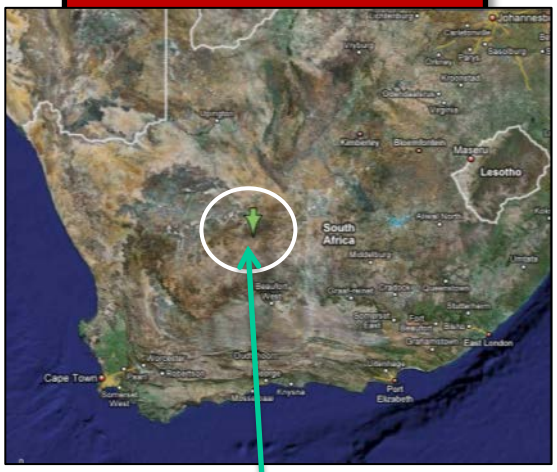

SKA Low Frequency
Andrew Faulkner
Aperture Array Design

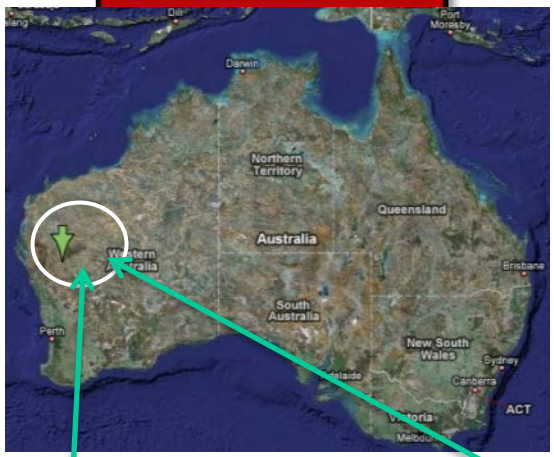
# SKA Phase 1 Implementation

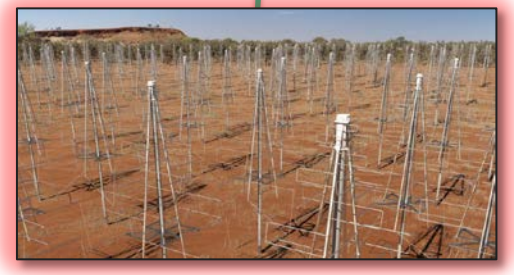
## Southern Africa




**$SKA_1$-mid**
250 15m dia.
Dishes
0.4-3GHz

## Australia



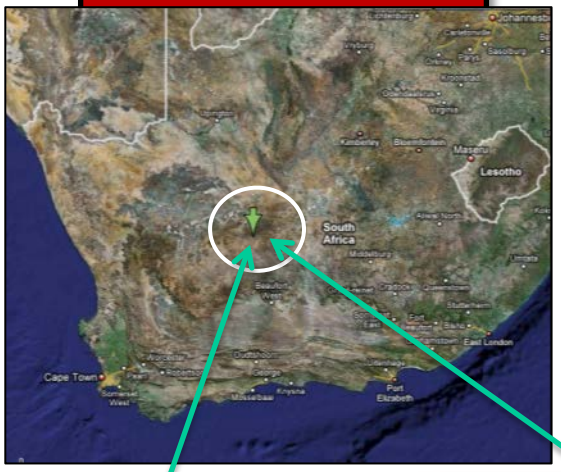
**$SKA_1$-low**
256,000 antennas
Aperture Array Stations
50 – 350/650MHz

**$SKA_1$-survey**
90 15m dia.
Dishes
0.7-1.7GHz

**Construction 2017 start**

# SKA Phase 2 Implementation

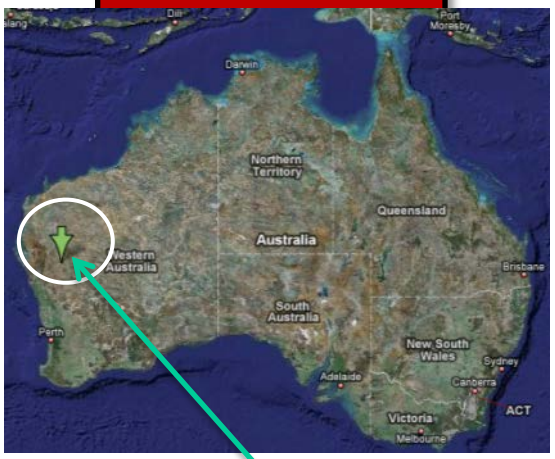
Southern Africa




**$SKA_2$-mid**
2700 15m dia.
Dishes
0.4-10GHz

**AA-mid**
256 60m dia.
Aperture Array Stations
400 – 1450MHz

Australia



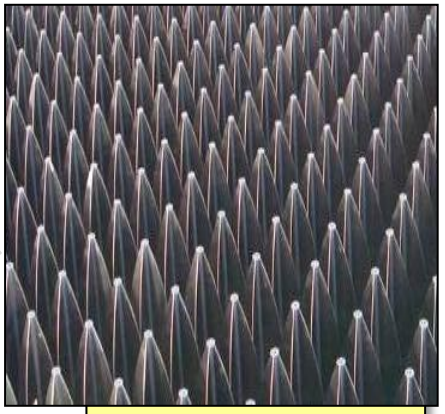

**$SKA_2$-low**
3,000,000 antennas.
Aperture Array Stations
50 – 650MHz

Construction 2020's

# AA selection

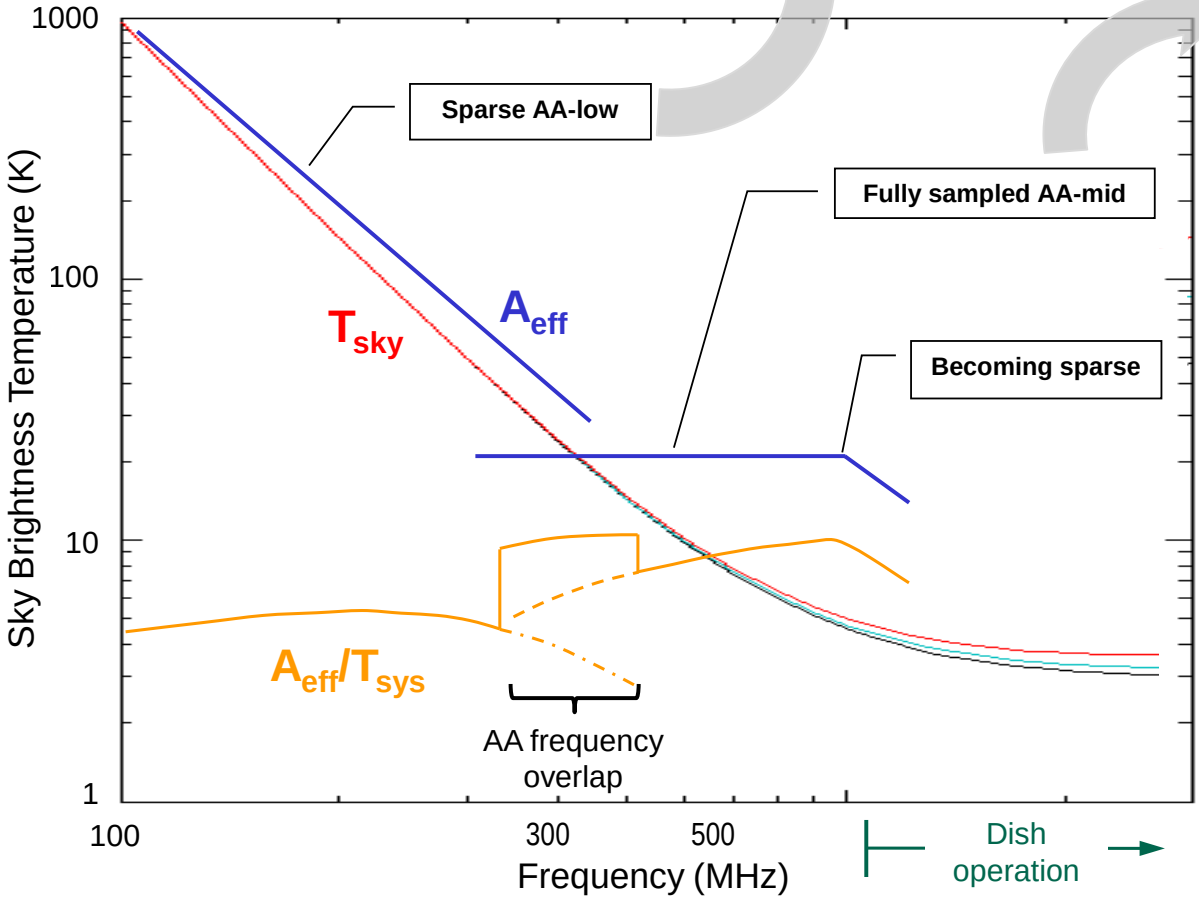
**Sparse:** >λ/2

- $A_{eff}$ increases as $\lambda^2$
- Layout irregular
- Increased skynoise from grating lobes
- Small beam at high frequencies



**Dense:** ≤ λ/2

- Constant $A_{eff}$
- Fully sampled wavefront
- Excellent side lobe control
- Regular layout



# Basic and stretch…

- SKA Office appointed Consortia to produce the major "Elements"
  - **Low Freq. AA** - Science Data Processor - Communications
  - Dishes - Correlator+Beamformer - Infrastructure
  - Integration
- Issued a "Baseline Spec." now as "Level 1 Requirements"
- LFAA **must** meet the Level 1, or *Baseline* requirements

