

The Square Kilometer Array is Alive!

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K 
KAMPUTED



 **MulticoreWorldXIII** 2026

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Photo: SKAO/Max Alexander¹

About Me - William Kamp



KampUTED

Ph.D from the University of Canterbury

5 years at Endace building network monitoring

11 years on the SKA project.

Auckland University of Technology

National Research Council of Canada

Contracting as Kamputed



MulticoreWorldXIII 2028

SKAO

Square Kilometre Array Observatory

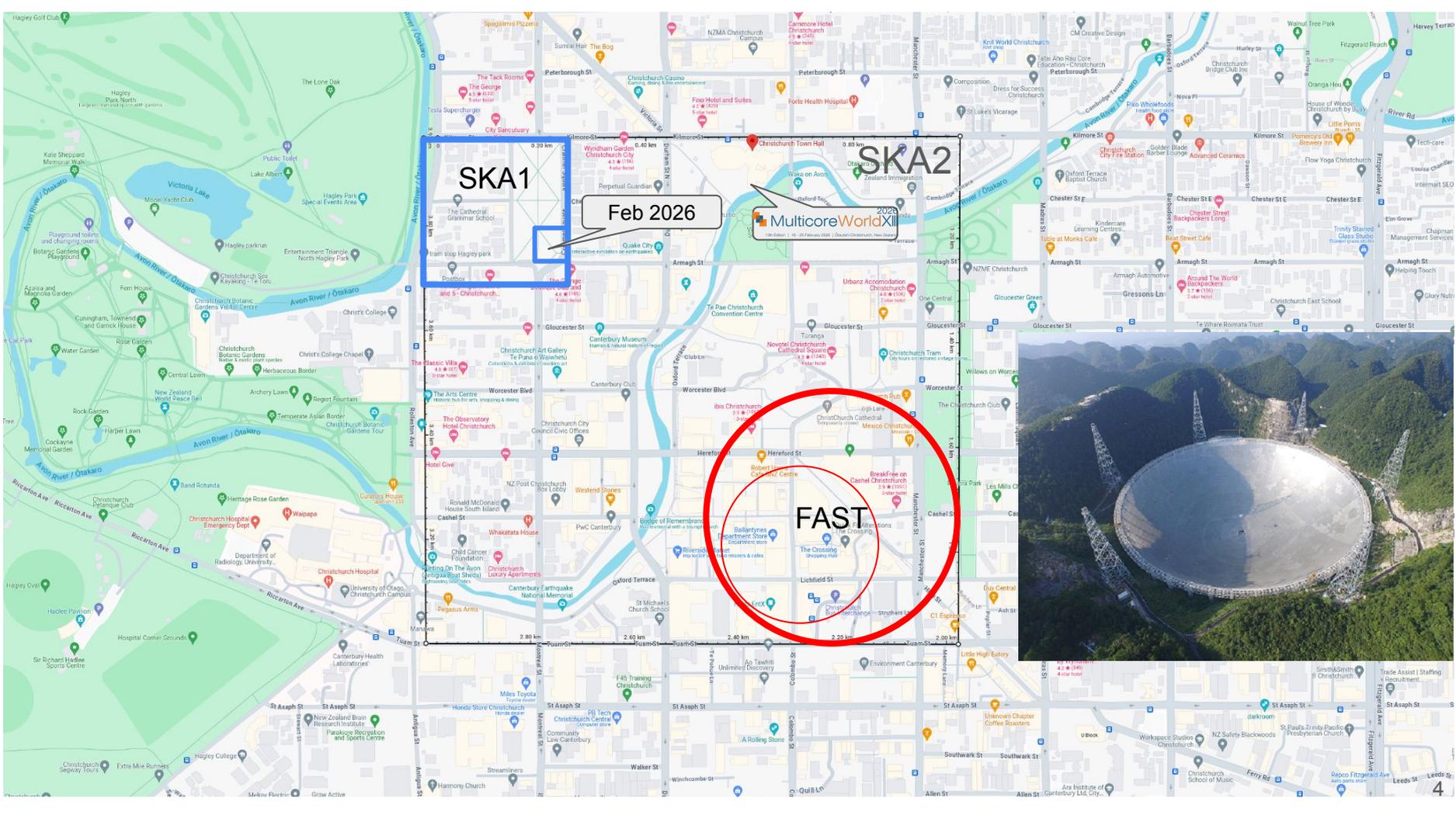
One Observatory, Two Radio Telescopes, Three Continents.

SKA1 - 10% of the million square meters.

700 million Euro budget.

SKA2 - The remaining 90%

Budget ???

