An SKA System Overview
East-Asia Consortium Meeting
Korea

P. Dewdney

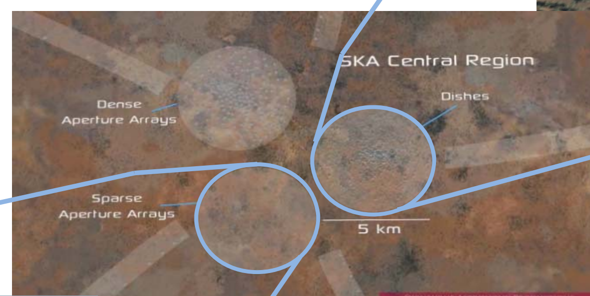
Nov 30, 2011

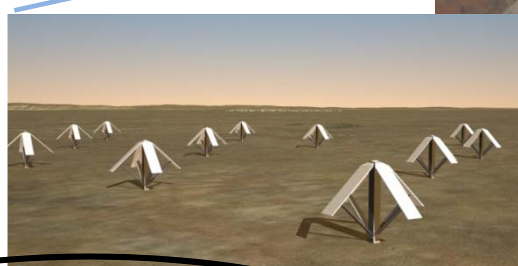
SKA1 Technologies

• Huge frequency range demands multiple technologies.
• Technologies mature enough to enter the design phase.

250 Dishes

Central Region

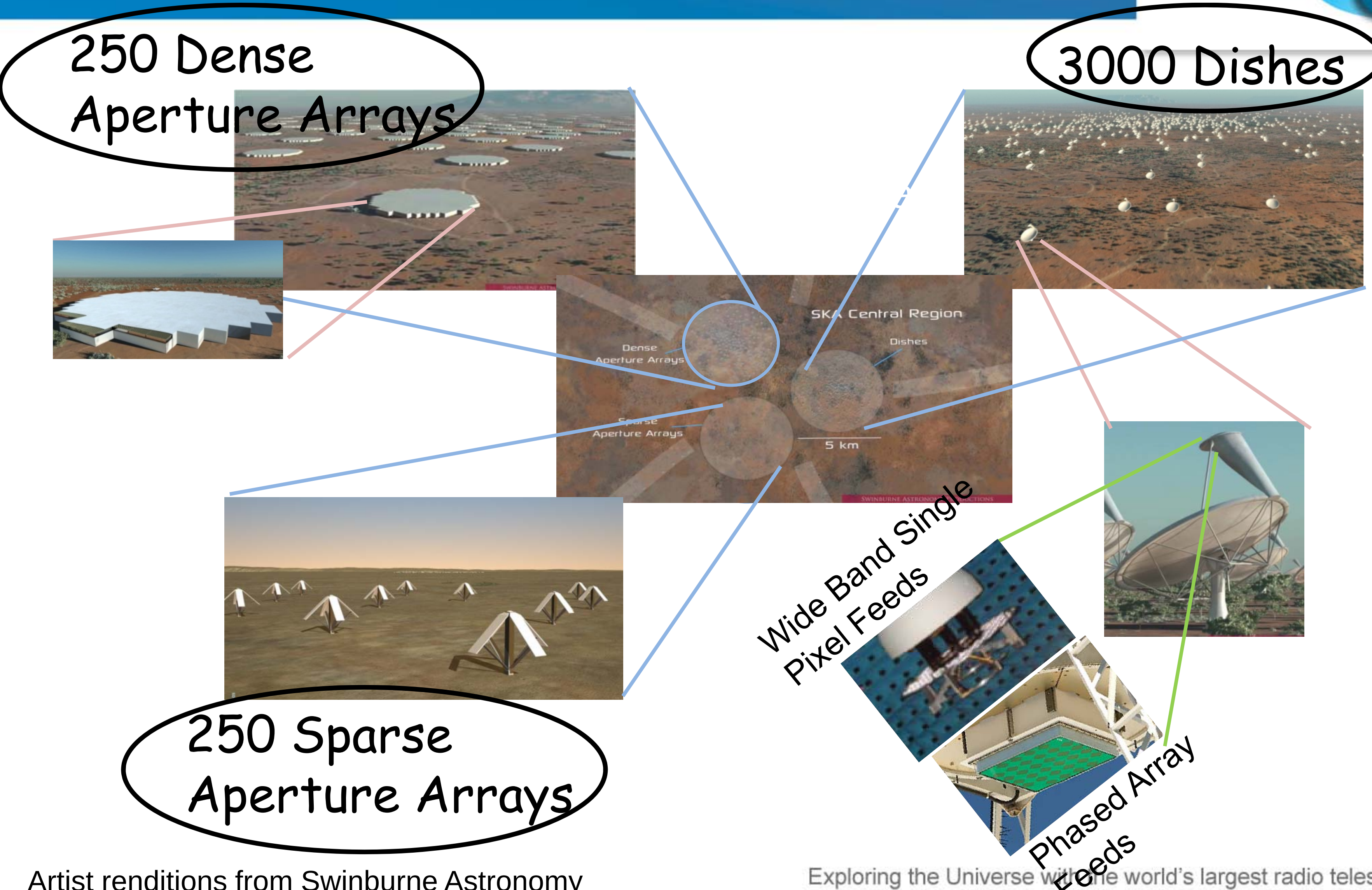




50 Sparse Aperture Arrays

Single pixel feed

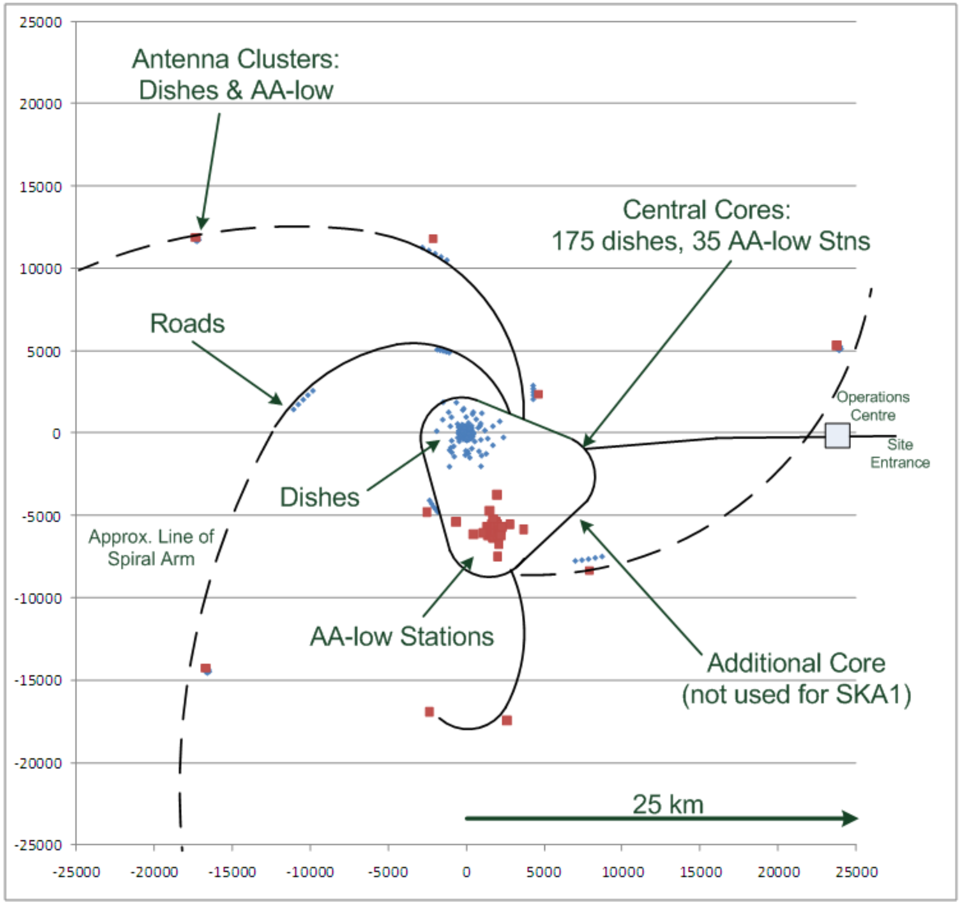
SKA2 Technologies



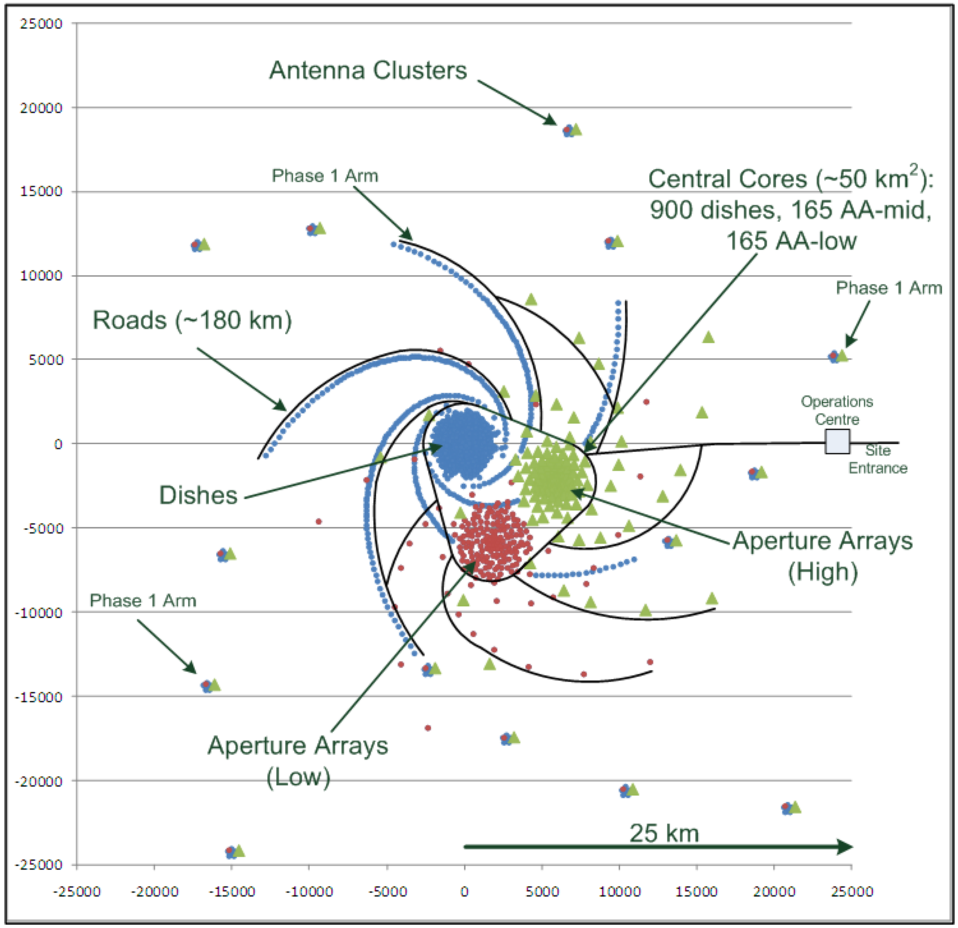
Artist renditions from Swinburne Astronomy Productions

