I would like to begin by acknowledging the Traditional Owners of the lands that we host our facilities on across Australia, and pay my respect to their elders past and present.

Australia's Indigenous people are our first astronomers and have long standing knowledge of the Universe that we continue to build on today.

Introducing “CNIC” Enabling SKA Low Realtime In-System Testing

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CSIRO

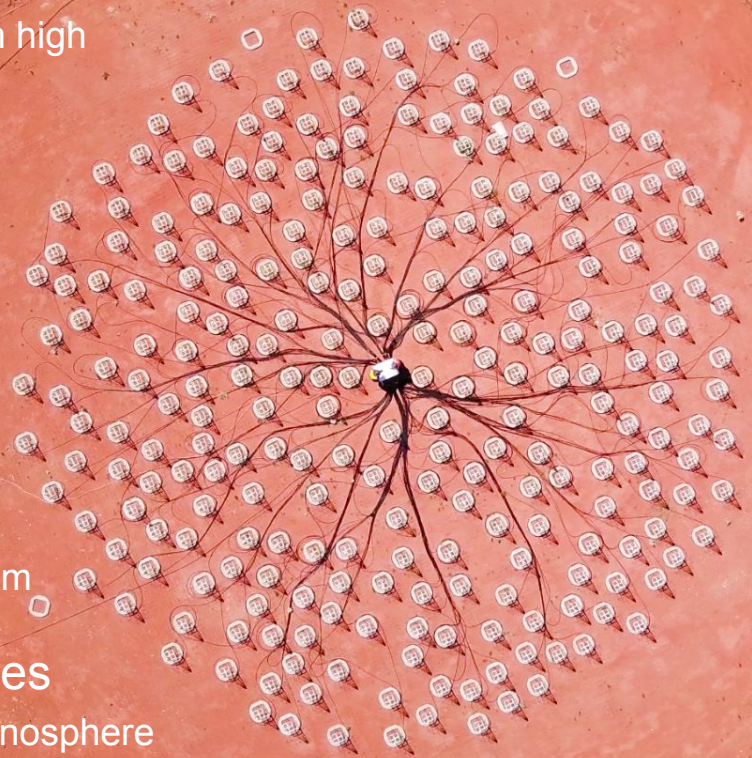
All good tales start with lizard walking by a telescope, but not just any telescope …

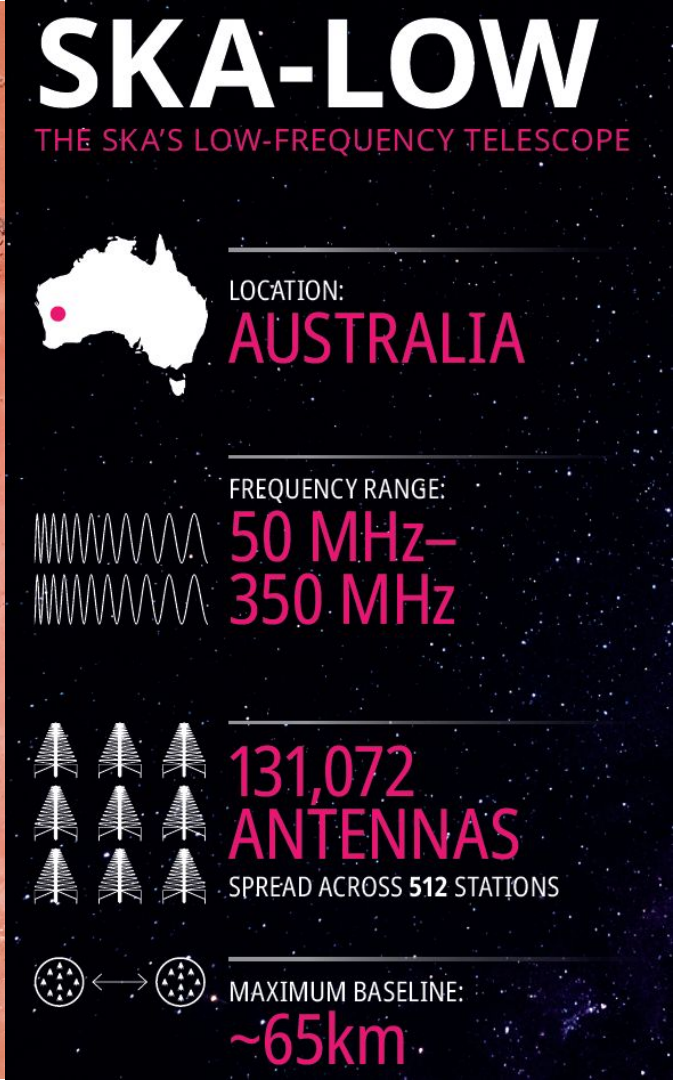
https://twitter.com/SKA_Australia/status/1361179178322681857 Pic: @ICRAR/@CurtinUni

