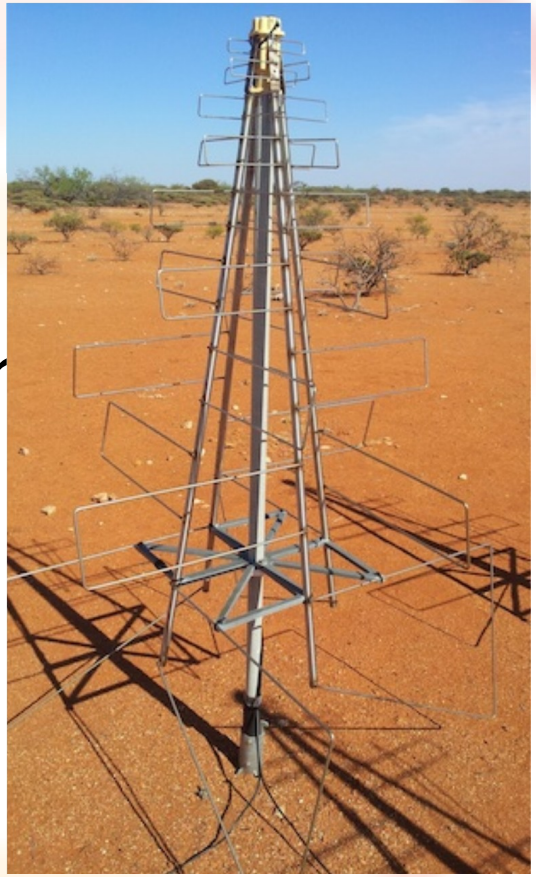
SKA-low and the Aperture Array Verification System



International Centre for Radio Astronomy Research

SKA SQUARE KILOMETRE ARRAY

LOW-FREQUENCY APERTURE ARRAY

Randall Wayth – AADCC Project Scientist

On behalf of the Aperture Array Design & Construction Consortium (AADCC)

Curtin University

The Government of Western Australia

The University of Western Australia

AADCC partners

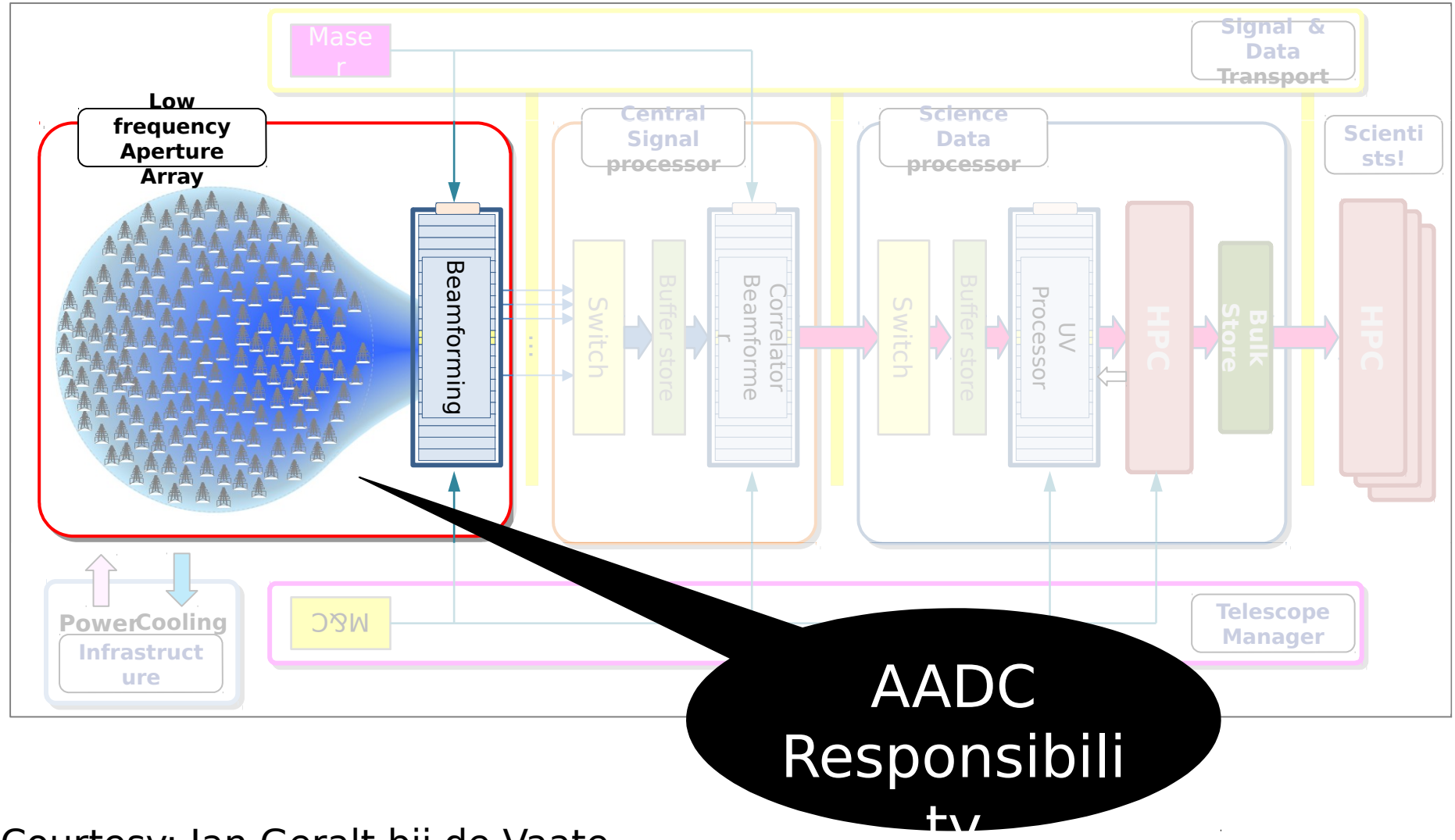
- ASTRON (Netherlands)
- ICRAR/Curtin University (Aus)
- INAF (Italy)
- University of Oxford (UK)
- University of Cambridge (UK)
- KLAASA (China)

