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 (~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 ≥ 1-2 people/group**

- ***New People:*** *Marcus Wiedemann (Space); Andrew Bolin (DSP); Xinping Deng (GPU)*
- ***Secondment****: Mark Bowen (SKA) (LWP) (Return Aug 2019) – Deputy Program Lead*
- ***Changes****: Aaron Chippendale replaced John Tuthill as leader in Digital Group.*

Directions for ATNF Engineering

** **Broad directions largely unchanged**

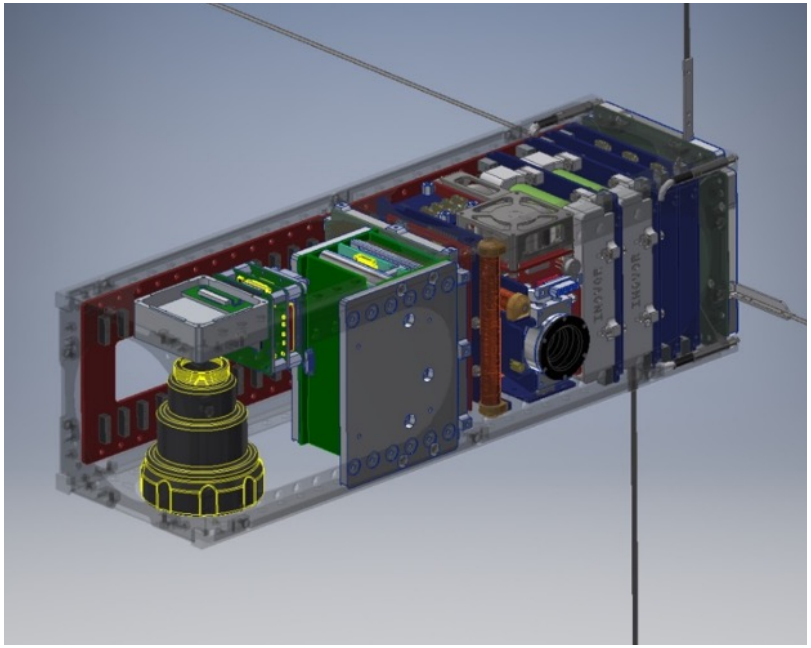
- **ASKAP-X & SKA**: Core business of the Engineering Program.
  - Much of the program's people and effort at present.
- Development projects for all ATNF facilities.
  - Budgetary constraints ☾ Priorities
- Strategic developments – develop capabilities.
- External contracts – maintain capabilities.

Current Technologies Projects (FY 2019-20)

1. **ASKAP-X:** Highest Priority; ~6 FTE (Engineering)
   - Enhanced modes (including FRB searching)
   - ADE PAFs for **Effelsberg** & **Jodrell Bank** (External contracts)
     - Effelsberg operational
     - Jodrell Bank – digital installation and testing. Feed waiting for antenna.
2. **SKA:** International commitment. ~8 FTE (Engineering)
   - Bridging activities (CSP; AIV; SDP; SaDT…)
   - AIP/ODP **technology developments** – PAF & Single Pixel consortia
3. **UWB:** System for Parkes ~2-3? FTE (Engineering)
   - 700-4000 MHz; novel technology
   - Operational at Parkes. Great results!!
   - Some development still necessary…
4. **Rocket PAF ☾ CryoPAF LIEF proposal – Result in Nov 20**
   - Extensive R&D continuing in CASS. Cryo prototype.
   - Design for new Digital back-end (RFSoC)
   - Construction pending LIEF outcome. (~7 FTE)

Space Technologies

- **CSIROSat-1: 3U CubeSat. (~3 FTE)**
  - Hyperspectral IR Earth imaging
  - On-board FPGA and SoC image processing
    - Strong CASS technical involvement
  - In-orbit re-programming
  - S-Band down-link
  - Technology demonstrator
  - Capability building



- **Future Science Platform (FSP)**
  - CASS involvement already in small projects
  - Space Situational Awareness; Satellite ground station; …
- **Space - Exciting new R&D**
  - **Impact on ATNF?? ☾ New resources needed!**
  - **Space research Group??** (But note potential impact of ASL restrictions!)