The SKA-Low telescope, soon to begin construction at Inyarrimanha Ilgari Bundara, the CSIRO Murchison Radio-astronomy Observatory, on Wajarri Country in Western Australia

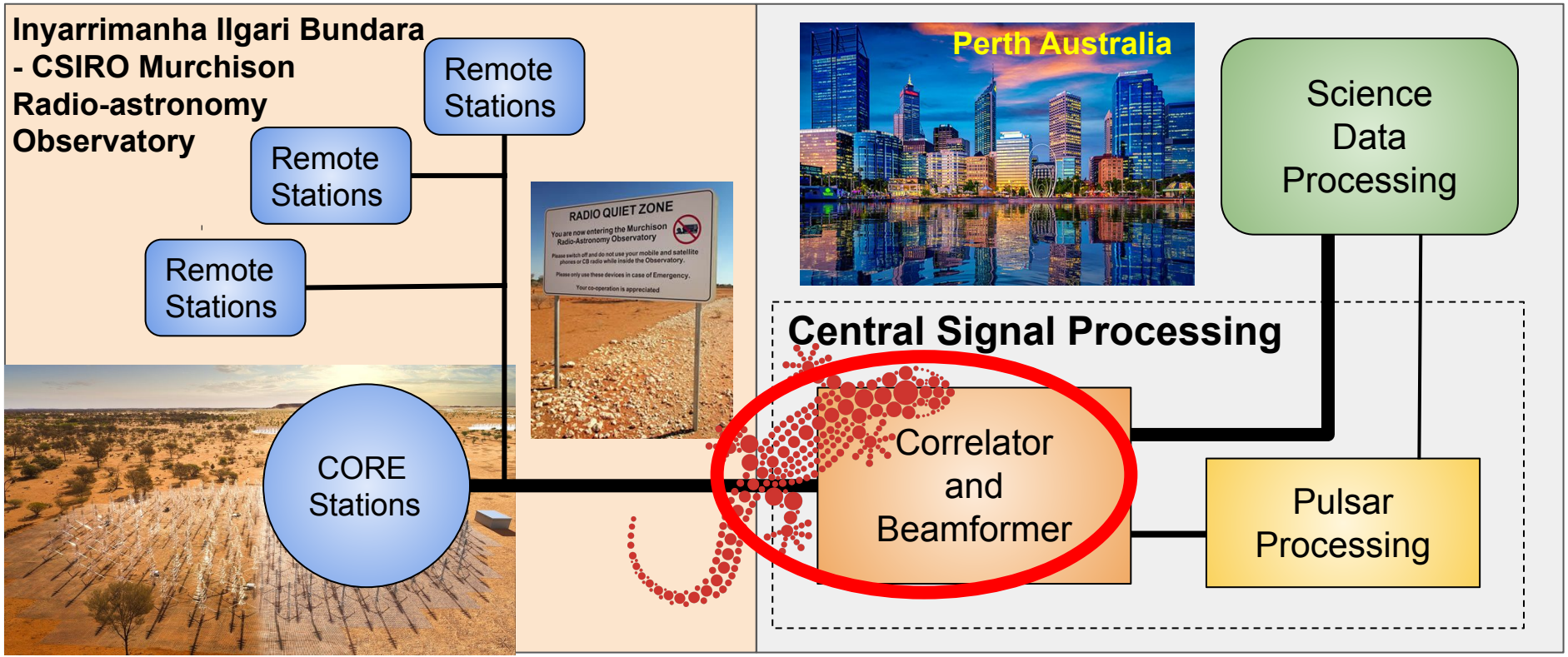
All Sky Field of View

- ~VHF signals
  - Wavelength 1 to 6 metres
  - Antenna is ~2m high
- Bandwidth not a challenge … but 256k signal paths is!
- Can see the whole sky simultaneously
  - Digital multibeam steering
- Further challenges
  - Interference, ionosphere
  - Thousands of instrument configurations



