Blue Computing

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Bluering

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CSIRO Astronomy and Space Science
Signal Processing Technologies Group

SKA Low Computing

Outback dirt is red, The sky is blue,

Blue can be green, And computing can be too!

What is “Blue” computing?

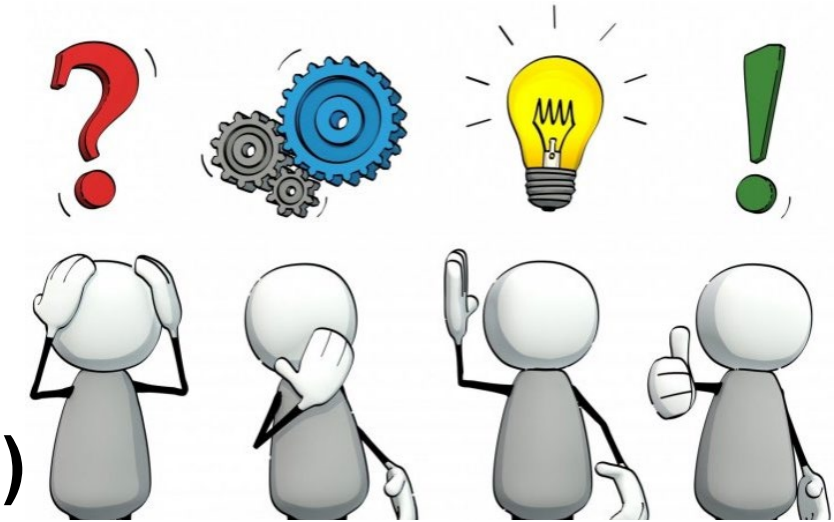
- Liquid Cooling
- Low Power
- Fast Coding
- Reliable operation
- Fast connectivity
- EMI compliance
- Reduced Cost
- Flexible platform
- Having fun ...

SKA Low Station Beamformer

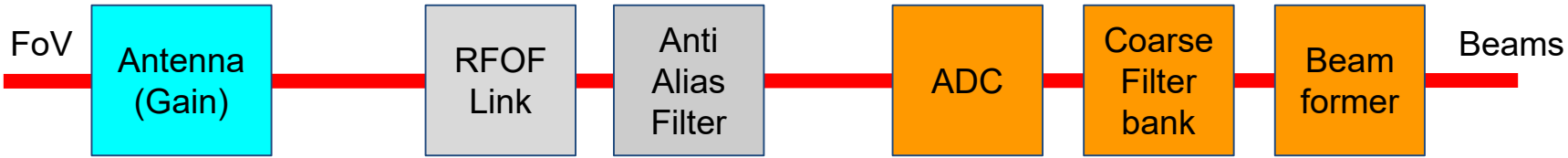
Fixed antennas with electronic beam steering

How much “computing” is a station beamformer?

- **512 stations**
- **256 antennas**
- **Dual polarisation**
- **300MHz bandwidth**
- **“One” beam (can trade bandwidth for more beams)**



Beamformer Compute



Beamforming is the last compute process, however the most compute intensive process is the oversampled coarse filterbank (FIR & FFT)

- **Filterbank enables the beamformer to be implemented using phase shifts … multiple beams possible using different phase shifts**

Compute Comparison

Each one of the 256k signals require a filterbank:

- **Each filterbank is ~61 DSP running at ~481MHz**
- **Total compute ~7.7 Peta multiplies per second**

The station beamformer requires a complex multiplier for each signal:

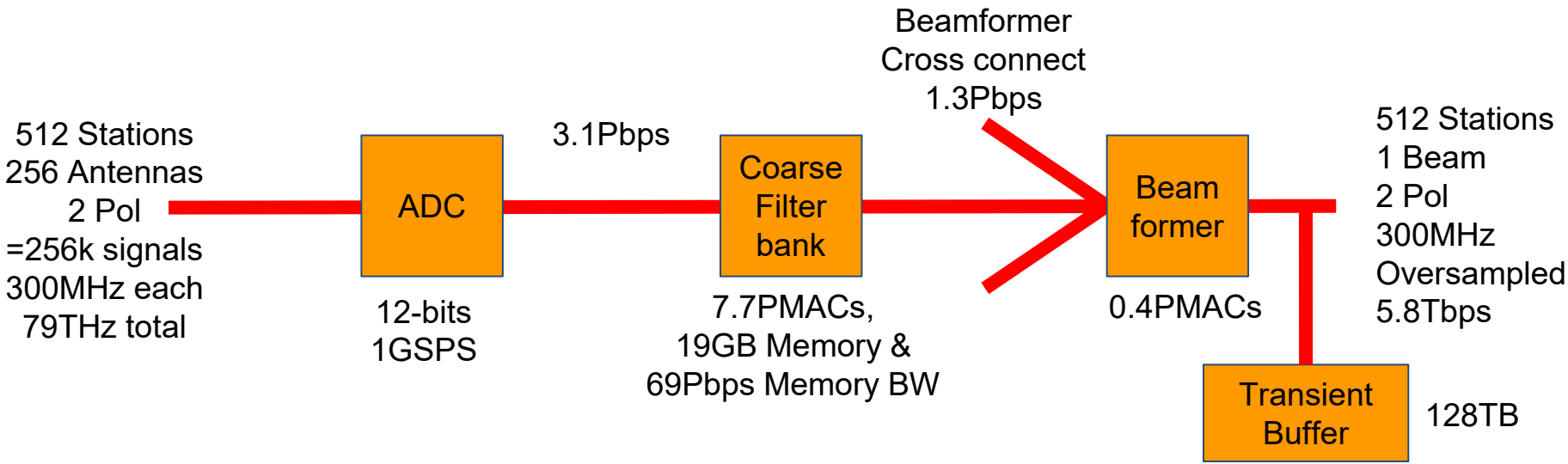
- **Total compute ~0.4 Peta multiplies per second, or ~5% of the total compute**

Total of ~8PMACs required

8PFLOPs is 22nd largest supercomputer in the world https://www.top500.org/list/2018/11/?page=1

Not only Compute

- Looking at the system as a whole
- Compute doesn't work without communications or memory bandwidth



Relative SKA Low compute

CSP Low is ~1 Peta MACs

SDP Low is limited to ~2.5 “effective” Peta FLOPS

- **LFAA has to be compute & power efficient as it is two third’s of the total compute!**
- **Cooling is also harder on site**

This can only be realised in an ASIC, or the latest generation FPGA

- **Not a GPU as these have been shown to have low performance for filterbanks**

“A polyphase filter for many-core architectures” (https://arxiv.org/pdf/1511.03599.pdf)

Project Bluering

Bluering is a project name, inspired by small size, liquid cooling and it's a nice colour ...

The motivation for Bluering is a CryoPAF beamformer and building a lower cost and lower power receiver for radio astronomy

(AAP Image/Supplied by World Surf League)

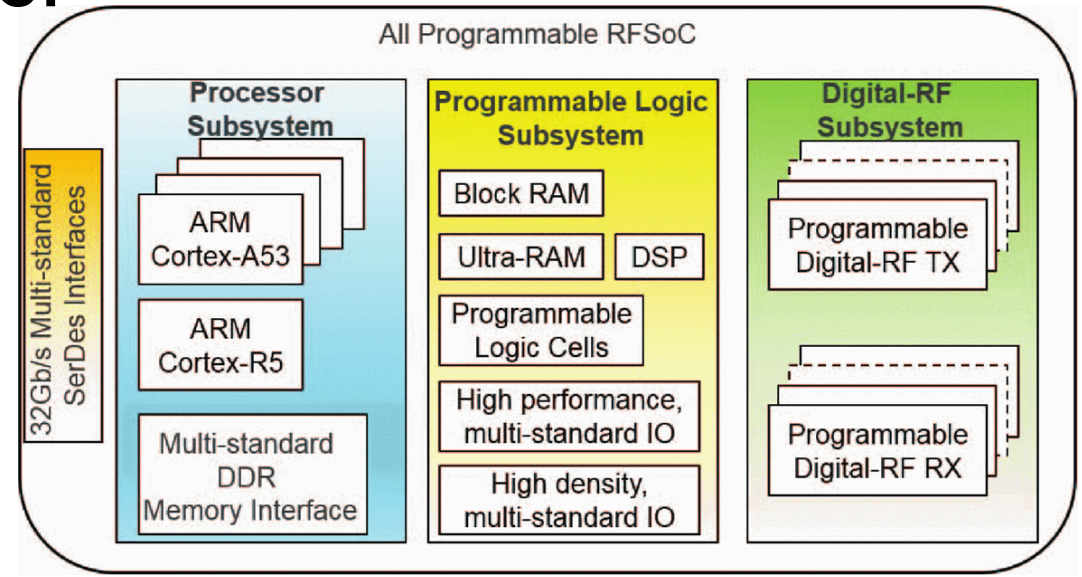
What Bluering seeks

- Cost - reduce the station beamformer cost
- Power - don’t want huge power bill every day
- Liquid Cooling - efficiency = less power
- EMI - less infrastructure
- Performance - great performance for astronomy
- Software - flexibility in application
- Integration - building for an optimised solution