Central SKA Site

Central SKA1 Site

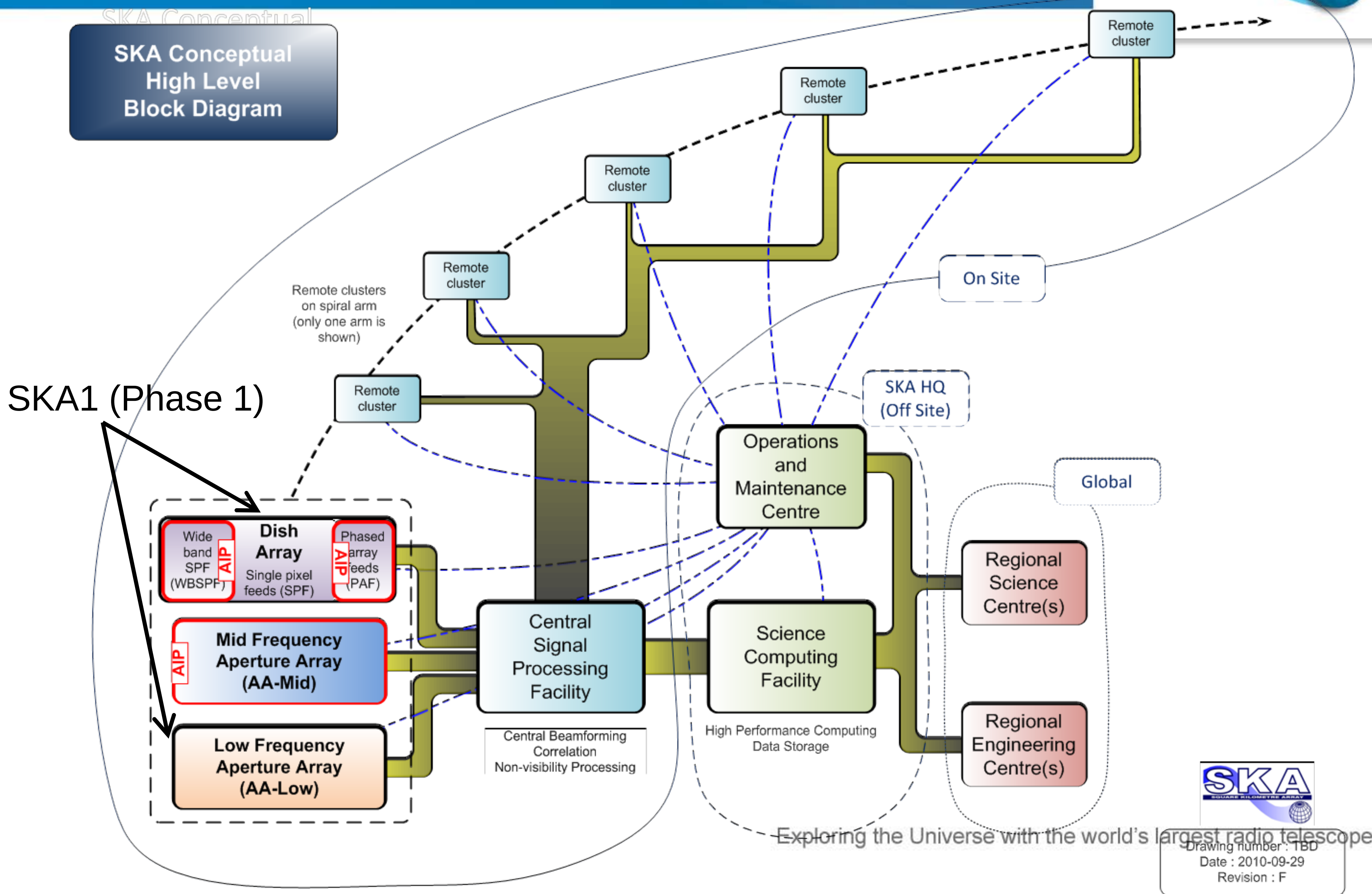


Central SKA2 Site

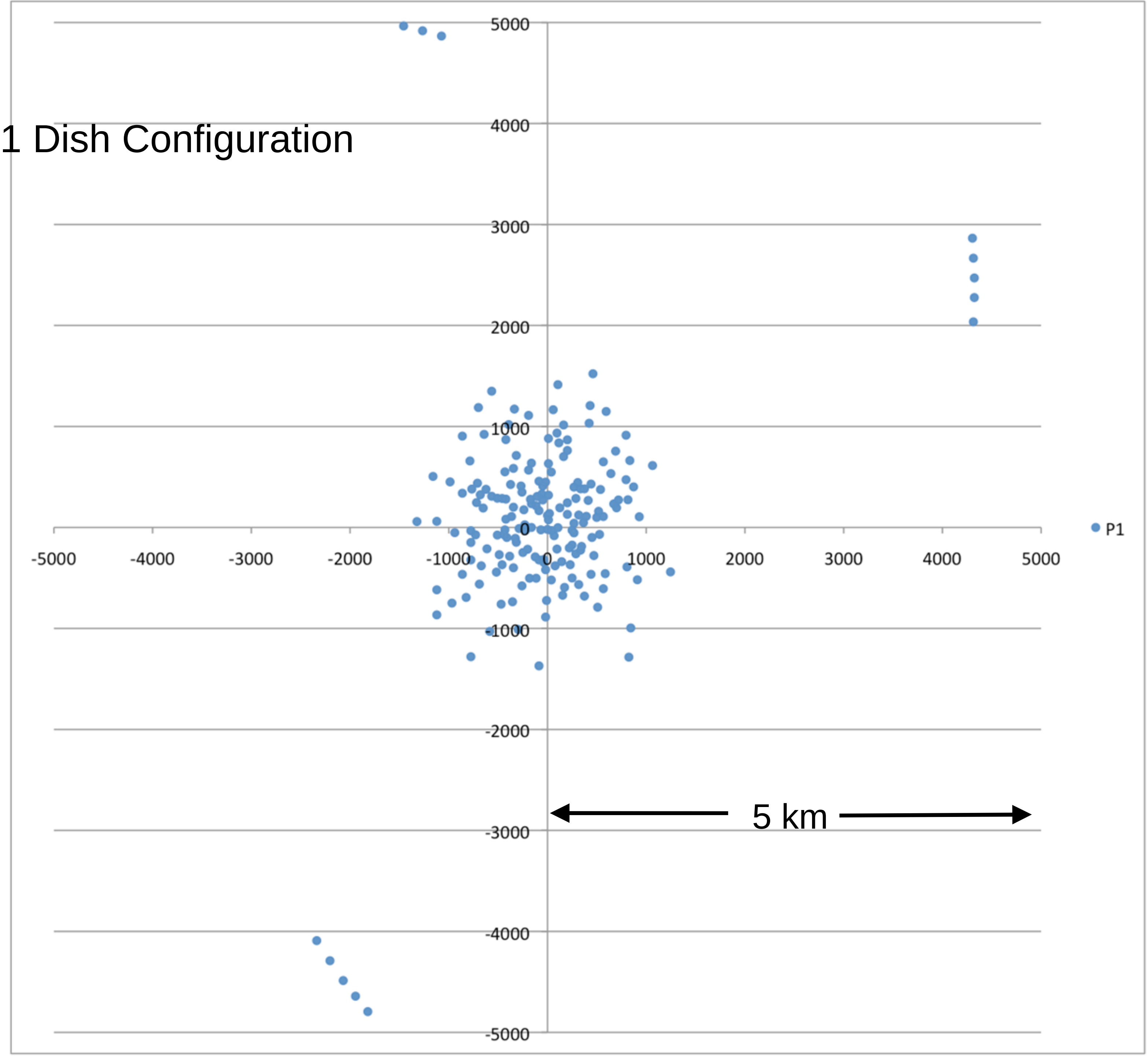


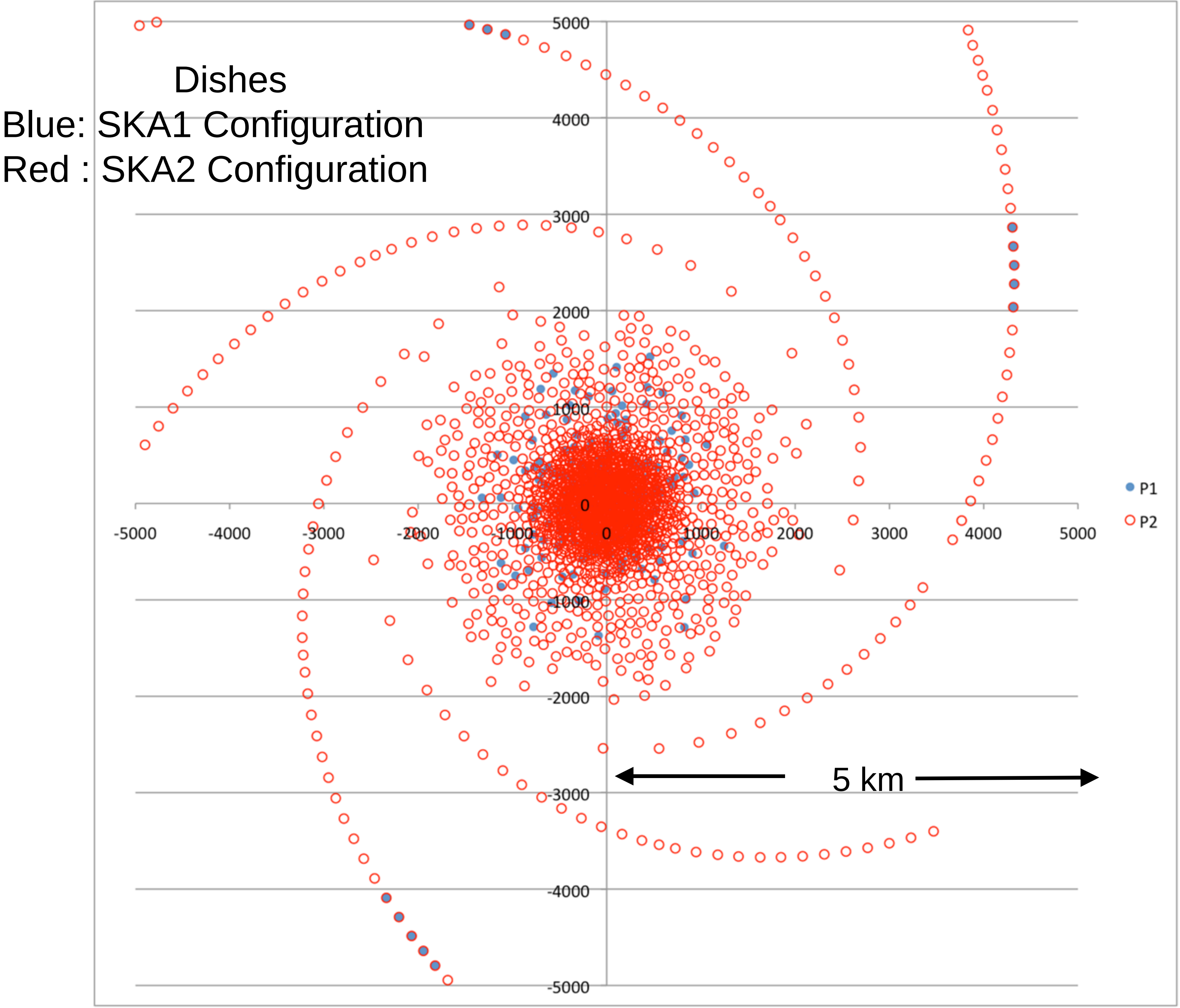
- SKA2 is ~10 x the collecting area of SKA1.
- Density increase of antennas is even larger in the central site.

SKA System Diagram



SKA1 Dish Configuration

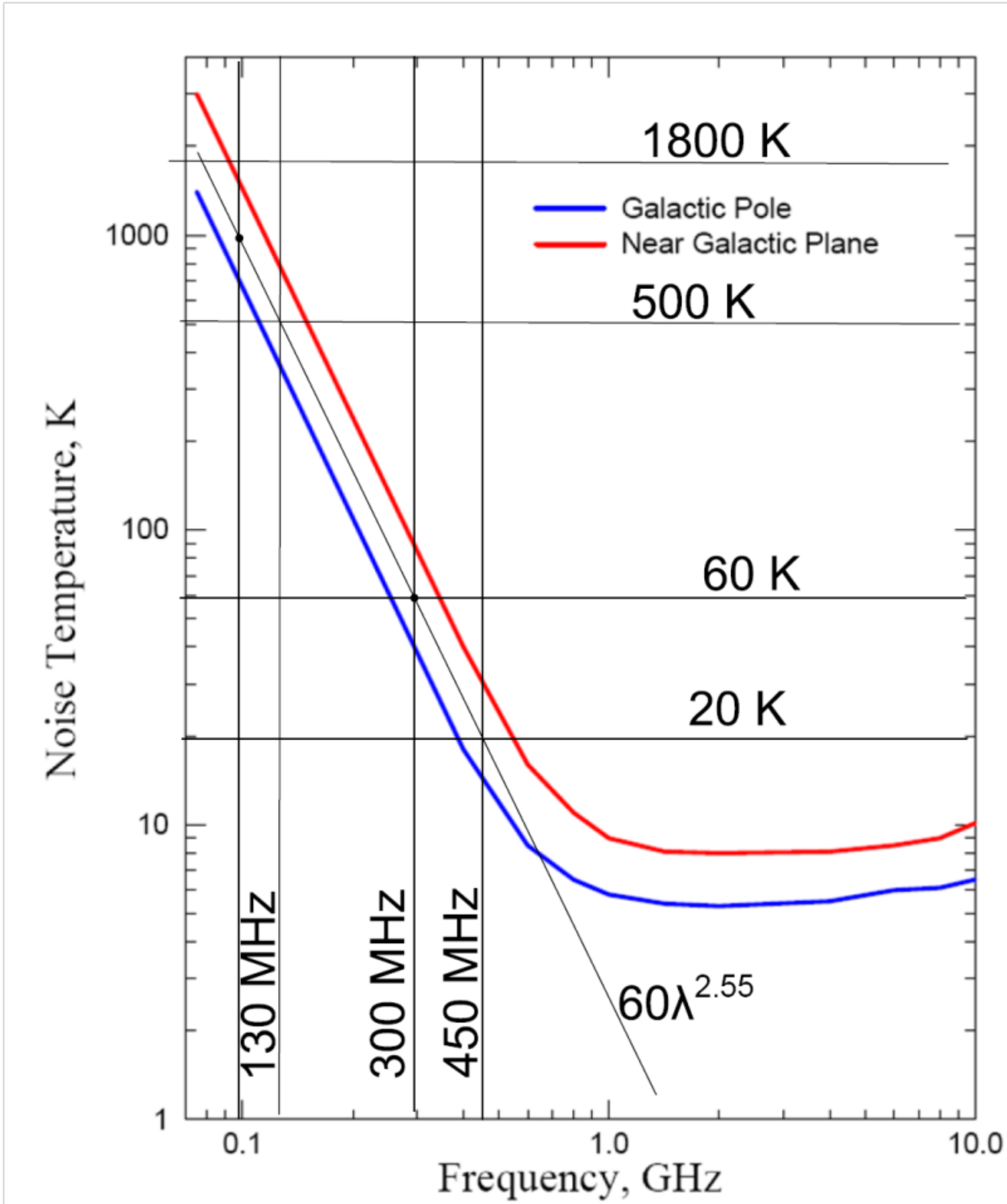



Dishes
Blue: SKA1 Configuration
Red : SKA2 Configuration
5000
4000
3000
2000
1000
0
-1000
-2000
-3000
-4000
-5000
-5000
-4000
-3000
-2000
-1000
0
1000
2000
3000
4000
5000
P1
P2
5 km

High Sensitivity & Signal Path Design

- The “theme of the SKA” is high sensitivity – well beyond any existing radio telescope.
    - more collecting area; larger fields of view.
    - lowest possible noise.
- Note that high resolution is a “solved problem” in radio astronomy.
    - Just make the interferometer bigger.
- But reaching high sensitivity implies sufficient control of instrumental artefacts (imaging, spectral, time-domain) to remain below the noise.
- Attaining high sensitivity implies a high quality signal path.
    - beginning when the wavefront hits the upper atmosphere to the output of the science data processing.
- **Design theme => high quality signal path.**

Sky Noise



1800 K
Galactic Pole
Near Galactic Plane
500 K
60 K
20 K
130 MHz
300 MHz
450 MHz
60λ^2.55
1000
100
10
1
0.1
1.0
10.0
Noise Temperature, K
Frequency, GHz

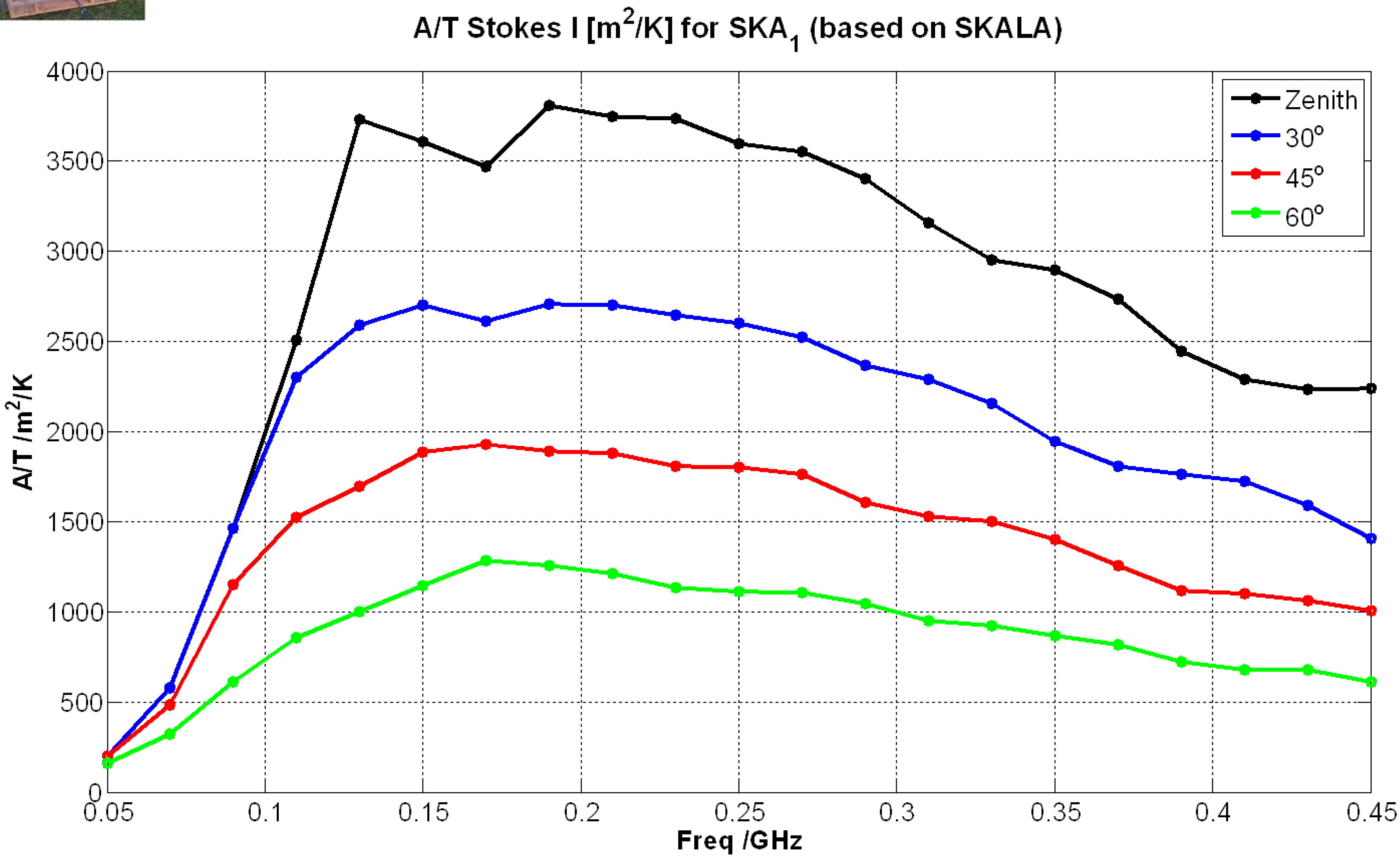
Low Frequency Aperture Arrays

Cambridge University
Log Periodic
(wide-band)
Prototype array element

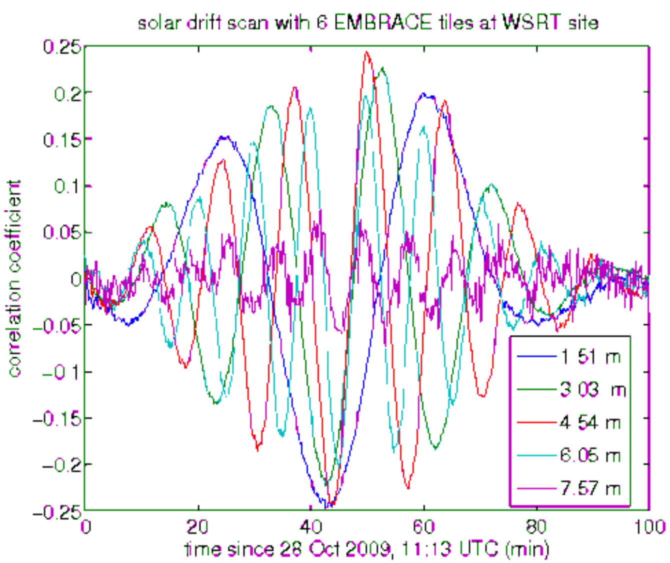
LOFAR (Netherlands et al)