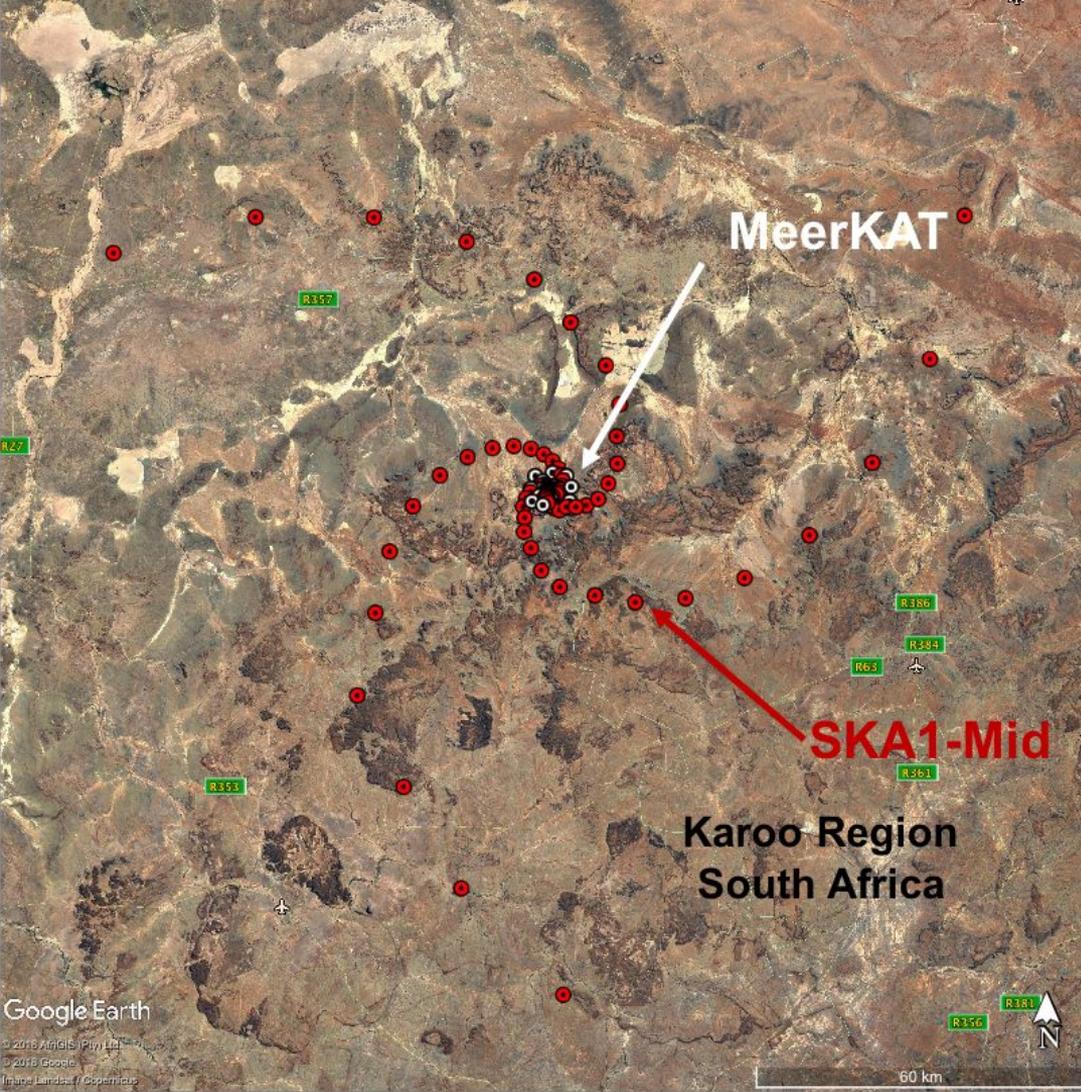


Feb 2026

MulticoreWorldXII

FAST





SKA1-Low the SKA's low-frequency telescope



Location: Australia



131,072
antennas, spread between
512 stations



Maximum baseline:
~65km



SKA1-Mid the SKA's mid-frequency telescope



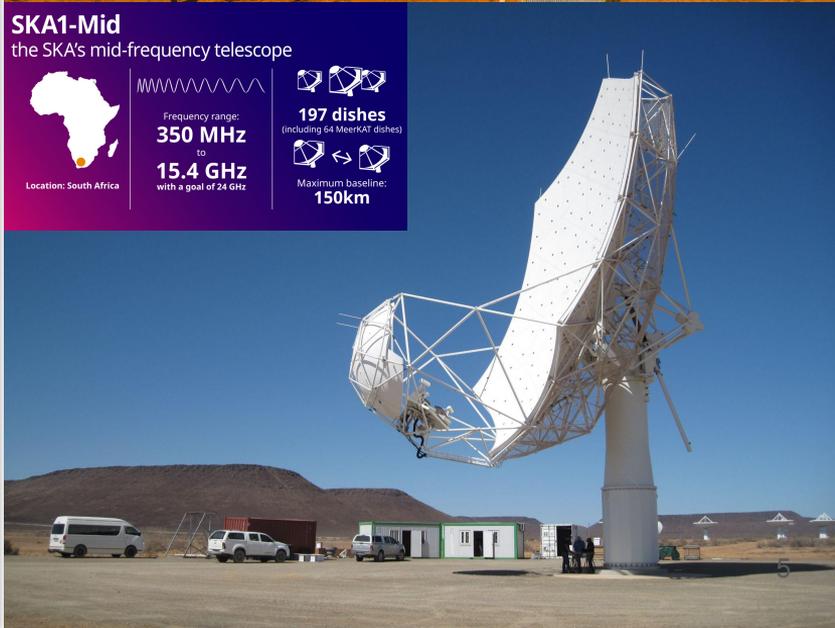
Location: South Africa

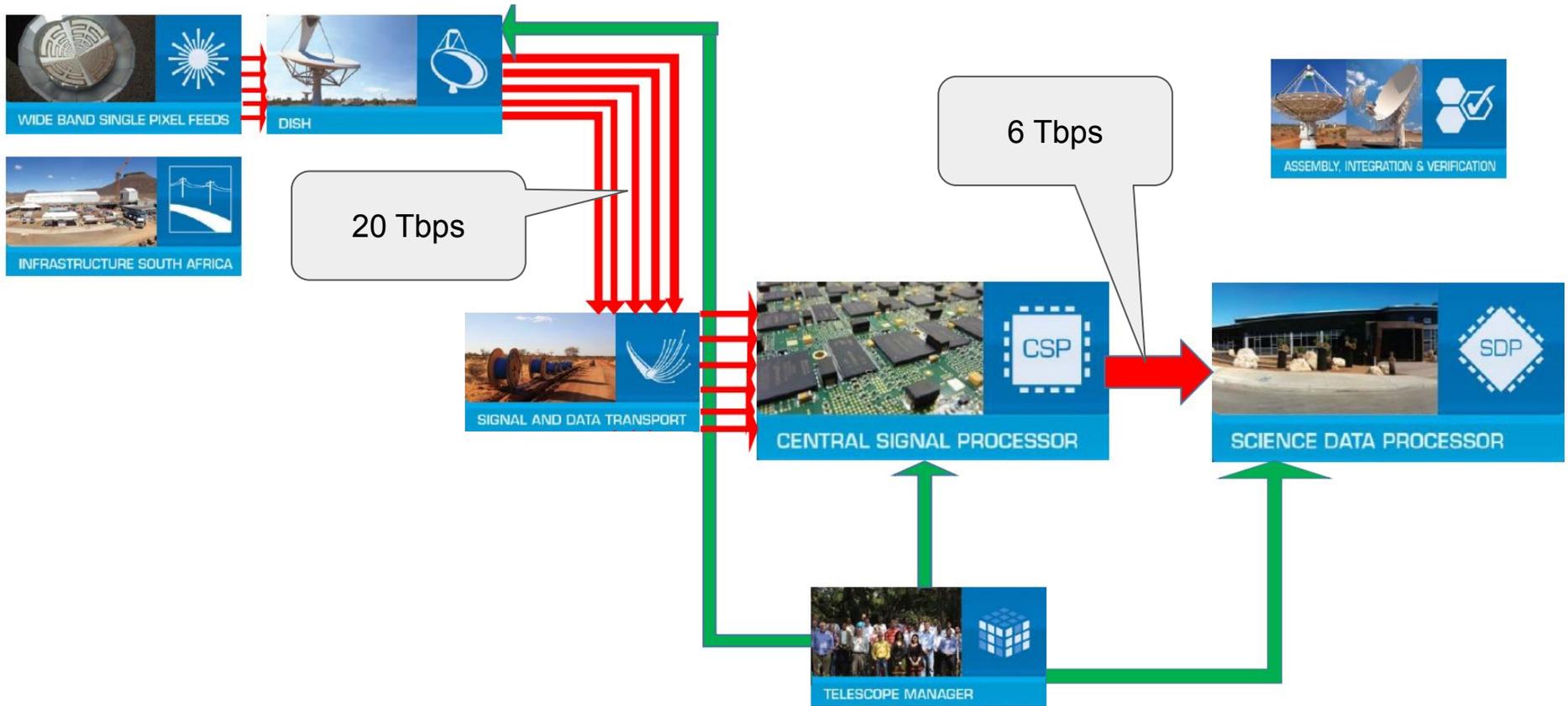


197 dishes
(including 64 MeerKAT dishes)

