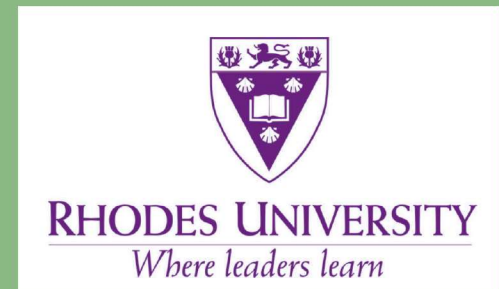


# MeerKAT Update



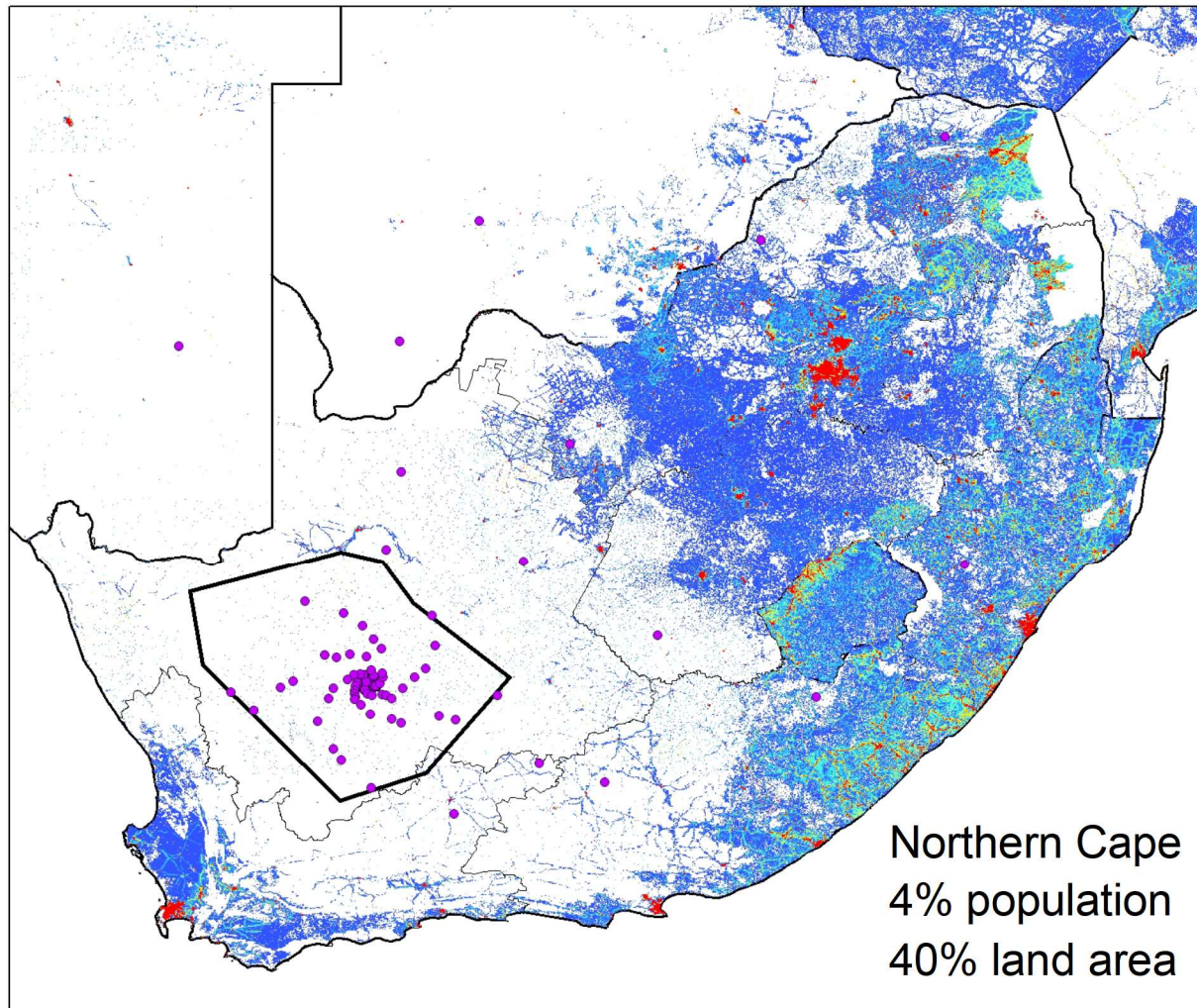
Justin Jonas

on behalf of the SKA  
South Africa Team

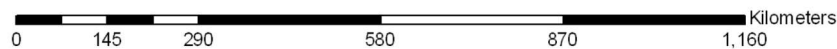


HI Workshop – Madrid – 17<sup>th</sup> June 2016

# Population Density (and RFI)



Northern Cape  
4% population  
40% land area



## Legend

- SKA\_Configuration\_SPDO\_Dish\_Full
- AA1\_SPDO\_Version1
- AA2\_SPDO\_Version2

□ KCAAA1

## Population (per sq km)

Value

- 0 - 4
- 4.00000001 - 14
- 14.00000001 - 29
- 29.00000001 - 47
- 47.00000001 - 68
- 68.00000001 - 91
- 91.00000001 - 116
- 116.00000001 - 142
- 142.00000001 - 169
- 169.00000001 - 197
- 197.00000001 - 225
- 225.00000001 - 255



Contact:  
Dr. Adnan Tiplady  
SKA South Africa  
17 Baker Street  
Rosebank  
2196  
South Africa  
Tel: +27 11 442 2434  
Fax: +27 11 442 2454  
Email: atiplady@ska.ac.za



# RFI Survey (with students & ICASA)





# “Green Field” site (2005)





Let's put it here...





# South of the Karoo Site





# The MeerKAT Programme



- Africa must have a legacy of a large radio telescope
  - Irrespective of the outcome of the SKA site competition
  - But not independent of the SKA
- MeerKAT is an SKA “precursor”
  - Engineering prototype
  - Early science (SKA “Phase 0”)
  - Largest array radio telescope in the world
    - 64 13.5m dishes
- Build up a science and engineering team
  - To build MeerKAT and SKA, and use them
  - Over 200 engineers and scientists currently employed
- Phased development
  - XDM, KAT-7, MeerKAT, SKA<sub>1</sub>, SKA<sub>2</sub>
- MeerKAT will be make up 30% of SKA<sub>1</sub>
  - The strategy was successful

# Karoo Infrastructure



- **Designed** to accommodate SKA-1 from the start.
  - Land and roads
  - 6 MVA grid power line
  - Power reticulation and transformers on site
  - Electrical substation & power conditioning
  - Data rack area
  - Maser time and frequency reference
  - Operations centres
  - Optical fibre
- **Fitted** for MeerKAT requirements
  - 3 DRUPS units (+2 for SKA-1)
  - Air conditioning and power distribution in data rack area



# Establishing the Karoo site



Power



Roads



Tracy Cheetham



Data



Buried reticulation



# Carnarvon S/S upgrade to 10 MVA





# MeerKAT Foundations





# MeerKAT Array





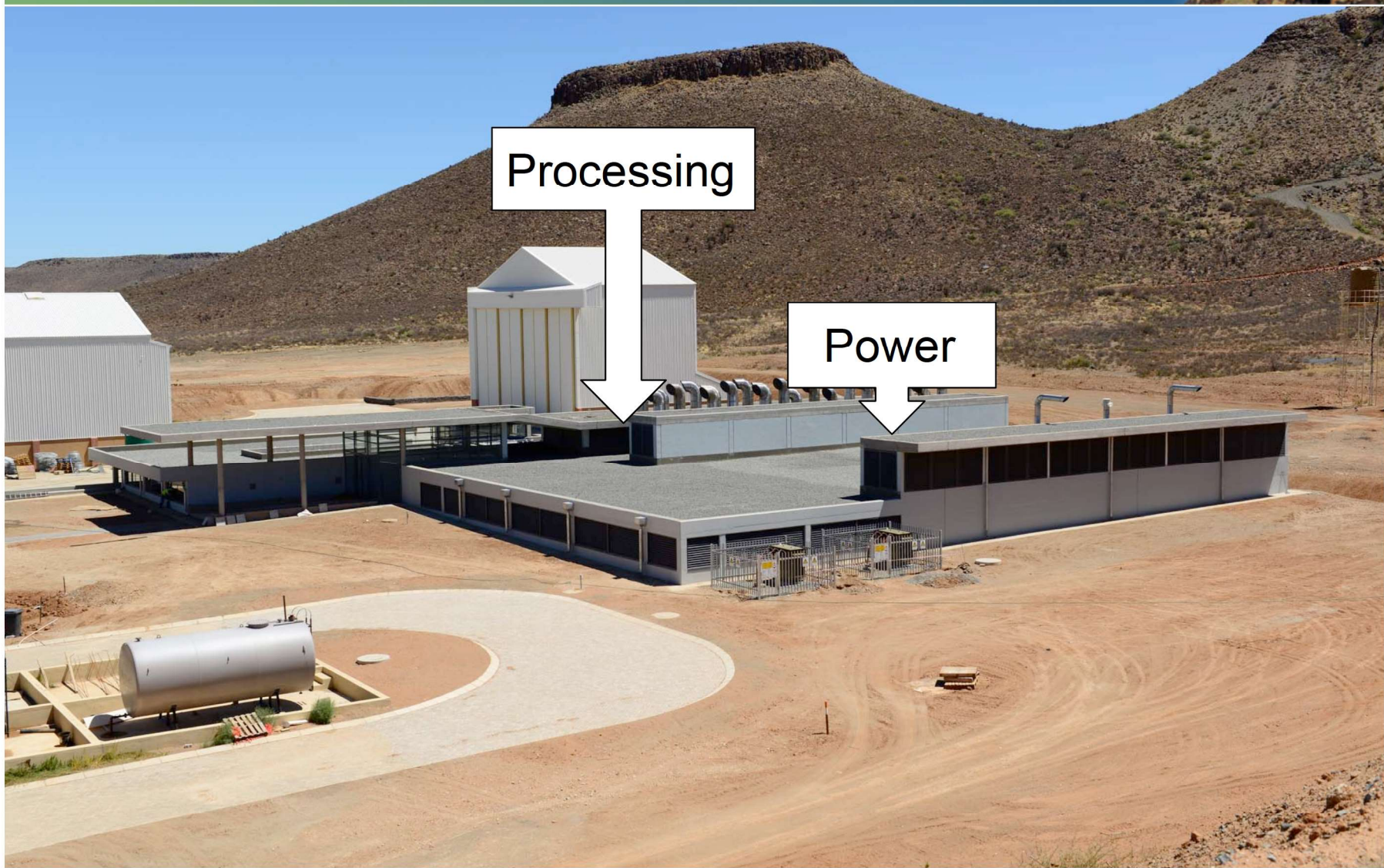








# Bunker – RFI & temperature





# 3 x 1.25 MVA DRUPS



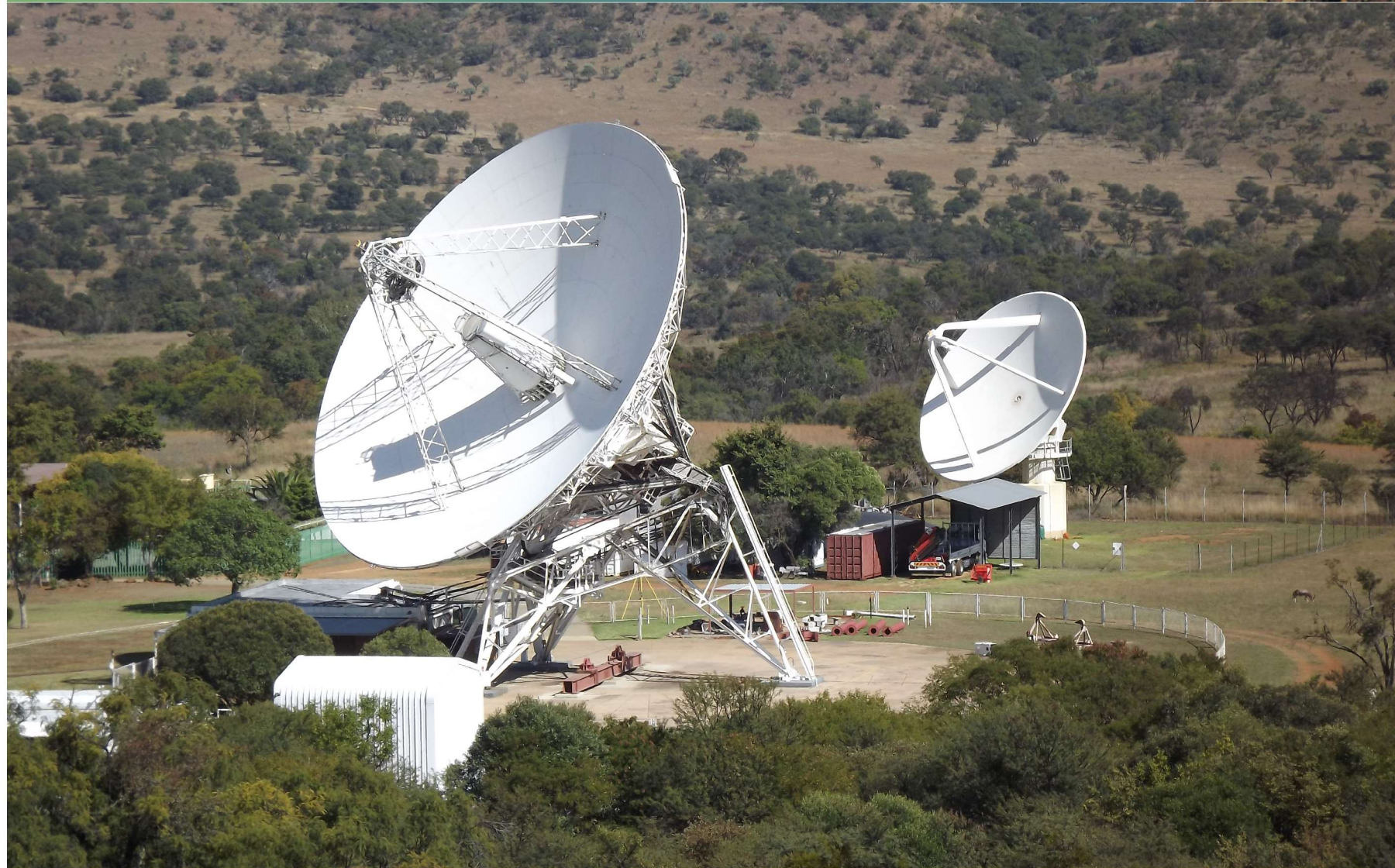


# Shielded Room & Equipment Racks





# XDM – “HartRAO Mini Me”





# KAT-7 Array





# MeerKAT Phase 1 (Baseline 1.0)



- 64 x 13.5 m gregorian offset antennas
  - Sensitivity > 300 m<sup>2</sup>/K
- 8 km maximum baseline
  - 70 % in < 1km diameter core
- 0.9 – 1.670 GHz cryogenic single-pixel receiver (L-band)
  - $z = 0 - 0.58$
- 0.58-1.015 GHz cryogenic single-pixel receiver (UHF-band)
  - $z = 0.42 - 1.45$
- Correlator/Beamformer
  - Full RF bandwidth, full Stokes
  - Continuum and Spectral Line Imaging
  - Pulsar Timing
  - Transient Search (including Pulsars)
- Data Processing, Archive & Delivery
- Infrastructure for all of the above