MWA (USA, Australia, India)

Sensitivity of AA-low vs Freq and ZA Using Log-Periodic Antenna



EMBRACE Prototype for AA-mid

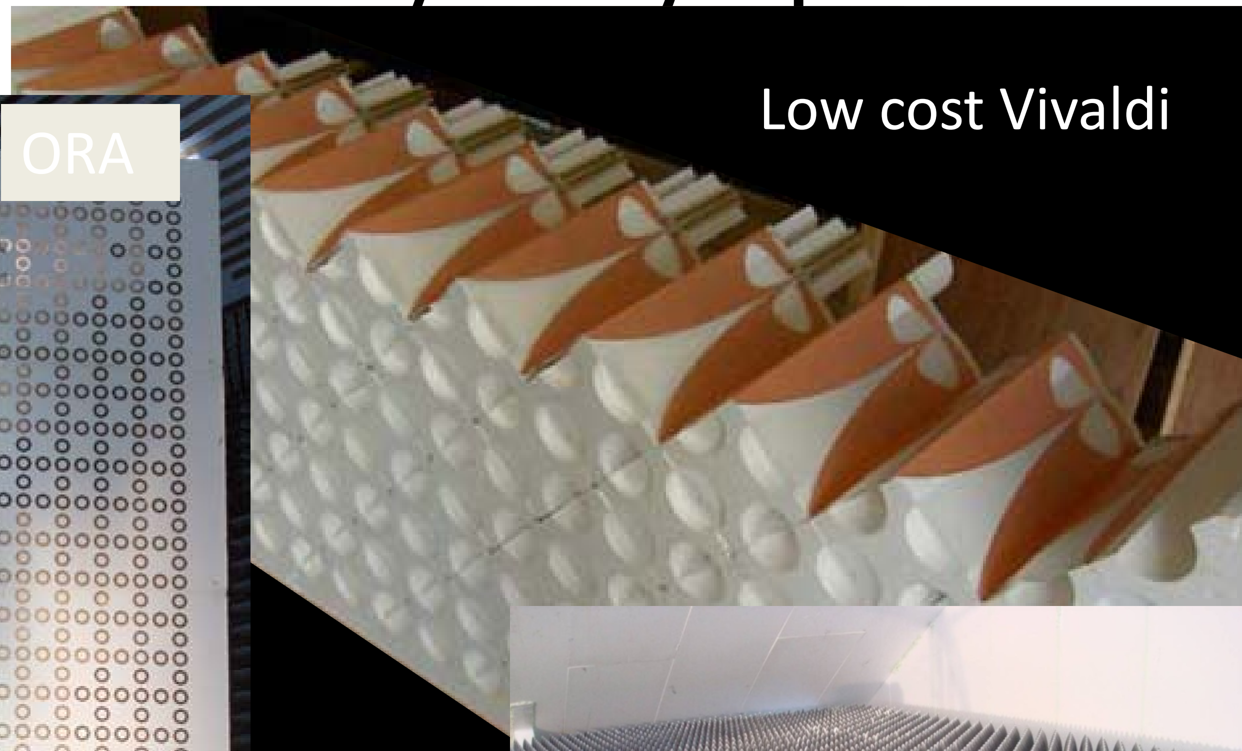


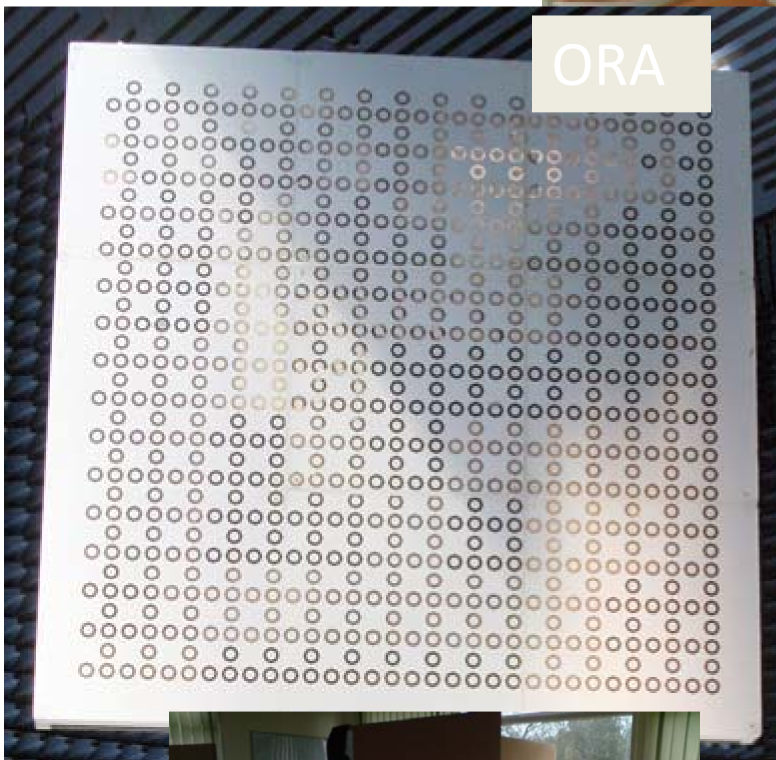
Industry already involved in production.

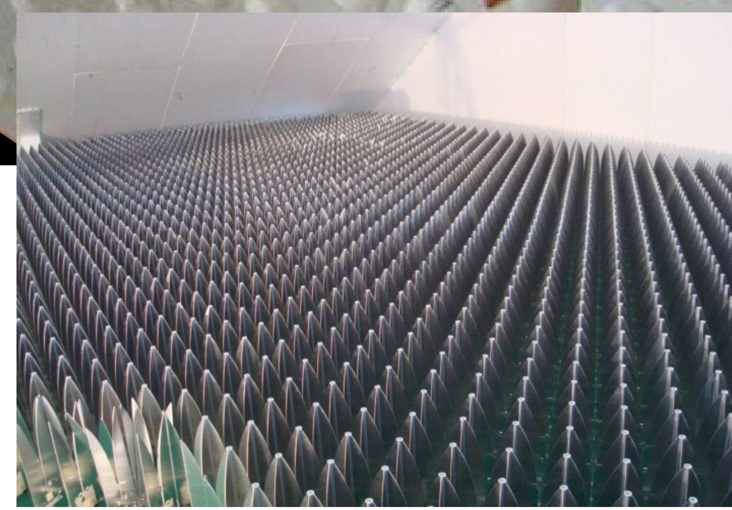
First Fringes

Potentially very large fields-of-view

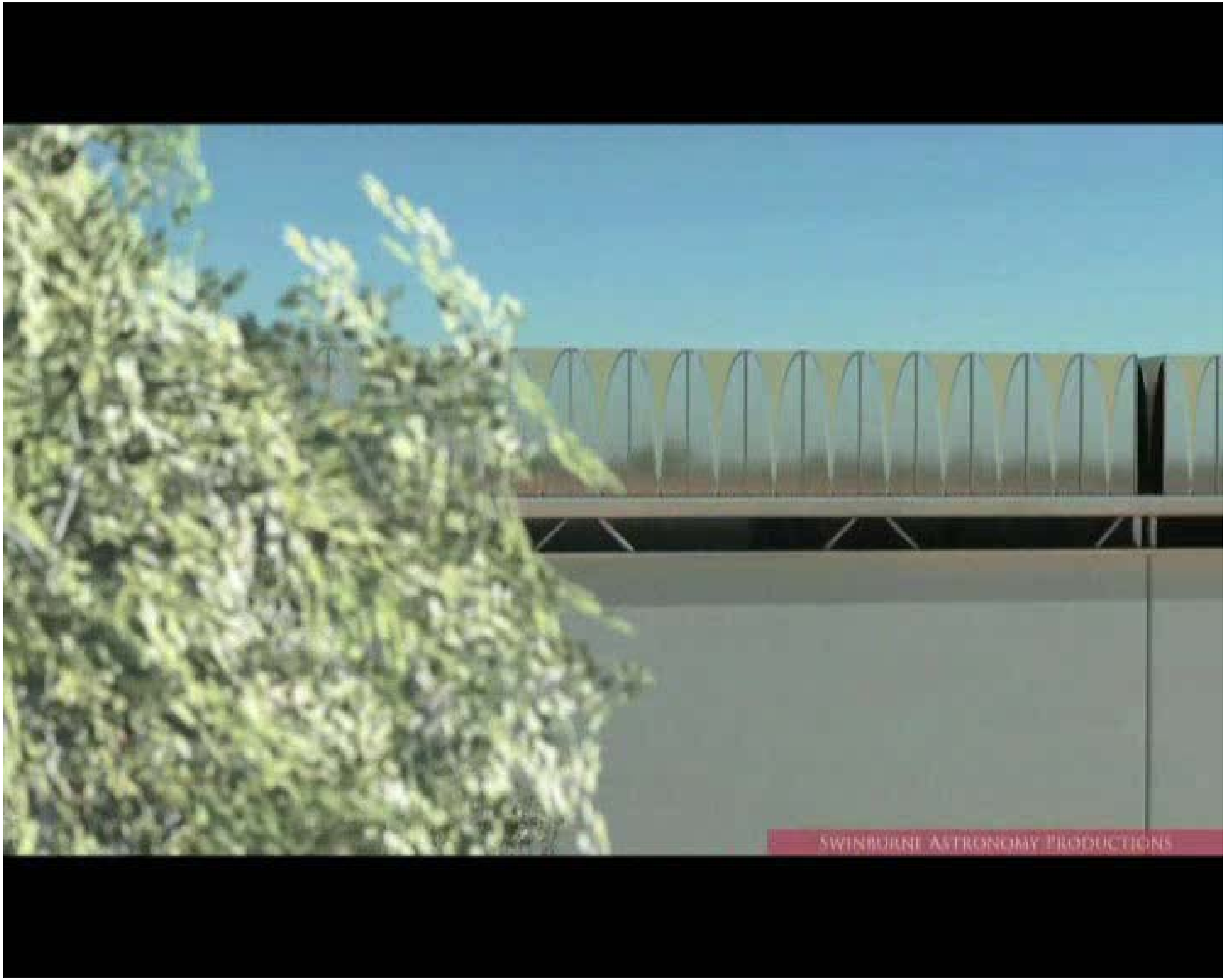
AA-mid element/array options







Dense AAs – medium frequencies, large



Dishes – medium-high freq., medium FoV

Key Requirements: Frequency range

- SKA1 requires 0.45 to 3 GHz
- SKA2 extends this to 10 GHz: this has implications for the dish design
  - Dish performance must meet specifications up to 10 GHz (SKA1 dishes will not be replaced in SKA2).
  - Dishes must be capable of accommodating feed payloads to cover 0.45 (possibly ~0.30 MHz) to 10 GHz.

Key Requirements: Sensitivity (Aeff/Tsys)

- The Phase 1 Dish Array shall have a sensitivity of 10^3 m^2 K^{-1} in the frequency range 450 MHz - 3 GHz.
- SKA2 requirement is 10^4 m^2 K^{-1} up to 10 GHz:
  - The aim will be to maximize sensitivity per €/$ *total system cost of ownership* whilst meeting other requirements.

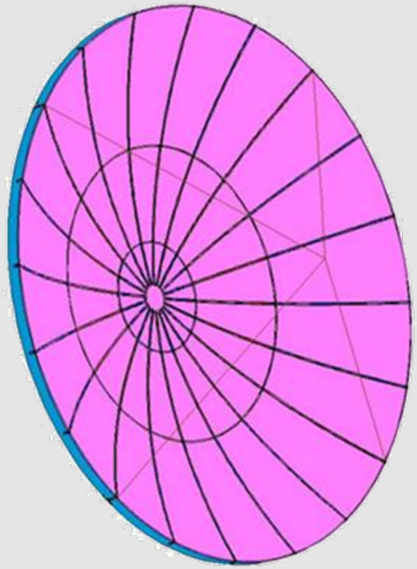
Options under consideration: Dishes and Payloads

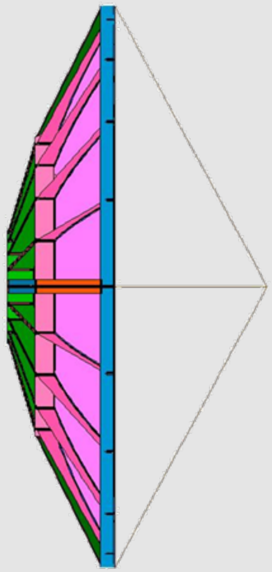
1. Dishes
   a) US TDP/DRAO
   b) NAOC/JLRAT/CETC54
   c) ASTRON/Airborne
   d) NRF – MeerKAT design
2. Feeds/Receivers and other "payloads"
   a) Single-pixel Feeds (corrugated horns)
   b) Wide-band SPFs (to be discussed under AIP session)
   c) Phased Array Feeds (PAFs) (to be discussed under AIP session)
   d) Receivers (various types of receiver systems)
   e) Other equipment: digitizers, optical modulators

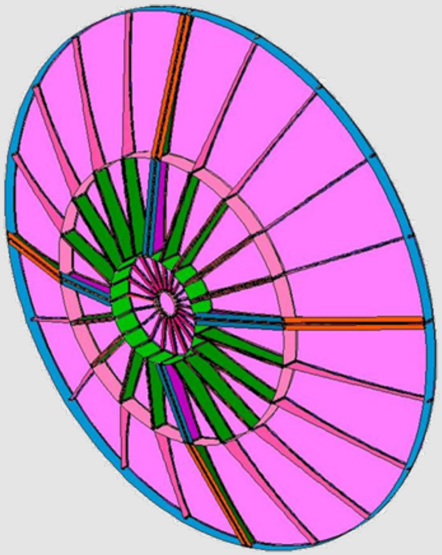
Thermoplastic Reinforced Composite Reflector

Structural Design

- Baseline design reflector:
  a stiffened skin with several different stiffeners.
  entire structure same thermoplastic carbon based material.
  manufactured using a single automated production process.