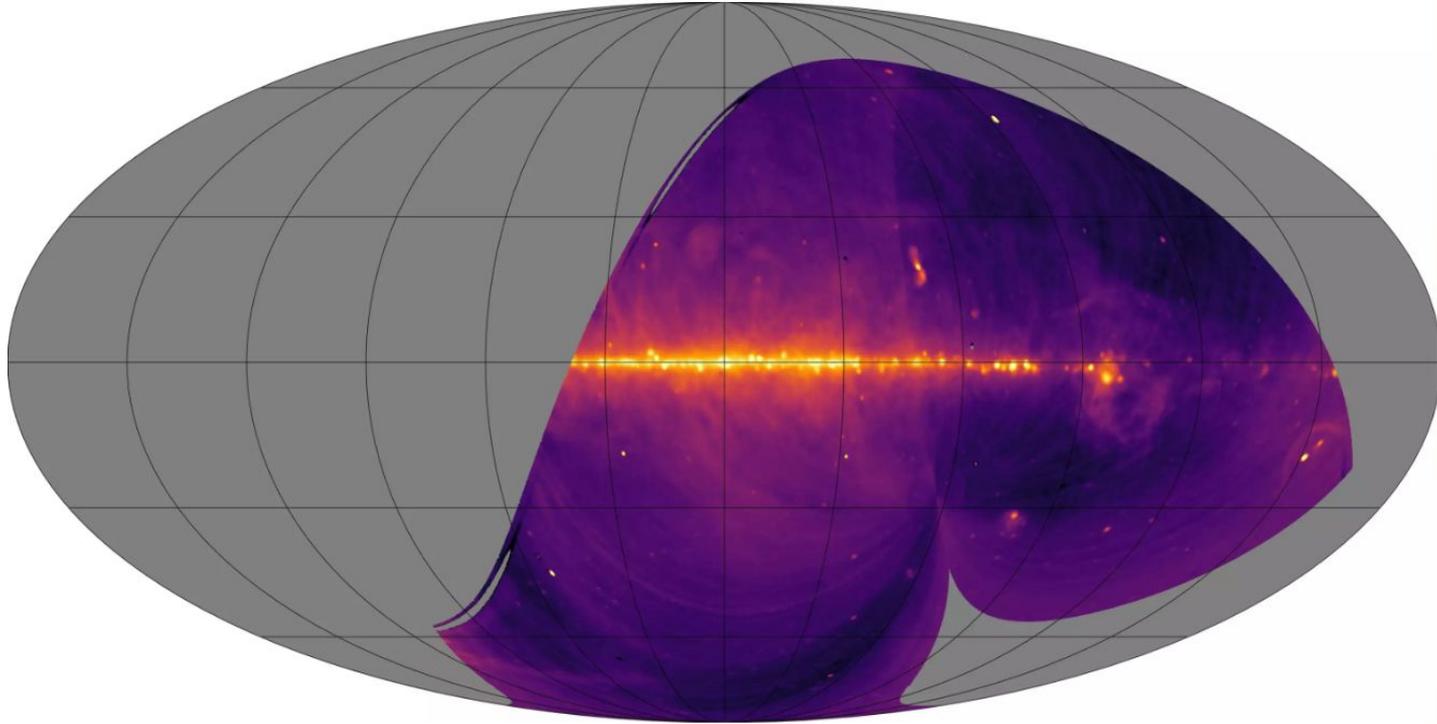


Maximum baseline:
150km



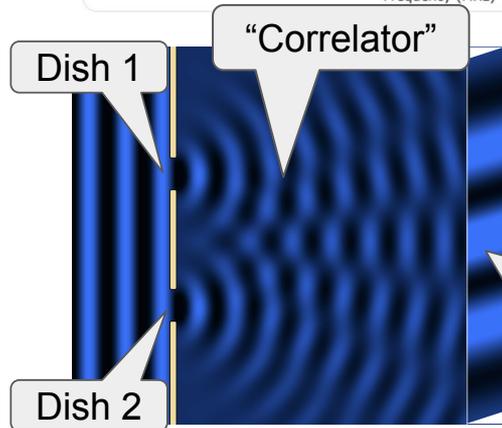
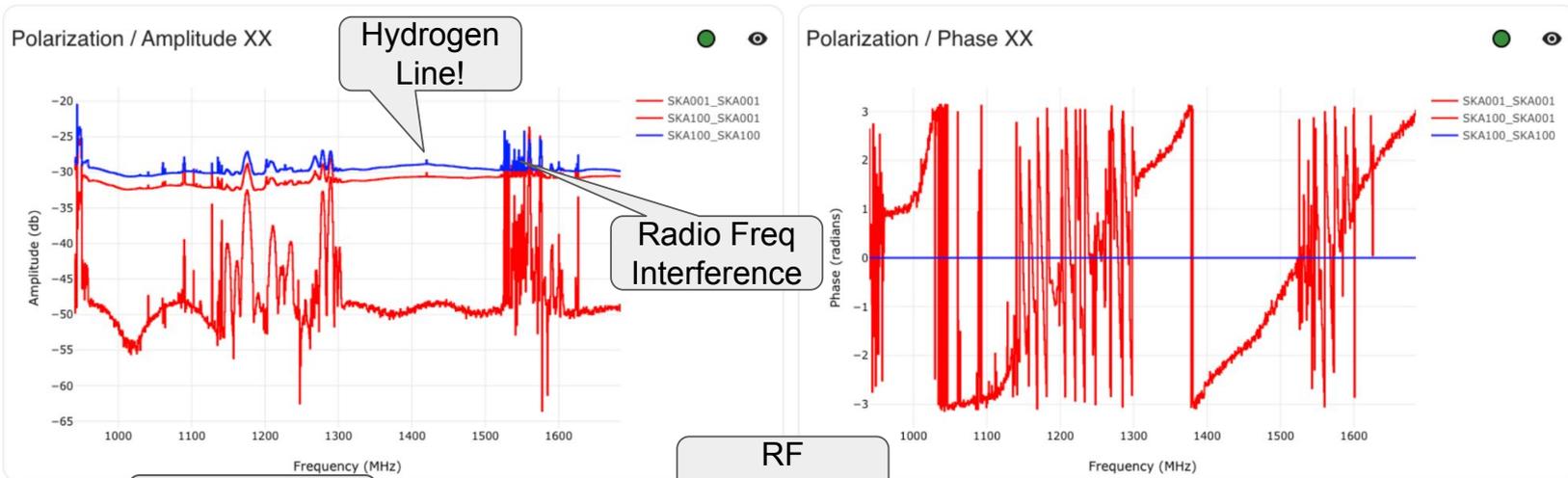


Single Dish - SKAMPI - Raster Scan- 2024



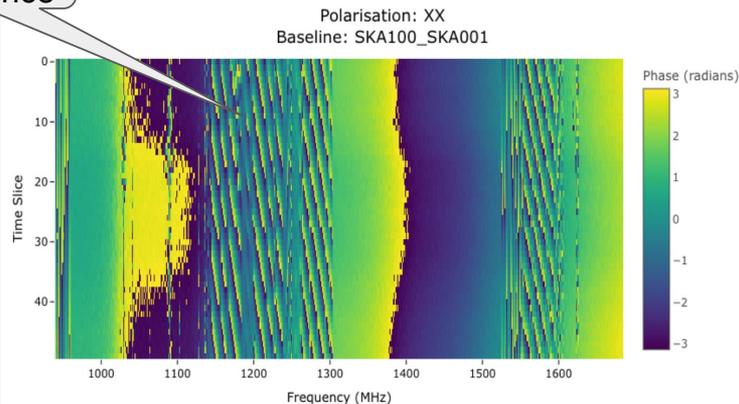
Above: First light SKAMPI image of the Southern Sky at 2.5 GHz wavelength. The frame (in grey) shows the complete sky in galactic coordinates with the Galactic centre in the middle. The false colour image shows radio emission from the part of the sky which is accessible to the telescope in South Africa. Besides radio emission from the Galactic centre (Sgr A), the bright radio galaxy Cen A, both Magellanic clouds and star forming areas in Orion and Vela show up in the image. **Credit:** SKAMPI Team

Two Receptors - First Correlation Fringes!