Associates:
- Jive
- University of Manchester
- University of Malta

Large, international effort.
~$50M budget to pre-construction

Acknowledgements:
CSIRO,
Pawsey Supercomputing Centre

SKA-low: end-to-end



Courtesy: Jan Geralt bij de Vaate

SKA1-Low: Aperture Array Verification Systems

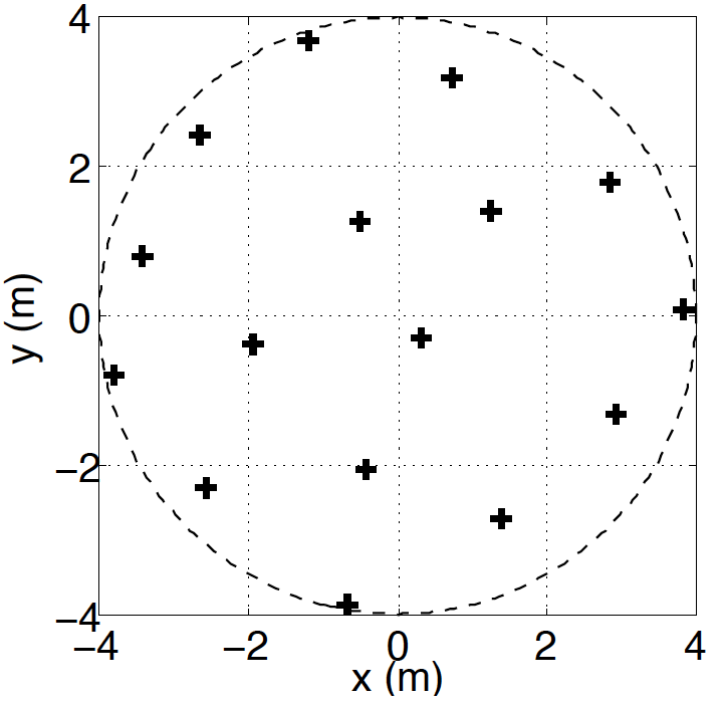
- **Task:** Demonstrate LFAA functionality/performance of baseline design through accurate, in-situ measurement
  - i.e. can we show that LFAA designs meet requirements?

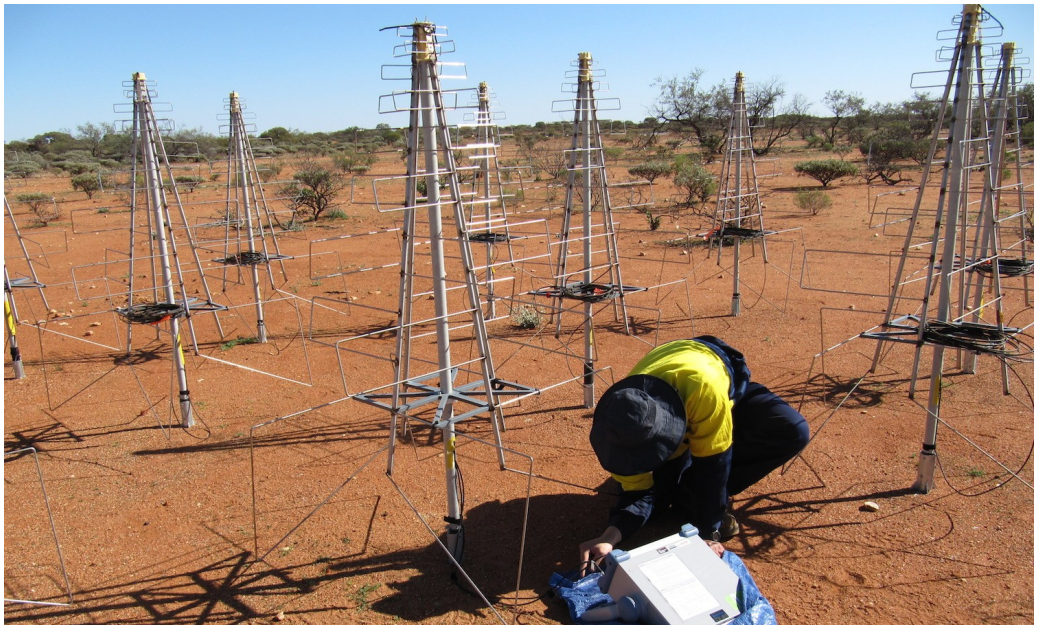
- **Solution:** use an existing radio telescope (MWA) and well-known properties of radio sky for:
  1. absolute measurements of array sensitivity (A/T) and
  2. beam pattern

- A. Sutinjo et. al., *Characterization of Aperture Array Verification System 0.5: Radio Astronomy Interferometry and Full-Wave Simulation*. IEEE TAP submitted
- T. Colegate et. al., *Antenna array characterization via radio interferometry observation of astronomical sources*, IEEE CAMA, 2014
- P. Hall et. al., *First results from AAVS 0.5: A prototype array for next-generation radio astronomy,* ICEAA, 2013`

Aperture Array Verification System 0.5

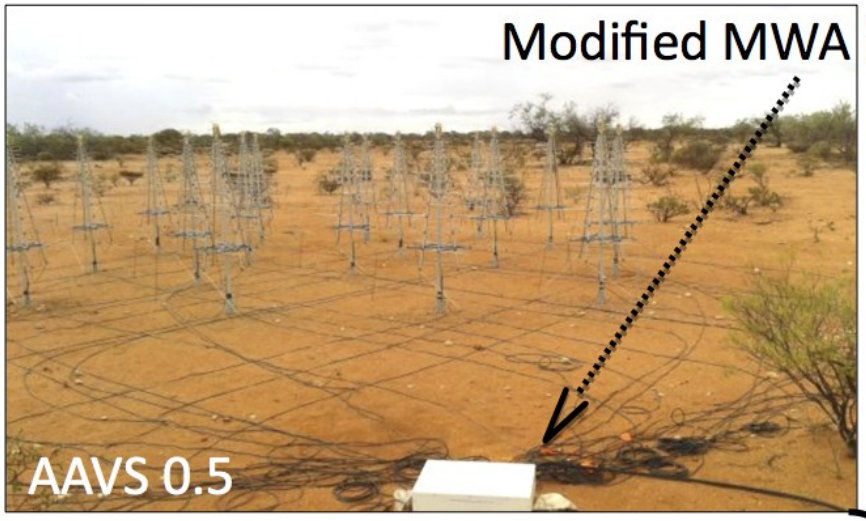
- 16 log-periodic ‘SKALA’ antennas as a beamformed ‘tile’
- 50-350+ MHz
- deployed near SKA1-Low site under the MWA external instrument policy