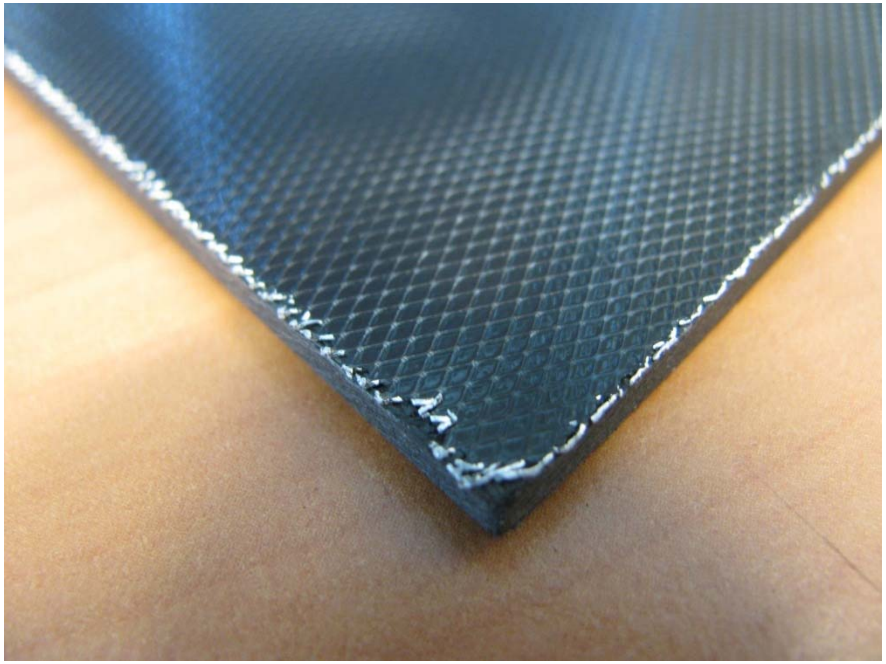
Thermoplastic Reinforced Composite Reflector

Thermoplastic carbon reinforced composite material

Benefits

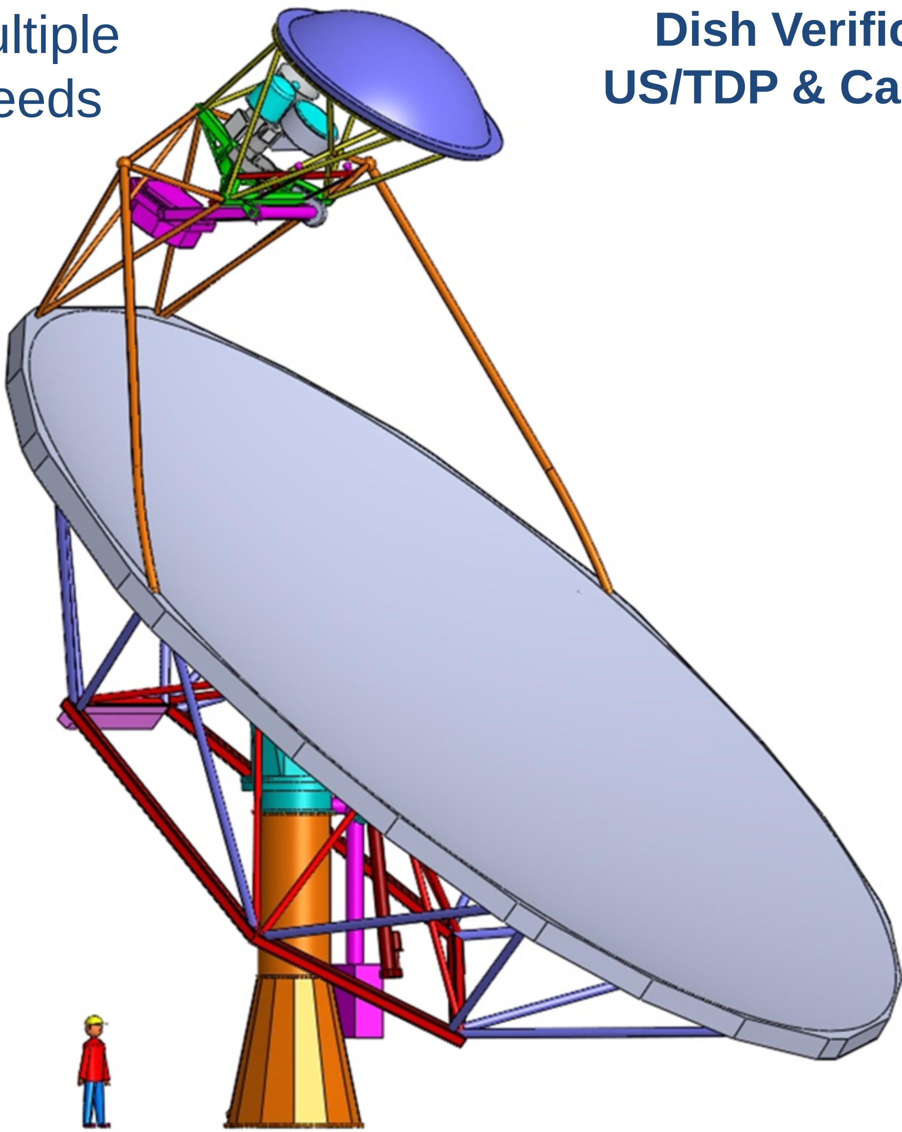
- Embed a thin metal mesh to add reflectivity performance
- Low thermal coefficient
- Low weight (-30%: metal option)
- Coating to protect from atmospheric influences easily applied
- Suitable for recycling and repairs

- Thermoplastic composite
  - tougher, more ductile and robust compared to metal options,
  - Combined with carbon fibres outperforms aluminium and steel constructions
- ***Reflectivity:*** Embedded thin metal mesh for good reflectivity; initial studies show >99% reflectivity

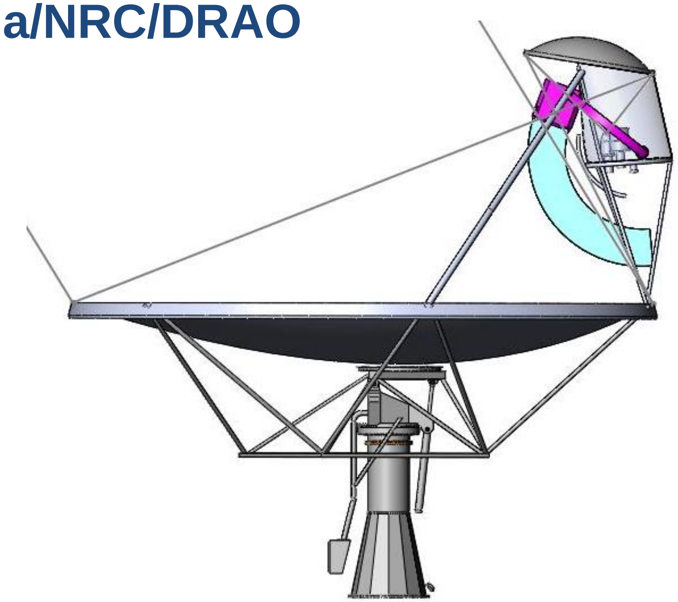


Offset-Optics Antenna Design

Multiple
Feeds



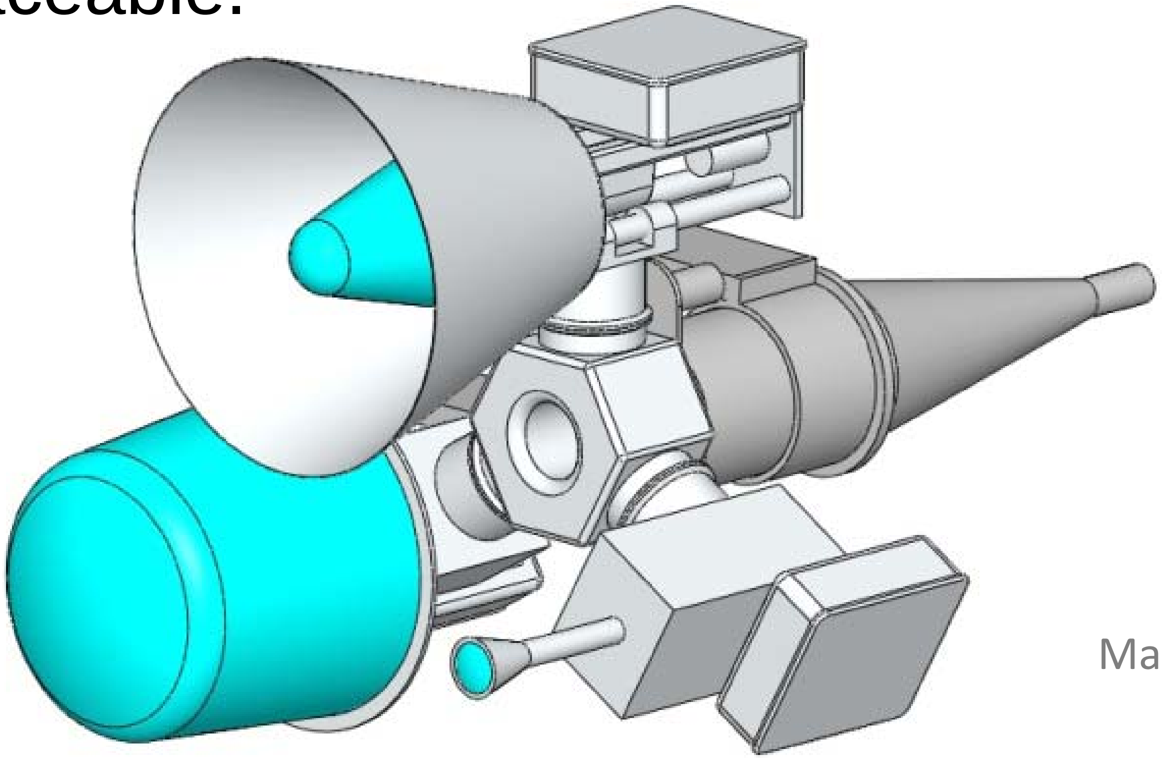
Dish Verification Antenna
US/TDP & Canada/NRC/DRAO



Deployment of PAFs.
Mid-freq. Wide-Field.

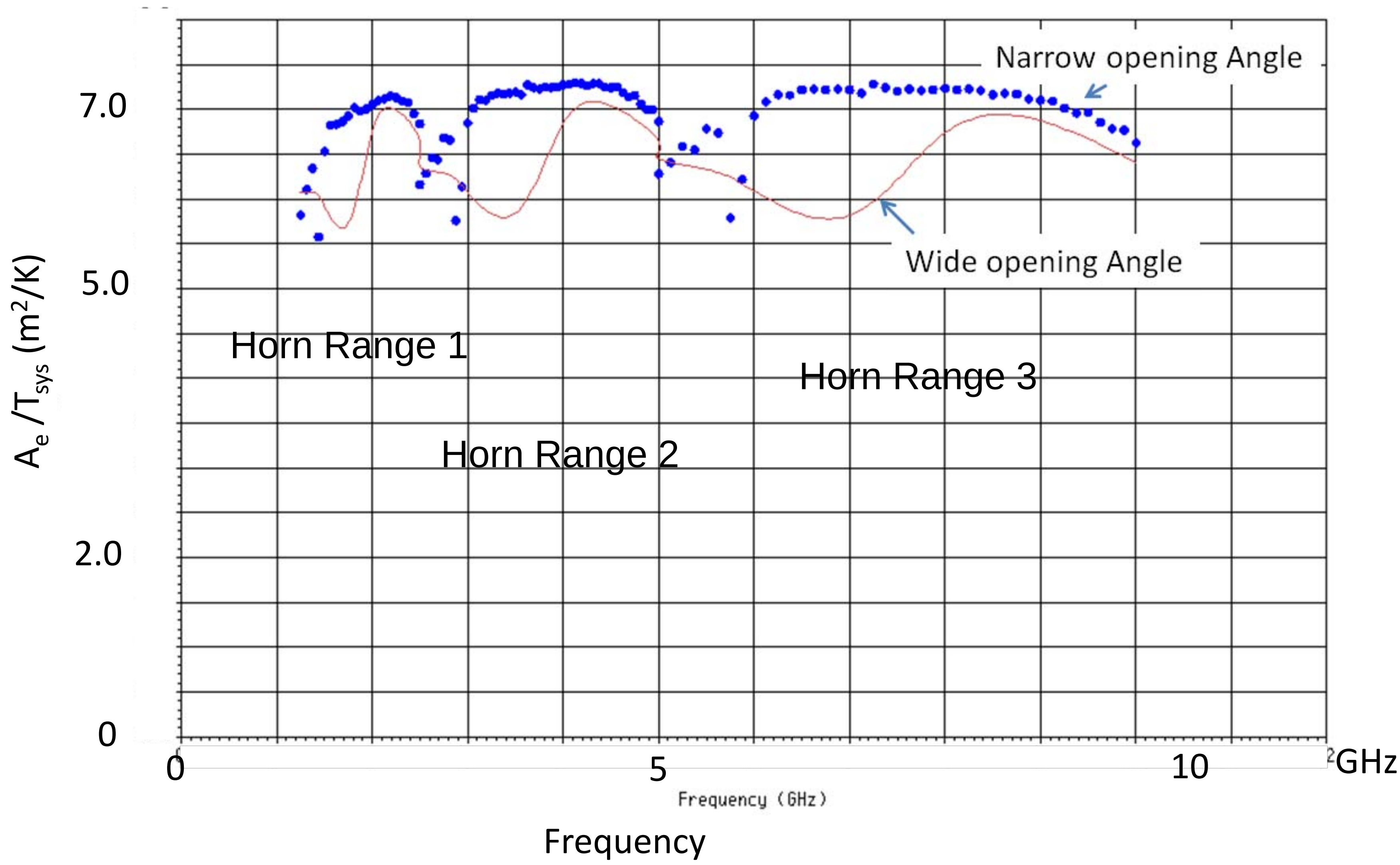
SPF feed payloads

- This shows one concept to accommodate multiple feed payloads on a ‘feed indexer’, individually replaceable.