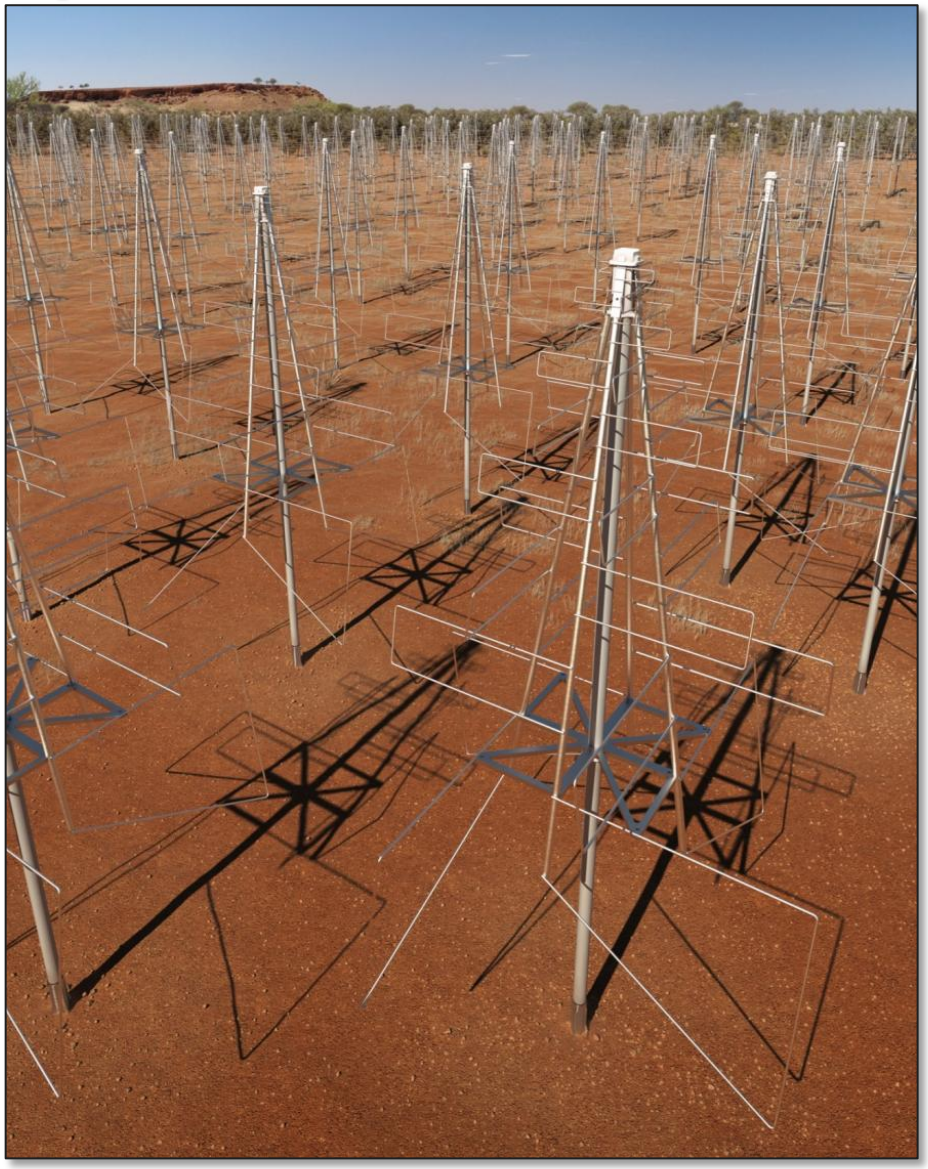
Baseline spec. misses a lot of opportunity from AAs, so…

- LFAA **may** meet *Target* requirements (self-imposed…),
  - Low cost or traded with other aspects of SKA1 (e.g. dish performance)

# $SKA_1$-low *Baseline* specs

**Strongly configured for EoR**

| | |
|---|---|
| *Frequency:* | 50MHz – 350MHz |
| *Bandwidth:* | 300MHz |
| *Sensitivity :* | 1000$m^2$/K (110–350MHz) |
| *Polarisation:* | Dual (of good quality) |
| *Beam size:* | >5° (no beam stitching) |
| *Scan angle:* | 45°max. |
| *# of beams:* | Single (!) |
| *Configuration:* | 50% <600m radius<br>75% <1km radius<br>95% <3km radius<br>3 spiral arms of 50km |
| *Output Data rate:* | ~10Tb/s (total) |



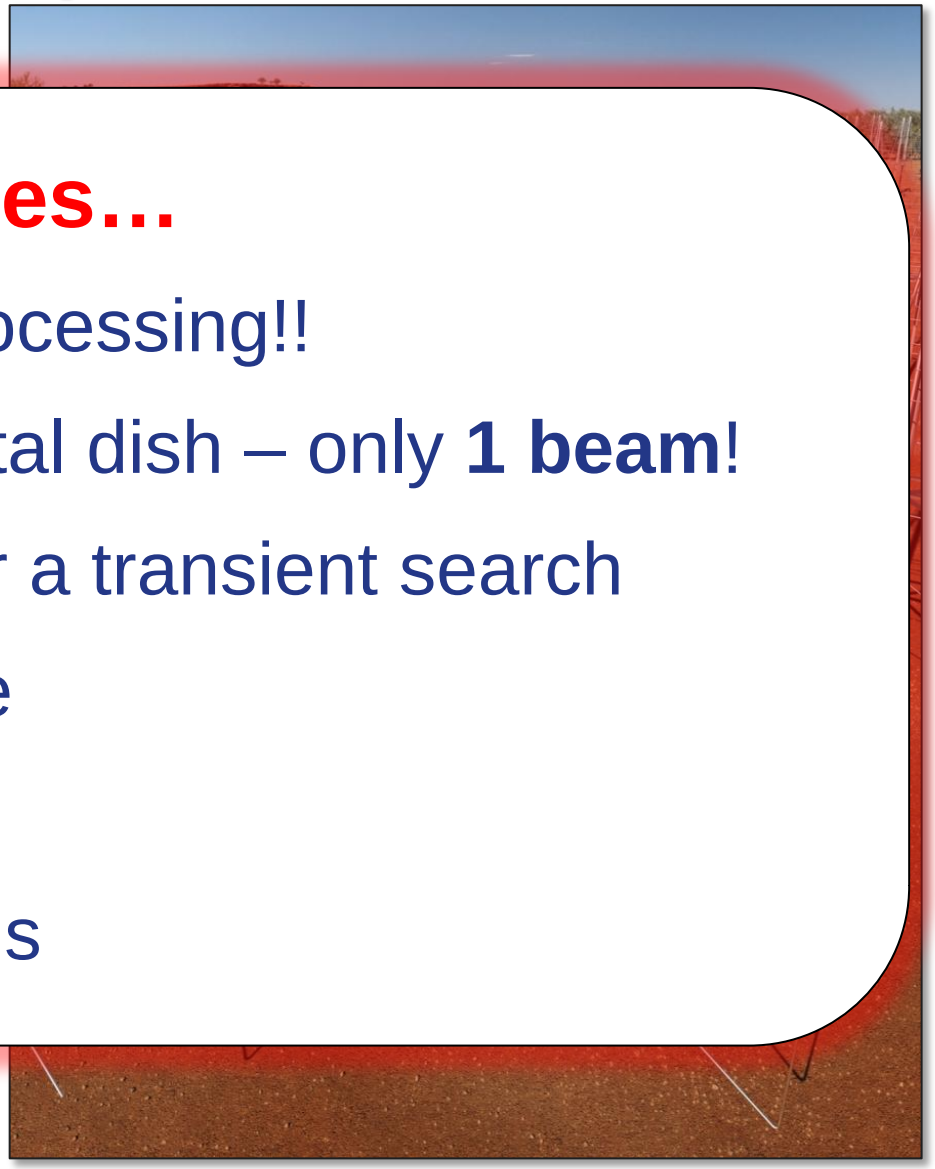
# $SKA_1$-low *Baseline* specs

**Strongly configured for EoR**

*F*

*Output* ~10Tb/s (total)

*Data rate:*



## Issues…

Excludes **any** pulsar processing!!

Pretends an AA is a metal dish – only **1 beam**!