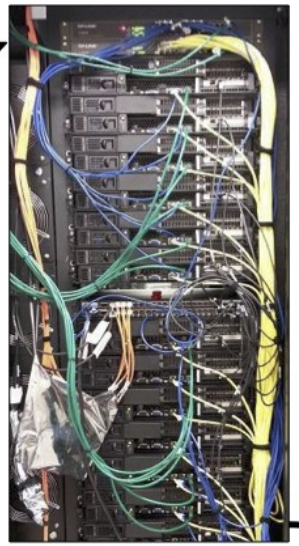


Aperture Array Verification System 0.5

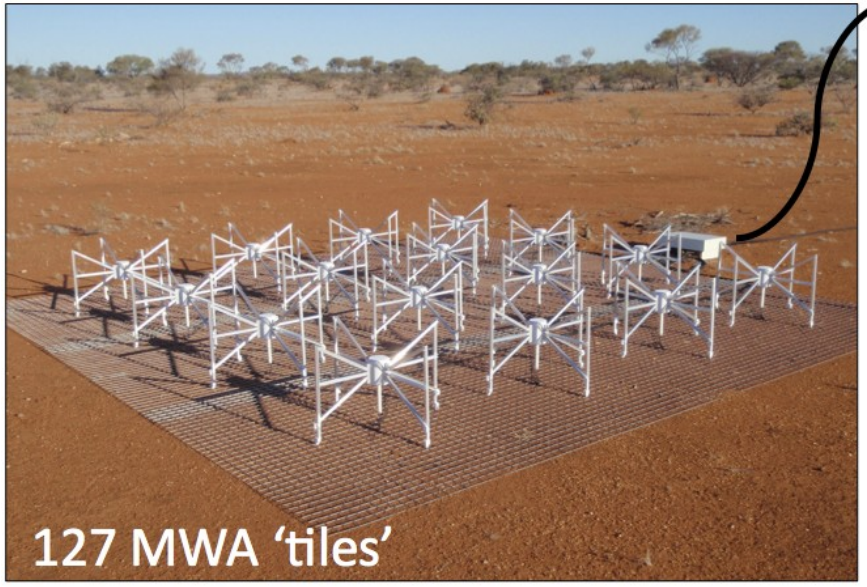
For measurement: swap 1 MWA tile with AAVS 0.5