RFSOC - more than an FPGA

Four major parts to RFSOC:

1. **Digital-RF subsystem (ADC/DAC)**
2. **Programmable logic (FPGA core fabric)**
3. **Processor System (ARM Cortex)**
4. **SerDes interfaces (high speed serial IO)**



Powerful combination of four technologies in one - all four are utilised by astronomy

Bluering Compute Technology

Bluering uses the latest FPGA technology from Xilinx

- reduces compute and interface power

It integrates low power RF ADCs directly onto the FPGA

- results in very low interface power (compared to external)

It uses 16nm technology for the computations

- results in lowest power consumption for DSP

It also contains a processor

- Tango SW can execute directly on this to access monitoring/control points, RFI algorithms are possible

https://www.xilinx.com/products/silicon-devices/soc/rfsoc.html

Compute Technology ...

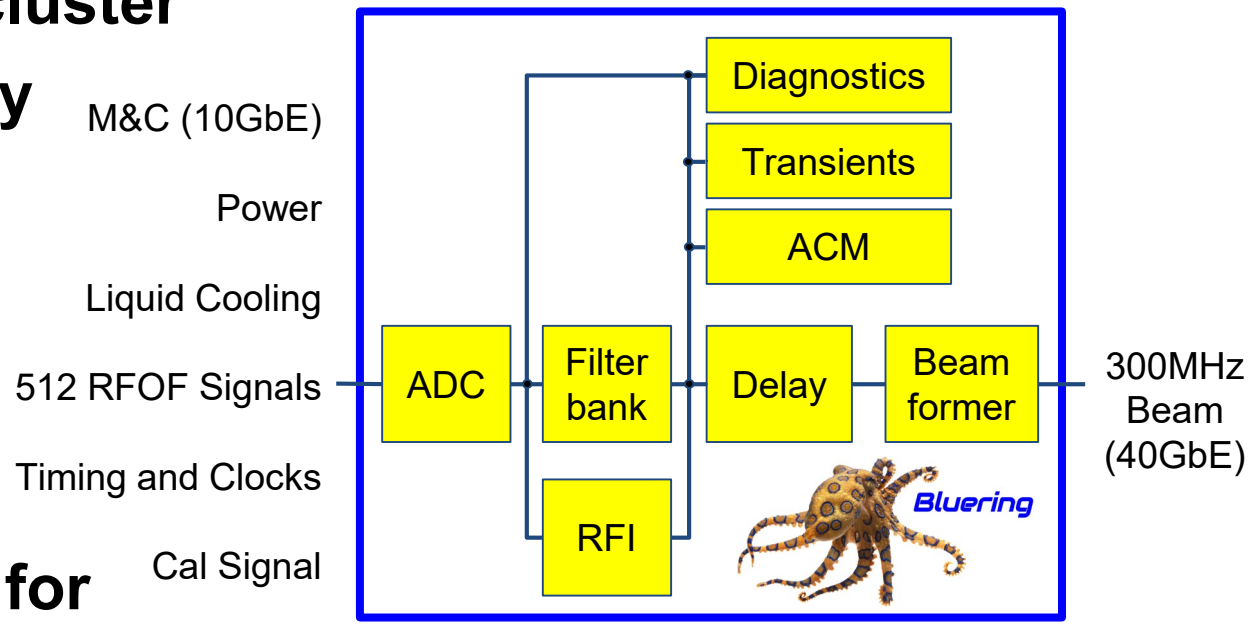
Array Covariance Matrix is computed on the FPGA