(deviation from original published baseline for large survey proposals in red)



# Design Parameter Space

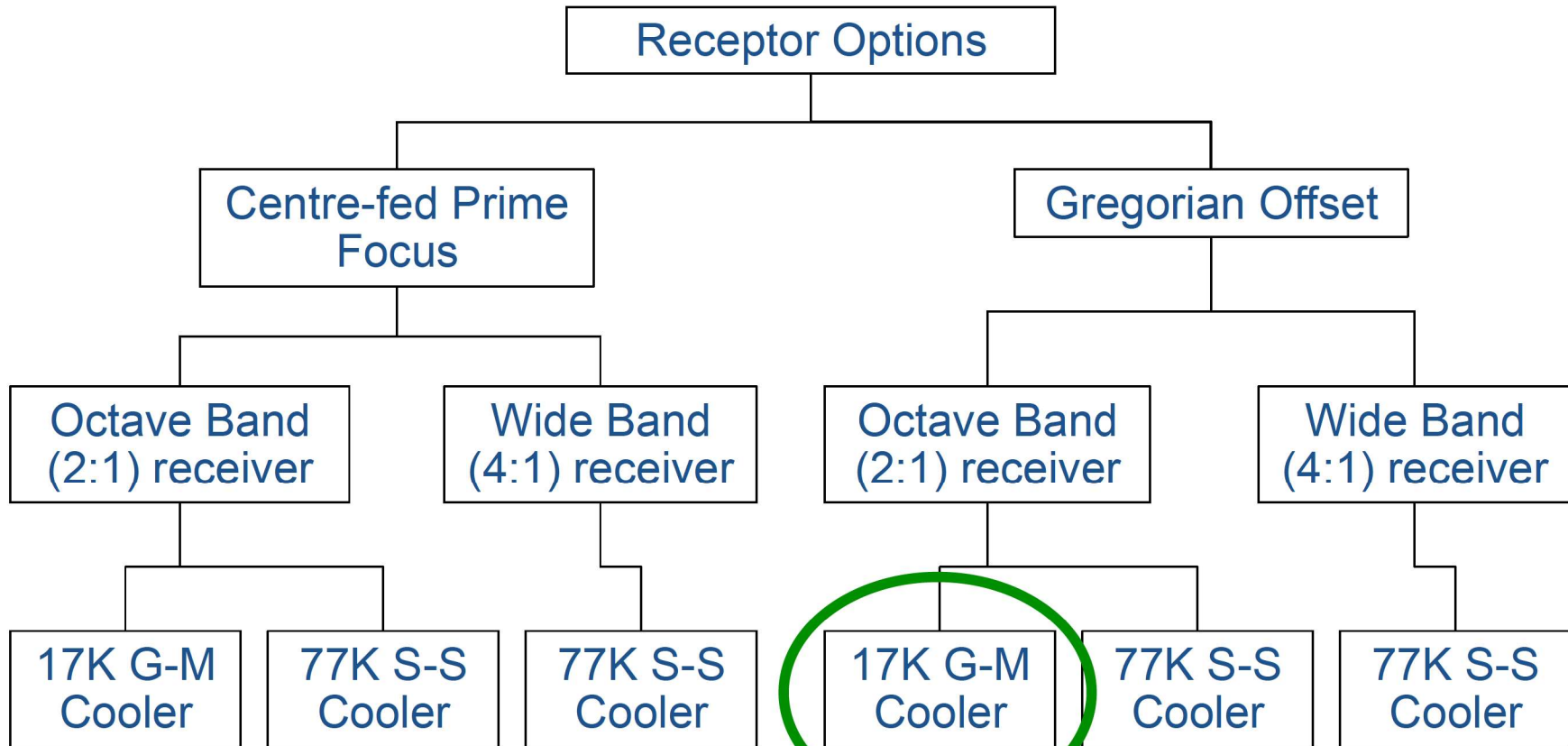


- Sensitivity
- Field of View
- Angular resolution
- Instantaneous bandwidth
- Sky coverage
- Dynamic range
- Stability
- RFI/EMC
- Reliability/availability
- Capital cost
- Power consumption
- Compute cost
- Data transport cost
- Data storage cost
- Maintenance cost

Need to do a thorough Concept Exploration to fully sample this parameter space and perform trade-offs.

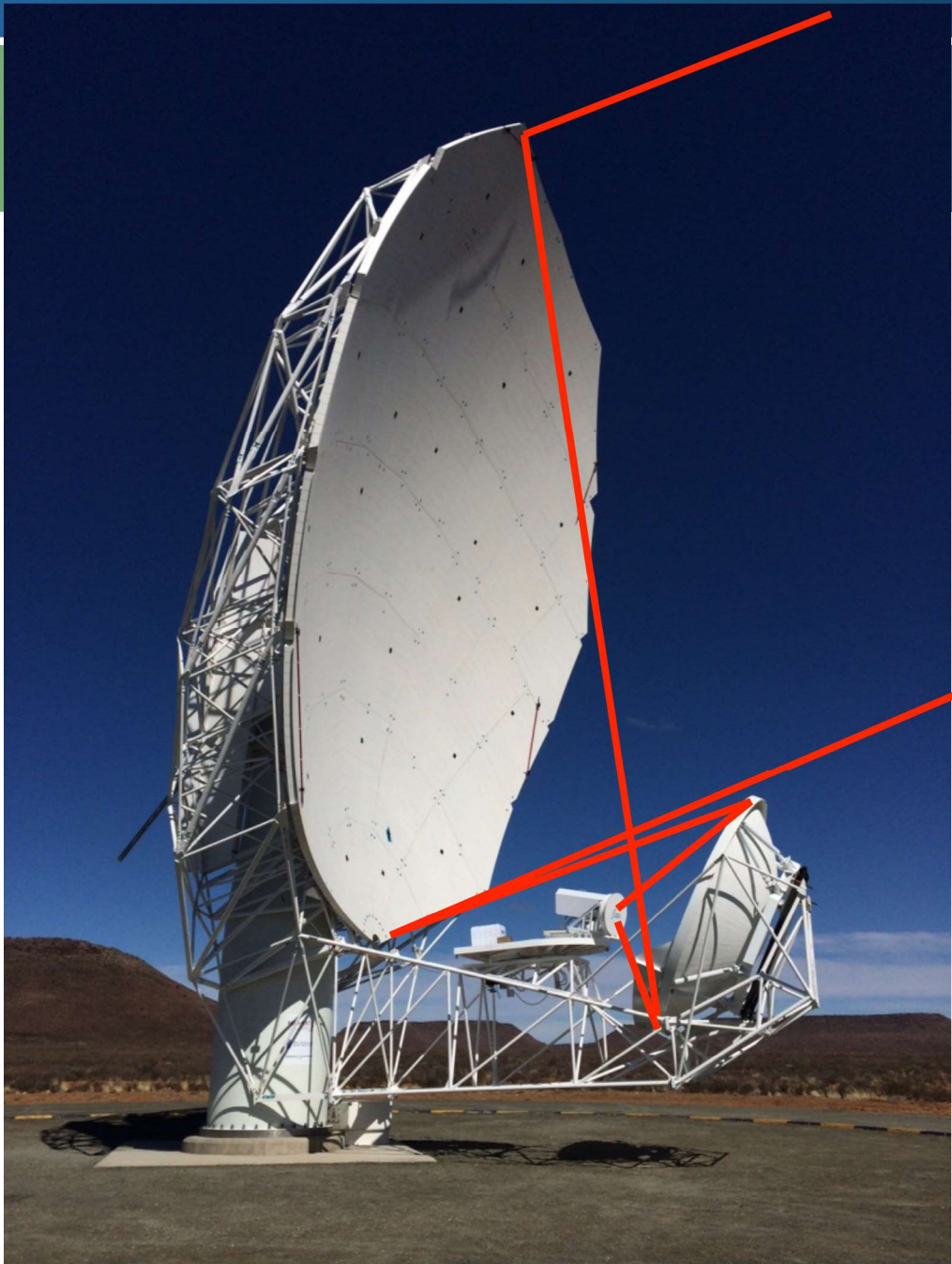


# Example of CoDR Study: Receptor



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





Unblocked Aperture,  
high effective  
aperture

Large volume for  
multiple receivers  
and associated  
services

Low ground spillover

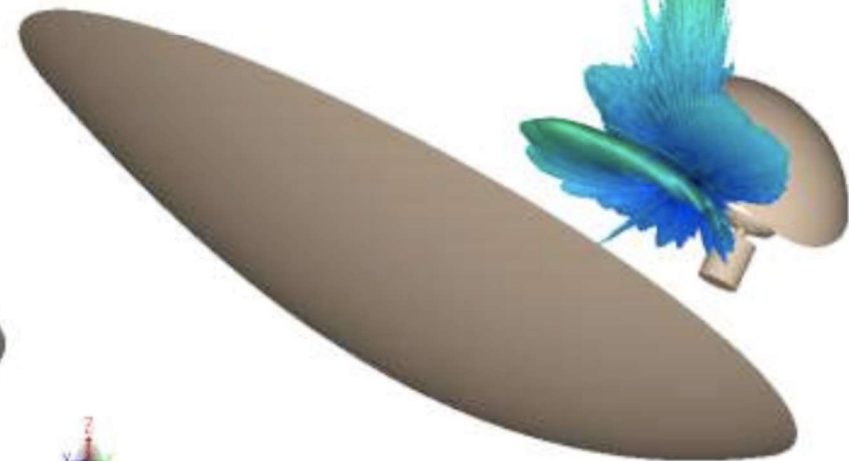
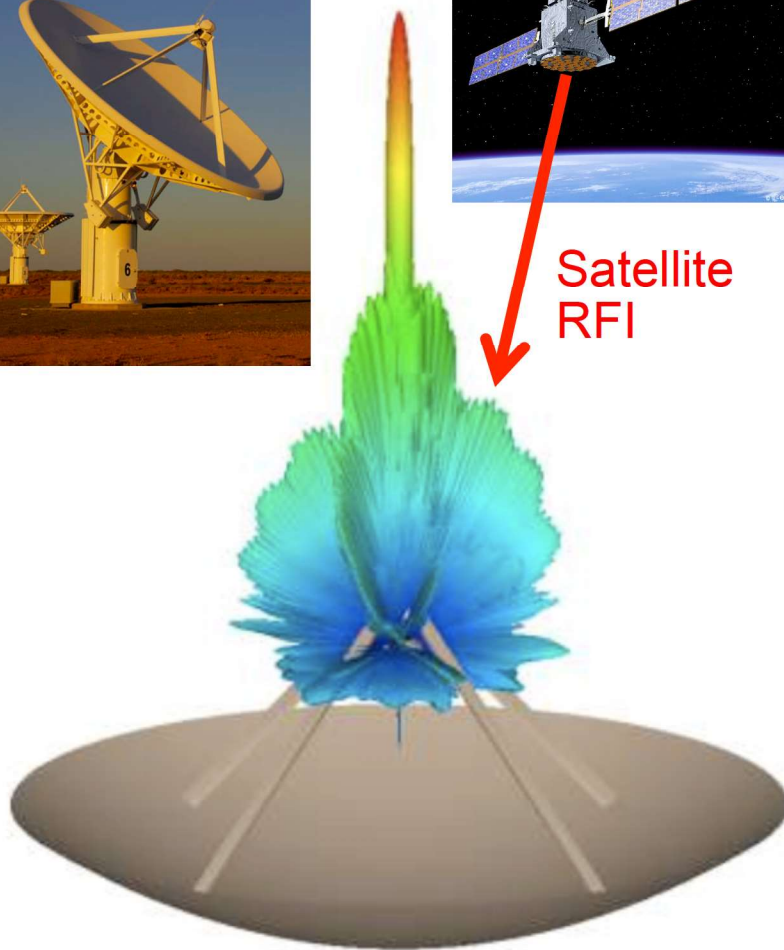