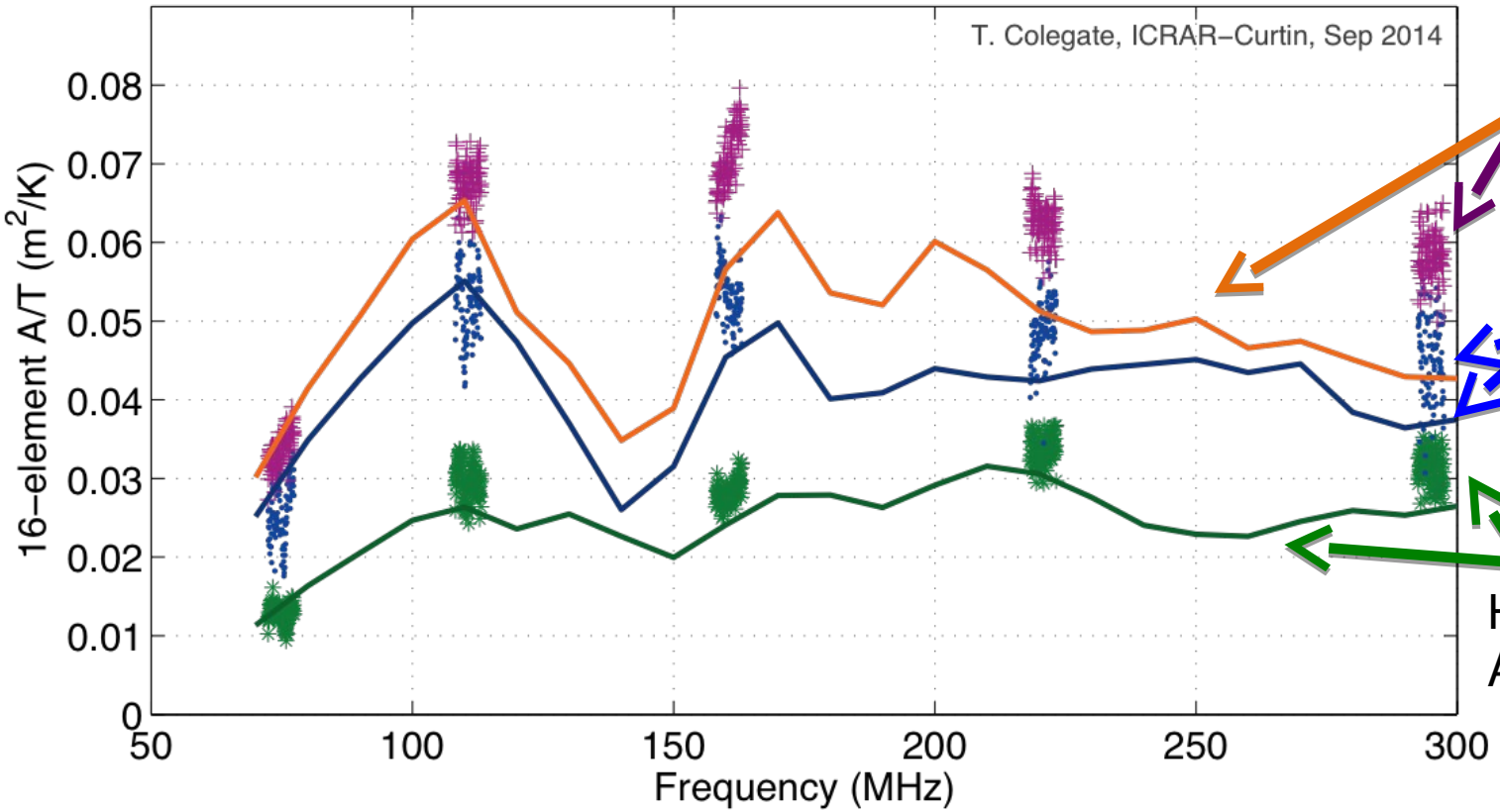
MWA receivers



MWA correlator



Measured and simulated sensitivity (A/T) for three calibrators and pointings



Hydra A
Az=0°,
El=75.4°

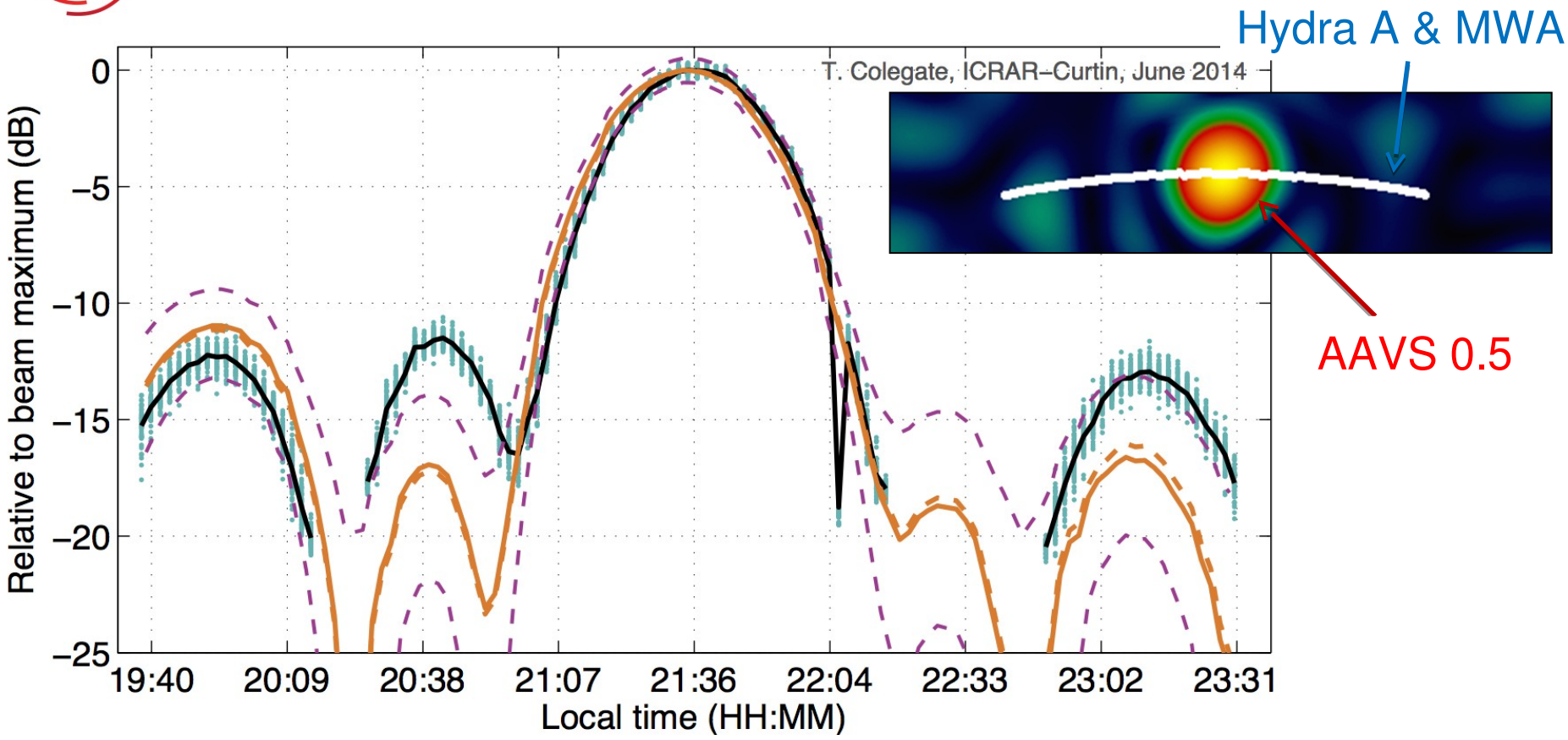
3C444,
Az=0°, El=81.3°

Hercules A,
Az=0°, El=58.3°

Hyd A (22 May), X–pol (magenta)
3C444 (22 May), X–pol (blue)
Her A (19 Aug), X–pol (green)
Simulated, pointed to sky at Hyd A, 2% soil moisture
Simulated, pointed to sky at 3C444, 2% soil moisture
Simulated, pointed to sky at Her A, 2% soil moisture

Note: simulations include measured T_{RX}

AAVS 0.5 beam pattern at 220 MHz: X-polarization



- AAVS 0.5: Az=0°, ZA=14.6°
- Earth rotation: source passes through AAVS 0.5 beam
- MWA tiles track source

Antenna array characterization - summary

- Demonstrated measurement and simulation tools to test array performance characteristics

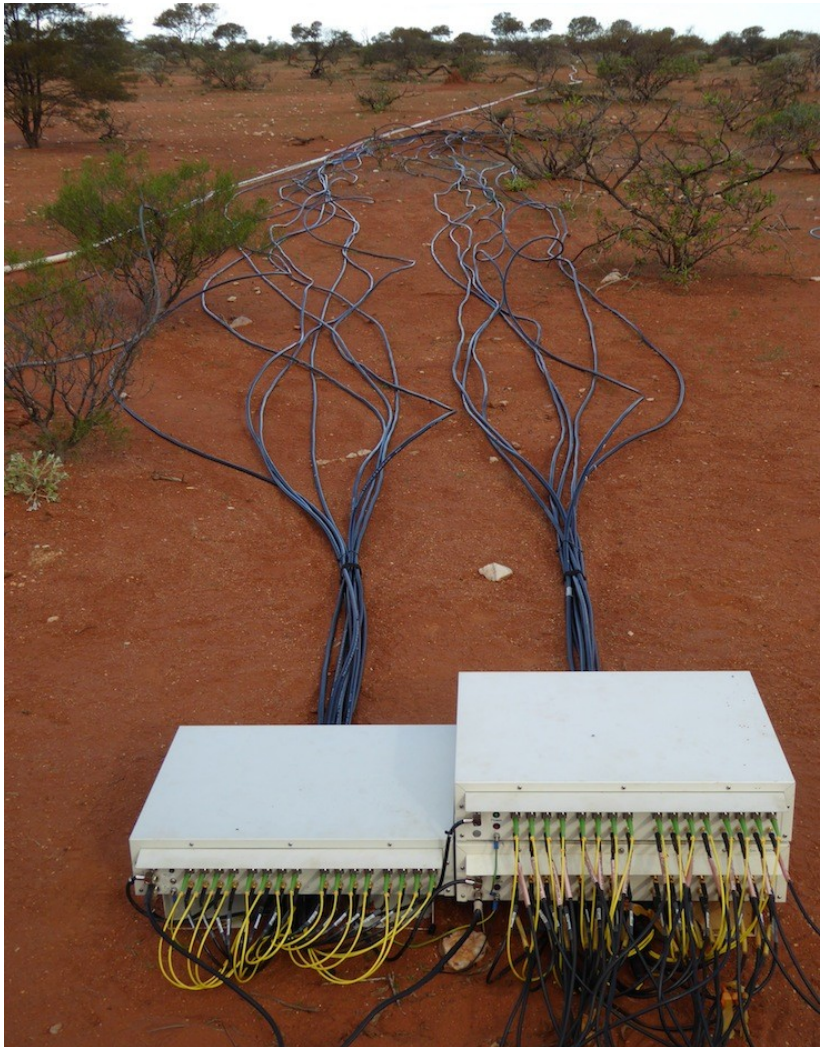
- Our simulations generally show good agreement with measurement, but we must ensure:
  - simulations accurately represent the observation (soil, sky, beam pointing)
  - measurements are accurate (correct calibration!)

