MeerKAT

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SKA South Africa
Centre for Radio Astronomy
Techniques & Technologies
Rhodes University

URSI BEJ session – Mauritius – September 2013

Prologue

"If you build it, (they) will come"

Steve Rawlings (mis)quoting a line from the film *Field of Dreams*

Other things we do…

AVN

PAPER

HCDP

C-BASS

SKA Research Chairs and Groups

Research chair/group	University	Professor
Electromagnetic Systems and EMI (Electromagnetic Interference) Mitigation	Stellenbosch	Prof. David Davidson
Radio Astronomy	Wits	Prof. Sergio Colafrancesco
Astrophysics	UWC	Prof. Roy Maartens
Multi-Wavelength Extragalactic Astronomy	UCT	Prof. Claude Carignan
Radio Astronomy Techniques	Rhodes	Prof. Oleg Smirnov
DSP for Radio Astronomy	UCT	N/A
HPC for Radio Astronomy	UCT+UWC, Stellenbosch	N/A
Fibre Optic systems for Radio Astronomy	NMMU	N/A

Karoo Radio Astronomy Reserve
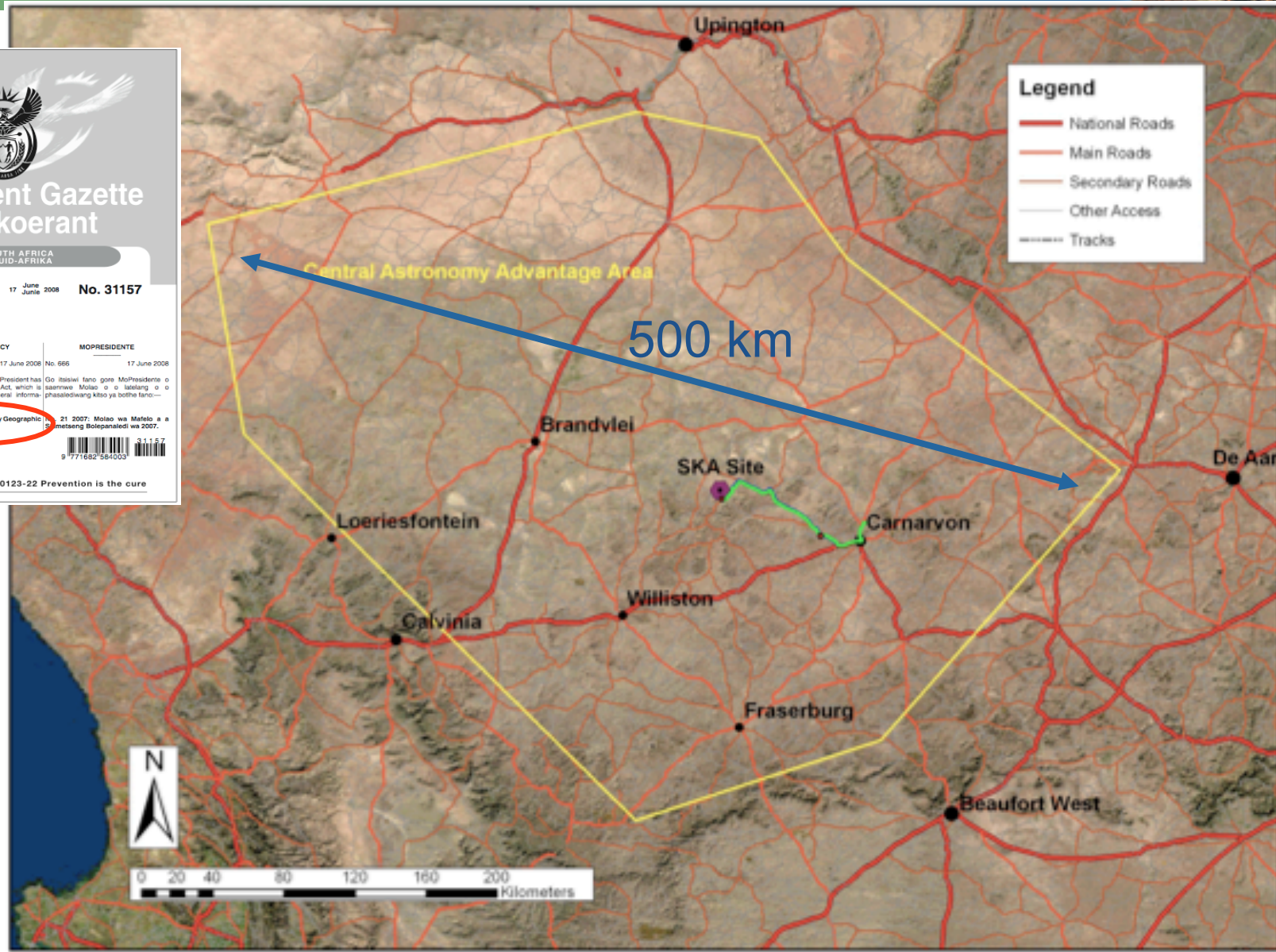
South of the Karoo Site

MeerKAT high-level spec

- The most sensitive cm-wavelength telescope in the southern hemisphere (aspiration: world)
- 580 MHz – 15(+) GHz (i.e. SKA-mid +)
- Imaging and non-imaging capability:
  - Resolution and dynamic range to match the continuum sensitivity (extendable to SKA)
  - High sensitivity to extended low-brightness emission
  - Ability to conduct blind fast transient surveys

MeerKAT Phase 1 (2016)

- 64 x 13.5 m gregorian offset antennas
  - \> 220 m^2/K *(goal ~300 m^2/K)*
- 8 km maximum baseline
  - 70 % in < 1km diameter core
- 0.9 – 1.670 GHz cryogenic single-pixel receiver (L-band)
  - z = 0 – 0.58
  - Multiple feed indexer (4 position)
- Full 770 MHz RF bandwidth digitized and processed (×2 polarizations)

Performance @ 1420 MHz

	JVLA	ASKAP	MeerKAT	SKA-Mid	SKA-Survey
N_{dish}	27	36	64	254	96
D_{dish}	25 m	12 m	13.5 m	(13.5 m)	(15 m)
T_{sys}/ε_a	47.3 K	62.5 K	29.4 K	29.4 K	62.5 K
N_{beam}	1	36	1	1	30
BW	1 GHz	300 MHz	750 MHz	(750 MHz)	(300 MHz)
A_e/T_{sys}	280 m^2/K	65 m^2/K	311 m^2/K	1 236 m^2/K	271 m^2/K
SS m^4 K^{-2} deg^2	17 368	127 312	73 510	1 157 857	2 210 286

Survey Speed proportional to λ^2

Future Phases

- 580 - 1000 MHz (UHF-band)
  - Receiver currently being designed
  - $z = 0.42 - 1.45$
- 8-14.5 GHz (X/Ku-band)
  - design contingent on funds and technology
  - needs wideband correlator
- Aspirations (contingent on money and/or technology availability):
  - 0.6-3 GHz for pulsar timing (NanoGrav?)
  - ~5-22 GHz wideband receiver
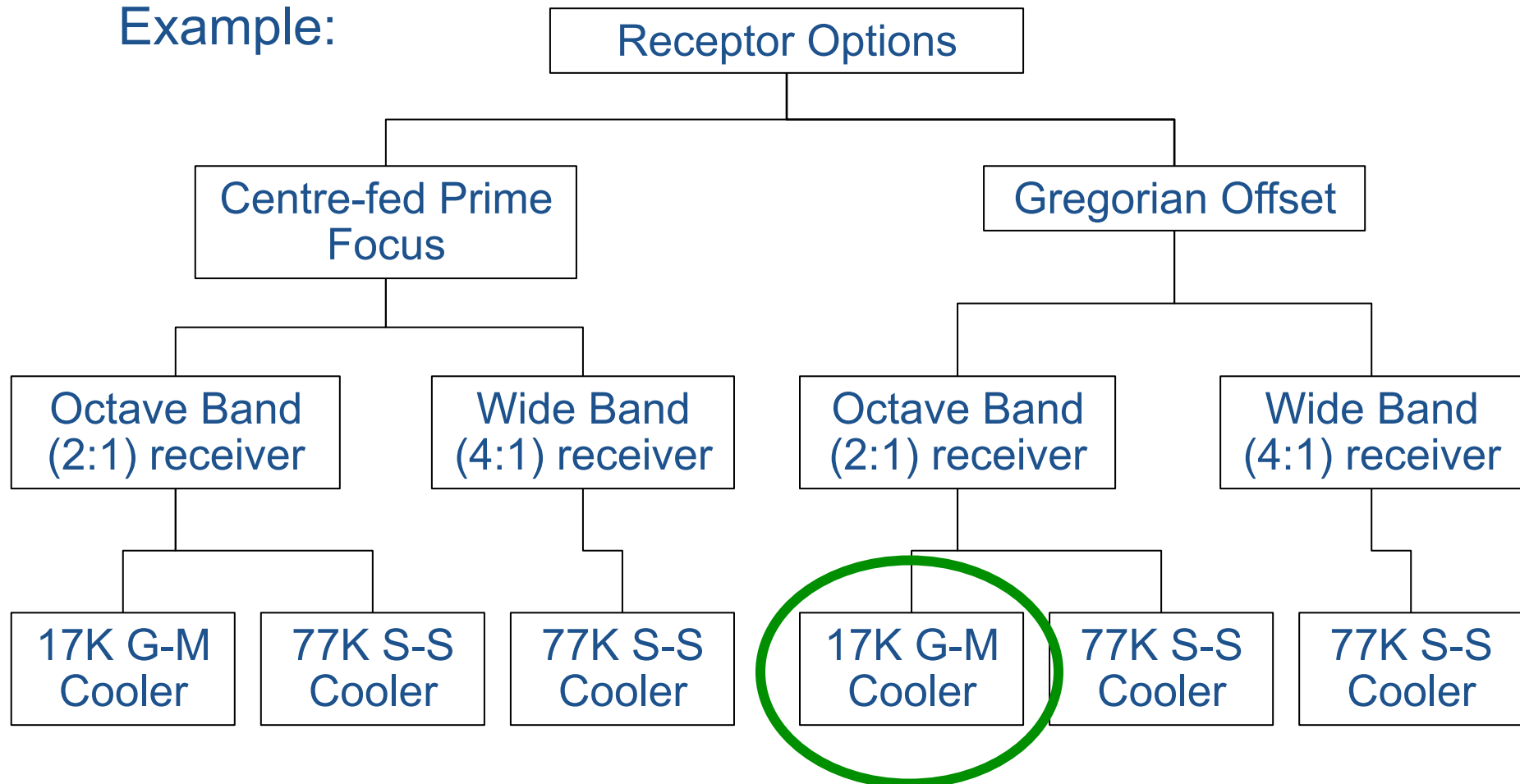- SKA-mid P1
  - Long baselines
  - 300(?) MHz – 3 GHz

