Radio Astronomy Technologies at CSIRO

Tasso Tzioumis | 18 November 2020

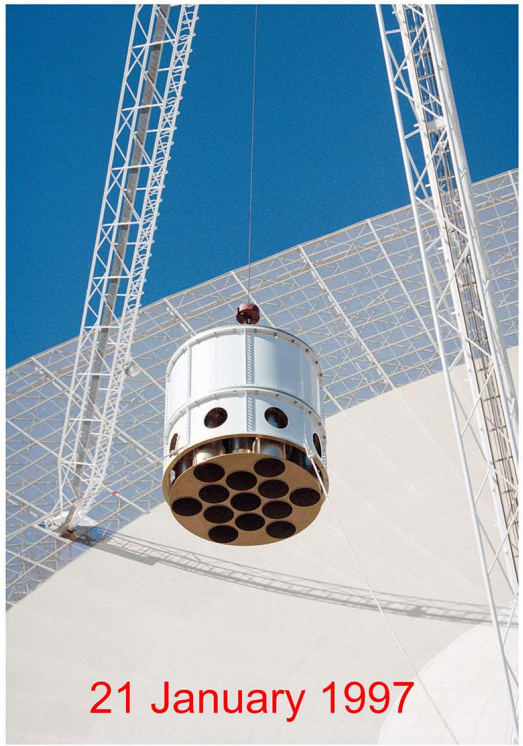
ATNF Technologies Capabilities

- **Antennas & Receivers (Front-end) (~15):** RF technologies (Feeds; OMTs; LNAs; RF Electronics; Cryogenic systems; Mechanical design; …)
  - **Workshop (~5):** Mechanical systems (Machining; Fitting; Production;…)
- **Signal processing (Back-end) (~19):** Digital technologies (RFoF; Samplers/Digitisers; Timing systems; Beamformers; Correlators;…) - Digital Signal Processing & FPGAs
- **Scientific Computing (~13):** Control and monitoring systems; calibration strategies and algorithms; data processing (e.g ASKAPsoft).
- **Engineering Generalists (~5):** System Scientists/Engineers; System integrators; New Ideas; …

** **Produce fully integrated radio telescope systems!**

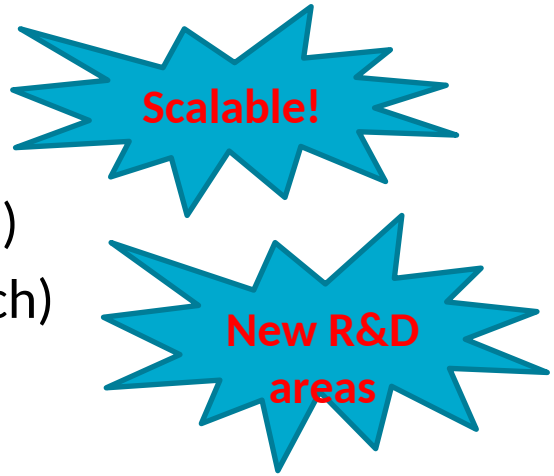
  – **Concept; design; construction; testing; commissioning; operation; science.**

Multibeam Systems – Parkes & FAST

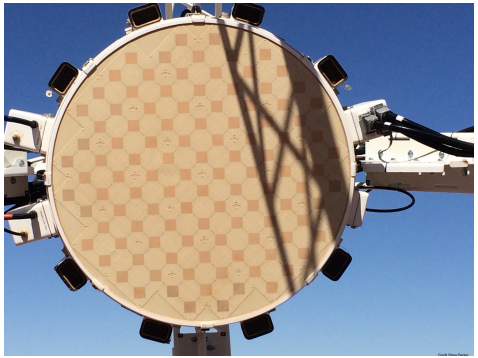


Next generation
Radio Astronomy Technologies

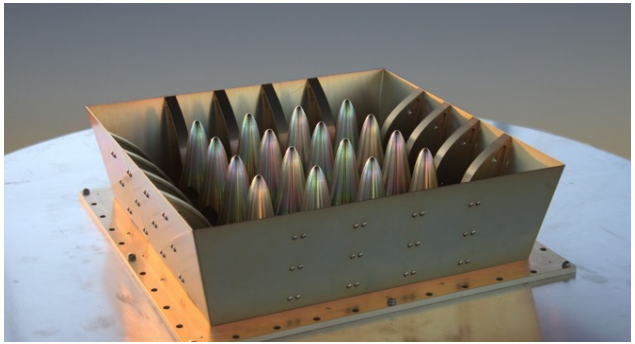
- CSIRO Research and development:
  - Phased Array Feed systems (**PAF**s)
  - Ultra Wide Band systems (**UWB**s)
  - FPGA-based Digital Signal Processing (**DSP** systems)
  - (COTS-based back-end systems – GPU, FPGA, Switch)
  - (Space systems?)