- These measurements were an important contribution to the Square Kilometre Array preliminary design review
  - AAVS 0.5 results, extrapolated to full-sized telescope, meet current specifications

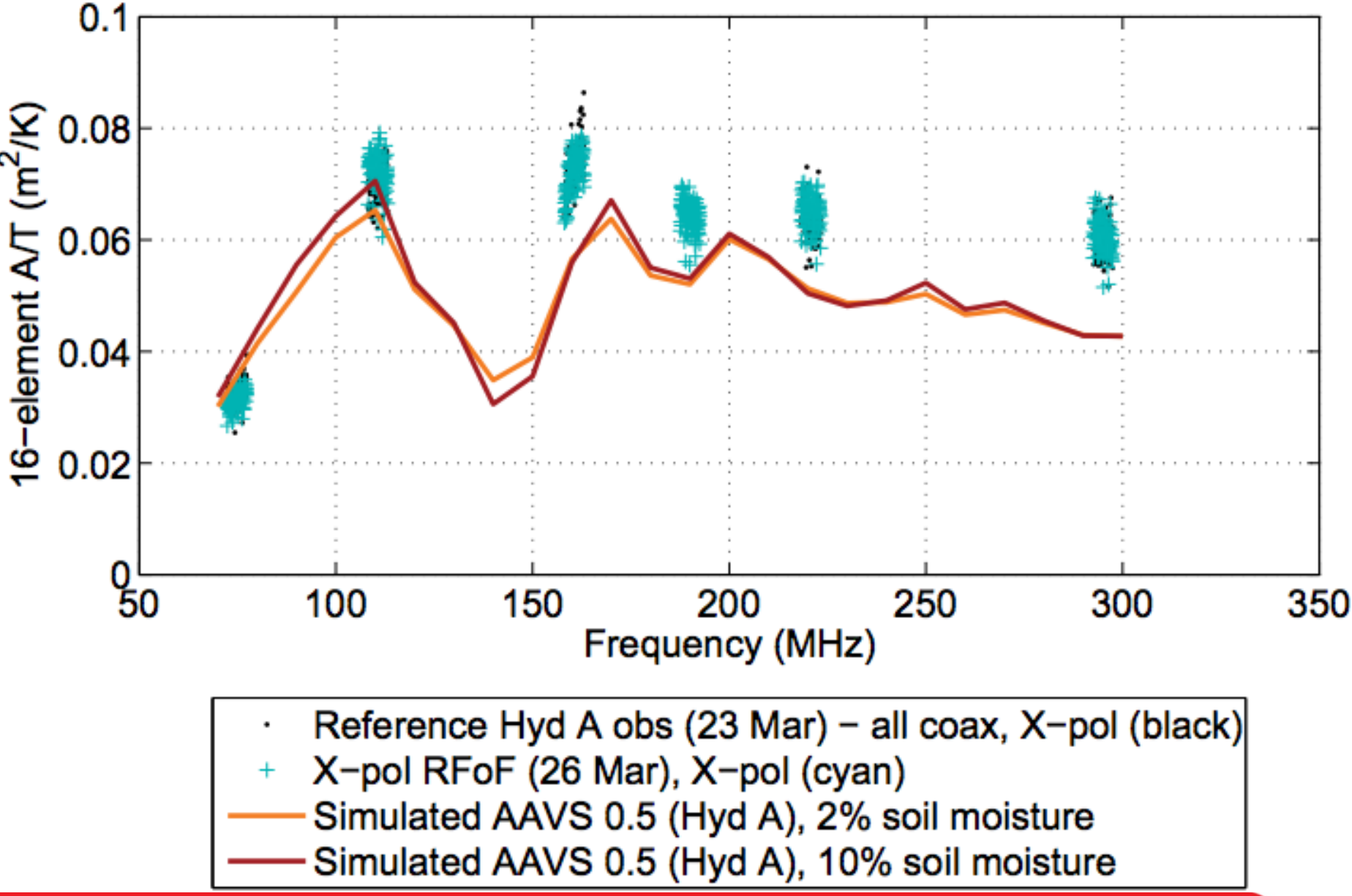
AAVS0.5 RFoF tests

- 2015 March

- RF over fibre (RFoF) test system for a single polarisation on AAVS0.5 test tile
- Perform same A/T test as previous, compare results



