Technologies for Radio Astronomy

CSIRO Astronomy and Space Science
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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) (~15):** 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). (*Operations Program*).
- **Engineering Generalists (~5):** System Scientists/Engineers; System integrators; New Ideas; …

***1: Small groups → Single subject experts → (Risk: Single-point failures?)**

***2: Critical mass issues → Could not lose ≥ 1-2 people/group**

- ***People:*** *Andrew Brown left Sept – job(s) advertised*
- ***Secondments****: Alex Dunning (MPIfR); Mark Bowen (SKA) (LWP)*
  - *Return early 2019.*

Directions for ATNF Engineering

**** Broad directions largely unchanged**

- **ASKAP & SKA**: Core business of the Engineering Program.
  - Most of the program's people and effort at present.
- Development projects for all ATNF facilities.
  - Budgetary constraints → Priorities
- Strategic developments – develop capabilities.
- External contracts – maintain capabilities.

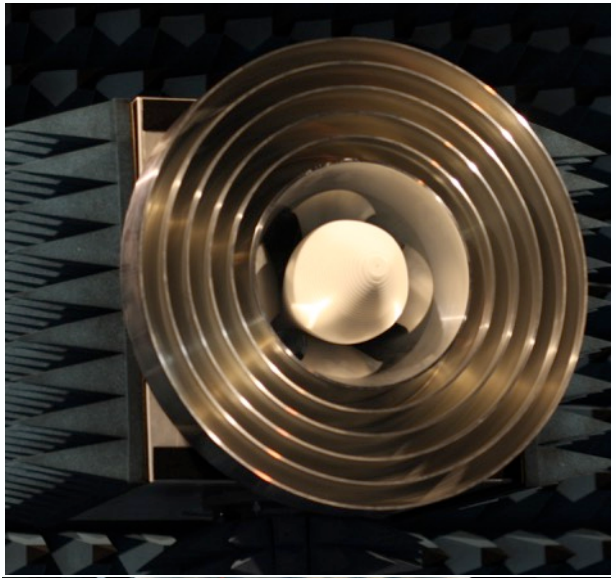
Current Technologies Projects (FY 2018-19)

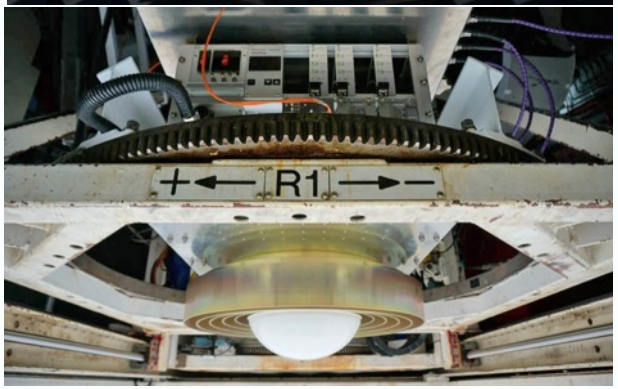
1. **ASKAP:** Highest Priority; ~10 FTE (Engineering)
   - PAF systems technologies
   - ADE PAFs for **Effelsberg** & **Jodrell Bank** (External contracts)
     - Effelsberg Commissioned; - searching for FRBs
     - Jodrell Bank – digital back-end installed. Feed waiting for antenna.
2. **SKA:** International commitment. ~10 FTE (Engineering)
   - Pre-construction consortia (CSP; AIV; SDP; SaDT…)
     - CSP system CDR passed!!
   - **PAF technology development** (AIP/ODP) + some internal resources
3. **FAST 19-beam receiver –** external contract → Completed!
   - Commissioned (May 2018) – Tsys 16-17 K on dish.
4. **UWB:** System for Parkes ~3-4 FTE (Engineering)
   - -- 700-4000 MHz; novel technology
   - Commissioning at Parkes. Great results!!
5. **Rocket PAF → CryoPAF LIEF proposal – result in Nov 2018 !!**

Parkes UltaWideBand system (UWB)