Phased Array Feeds –Large Field-of-View (FoV)



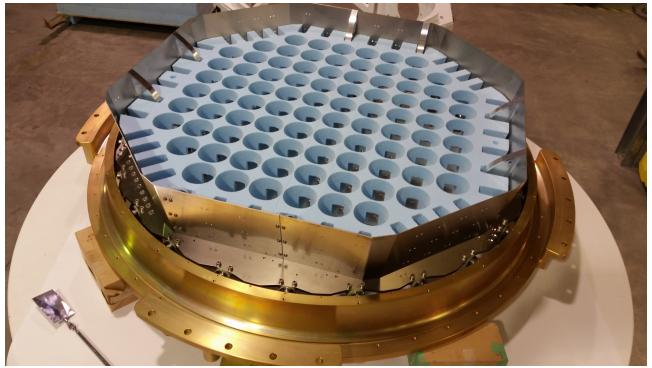
- Surveys
- Imaging
- FRB searches & localisation

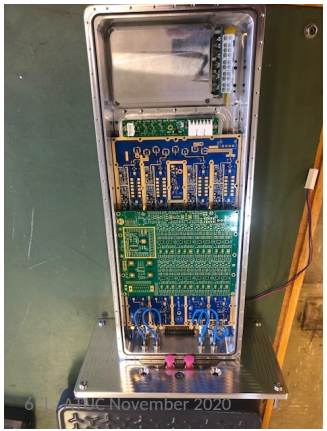


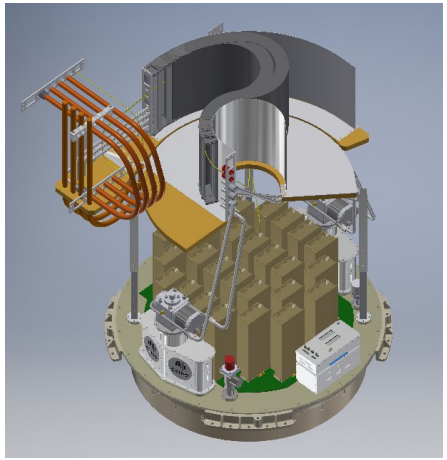
- ASKAP – Chequerboard PAF
  - 36 x 12m antennas
  - 94 x 2 pols PAF
  - 36 x 2 pols beams
  - 30 deg^2 FoV
  - 700-1800 MHz; 300 MHz BW
  - Tsys ~60-70K (uncooled)

- Next generation “Rocket” PAF
  - “rocket” elements; “edge” elements
  - Superb LNA matching
  - Wider BW (~3:1)
  - Cryo-Cooled for Tsys <20K

Parkes cryo-Cooled Phased Array Feed





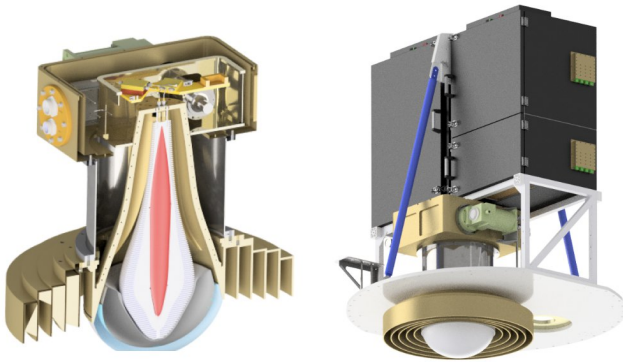


Funded and construction underway

- 700 MHz - 1950 MHz
- ~20-25 K System Temperature
- ~3 x Multibeam footprint with Nyquist sampling
- Combined 10-30 fold survey speed increase
- ~1.5 deg^2 FoV
- Up to 70 x 2 pol beams
  - Less beams needed at low frequencies
  - Multiple modes – many commensal
- Prototyping construction underway
  - Structural Thermal Model complete
  - RF electronics boards – screened

