

Technologies for Radio Astronomy



CSIRO Astronomy and Space Science

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Directions for ATNF Engineering

(Update since last ATUC meeting) - Review

- **Broad directions largely unchanged (Jun 2017)**
- **ASKAP & SKA:** Core business of the Engineering Program.
 - Most of the program's people and effort at present.
- Development projects for all ATNF facilities. **Budget??**
- Strategic developments – develop capabilities.
- External contracts – maintain capabilities.
 - **FAST 19-beam system completed!**



ATNF Technologies Capabilities

- **Front-end (~15FTE):** RF technologies (Feeds; OMTs; LNAs; RF Electronics; Cryogenic systems; Mechanical design; ...)
- **Workshop (~5FTE):** Mechanical systems (Machining; Fitting; Production;...)
- **Back-end (~15 FTE):** Digital technologies (RFoF; Samplers/Digitisers; Timing systems; Beamformers; Correlators;...) - Digital Signal Processing & FPGAs
- **Scientific Computing (~13 FTE):** Control and monitoring systems; calibration strategies and algorithms; data processing (e.g ASKAPsoft). (Operations Program).
- **Engineering Generalists (~5FTE):** System Scientists/Engineers; System integrators; New Ideas; ...
- (*Management: ~ +5 FTE*) → *Total: ~45FTE in Engineering*

NB1: Small groups → Single subject experts → (Risk: Single-point failures?)

NB2: Critical mass issues → Could not lose ≥ 1-2 people/group

Current Technologies Projects (FY 2016-17)

(fully resourced)

- 1. ASKAP:** Highest Priority; ~15 FTE (Engineering)
 - PAF systems technologies
 - ADE PAFs for Effelsberg & Jodrell Bank (External contracts)
 - Showcasing PAFs on single dishes
 - Collaborative effort on Commissioning
- 2. SKA:** International commitment. ~12 FTE (Engineering)
 - Pre-construction consortia (Dish; CSP; AIV; SDP; SaDT...)
 - **PAF technology development** (AIP/ODP) + some internal resources
 - Strategic to maintain PAF technology lead
- 3. FAST 19-beam receiver** – external contract → **Completed!**
 - **Only ~2 FTE-months remaining commitment for installation**
- 4. UWB:** System for Parkes - 700-4200 MHz; novel technology
- 5. Rocket PAF**

FAST 19-beam Receiver

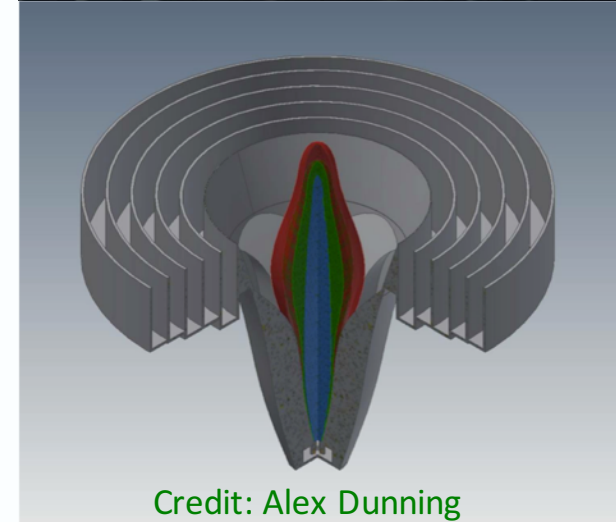
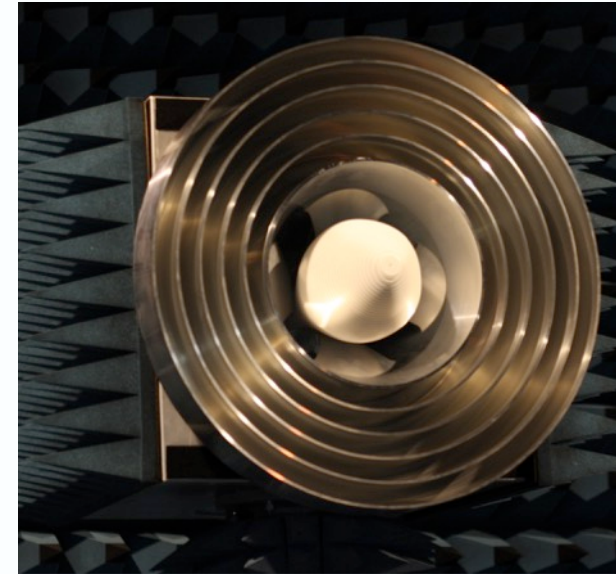
- Receiver system for FAST 500m telescope
 - 1050-1450 MHz
 - 19 dual-pol beams
- Contract with NAOC
 - Acceptance May 2017!!
 - Ready for shipment
- Largest Rx system made in CSIRO
 - Diameter 2m & weight > 1ton
 - Special lab for construction
- State of the art performance
 - Treceiver 7K (spec 10K)
 - Expected Tsys ~15K (cf Parkes >25K)
- CSIRO sole-supplier
 - Unique capability
 - Enquiry about another system
- **Capability generates opportunity!**