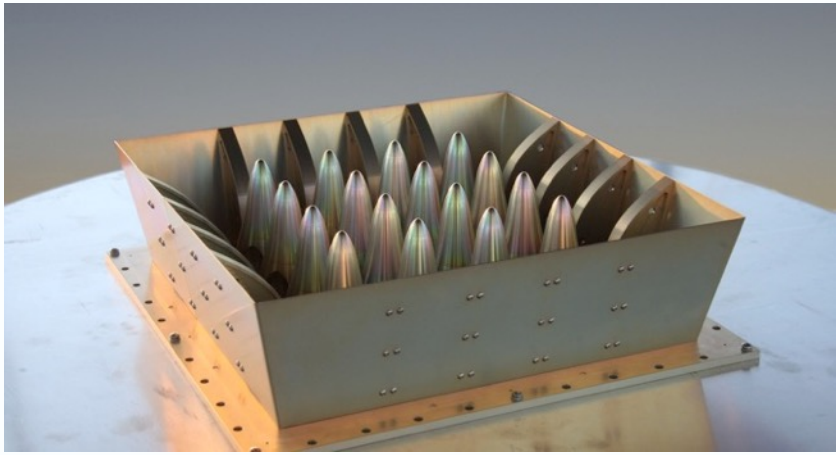
- Band 700 – 4000 MHz; Tsys <20K
- Consortium funding + ARC + CASS (labour: 6.5 FTE)
- Novel feed: ridged-horn+rings+dielectric
- LNAs designed & chips fabricated in foundry
  - Final LNAs installed in Oct'18
- Sampler/digitiser and timing (Back-end)
- Ethernet switch and GPU cluster (2016)
- Software – led by Swinbourne → Installed
- RFI mitigation built-in – reference antenna
  - Chinese (XAO) secondment for 1-year
- Installed May 2018 → In Commissioning
- Fantastic results!!
  - Pulsar obs (replaced 10/50)
- Shared-risk observing underway → NF

- Oversampling - to be done
- New Cal unit under development

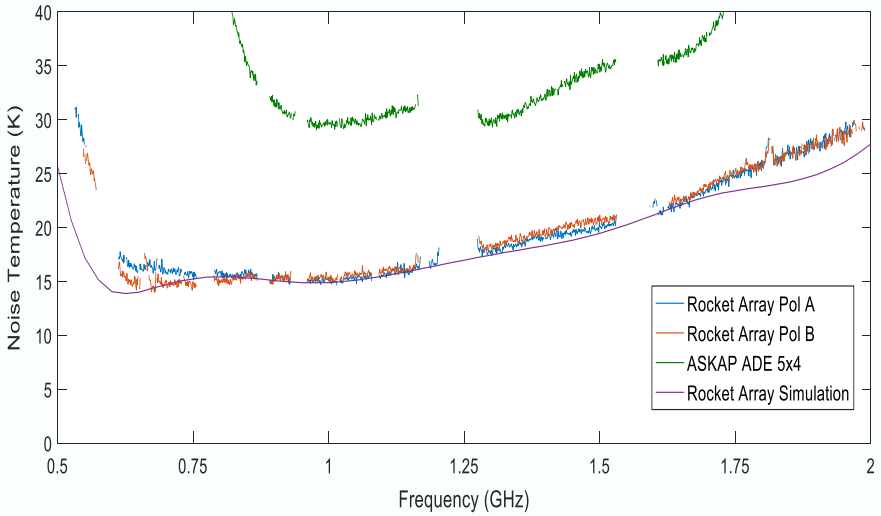




"Rocket" PAF → CryoPAF



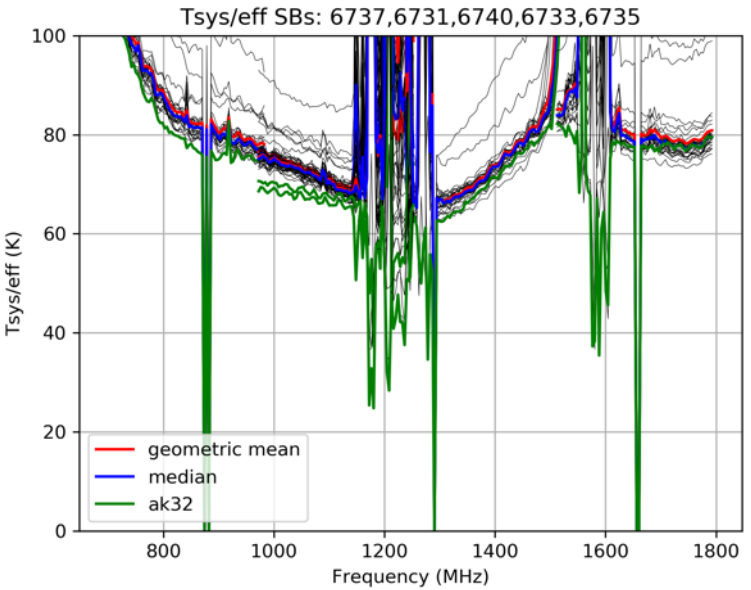
- Next generation PAF
  - "rocket" elements; "edge" elements
- Superb matching with LNA
  - Key to improved performance
  - Noise Temp due to uncooled LNAs
- 4x5 prototype constructed
  - tested as aperture array
  - ~15K better than equivalent ADE tests
  - Tested on Parkes
- Design better suited to cooling
  - → **CryoPAF for Parkes** proposal – Tsys <20K !?
  - Cost: ~$3M (incl >7 FTE from CASS)
  - LIEF led by UWA – Result in Nov 2018
    - ~7 FTE allocated this FY
- Limited R & D underway → Prototyping.
- **Strategic priority – (Possible external contracts)**