System Engineering & Design

- Science-led process
    - Science case and operations model
    - > User Requirement Specification
    - > Requirements Review
    - > System Specification
    - > Concept exploration and prototypes
    - > Concept and Preliminary design reviews (system)
    - > Subsystem specifications, design and reviews

# CoDR: Concept Exploration & Trade-offs

Example:

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                          ┌─────────────────────┐
                          │   Receptor Options  │
                          └─────────────────────┘
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Centre-fed Prime Focus		Gregorian Offset	
Octave Band (2:1) receiver	Wide Band (4:1) receiver	Octave Band (2:1) receiver	Wide Band (4:1) receiver
17K G-M Cooler / 77K S-S Cooler	77K S-S Cooler	**(17K G-M Cooler)** / 77K S-S Cooler	77K S-S Cooler

Cost functions traceably linked to Science & Operations Requirements
NOT post-facto justification for technology choice

Comparison of beam patterns
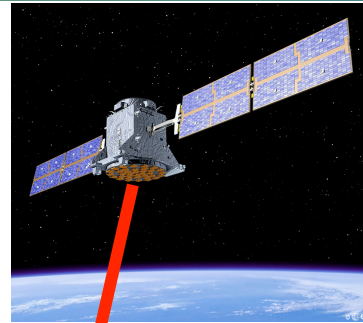
Satellite RFI
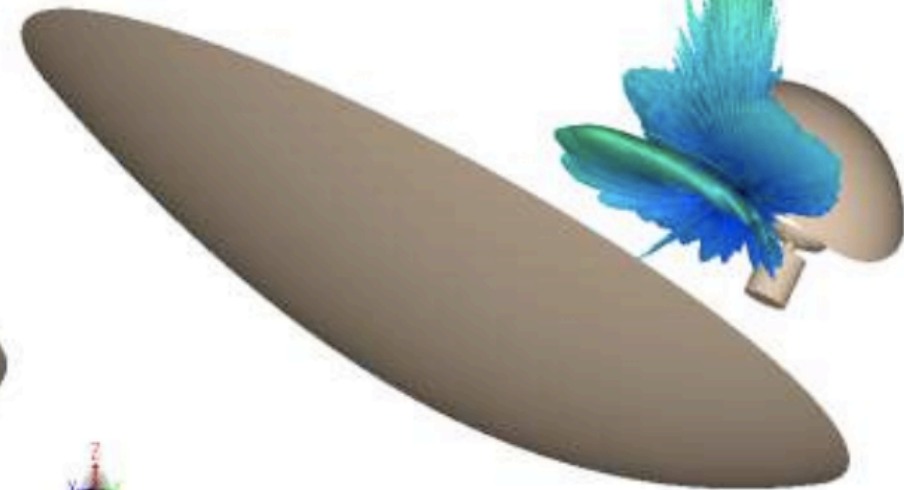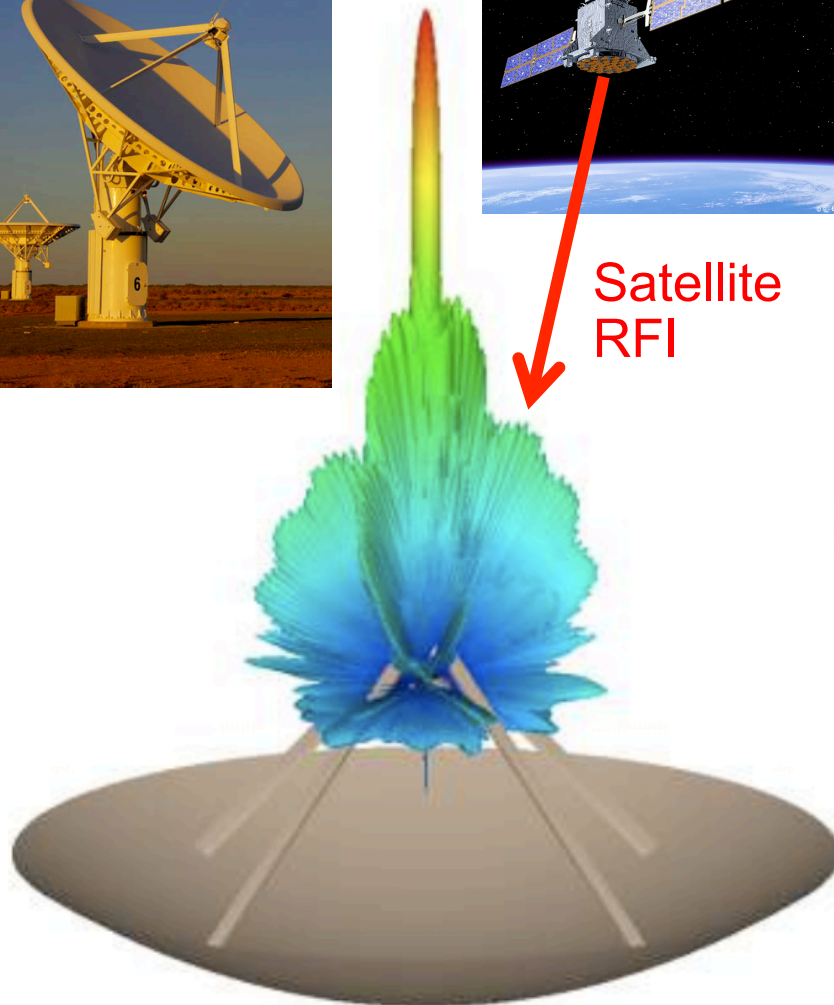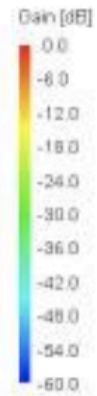
System Description

- Gregorian offset antennas ("feed low")
  - Multiple receivers
  - RFI rejection
  - Spectral & imaging dynamic range
  - Sensitivity
  - 64 x 13.5 m
- Cryo-cooled, octave band, single pixel receivers
  - Sensitivity
  - Stable and smooth/flat bandpass
- Compact array configuration
  - Imaging dynamic range and resolution
  - Sensitivity to extended low brightness structures
  - Transient detection
- Direct digitization at the receiver
  - No analog heterodyne stage
  - Spectral dynamic range
- FX correlator
  - Packet switched architecture
  - Heterogeneous processors
- 3G+ calibration
  - "exact" treatment of calibration solution

Virtual MeerKAT

MeerKAT Large Surveys

- **Highest priority** (cf SKA_1):
  - Deep HI field
  - Radio Pulsar Timing

- Compelling:
  - HI and continuum mapping of 30 nearby galaxies
  - Absorption line survey
  - Molecules in the EoR
  - Detecting fast transients and pulsars

  - HI survey of Fornax
  - X-band Galactic plane survey
  - Tiered continuum survey
  - Slow radio transient survey

- Also
  - VLBI
  - Cosmic Magnetism

MeerKAT Large Surveys

Chart: Individuals (360) and Institutes (121) by country

Country	Individuals (360)	Institutes (121)
South Africa	66	12
Mauritius	3	1
Burkina Faso	1	1
UK	89	26
Netherlands	28	7
Germany	24	8
France	19	7
Italy	9	4
Sweden	4	2
Spain	3	2
Portugal	3	2
Poland	2	1
Belgium	1	1
USA	51	23
Canada	13	7
Chile	3	2
Argentina	1	
Australia	31	8
India	5	2
Japan	1	1
Korea	2	2
Russia	1	1

22 Countries
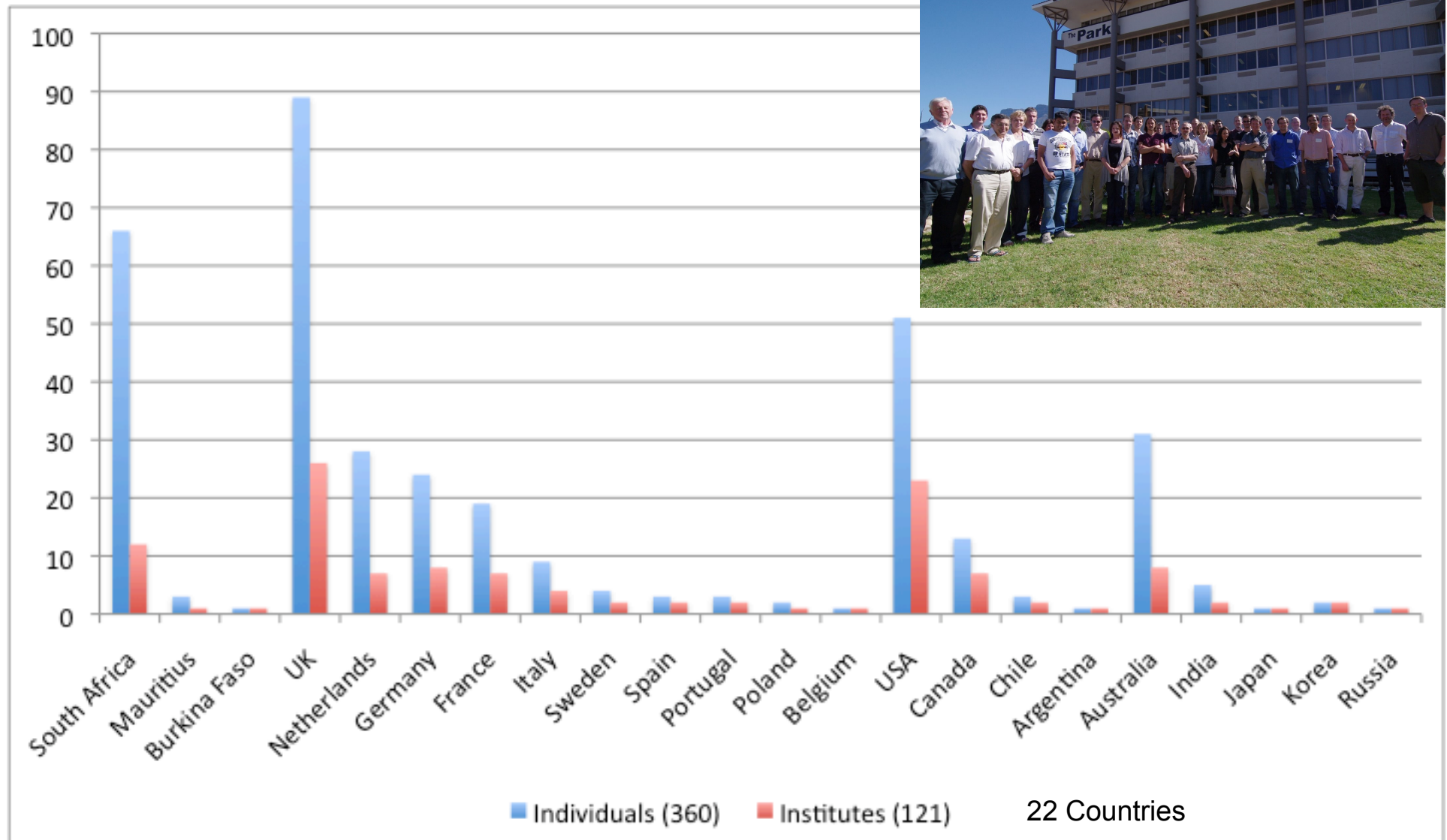
Time Allocated – > 5 years

Survey	L-Band	UHF	X/Ku-Band
Deep HI	5 000	5 000	
Pulsar Timing	7 860		
30 Galaxies	6 000		
HI Absorption	2 000	2 000	
EoR Molecules			6 500
Fast Transients	3 080		?
Fornax HI	2 450		
X/Ku-band Galaxy			3 300
Deep Continuum	1 950		
Slow Transients	3 000	?	?
TOTAL	31 340	7 000	8 800