Parkes UltraWideBand system (UWB)

- Band 700 – 4000 MHz; $T_{\text{sys}} < 20\text{K}$
- Consortium funding + ARC + CASS (labour)
- Novel feed: ridged-horn+rings+dielectric
 - Cooled Rx version – in construction
- LNAs designed & chips fabricated in foundry
 - Delivered and LNA construction started
- Sampler/digitiser and timing (Back-end)
 - Fully prototyped and tested
- Ethernet switch and GPU cluster
 - Installed 2016 & used PAF@Parkes
 - Software - collaborators
- RFI mitigation built-in – reference antenna
- Installation & Commissioning – within 2017

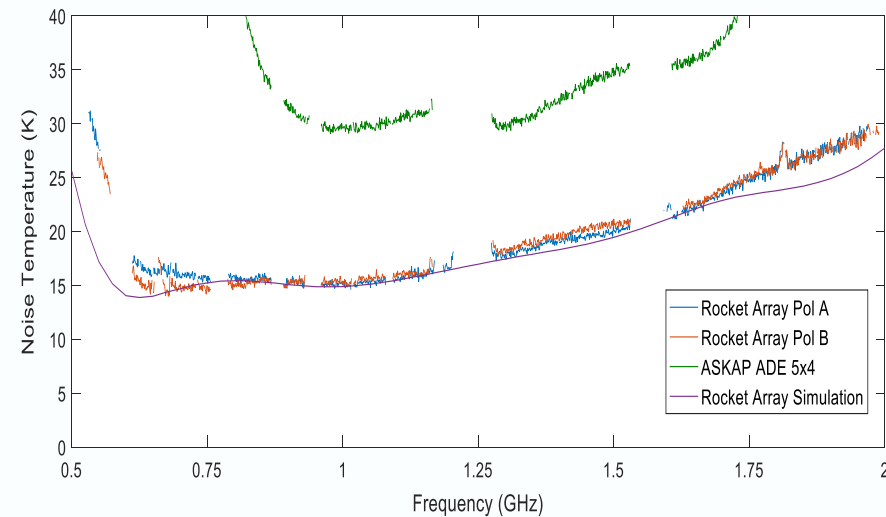
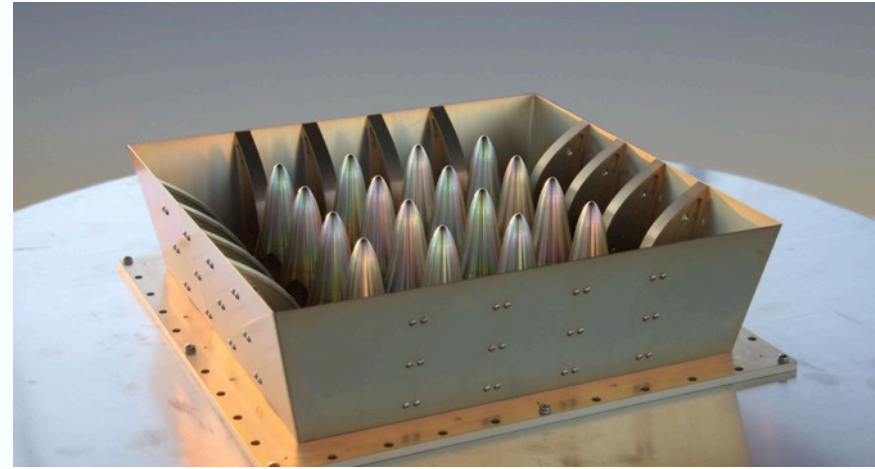
- **Digital system → Switch → GPUs**
- **** Common for all receivers (future & legacy)**
 - **Replace VLBI system!!**