Restricts parameters for a transient search

Limited frequency range

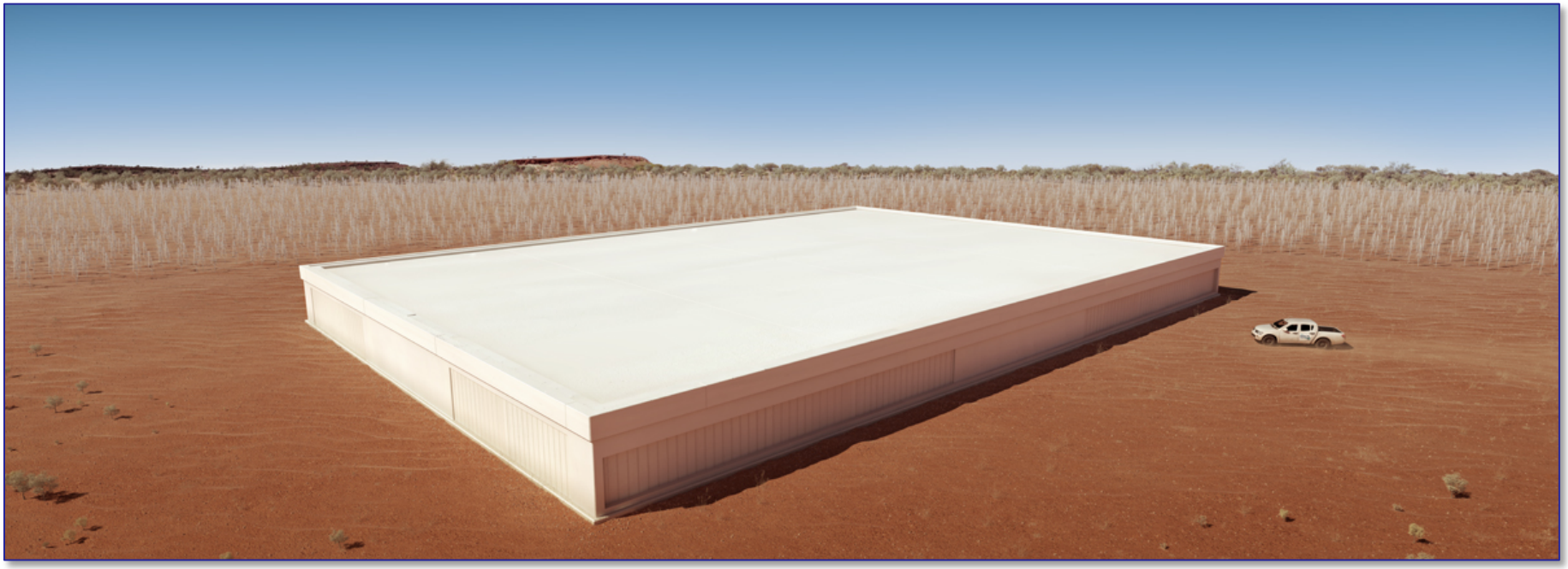
Fixed station size

No autonomy for stations

# Technical implementation

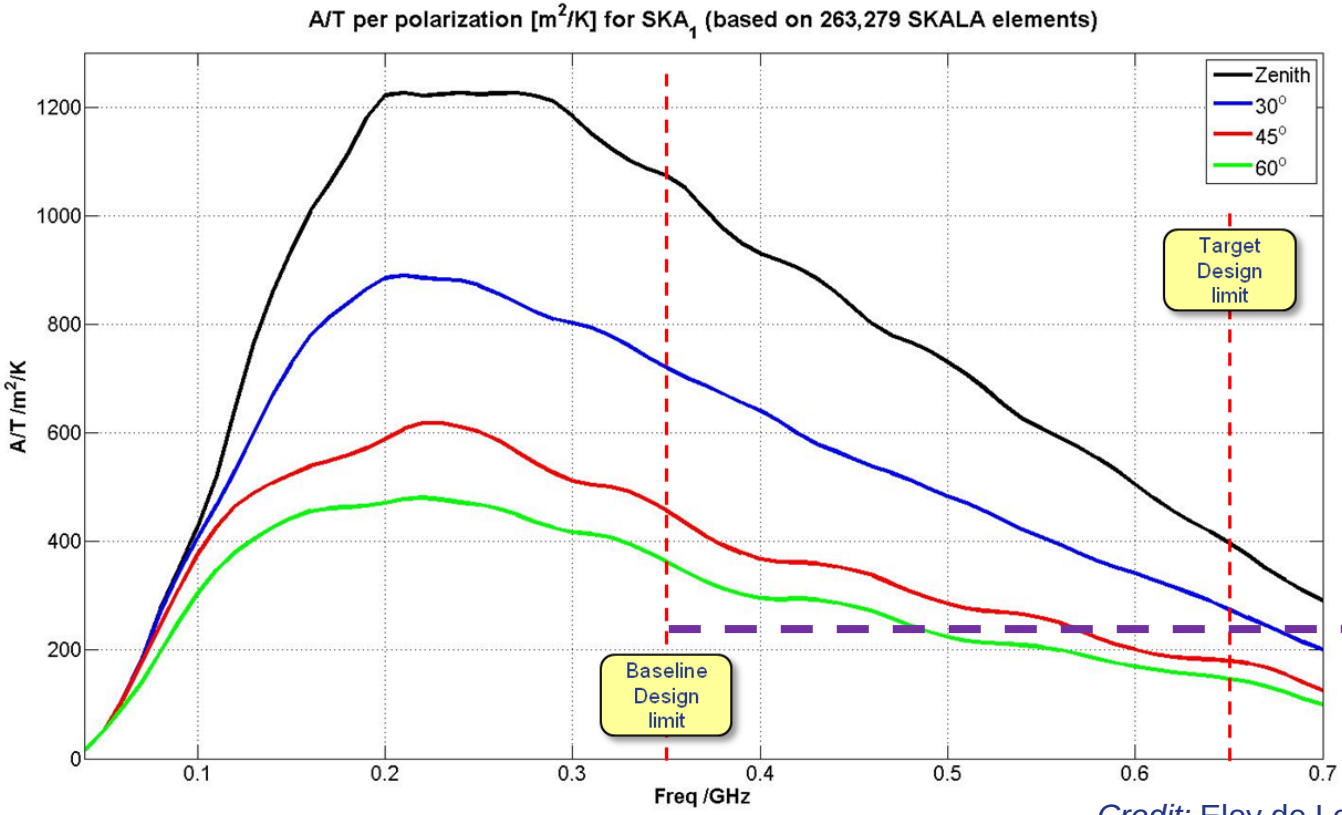
| | |
|---|---|
| *Antenna:* | Log Periodic |
| *No. of ant.:* | 256,000 ($2^{18}$) |
| *Ant. placement:* | Random. 1.5m min. |
| *Station size:* | 256 / 512 / 1024 ant.<br>35m / 50m / 70m dia. |
| *No. of stations:* | 256 - 1024 |

| | |
|---|---|
| *Signal transport:* | Analogue fibre |
| *Processing:* | Digital |
| *Sample res.:* | 8-bit or 4-bit real |
| *Tiles:* | 16 antenna per Tile |
| *Data routing:* | Switch network |



# Array sensitivity vs. frequency

$T_{rec}$ ≤35K
>100MHz




SKA Survey Band 1

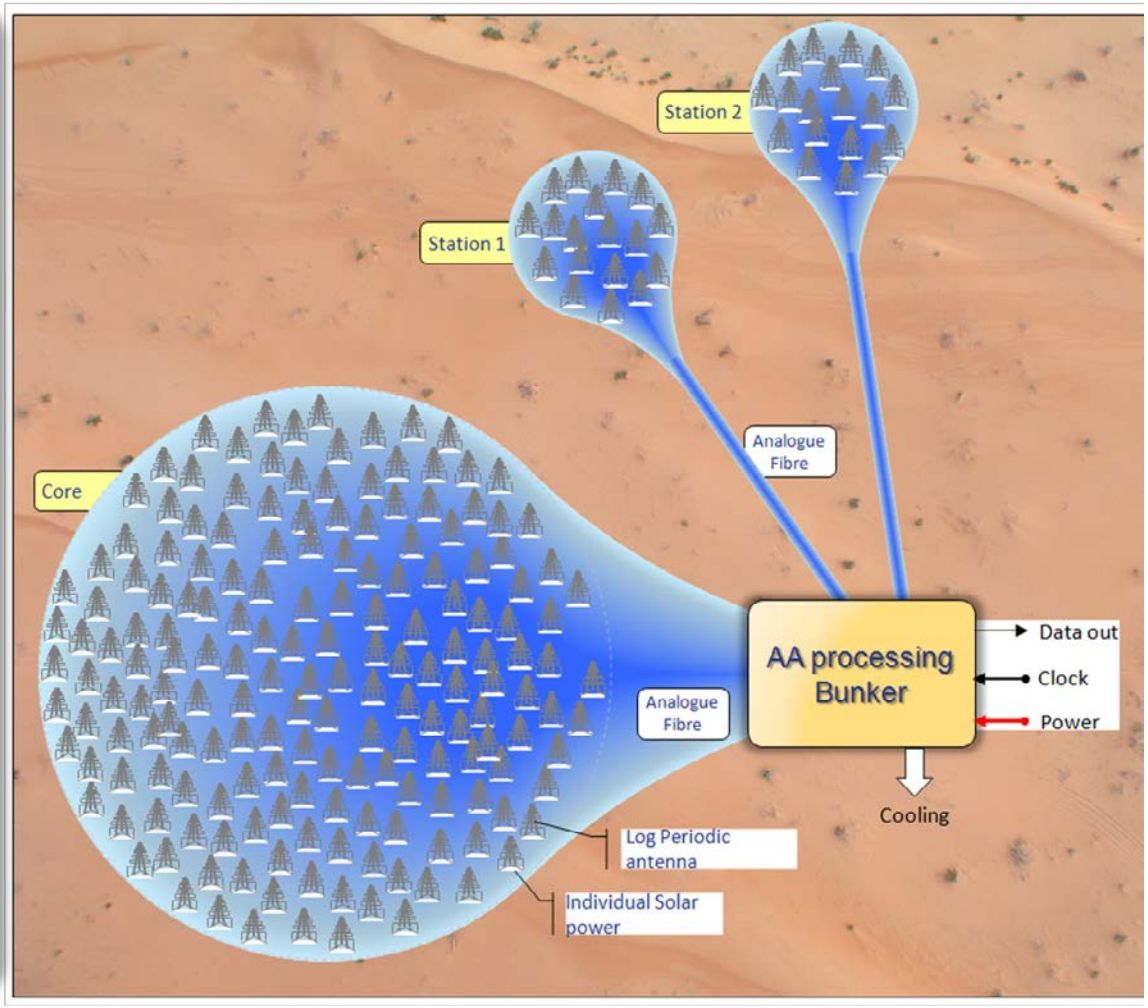
*Credit:* Eloy de Lera Acedo

EM simulations (CST) and LNA electronic simulations (Microwave Office).