1 yr = 8 760 hr

XDM @ HartRAO
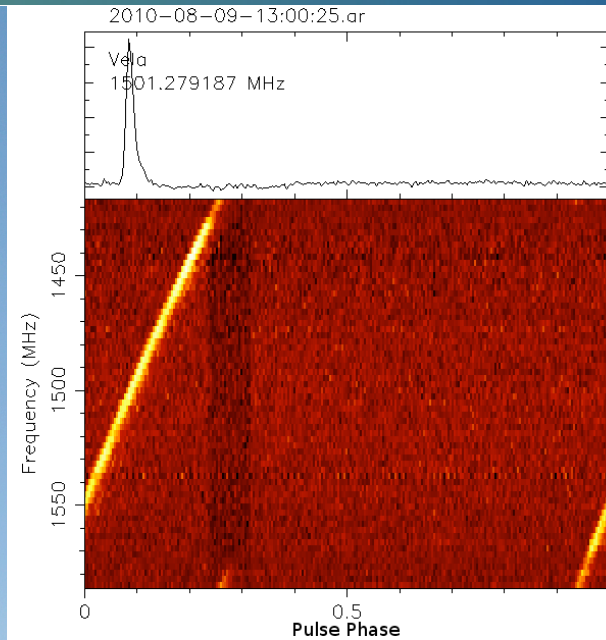
Pulsar
Monitoring

Geodetic
VLBI
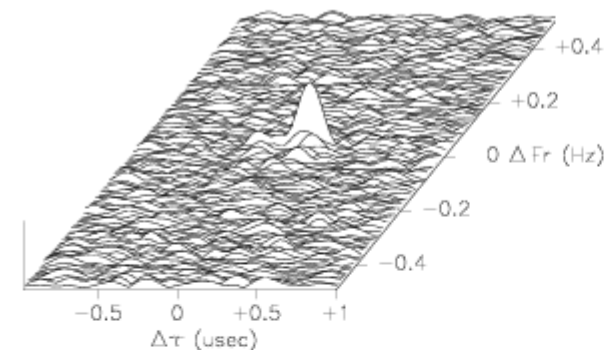
KAT-7

KAT-7 Science
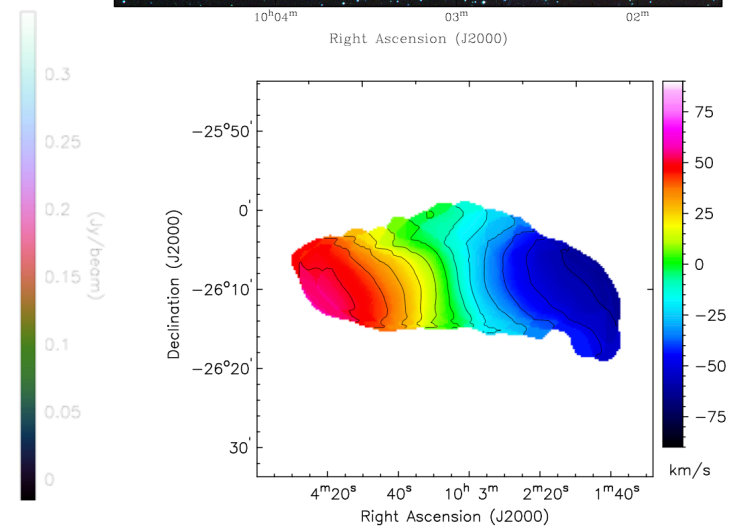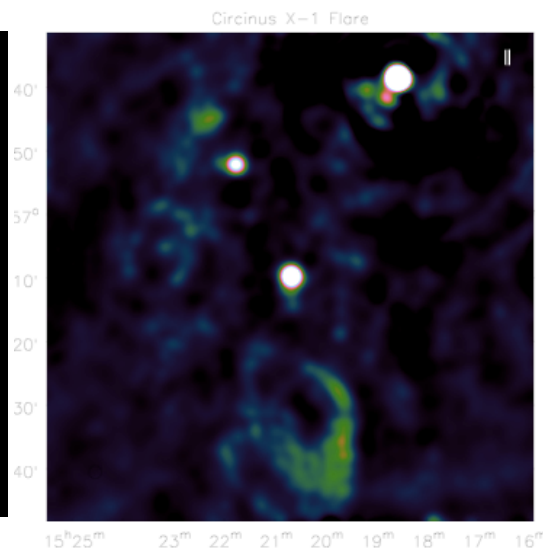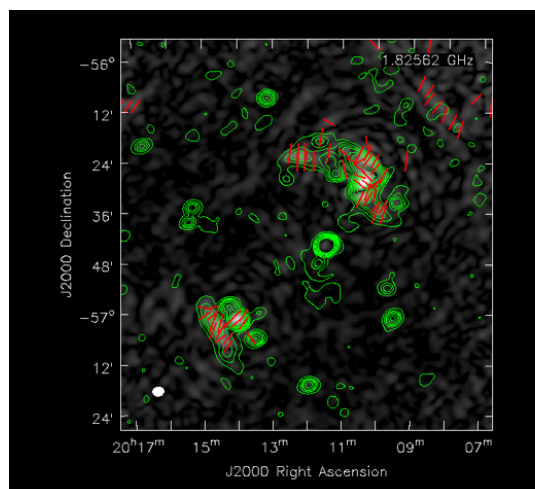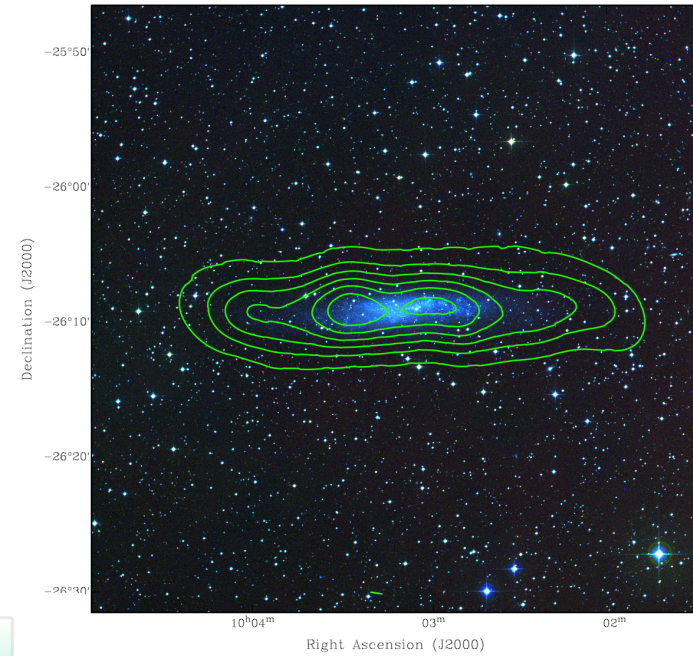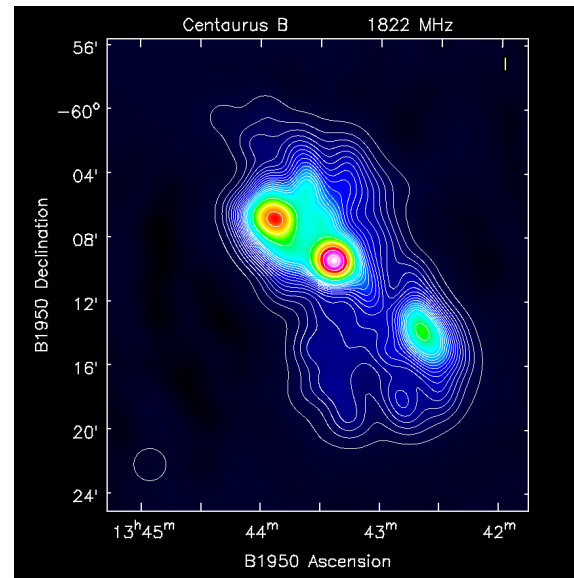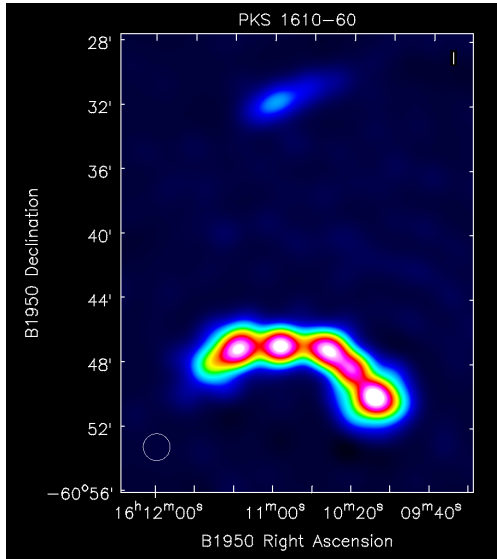
MeerKAT Dish

- 13.5 m gregorian offset antenna with receiver indexer
- Local/international consortium
  - 75% local content and labour
  - IP transfer to local industry
  - Skills development within local industry
- First article of 64 completed end December 2013