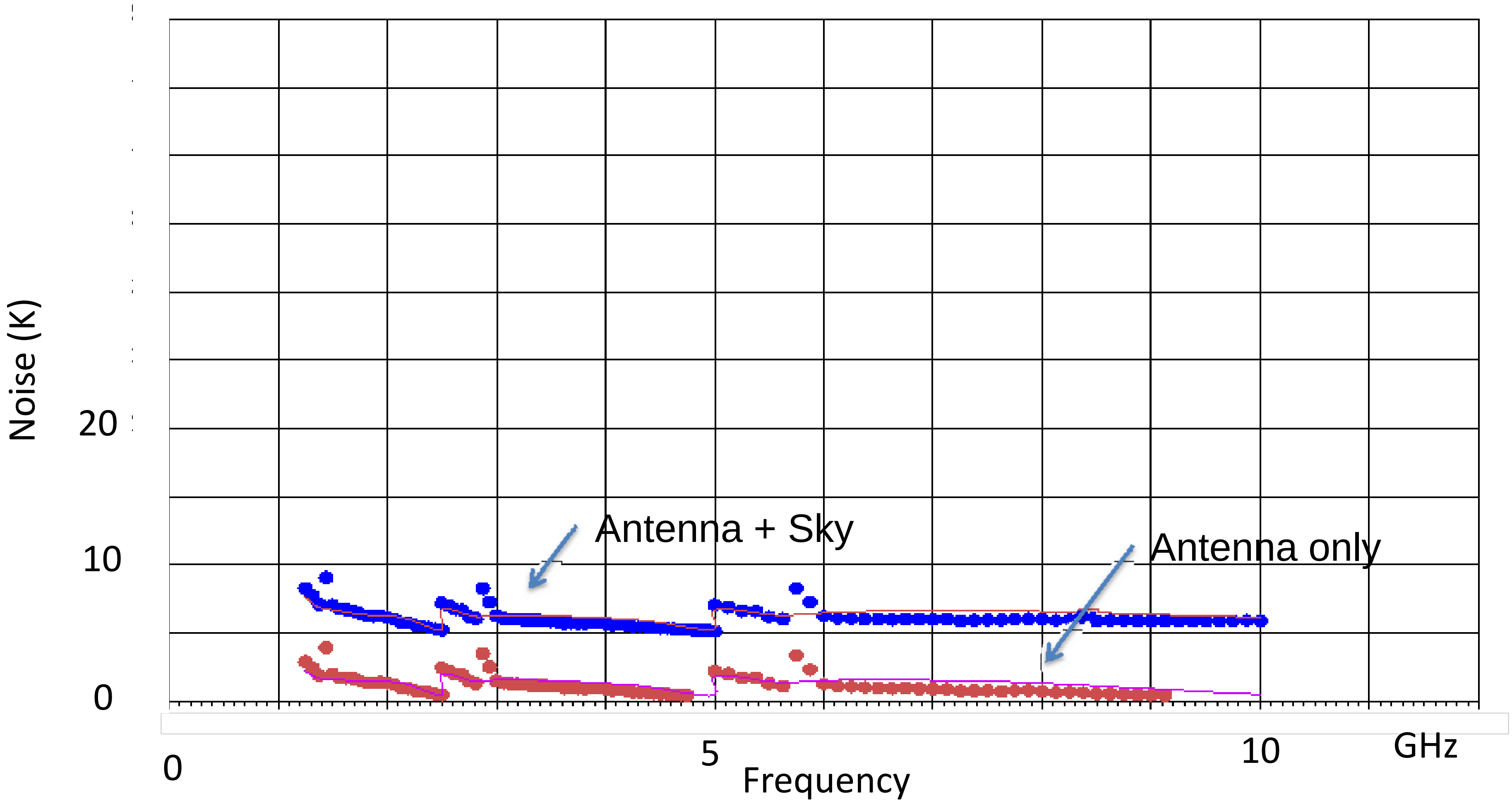


Matt Fleming

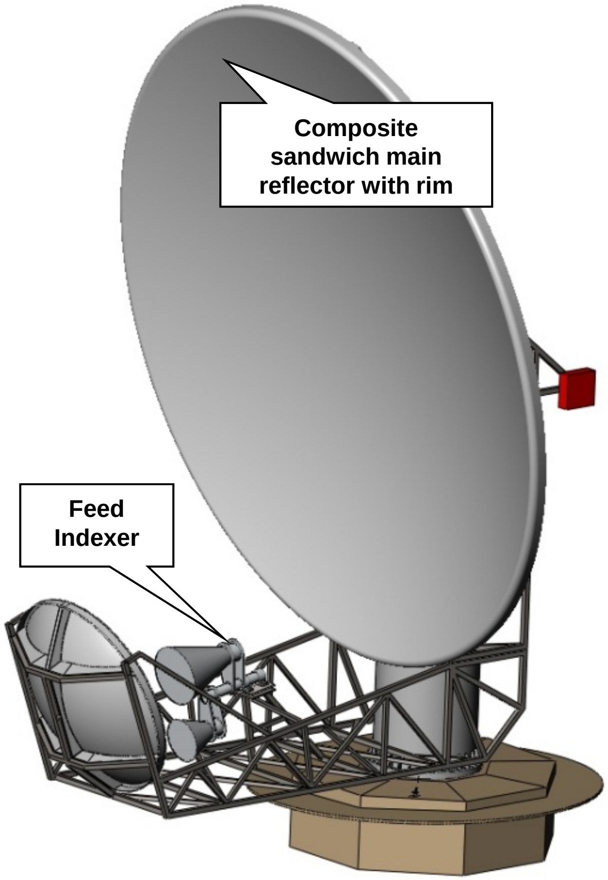
Octave Bandwidth Corrugated Horns: A_e/T_{sys}

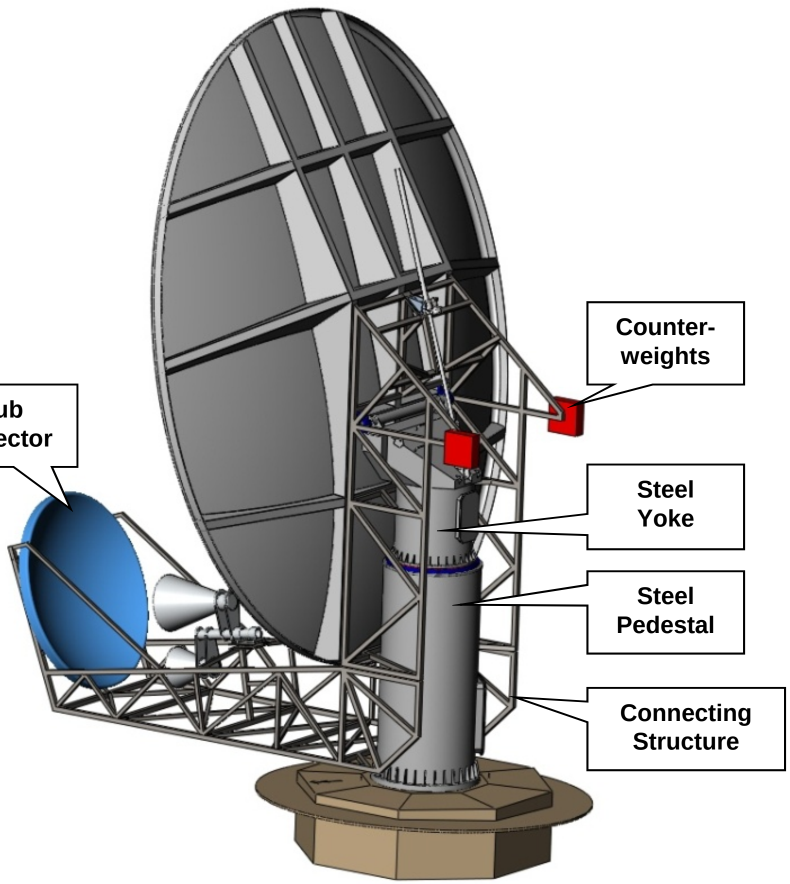


Octave Bandwidth Corrugated Horns
Noise Temperature



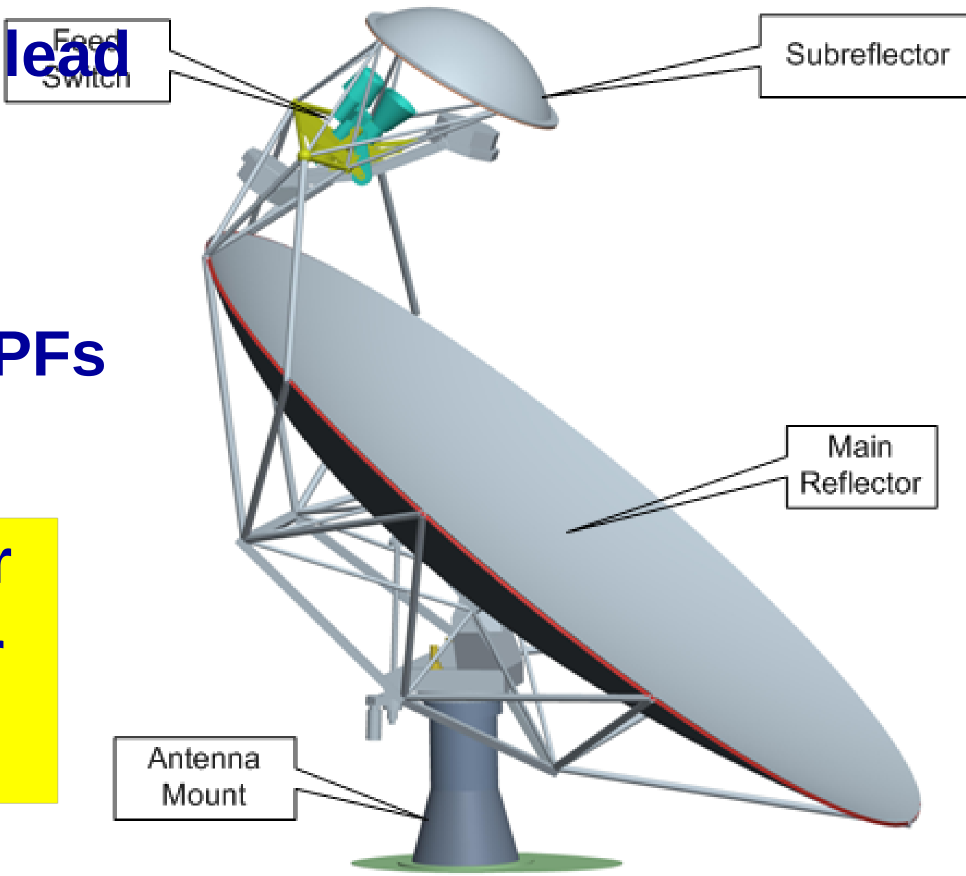
MeerKAT Dish Concept





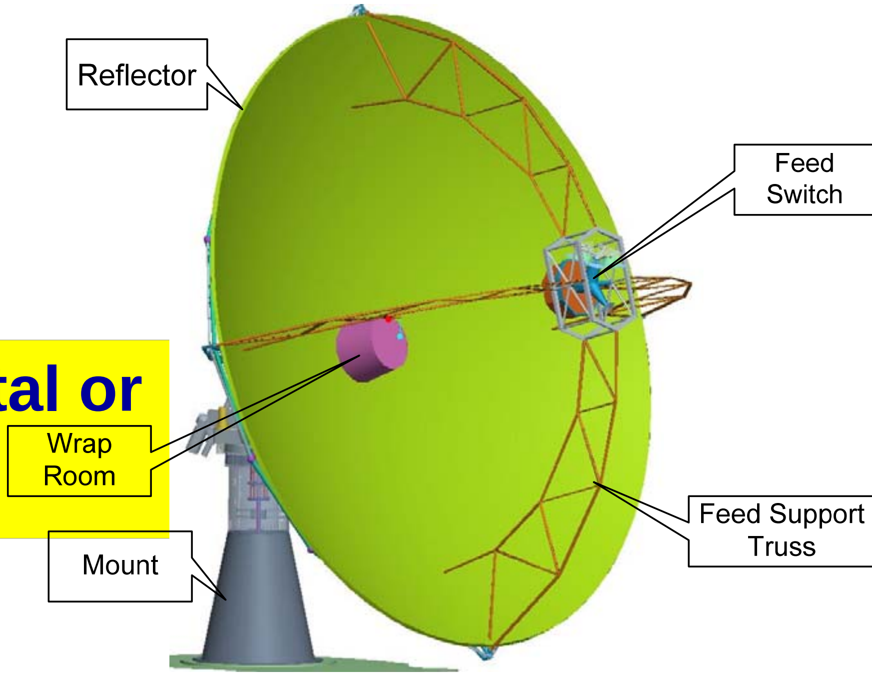
DVAC-1 : Offset design from JLRAT (China)

- **Single integrated main reflector**
- **Minimal spar structure**
- **Turning head design with a lead screw elevation actuator**
- **Support and interchange mechanism for a PAF and 3 SPFs or 2 WBFs.**
- **Can be designed with either metal or carbon fibre reflector skins**



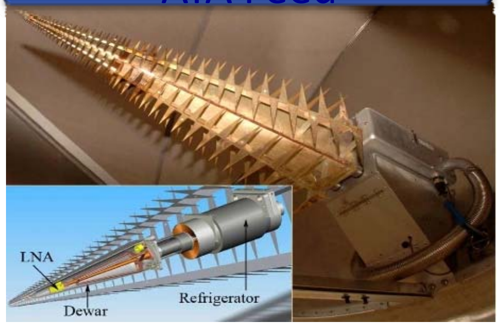
DVAC-2 : Symmetric design from JLRAT (China)

- **Single integrated main reflector**
- **Minimal spar structure**
- **Turning head design with a lead screw elevation actuator**
- **Four support legs and interchange mechanism for a PAF and 3 SPFs or 2 WBSPFs.**
- **Can be designed with either metal or carbon fibre reflector skins**

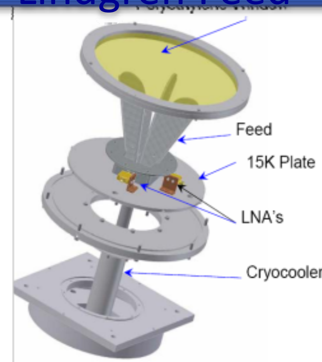


Wide Band Single Pixel Feeds

ATA Feed



Lindgren Feed

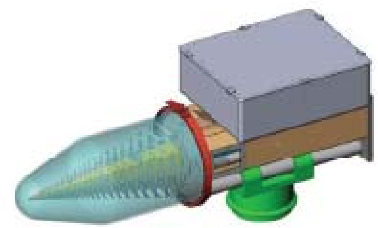


QSC Feed

Eleven Feed

Inverted Sinuous Feed

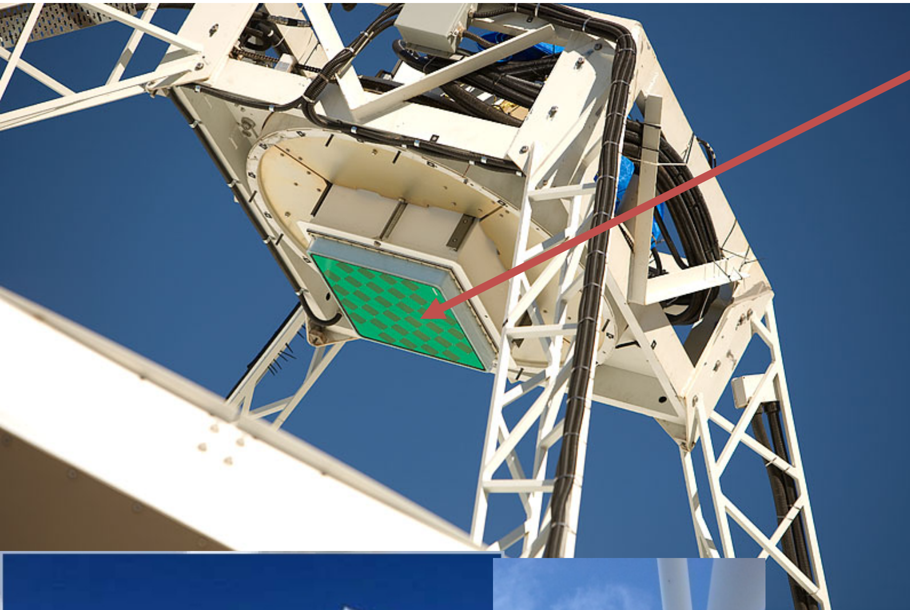
Cooled ATA Feed



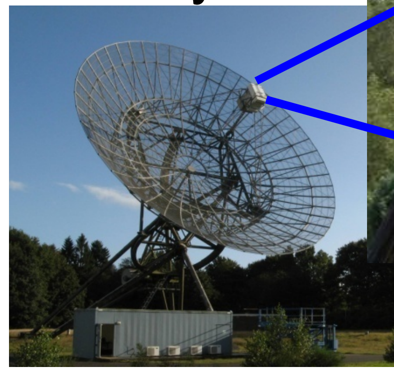
Quad-Ridge Flare Horn

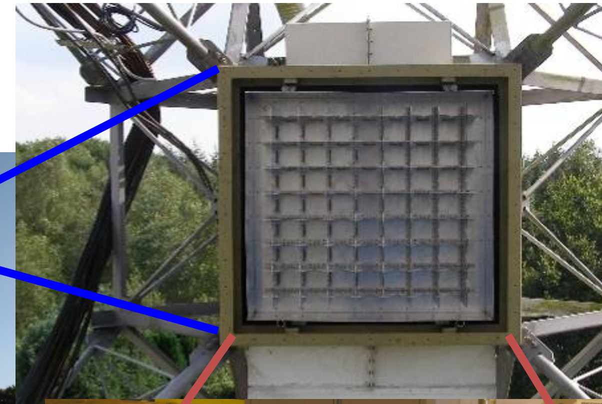
Log-Periodic Log Spiral

Phased Array Feed Concepts

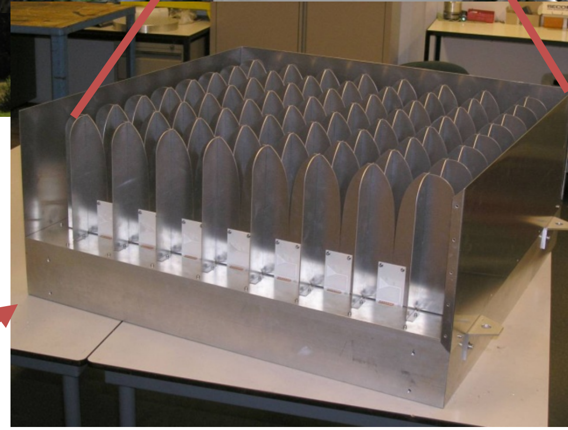


ASKAP chequer board array





APERTIF (Astron, NL)