Further optimisations to perform

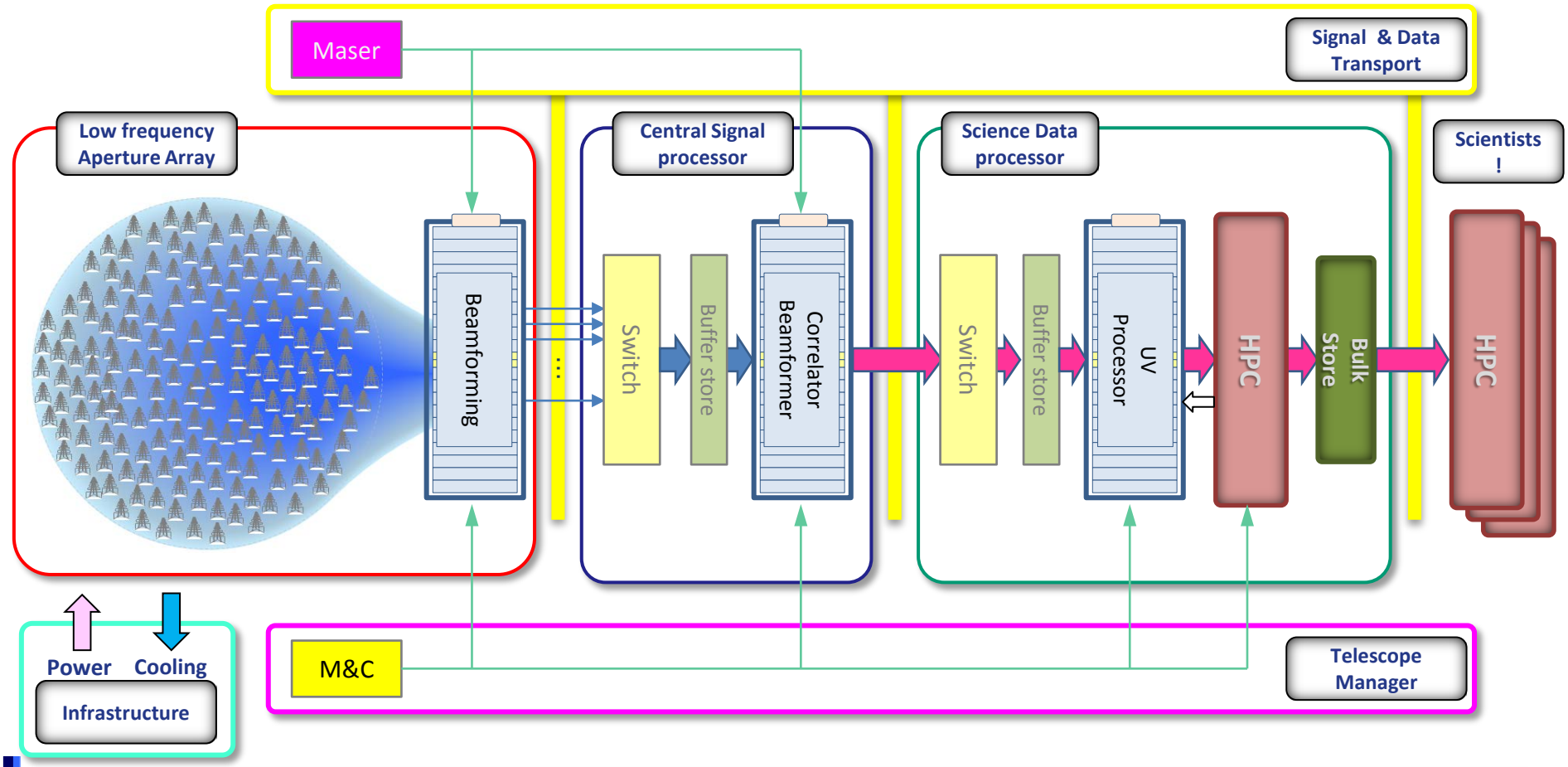
# Target Implementation

- Individual **Log-periodic antennas** – single array
- **Analog fibre** signal transport from each antenna
- Individual **solar power** (+battery) at each antenna
- **Single** (large) processing bunker (256 racks)
- Band selection using ADC baseband or first alias
- Data routing inside bunker using COTS switches



# Example bunkers…

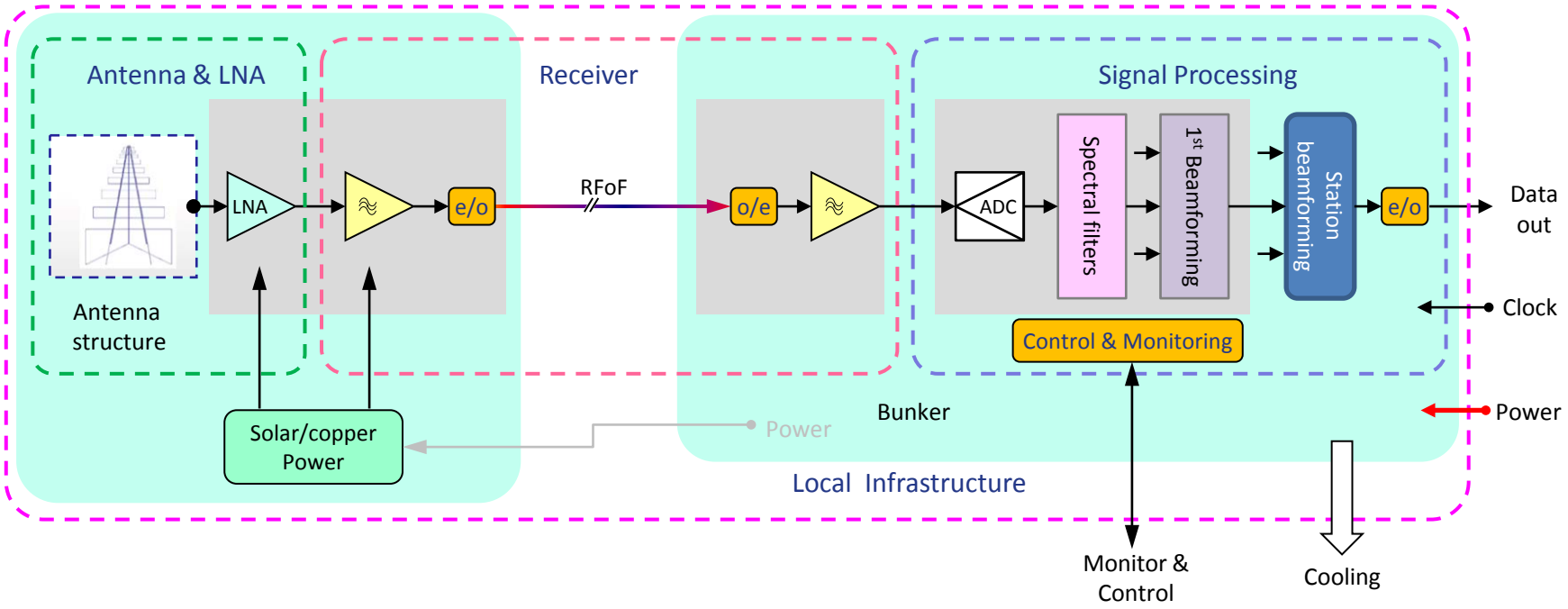
# SKA-low: end-to-end



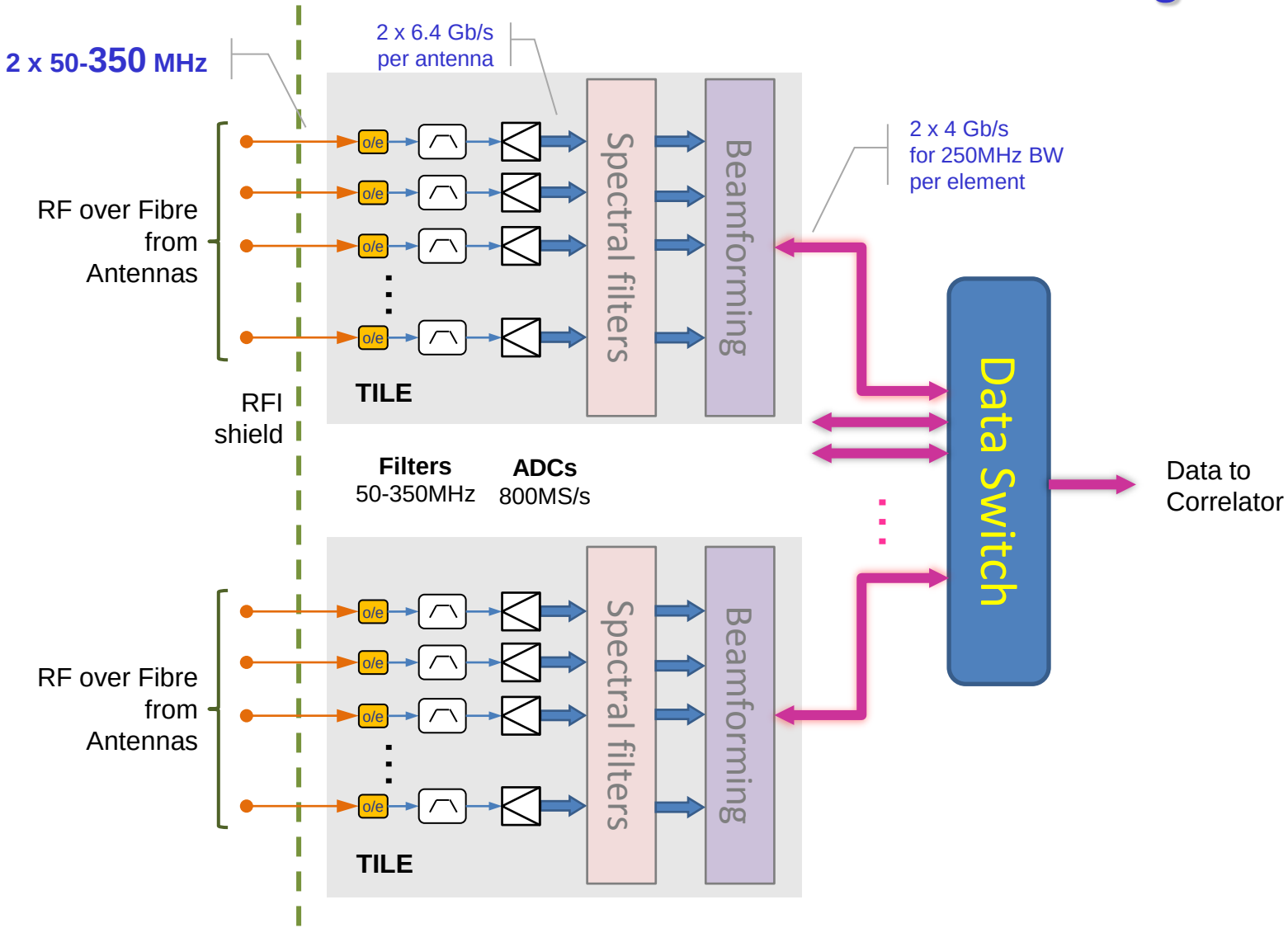

**Central Bunker can integrate:**

- LFAA Beamforming
- LFAA Correlator
- Signal transport
- Maser clock
- Local M&C