# Electromagnetic Modeling



Satellite  
RFI

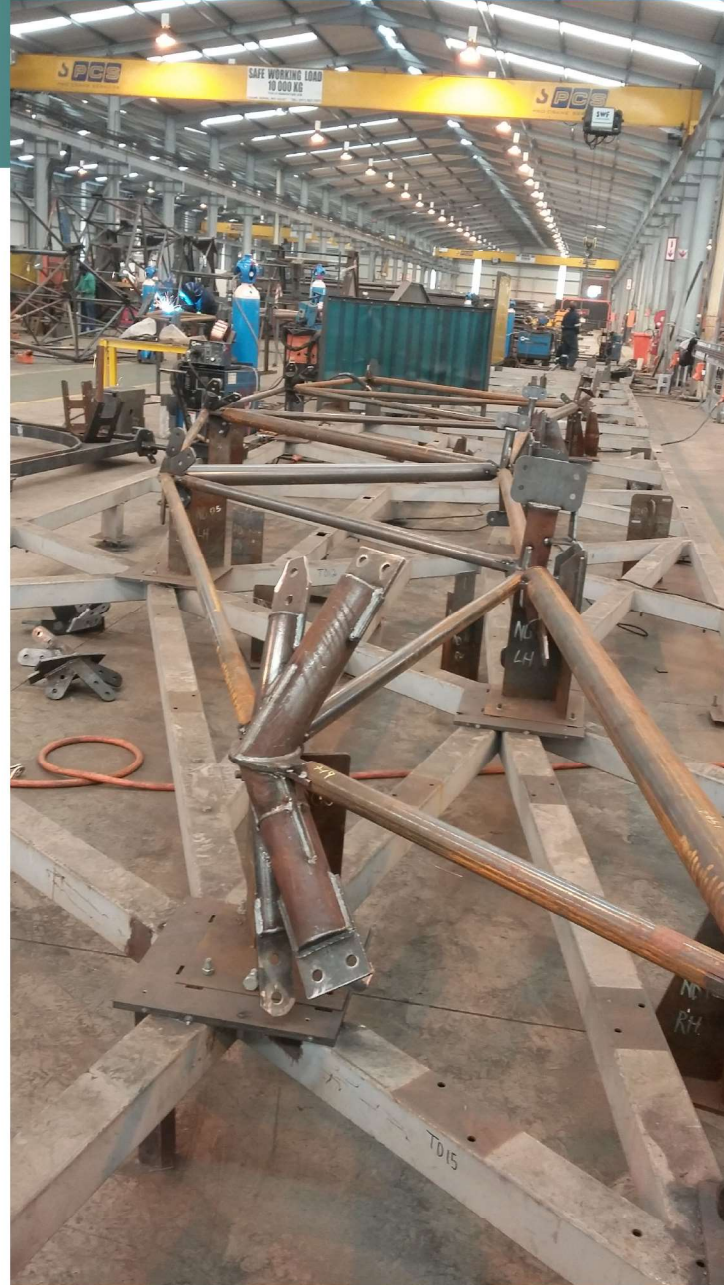


# Pedestal fabrication & integration





# Welding (lots)



# Dish panel factory





# Sub-reflector Moulding

















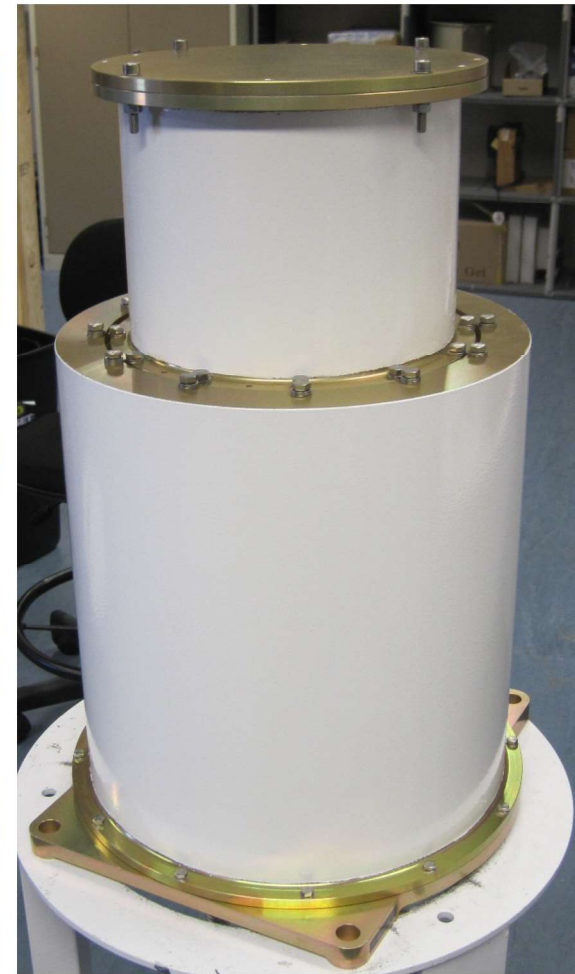
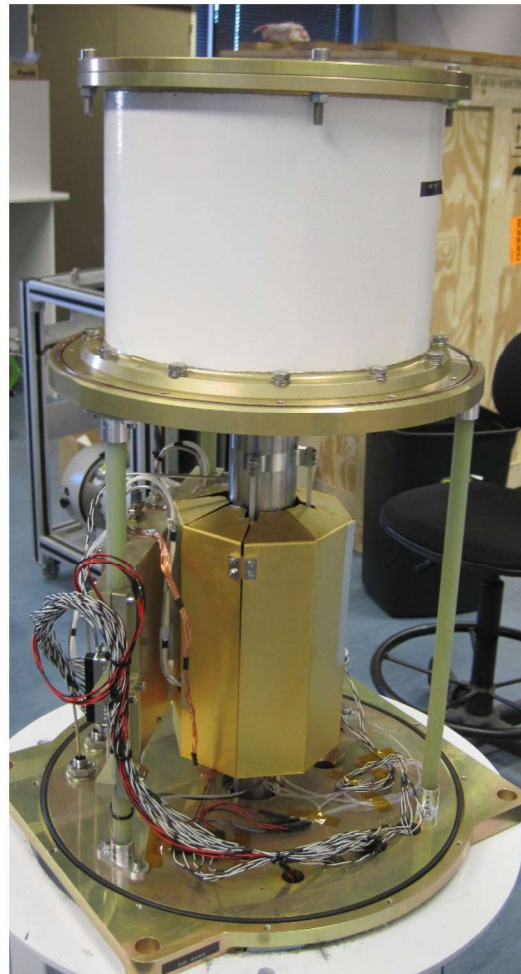
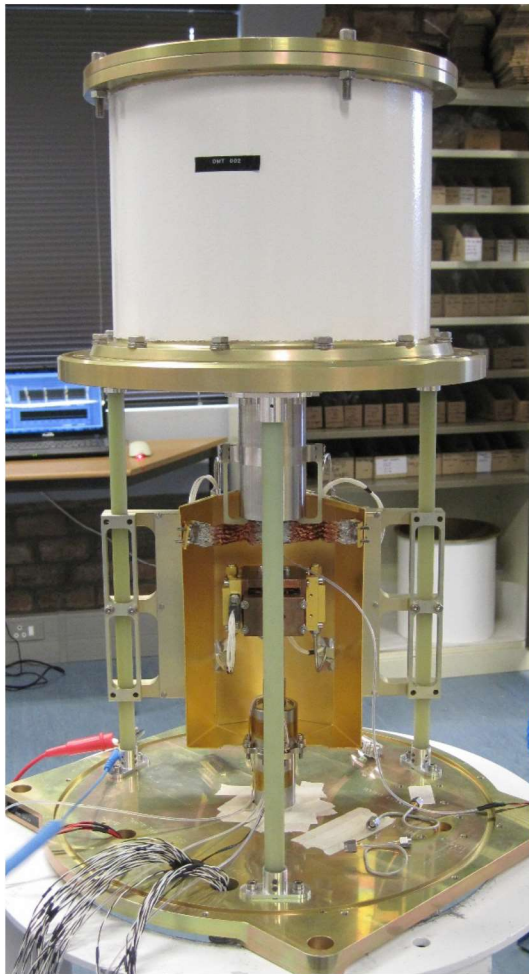
# The BUS ride







# Cryogenic Receivers



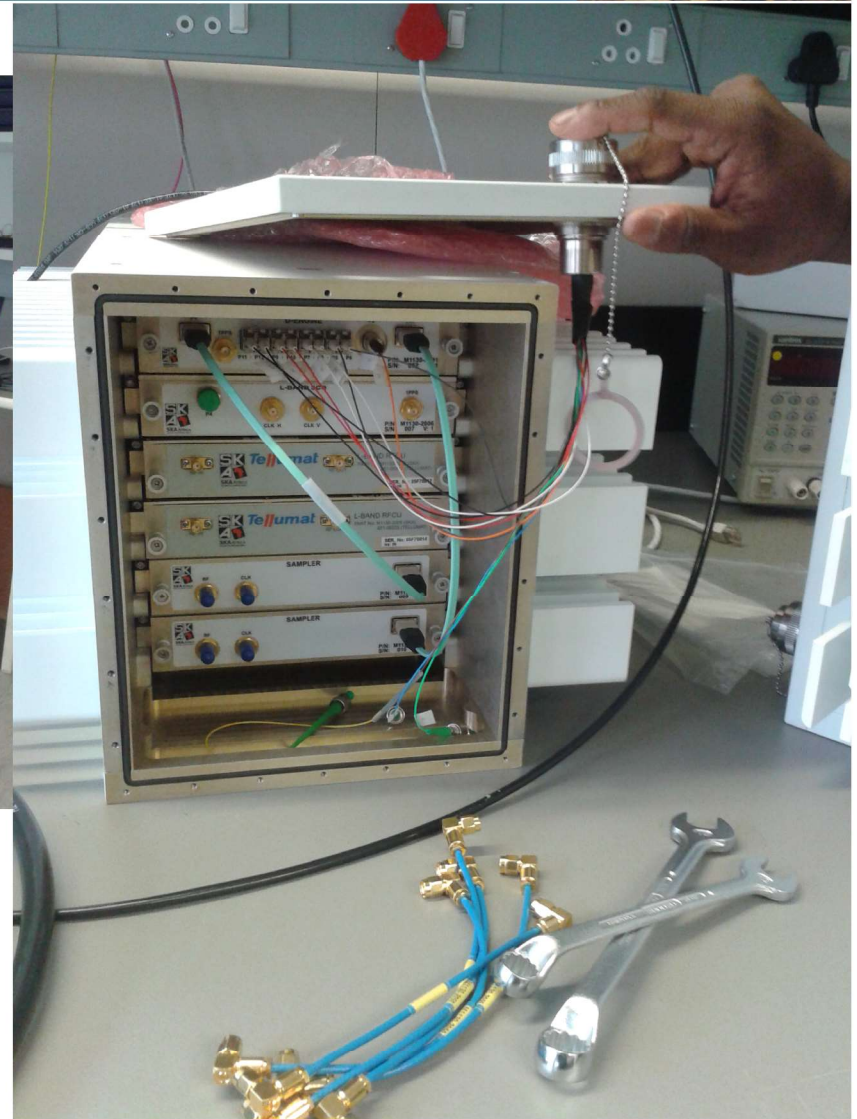


# EMSS Rx Production Facility





# Digitizer Assembly

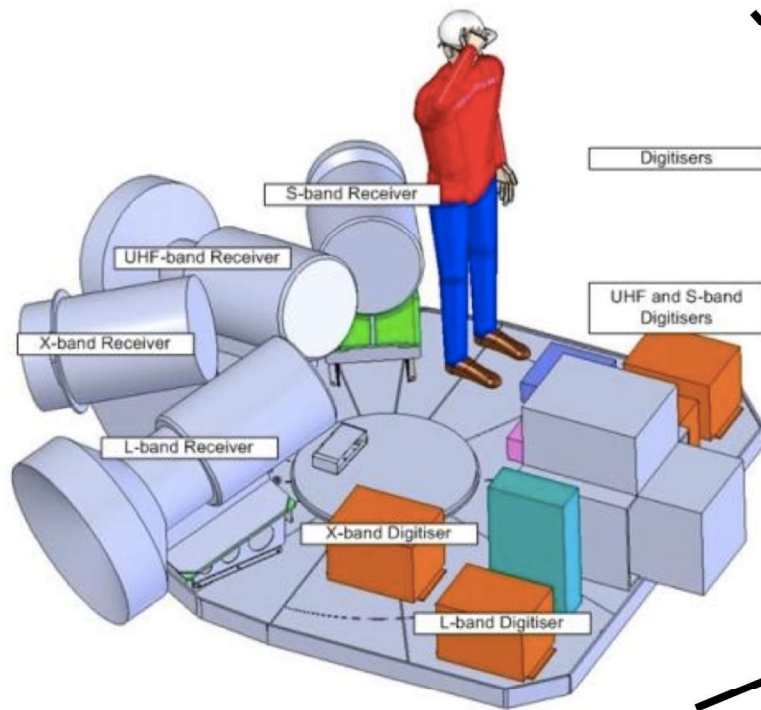


- >1 DVD per second per antenna
- Array would produce a 12 km high stack of DVDs per day

# MeerKAT Dish

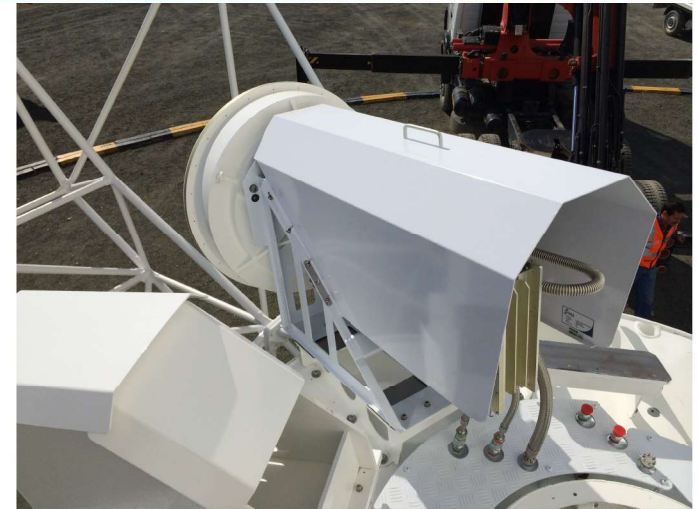


Receiver Indexer with Horns,  
Receivers, Digitizers and  
Services



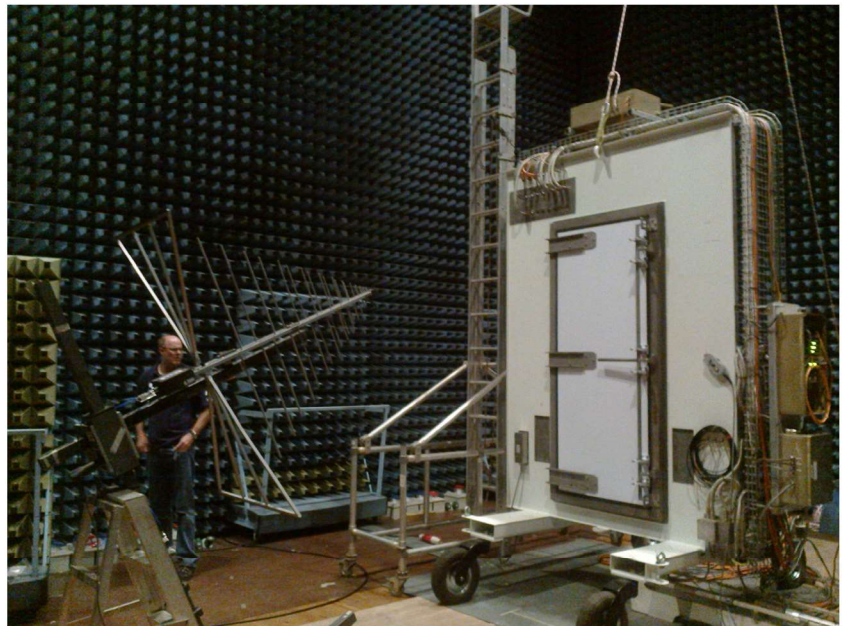
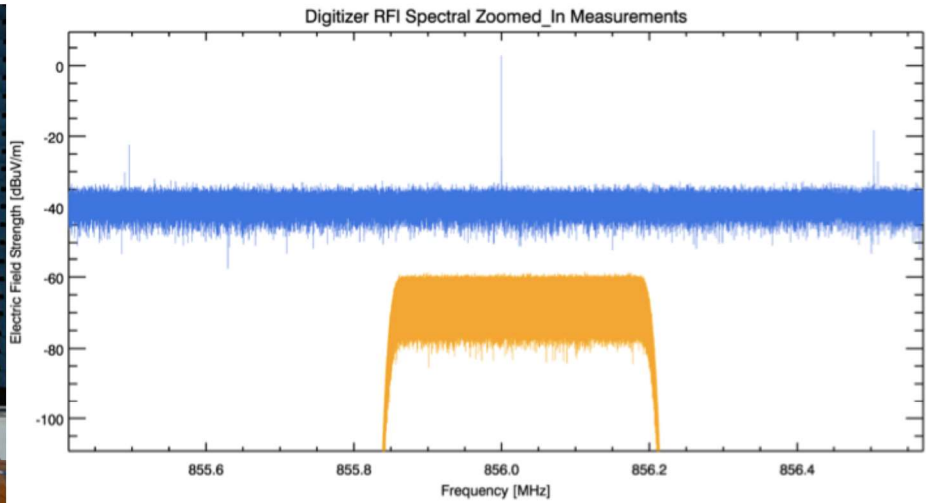
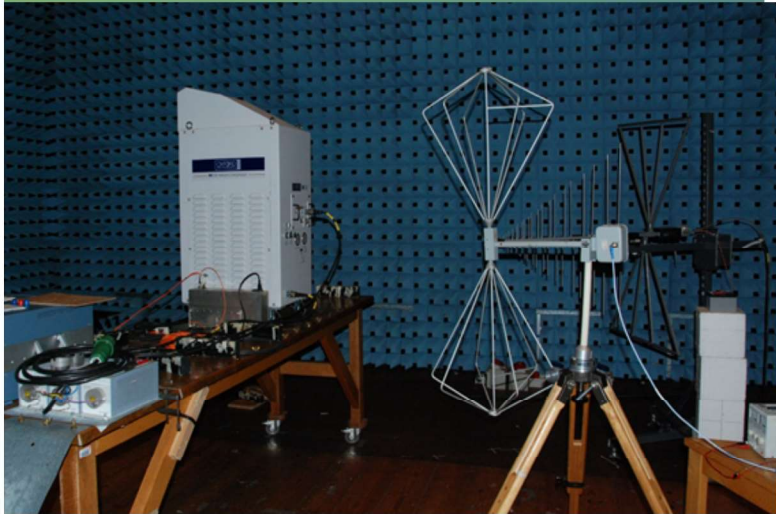