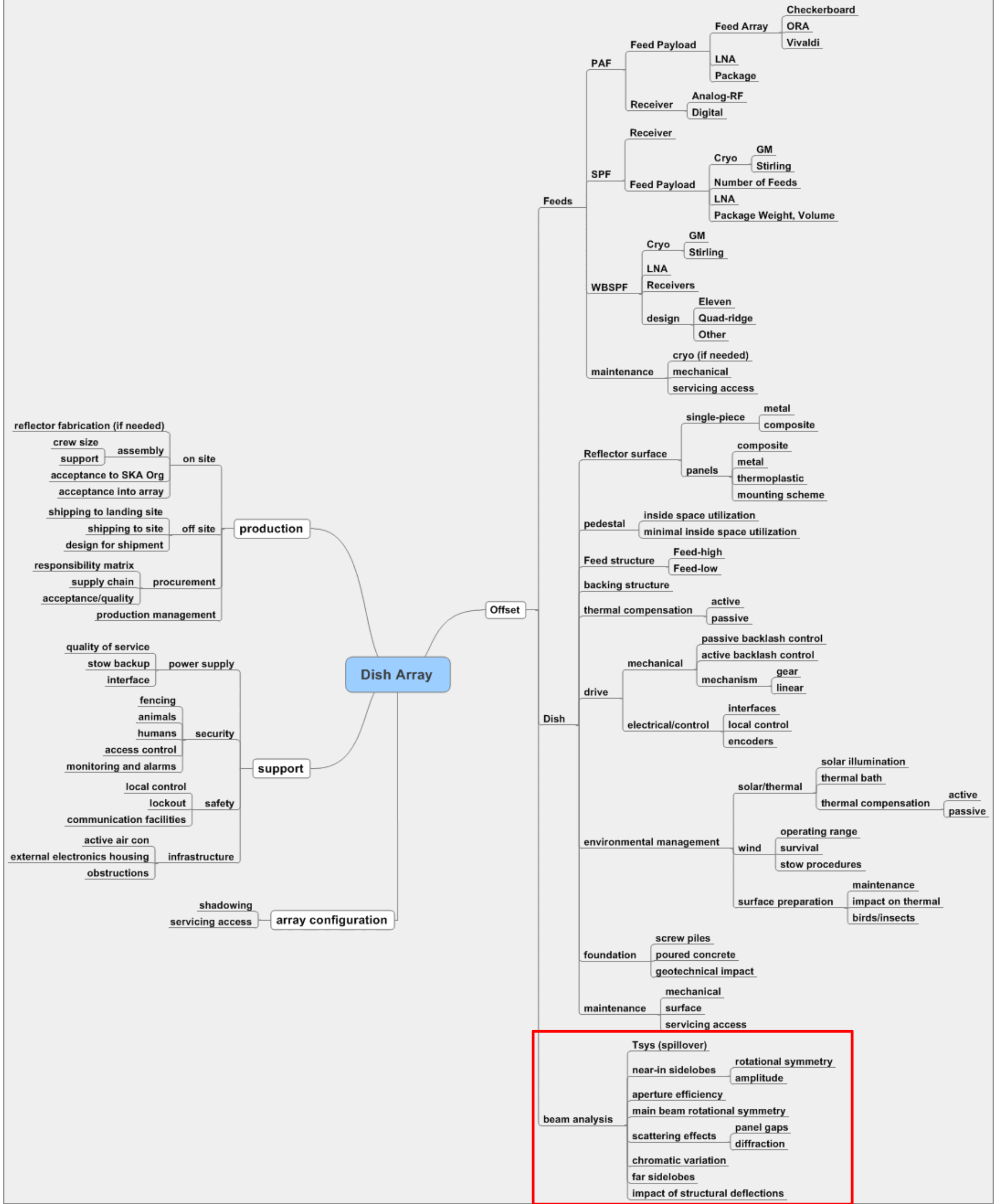


DRAO Canada

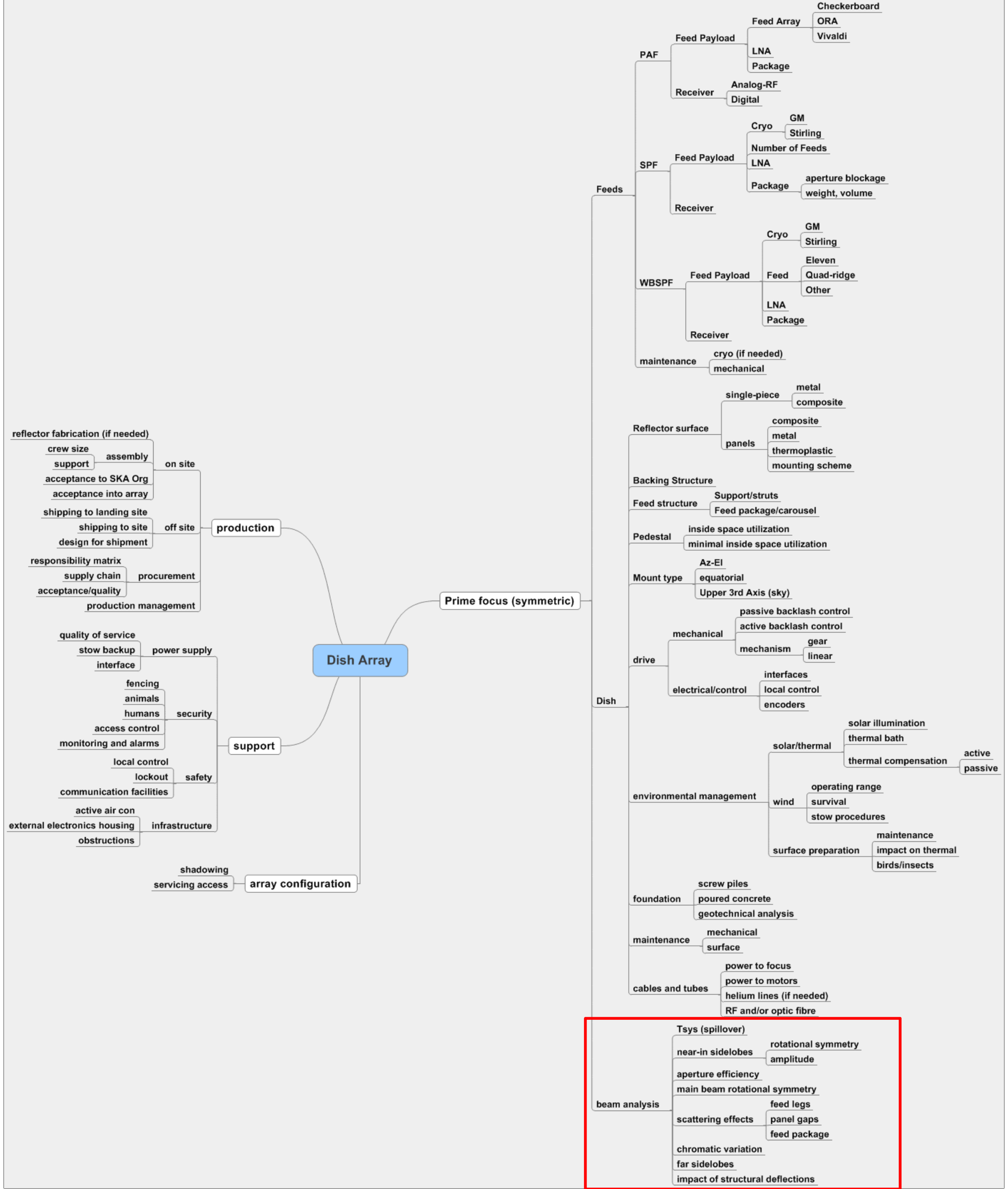
Vivaldi arrays

Dipole array (cooled version)

