

Technologies for Radio Astronomy



CSIRO Astronomy and Space Science
Facilities Program Director - Technologies
April 2019

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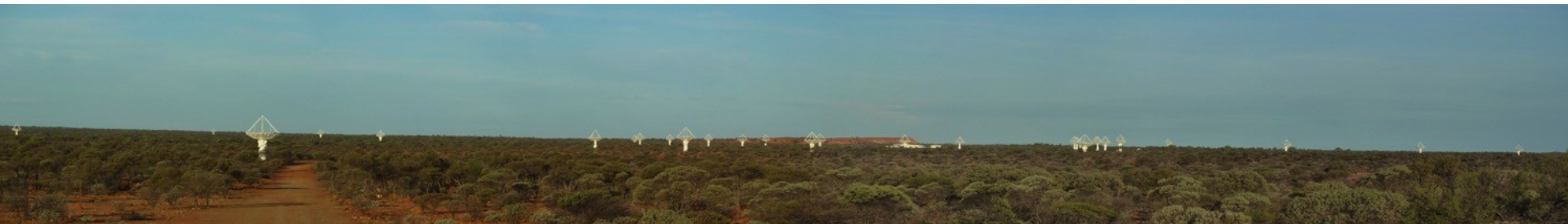
ATNF Technologies Capabilities

- **Antennas & Receivers (Front-end) (~15):** RF technologies (Feeds; OMTs; LNAs; RF Electronics; Cryogenic systems; Mechanical design; ...)
 - **Workshop (~4):** 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 (~4):** System Scientists/Engineers; System integrators; New Ideas; ...
- **(Program support (4):** Systems engineering; Program & Project support)
- *1: **Small groups** □ Single subject experts □ **(Risk: Single-point failures?)**
- *2: Critical mass issues □ **Could not lose \geq 1-2 people/group**
- **People:** *Andrew Brown left Sept – job(s) advertised*
- **Secondments:** *Alex Dunning (MPIfR); Returned march 2019*
 - *Mark Bowen (SKA) (LWP) (Return Aug 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

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 ☐ “Expectations exceeded”!

- Commissioned (May 2018) - Tsys 16-17 K on dish.

4. **UWB**: System for Parkes ~3-4 FTE (Engineering)

- 700-4000 MHz; novel technology
- Commissioned at Parkes. Great results!!

5. **Rocket PAF** ☐ **CryoPAF** LIEF proposal - not funded in Nov 2018 !!

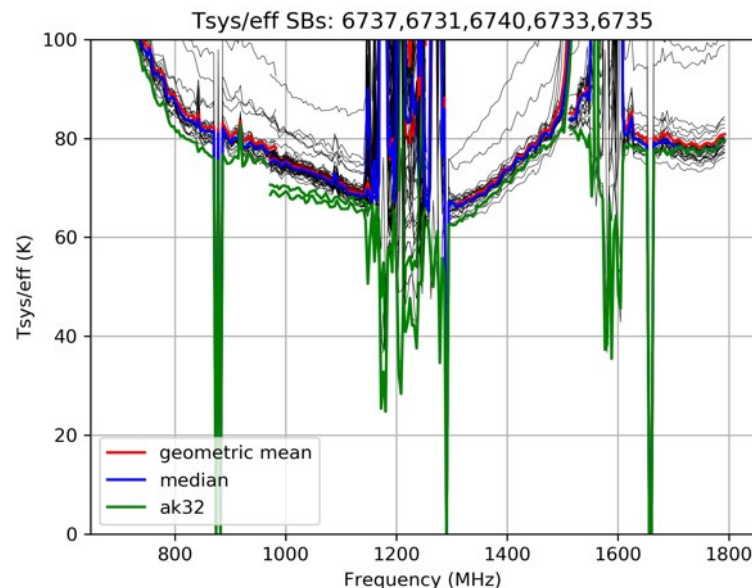
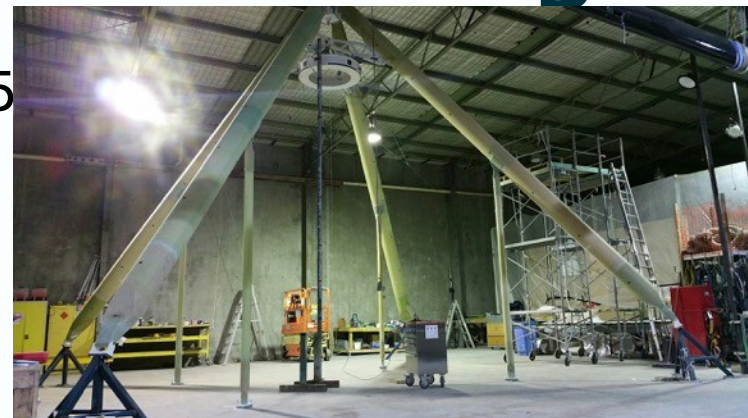
- R&D continuing in CASS.