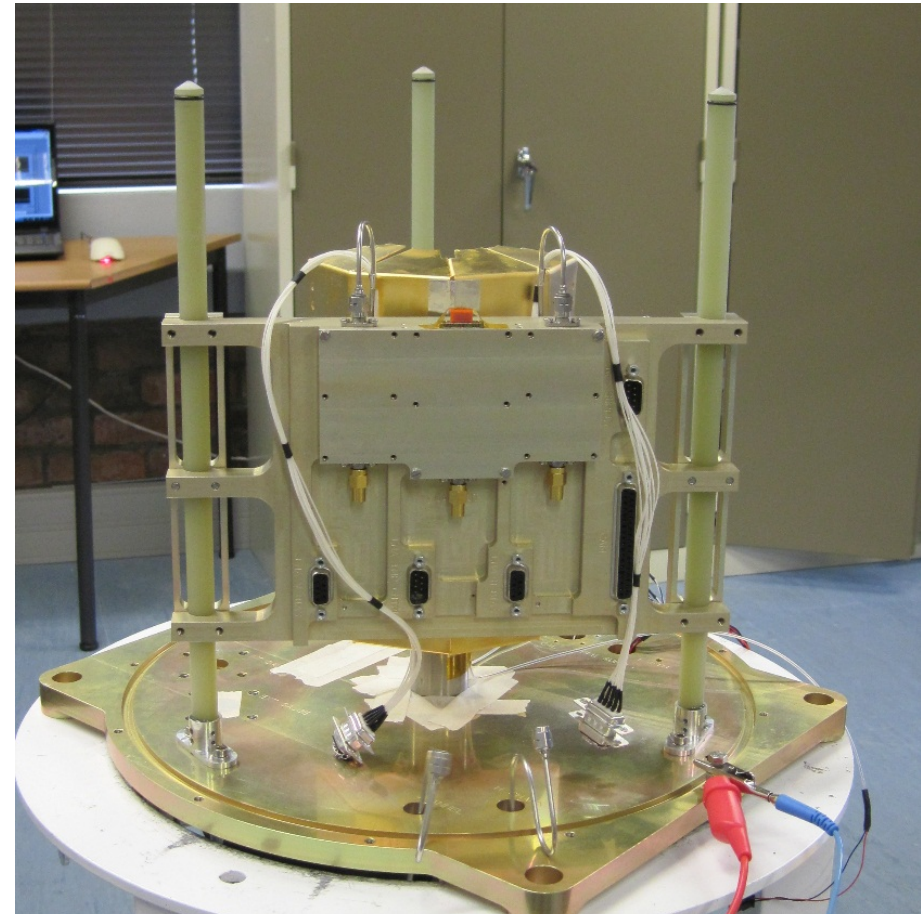# L-band Receiver
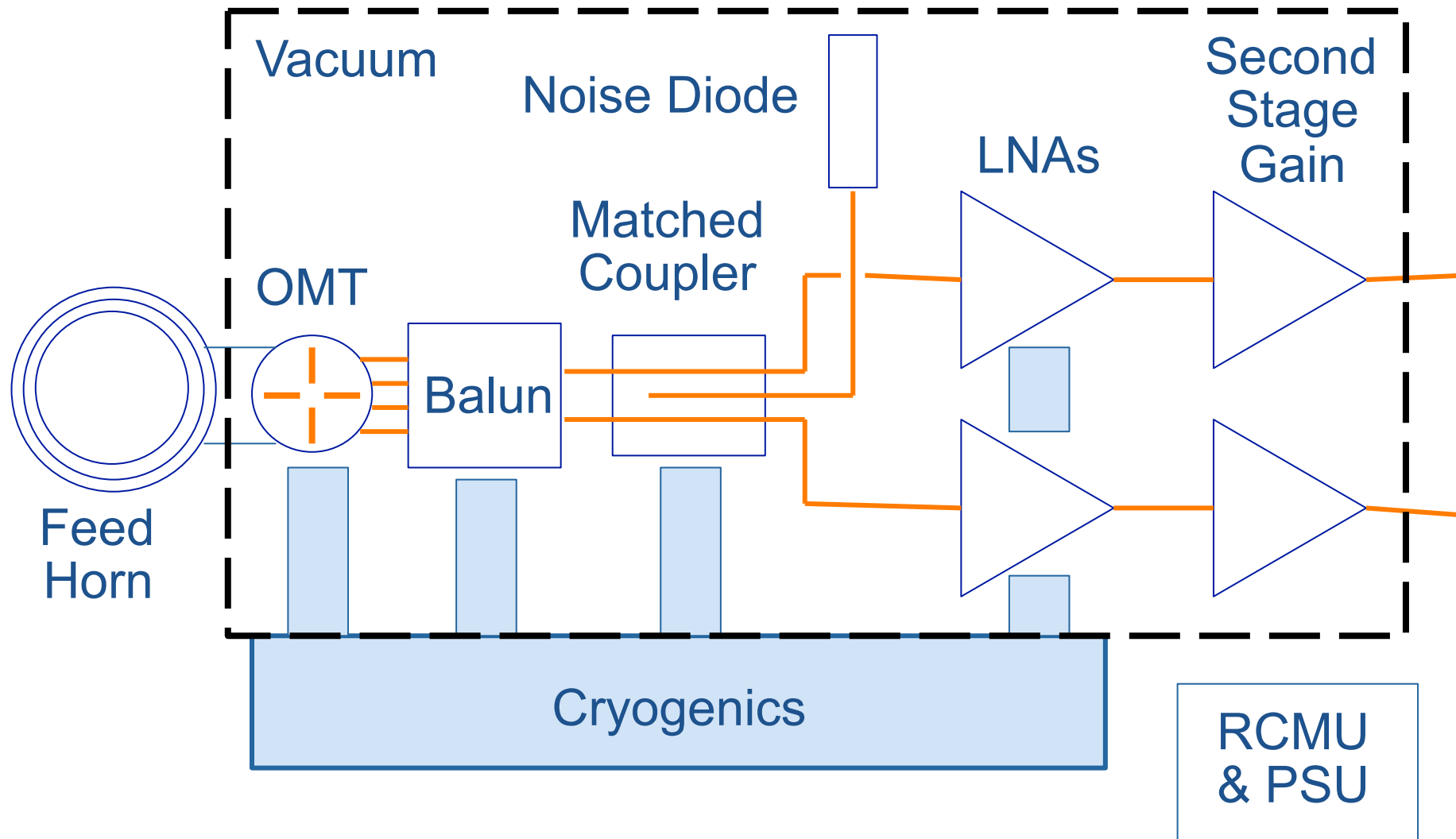
Horn, OMT, balun, coupler