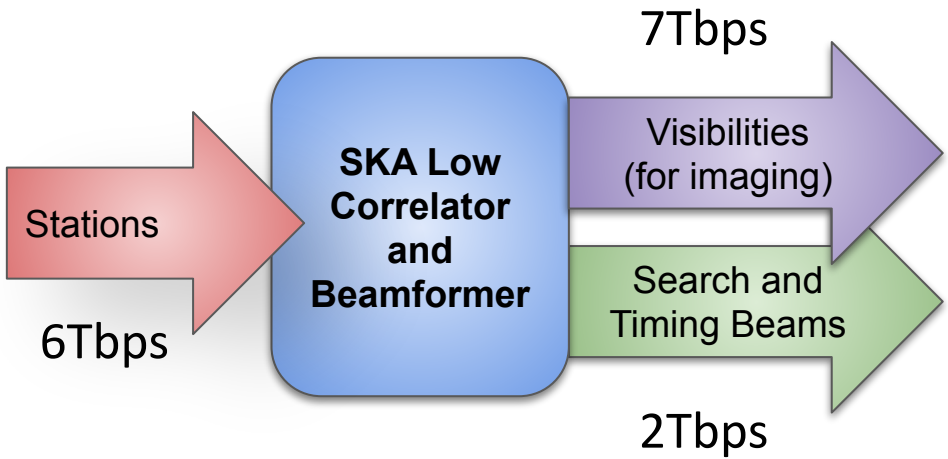


This work is done as part of the SKA Low Correlator and Beamformer



Perentie is massive “in-network” processing System

- Up to 512 stations @ 300MHz
- Multiple simultaneous station beams
- Can divide stations into many smaller “substations”