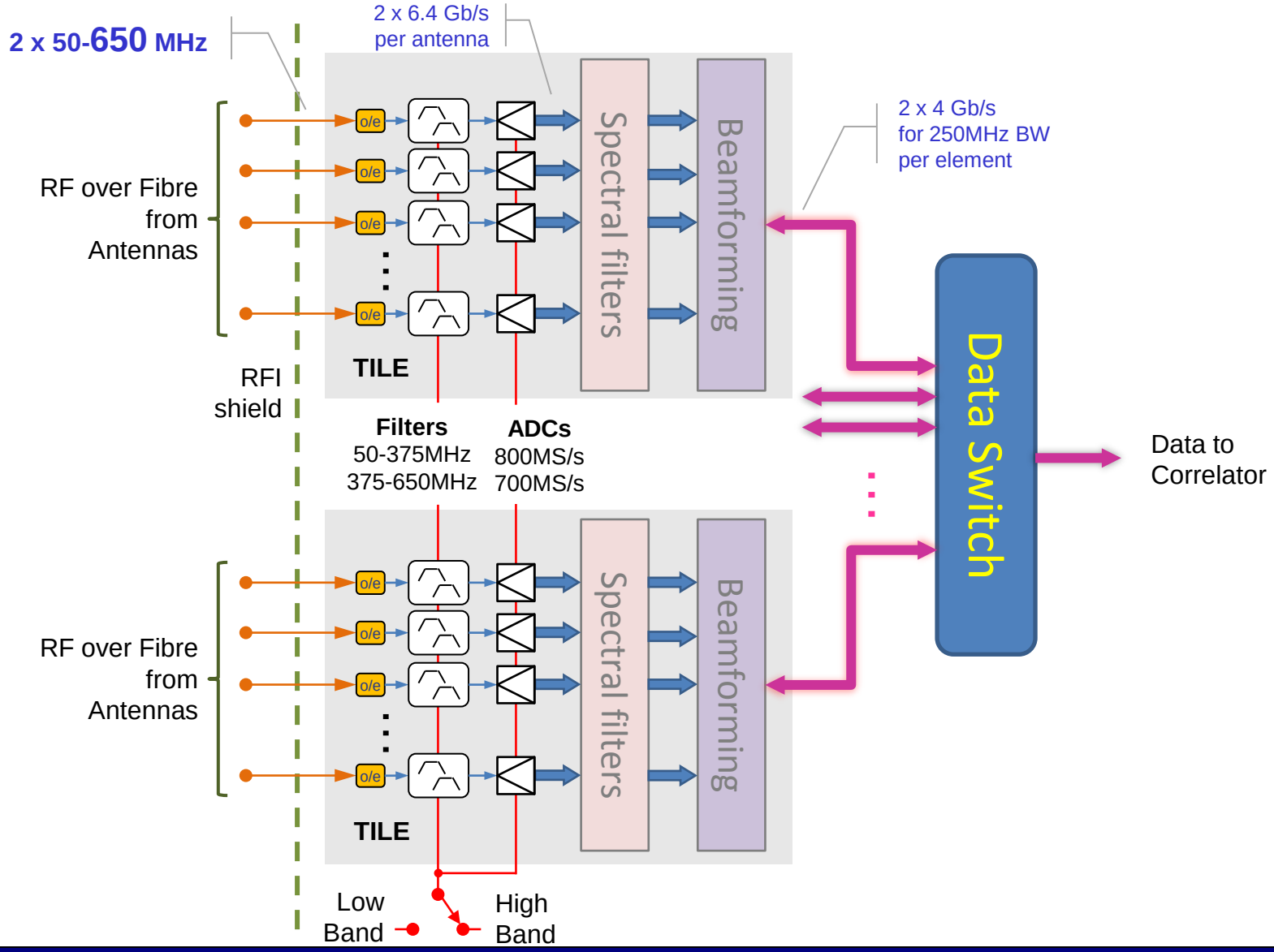
# Signal flow through AA



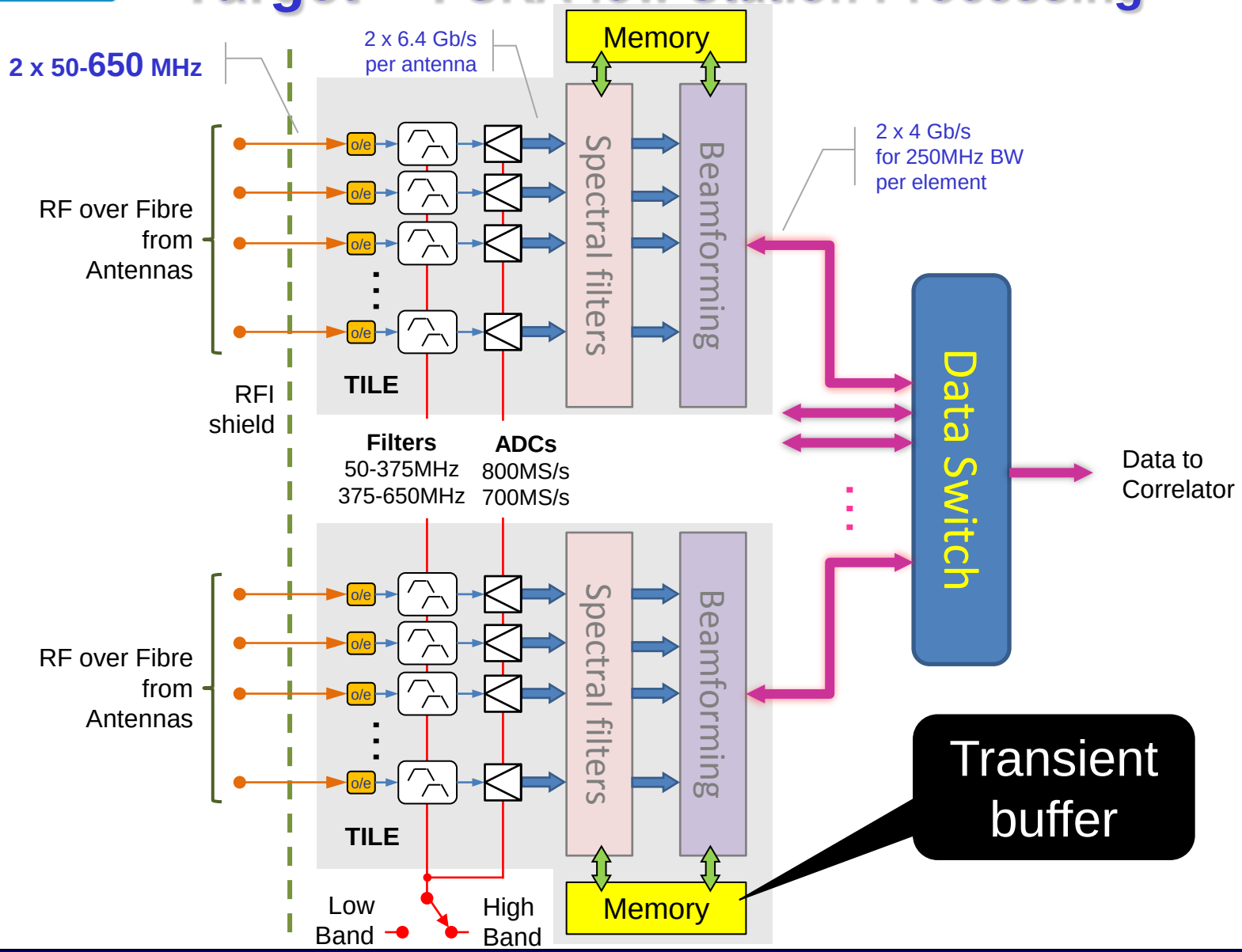
# Baseline: SKA-low Station Processing



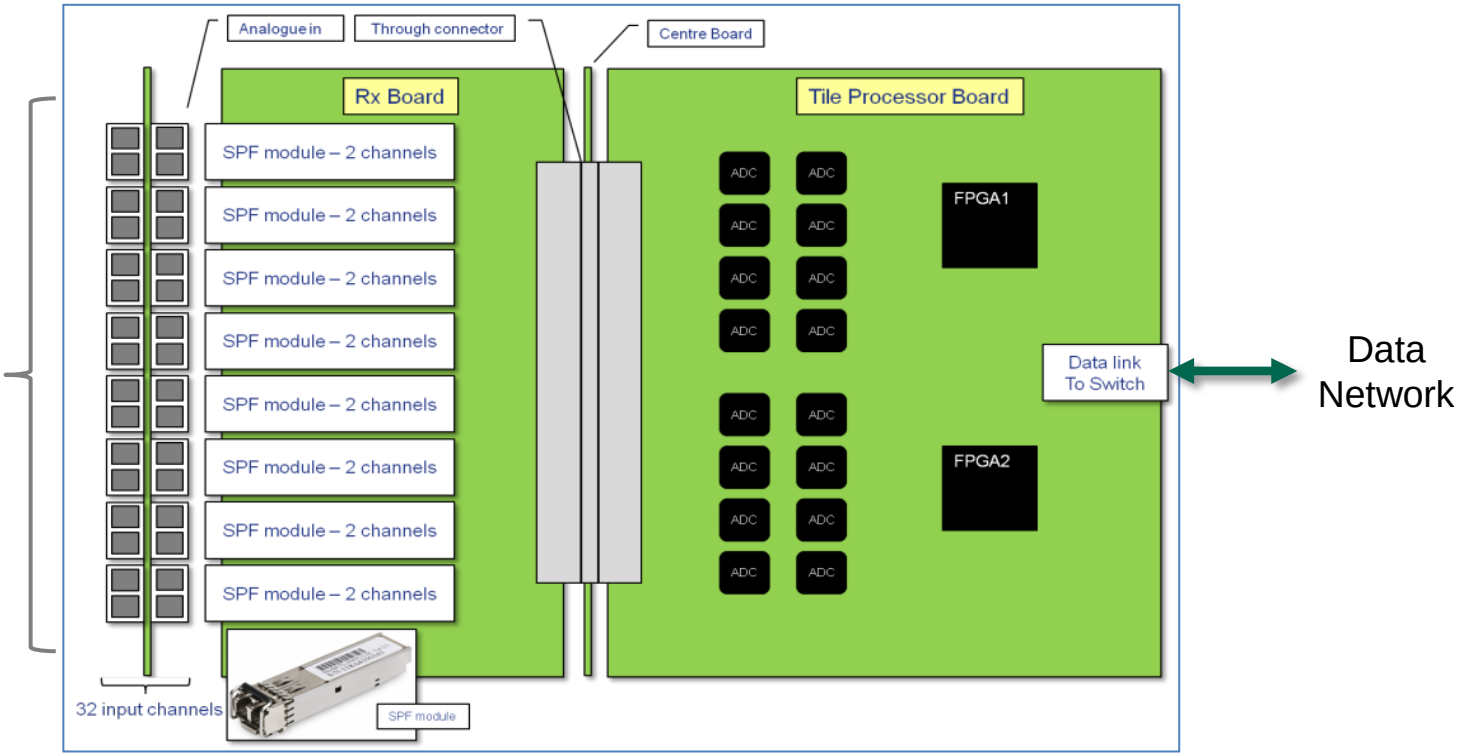
# Target: SKA-low Station Processing



# Target++: SKA-low Station Processing



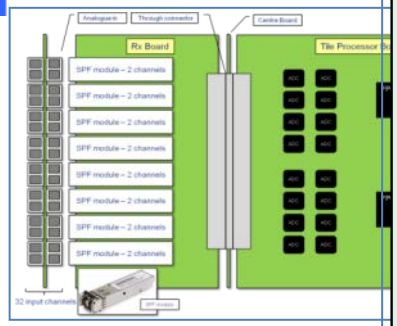
# Implementation …

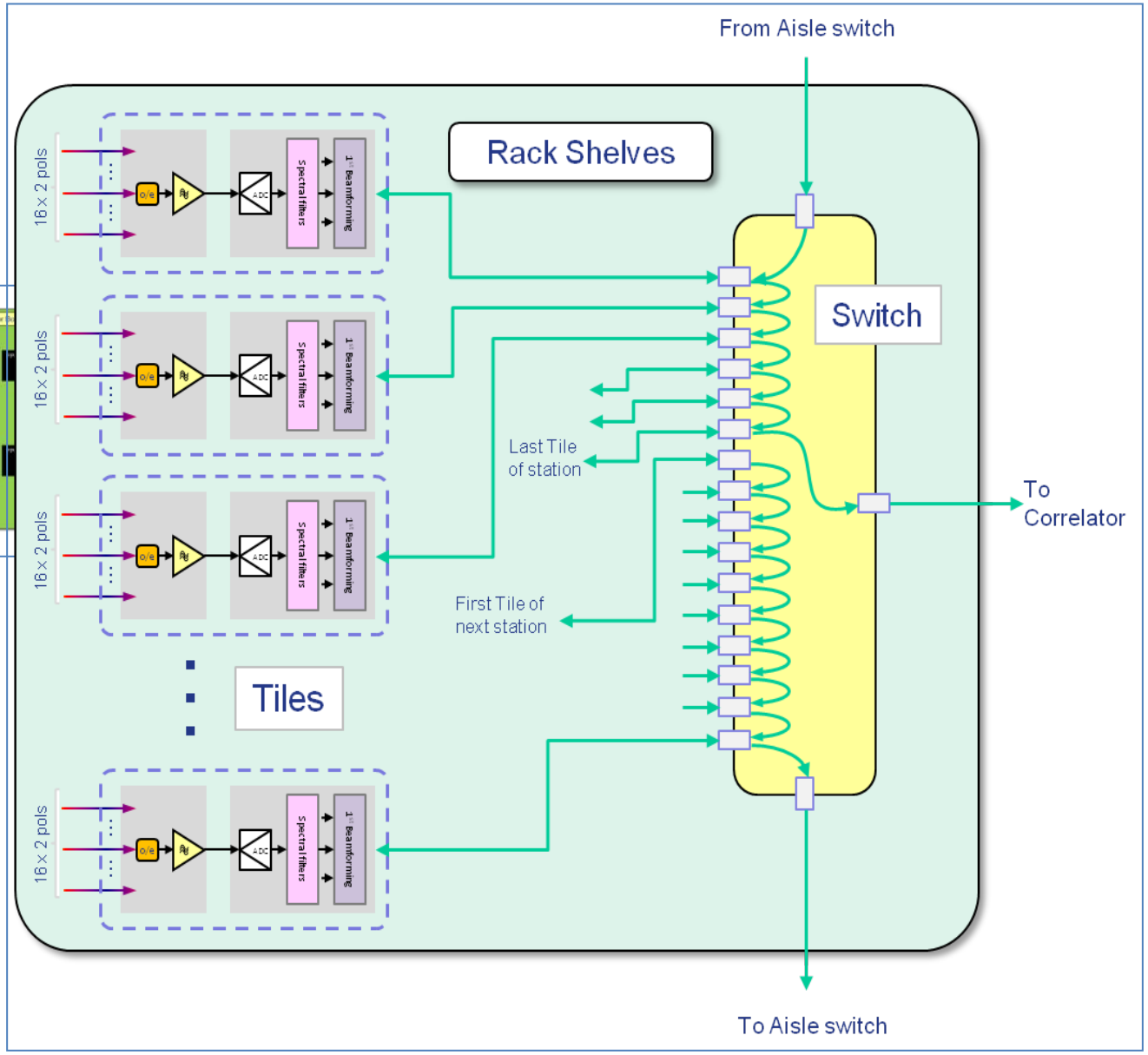