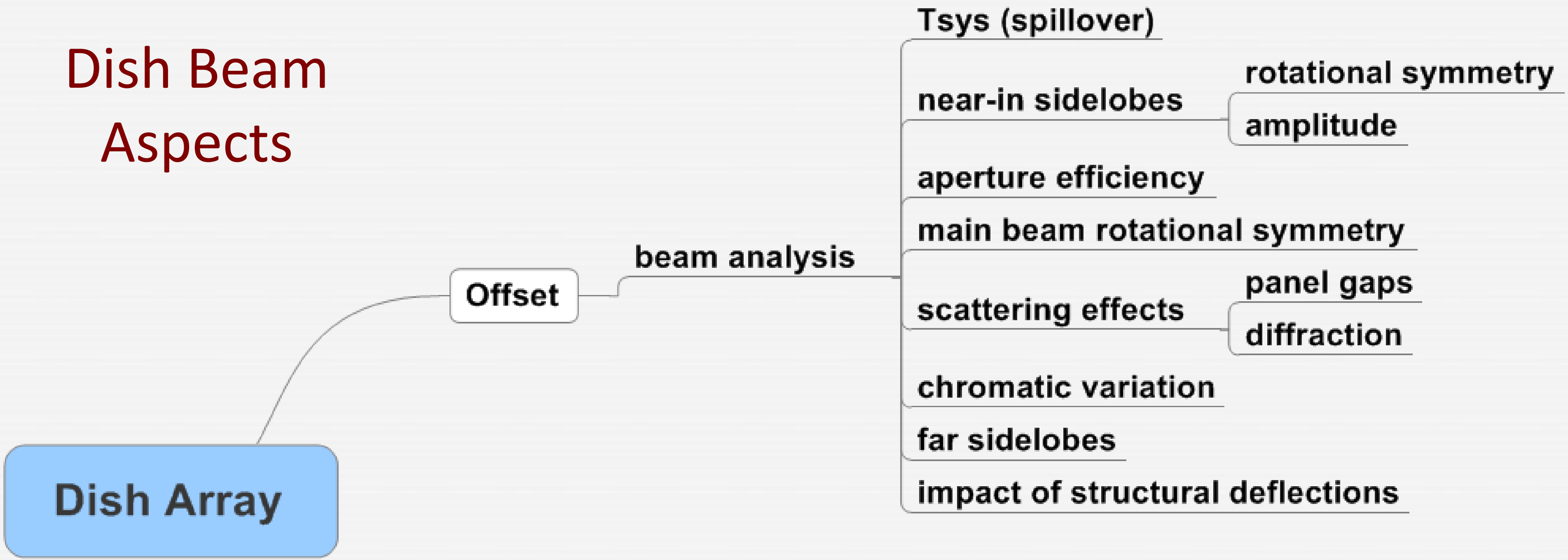
Offset Dish Decision/Option Tree

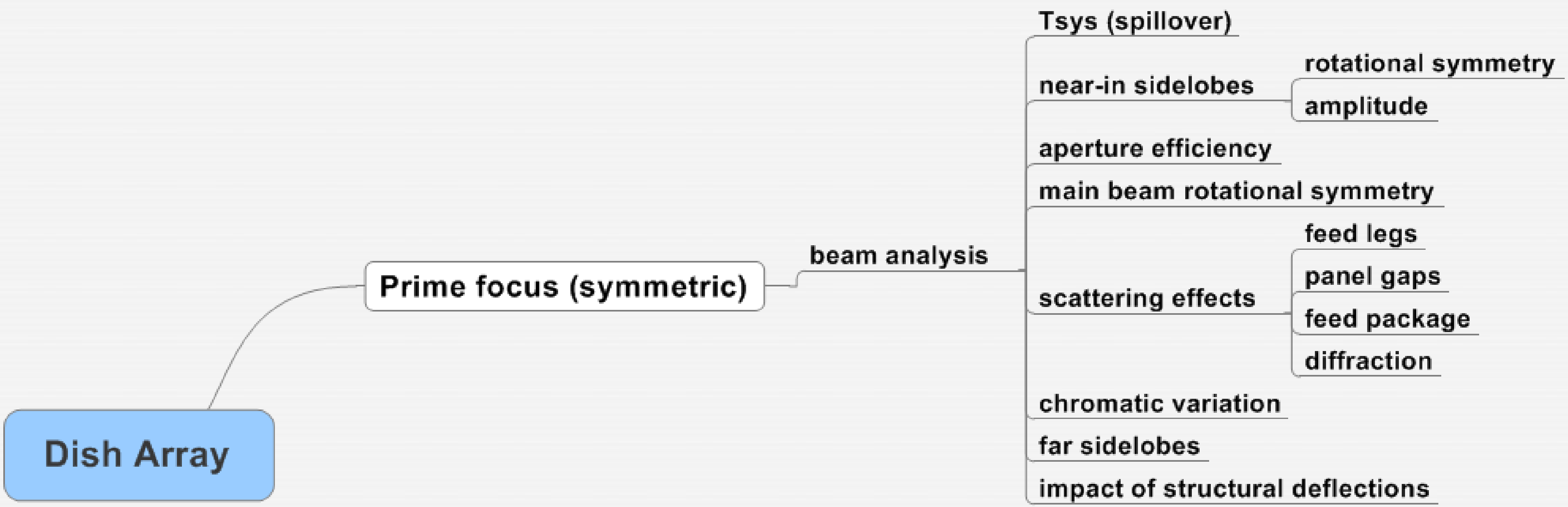


Symmetric Dish Decision/Option Tree

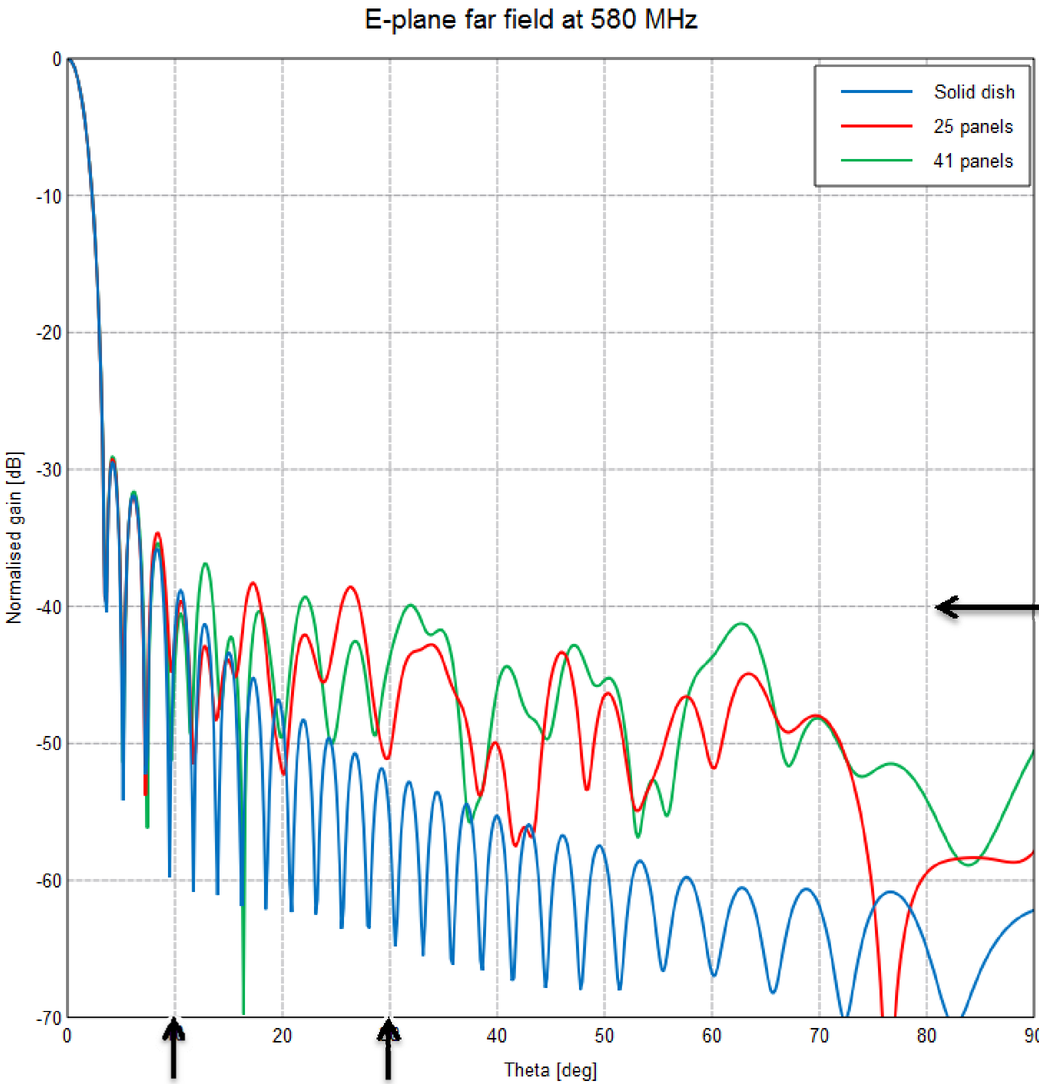


Dish Beam Aspects





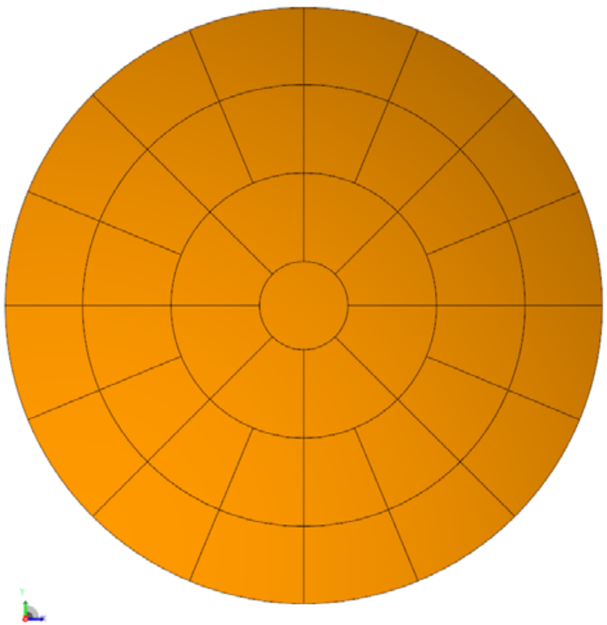
Panel Gaps – sidelobe pattern



-40 dB

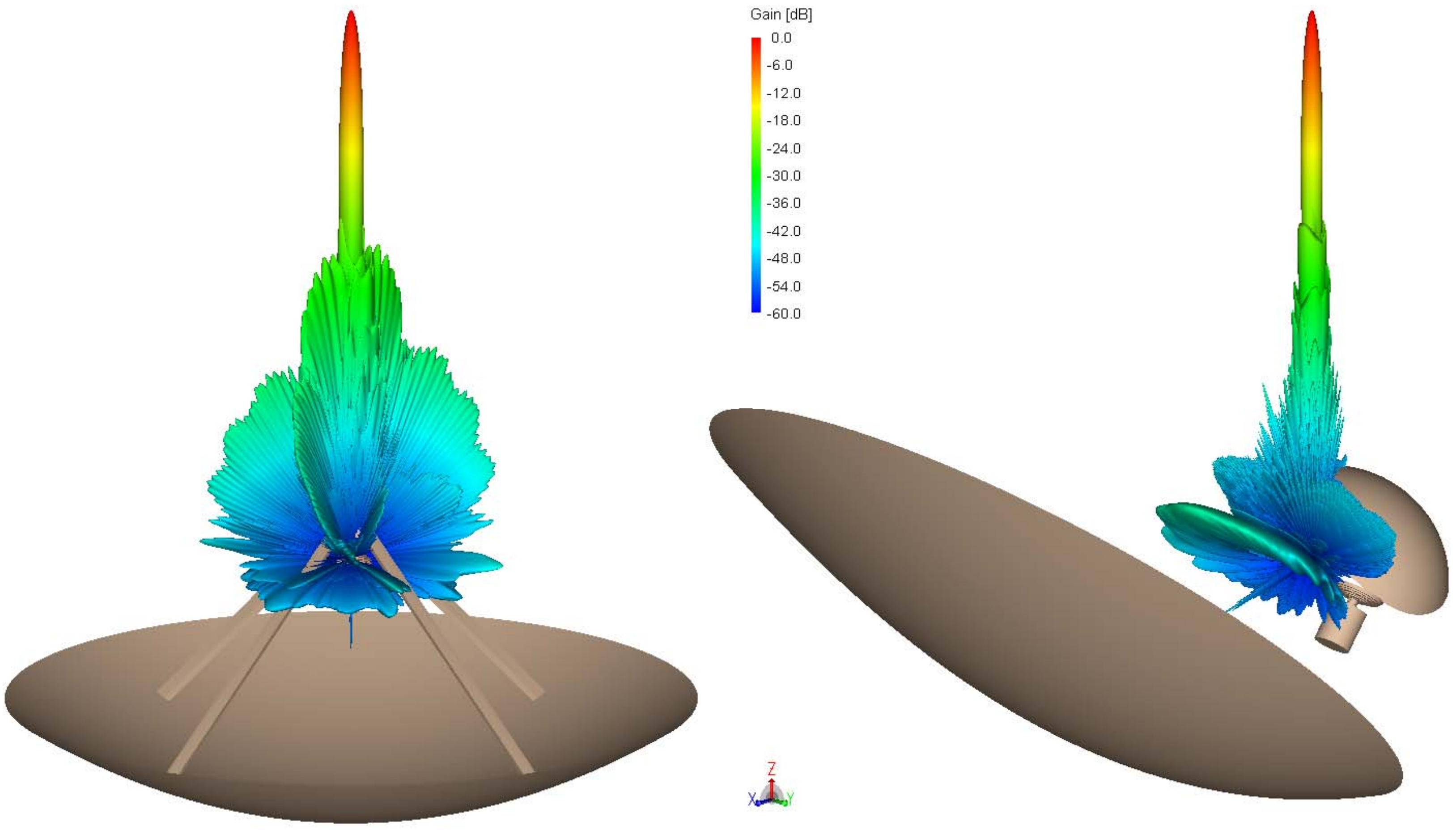
10 deg

30 deg



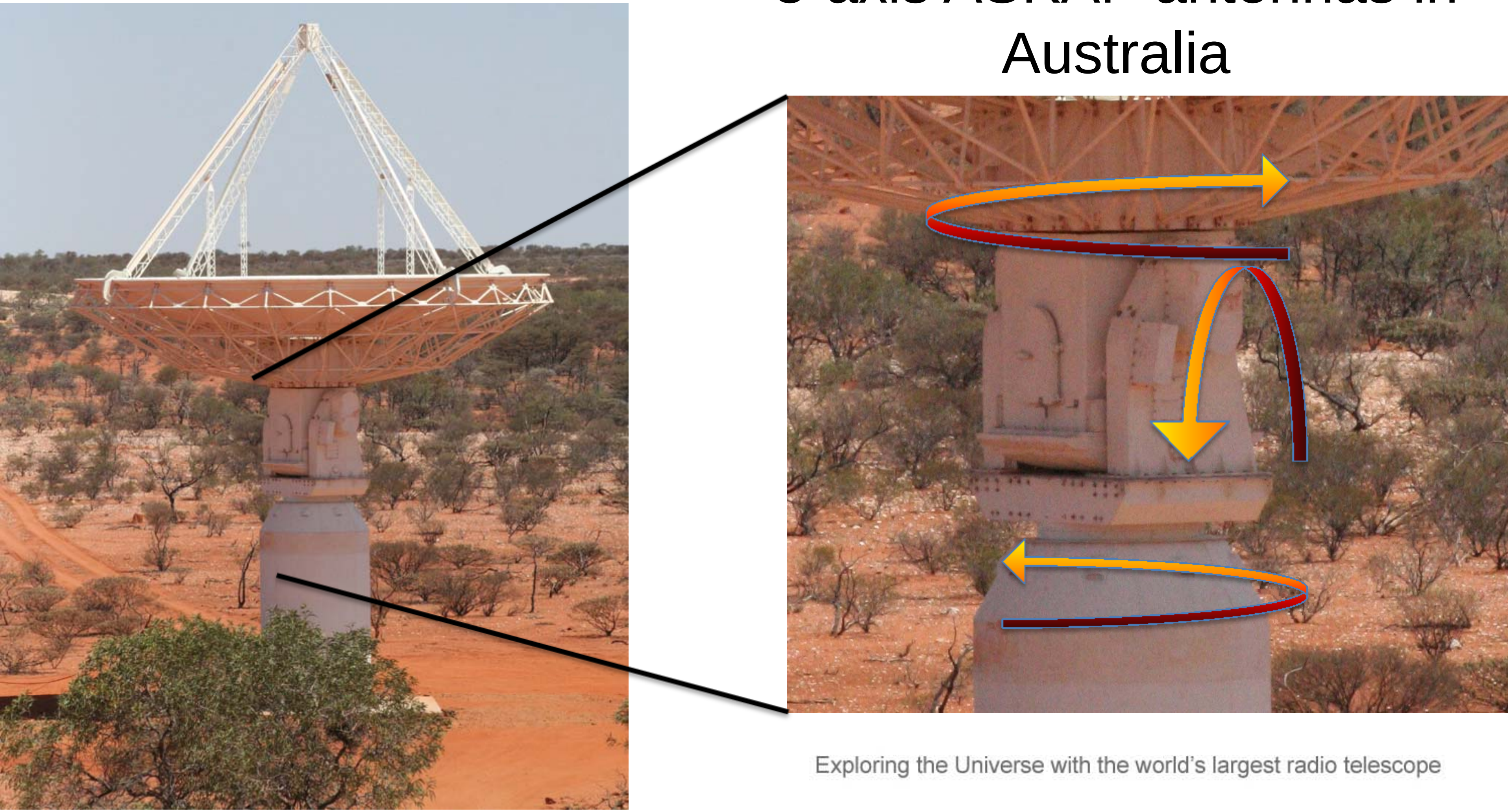
EMSS, South Africa

Symmetric vs Offset Beam



ASKAP 3-axis Antenna Design

3-axis ASKAP antennas in Australia

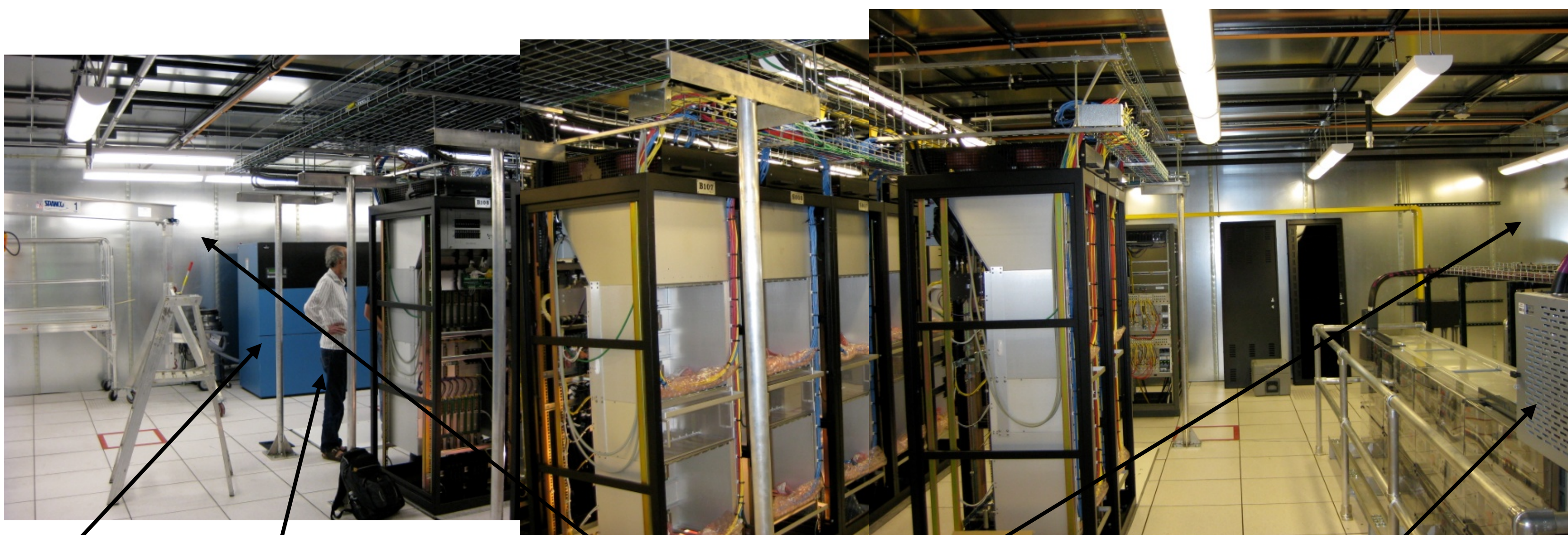


Exploring the Universe with the world's largest radio telescope

Signal Processing

EVLA Correlator

170 KW power, and 120 tons of cooling
17308672 control/monitor bits
1473536 registers
24832 FPGAs
256 boards
16 racks
1 room



Air Conditioners

Ken Sowinski
(6'0")

