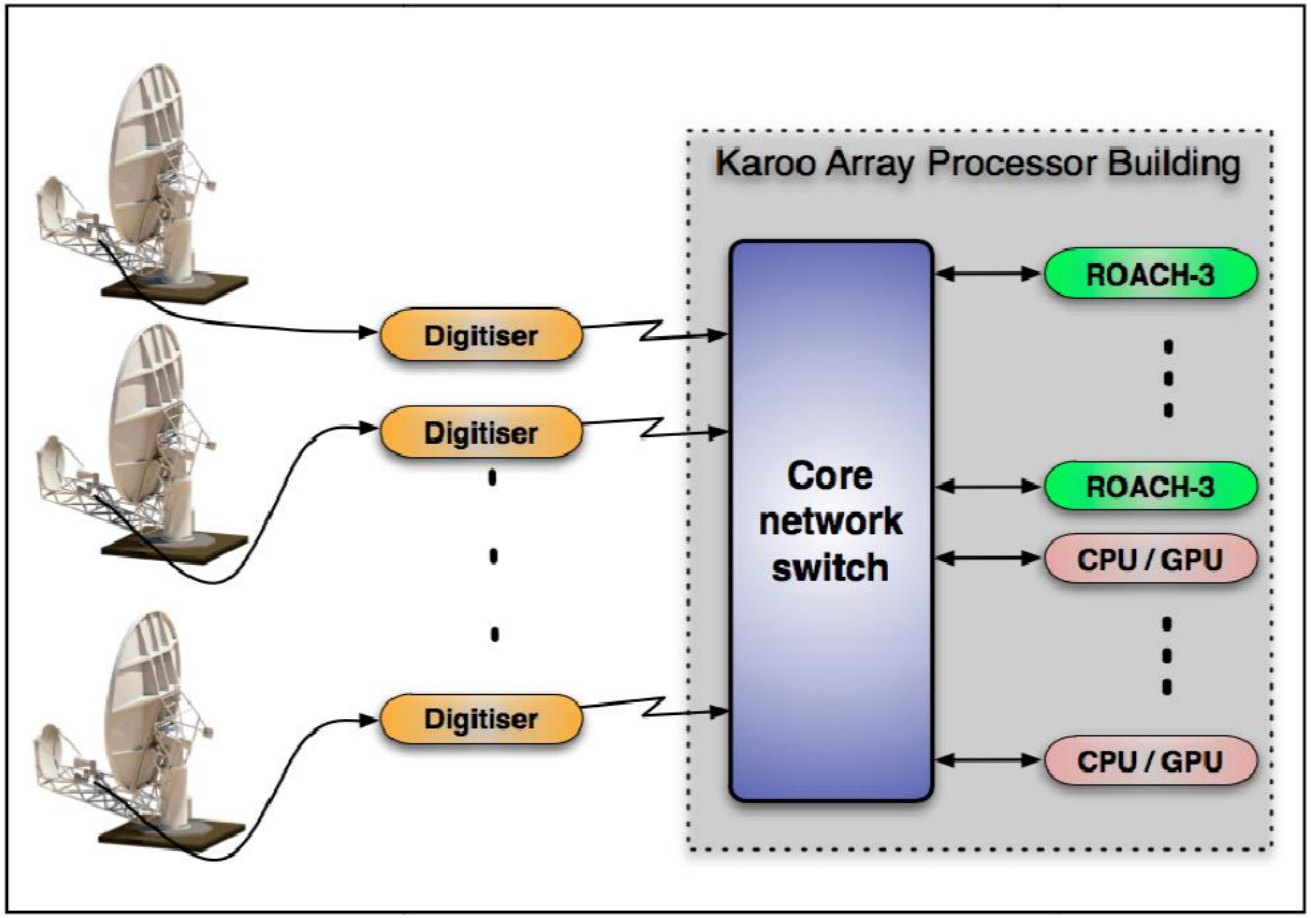
Digitiser


ADC1: Integration number 23, Nyquist Zone 2, Peak Power -0.367
Spurious-free dynamic range
Power (dBm)
0
−10
−20
−30
−40
−50
−60
−70
800
1000
1200
1400
1600
1800
Freq