# Receivers & Services Installed



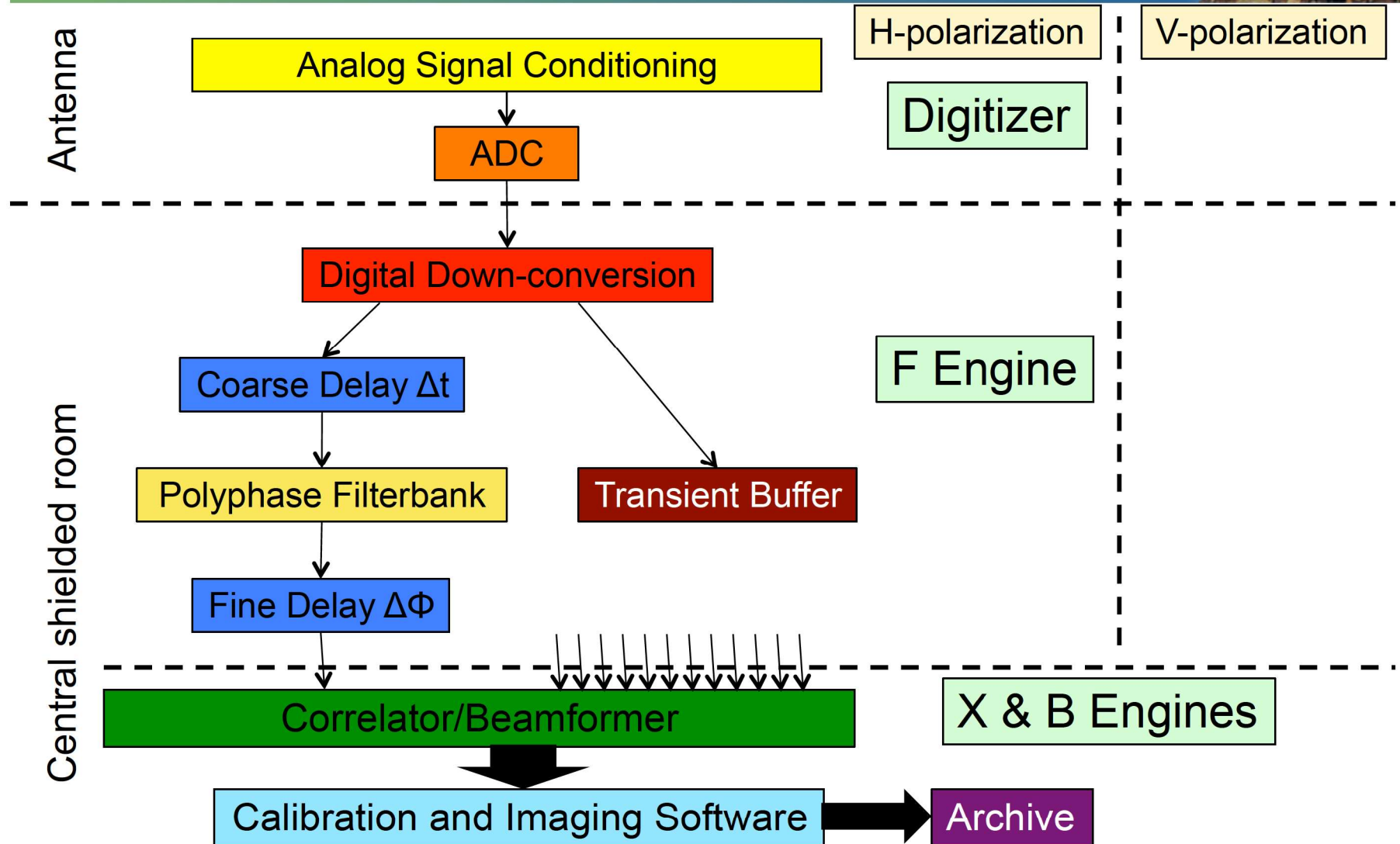


# RFI Qualification and Testing

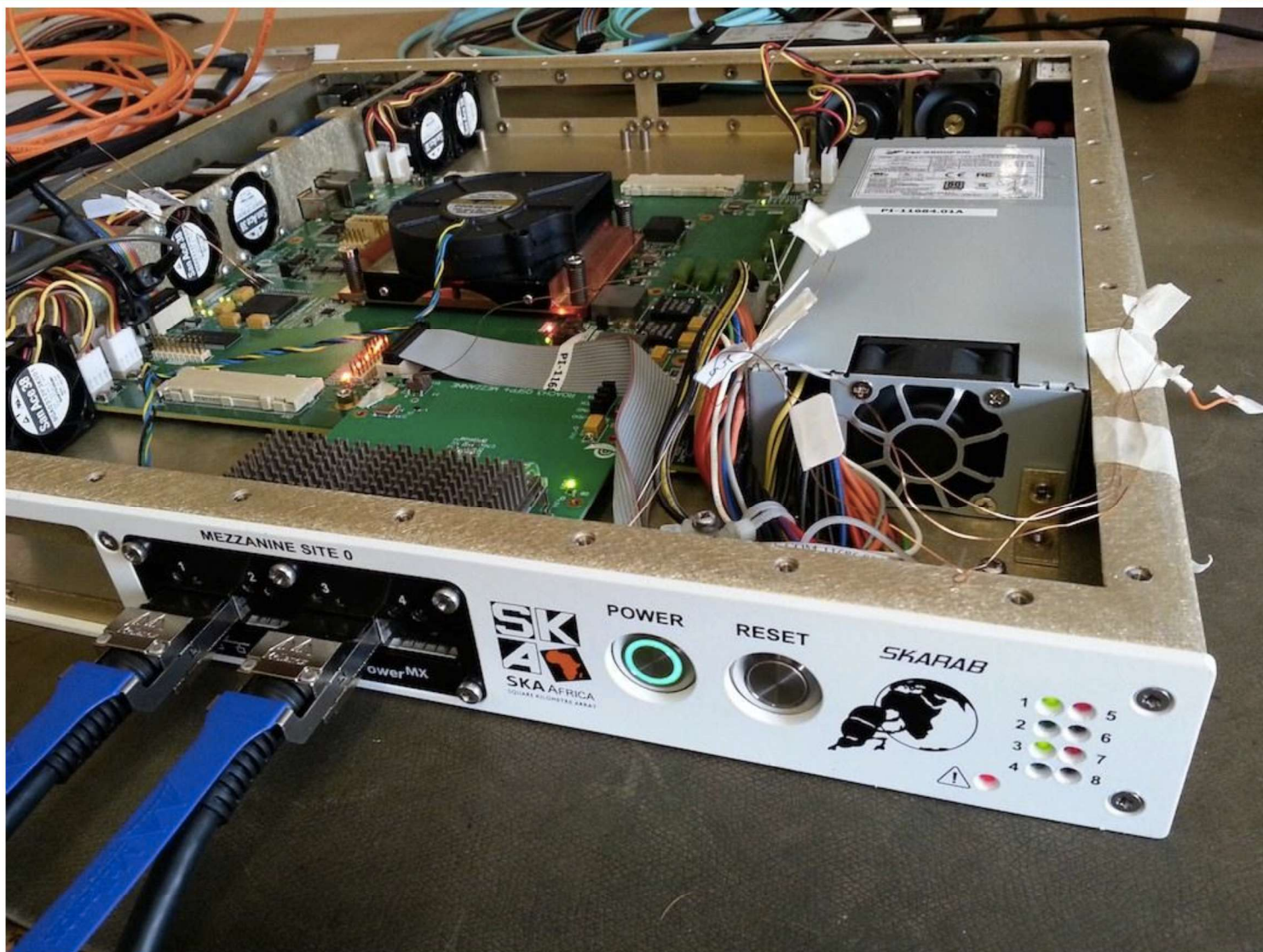




# Digital Signal Path

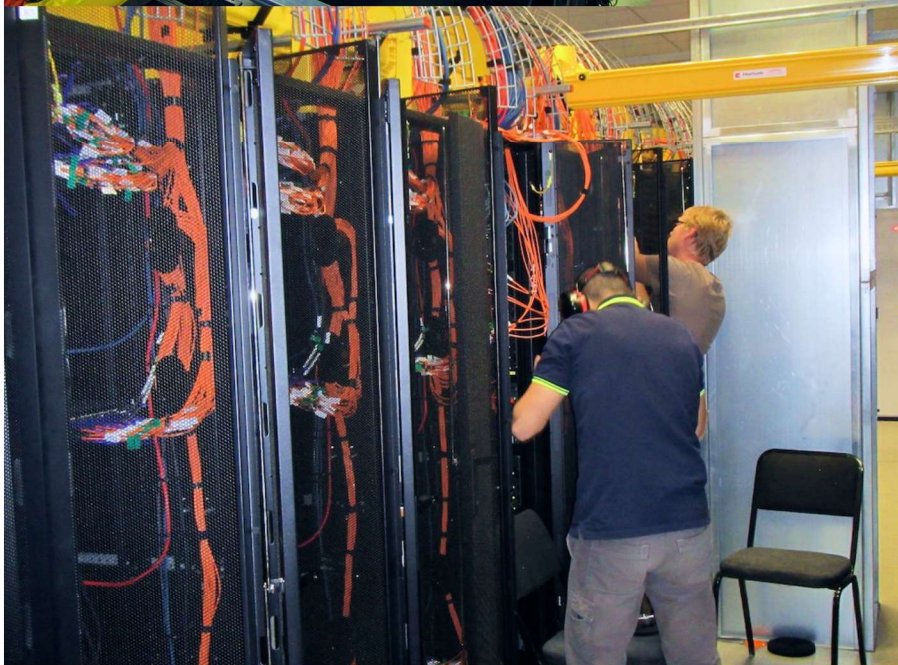


# SKARAB (ROACH-3)





# CBF Switch Installed





# Science Data Processing





# Science Data Processing



## Storage



## Micro-servers



# Calibration & Imaging



Measurement equation:

$$V_{pq} = \prod_k [G_p^k \otimes G_q^{k*}] \int_{\Omega} \prod_k [T_p^k(\vec{\rho}) \otimes T_q^{k*}(\vec{\rho})] e^{-2\pi j \vec{b}_{pq} \cdot (\vec{\rho} - \vec{\rho}_s)} K S(\vec{\rho}) d\Omega$$

Kemball, Cornwell & Yashar, *CPG Memo #4*

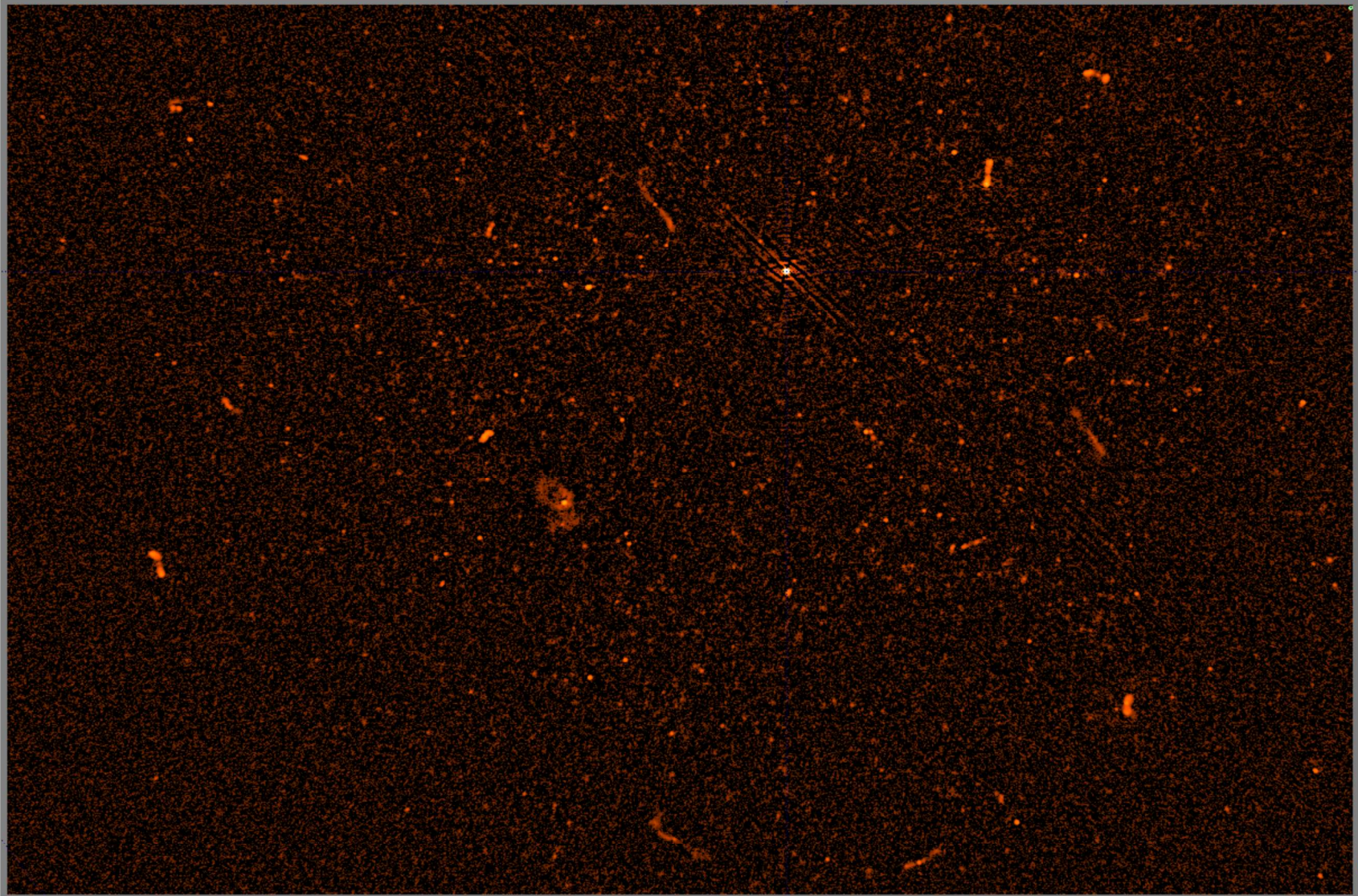
$$V_{pq} = G_p \left( \sum_{\rho=1}^N T_{p\rho} X_{\rho} T_{q\rho}^* \right) G_q^*$$