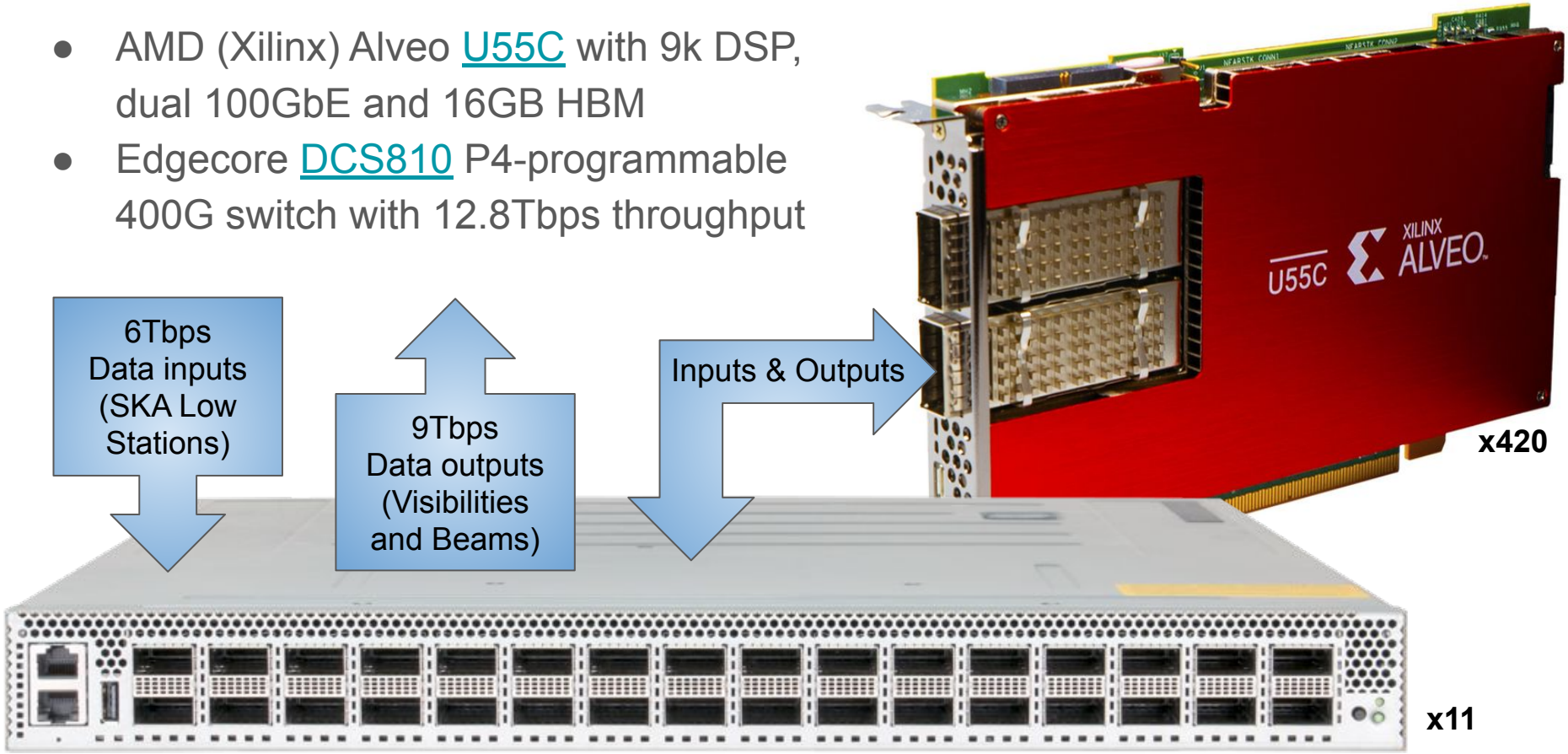
- 16 independent Subarrays
- Standard 5.4kHz and Zooms to 14Hz
- Integration time 0.28 to 0.85 seconds
- 16 Timing beams 300MHz
- 500 Search beams 118MHz

SKA is more than just achieving functionality

How to test Tbps?

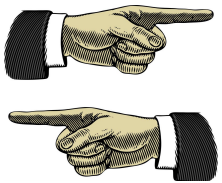
SKA Low Correlator and Beamformer Building Blocks

- AMD (Xilinx) Alveo U55C with 9k DSP, dual 100GbE and 16GB HBM
- Edgecore DCS810 P4-programmable 400G switch with 12.8Tbps throughput

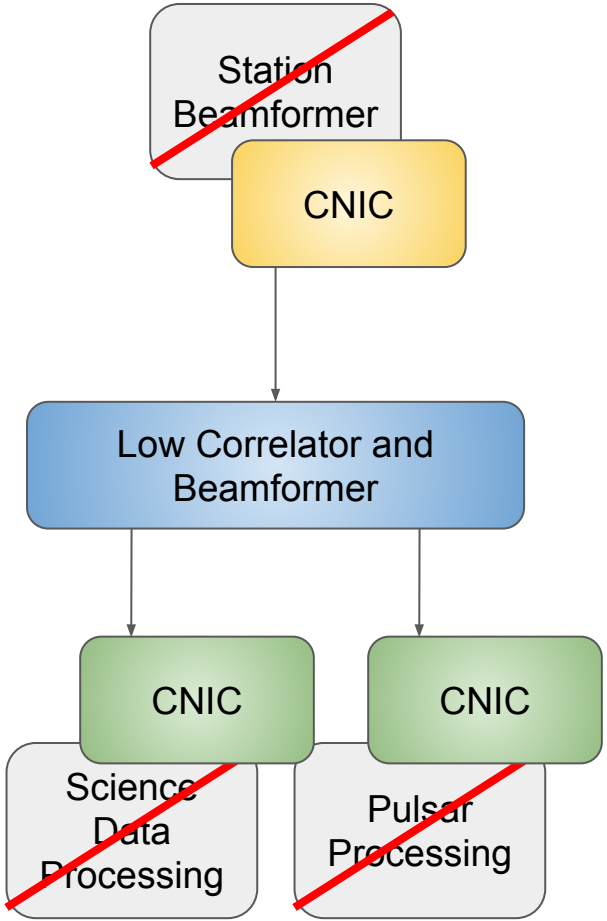


SKA Low Construction and “how to test?”