Future Projects

Priorities and Funding proposals

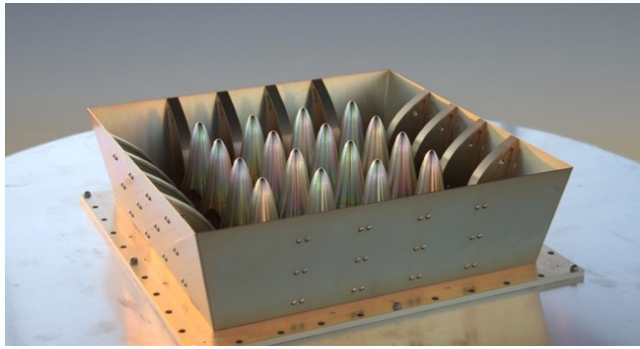
- Any future project requires large CASS contributions
  - e.g. LIEF proposals >50% from CASS (mainly labour)
  - Limited CASS annual budgets – Labour + CAPEX
  - ☾ Need to prioritise what proposals go forward each year
  - Implications for future years; Strategic considerations.
- ATUC link to community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

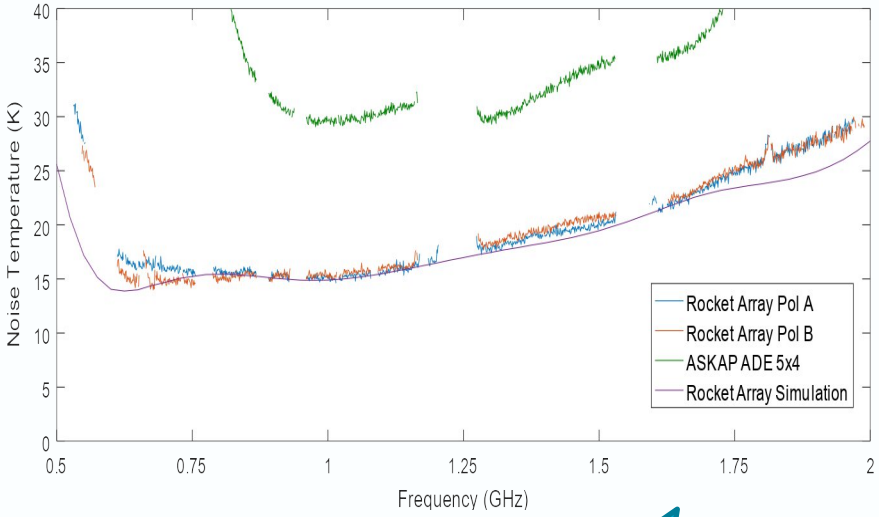
Expression of Interest (EoI)

- October 2018 - current proposals (**CryoPAF; BIGCAT)** – Nov 2019 decisions
- New EoI call – October 2019
  - CASS Exec to review (Nov); ATSC for comment (Dec)
  - Possible candidates: BIGCAT(?); ASKAP Coherent detector; UWB-H @ Parkes
  - LIEF proposals deadline (Feb-Mar 2020)

"Rocket" PAF ☾ CryoPAF

- Next generation PAF - "rocket" elements
- Superb matching with LNA ☾ improved performance
  - Noise Temp due to uncooled LNAs
- 5 x 4 prototype constructed & tested on Parkes
  - ~15K better than equivalent ADE tests
- Design better suited to cooling ☾ **cryoPAF**
  - ☾ **CryoPAF for Parkes** proposal – Tsys <20K !?
  - Cost: ~$3M (incl >7 FTE from CASS)
    - ~7 FTE allocated this FY
- LIEF led by UWA – Decision Nov 2019
  - 3rd and final? attempt…
- R&D underway
  - Prototyping – EM design; cooler; LNA
  - RFSoC based back end
- **Strategic priority – (Possible external contracts)**
  - **Continuing commitment by CASS**





Parkes Talk by Jimi

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;
    - RFSoC design underway – Board in production **
    - GPU tests underway
    - ** Tested RFSoC to GPU transfers in lab
    - Software Correlator design (GPU "hackathon" @ Pawsey) – April 2018
      - Initial effort underway