- **Unlike the current solution that computes this in a large server cluster**

The transient memory is attached to FPGA

- **Lower power interface direct to FPGA processor**

Also have Cal signal for continuous calibration



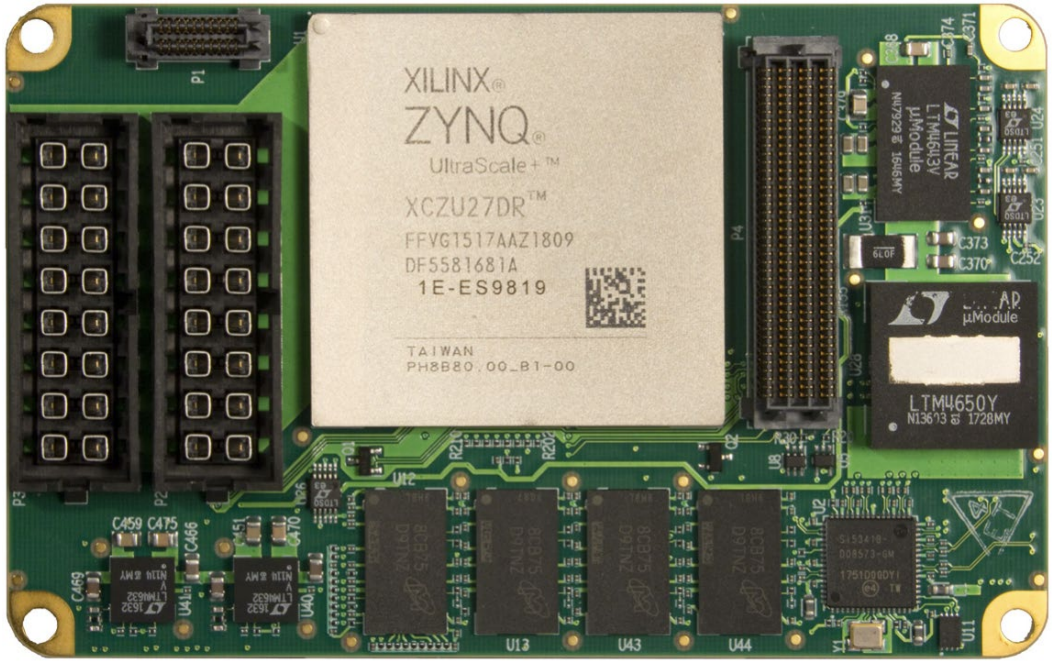
Commercial RFSOC Offerings

There are several commercial boards available

- **Not economically viable in quantity**

https://www.pentek.com/

Bluering will be a custom RFSOC board with 16 signal inputs, as well as a custom RFOF receiver board tailored for SKA Low