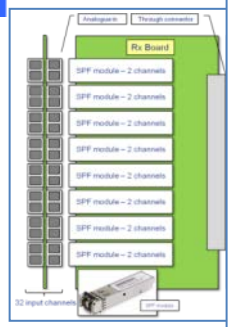

Analogue inputs

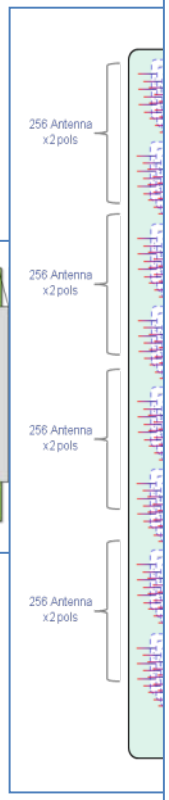
16 dual pol. antennas

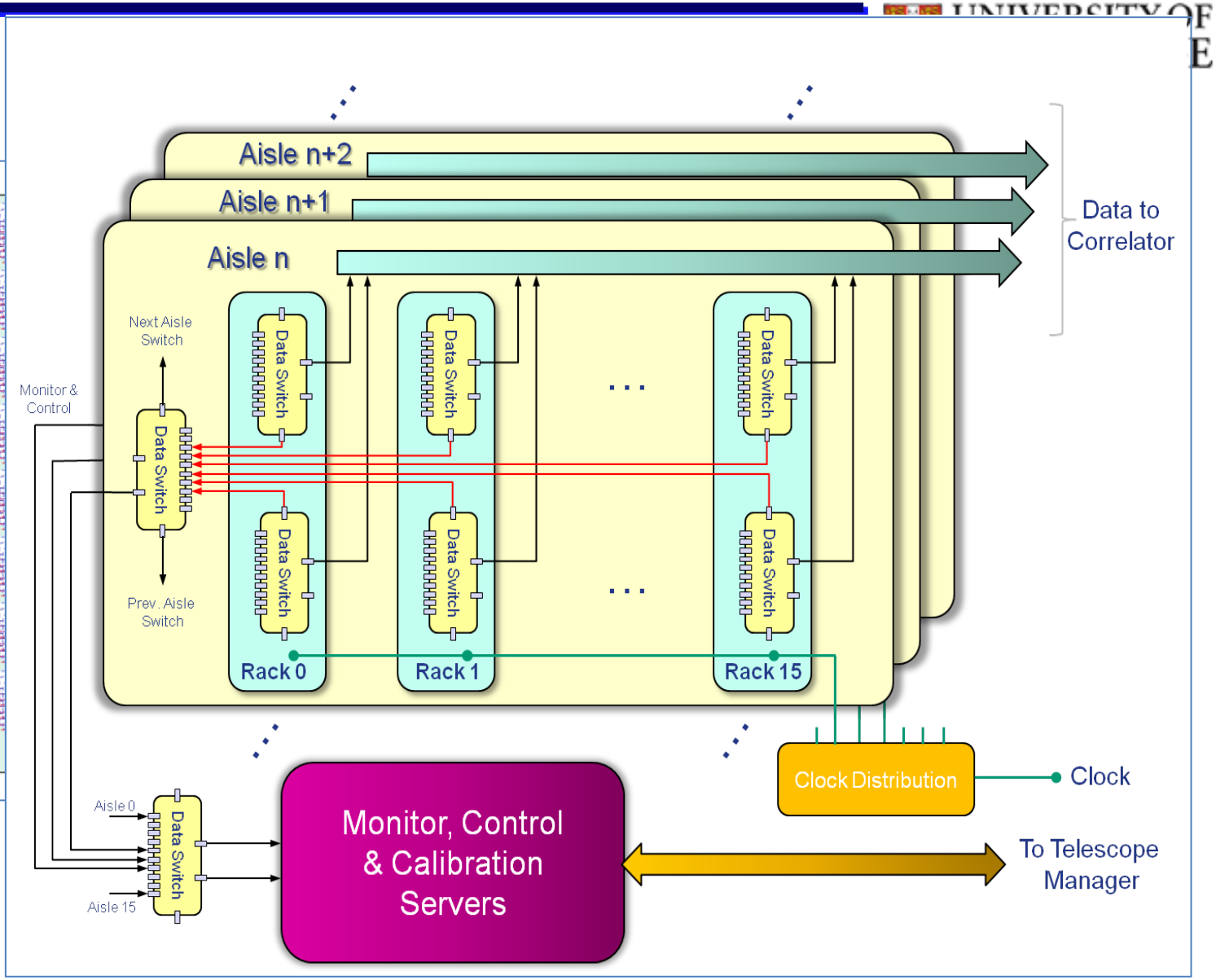
Digitise and beamform




From Aisle switch
Rack Shelves
16 x 2 pols
Spectral filters
Beamforming
Switch
Last Tile of station
First Tile of next station
To Correlator
Tiles
To Aisle switch