ASKAP RF-transparent feed-legs

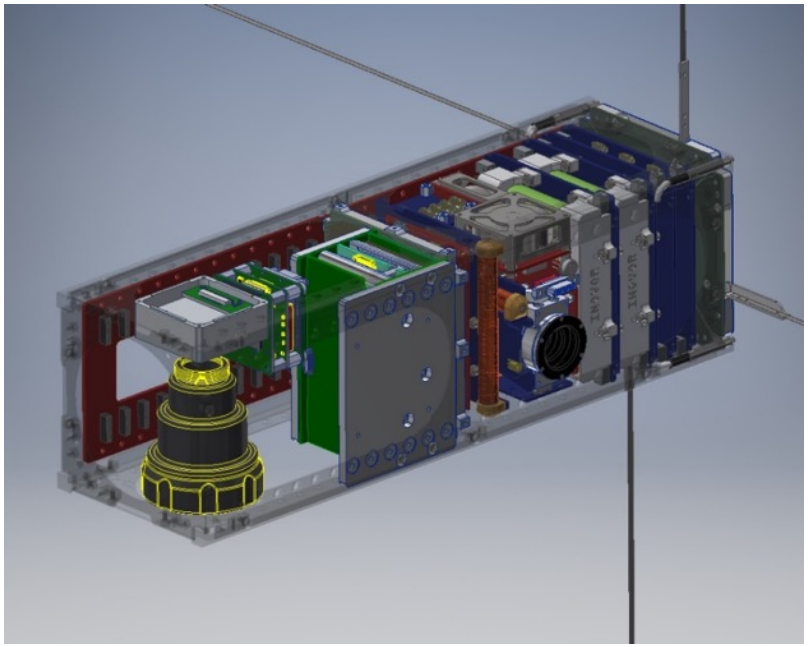
- **Proof-of-concept system:** (1FTE + $250k)
  - Improve ASKAP Tsys by 10-20K
    - (→ achieve original ASKAP spec)
    - Survey speed x2
  - Test feasibility on 1 antenna
    - System shipped to MRO (May 2018)
    - Installed on AK32 in July 2018
      - Smooth changeover (video)
    - Aim to complete testing within 6 months
      - Delayed due to other ASKAP pressures
  - Preliminary tests inconclusive/mixed
    - Definite improvement at low end of band
    - Results so far not conclusive
  - Decision deferred until final report.
    - Report back to next ATUC and ATSC mtgs

- → Priority?? Funding proposals??



Space Technologies

- **CSIROSat-1: 3U CubeSat**
  - Hyperspectral IR Earth imaging
  - On-board FPGA and SoC image processing
    - CASS technical involvement
    - Short-term impact on resources
  - In-orbit re-programming
  - S-Band down-link
  - Technology demonstrator
  - Capability building
- **Future Science Platform (FSP)**
  - Just announced by CSIRO ($16M)
  - Future CASS involvement with new resources?



Future Projects

GPU upgrade of ATCA

- Update CABB and double BW (sensitivity increase) *(ATUC Jun 2017)*
  - Versatile; flexible; fast transients; maintainability; unattended observing; support
  - SIEF proposal for ~$3M ; ~$2M external & ~$1M from CASS (not funded)
  - **CABB Update:** ~$1M. Possible within ~6 month period
    - **Fallback** if major CABB failure
  - CASS continues R&D;
    - ADC design from UWL system;
    - Possible RFSoC design – Prototype board; results encouraging! **
    - 4 GPU test system now
    - Software Correlator design (GPU "hackathon" @ Pawsey) – April 2018
  - → **Full system needs external funds! LIEF proposal?? University to lead?**
  - **Priority??**