Parkes
Talk by
Jimi

ASKAP RF-transparent feed-legs

- **Proof-of-concept system:** (1FTE + \$25M)

- Improve ASKAP T_{sys} 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 (~5K ?)**
 - **More testing??**
 - Decision deferred until final report.
 - **Delayed - ASKAP priorities**

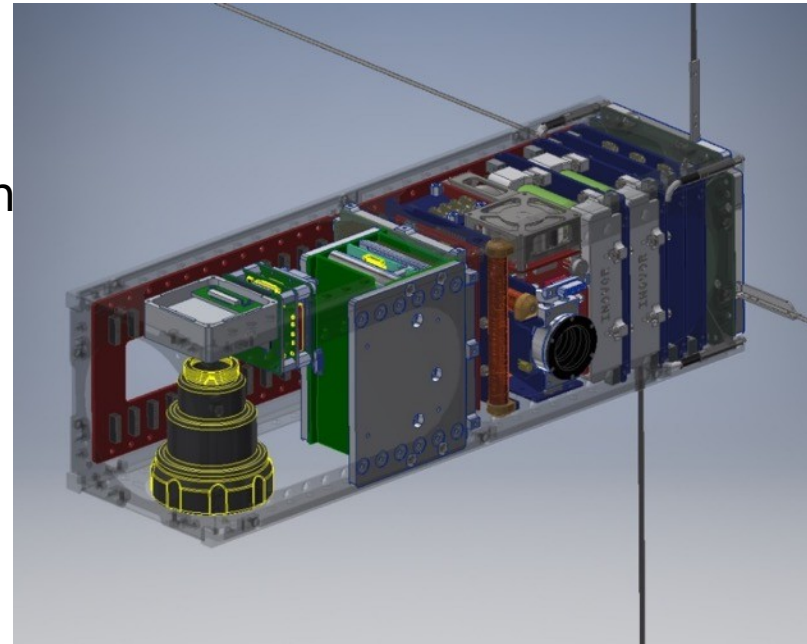


- □ Future?

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)**

- Funded end 2018 by CSIRO (\$16M)
- CASS involvement already in small projects (to June 2019)
- Proposals for larger projects submitted (26 April)
- Space Situational Awareness; Lunar radio astronomy mission!; ...

- **Space - Exciting new R&D**

- Impact on ATNF?? ☐ New resources needed! (SmartSat CRC?)
- Space research Group??

Future Projects

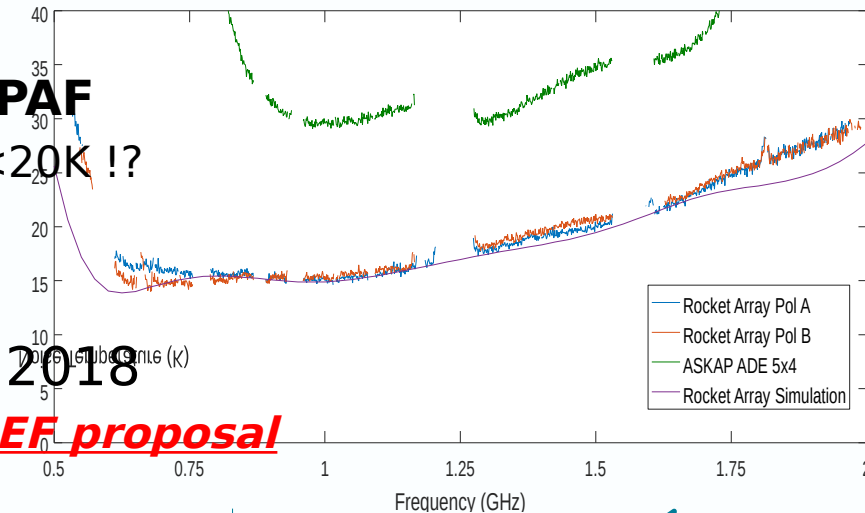
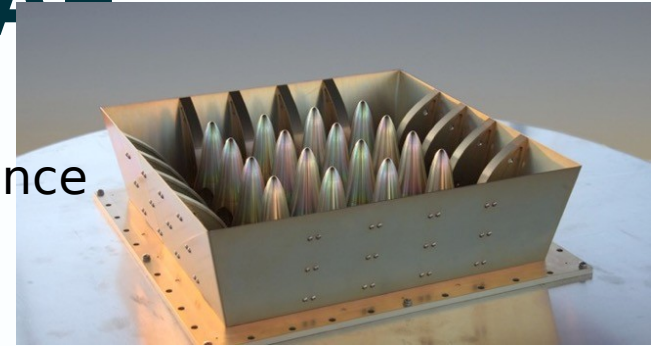
Priorities and Funding proposals