- SKA Low is divided into a number of construction phases
  - About one Array Assembly per year
- We need a way to verify our designs before other product teams are ready or able to provide interfaces
  - Independent testing before integration testing
  - Saves blaming each other, and waiting for each other
- “CNIC” temporarily assumes the place of those final products
  - It can be a data “source” as well as a “sink”

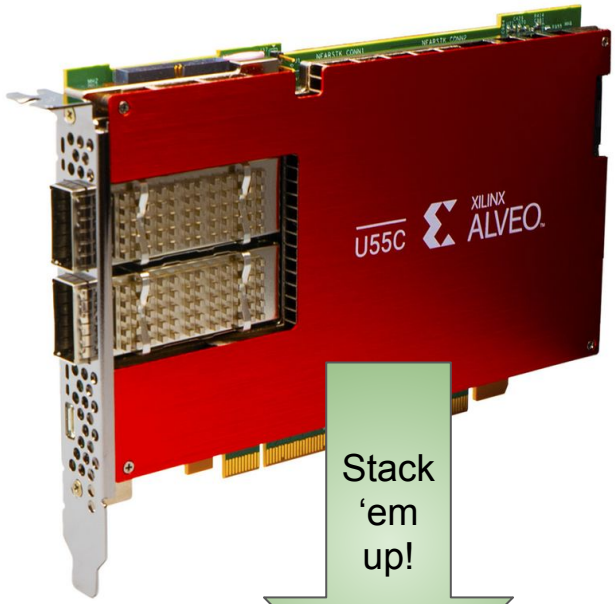


It’s your fault, no it’s yours



What is CNIC?

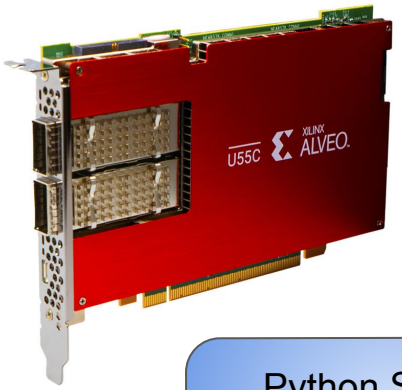
- Firstly, NIC = Network Interface Card
  - Typically used to connect a server to a network
- “C” can mean many things!
  - CSIRO, 100G, 100%, Customisable, etc.
- The key here is customisable!
  - Make it do what the tests require it do
  - Don’t design a test around testgear limitations
- For the Alveo U55C it’s
  - 100GbE transmitter or receiver
  - Hardware assured transmission timing
  - 16GB HBM buffer for storing Ethernet packets
  - PTP timestamping of received packets
  - PTP synchronization across many CNICs

