

MeerKAT Overview Jan16

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science and technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

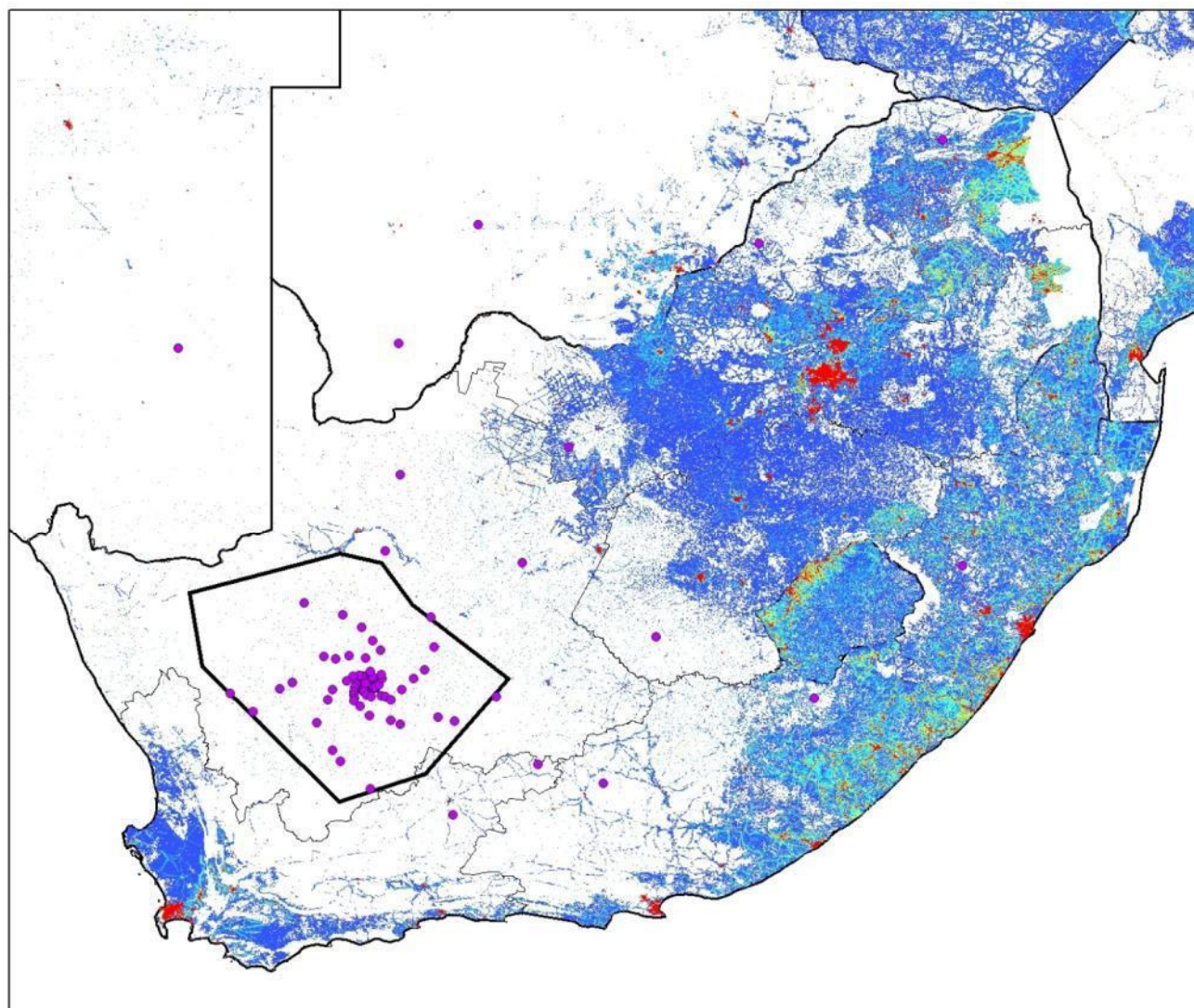


Introduction



- SKA (quick update)
- Infrastructure (MeerKAT/SKA)
- MeerKAT
 - Schedule (including SKA)
 - Science Capability
 - Antenna Structures
 - Receivers
 - Digitizers
 - Optical Fiber Network
 - Correlator
 - Control and Monitoring
 - Science Data (talk after this)
 - Acceptance/Verification
 - System Noise
 - Tipping Curves
 - Pointing
 - Holography (Aperture phase efficiency (surface accuracy))
 - Risks
 - Logistics
- Conclusion

AGA Area



Legend

● SKA_Configuration_SPDO_Dish_Full

● AA1_SPDO_Version1

● AA2_SPDO_Version2

□ KCAAA1

Population (per sq km)

Value

0 - 4

4.000000001 - 14

14.000000001 - 29

29.000000001 - 47

47.000000001 - 68

68.000000001 - 91

91.000000001 - 116

116.000000001 - 142

142.000000001 - 169

169.000000001 - 197

197.000000001 - 225

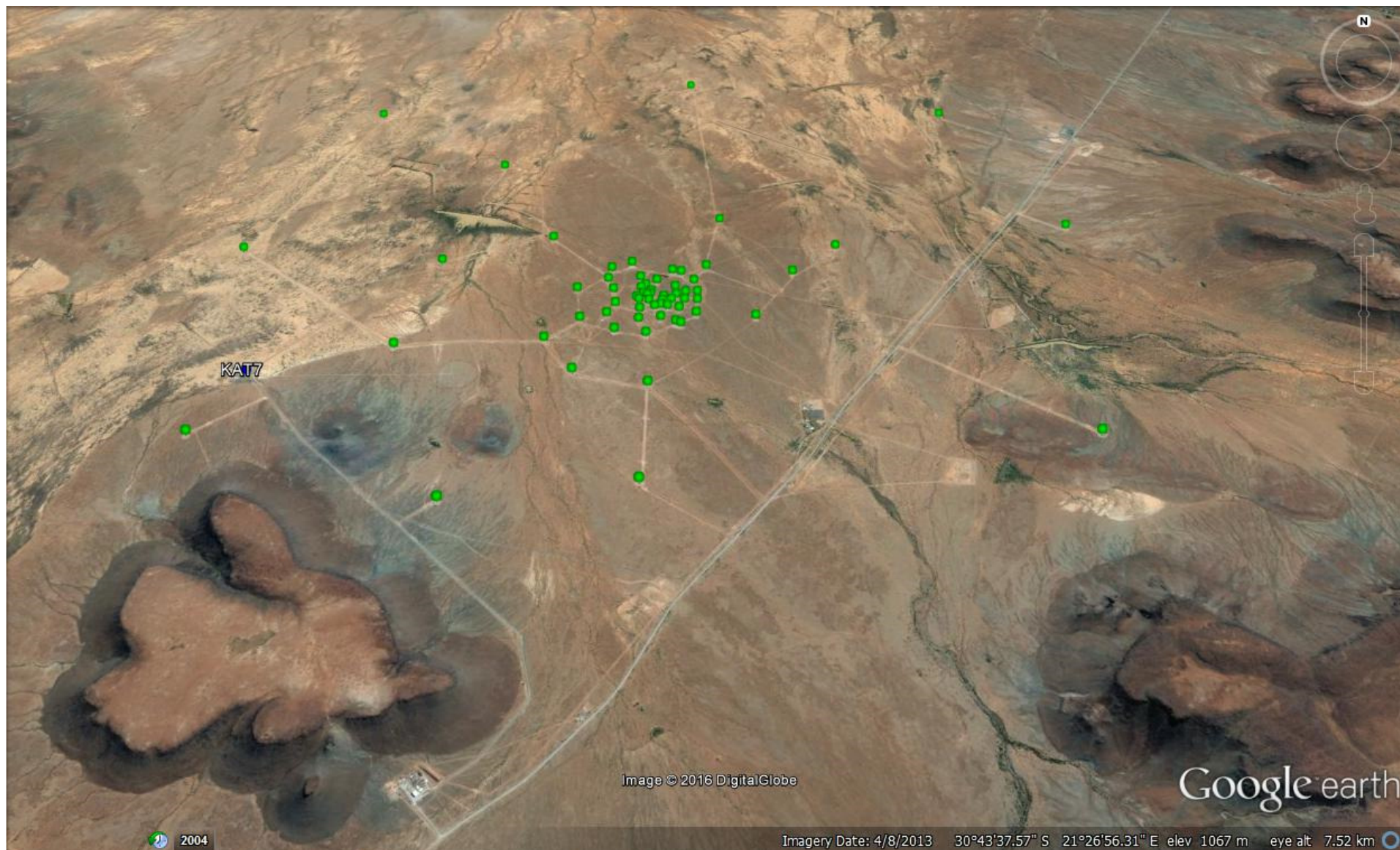
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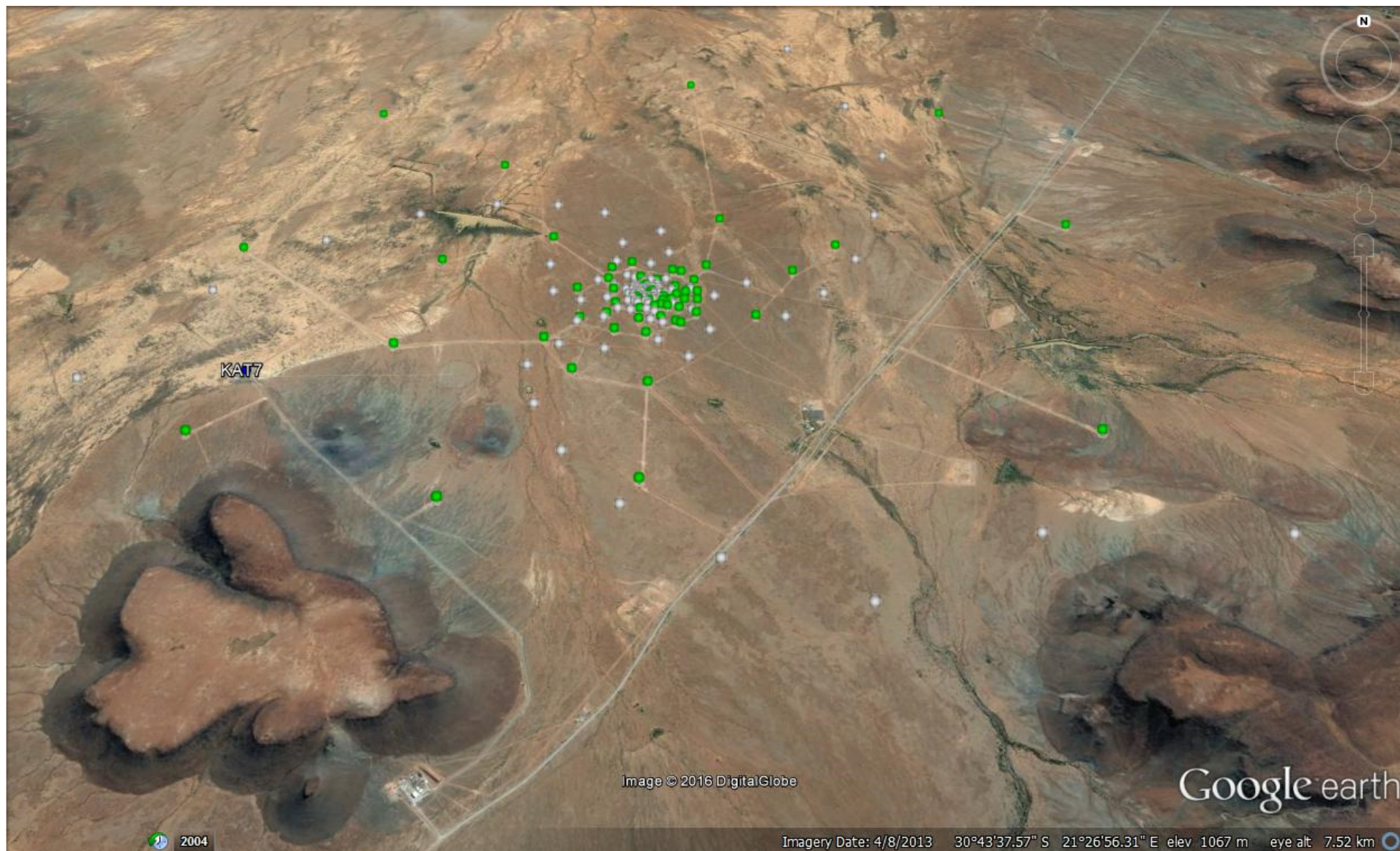
Contact:
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0 145 290 580 870 1,160 Kilometers