Noordam & Smirnov, *MeqTrees*



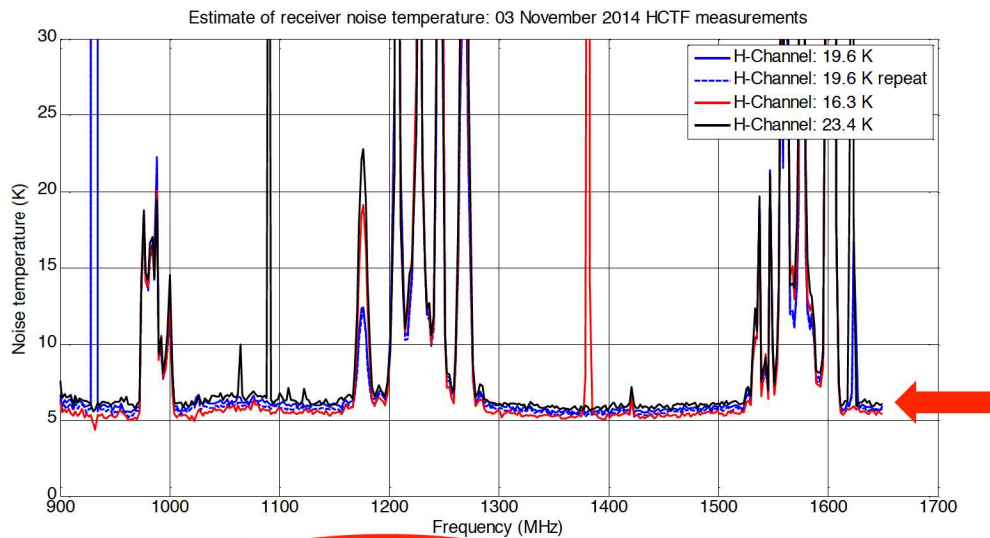


# JVLA BnA – 5 000 000 : 1 DR



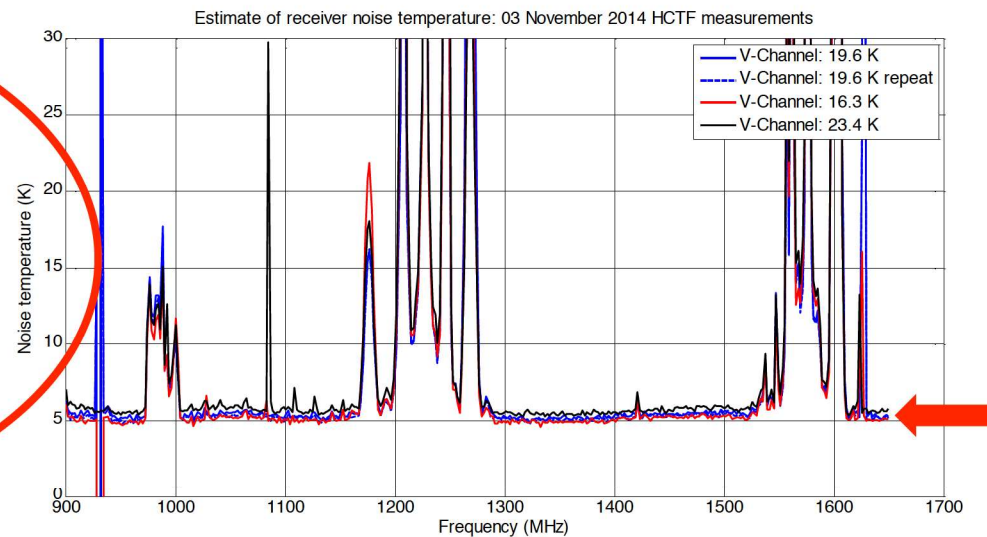


# Results from Penticton (DVA-1)



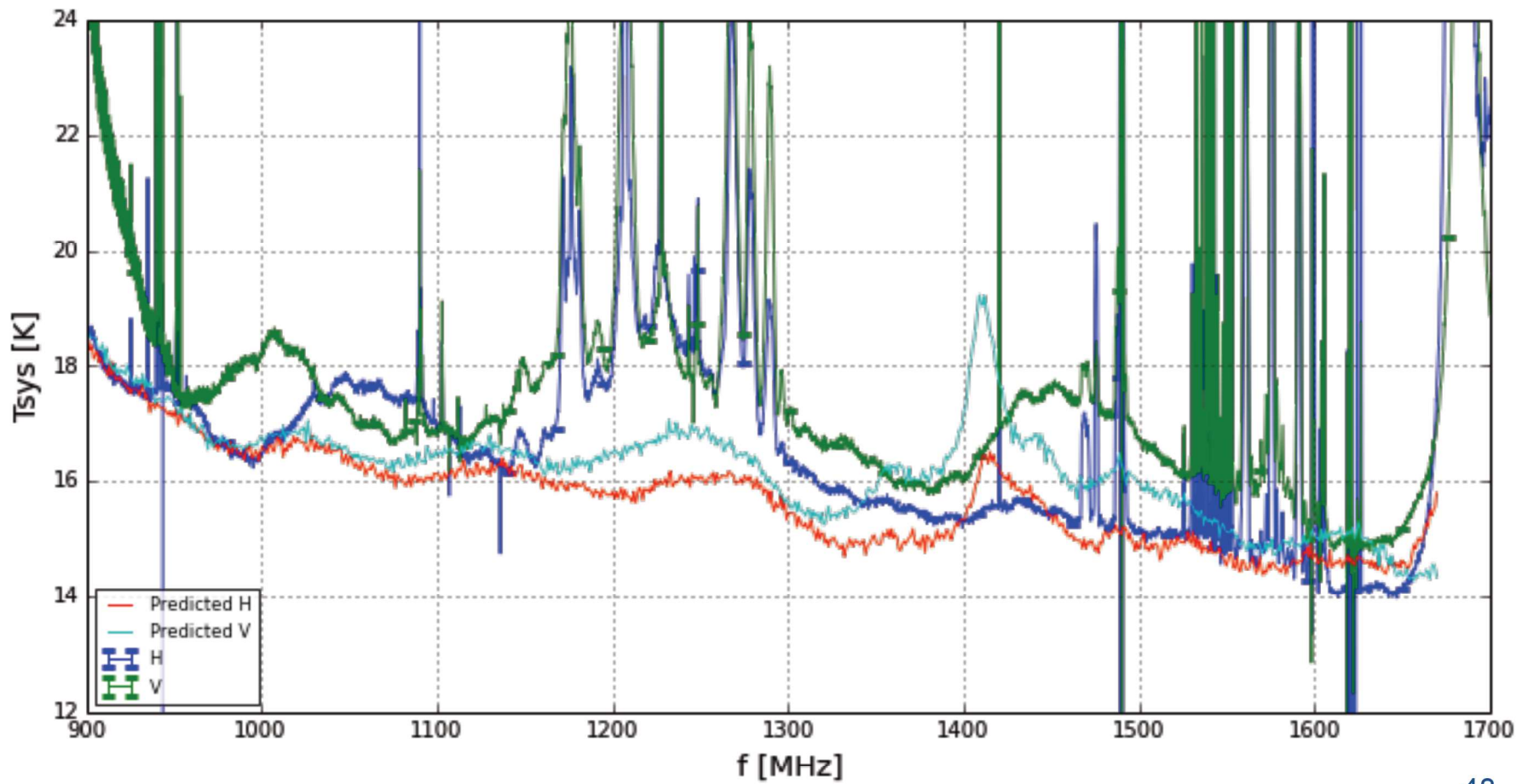
- MeerKAT L-band receiver to be installed on DVA-1
- Results from Penticton Hot/Cold Test Facility

- Receiver noise temperature  $T_{rx} < 7$  K
- Consistent with laboratory measurements at EMSS
- Translates to  $T_{sys} \approx 18$  K (see next slide)

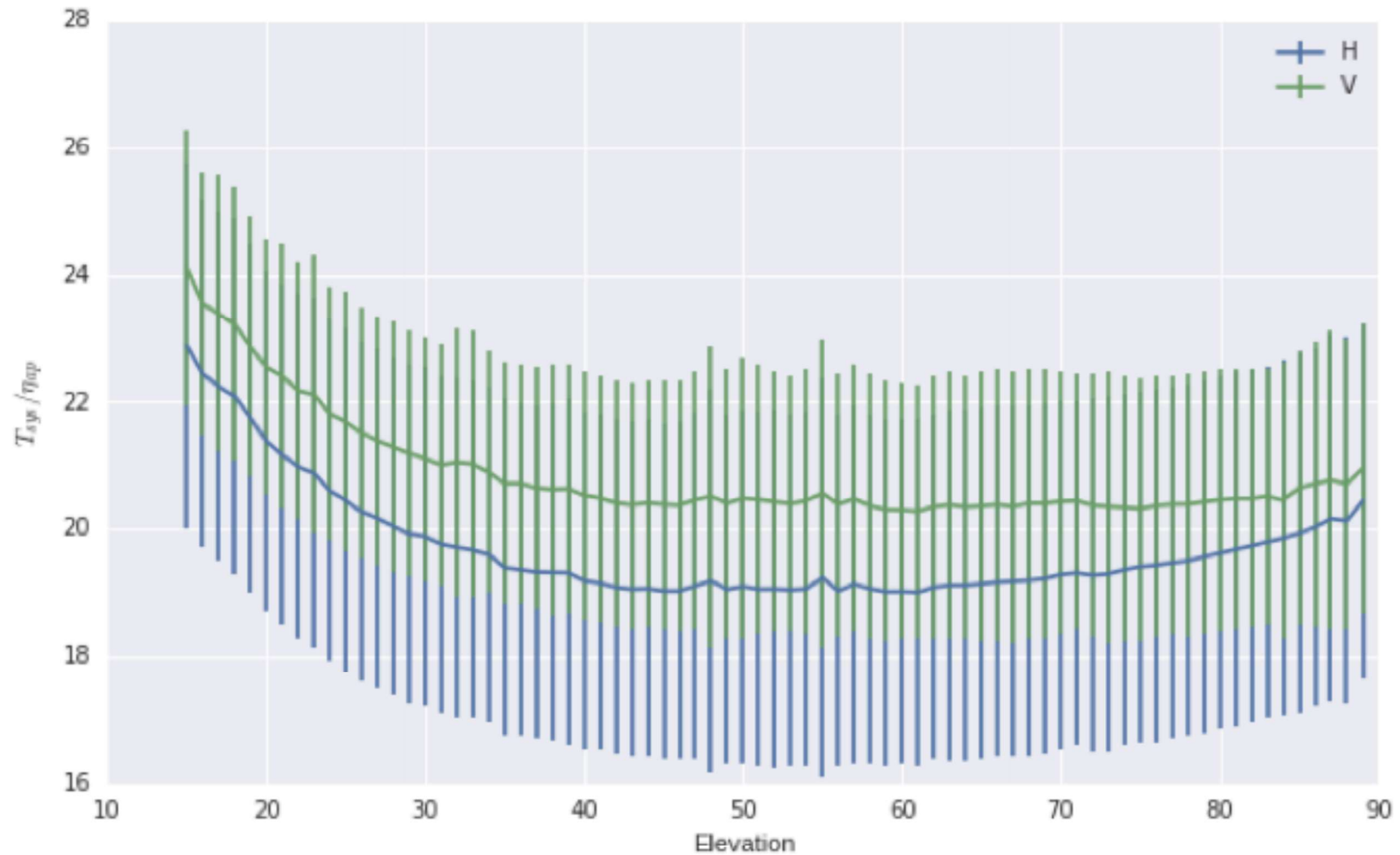




# Tsys @ 65° Elevation



# Tipping Curve - ~1400 MHz



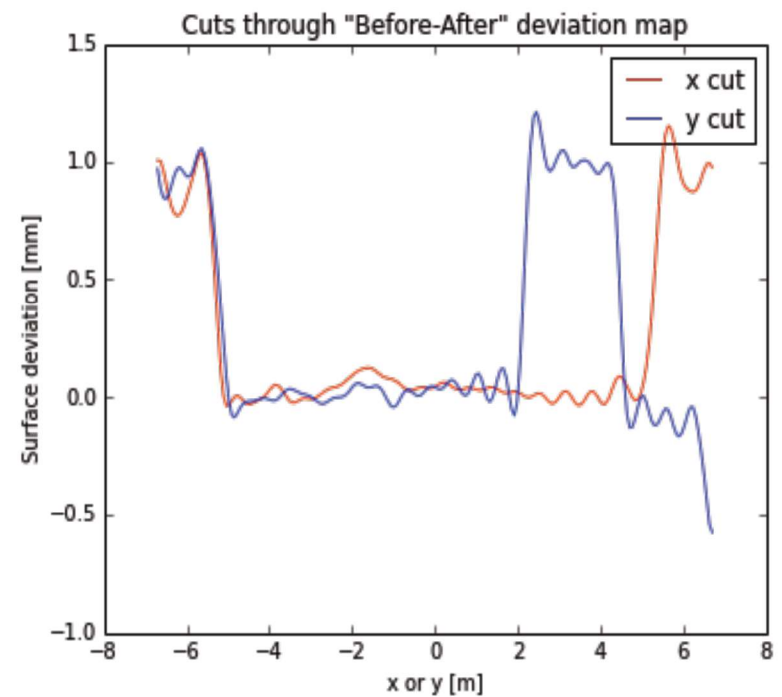
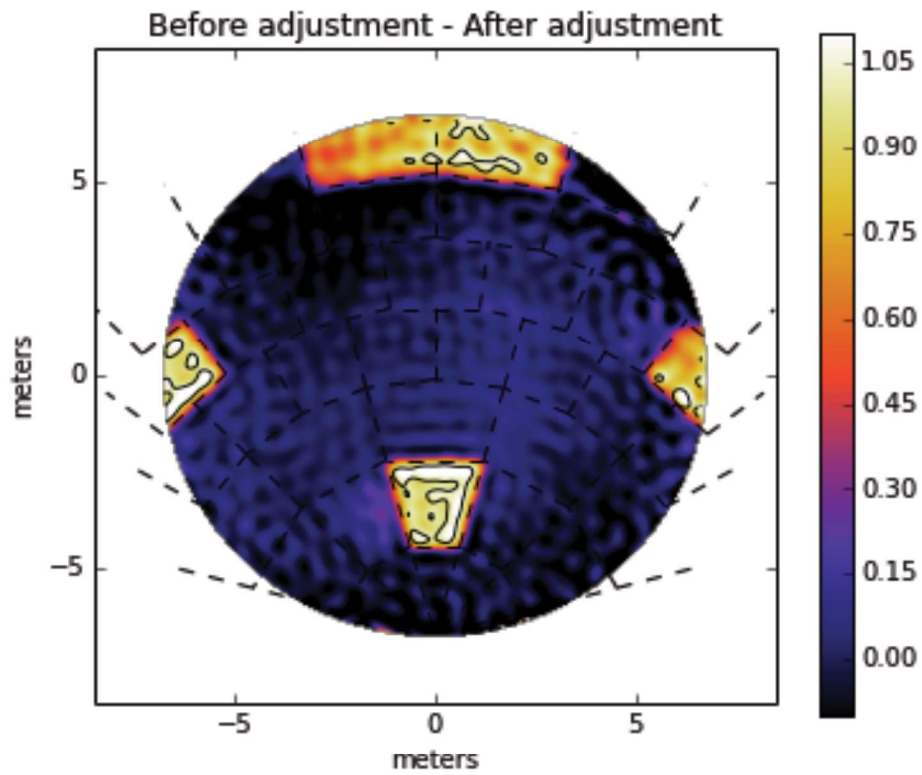