Parkes UWB Mid/High

Based around UWBL and compact array CX system

Utilising much of the UWBL system; i.e. Samplers; Back-end; GPUs; Software

Current Bands are

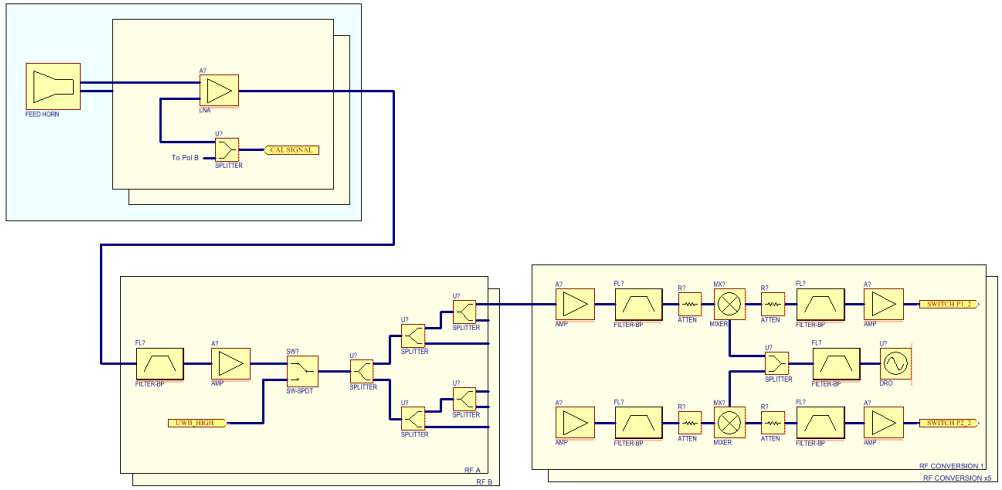
- 4.0-15.4GHz
- 15.4-26.9GHz

Using 12 UWBL digitizers (6 per polarisation)

4-15 GHz band is sampled using 6 digitizers at 4096MSPS

15-27 GHz band is converted down to 4-15 GHz band

4-24 GHz system may be possible but is problematic, would be very attractive for other telescopes



UWB Mid preliminary circuit diagram

- **Discussed at ATUC 2014; Chose UWL first**
- **Cost: ~$0.5M h/w; + 5 FTE Labour.**
- **Needs funding. LIEF??**
- **Priority?**

Digital systems

- ADC: Faster designs
  - Current: 4 Gsps; New: 6 Gsps avail; Future: 8 Gsps & 16 Gsps!
- **Xilinx RFSOC: Integrated ADC + FPGA**
  - 8 x 4 Gsps ADCs or 16 x 2 Gsps ADCs
  - Chips now available; Board acquired;
  - R&D projects e.g CABB prototype
- CryoPAF back-end:
  - Now using ASKAP ADE; New RFSoC system?
  - Also for SKA?
- "Bluering" RFSoC prototype
  - Modular, scalable to 512 RF inputs
  - (32 RFSoC devices)
  - RFoF inputs; Direct RF sampling (12-bits)
  - Array-based DSP
  - Optical data transport

Priorities and Funding proposals

- Any future project requires large CASS contributions
  - e.g LIEF proposals >50% from CASS (mainly labour)
  - Limited CASS annual budgets – Labour + CAPEX
- → Need to prioritise what proposals go forward each year
  - Implications for future years; Strategic considerations.
- ATUC link to community input in prioritisation.
  - LIEF are university led.
  - Strong science case and support from community essential.

→ **Expression of Interest (EoI)** call – September 2018 (as agreed last ATUC)

- Received 3 EoIs; (available to ATUC if needed)
  - CASS Exec reviewed (15 Oct);
  - ATSC for comment (5 Nov)

EoI proposals & comments

- **CryoPAF** for Parkes
  - Decision expected Nov'18; Proposal to re-submit if unsuccessful.
  - Remains #1 strategic priority for CASS; R & D in progress
  - Comments/Questions:
    - Unclear if 3rd LIEF proposal wise?
    - Find alternative ways to fund??
- **BIGCAT:** GPU upgrade for ATCA (details in earlier slide)
  - GPU ATCA correlator; also needs sampler upgrade (RFSoC?)
  - x2 BW; needs expensive RF upgrade (~$1M)
  - Comments/Questions:
    - Needs technical update (RFSoC) – ATNF technologies
    - Fits well LIEF guidelines; Needs strong science case.
    - → Proceed with full LIEF proposal?
- **ASKAP coherent FRB detector** (+ tied-array VLBI)
  - GPU cluster needed (~$1M); Commensal; 1" localization
  - x5-10 than best current systems on ASKAP
  - Comments/Questions:
    - Very high science return!! But competition means time critical?
    - LIEF funding (if successful) can only start to flow in 2020! Can we wait?
    - Find alternative funding in community and start NOW??

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