Receiver package

Vacuum
radome

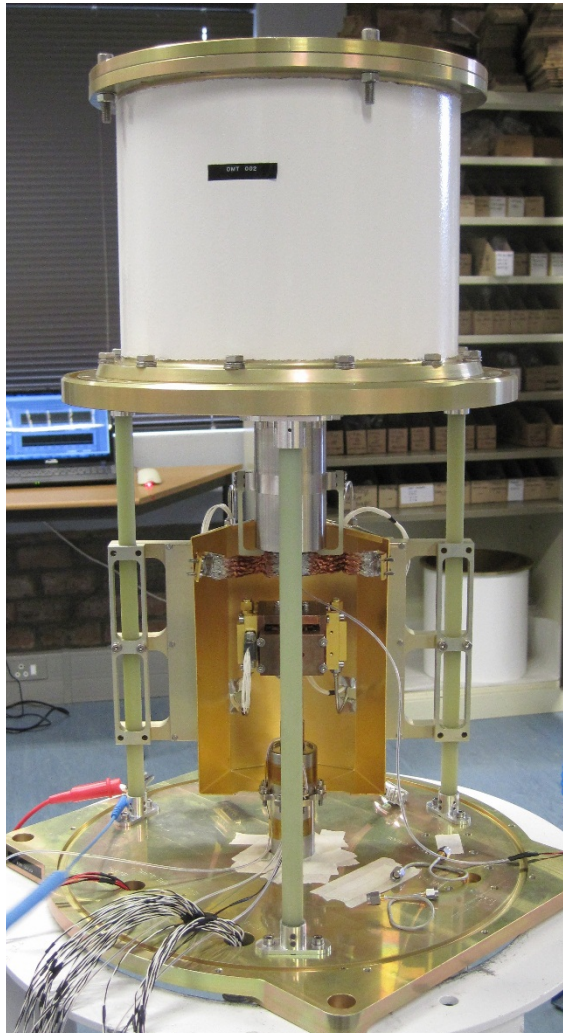Cryo
crosshead

Thermal break
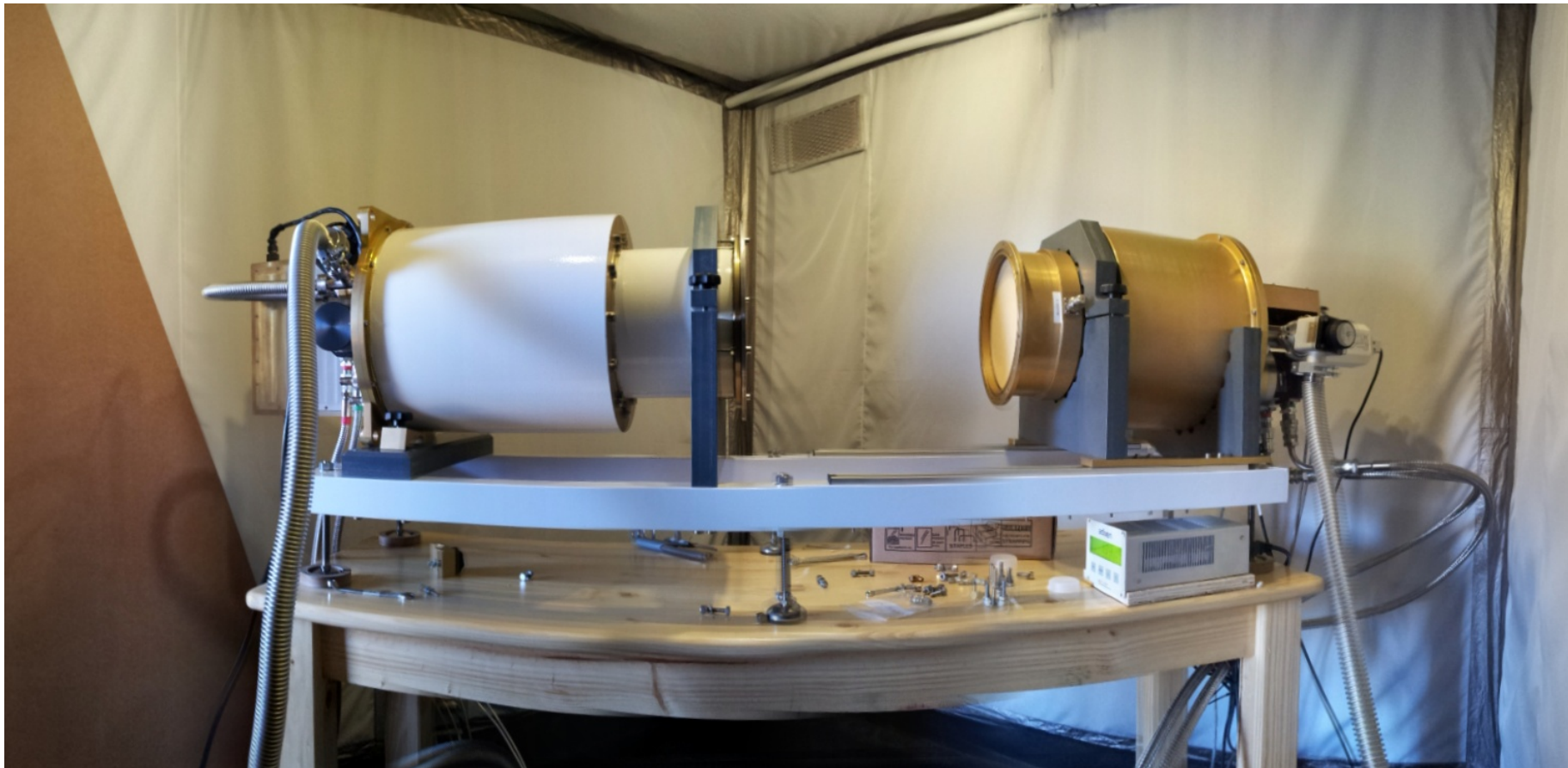
Vacuum
plumbing

•25
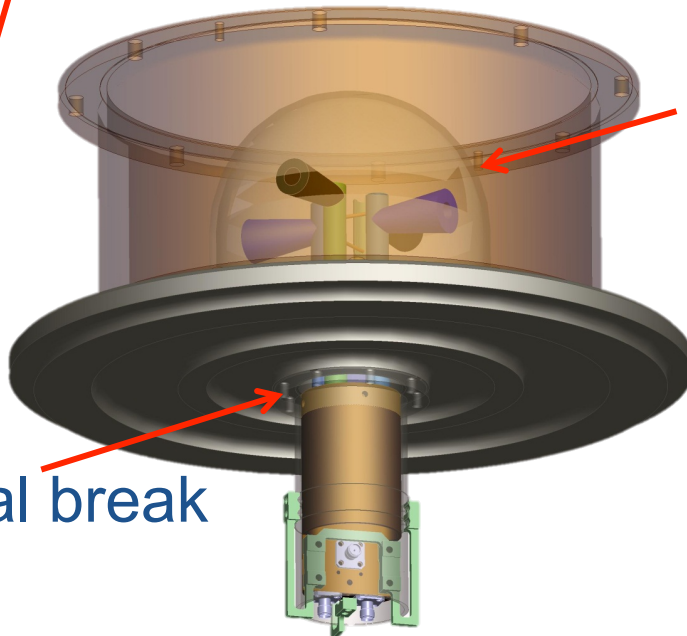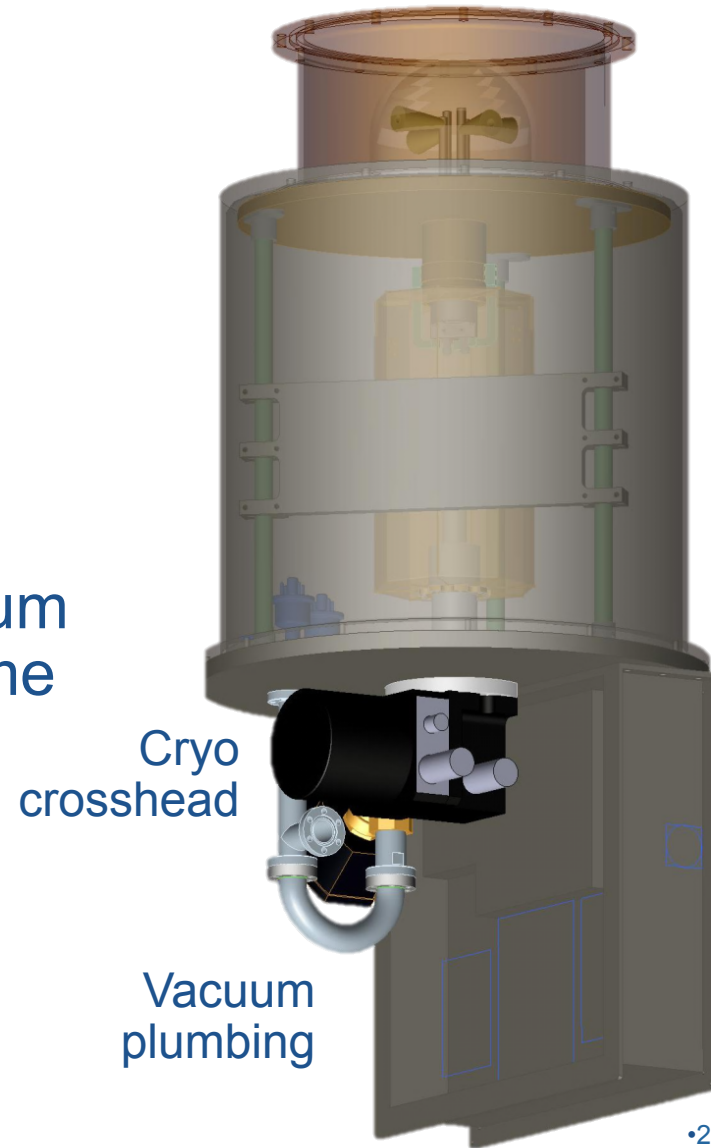
Cold Finger and HIA LNA