- 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 proposals are university led.
 - Strong science case and support from community essential.

- ☐ **Expression of Interest (Eoi)** call – September 2018 (as agreed last ATUC)
 - Received 3 Eols; - **CryoPAF; BIGCAT; FRBs at ASKAP**
 - CASS Exec reviewed (15 Oct);
 - ATSC for comment (5 Nov)
 - LIEF decisions made (Feb-Mar 2019)

“Rocket” PAF CryoPAF

- Next generation PAF - “rocket” elements
- Superb matching with LNA improved performance
 - Noise Temp due to uncooled LNAs
- 4x5 prototype constructed & tested on Parkes
 - ~15K better than equivalent ADE tests
- Design better suited to cooling **cryoPAF**
 - **CryoPAF for Parkes** proposal - $T_{\text{sys}} < 20\text{K} !?$
 - Cost: ~\$3M (incl >7 FTE from CASS)
 - ~7 FTE allocated this FY
- LIEF led by UWA – Not funded Nov 2018
 - Failed on technicality **Resubmitted LIEF proposal**
- R & D underway
 - Prototyping – EM design; cooler; RFSoc
 - CoDR on tomorrow



- **Strategic priority - (Possible external contract)**
- **Continuing commitment by CASS**

GPU upgrade of ATCA - BIGCAT

- Update CABB and double BW (sensitivity increase) (*ATUC Jun 2017*)
 - Versatile; flexible; fast transients; maintainability; unattended observing; support
 - Full proposal ~\$2.5M - Capital ~\$1M; Labour ~\$1.5M (mainly from CASS)
 - **CABB Update:** ~\$1M. Possible within ~6 month period
 - **Fallback** if major CABB failure
 - **** ☐ LIEF proposal submitted;** Led by WSU
- CASS continues R&D;
 - ADC design from UWL system;
 - Possible RFSoc design - **Prototype board; results encouraging! ****
 - 4 GPU test system now
 - **** Tested RFSoc to GPU transfers in lab (April 2019)**
 - Software Correlator design (GPU “hackathon” @ Pawsey) - April 2018

ASKAP coherent FRB detector

- **ASKAP coherent FRB detector** (+ tied-array VLBI)
 - GPU cluster needed (~\$1M); Commensal; 1" localization
 - x5-10 than best current systems on ASKAP
 - Comments/Decisions:
 - Very high science return!! But competition means time critical.
 - ☐ NO LIEF proposal! (would start only in 2020!)
 - **Find alternative funding in community and start immediately!!**
- Discussions on collaborative effort/funding ongoing
 - Requires ASKAP array fully operational
 - And ~2FTE of FPGA re-development of ASKAP
 - Highest priority for "ASKAP enhancements"
 - Some ongoing R&D; First review June 2019
 - Critical Concept Design Review September 2019.

Digital systems R&D

- ADC: Faster designs
 - Current: 4 Gbps; New: 6 Gbps avail; Future: 8 Gbps & 16 Gbps!
- **Xilinx RFSOC: Integrated ADC + FPGA**
 - 8 x 4 Gbps ADCs or 16 x 2 Gbps ADCs
 - Chips now available; Board acquired & tested.
 - 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-bit)
 - Array-based DSP
 - Optical data transport
- **RFSoc systems: game-changer**
 - UWB; CABB; cryoPAF; SKA; Space?, ...