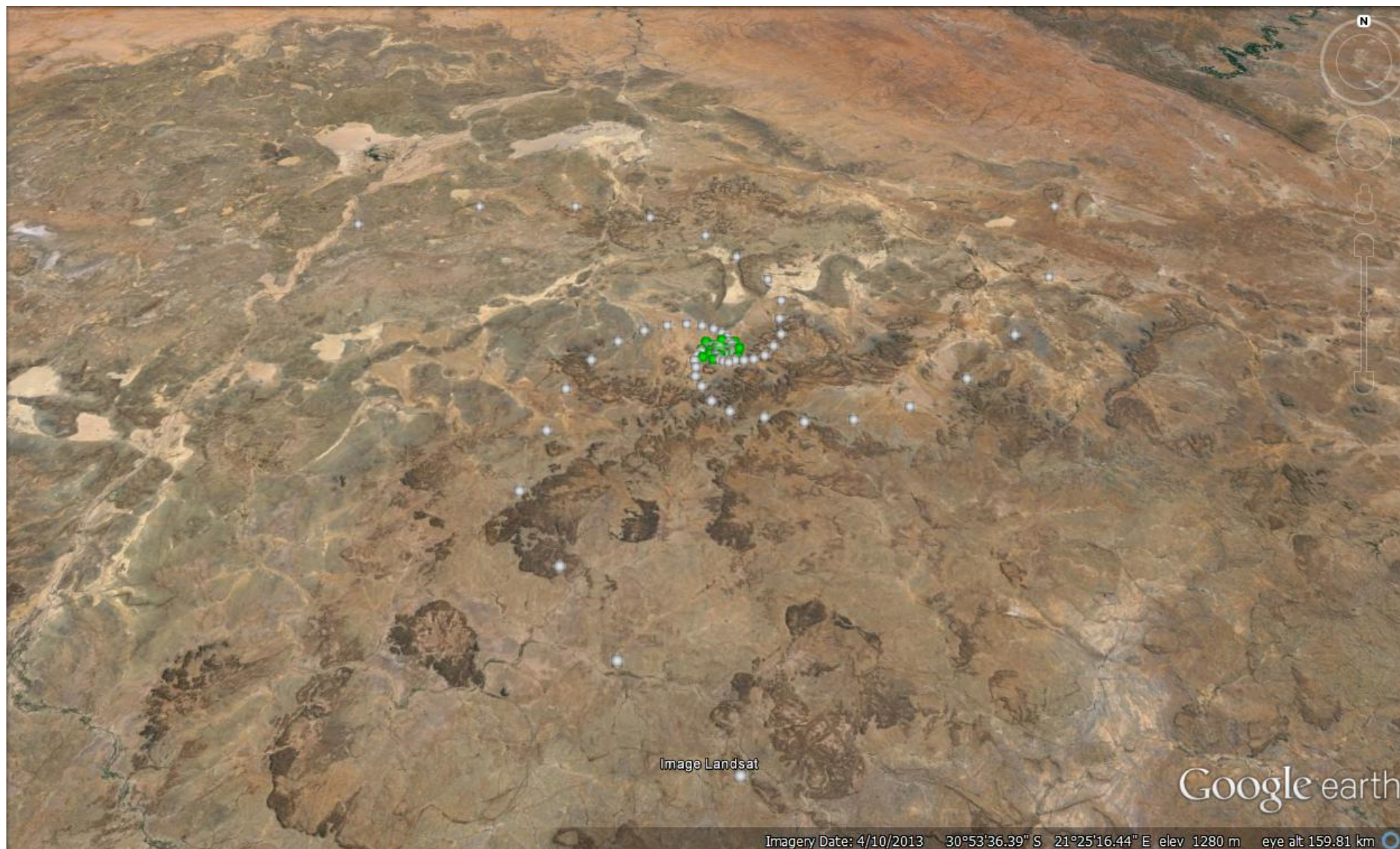
MeerKAT Layout



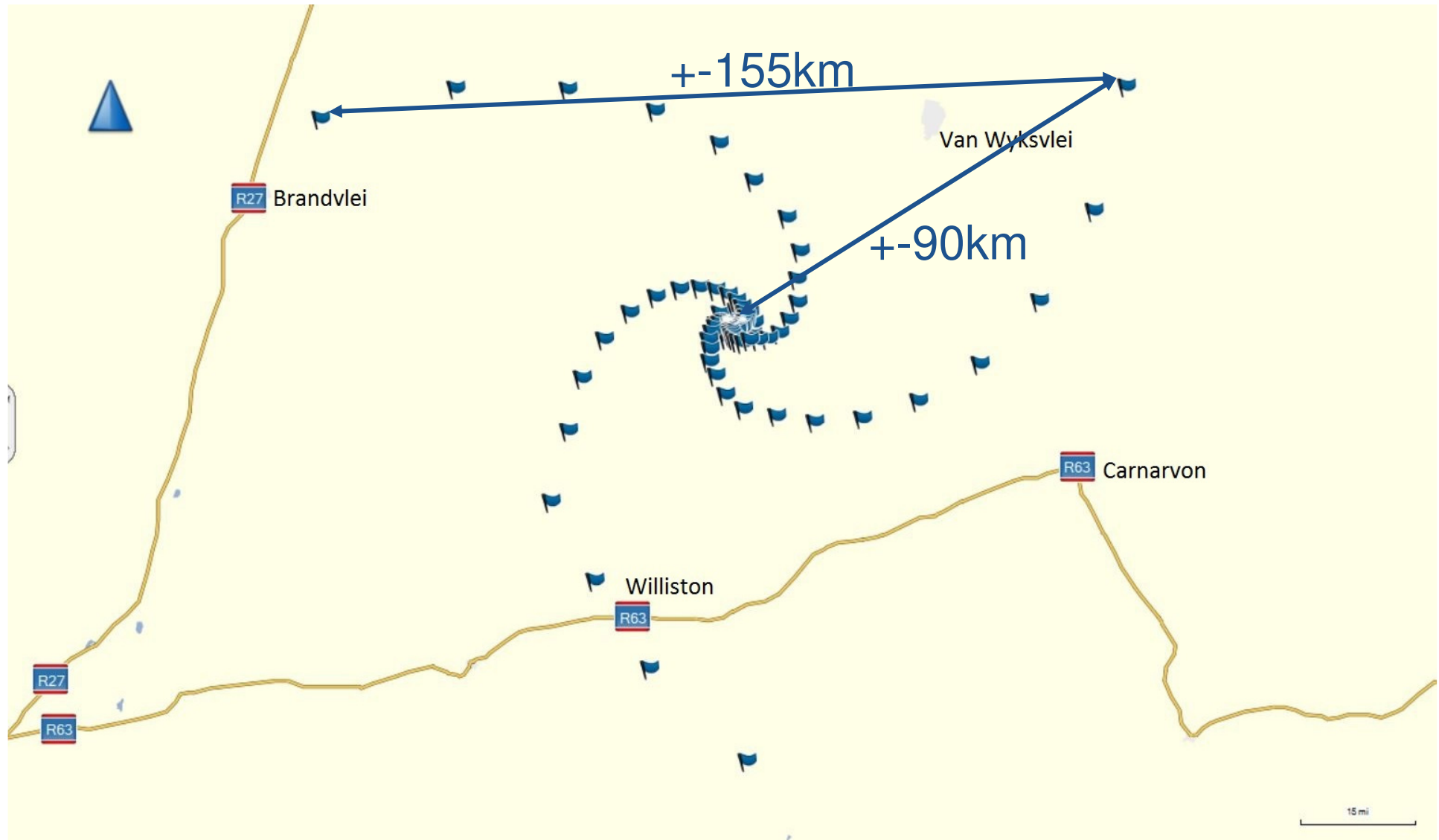
SKA Mid1 Layout – Core



SKA Mid1 Layout – Spiral Arms

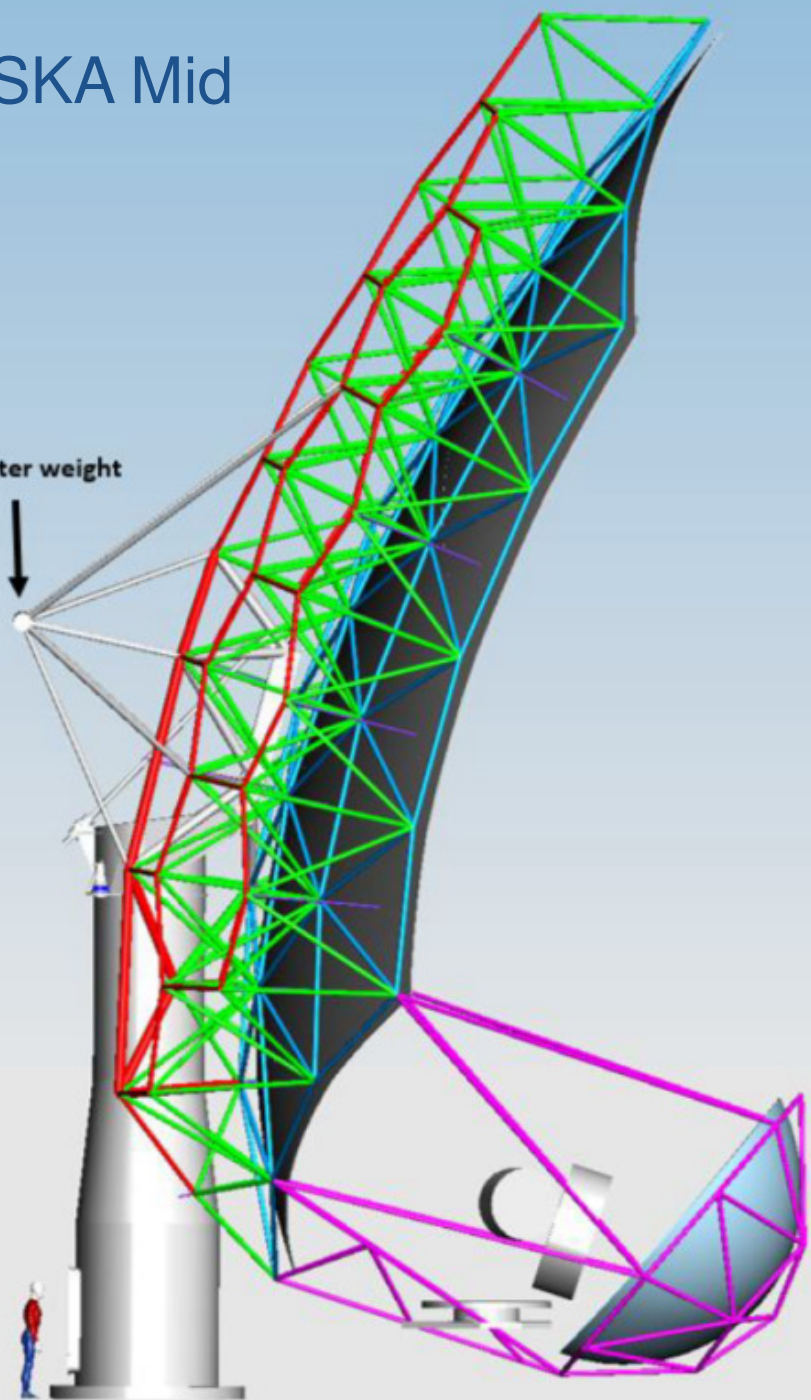


SKA Mid1 Layout – Spiral Arms

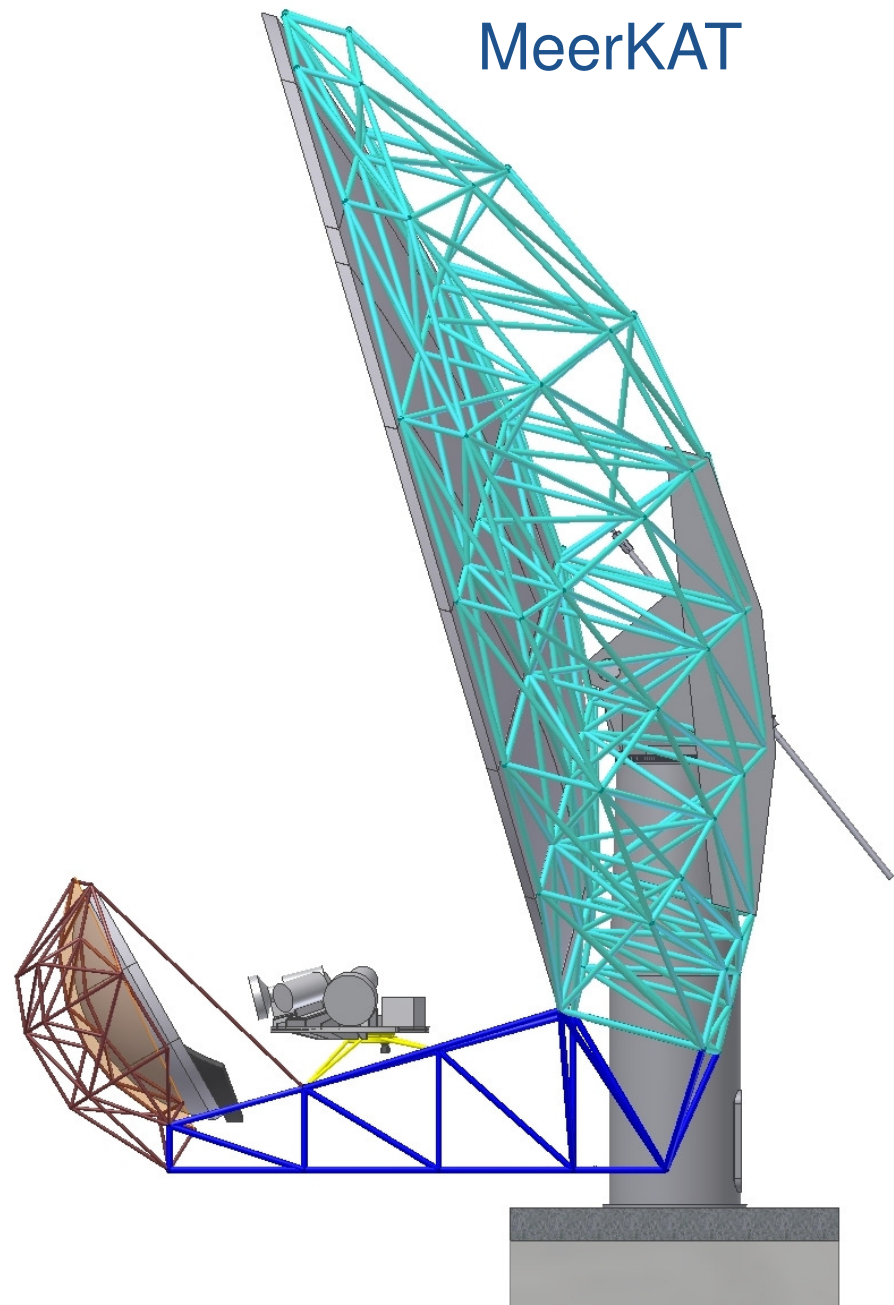


SKA Mid

counter weight



MeerKAT



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