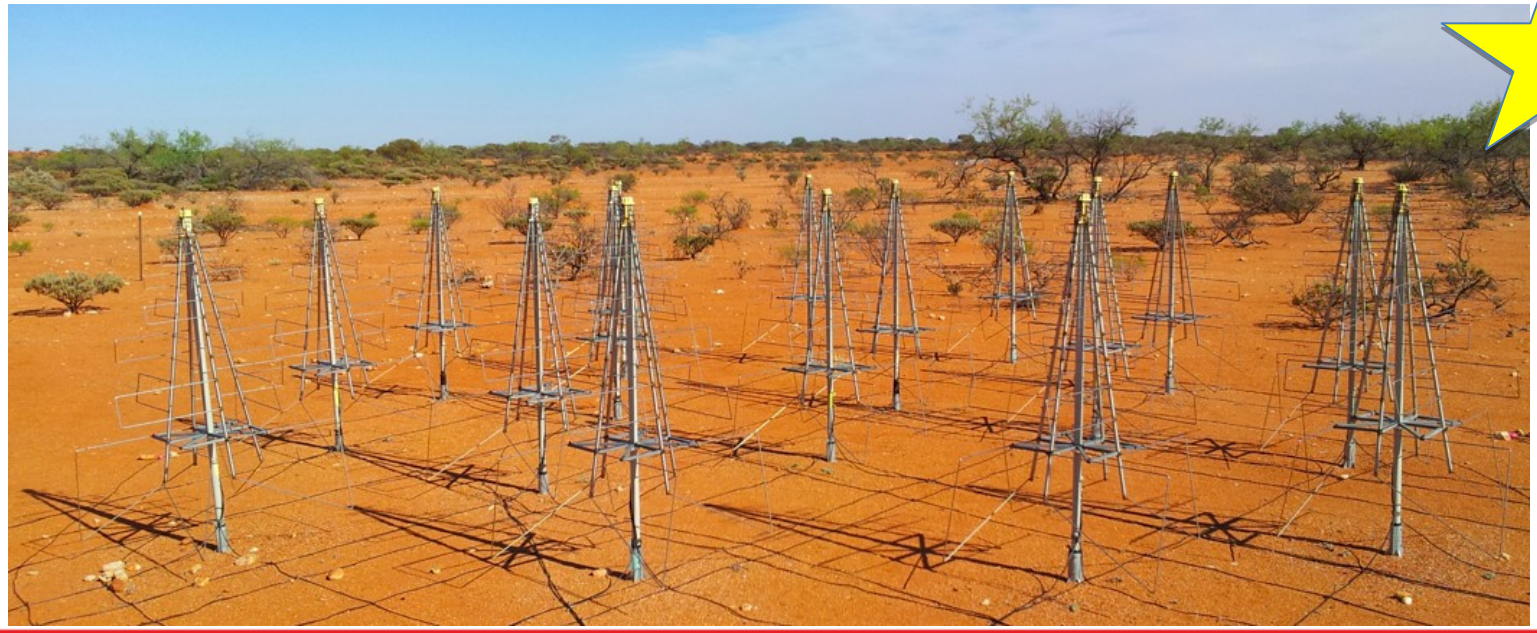
AAVS0.5 RFoF A/T results



Timeline and recent history

History

- 2012: initial antenna design/LNA testing in UK
- 2013+: installation of AAVS0.5 at MRO, connection to MWA
- 2014: development of prototype RF, receiver & digital gear by AADCC members
- 2015: successful PDR with special mention for prototyping



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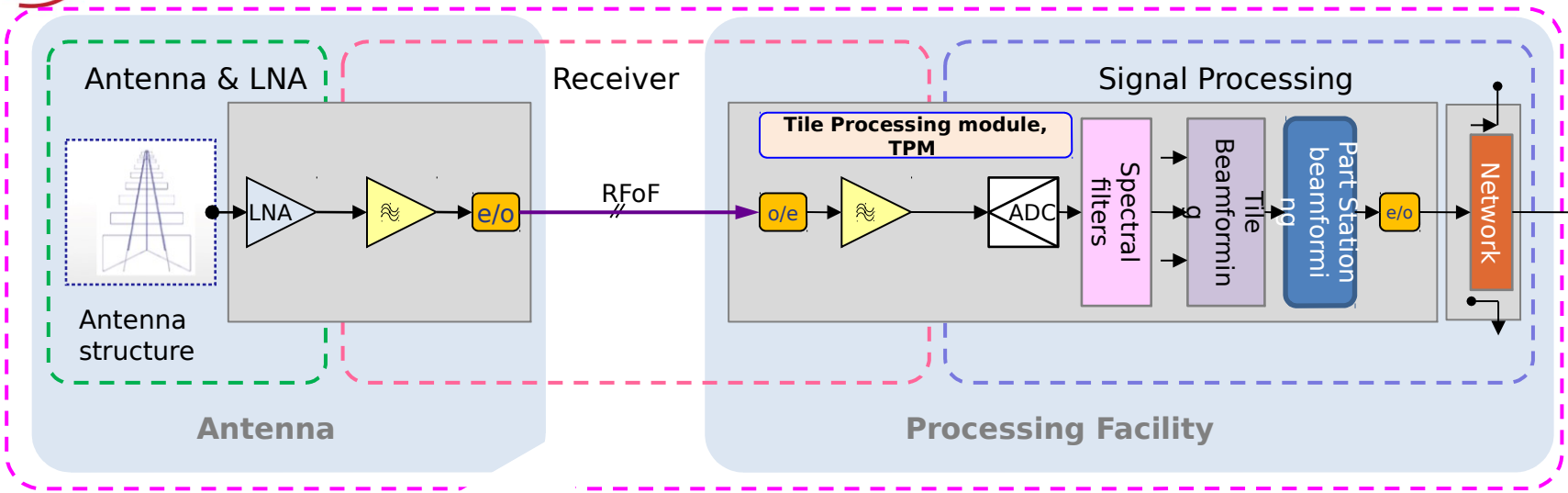
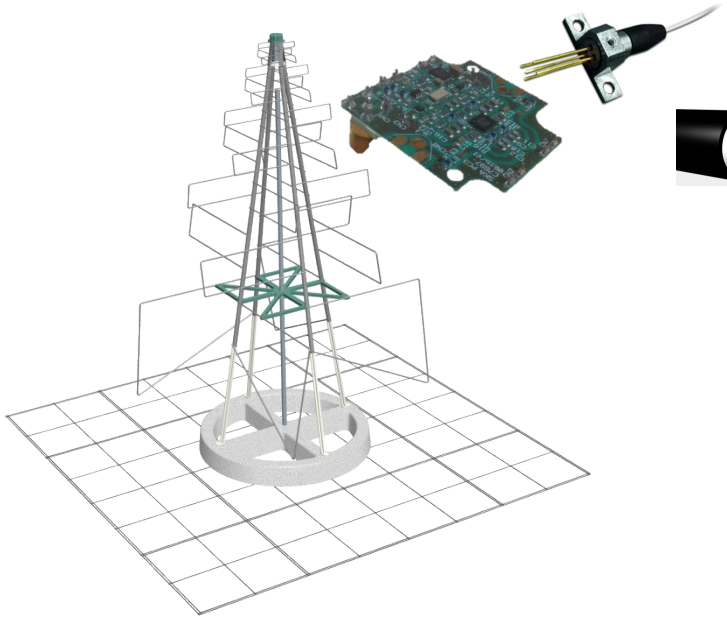
Future:

Aperture Array Verification System #1 (AAVS1)

- Q1 2015: new LNAs, receivers, digital systems delivered
- Q3 2015: initial UK-based testing of ant->receiver->digital systems
- Q4 2015: conformance testing & delivery to MRO
- 2016: AAVS1, installation at MRO, integration with MWA