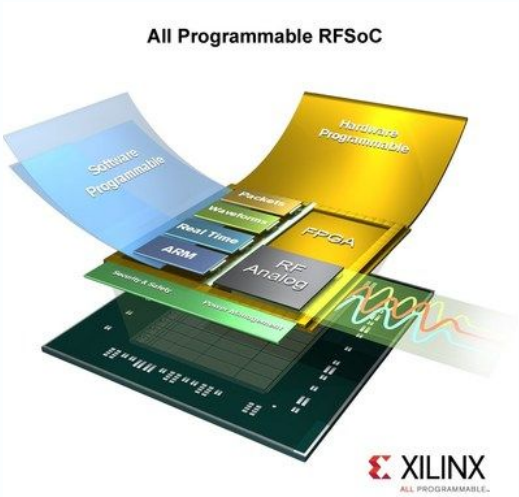
  - Full Construction contingent on LIEF outcome

ASKAP coherent FRB detector

- **ASKAP coherent FRB detector** (+ tied-array VLBI)
  - GPU cluster needed (~$1M); Commensal; 1” localization
  - x 5-10 than best current systems on ASKAP
  - Comments:
    - Very high science return!! But competition means time critical.
    - ☾ NO LIEF proposal in 2019
    - Find alternative funding in community and start immediately!!?
    - R & D has continue – alternative funding not yet secured.
- 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
  - Concept Design Review in progress

Digital systems R&D

- 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 &tested.
  - R&D projects e.g. CABB prototype
- CryoPAF back-end
  - Previous intent to use ASKAP ADE
  - Now in design phase for New RFSoC system
  - Also for SKA?
- "Bluering" RFSoC prototype
  - Modular, scalable to 512 RF inputs
  - Direct RF sampling (12-bits)
  - Array-based DSP
  - Optical data transport
  - Prototype board in construction
- **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; Back-end; GPUs; Software

Current Bands are

- 4.0-15.4GHz
- 15.4-26.9GHz

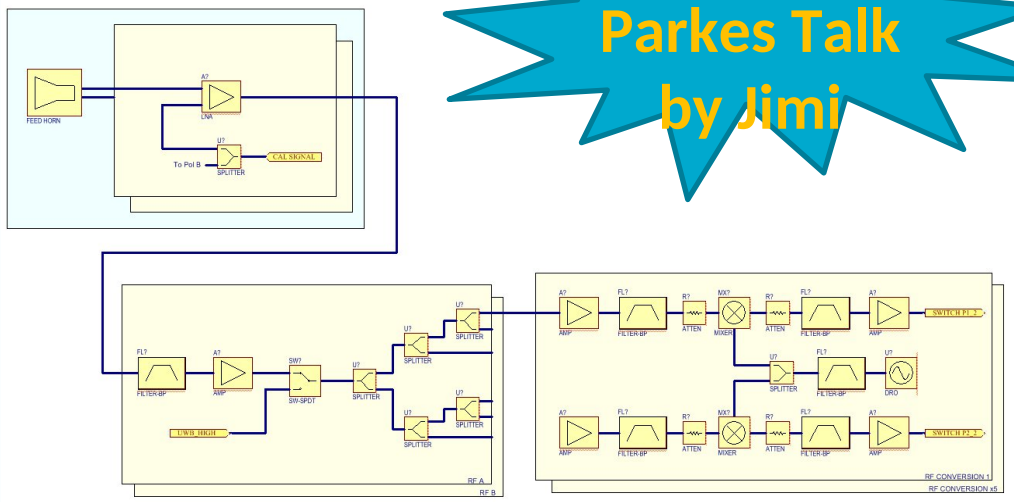
Using 12 UWBL digitizers (6 per polarisation)

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

Parkes Talk by Jimi



UWB Mid preliminary circuit diagram

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

- **NOT currently funded**

Low-Frequency Long-Baseline Interferometer

- (sub)arcsecond 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
  - VLBI expertise & correlator (LBA)
- Basic R&D development underway
  - Small test array with MWA tiles?
  - Possible tests on MWA?

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.
  - Parkes UWB-L collaboration with Swinburne
  - Planned for future ATCA correlator and PAF systems

Summary & Questions

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

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