- **MeerKAT scope completed**

Establishing the Karoo site



Power



Roads



Data



Tracy Cheetham



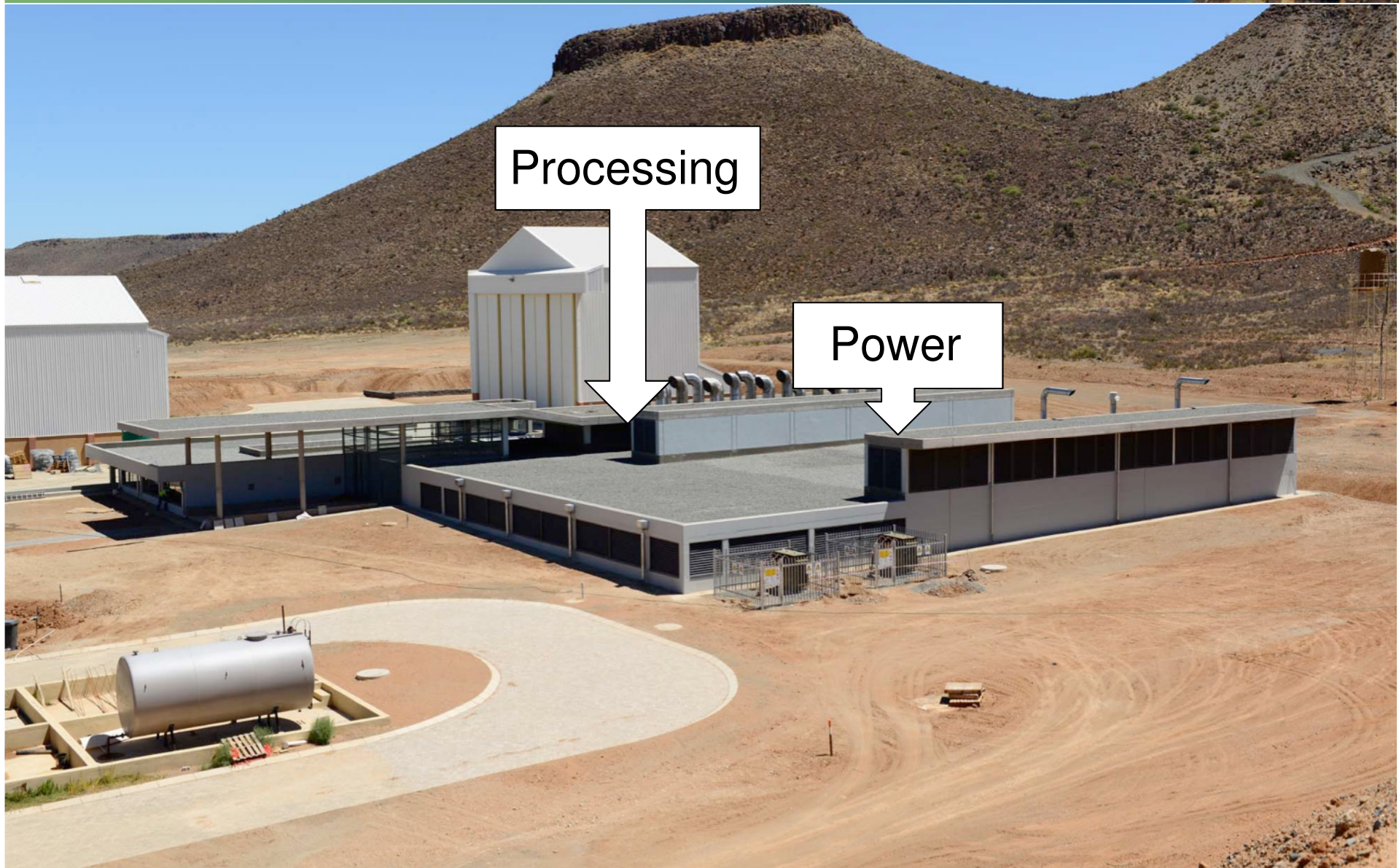
Buried reticulation



Site Complex Completed



Bunker – RFI & temperature



3 x 1.25 MVA DRUPS



Shielded Room & Equipment Racks



MeerKAT Core

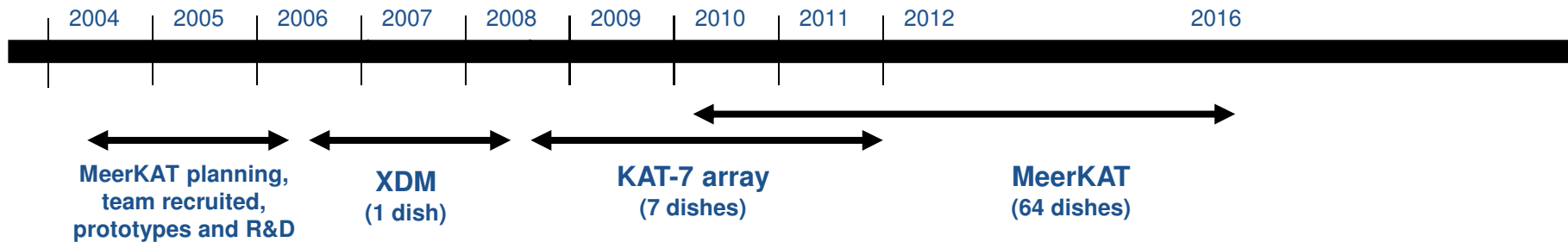




Landing Strip



Timeline (Phases)