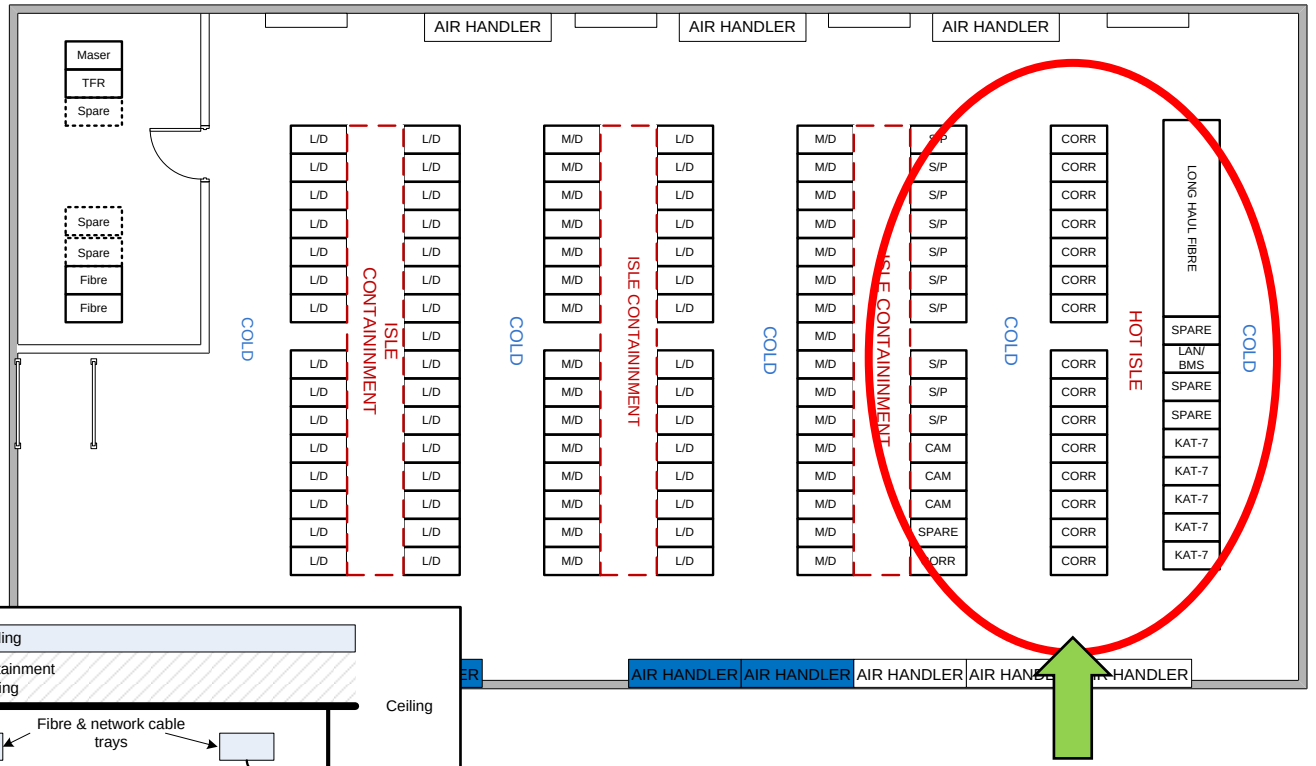

Digitizer RFI Measurements
Radiated RFI test results
Blue – measurement noise floor
Orange – digitiser noise floor
Electric Field Strength [dBuV/m]
0
−20
−40
−60
500
1000
1500
2000
2500
3000
Frequency [MHz]

Array Processor architecture

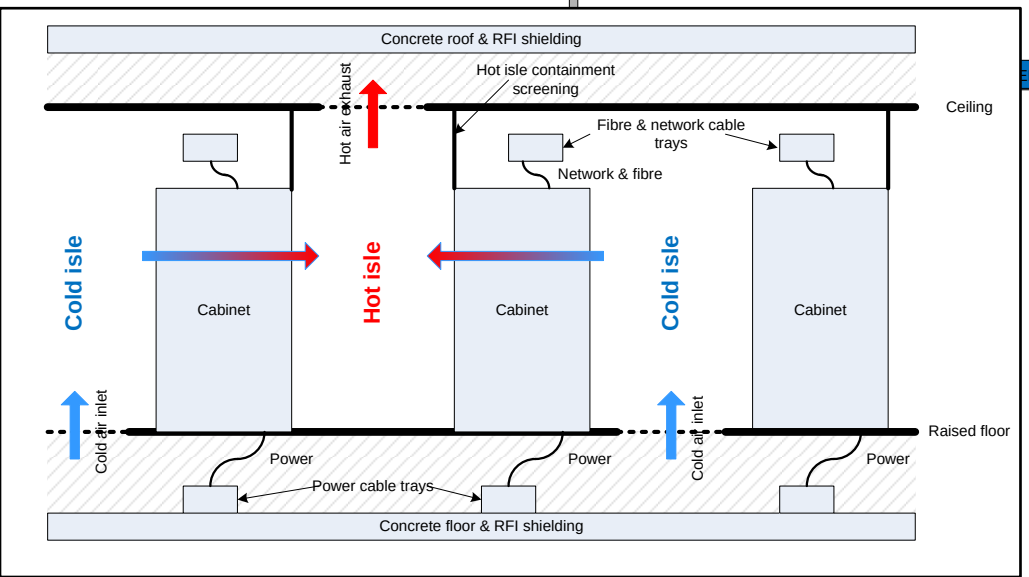


Site complex layout

Karoo Array Processor Building



Used for MeerKAT & KAT-7



End

Questions?