256 racks in 16 aisles

High speed switched network

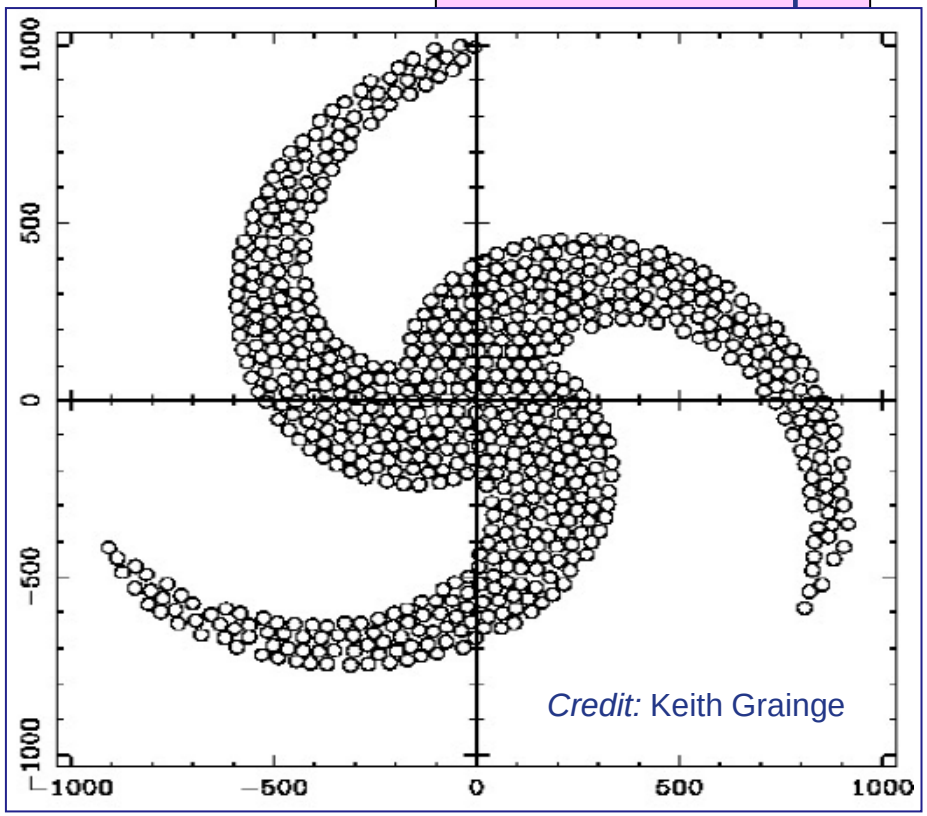
Flexible beamforming

Overlayed monit. & control

# Capabilities of the design…

| | |
|---|---|
| *No. of stations:* | 1024 *or* 512 *or* 256 |
| *Station dia,:* | 35m *or* 50m *or* 70m |
| *Multiple Beams:* | Flexibly allocated in available data rate |
| *Beam forming:* | Improved apodisation |
| *Scan angle:* | 60°max. |
| *No. of Bands:* | 2 |
| *Frequency Ranges:* | 50MHz – 375MHz<br>375MHz – ≤650MHz |
| *Data rate:* | ≥10Tb/s |

Core close-up




**REDUCING** SKA1 system cost and/or
**IMPROVING** performance….

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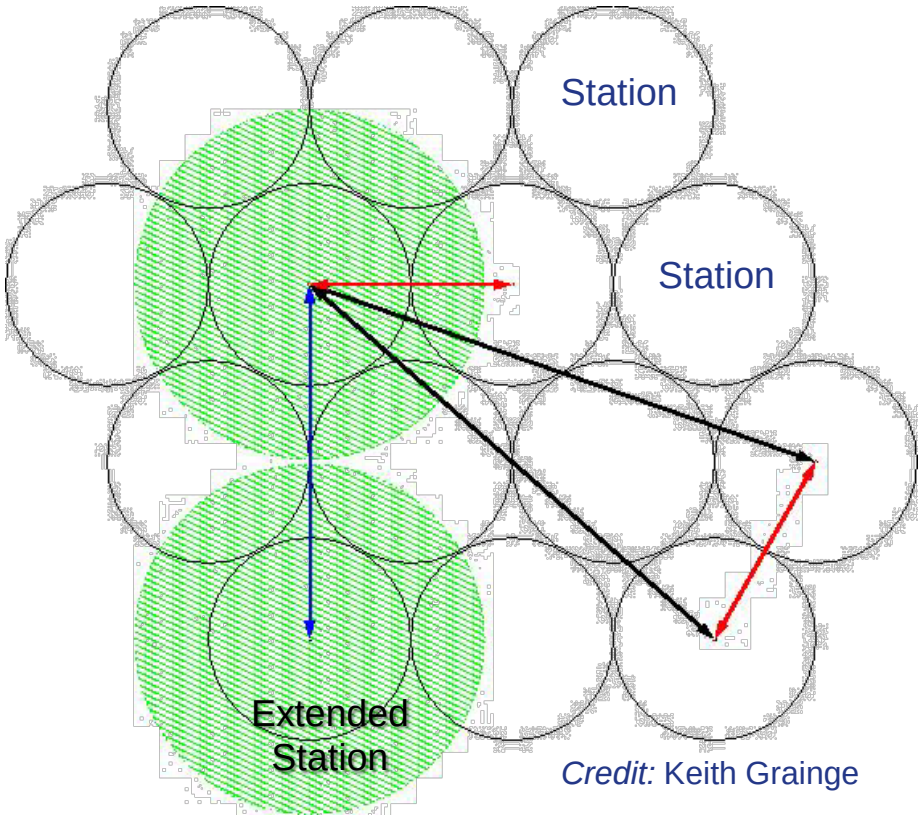
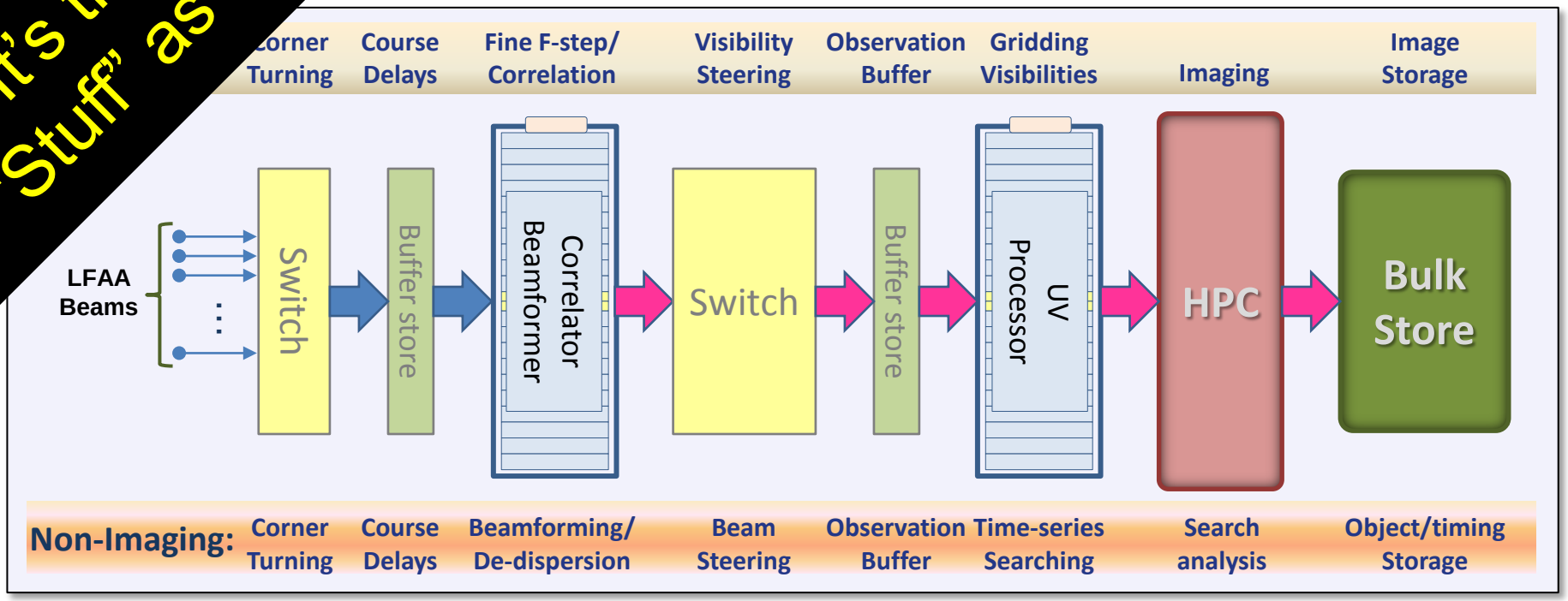
Better Stations




**REDUCING** SKA1 system cost and/or
**IMPROVING** performance….

# ...w could observe Pulsars!

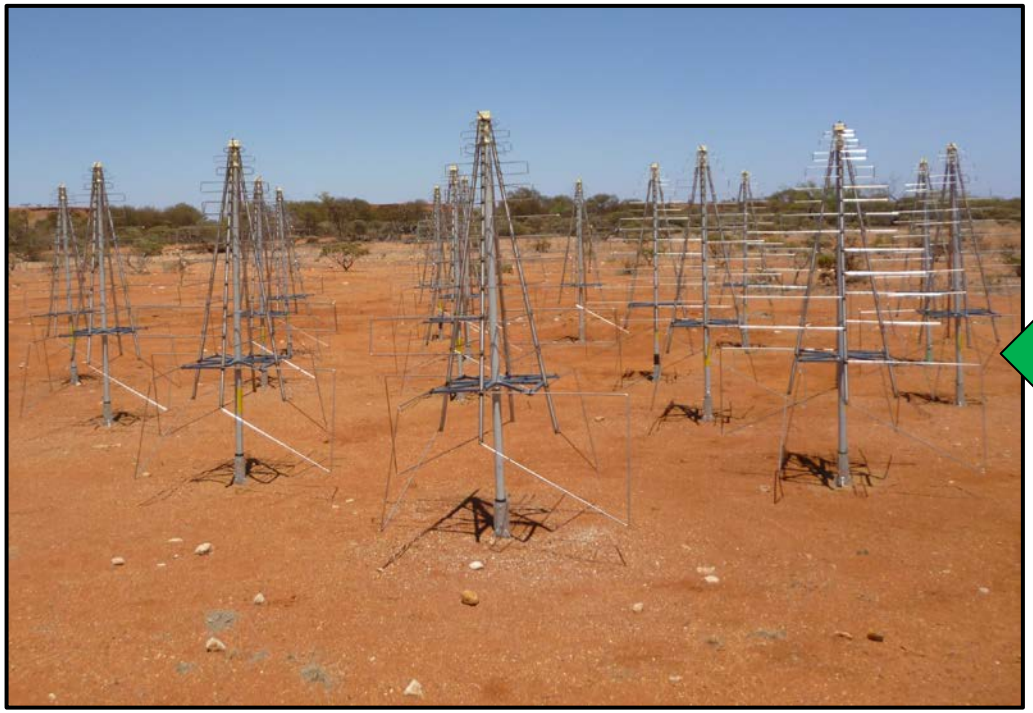
It's the same "Stuff" as imaging!