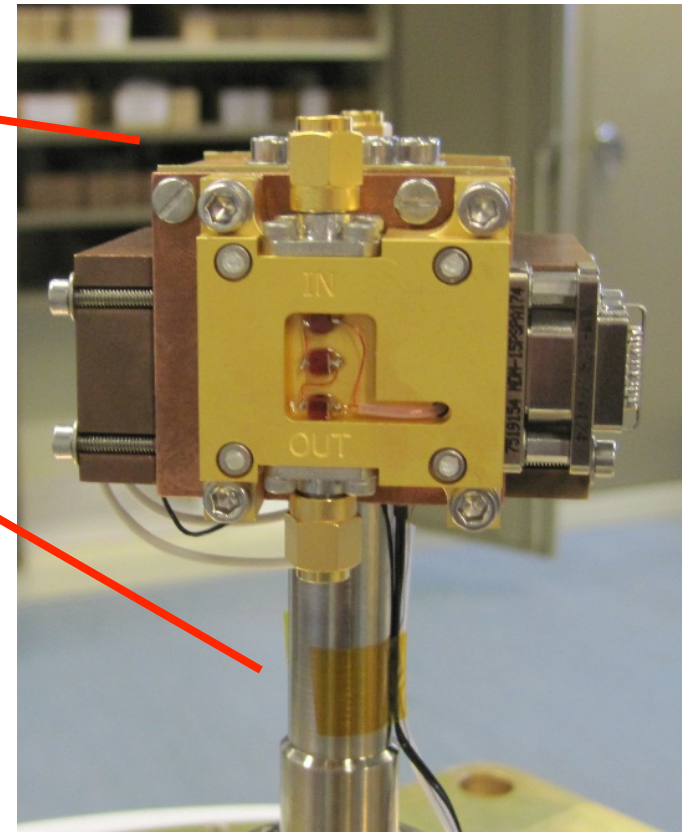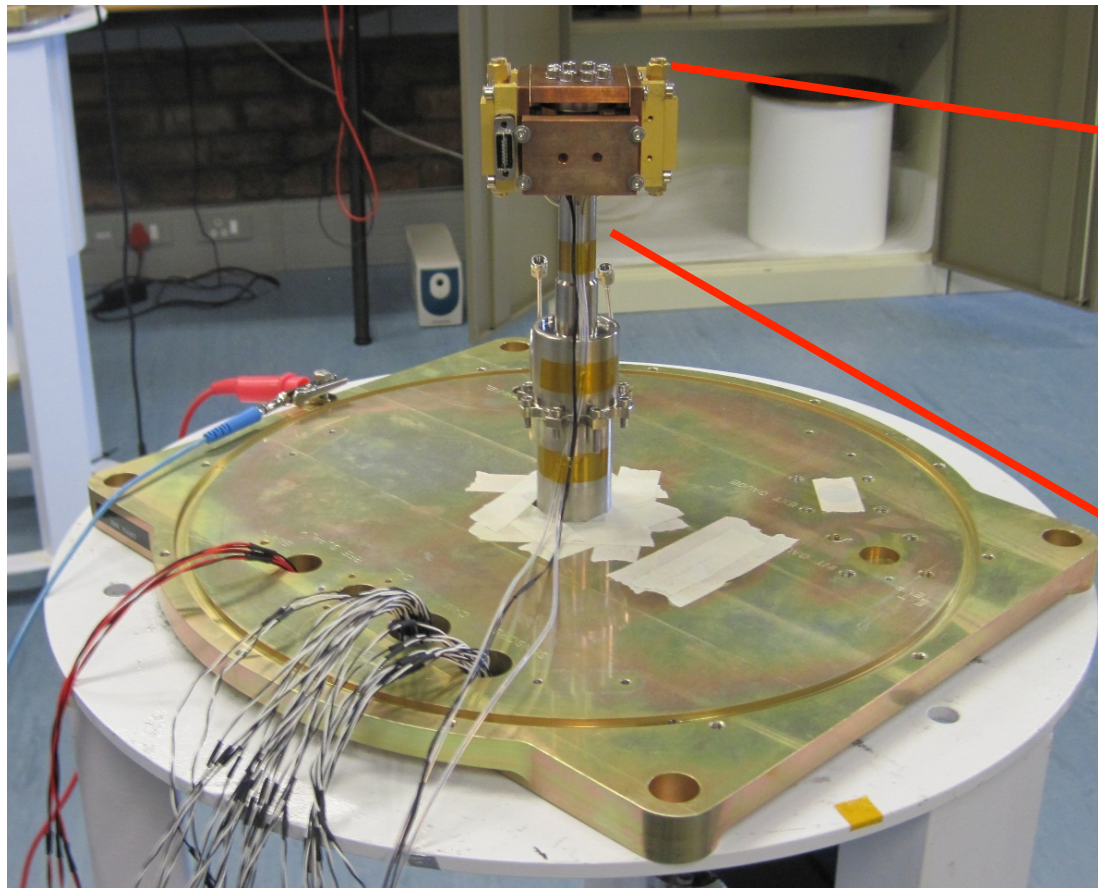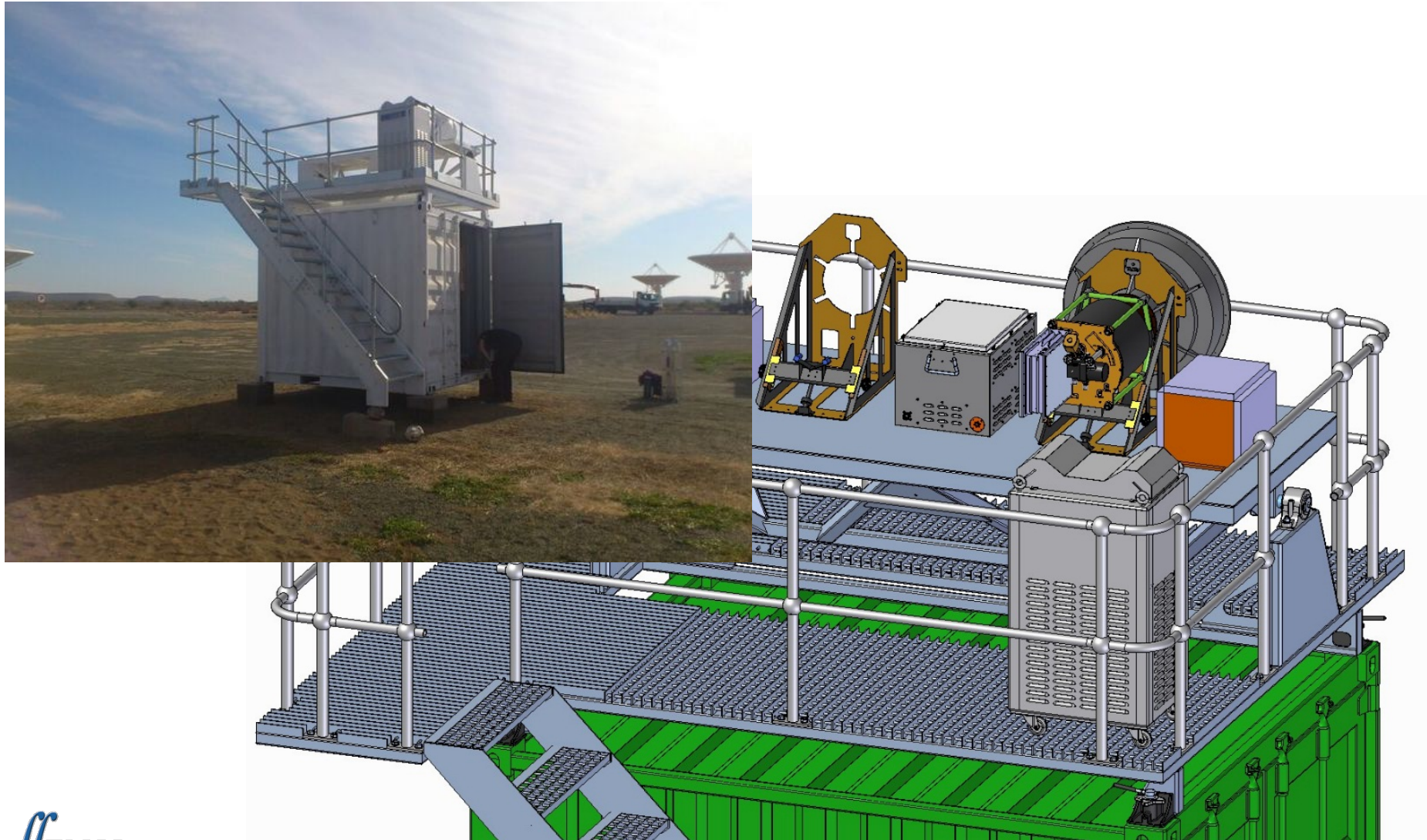
Radiation shields & 2nd Stage
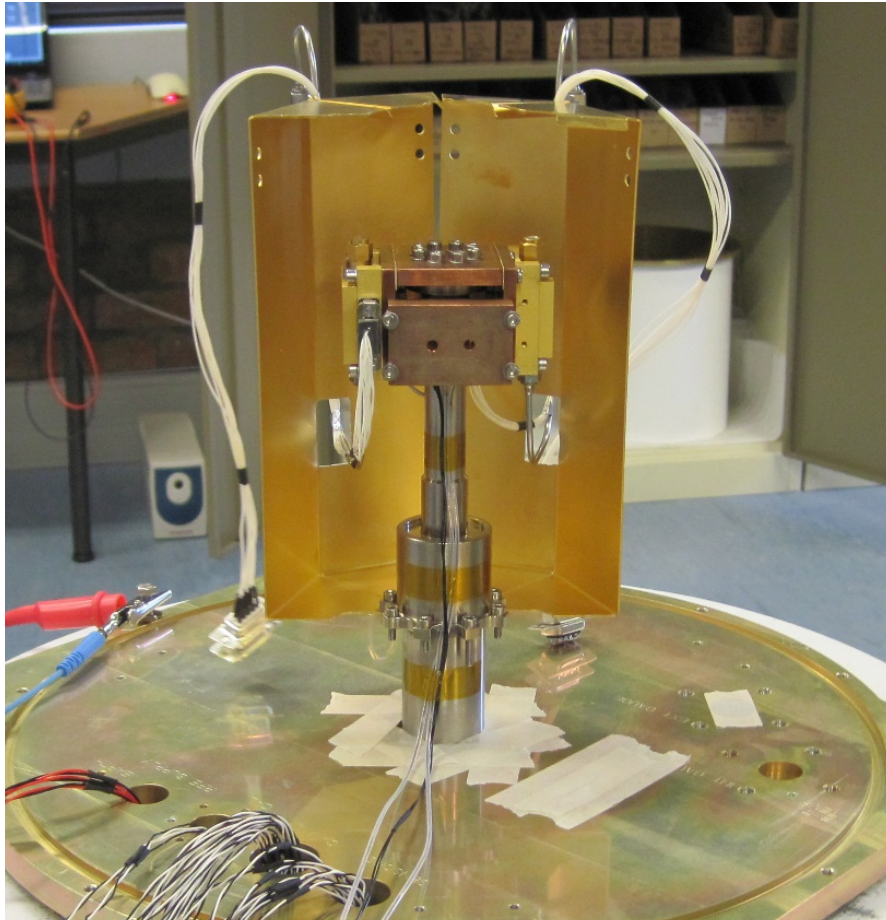
OMT and Cryostat Body
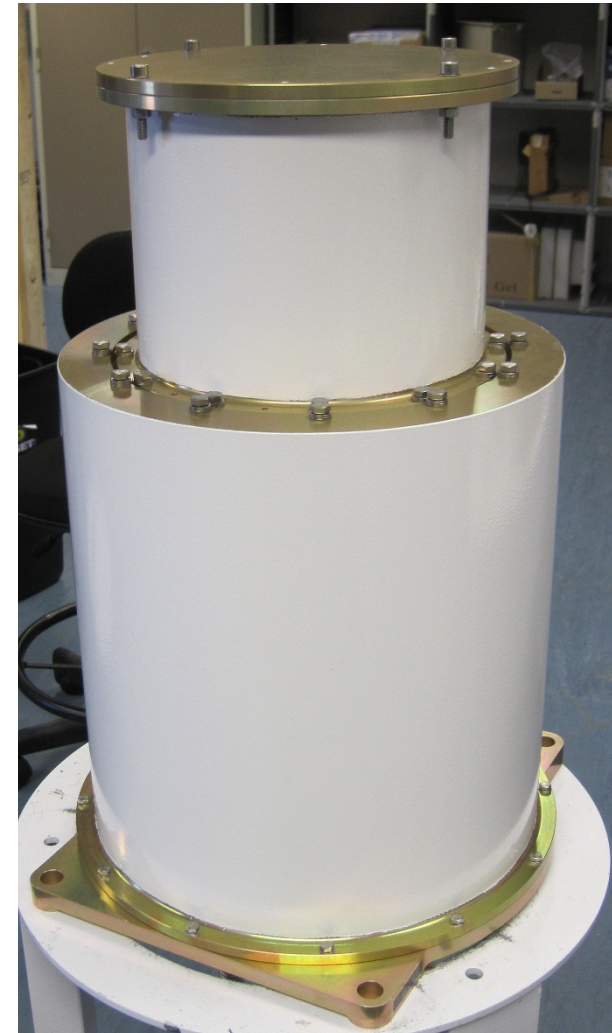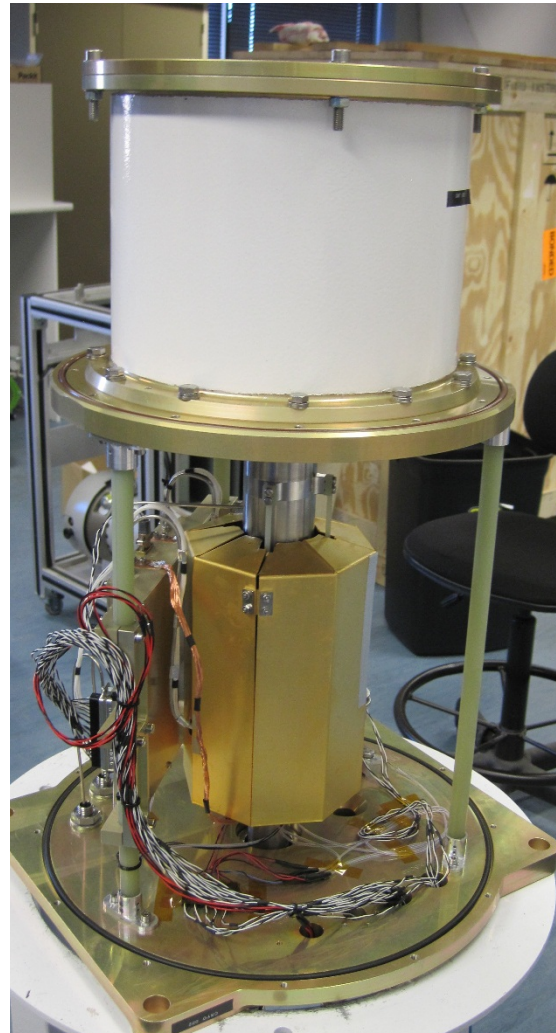
Receiver Test Facility