Credit: Alex Dunning

“Rocket” PAF

- 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
 - Measurements affected by RFI
- Design better suited to cooling
 - → **CryoPAF**
 - $T_{\text{sys}} < 20\text{K} !?$



FY 2017-18 – Detailed plan

- **CryoPAF for Parkes:** (5 FTE) proposal led by UWA.
 - “rocket PAF” with ~\$20K Tsys; ~2-3 x ADE
 - Cost: ~\$3M; ~\$1.5M external; CSIRO labour; 2 years
- **ASKAP completion:** (10-12 FTE) from Technologies
 - ASKAP upgrade (36); ASKAP Documentation and Commissioning
 - ASKAPSoft needs +6FTE from computing group.
- **SKA:** (11 FTE) from Technologies, externally funded.
 - Software request for +6 FTE; only 1 externally funded.
- **UWB@Parkes:** (6.5 FTE) to be completed by end 2017.
- **UWB for MPIFR:** (~2 FTE) parts of the UWB in early 2018.
 - Details to be negotiated. Minimum project cost ~\$100k.
- **ASKAP transparent feedlegs:** (1FTE + \$120k) test system
 - Improve ASKAP Tsys by 10-20K (→ achieve original ASKAP spec)
 - Test feasibility on 1 antenna in 2017
 - Full ASKAP conversion >\$2M in parts + \$1M in labour effort
 - Maximum benefit if done within ~2 years.
- **GPU upgrade of ATCA:** Update CABB and double BW (sensitivity increase)
 - Versatile; flexible; fast transients; maintainability; unattended observing; support
 - SIEF proposal for ~\$3M ; ~\$2M external funding and ~\$1M from CASS
 - *(See Chris Phillips talk for details)*

Mid term projects (2018-22) - CASS

- SKA: ~\$2M p.a. continuing external funding
 - SKA Construction and Integration and Commissioning; Computing
- ASKAP: completion and enhancements
 - Commissioning; Transparent legs; Transients; Pawsey upgrade
- GPU upgrade of ATCA: – Completion FY2018-19
- UWB-high at Parkes: (~4-30 GHz)
 - Utilise UWB(low) digital subsystem and GPUs
 - RF-system cost ~\$0.5M
- PAF development:
 - ** Complete CryoPAF@Parkes in 2019
 - SKA development program
 - ** PAF digital back-end development – leverage SKA designs?
 - PAFs at higher frequencies?

Strategic Goals and Outcomes

- Simplify operations & maintenance → reduce ops costs
 - Remote and unattended observing → efficient observing / less costs
 - Receiver fleet permanently installed → versatility & less costs.
- Parkes systems strategy (ATUC 2012!)
 - Ultra Wideband Low (700 – 4000 MHz) - funded (install 2017)
 - Ultra Wideband High (4 -24 GHz) - unfunded BUT incremental cost ~\$0.5M
 - cryoPAF to replace MultiBeam (700-1800 MHz) – LIEF proposal (install 2019)
- Parkes back-ends – 1 Digital DSP + GPUs for ALL receivers!!
 - Demonstrated with the Bonn PAF@Parkes → GPU system installed
 - Can be used by UWB systems (Low and High)
- ATCA: Must operate till SKA operational (5+ years)
 - → CABB replacement and enhancement → GPUs - SIEF proposal (install 2019)
 - Now vulnerable to CABB failures → GPUs for maintainability
 - Versatility and New Modes (Zooms; transients,...)
 - ** Strategic development of GPU capabilities