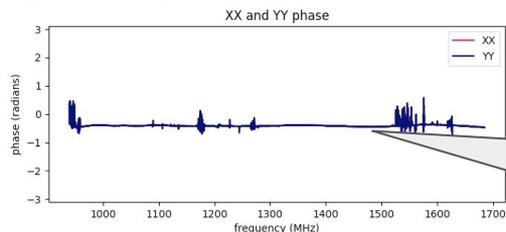
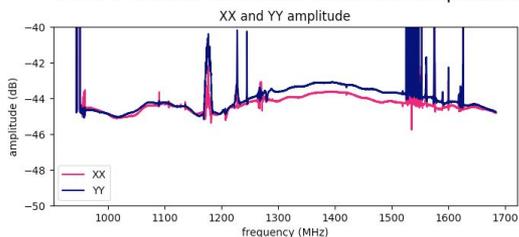
A “visibility” describes the magnitude and **phase** (position) of the interference pattern.

RF Interference

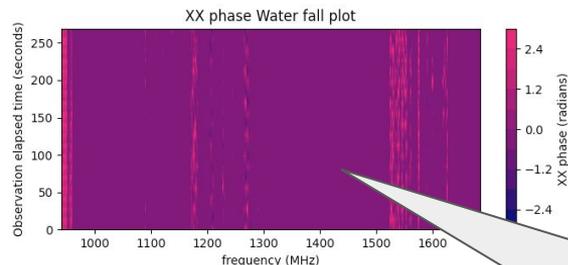
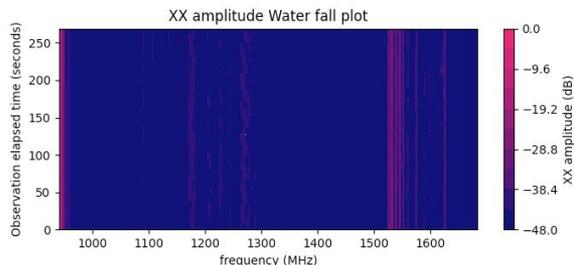


Two Receptors - Fringes Stopped (Delay Corrected)

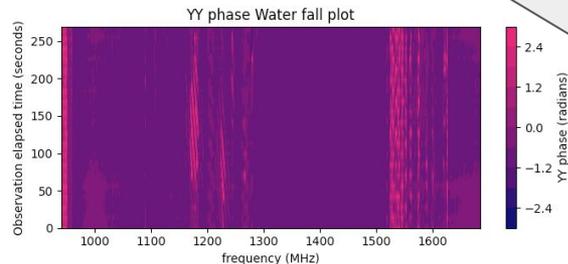
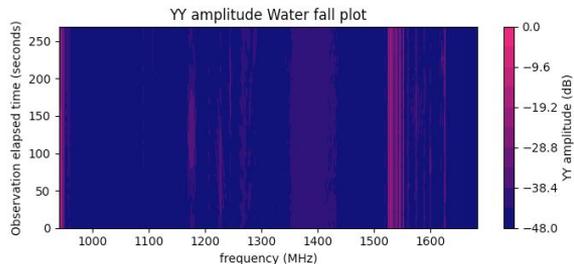
Band 2 SKA001-100 cross-correlation amplitude and phase toward J1939-634 on 5 December 2025



The phase is flat across the spectrum indicating zero residual delay



And phase is static across time showing delays are continuously corrected as the earth spins



“This source [J1939-634] has been well studied so we know what the signal should look like, and that’s what we observed with this first fringes result. It confirms that all our hardware and software systems are working as we designed them to do, giving us confidence as we begin to commission the telescope,”

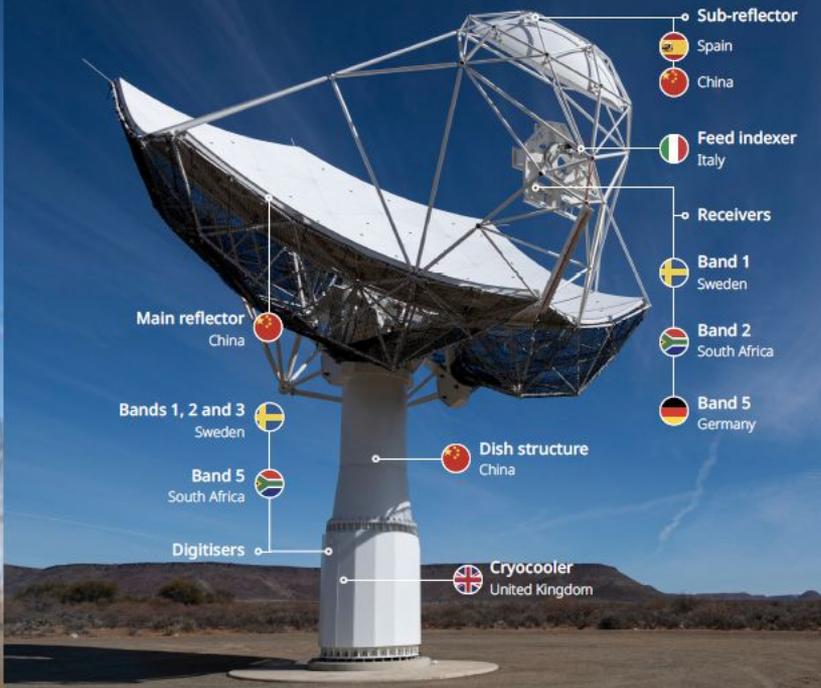
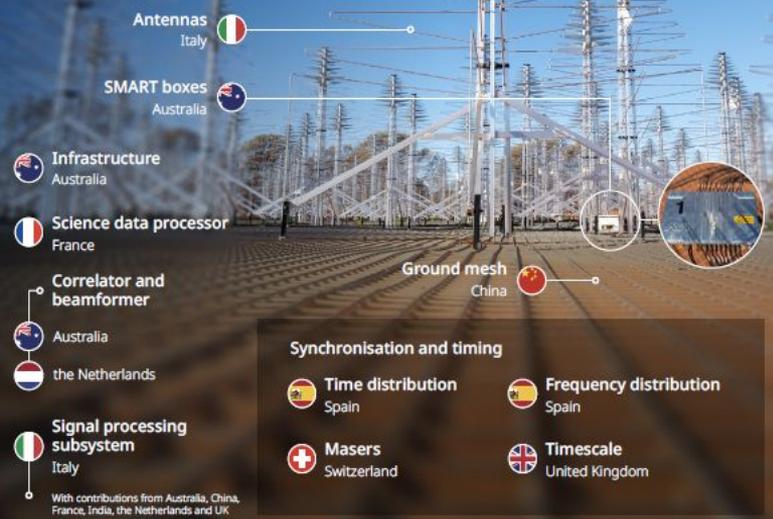
“That includes seeing that the *dishes can track* across the sky in a coordinated way under the control of the telescope manager software, the receivers are being *cooled to* the required temperature of *minus 250°C*, the synchronisation and timing system is *accurately timing signals* from the different dishes to a *billionth of a second*, and the correlator is correctly processing and *aligning the data.*”