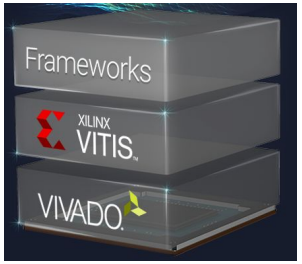


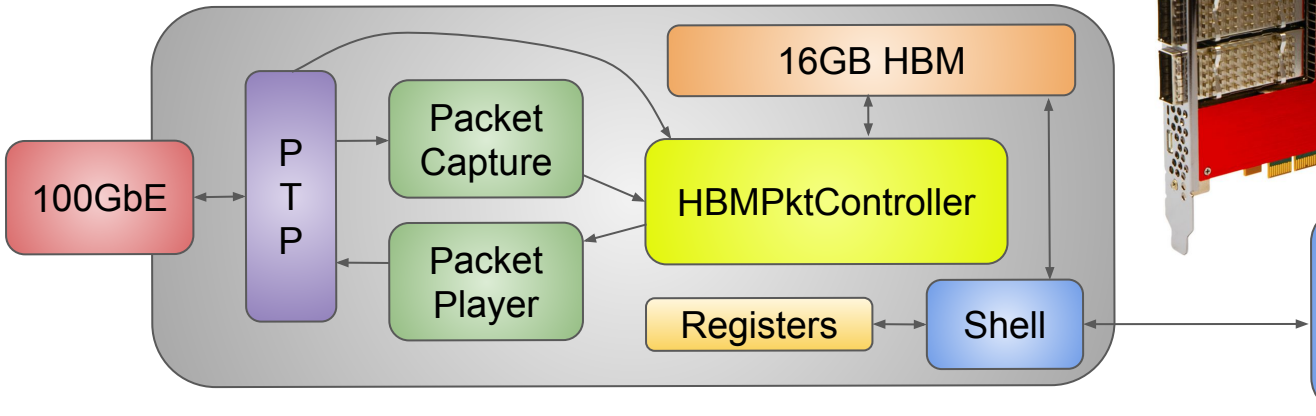
Stack ‘em up!

The Alveo Customisable-NIC

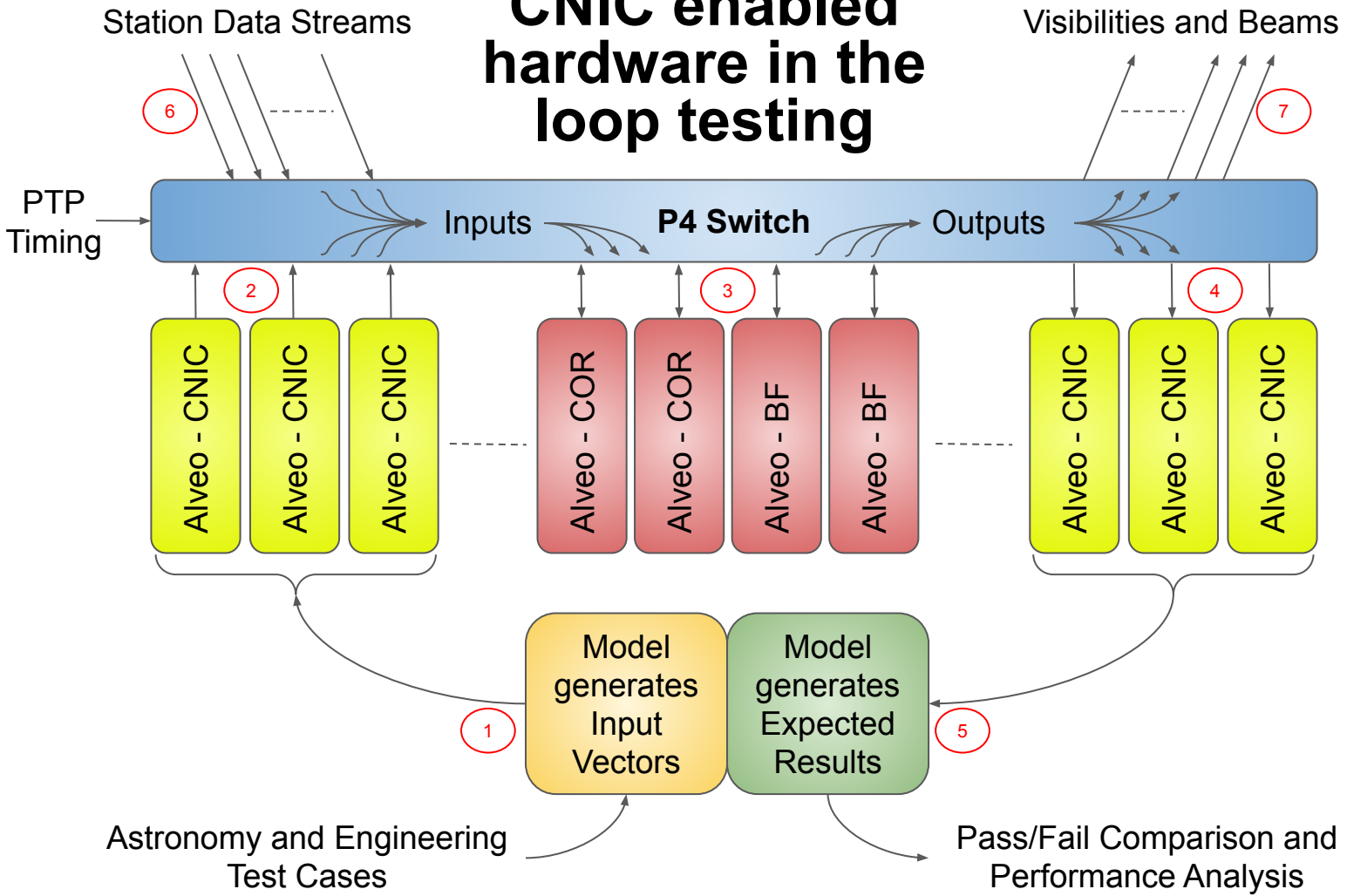
- Any Alveo in the SKA system can change “personality” from a beamformer or Correlator into a CNIC
  - So a processing system morphs into a test system in less than a minute with no hardware changes
- Relatively “simple” design based heavily off existing IP
  - Essentially added a packet controller and software to control it
  - Uses PTP Timeslave IP from AtomicRules for timing