Mid term projects (2018-22) - External

- UWB-low for other telescopes:
 - Interest from China (~3 systems);
 - Contingent on proven UWB-low at Parkes
- UWB (high) for Thai 40m antenna
 - Possible new development, required mid-2019
- CryoPAF for other Telescopes
 - strong interest in a cryoPAF (MPIfR, FAST, XAO, Thailand).
 - Contingent on successful deployment of a cryoPAF at Parkes
 - AND development on new PAF back-end (unless local DSP available)
- Multi-beam systems
 - Commercial enquiry from China

Capability planning (< 5 years)

- Focus on **core** capabilities
 - unique and internationally recognised expertise, built over time
 - RF systems; Digital systems; Scientific computing; System specialists
- No drastic changes of direction are envisaged,
 - remain dynamic and adaptable to external changes.
- Present Program size (~45 FTE) optimal
 - Only minor reductions; critical mass issues
- Funding plan:
 - **Appropriation funding** (about 30-40% of annual budget) for core capabilities and R&D,
 - **Additional funding** (incl CSIRO Capex) for deployment on CASS telescopes or elsewhere. Past funding sources: LIEF, SIEF, AAL, external contracts
- **Aim: Sustainable achievable budget support of ~40 FTE**
 - → Small staff reduction (~5 FTE)

Strategic directions (5+ years) - Capabilities

CSIRO Engineering capabilities:

- **RF systems:** Cutting edge e.g. UWB, PAF, Multi-beam
 - Mainly cm-bands; some mm-experience; little low-freq
- **Digital Systems:** FPGA expertise – hardware and firmware
 - World-leading in DSP – collaboration with ASTRON
 - RF-over-Fiber expertise (from ASKAP)
- **Complementary** skills/capabilities (Operations & Engineering):
 - **Software** development: Telescope control/monitoring; Big Data
 - **GPU** support and programming
 - **Networking** expertise
 - **Systems** engineering: Commissioning
- **Maintain & Enhance; Adaptability? Mix of skills? - FPGAs vs GPUs**
- **→ Talent management and succession planning**
 - **Pool of students/post-docs; Visiting/Joint appt; Exchanges; Diversity**

Strategic directions (5+ years)- Projects

- SKA involvement
 - SKA dominant player in radio-astronomy
 - PAFs for SKA2?
 - **Maintain involvement in SKA Observatory Development Program (ODP)**
- Digital Signal processing
 - Rapidly evolving technologies
 - FPGA and GPU convergence?
 - **Retain technical edge and maintain adaptability**
- Scientific Computing
 - Algorithms and software (calibration and imaging)
 - High Performance Computing
 - Big Data
 - **Enhance capabilities?**


Instruments (5+ years)

- **ParkeS:** There is always a complementary need for large antennas (zero spacing). And the availability of ParkeS as a test instrument for new systems (e.g. UWB, CryoPAF,...) is essential in the continuing development of new systems. External clients are much more interested in well-demonstrated systems.
- **ATCA:** Coverage of the 5-50 GHz frequency range in the southern hemisphere is not going to be available in SKA1. Hence ATCA will have a critical follow-up role. New capabilities need to be also planned.
- **ASKAP:** In the 10-year time frame ASKAP would likely complete its planned survey projects. It may need an upgrade to remain competitive.

→ Maintain and develop ATNF instruments till SKA science (+10 years!!)

Summary

- CASS Engineering/Technologies:
 - World-class radio-astronomy instrumentation
 - Pioneering cutting-edge technologies: PAF; UWB; DSP; RFoF
 - For world-wide radio-astronomy facilities
 - International reputation – Key player in **SKA**
 - → **MUST maintain/enhance/develop**
 - Need vibrant world-class radio-astronomy unit
 - (Science+Engineering+Software)
 - CSIRO instruments (ASKAP; Parkes; ATCA) provide impetus/platforms/passion
 - Extensive “sales” and collaborations in radio-astronomy
 - Trusted advisor and partner
 - Exploring plans for possible wider “commercialisation”
 - **Must NOT Risk** losing R&D focus in radio-astronomy
- **Overall Strategy endorsed by ATSC**



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