World class operational radio telescope
SKA pre-cursor



	2016	2018
Phase	Phase 1	Phase 2
Number of dishes	64 x 13.5 OG	64 x 13.5 OG
Receiver bands (GHz)	0.9 - 1.67 0.58 - 1.015**	0.9 - 1.67 8.0 - 14.5
Max processed bandwidth (GHz)	0.75	2.0 (goal of 4.0)
Max baseline (km)	8	8
Min baseline (m)	29	29



SKA Schedule



		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	----
MeerKAT	MeerKAT Completed	x	x	x	x														
	MeerKAT Early Science				x														
	MeerKAT Full Science					x	x	x	x	x									
SKA1-Mid	SA Infrastructure Design	16 Antenna Array Science capable by 30 June 2016																	
	SA Infrastructure Construction																		
	SKA1 Mid Design																		
	SKA1 Mid Procure																		
	SKA1 Construction																		
	SKA1 Mid/MeerKAT Integration									x	x								
	SKA1 Early Science																		
	SKA1 Full Science											x	x	x	x	x	x	x	
SKA2	SKA2 Design																		
	SKA2 Procurement																		
	SKA2 Construction																		
	SKA2 Science																		

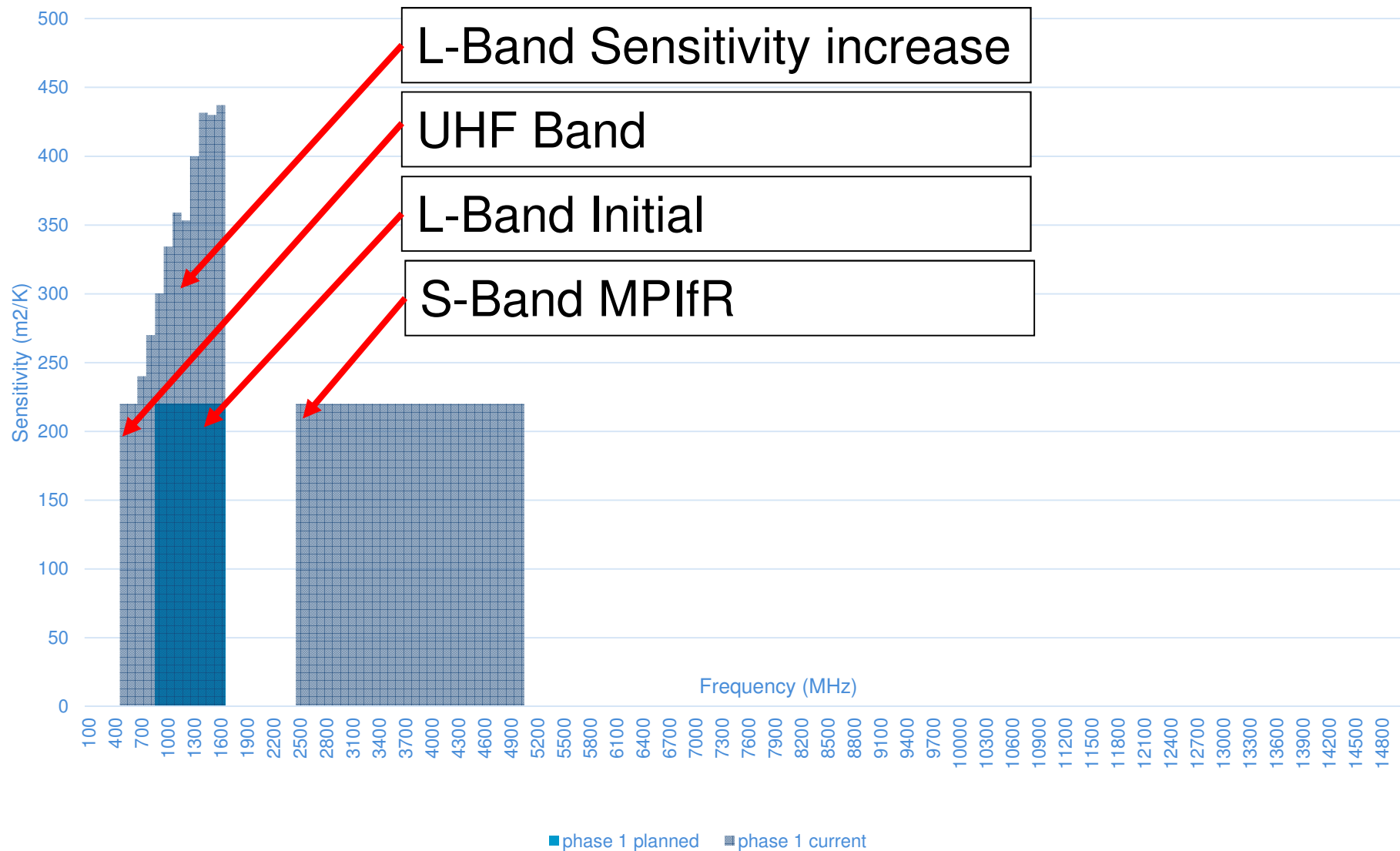
Aligned with 5 year survey time allocation

Schedule



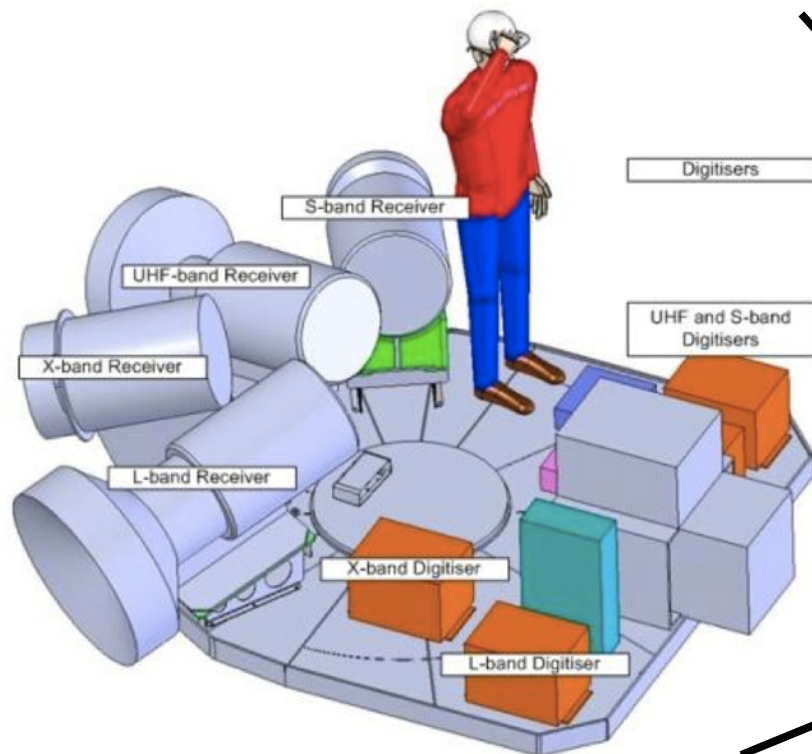
- 14 structures installed, #5/6 being integrated
- 31 Mar 2016 – 21 structures installed
- 30 June 2016 – 16 Antenna Array (AR1)
- 31 Mar 2017 – 64 structures installed
- 31 Mar 2017 – 32 antenna array
- June 2017 – shared risk science 32 dishes
- Dec 2017 – 64 antenna array

Science Capability



MeerKAT Dish

Receiver Indexer with Horns,
Receivers, Digitizers and
Services



Main
Reflector

Sub
Reflector



Antenna Structures

- Full Production
- No CVO's or cost overruns at this stage and non foreseen
 - SE process executed well
 - Fixed price contract (x-change rate risk low)
- Technical risk low
 - Pointing/APE verified
 - Tighter specification than required to future proof
- Schedule risk reduced
- Lead SE on SKA Dish Consortium



MeerKAT Antenna Key Specs



	Originally Specified (Tender)	Contracted
Configuration	13.5m OG	13.5m OG
Sub-reflector size	3.8m	3.8m
Aperture Phase Efficiency	0.67 (at 14.5 GHz)	0.91 (at 14.5 GHz)
Surface Accuracy (derived from aperture phase efficiency)	1.0mm RMS	0.6 mm RMS
Pointing Accuracy	5" (optimal conditions, 20 min) 25" (normal conditions, 20 min)	5" (optimal conditions, 20min) 25" (normal conditions, 4 h)
Pointing Jitter	<15"	<15"
Wind Optimal (mean/gust)	10/15 km/h	10/15 km/h
Wind Operating (mean/gust)	35/48 km/h	35/48 km/h
Wind Stow (gust)	68.4 km/h	68.4 km/h
Wind Survival Gust	144 km/h	144 km/h
Reflector noise contribution	<1K	<1K
Reflector reflecting efficiency	>99.5% (main and sub)	>99.5% (main and sub)
Azimuth	2deg/s (-185 to 275 deg)	2deg/s (-185 to 275 deg)
Elevation	1 deg/s (15-88 deg)	1 deg/s (15-88 deg)
Indexer	4 receivers, 1min switchover	4 receivers, 1min switchover
Lowest Elevation	15 deg	15 deg