Dr Betsey Adams, SKA-Mid Commissioning Scientist

Driving industrial innovation globally

Hardware and software for the SKA telescopes are being manufactured and developed across SKAO member states before being shipped to the telescope sites in Australia and South Africa. This global model leverages industrial expertise, fuels innovation and skills transfer, and spurs public-private partnerships. Above all, it reflects the strength of the collaboration at the heart of the SKAO, with thousands of people worldwide helping to deliver this groundbreaking facility.



Software, networks and computing
Resources from 30+ suppliers in 10 countries:

- Australia
- China
- France
- India

- Italy
- the Netherlands
- Portugal
- South Africa
- Switzerland
- United Kingdom

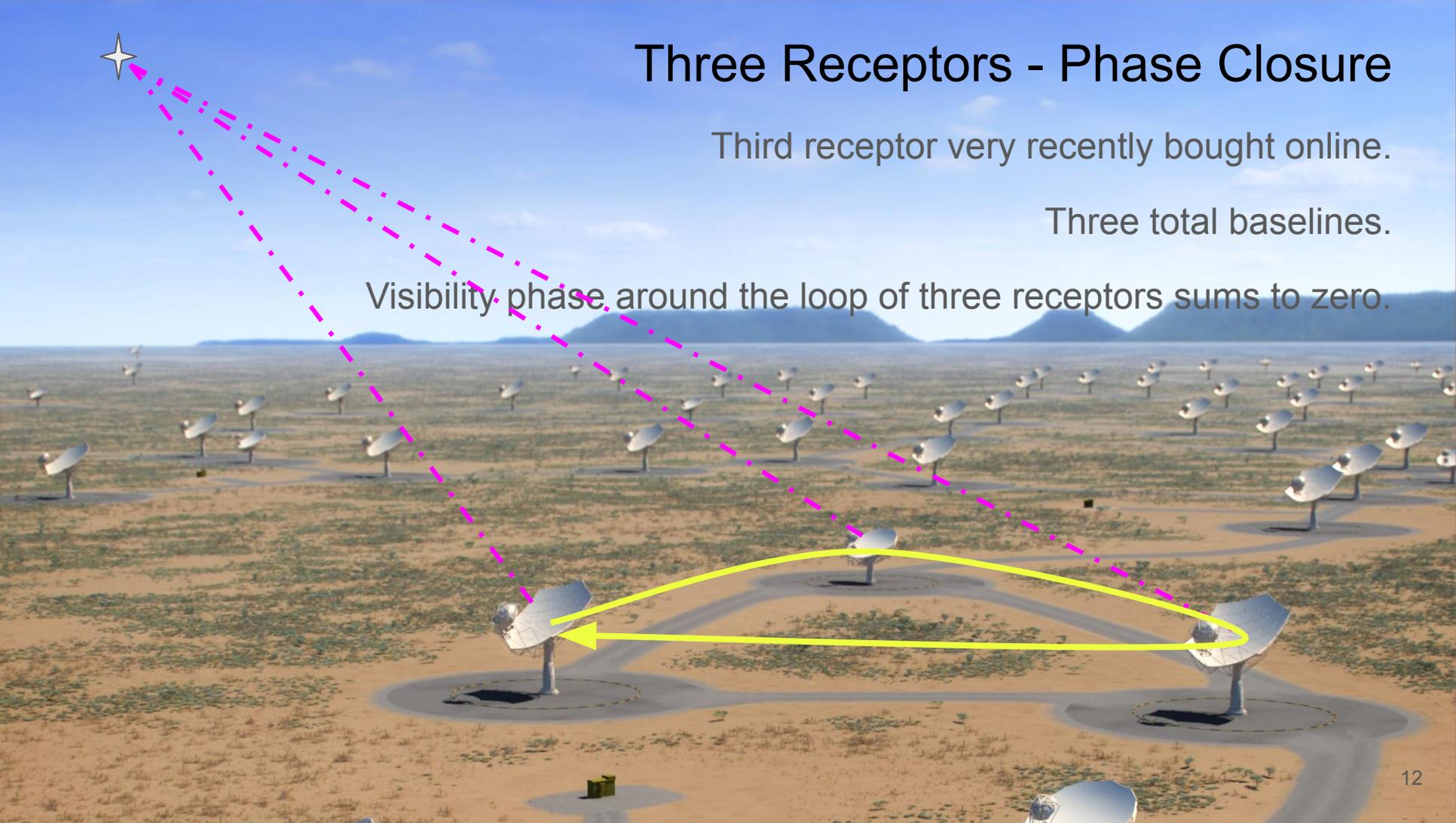


Three Receptors - Phase Closure

Third receptor very recently bought online.

Three total baselines.

Visibility phase around the loop of three receptors sums to zero.



An aerial photograph of an industrial construction site in a vast, arid desert landscape. The site features several large, white, rectangular buildings under construction, with some roofs partially completed. A network of dirt roads and access paths crisscrosses the site. In the background, rolling brown hills and mountains stretch across the horizon under a clear blue sky. The foreground is dominated by large, dark, rounded boulders and sparse, dry vegetation, suggesting a high-altitude or rocky terrain.

Great Achievement - a relief but not a surprise :wink:

A huge integration effort and a lot of individual component testing in the last year.

Four Receptors - Calibration & Imaging

Sufficient receptors to calibrate the telescope.