LFAA Signal Chain



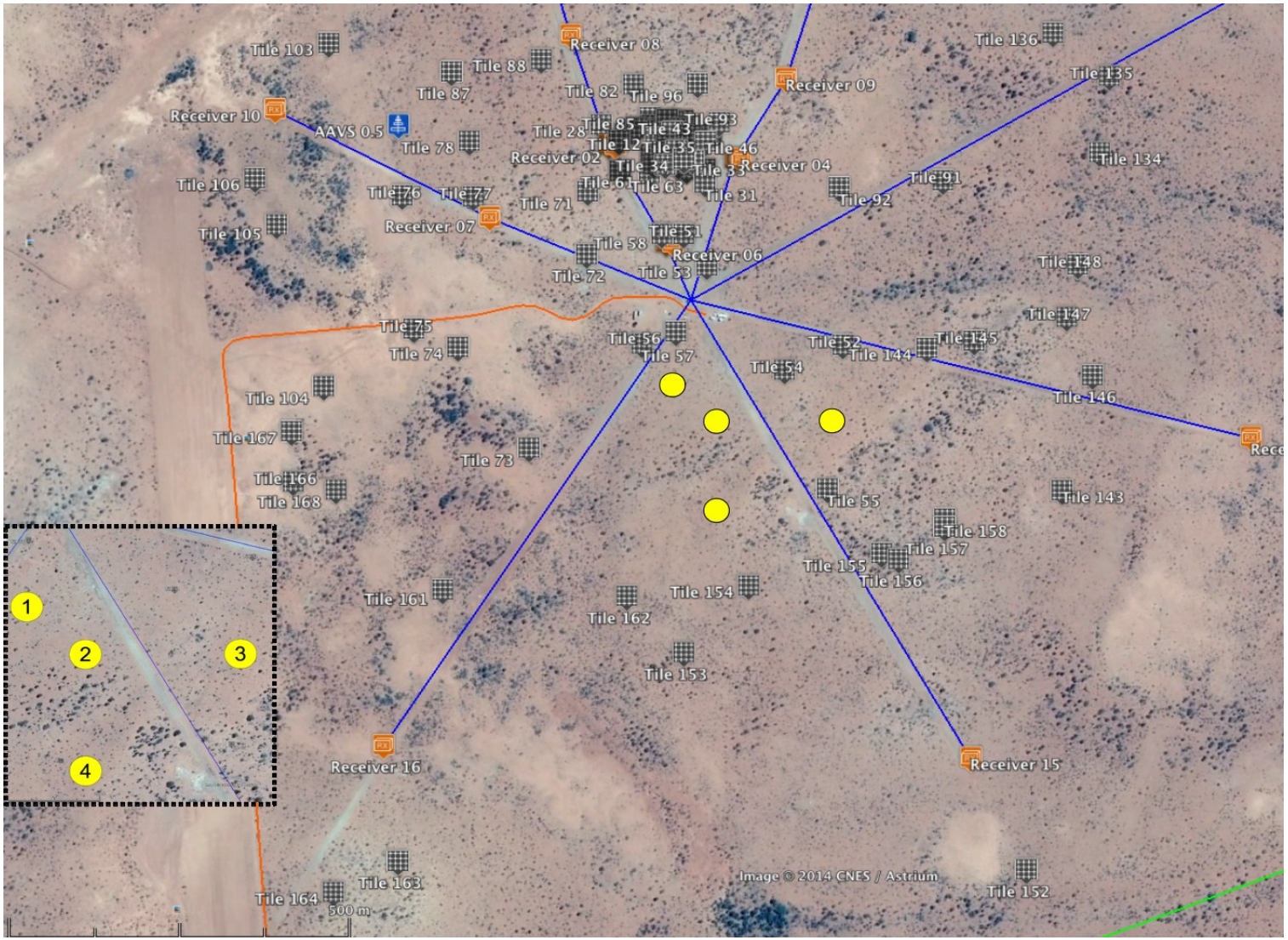


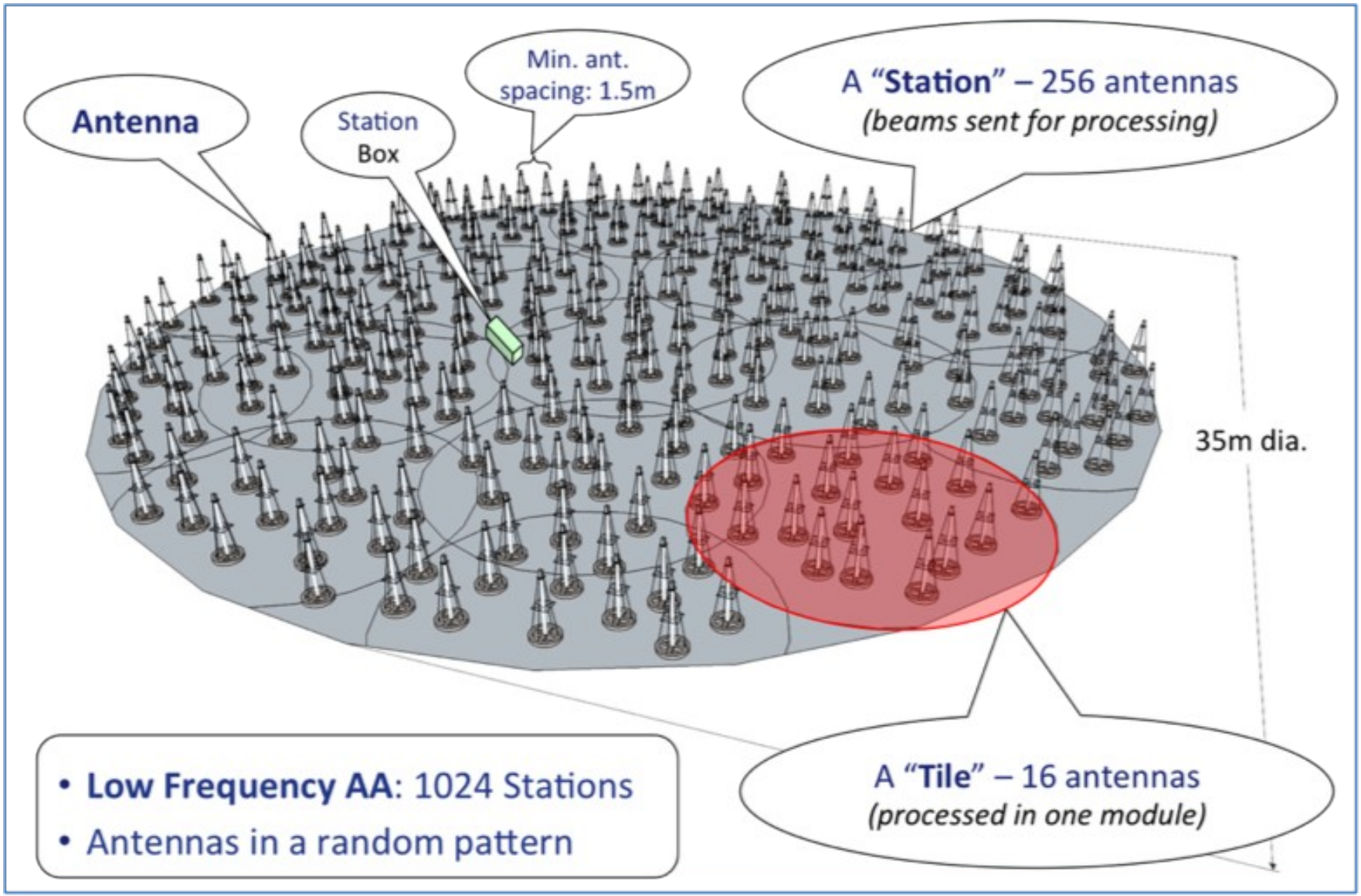
Aperture Array Verification System #1 (AAVS1)