# Performance @ 1420 MHz



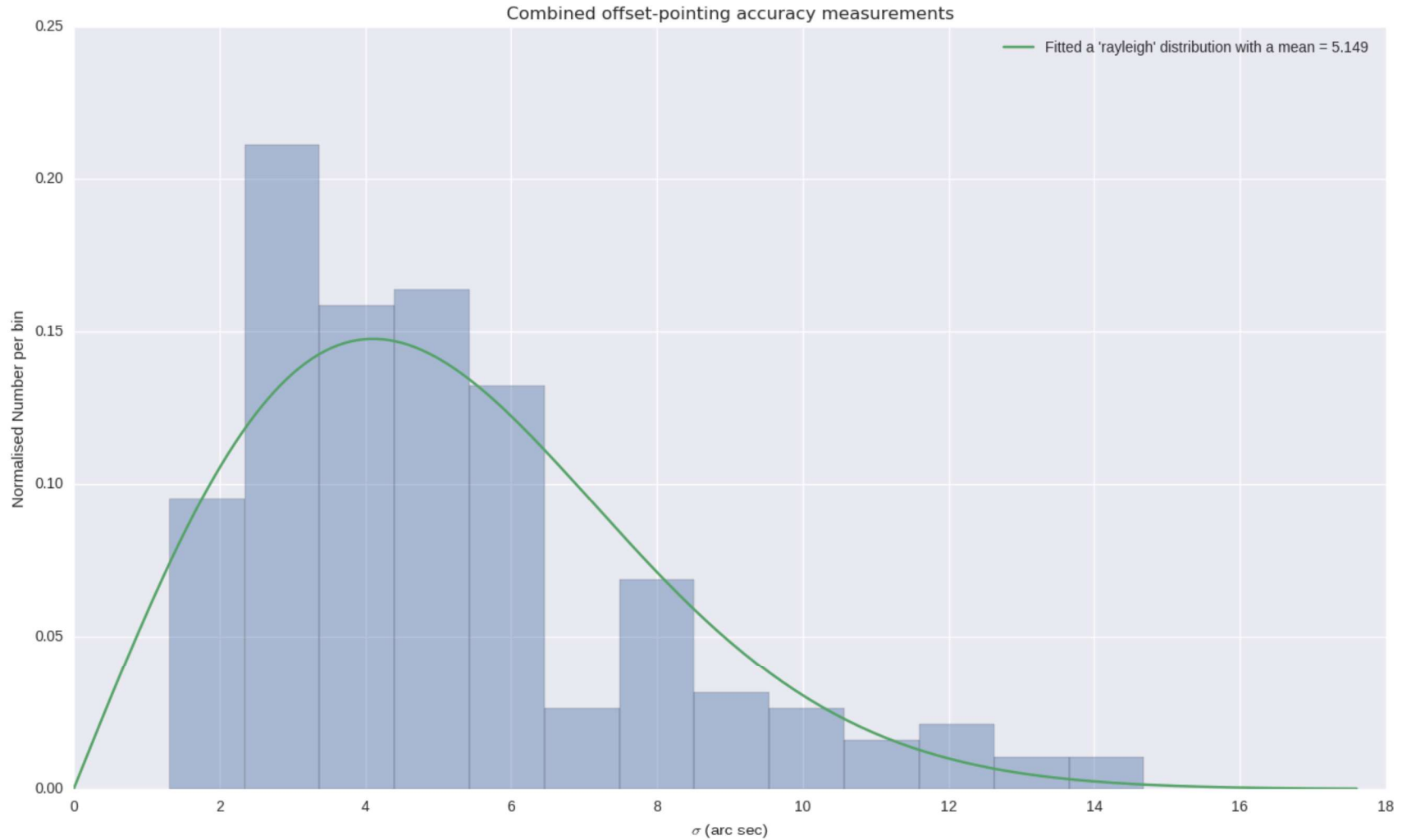
	JVLA	MeerKAT RfP	MeerKAT 2013	MeerKAT 2014
$N_{\text{dish}}$	27	64	64	64
$D_{\text{dish}}$	25 m	13.5 m	13.5 m	13.5 m
$T_{\text{sys}}/\epsilon_a$	47.3 K	44.1K	29.4 K	22.5 K
$N_{\text{beam}}$	1	1	1	1
BW	1 GHz	750 MHz	750 MHz	750 MHz
$A_e/T_{\text{sys}}$	1	0.74 ( $\times 1$ )	1.11 ( $\times 1.5$ )	1.45 ( $\times 1.96$ )
SS	1	1.88 ( $\times 1$ )	4.24 ( $\times 2.25$ )	7.24 ( $\times 3.84$ )