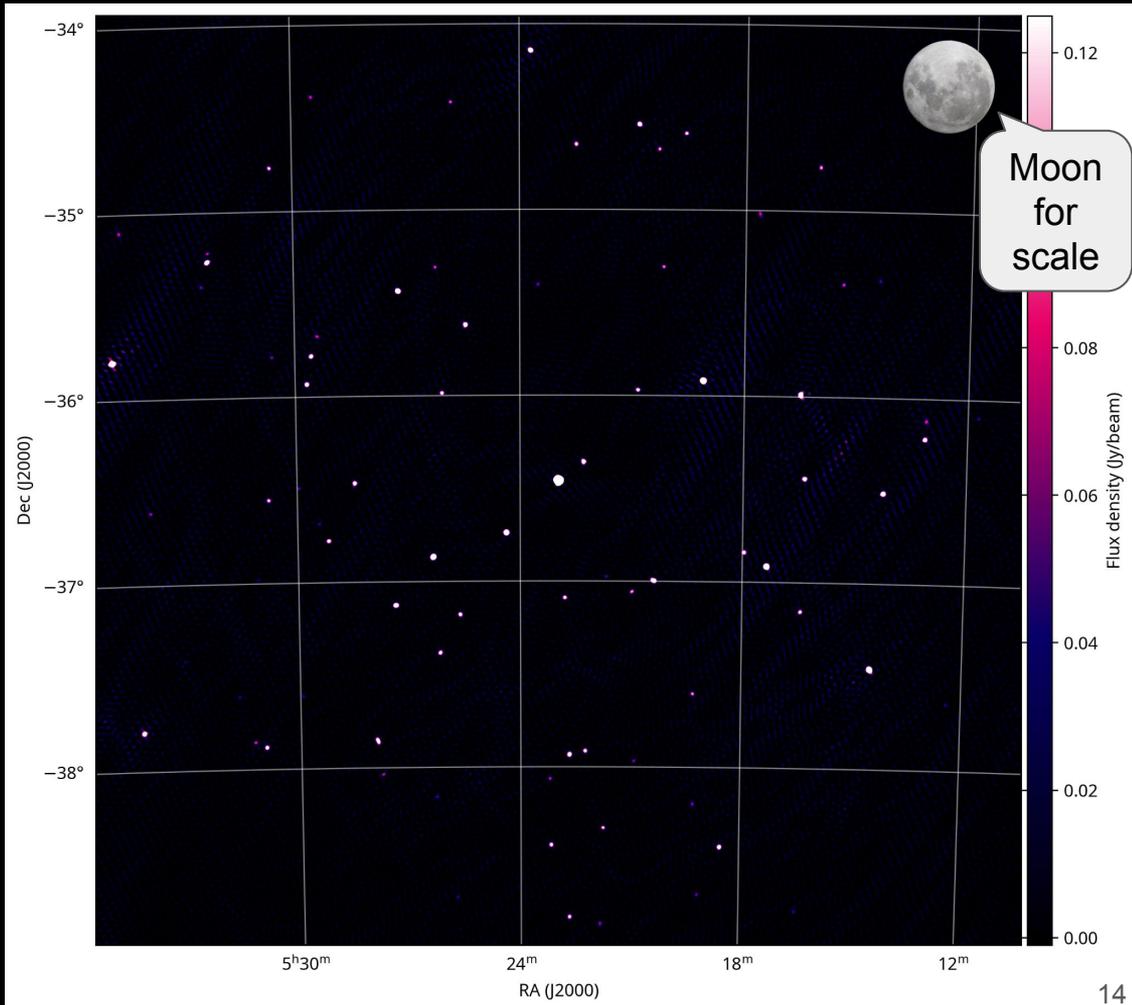
Allows for the first images to be generated.

SKA-Low achieved this milestone in mid 2025

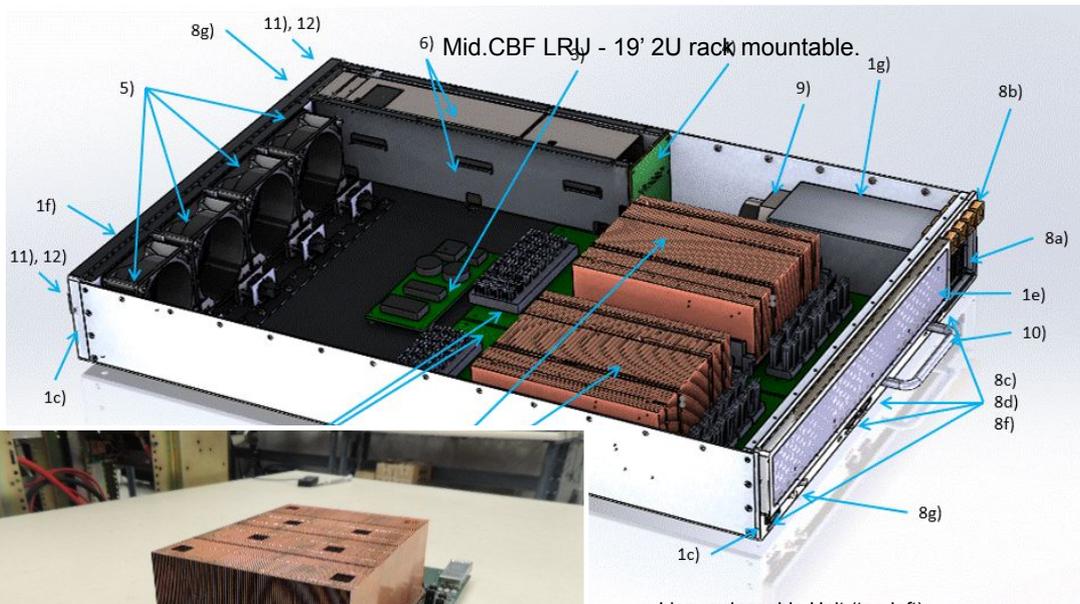
- 7 hour observation
- 85 radio galaxies detected

SKA-Mid will achieve this in early 2026.

- A narrower field of view.



Talon Demonstration Correlator - for up to 8 receptors

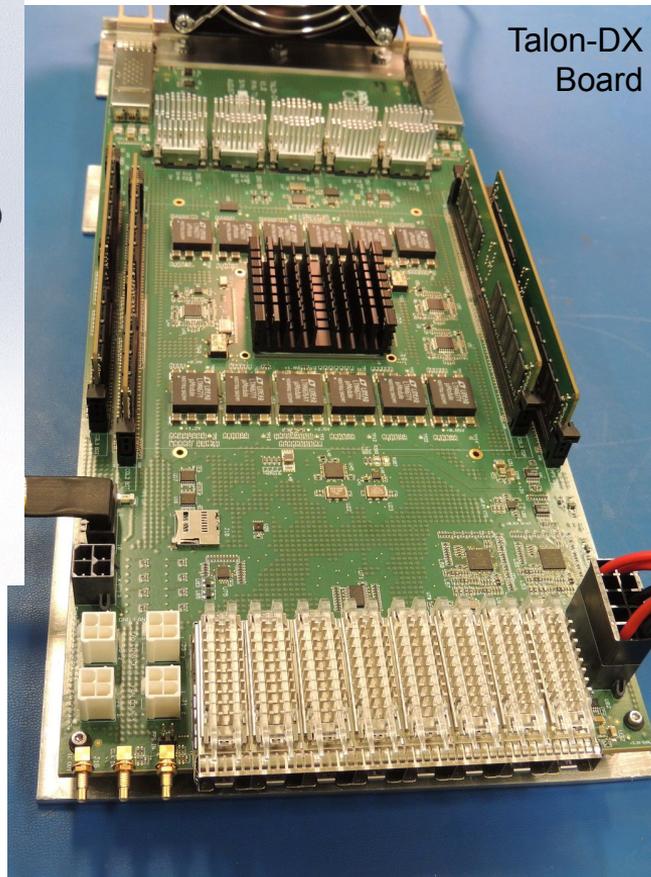


Line replaceable Unit (top-left)

- 2x Talon-DX boards, redundant AC power, fans, ... , all RFI sealed

Talon-DX Board (left)

- Intel Stratix 10 FPGA
- 4x DDR DIMMs, 256GB, 32GB, 32GB, 16GB (embedded CPU)
- Huge networking, upto 56x 25Gbps fibre links, + 2*100Gb Ethernet.