- Goal: Full-sized SKA station to properly test against requirements
  - Will use all proposed LFAA technology from antennas through to digital beamformer, including RF over fibre
  - Essential prototyping & development, but maximal re-use of MWA infrastructure & systems
  - Successful test will retire large amount of technical risk

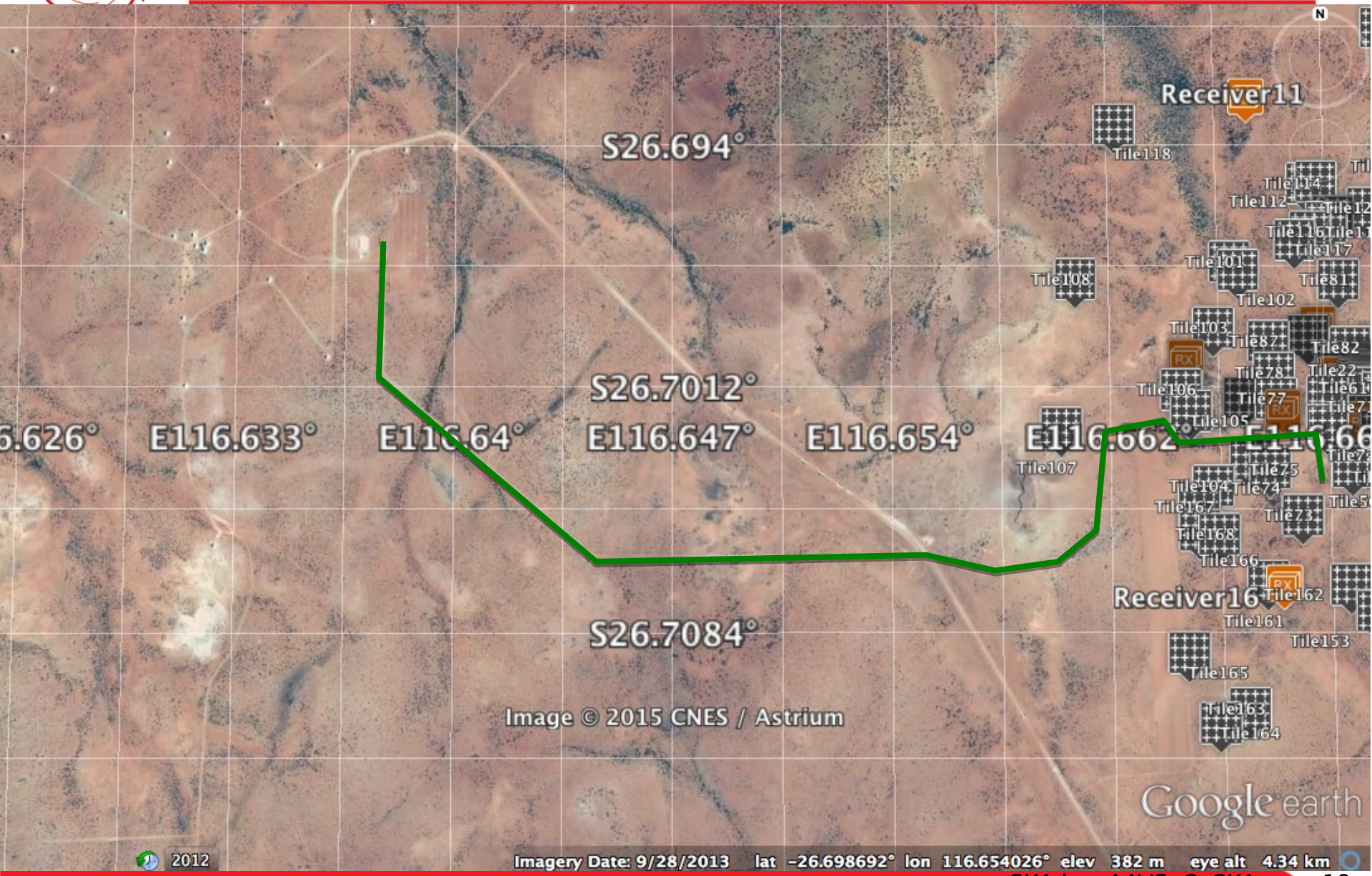
- Current thinking:
  - 1 x 256 antenna station; 3 x 48 antenna stations
  - 35 m diameter stations (at least for 256 antenna station)
  - Baseline lengths ~85–240 m
- Aim to use similar interferometric methods
- Much of the testing of array performance can be done via cross-correlation with MWA tiles (~75–300 MHz)

AAVS 1 – representative locations




Antenna
Station Box
Min. ant. spacing: 1.5m
A "Station" – 256 antennas
(beams sent for processing)
35m dia.
A "Tile" – 16 antennas
(processed in one module)
• Low Frequency AA: 1024 Stations
• Antennas in a random pattern

RF fibre path to MRO control



Summary

Aperture Array Design & Construction Consortium is making solid progress in development and verification during pre-construction.

- Aus involvement in AADCC is a comprehensive and essential part of the Aus SKA effort
- Test and verification systems are an essential part of SKA-low; On-the-ground prototyping avoids nasty surprises later.
- AAVS0.5 utilises MWA collecting area, signal chain, M&C & data processing expertise
  - AAVS0.5 system has demonstrated A/T meets spec at specified freqs
  - Beam model verification via drift scans of strong sources
- AAVS1 system to be deployed late 2015, again with focus on integration with MWA for mutual benefit.

Science with AAVS1

AAVS1 = full SKA-low station = substantial collecting area (~1 m^2/K @ 150 MHz = ~2700 Jy SEFD)

- 35m “single dish”
- Improved MWA calibration (collecting area, FoV)
- Hybrid array imaging/calibration
- Low freq flux scale (with calibrated element)
- EoR PS with hybrid arrays