# Holography

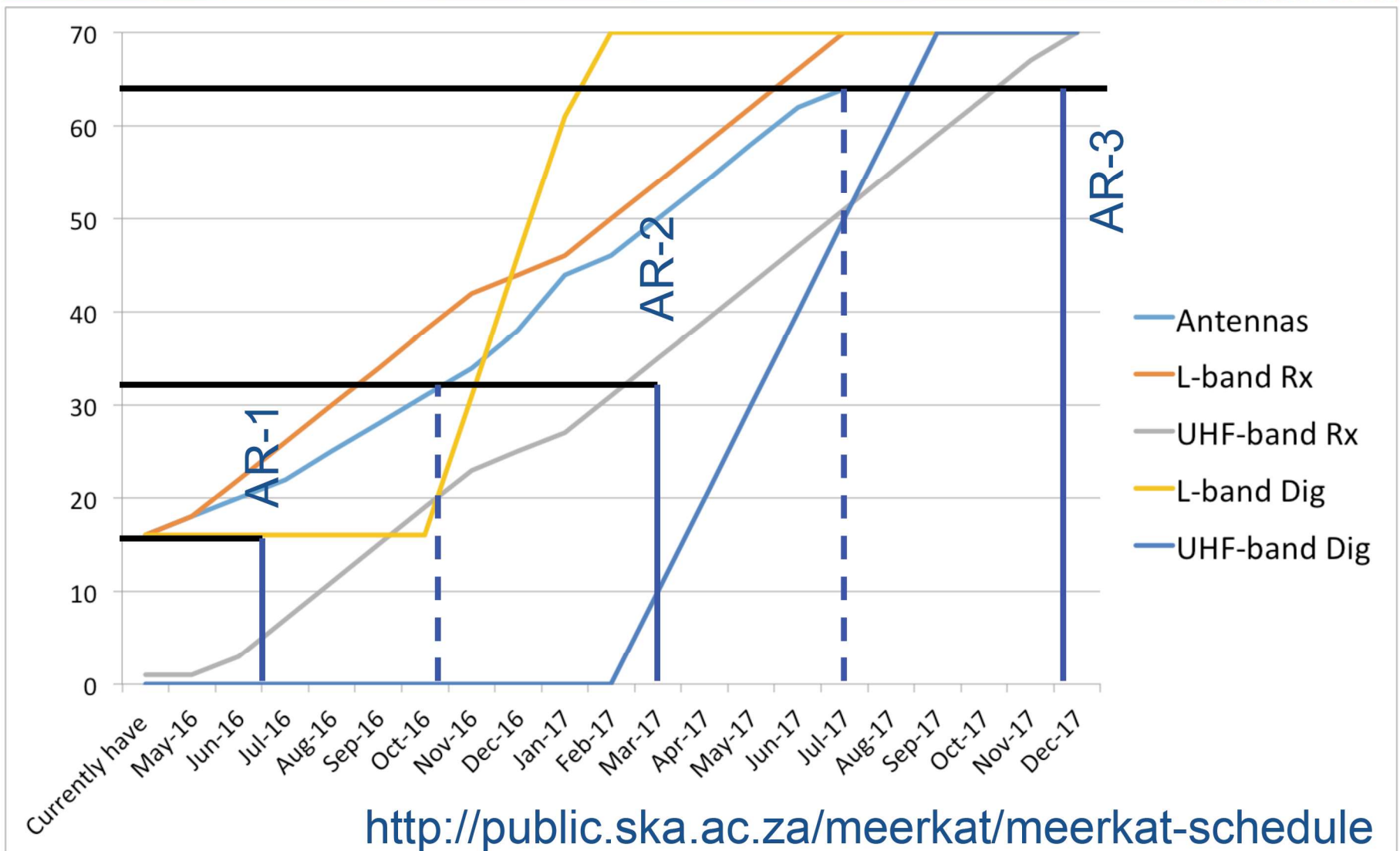




# Pointing – all conditions



# Schedule



<http://public.ska.ac.za/meerkat/meerkat-schedule>



# Receptor Switches













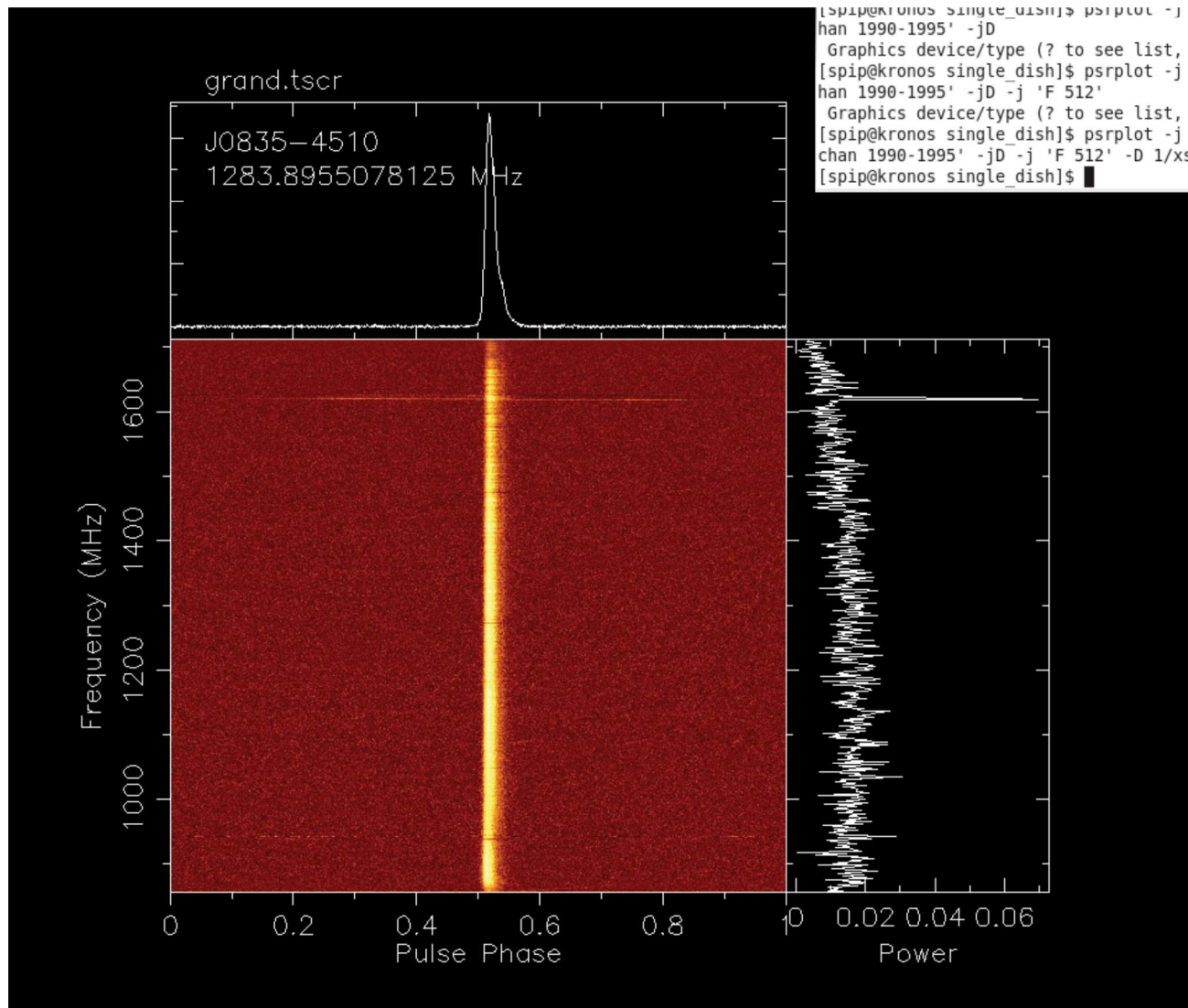




# First Pulsar

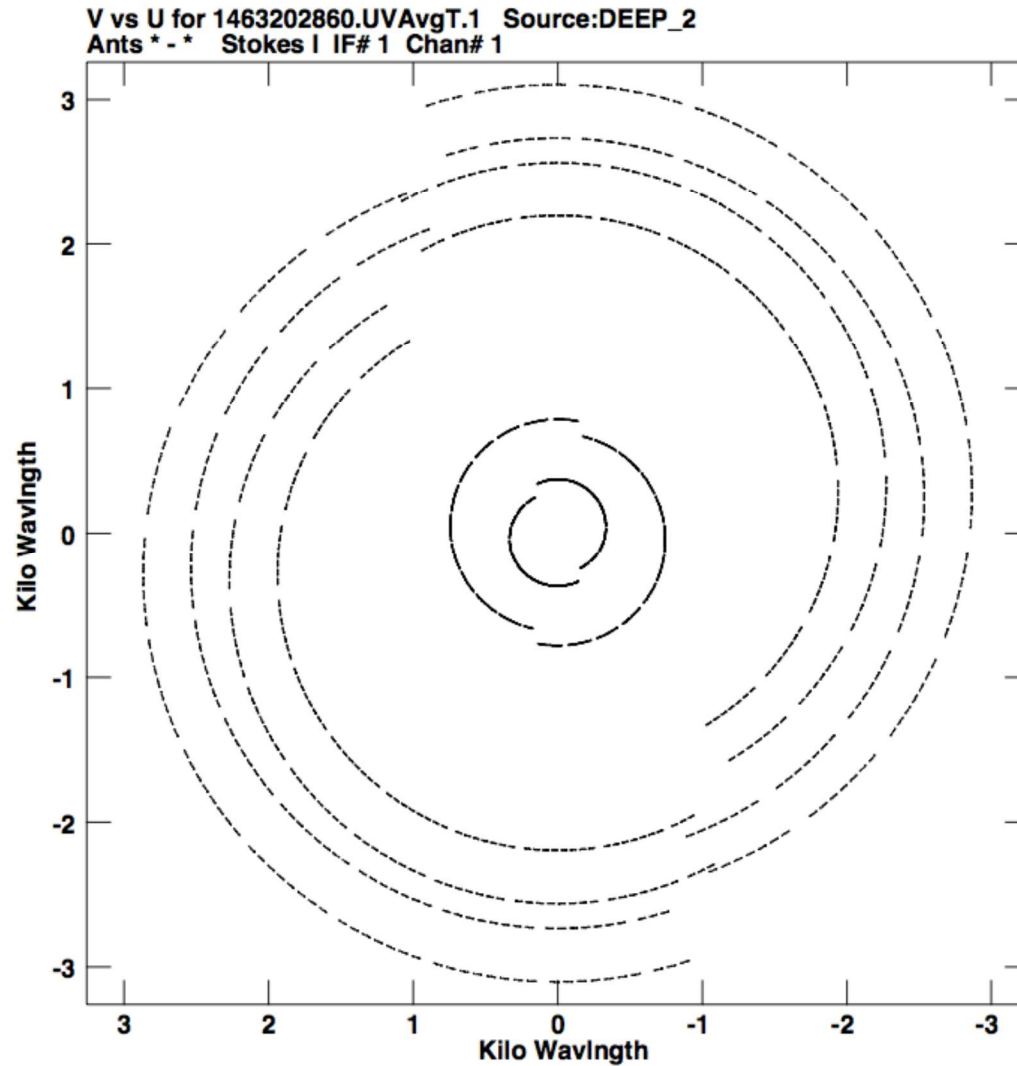


*Credit: Andrew Jameson*





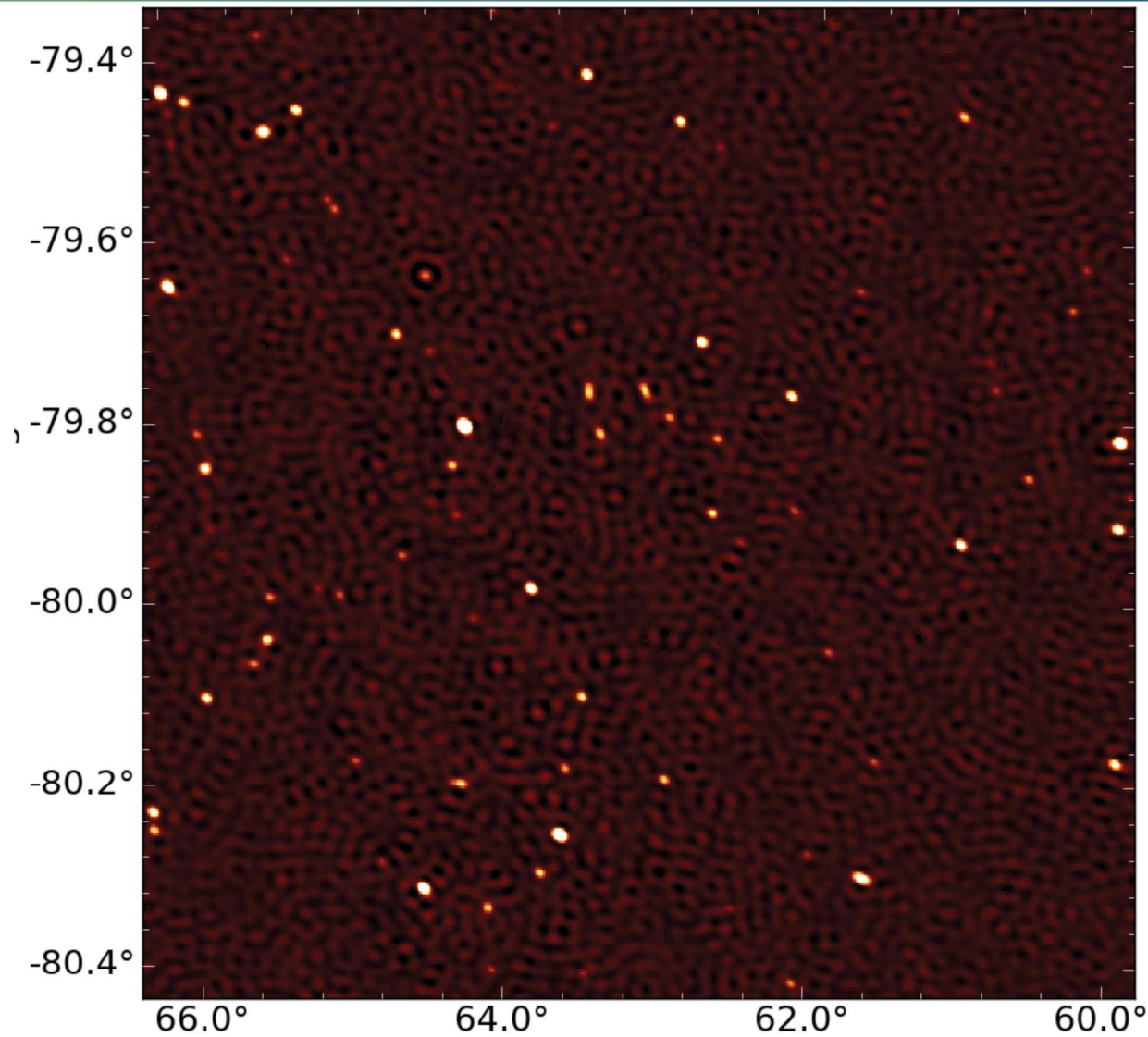
# Test Image – UV coverage



# 4-antenna test image



*Credit: Tom Mauch*

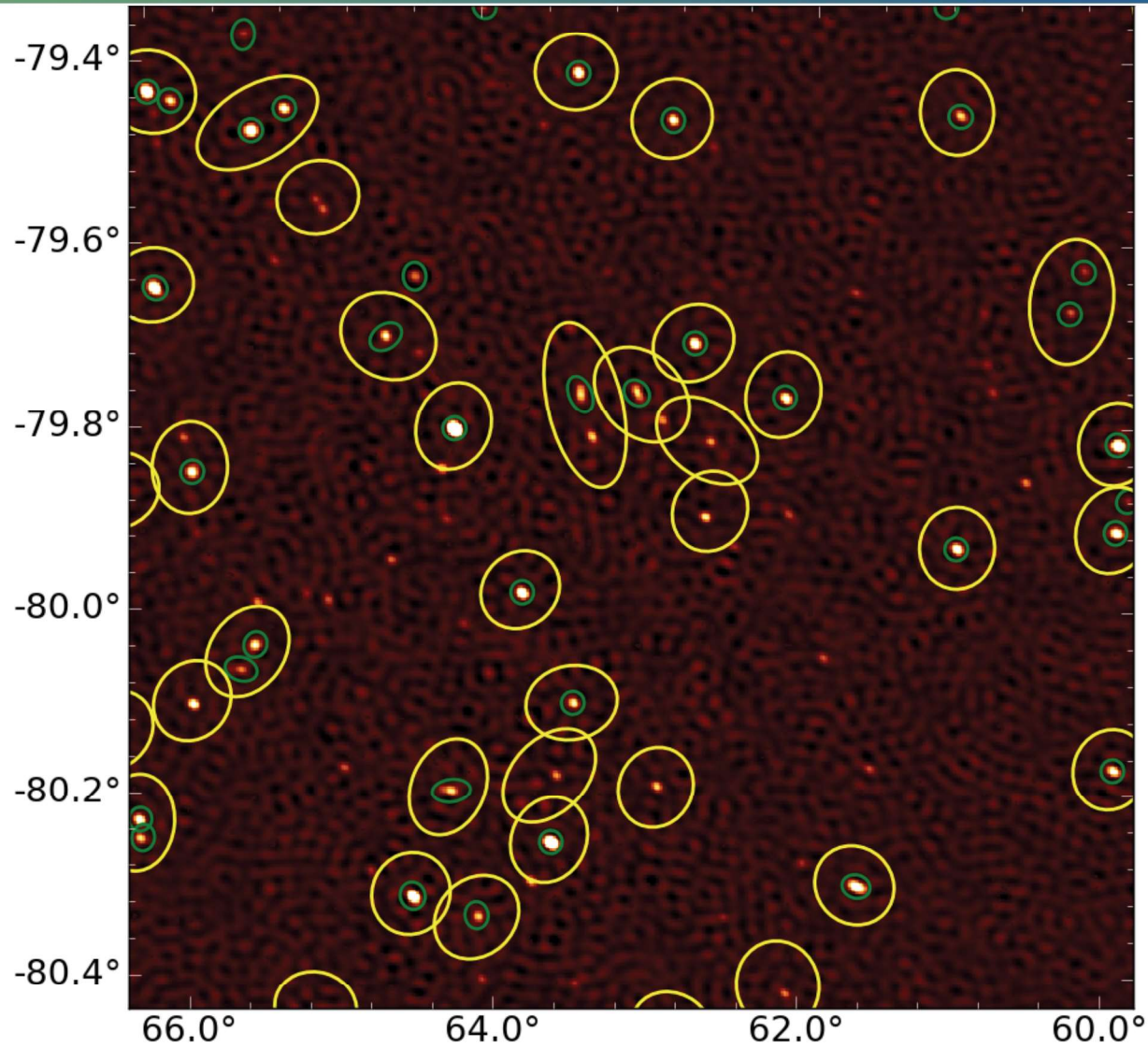




# SUMMS & KAT-7



*Credit: Tom Mauch*

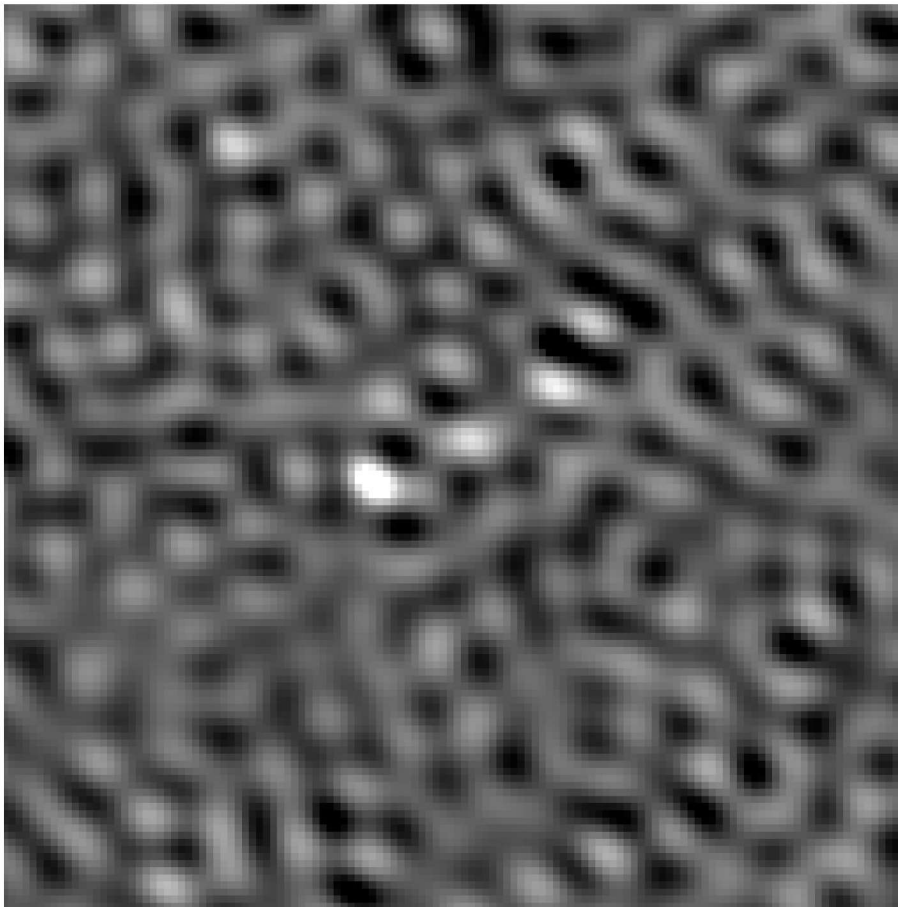


# Tripple source

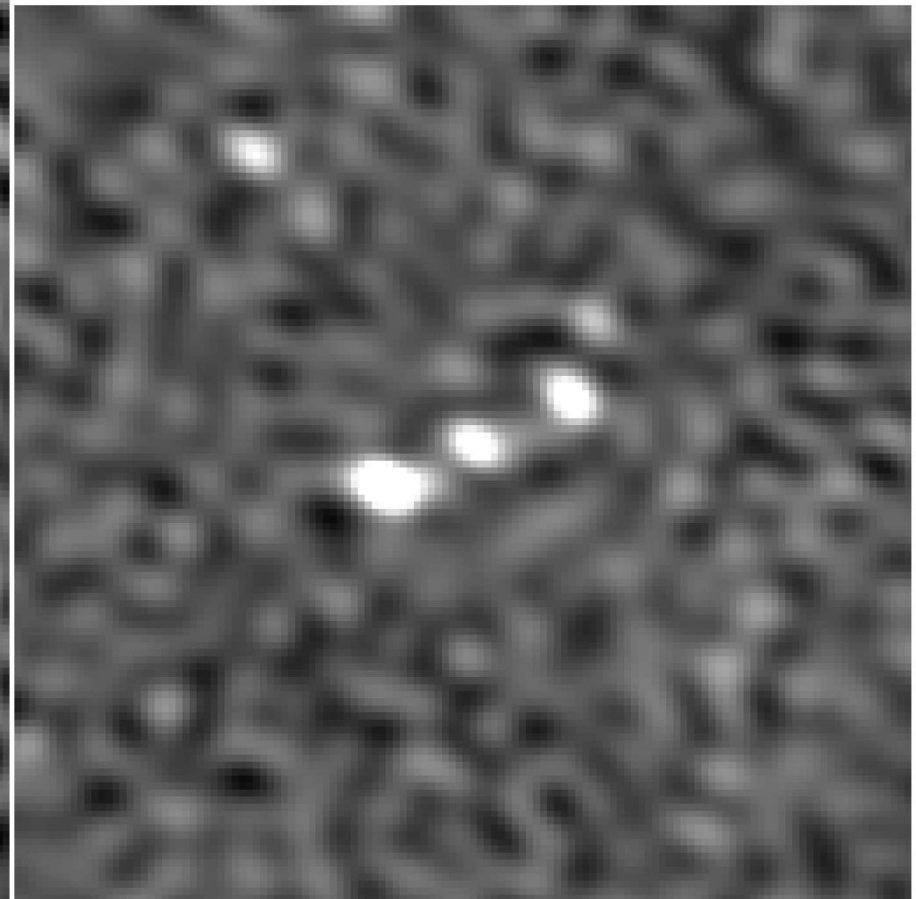


100 MHz

400 MHz



-0.2 – 0.7 mJy



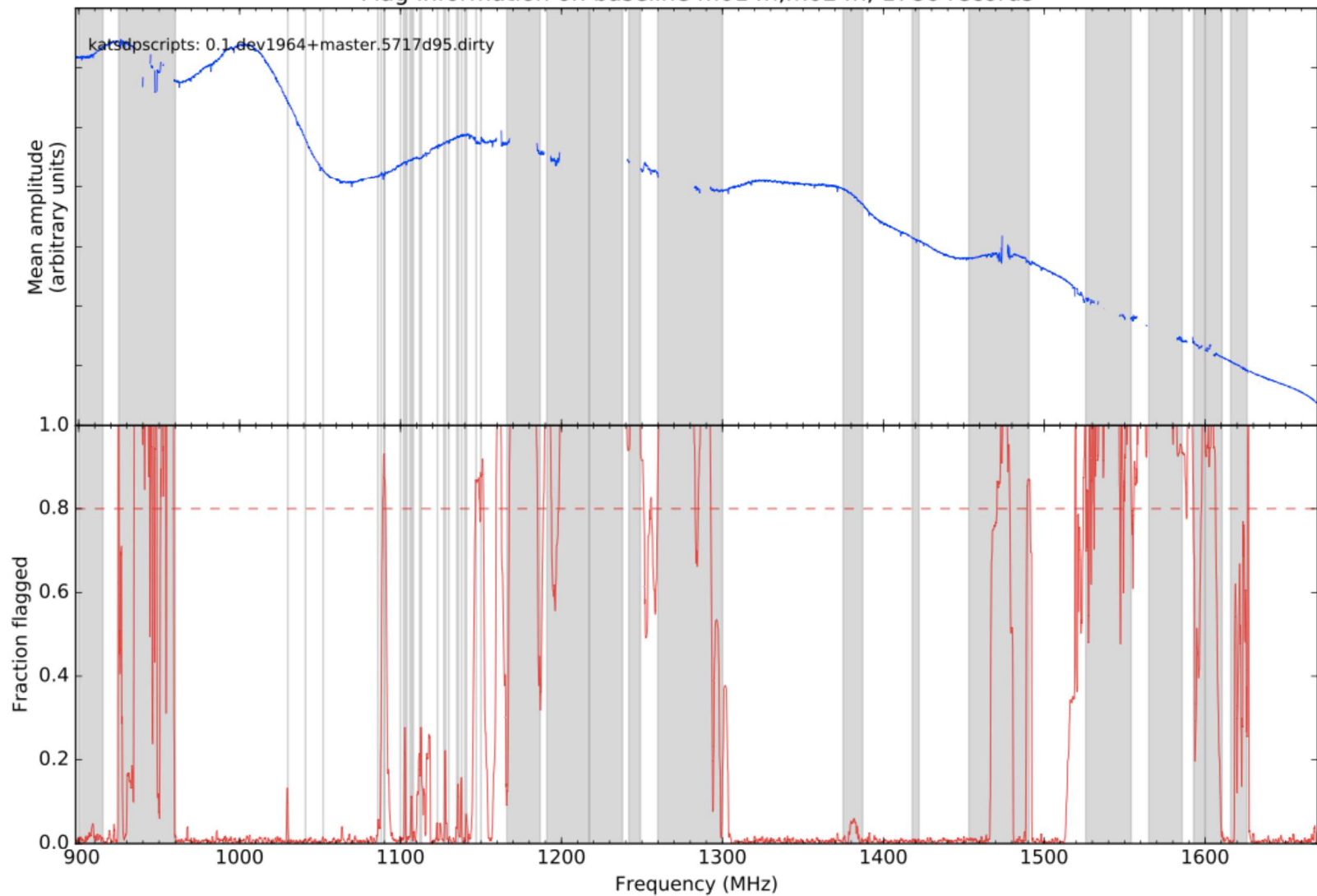
Credit: Tom Mauch



# RFI – core baselines



Flag information on baseline m014h,m024h, 1786 records



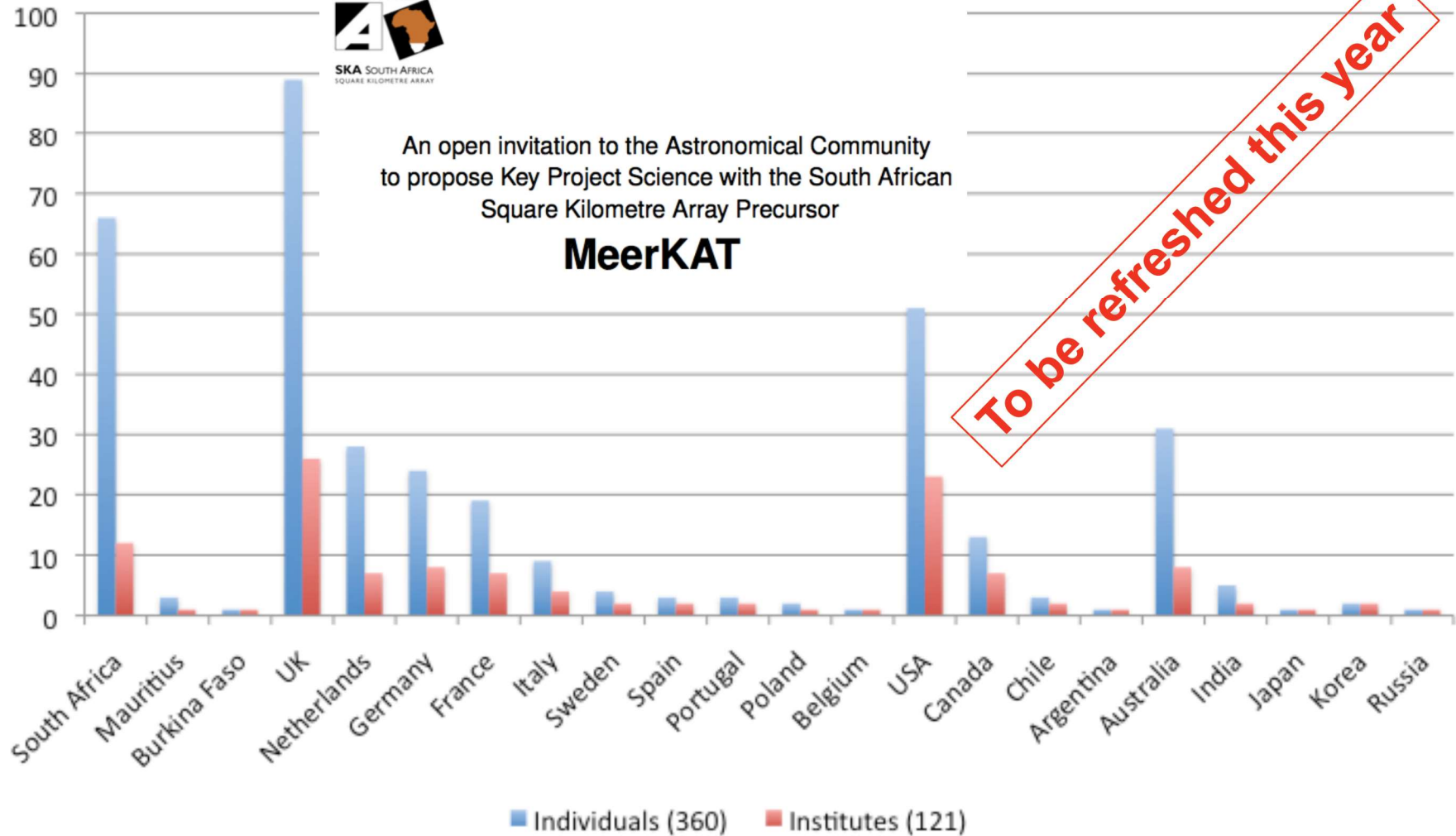
# MeerKAT Large Surveys



An open invitation to the Astronomical Community  
to propose Key Project Science with the South African  
Square Kilometre Array Precursor

## MeerKAT

To be refreshed this year





# MeerKAT Large Surveys



- Highest priority (cf SKA<sub>1</sub>):
  - Deep HI field
  - Radio Pulsar Timing
  - HI survey of Fornax
  - X-band Galactic plane survey