Parkes UWB Mid/High

Based around UWBL and compact array CX system

Utilising much of the UWBL system; i.e. Samplers; Backend; GPUs; Software

Current Bands are

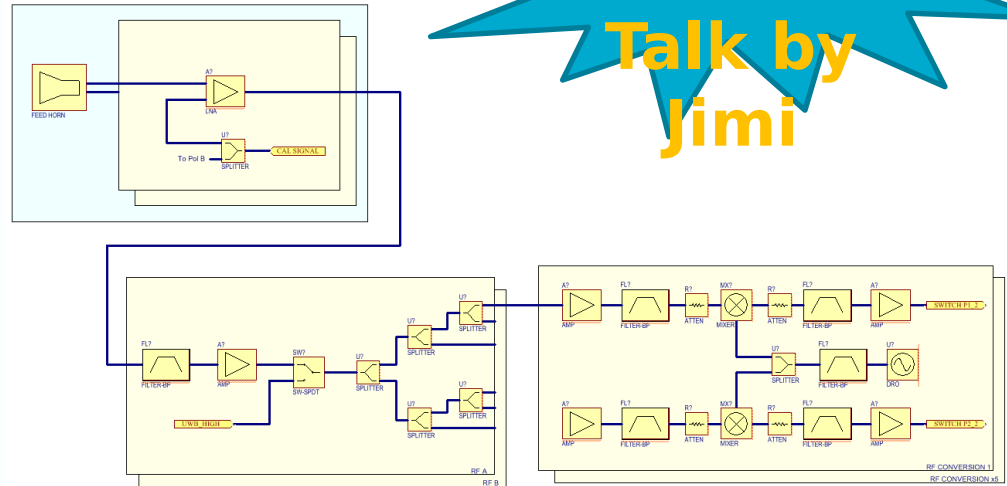
- 4.0-15.4GHz
- 15.4-26.9GHz

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
NOT currently funded



UWB Mid preliminary circuit diagram

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

Low-Frequency Long-Baseline Interferometer

subarcsecond imaging at LF in the Southern hemisphere.

- Leveraging MWA and SKA1-LOW
- High-quality imaging follow-up for MWA, ASKAP, and SKA;
- Radio galaxy evolution, exoplanets, pulsars, and the ISM
- Platform for ATNF low-frequency technical developments,
- Increase capabilities in the domain of space surveillance.
- Engineering components available i.e.
 - MWA or LFAA antennas & LNAs. (“tiles”)
 - “Bluering “ digital beamformers; FPGA (“Gemini”) for DSP
 - VLIW expertise & correlator (LBA)


Current world-leading R&D

areas

- **Phased Array Feeds (PAF) and receivers**
 - Demonstrated with ASKAP and provided for MPIfR & Jodrell Bank.
 - New “**rocket PAF**” feed and **cryoPAF** system for Parkes
 - **Wide-band** (3.4:1) & **Scalable** designs for ~0.5-30 GHz.
- **Ultra-Wide Band (UWB) feeds and receivers:**
 - Cover 6:1 BW with constant beams. UWB-L system (0.7-4 GHz) at Parkes.
 - **Scalable** designs that can be adapted to cover frequencies from ~0.5-30 GHz.
 - **High dynamic range** systems (>60 dB) with high RFI tolerance
- **State-of-the-art Digital Systems** for PAF & UWB systems
 - **Demonstrated** for PAF (ASKAP) and UWB-L (Parkes)
 - **R&D systems: Gemini FPGA** (SKA) & **RFSoc** (ADC+FPGA)
- **GPU back-end systems:** Emerging R&D.

Summary & Questions

- ATNF Technologies capabilities & world leading R&D
 - PAFs & UWB
 - FPGAs & RFSoc
 - GPUS
- Current, planned & future projects
 - ASKAP; SKA; UWB-L
 - CryoPAF; BIGCAT;
 - ASKAP coherent FRB detector - collaboration
 - UWB-High?; LF VLBI?;
 - ?? Suggestions ??
- Eol process again?
 - Feedback
 - Prioritisation process?
 - Open to suggestions & collaborations

A large radio telescope dish is shown in silhouette against a sunset sky. The dish is mounted on a complex metal structure and is tilted upwards. The sky is a mix of blue and orange, with scattered clouds. In the background, there are trees and a building.

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