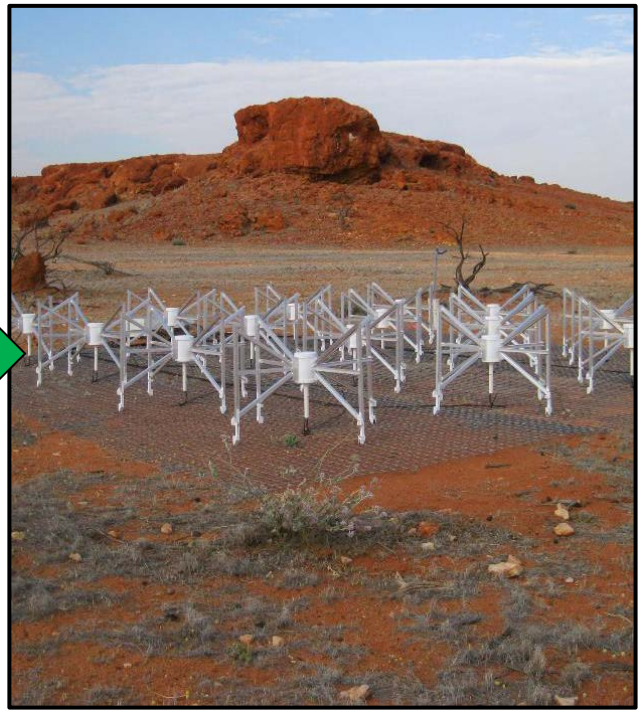



SKA-low Processing Chain

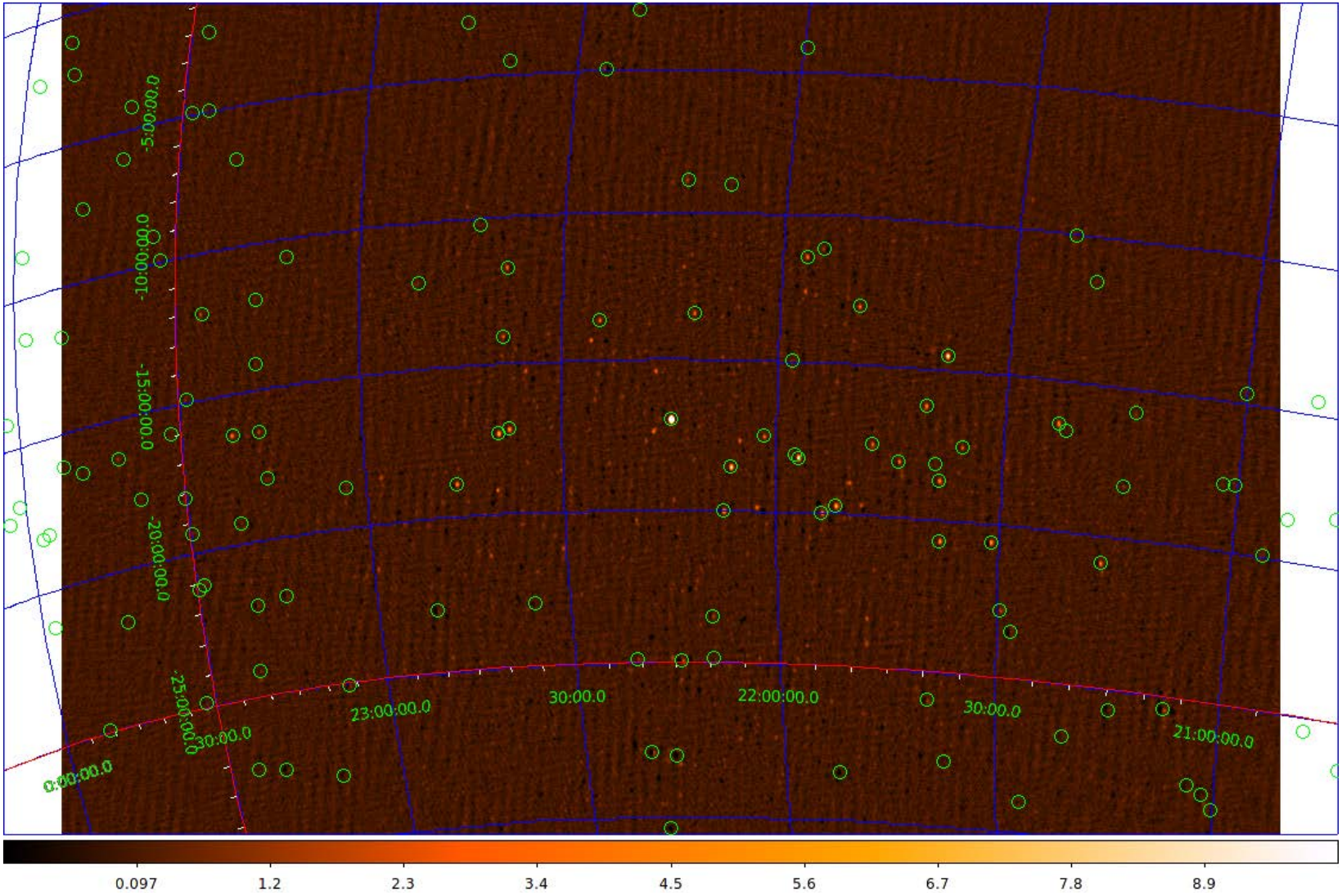
# First cross-correlation AAVS 0.5 tests

- Aims
  - Verify correct interferometer operation and calibration
  - Make a variety of test images
  - Extract key AAVS 0.5 parameters: SEFD, station beam characteristics, ….
  - Inform design of future verification activities (AAVS 1)
- Requires reliable and well-calibrated MWA





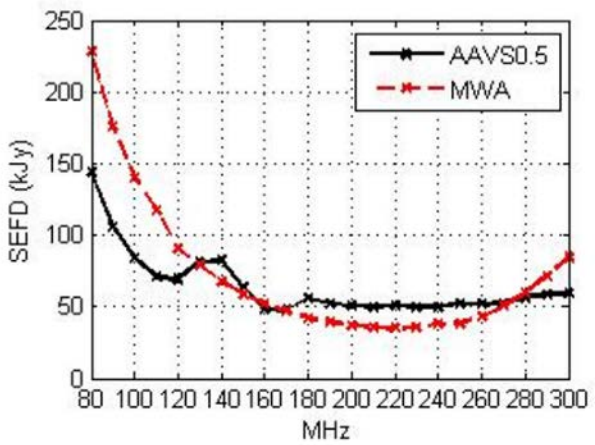
# First AAVS 0.5 image (using MWA)

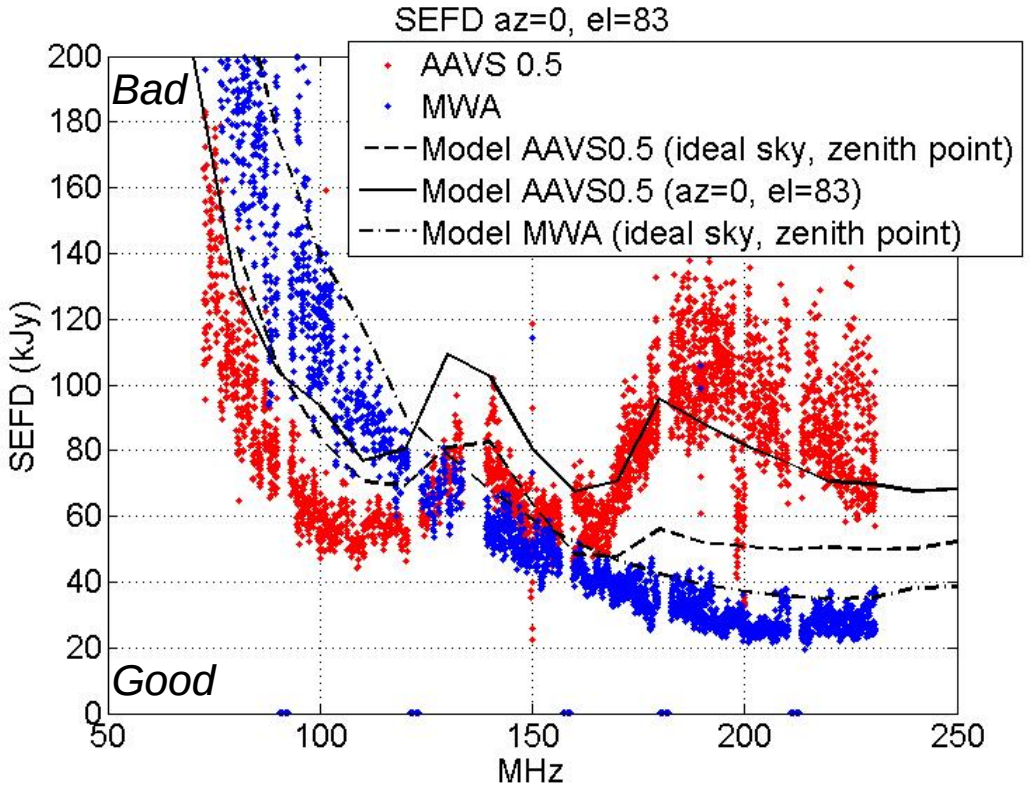



- 2 minute integration, wide-field snapshot, centred on 3C444
- AAVS 0.5 baselines only (but calibrated using whole MWA)
- No allowance yet for AAVS 0.5 point spread function, pointing or baseline errors

# AAVS 0.5 System Equivalent Flux Density (SEFD)

- 3C444 for 3 hrs from 1030 local time, 20/8/13
- 120˚ azimuth variation; modest variation around elevation 80˚
- MWA and AAVS 0.5 tiles connected to the same MWA receiver (#7)
- Good agreement between models and measurements
- NB: un-optimized AAVS configuration




Simulation: 2.5 % moisture soil, Trx = 50 K

# In conclusion….

# In conclusion….

## SKA-low *can* be superb for transients & pulsars!

- Low frequency aperture array is critical to SKA
- Wide-band log-periodic antennas give 13:1 freq. range
- RFoF enables a very flexible architecture
- Solar power reduces deployment and running costs
- Centralised processing enables:
  - Flexible station configuration
  - Improved beamforming
  - Simpler maintenance
  - Use of COTS components