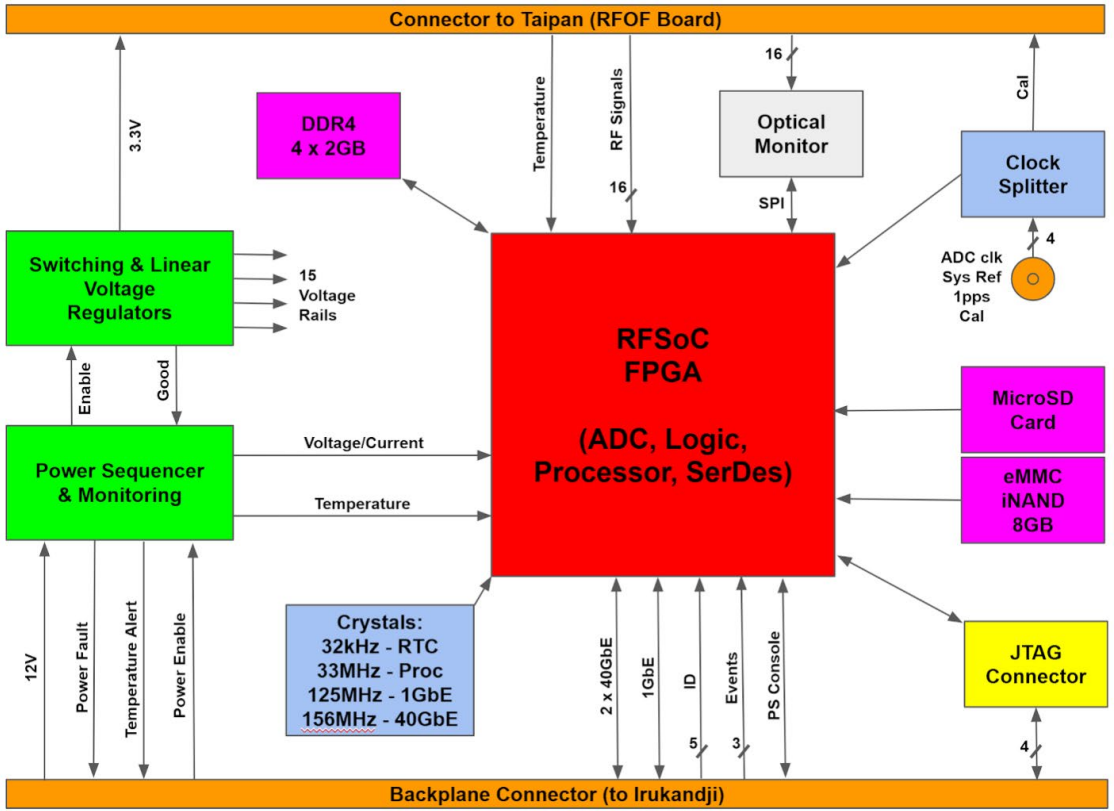
Initial Bluering HW Prototype

Two part solution

- RFOF
- RFSOC

Relatively simple boards, but still takes time to create

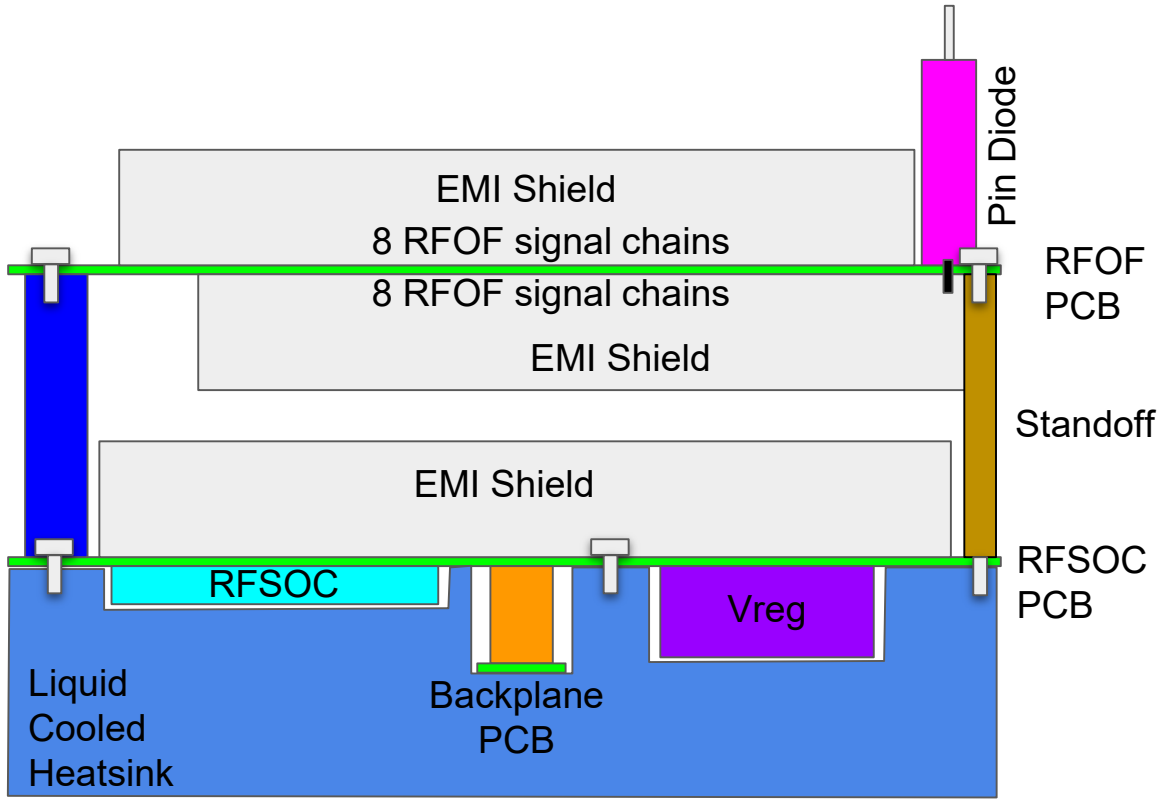
- RFSOC FPGAs have been received!



Sandwich Construction System

This optimises the performance, power, EMI, cost, size, efficiency and reliability.

The backplane creates an efficient fixed network of connections.



Note: Representative, not to scale!

Filterbank Power Measurement

What power will a Bluering filterbank require?

Bluering filterbanks are adapted from Perentie (CSP)

- 16 filterbanks consume 37000 LUTs, 62000 FF, 976 DSP, 279 BRAM, with most running at 480MHz

Slowest speed grade RFSOC meets timing.