- RFSoC board for digitisation at front-end (screened)
  - "Jimble" board tested
  - Up to ~920 MHz BW available
- COTS beamformer – designed and testing started
  - using ALVEO technologies & P4 Tofino switches
- Processed BW depends on digital and GPU cluster sizes

Parkes Ultra-Wideband -Low ‘UWL’



- 700MHz - 4 GHz, ~20 K System Temperature, Linear polarization feeds, Digitisation at focus
- Installed in 2018 – main low-freq system at Parkes
- Publications flowing

- Developments:
  - Commensal observing modes
  - Scanning

- Future Developments:
  - RFI mitigation tools (adaptive RFI mitigation, impulsive RFI mitigation, flag tables)
  - Oversampled filterbanks
  - Calibration schemes (pseudo-random noise etc.)
  - New observing modes (e.g., fold multiple pulsars simultaneously)

  - Update digitisation with RFSoC board (Jimble)

- UWL system for Arecibo – under discussion

Parkes Ultra-Wideband-Mid/High ‘UWM/H’

Seeking funding

- 4 GHz - ~25 GHz
- ~20 K System Temperature
- Linear polarization feeds
- Digitisation at focus – shares digitisers and backend infrastructure with UWL
- Essentially ‘just’ the frontend – frontend, RF electronics and conversion required
- Single feed for entire range would have sub-optimal feed illumination – engineering preference is for 2 feeds, 4-15GHz, ~15-27 GHz, or ~4-18GHz, ~18-32 GHz

- Will replace most high-freq feeds at Parkes
  - **All systems available on the antenna**

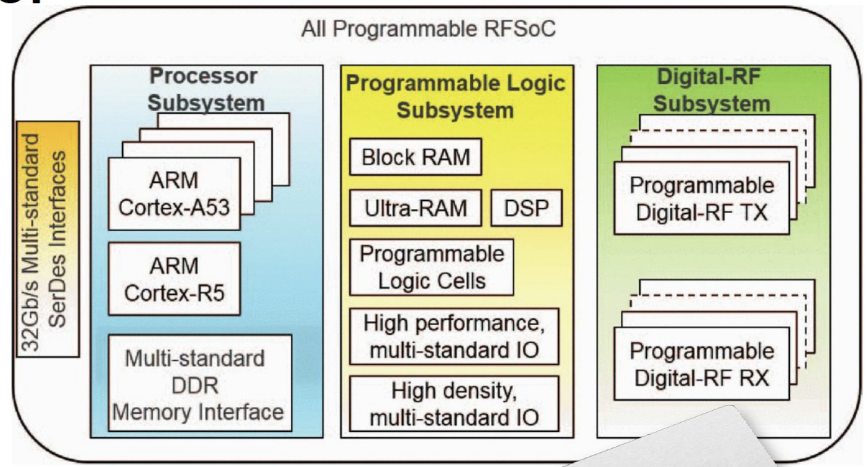
- ARC LIEF proposal under discussion
  - See Jimi’s presentation

RFSOC based digital back-ends

RFSoC - more than an FPGA

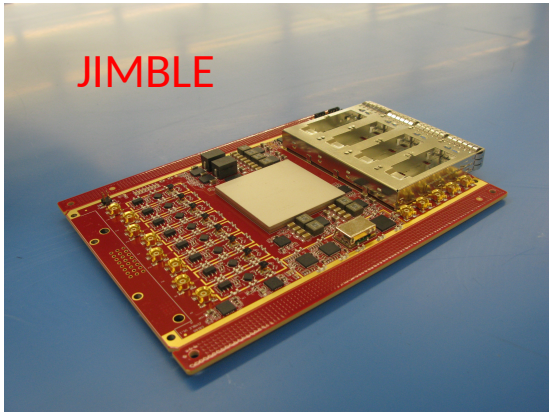
Four major parts to RFSOC:

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



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

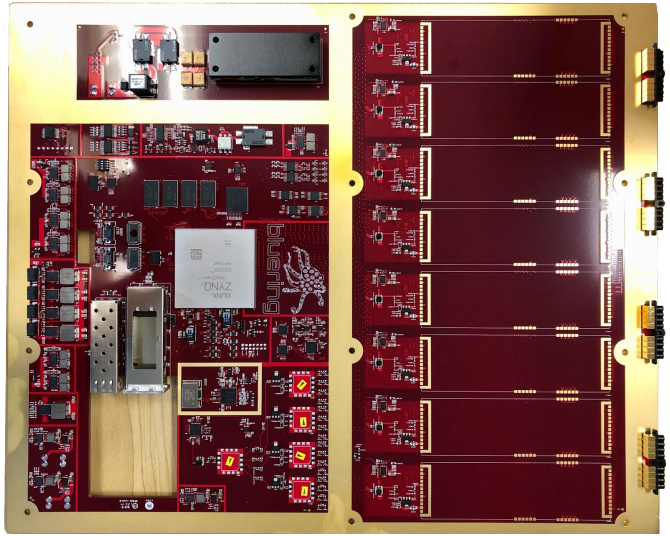
CSIRO RFSoC boards



- 8 x 2 GHz inputs; 12 bit outputs
- Optical outputs only (100 Gbps channels)
- Designed to be screened - install near feed.
- Adopted for cryoPAF, UWL, BIGCAT
- Versatile and programmable
- JIMBLE tested – going to Rev2

IRUKANDJI
Synchronisation board

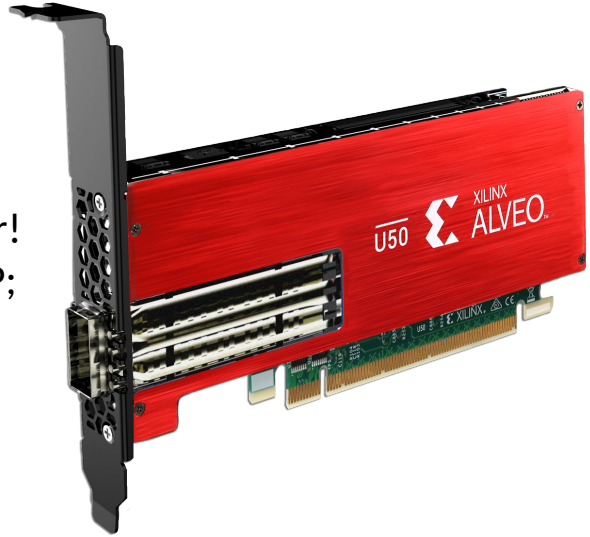
BLUERING



- 16 x 1 GHz inputs; 12-bit outputs
- Optical outputs
- Option for daughter RF input boards
- Great for low-freq arrays – **LBA-Low?**
- Protype built and tested – going to Rev2
- Test R&D array under development
  - MWA tile(s) @ Narrabri
  - Proof of Concept

COTS digital back-ends (ALVEO & P4 Switch)

- **Xilinx Alveo** U50 HBM Board.
- Very small & low power – 20 in server!
- 8GB HBM; 5952 DSP; 1x100GbE
- FPGA-based accelerator boards



- Bare metal h/w switch
- Fully user programmable
- P4 Tofino
- Versatile for one-way traffic
- System under testing in CSIRO.

- Faster and cheaper than own FPGA boards
- Many variants and prices cheaper than FPGA chip!
- System design and testing for cryoPAF
- ECP proposal for SKA1-LOW BF-Cor
- U280 version for ASKAP coherent FRB detector

GPU & ALVEO - BIGCAT & CRACO

PARKES

- GPU computer clusters at Parkes – collaboration with Swinburne
- The UWL uses the "Medusa" cluster & Breakthrough Listen a cluster for SETI
- The cryoPAF will also feed into an updated Medusa GPU cluster.

ATCA

- BIGCAT (Broadband Integrated GPU Correlator for the Australia Telescope)
  - 8 GHz of BW (x2 current capability)
  - Use "Jimble" RFSoC digitizer board (8 x 2GHz) and 12-bit.
  - Aging CABB correlator to be replaced with GPU cluster
    - Flexible and versatile - new modes ☾ New science
  - Funded via ARC LIEF proposal and construction underway.

ASKAP

- CRACO – Coherent FRB detection @ ASKAP
  - Sub-arcsecond localization & many more FRBs
  - Using ALVEO technology – utilises ASKAP correlator and all beams
  - Pilot/prototype under construction – small cluster + firmware/software development
  - LIEF proposal for full funding – awaiting decision.

Thank you

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