CNIC enabled hardware in the loop testing



CNIC Features

- Customisable to your system
- Independent of server bottlenecks and OS
- Never drops a packet
- Can have as many Alveo as you like
  - Can arrange in serial and/or parallel
- The test hardware can be processing hardware
- PTP timestamps on packets in
- PTP time sync to control data rate
- Programmable data rates up to 100% linerate
- Can loop the buffer infinitely
  - incrementing packet fields as required

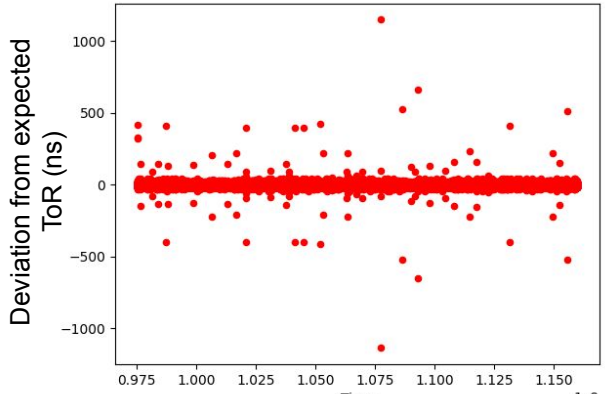
CNIC Future

- Not simultaneously bidirectional
  - (but could be)
- Not streaming to/from disk
  - (but could be)
- Future support for Alveo U280 and Versal