Have measured power on ZCU111 eval board

- Approximately 1W per signal which is a fraction of current solution

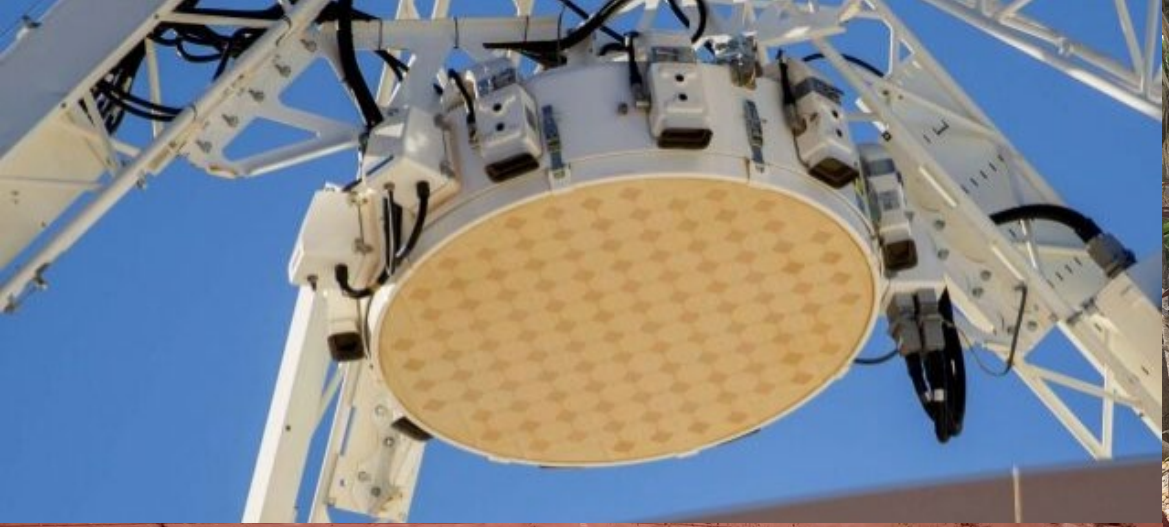
Conclusions

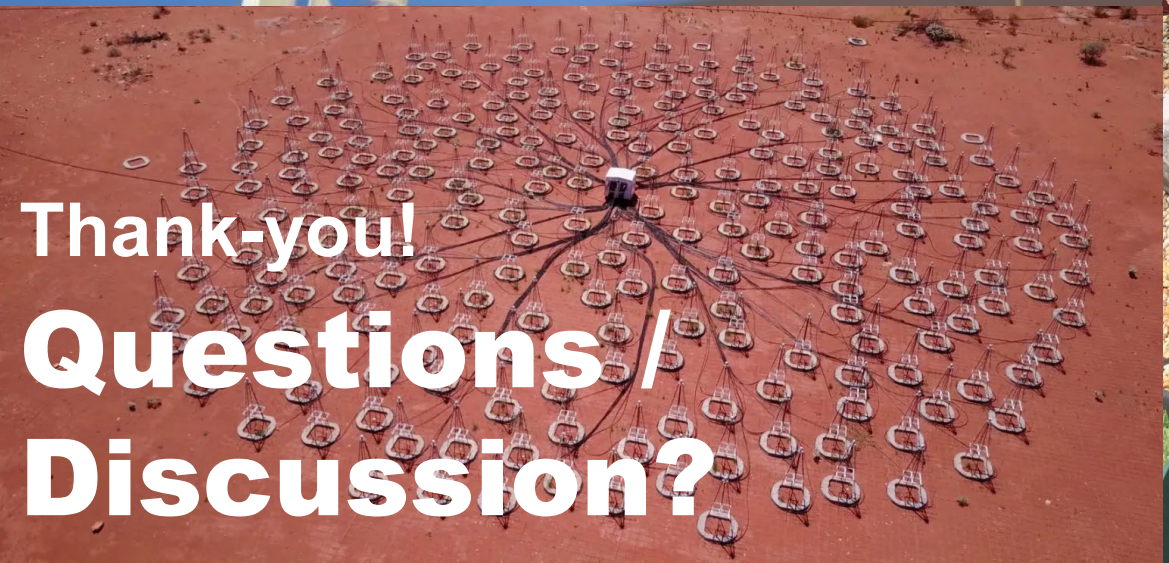
Station beamforming compute is a significant proportion of SKA1 Low computations

- **Being “onsite” compute efficiency is critical to lowering SKA Low future operating costs**
- **Bluering is such a solution**

Bluering RFSOC prototype is in development

- **FPGAs are in hand, PCBs in design stage**
- **Initial power measurements are very efficient**
- **Look forward to “blue” computing with RFSOC**





Thank-you!

Questions / Discussion?