  - Tiered continuum survey
  - Slow radio transient survey
- Compelling:
  - HI and continuum mapping of 30 nearby galaxies
  - Absorption line survey
  - Molecules in the EoR
  - Detecting fast transients and pulsars
- Also
  - VLBI
  - Cosmic Magnetism

# 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		
<b>TOTAL</b>	<b>31 340</b>	<b>7 000</b>	<b>8 800</b>

TO BE REVIEWED THIS YEAR

1 yr = 8 760 hr



# Guest Instruments



- Facility instruments
  - MPIfR S-band receivers
  - Swinburne pulsar timing machine
  - MPIfR back-end
  - MeerTRAP transient/pulsar machine (Manchester)
  - SETI (Breakthrough Listen)
- SKA prototypes
  - INFRA-SA prototype dish foundation
  - DVA-P DISH prototype
  - ProtoNIP
- **Guest Instrument Policy**
  - **Proprietary access**

Row 3 – Row 4 coming soon



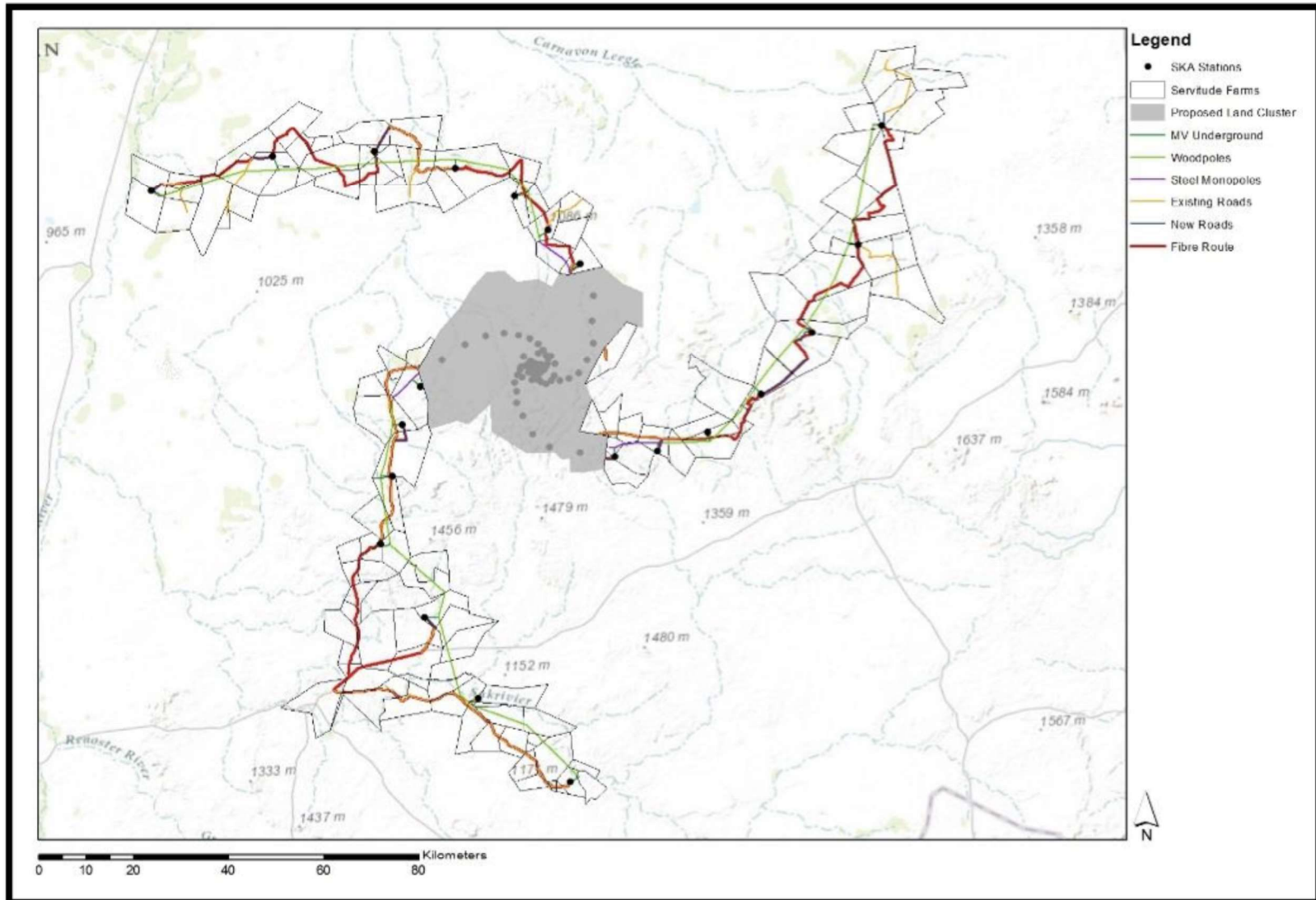


# MeerKAT -> SKA Mid



- SKAO has stated that MeerKAT science should be prioritized.
- A joint technical working group has been established to plan the engineering required to integrate MeerKAT.
- MeerKAT and SKA share a science community – please provide guidance.

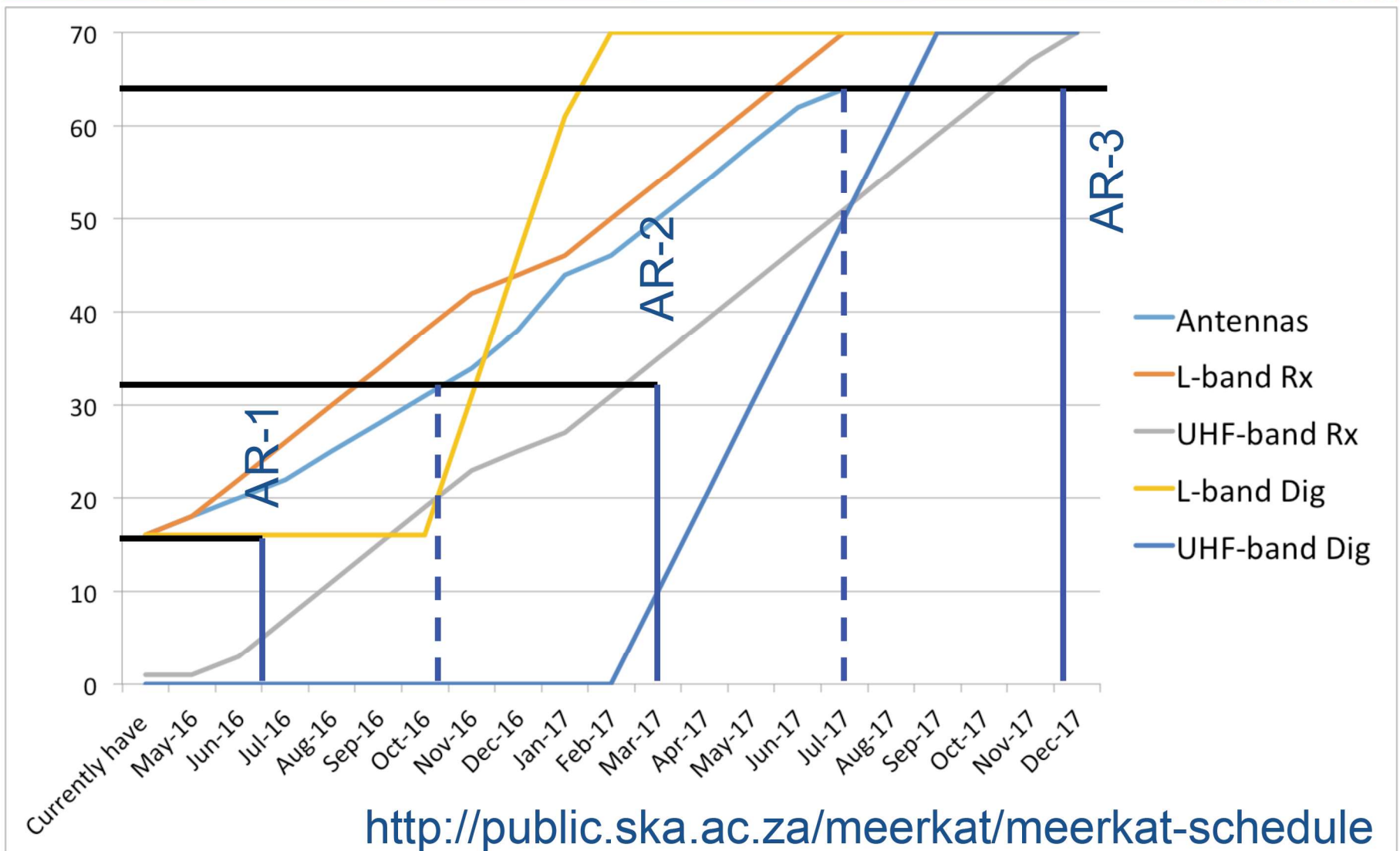
# SKA-1 Mid Spiral Arms







# Schedule



<http://public.ska.ac.za/meerkat/meerkat-schedule>