Further customisation is possible - limited by "need" and time

Example CNIC to CNIC transfer

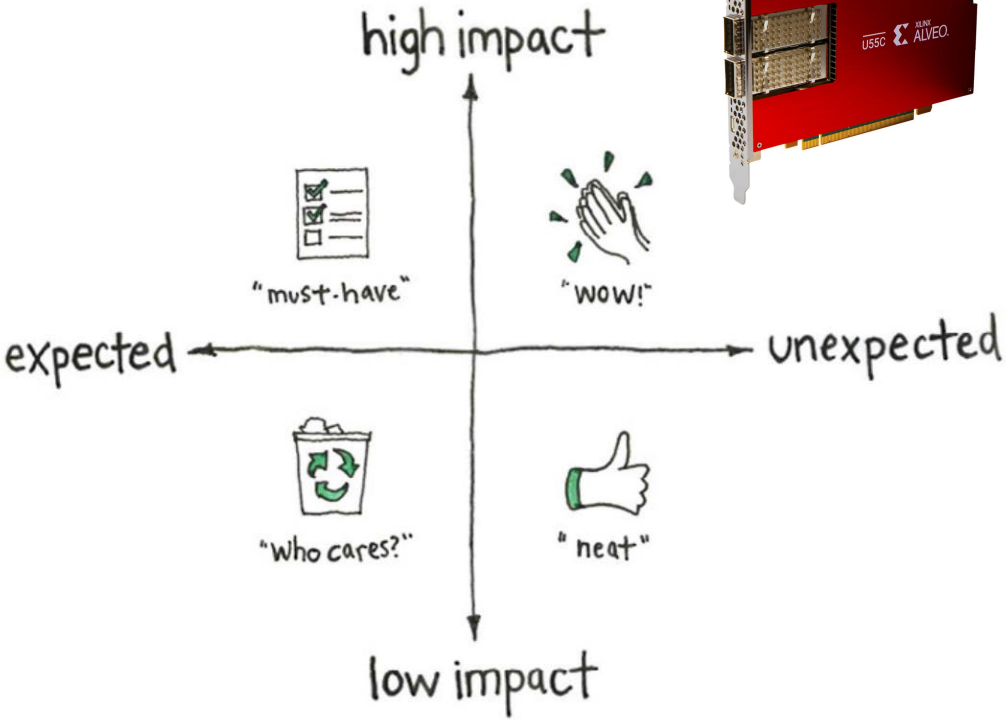
- Transmission of test SPEAD PCAP file, 1.4GBytes, 166346 packets, 8306 Bytes per packet
- CNIC transmit set at 60Gbps
- Data passes through the P4 switch
- Receiver captures packets as well as the PTP time-of-arrival for each packet
  - In general about a ±25ns spread
  - Some outliers due to the P4 switch latency and HBM cache fetching memory (under investigation)



No.	Time	Source	Destination	Protocol	Length	Info
1	2022-08-25 02:05:00.000003053	10.5.10.2	10.0.10.100	UDP	8306	61648
2	2022-08-25 02:05:00.000003718	10.5.10.2	10.0.10.100	UDP	8306	61648
3	2022-08-25 02:05:00.000004524	10.5.10.2	10.0.10.100	UDP	8306	61648
4	2022-08-25 02:05:00.000005189	10.5.10.2	10.0.10.100	UDP	8306	61648
5	2022-08-25 02:05:00.000005858	10.5.10.2	10.0.10.100	UDP	8306	61648
6	2022-08-25 02:05:00.000006522	10.5.10.2	10.0.10.100	UDP	8306	61648
7	2022-08-25 02:05:00.000007188	10.5.10.2	10.0.10.100	UDP	8306	61648
8	2022-08-25 02:05:00.000007852	10.5.10.2	10.0.10.100	UDP	8306	61648
9	2022-08-25 02:05:00.000008518	10.5.10.2	10.0.10.100	UDP	8306	61648
10	2022-08-25 02:05:00.000009185	10.5.10.2	10.0.10.100	UDP	8306	61648
11	2022-08-25 02:05:00.000009851	10.5.10.2	10.0.10.100	UDP	8306	61648
12	2022-08-25 02:05:00.000010515	10.5.10.2	10.0.10.100	UDP	8306	61648
13	2022-08-25 02:05:00.000011181	10.5.10.2	10.0.10.100	UDP	8306	61648
14	2022-08-25 02:05:00.000011845	10.5.10.2	10.0.10.100	UDP	8306	61648
15	2022-08-25 02:05:00.000012524	10.5.10.2	10.0.10.100	UDP	8306	61648
16	2022-08-25 02:05:00.000013190	10.5.10.2	10.0.10.100	UDP	8306	61648
17	2022-08-25 02:05:00.000013854	10.5.10.2	10.0.10.100	UDP	8306	61648
18	2022-08-25 02:05:00.000014523	10.5.10.2	10.0.10.100	UDP	8306	61648

Customisable-NIC Summary

- It's always great when there is a high impact byproduct that makes the product even better
- The CNIC is an extremely customisable testing platform for packetised data streams, scalable up to Tbps
- Upgrades happening to CNIC regularly
- About to start exhaustive testing in SKA using CNIC
- CNIC is also used in the CryoPAF beamformer
  - maybe CNIC is useful for your project too?



Thank you!

We acknowledge the Wajarri Yamaji as the Traditional Owners and native title holders of the observatory site

Grant Hampson

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