Pedestal fabrication & integration



Dish panel factory



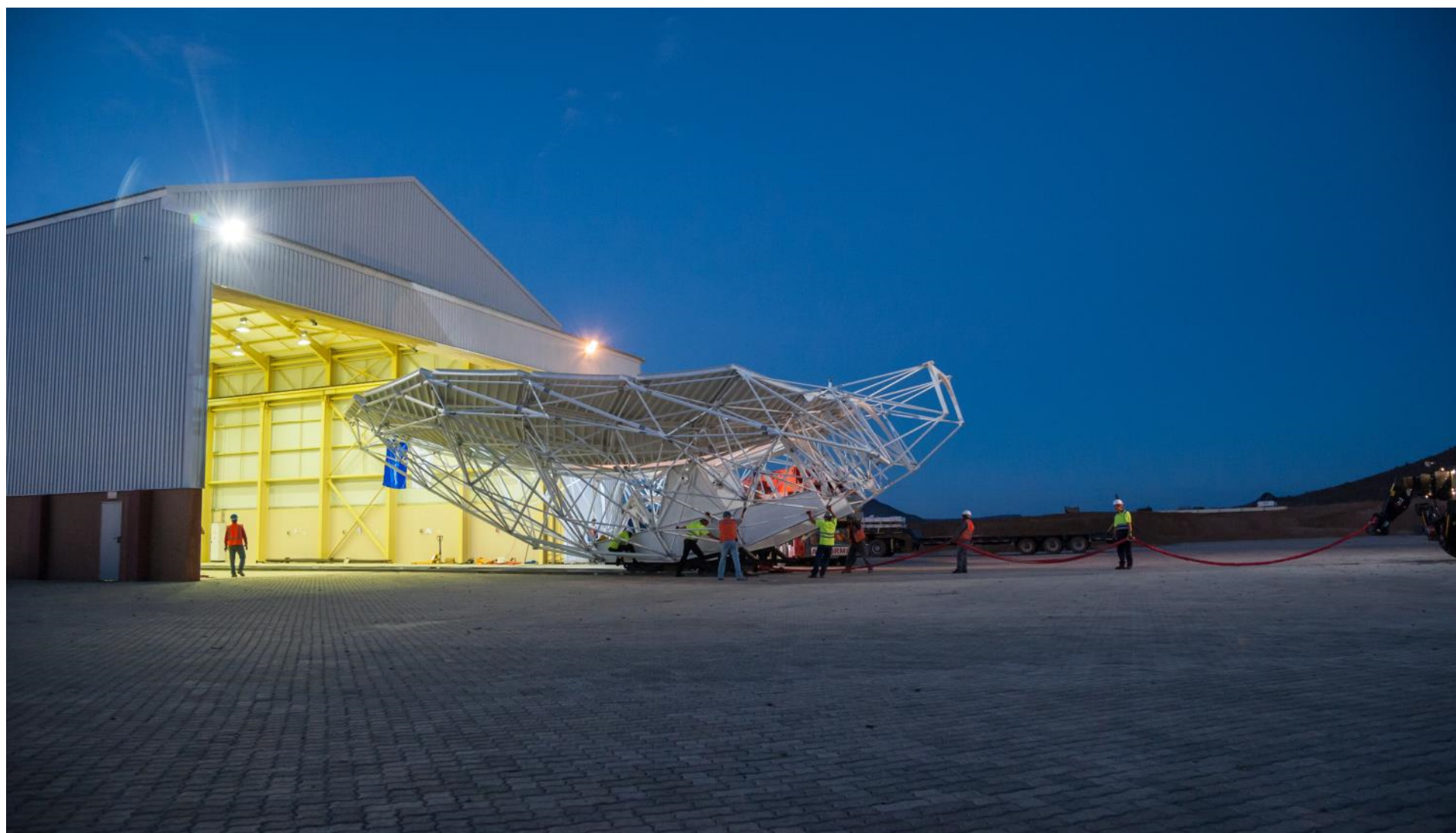
Carbon-fibre Subreflector



On-site Production Line



Dish Transported



Dish Transported



Crane Procured





MeerKAT Core



18/12/2015 17:00

Receivers



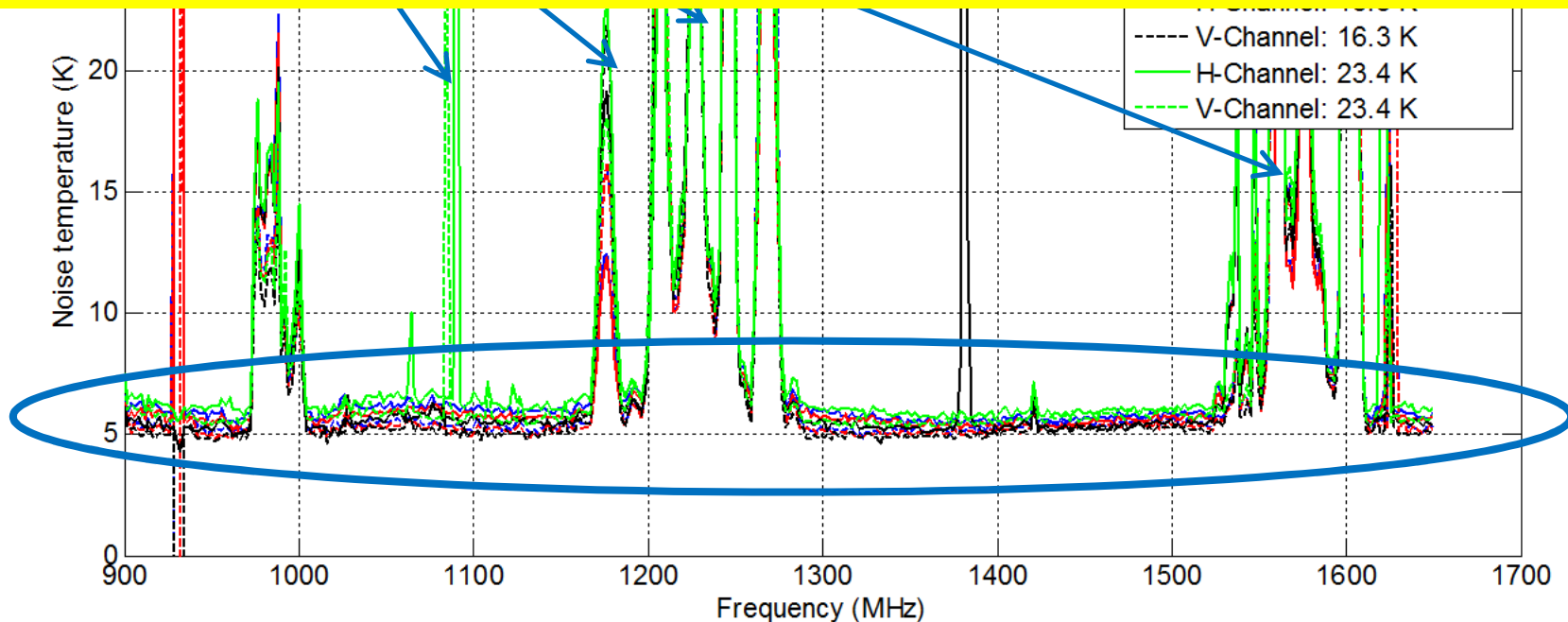
- Build on KAT7 development
- Best performance demonstrated by any 2:1 receiver in world – verified in Canada (independently)
- EMMS leads optical design and 2:1 receiver design for SKA
- Receivers for MeerKAT contracted to EMMS - low technical, schedule and financial risk
- Full Production
- Example of successful industry development associated with MeerKAT
- MPIfR investing €11m in S-band receivers and downstream capacity – MOU has been signed

Receivers & Services Installed



Receivers – independent verification

- “Gary just stopped by my office and said that sky-load (no DVA1 yet) measurements of the MeerKAT receiver are 5-6K. **That is very impressive.** Looks like very little noise is added going from the cold LNA input to the warm horn. **Excellent engineering.**” Bruce Veidt (Canada/NRC)



2012/13 Design goal ≈ 7.5 K

2013/14 Factory testing at EMSS Antennas ≈ 7 K

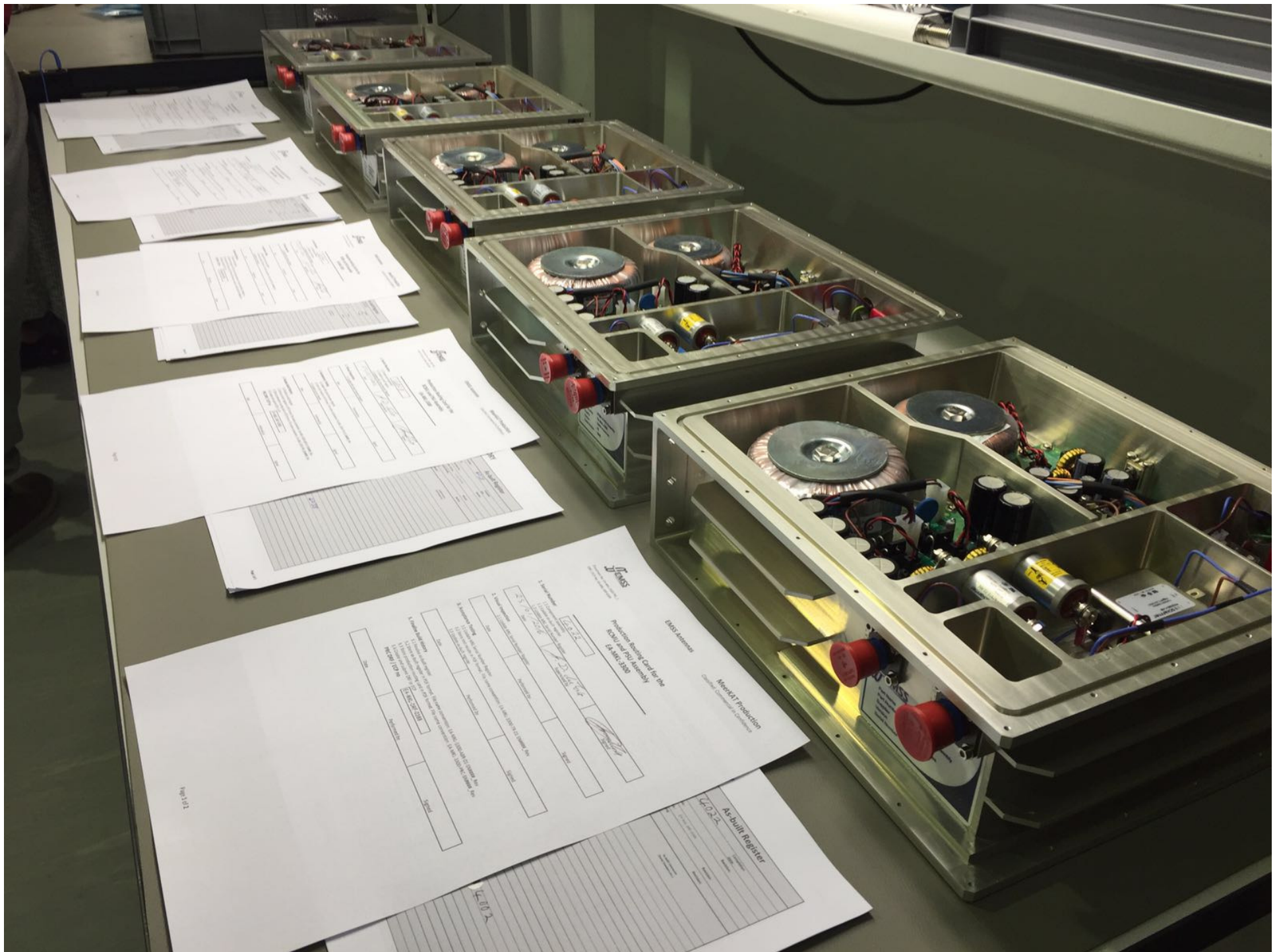
Nov. 2014 Confirmation testing at DVA₁ ≈ 6 K