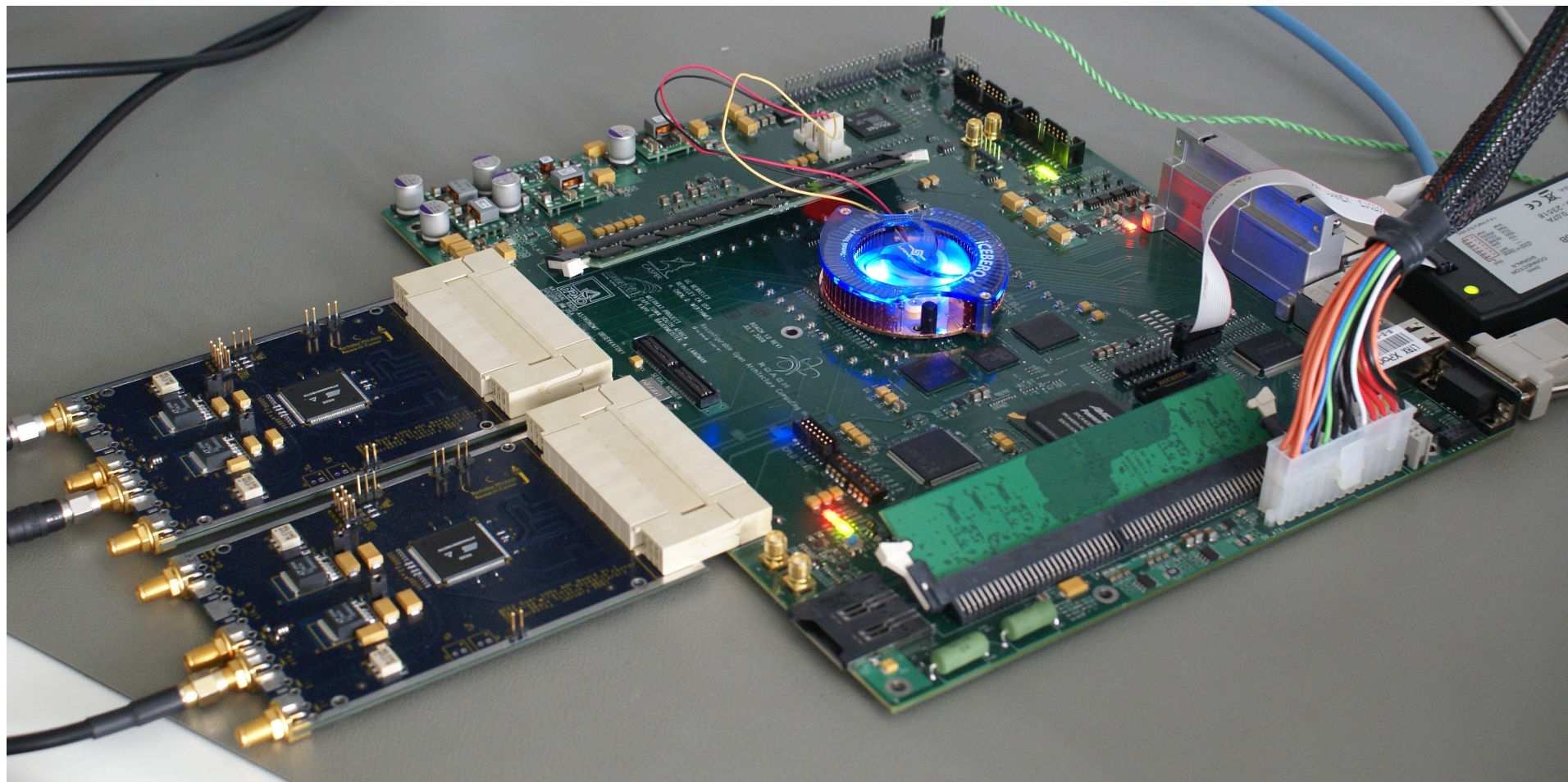Back to back measurement setup: RxUT vs. Noise Test Fixture
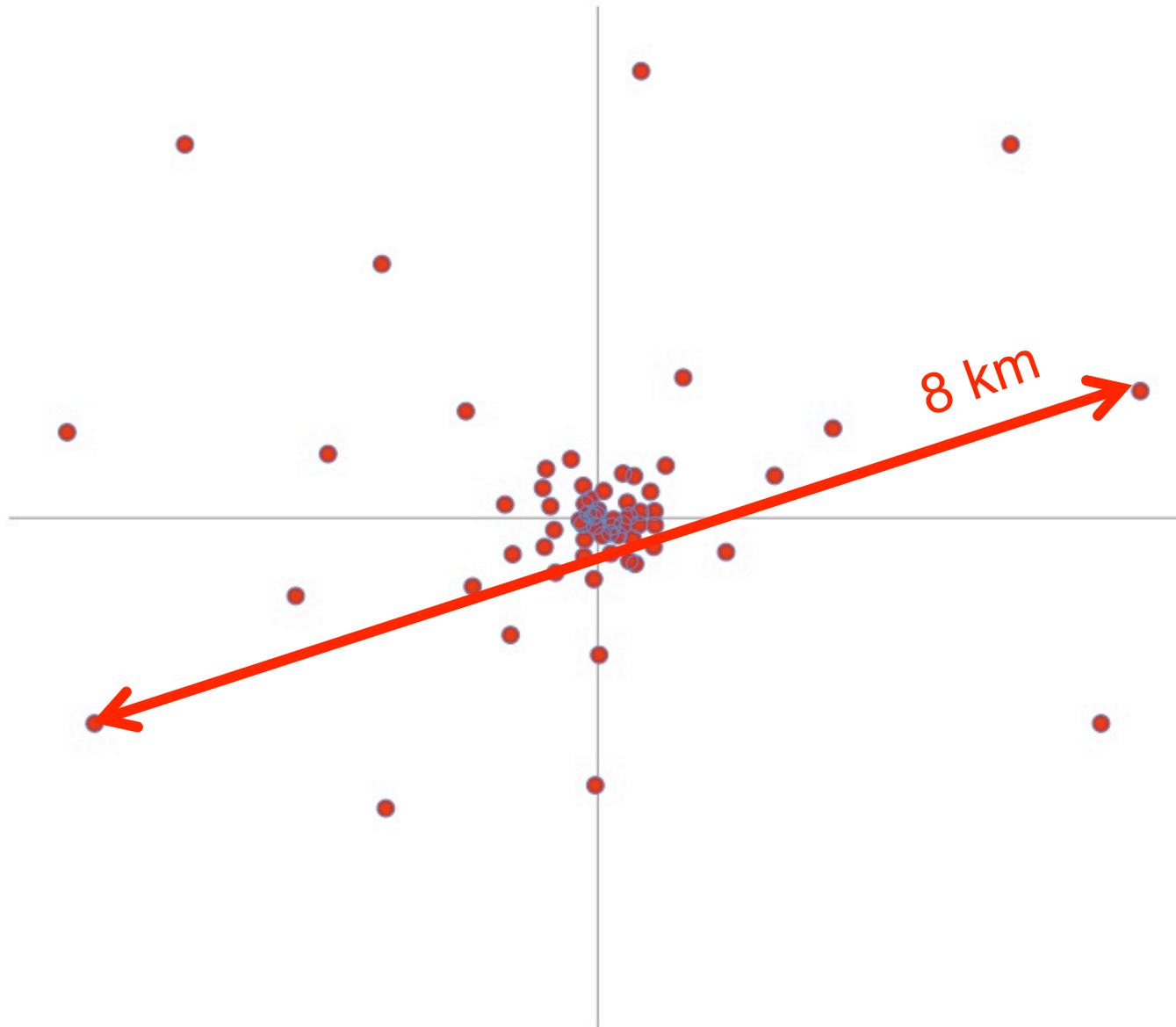
Receiver Site Test Facility