Beyond Eight Receptors - Correlator Redesign



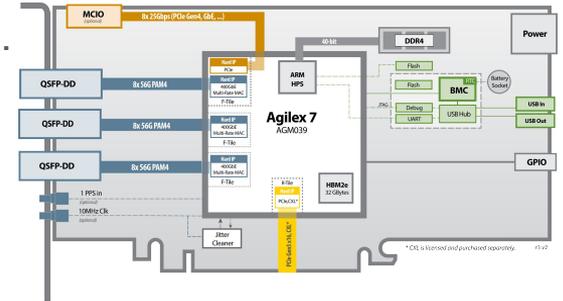
“Some” schedule drift.

Original design required a high technology readiness level to pass Critical Design Review.

That technology (Stratix 10 FPGA, DDR4 memory, 100GbE) is “old”.

Same algorithms and techniques, but with refreshed compute.

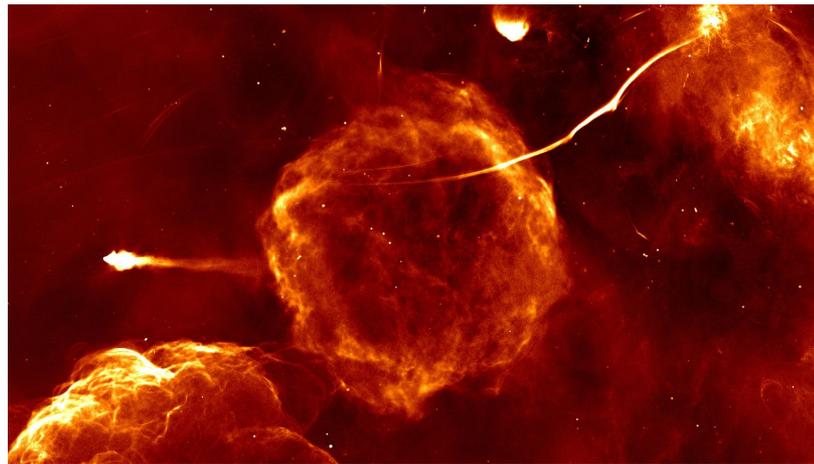
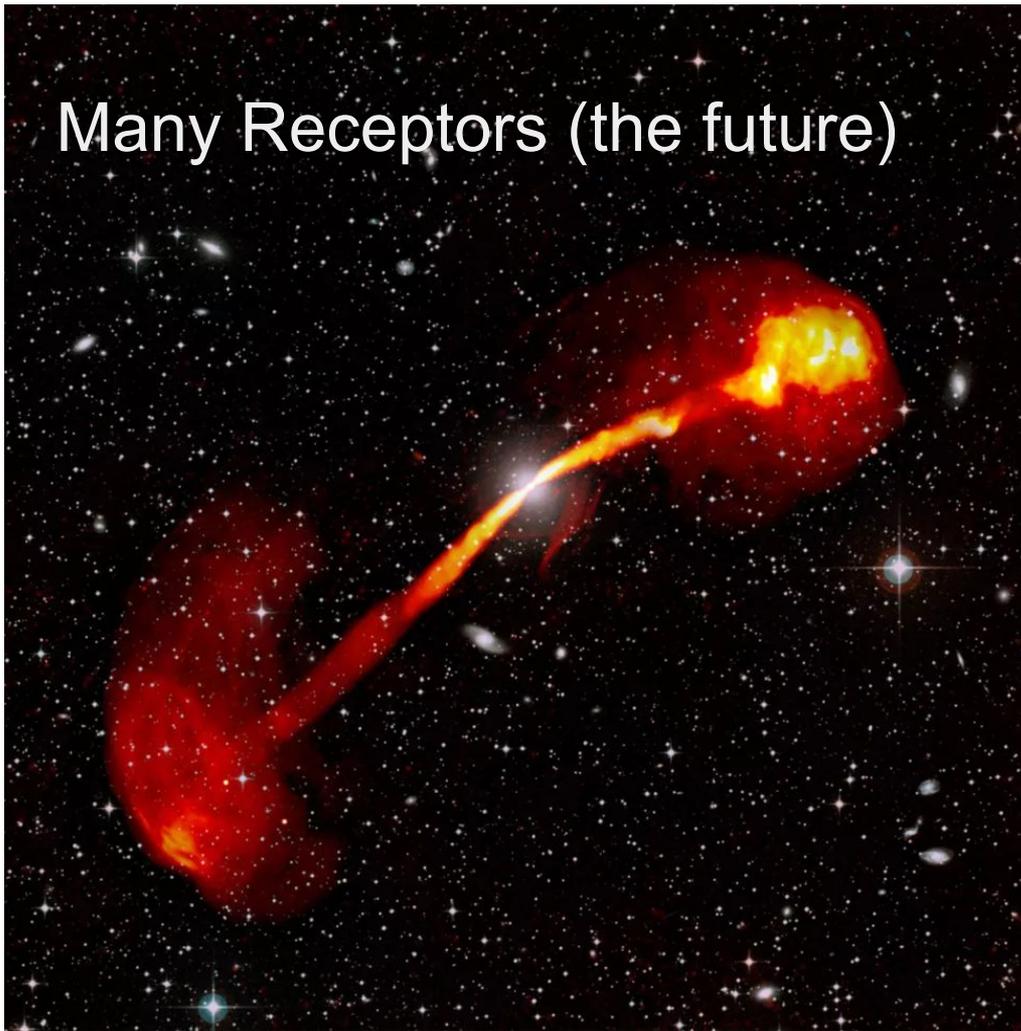
- Agilex7 FPGA in a PCIe Card form factor.
 - Embedded 400GbE MACs, 56Gbps PAM4 transceivers.
 - HBM2e (High Bandwidth Memory)
- COTS Server (TeraBox - from Bittware)
 - dual ia860m FPGA cards, and
 - 400GbE NIC
- 32-port 400GbE switches



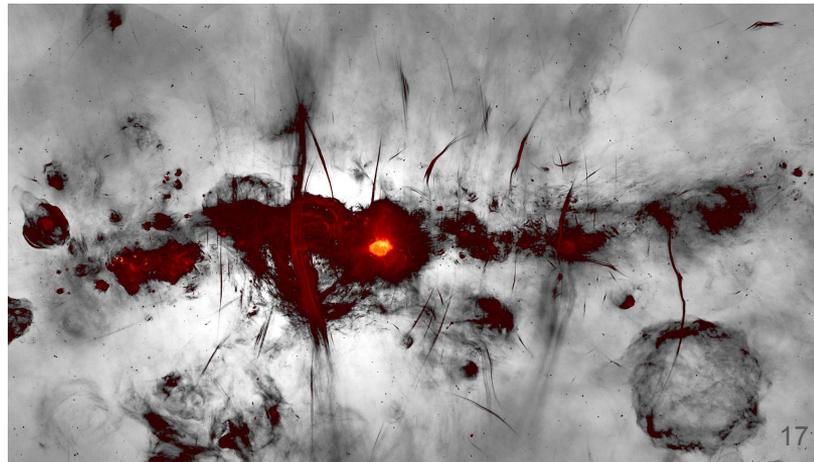
Better than double the density, and half the power.