Digitizers

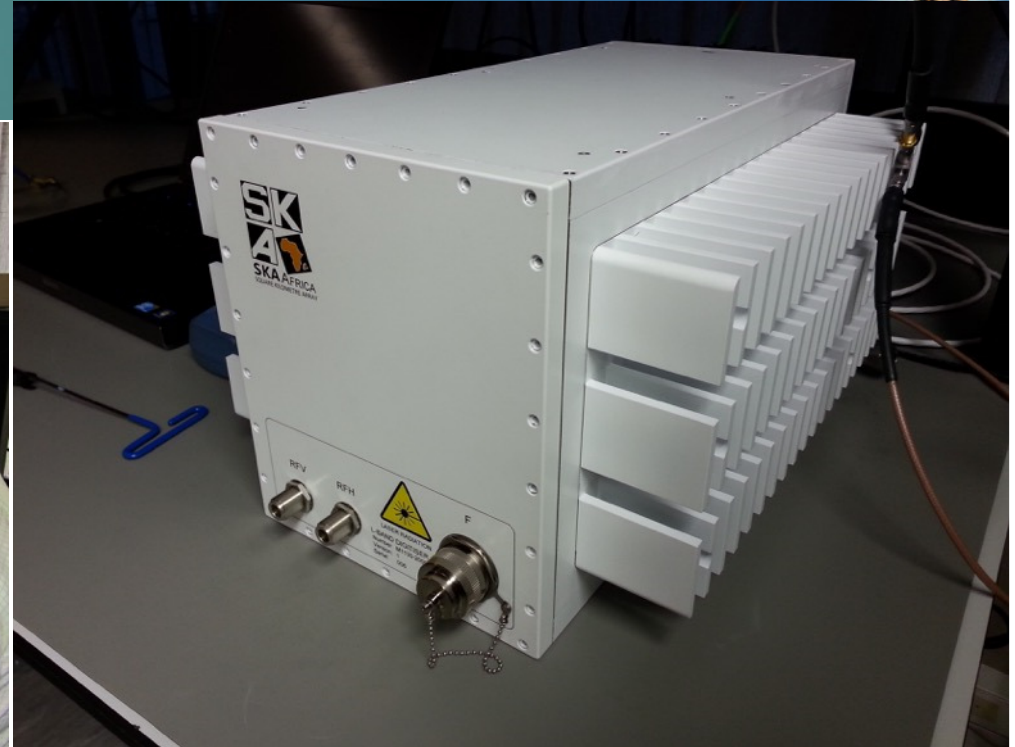


- L-band Digitizer
 - In-house (SKA SA) production facility has been set up
 - All major procurements completed
- UHF-band Digitizer
 - Schedule being finalized
- No formal SKA involvement, although qualified solution for digitizing at receiver

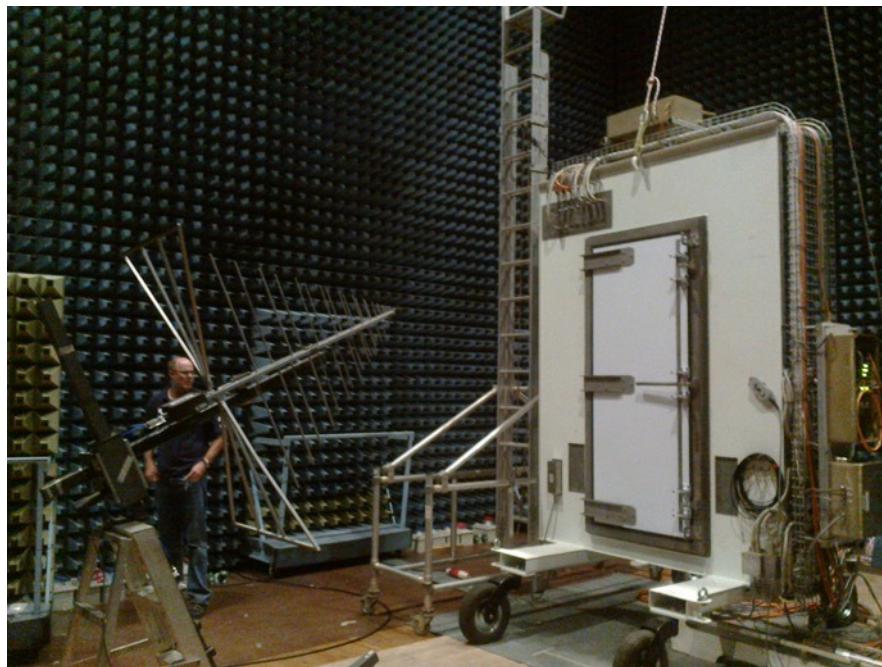
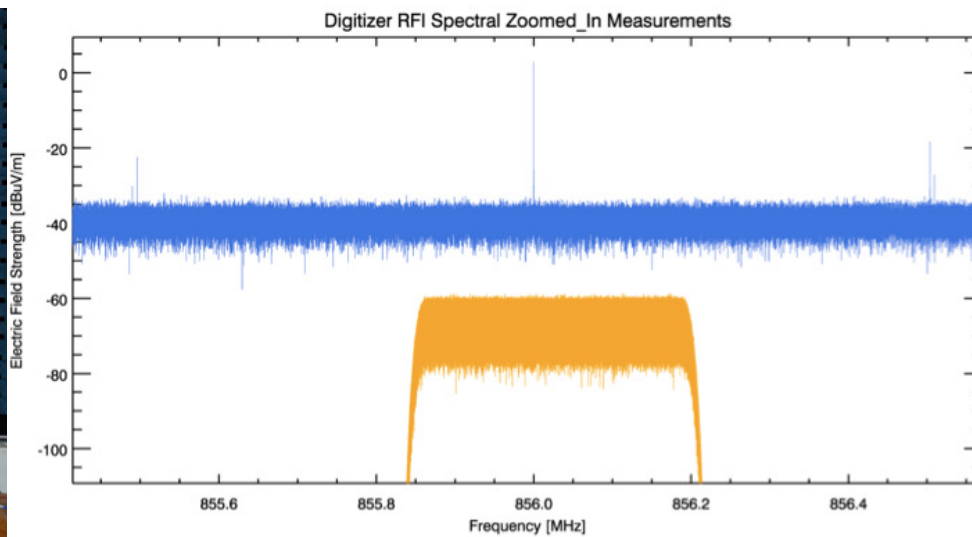
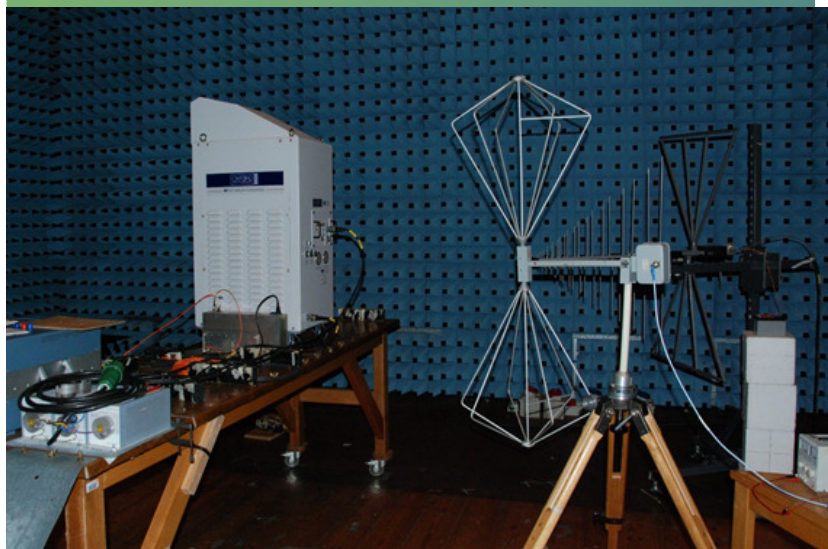
Digitizer Production



Digitizer



RFI Qualification and Testing

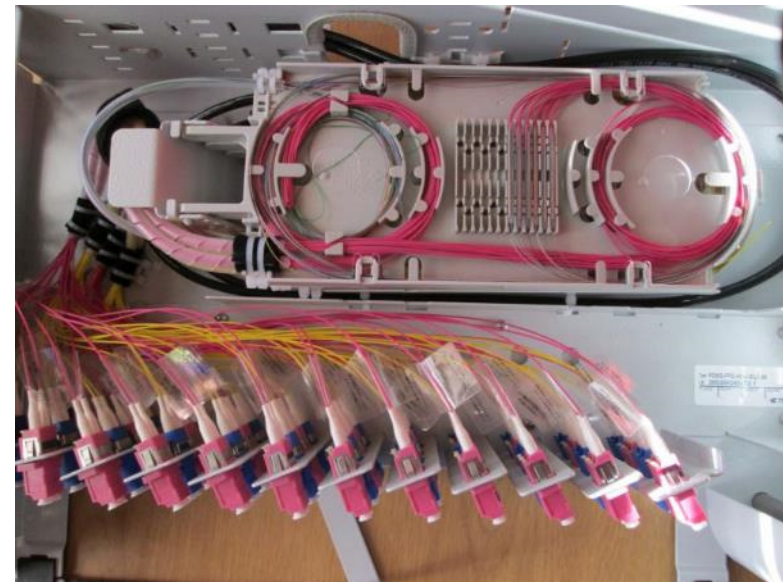
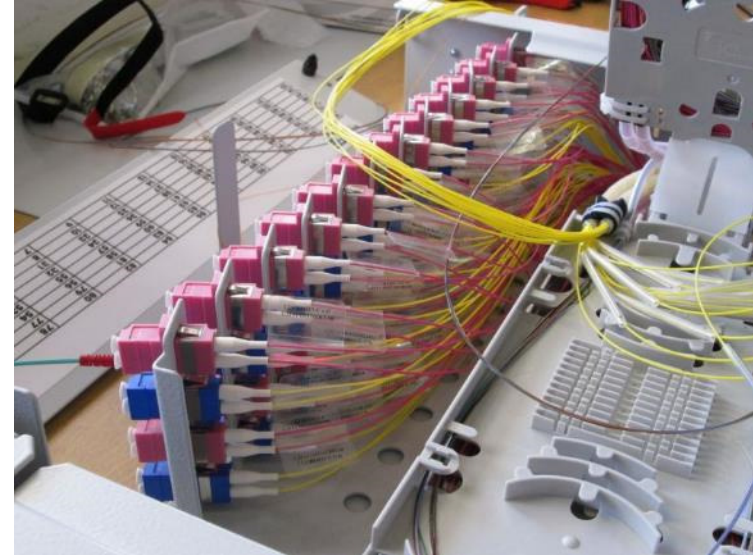