Digital Signal Path

Antenna

Central shielded room

Analog Signal Conditioning

ADC

Digital Down-conversion

Coarse Delay Δt

Polyphase Filterbank

Fine Delay ΔΦ

Transient Buffer

Correlator/Beamformer

Calibration and Imaging Software → Archive

H-polarization

V-polarization

Digitizer

F Engine

X & B Engines
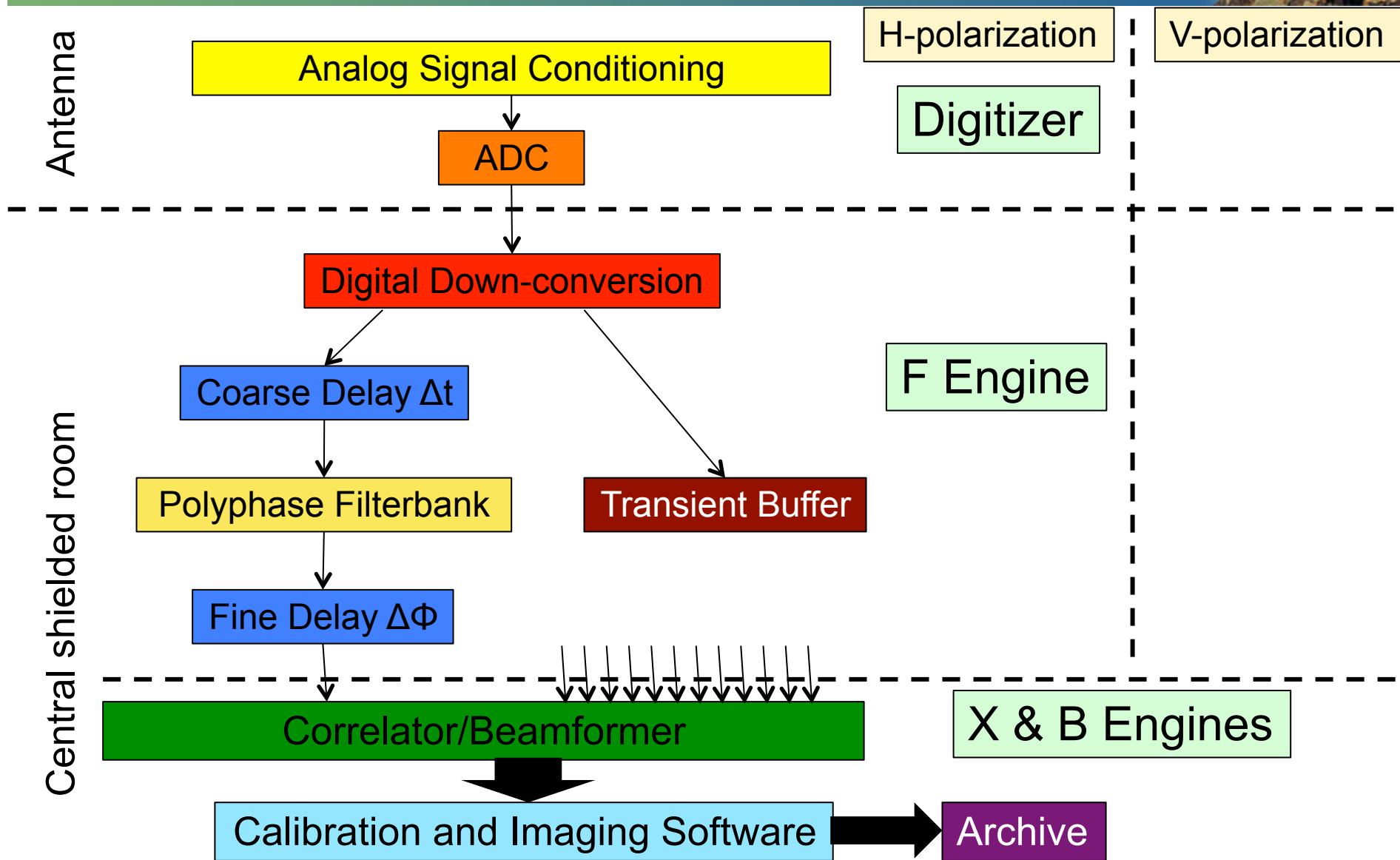
CASPER / ROACH
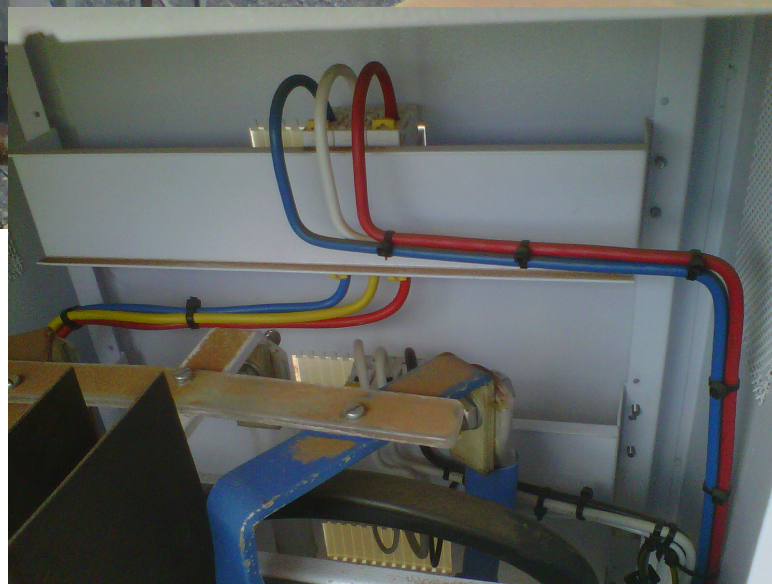
High Performance Computing

Optical Fibre Research

Configuration (64 antennas)

8 km

Road network near the core

Power and Infrastructure
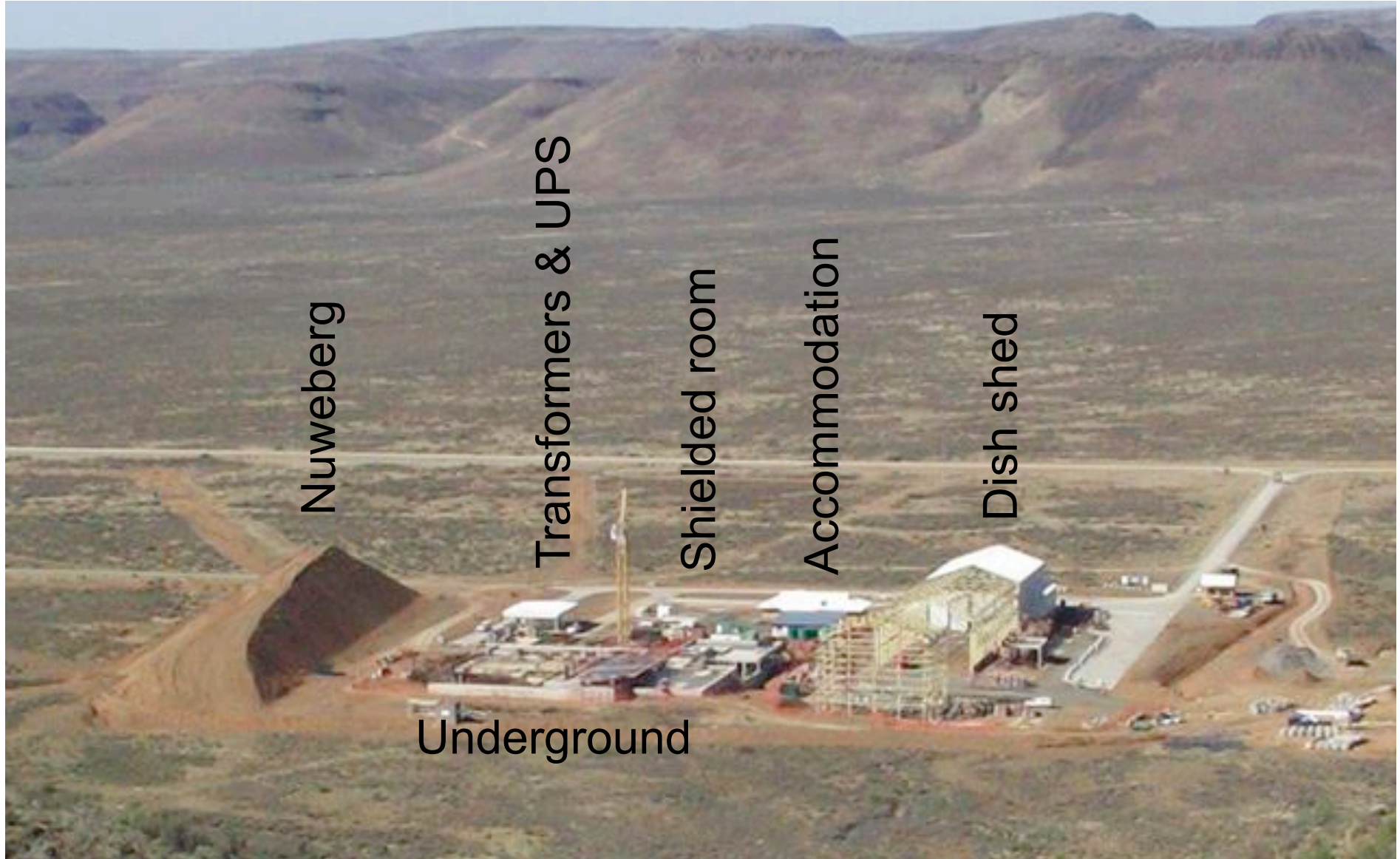
Site Complex extension for MeerKAT

Pedestal integration shed

Dish Assembly shed

Bunkered & RFI shielded processor building and power room
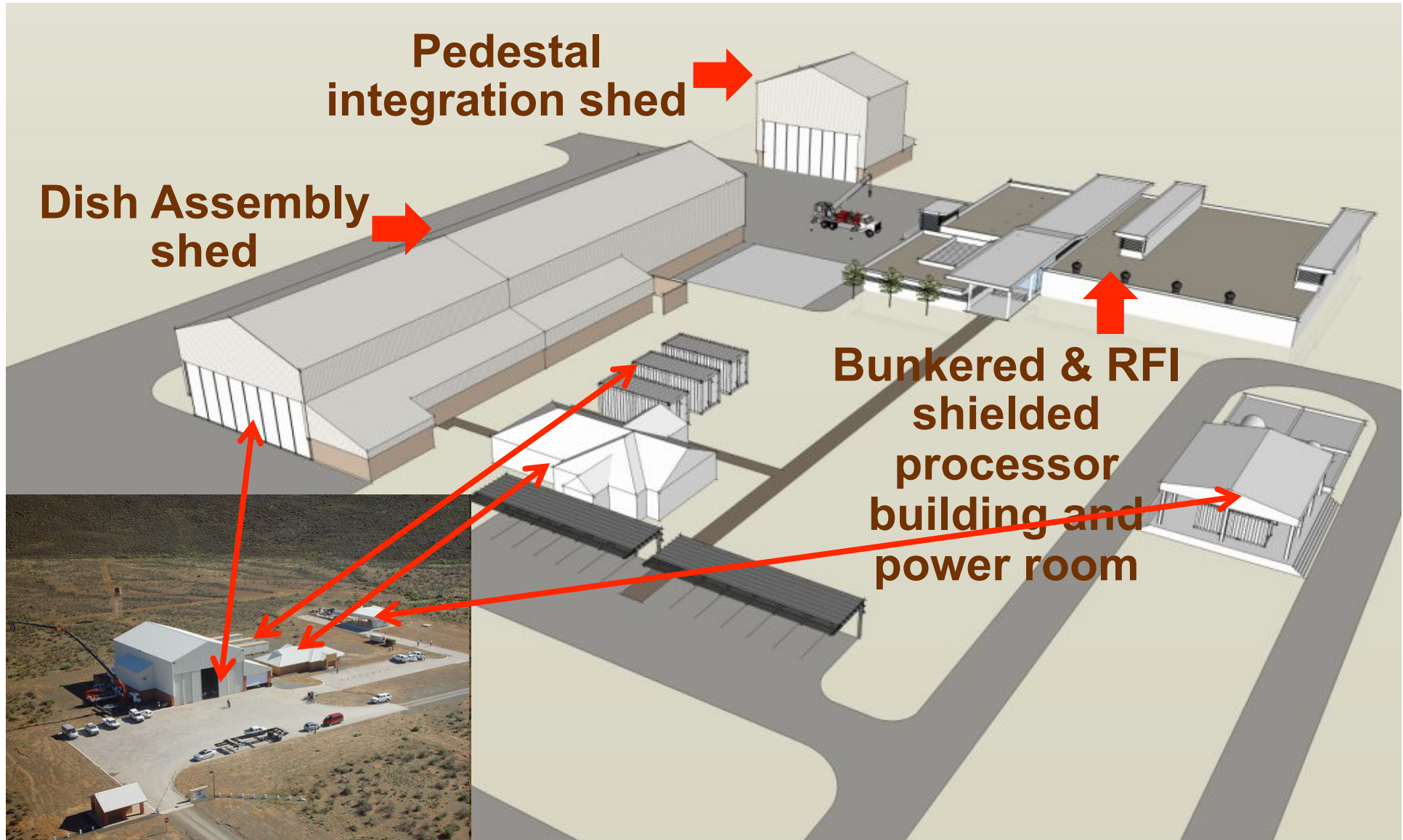
Dish and pedestal sheds

Site complex

Thank you