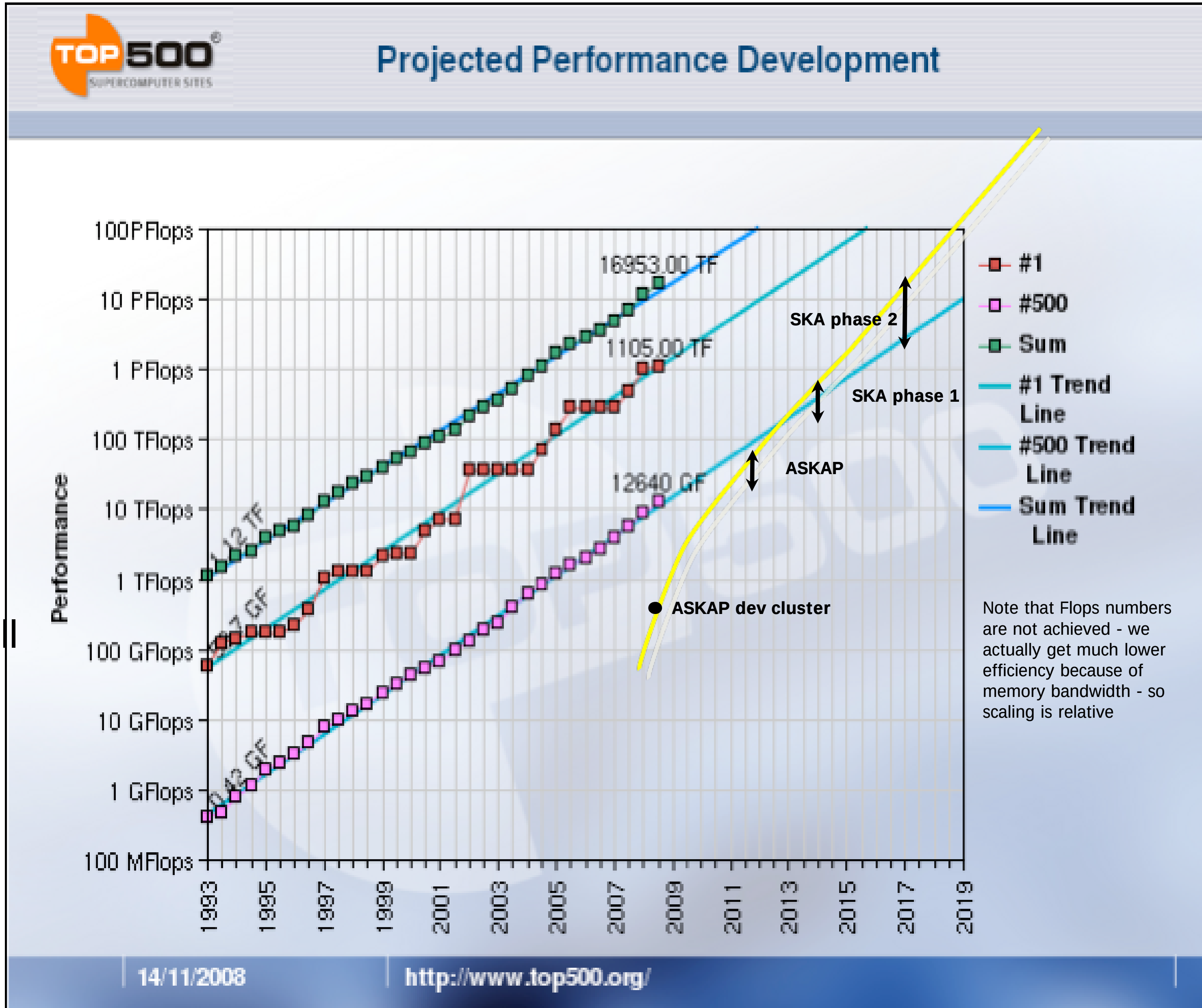
~100 dB
Shielded Chamber

Power Backup/Conditioners

Science/Image Processing

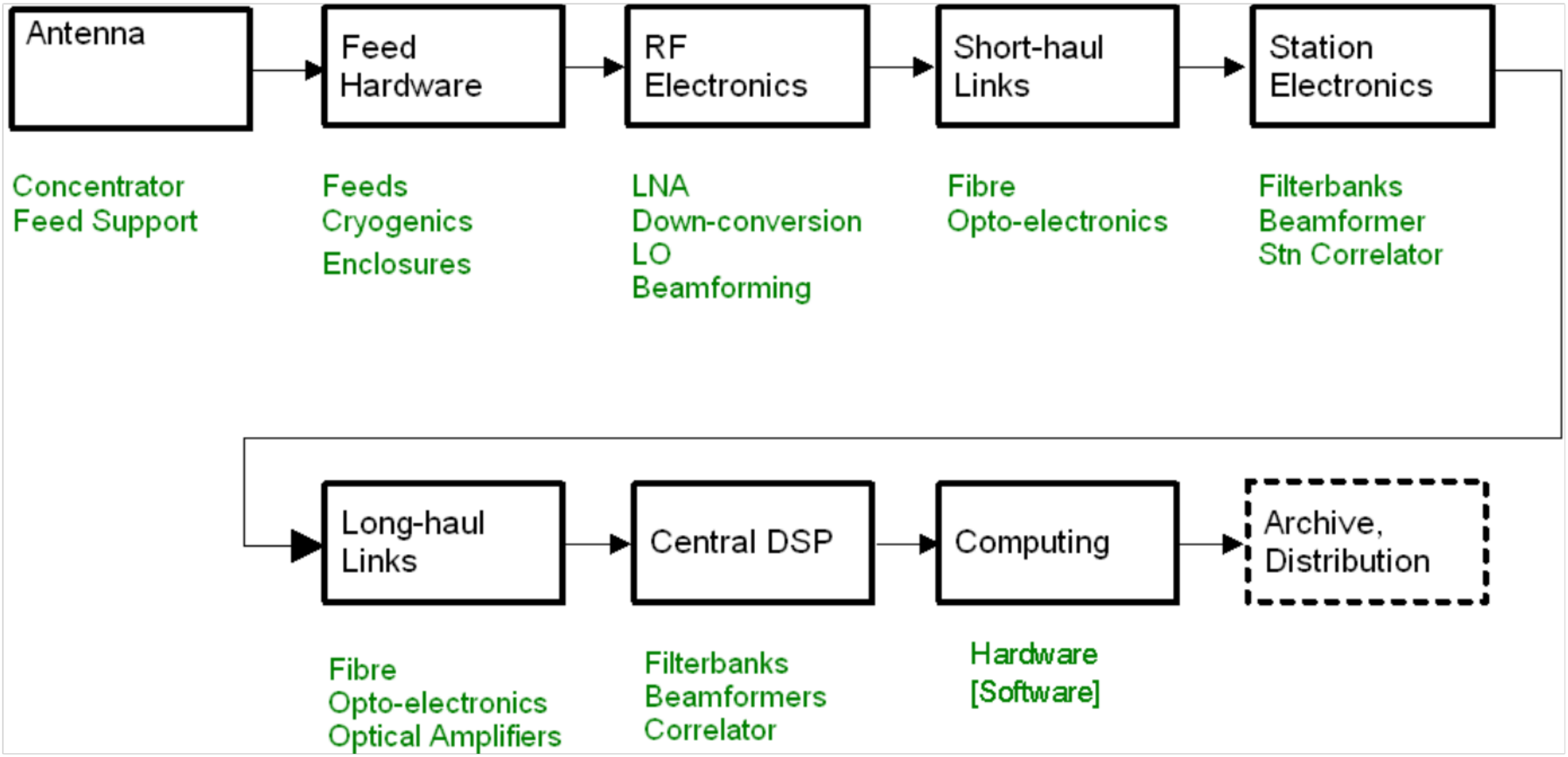
HPC (Supercomputer) performance needed for high-through-put image formation.

Software development for supercomputers will be one of SKA's major challenges. Primarily for SKA2.



Industry Opportunities

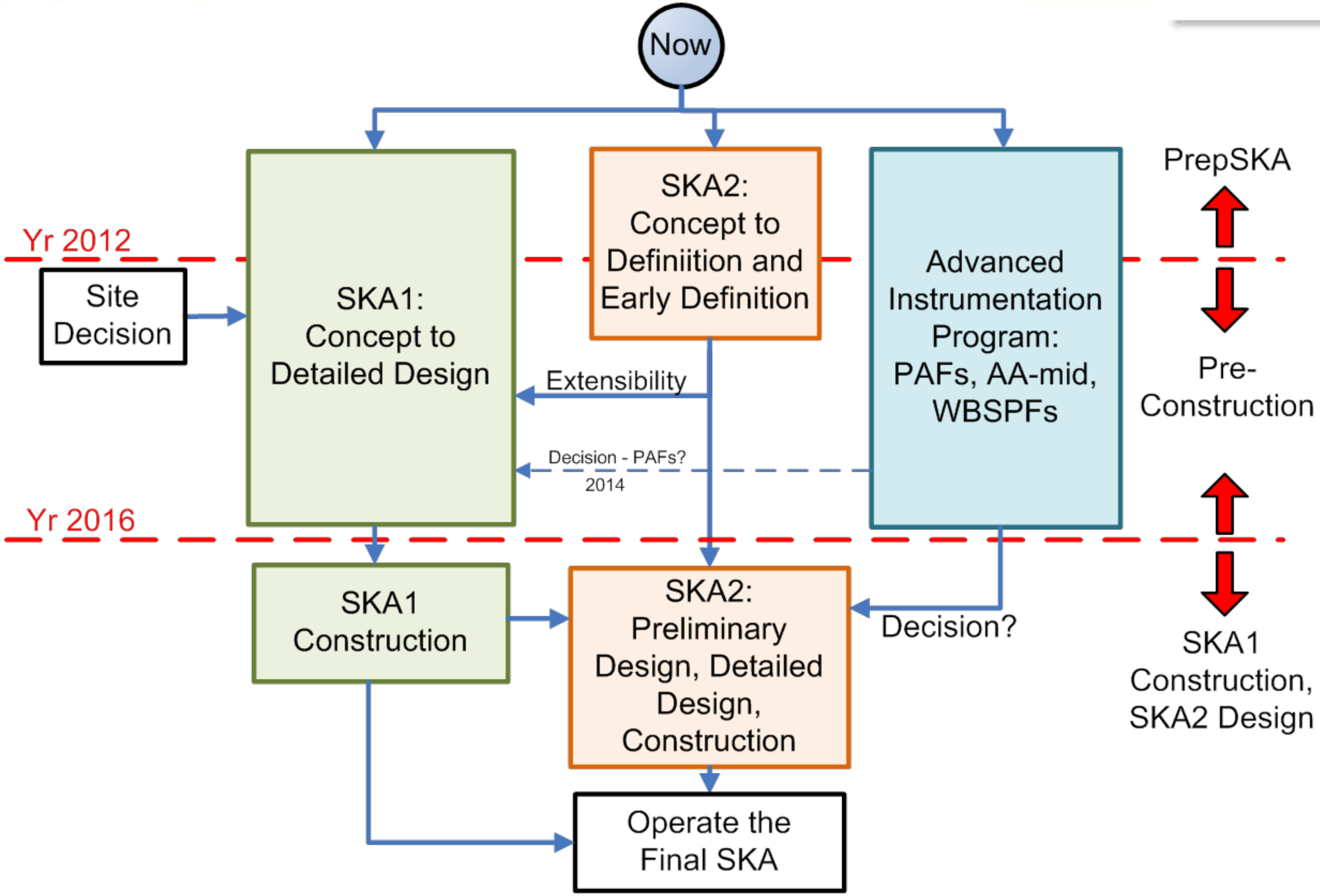
Summary of Opportunities in the SKA Signal Path



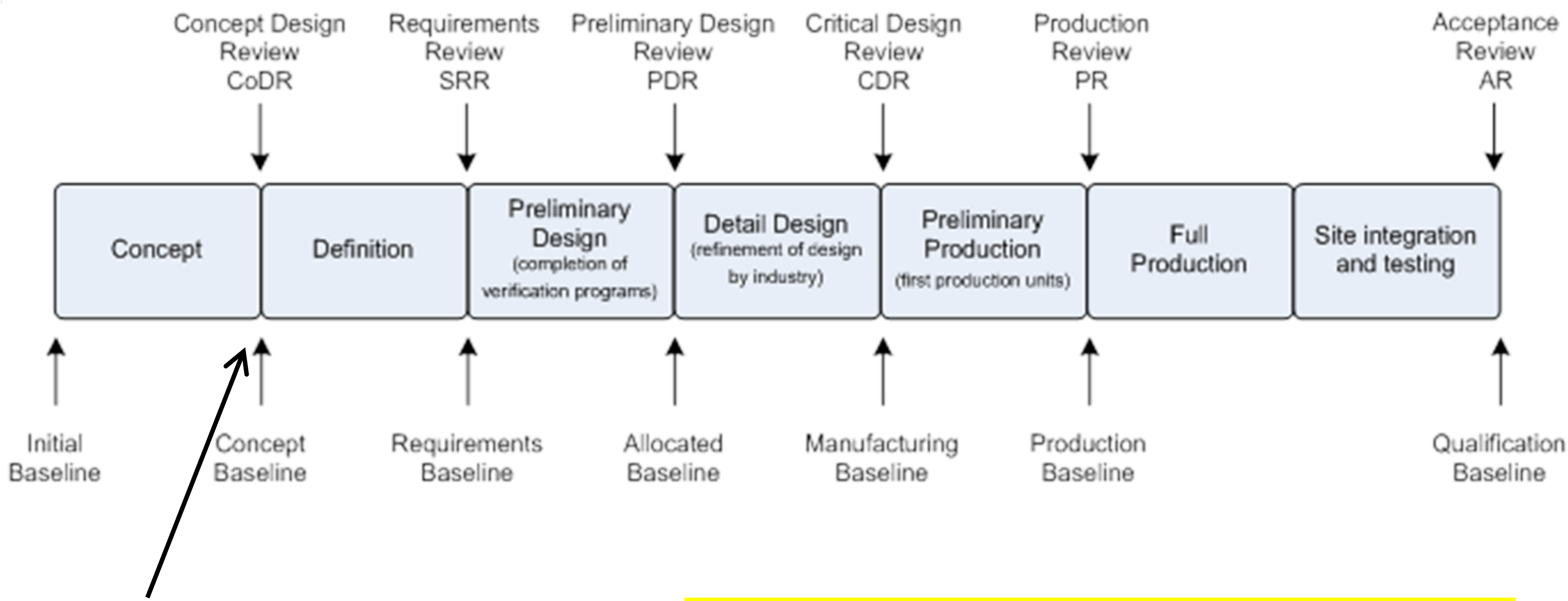
Potential Roles for Industry

- Managerial
  - Cost control
  - Contract management
  - Assisting with documentation management
  - Consultants on contractual matters
- Technical
  - Planning for operations
  - Site operations
  - RAM investigations
  - Carrying out some project management tasks
  - Design for manufacture
  - Linking infrastructure with other system elements
  - Detailed design work
  - Construction of verification program components
  - Assisting with the assembly of production data-packs
  - Power

Phased Approach to Technical Development



Design Review Series



"Element" level CoDRs in 2011

Industry Representation on Review Boards

Conceptual Design Reviews in 2011

- 23-25 Feb System delta-CoDR on SKA_1 ✓
- 14-15 Apr Signal Processing ✓
- 19-20 Apr Aperture Arrays ✓
- 28-30 Jun Signal Transport & Networks ✓
- 13-15 July Dish and Dish Arrays ✓
  - 2-3 Feb CoDR Dish Verification Antenna #1
  - 5-7 Oct PDR Dish Verification Antenna #1
- 9-11 Nov Monitor & Control ✓
- 27-28 Nov AA-mid ✓
- TBA Software & Computing

End