Optical fibre Network (OFN)



- Optical fibre Network
 - Receptor Fibre Network (RFN): fibres on Antennas
 - Design completed, installed as Antennas rolled out
 - Procurement for 10 Antennas completed
 - Array Fibre Network (AFN): fibres from Antennas to Processor Building
 - 170km optical fibre
 - Completed (Plessey) - local
 - KAPB Fibre Network (KFN): fibre network inside KAPB
 - Design completed, installation managed internally
- Training initiative has seen 6 local Carnarvon individuals being trained as OFN technicians, 2 has joined SKA SA at end of 2014
- New training group has been taken on beginning 2015
- Low financial, technical and schedule risk

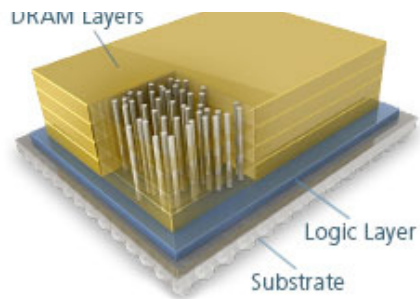
OFN Installations



SKARAB – in production

40 GbE
mezzanine

HMC mezzanine
(Micron not providing
production chips yet)



CBF Switch Installed



Control and Monitoring (CAM)



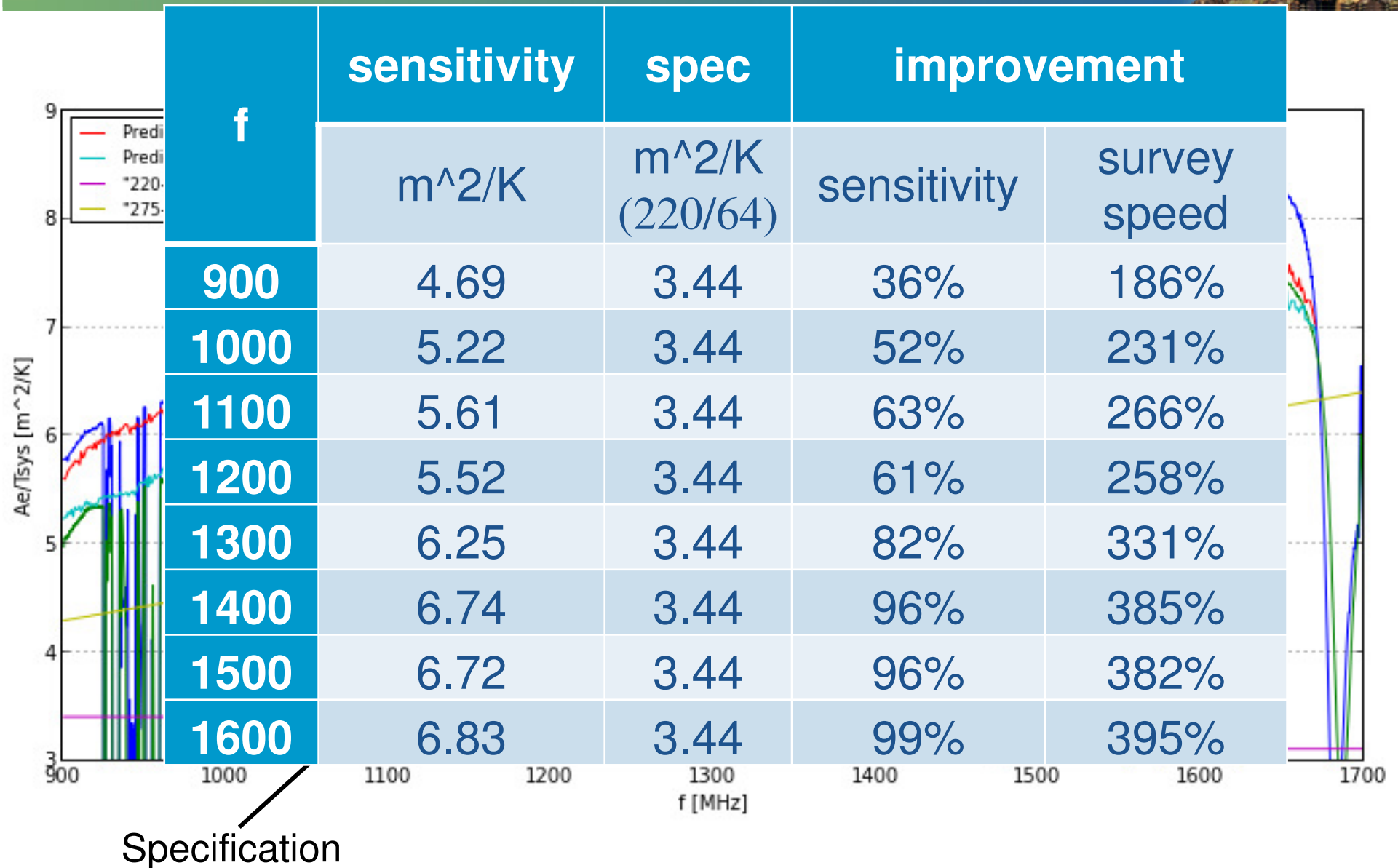
- Phased Implementation building on KAT7 experience
- RTS
 - Completed
- AR1
 - Servers procured and installed on site
 - Software release deployed to lab
 - Qualification review completed
- Integration with in-house ILS (Integrated Logistic Support) system progressing well
- Low financial, schedule and technical risk
- Lead Telescope Manager SE on SKA
- Quote from Dr Paul Alexander (Head Astrophysics, Cambridge)
 - *“Work on CAM at SKA SA is the best I have seen in the last few years anywhere in the world.”*

Recep

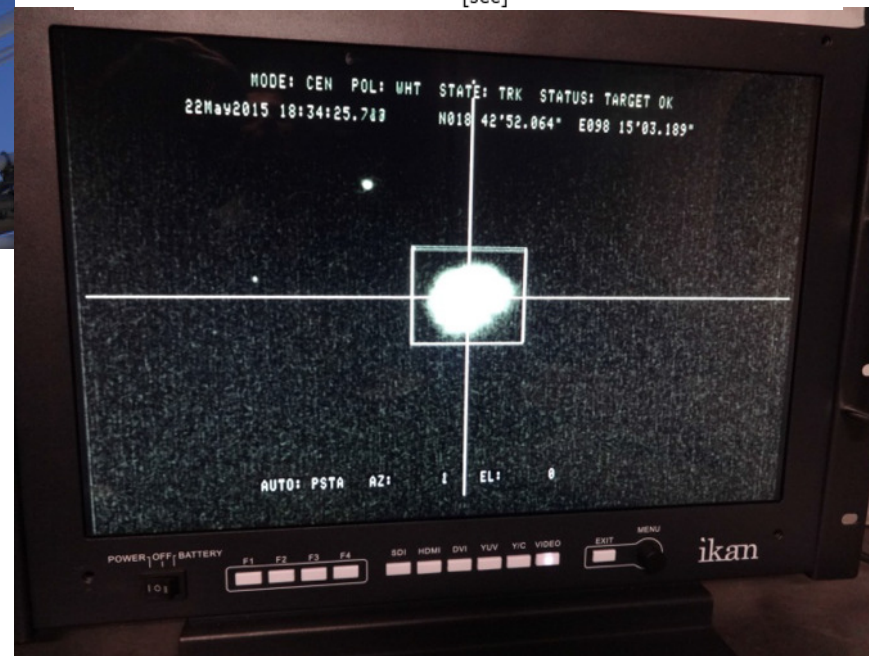
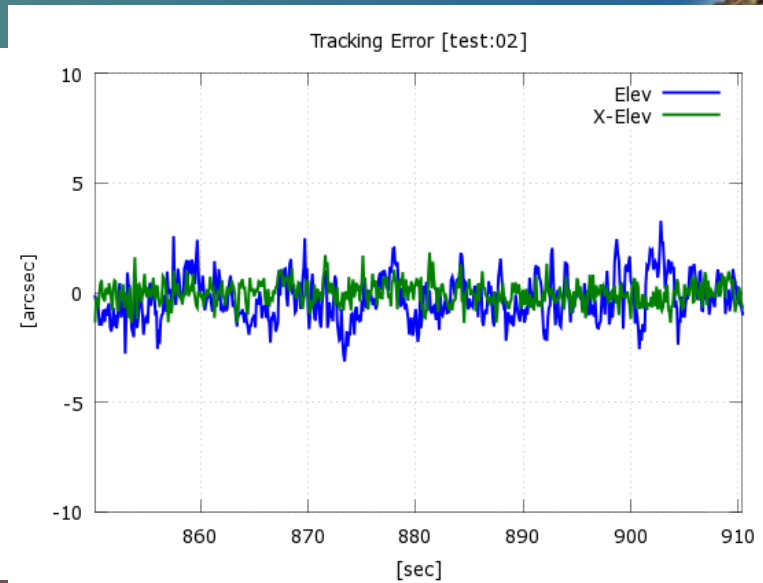
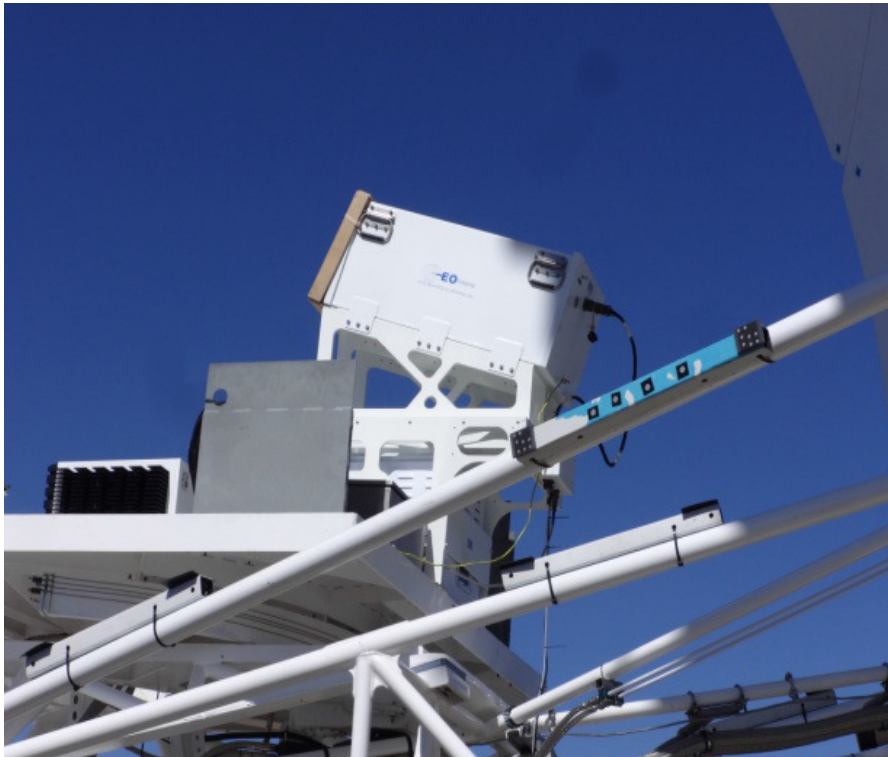
Test	Requirement	Performance Achieved	Pass/Fail
Ae/Tsys	200 - 220 m ² /K in L-band	300 - 400 m ² /K in L-band	PASS
Tsys & Tipping Curve	$T_{sys}/\eta_{illum} < 42$ K in L-band & full elevation	< 26 K	PASS
Gain Curve	≤ 5% at 14.5 GHz	≤ 8% at 12 GHz ≤ 12% at 14.5 GHz	FAIL ⁽¹⁾
Intrinsic Pointing (all sky)	≤ 5', acceptance conditions	≤ 5' normal conditions	PASS
Reference Pointing	≤ 5" RMS / 20 min, optimal conditions ≤ 25" RMS / 20 min, normal conditions	≤ 5" RMS / 20 min, optimal conditions ≤ 25" RMS / 20 min, normal conditions ⁽²⁾	PASS
Reference Pointing	≤ 25" RMS / 4 hr, 95% of normal conditions	≤ 25" RMS / 4 hr, normal conditions excl. 1 hr around sunrise & sunset ≤ 40" RMS / 4 hr, normal conditions	PASS
Pointing Jitter	≤ 15" RMS	≤ 3" RMS	PASS
APE: Holography	91% @ 14.5 GHz	>91% @ 14.5 GHz	PASS
APE: Photogrammetry	91% @ 14.5 GHz	92.1% @ 14.5 GHz	PASS
Error Beam: Photogrammetry	≤ -15 dB	-20.31 dB	PASS
RFI: AP	Refer [8] and [3]	Refer [8] and [3]	PASS
RFI: Rx			PASS
RFI: Digitizer	Refer [2]	Refer [2]	PASS
Antenna Leakage Reflector	≤ 0.5%	≤ 0.2% with gap covers	PASS