Many Receptors (the future)

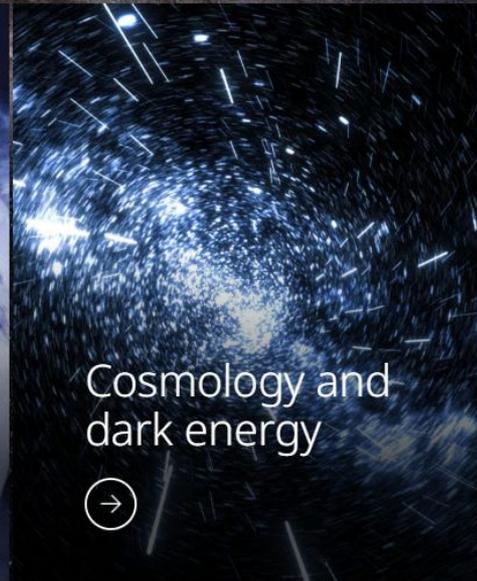
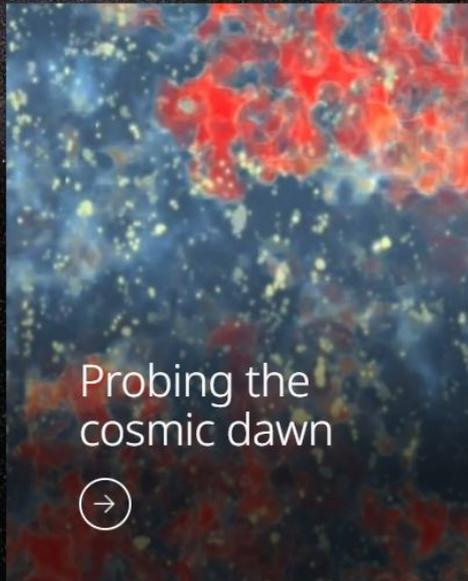


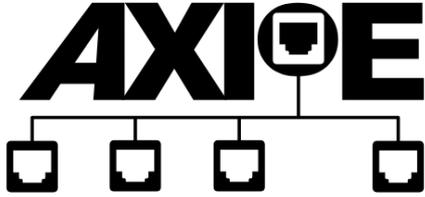
Reconstructed radio images from MeerKAT



Pushing the boundaries of science

The SKA telescopes will transform our understanding of the Universe, tackling some of the most fundamental scientific questions of our time.

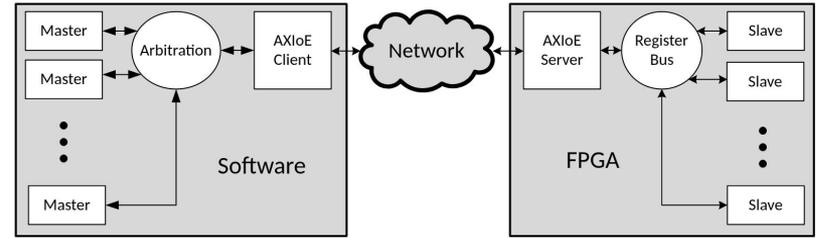




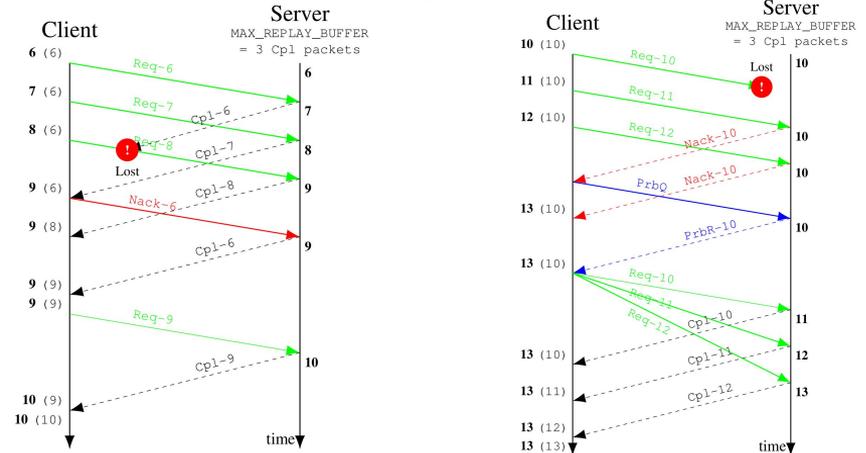
Memory Mapped Register access over Ethernet

- Reliable like TCP
 - In-order execution
- Asymmetric unlike TCP
 - Simple server on FPGA
 - Error recovery at the client
- High-performance
 - Many transactions in flight
 - Conditional Execution

W. Kamp,
 "AXI over Ethernet; a protocol for the monitoring and control of FPGA clusters,"
 2017 International Conference on Field Programmable Technology (ICFPT),
 doi: 10.1109/FPT.2017.8280120.



Asymmetric Sliding Window Protocol



<https://gitlab.com/axioe>

AXIoE in the Wild



Accelerating Innovation in 6G Research: Real-Time Capable SDR System Architecture for Rapid Prototyping

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M. Engelhardt et al.: Accelerating Innovation in 6G Research: Real-Time Capable SDR System Architecture

IEEE Access

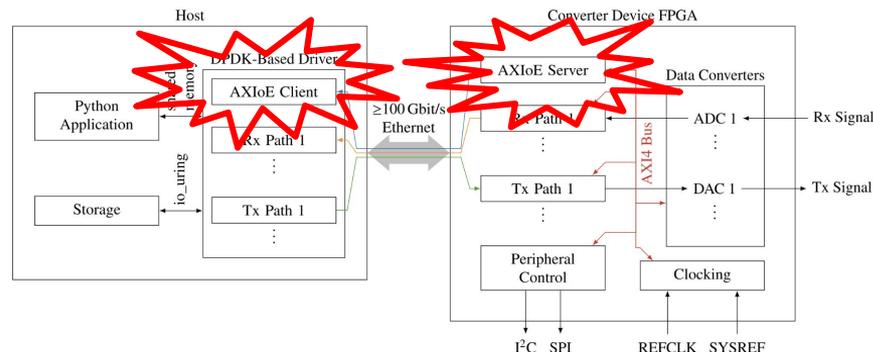


FIGURE 1. Overview of our system architecture, consisting of the converter device, which is operated by a driver software on the host computer via one or multiple high-speed Ethernet links. Its generic design allows for adaption and exchange of hardware components and high-speed data interface. This allows to achieve the individually desired performance parameters without requiring changes to the architecture. Encapsulation of base features in an abstraction layer on the host allows for interfacing with the system via the high-level scripting language Python.



in the Wild

Quantum Computer Manufacturer

- Controlling arbitrary waveform generator FPGAs

Reusable Rocket Company

- Rocket Science ;-)

IOT Device Developer

- Light-weight, low-energy, device control

Symbolically Addressable DRAM

- I know a guy (next up after lunch)

After work - Sailing, Brewing, and Hockey



Question time