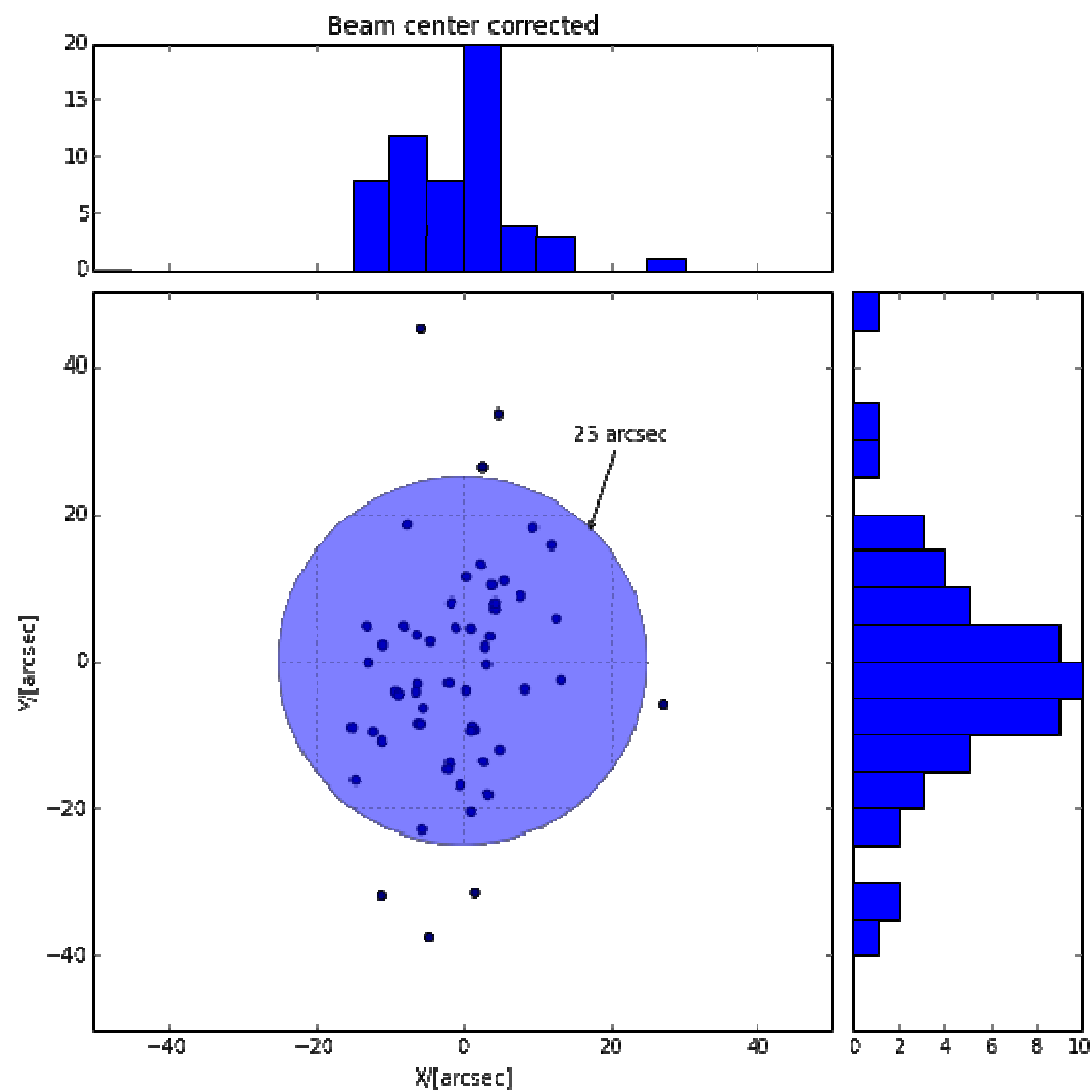
Receptor Performance – Ae/Tsys (L-band)



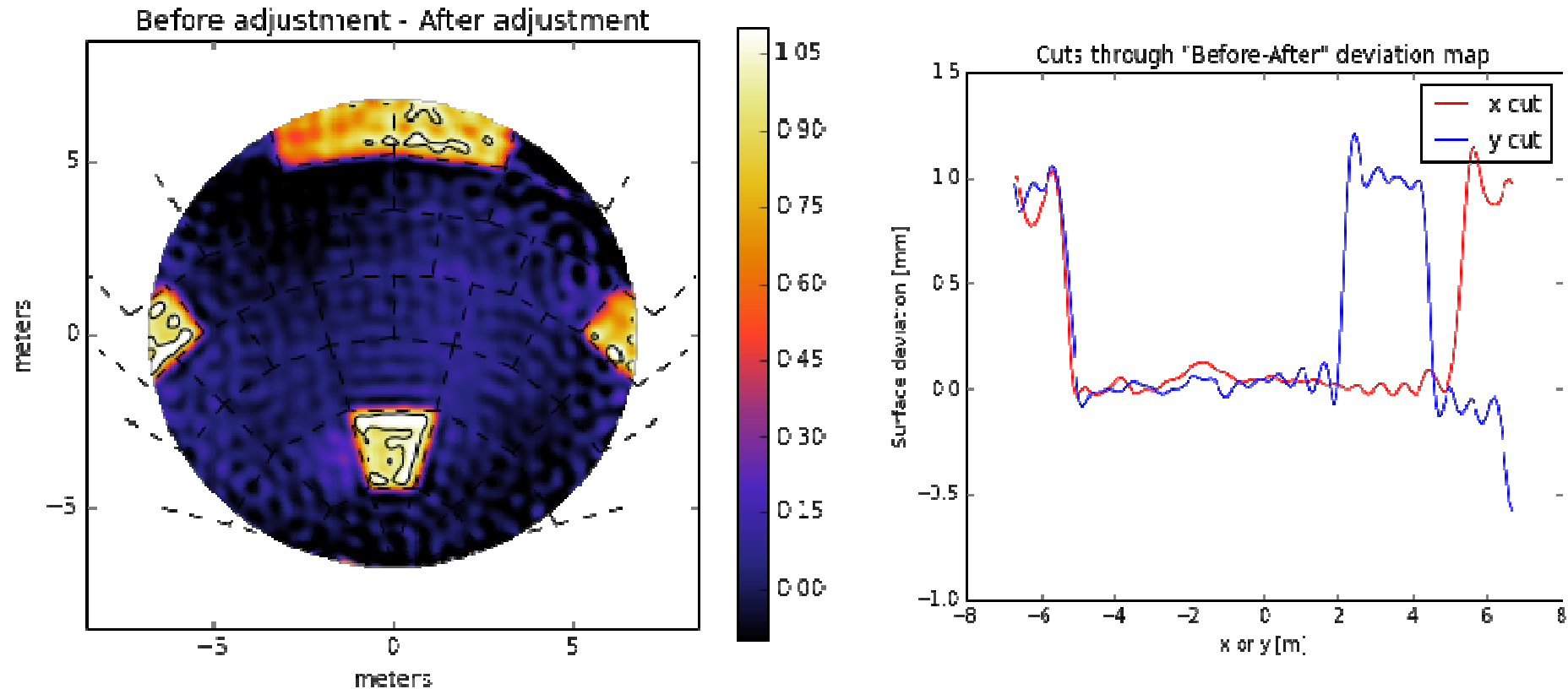
Optical Pointing



Ku-band Pointing



Holography



APE spec = 91% @ 14.5 GHz
APE achieved = 92% @ 14.5 GHz

Conclusion/Comments



- Stakeholder Relations good (scientists, farmers/locals, public)
- Skilled engineering AND support teams/systems have been established
 - Strong focus on training and people development – also from the local area
 - KAT7 invaluable in this regard
- MeerKAT Infrastructure completed
- MeerKAT set to perform much better than specification
 - Both in terms of sensitivity and frequency coverage (additional receivers)
 - Also strong focus on reliability and low maintenance cost
- MeerKAT Cost to Completion Budget has been stable for 2 years
- International investment in MeerKAT (S-band receivers)
- SKA SA strongly involved in SKA PEP – lead SA-Infra + AIV and SE lead on dishes + CAM – this should help ensure successful integration of MeerKAT into rest of SKA Mid
- Going well, lot of hard work has been done, but next 2 years will be tight
 - Next major milestone – 16 antenna array commissioned end June 2016

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Questions?

