# 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 (October 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;...) - <u>Digital Signal Processing</u> & FPGAs
- Scientific Computing (~13 FTE): Control and monitoring systems; calibration strategies and algorithms; data processing (e.g ASKAPsoft). (<u>Operations</u> <u>Program</u>).
- Engineering Generalists (~5FTE): System Scientists/Engineers; System integrators; New Ideas; ...
- (Management: ~ +5 FTE) → Total: ~45FTE in Engineering → To reduce by ~4

NB1: Small groups  $\rightarrow$  Single subject experts  $\rightarrow$  (Risk: Single-point failures?) NB2: <u>Critical mass</u> issues  $\rightarrow$  Could not lose  $\geq$  1-2 people/group



### **Current Technologies Projects (FY 2017-18)**

- **1. ASKAP:** Highest Priority; ~10-12 FTE (Engineering)
  - PAF systems technologies
  - ADE PAFs for <u>Effelsberg</u> & <u>Jodrell Bank</u> (External contracts)
    - Showcasing PAFs on single dishes; Collaborative effort in Commissioning
    - Efflesberg in Commissioning; Jodrell Bank built to be delivered
- 2. SKA: International commitment. ~11 FTE (Engineering)
  - Pre-construction consortia (CSP; AIV; SDP; SaDT...)
  - **PAF technology development** (AIP/ODP) + some internal resources
    - Strategic to maintain PAF technology lead
    - CASS leads PAF ODP Consortium (Chair: Jodrell Bank)
- 3. FAST 19-beam receiver external contract → Completed!
  - Only ~2 FTE-months remaining commitment for installation
- 4. Rocket PAF → CryoPAF LIEF proposal result in Nov 2017 !!
- 5. UWB: System for Parkes 700-4200 MHz; novel technology



#### FAST 19-beam Receiver (Jun 2017)

- Receiver system for FAST 500m telescope
  - 1050-1450 MHz
  - 19 dual-pol beams
- Contract with NAOC
  - Acceptance May 2017!!
  - Ready for shipment → Nov 2017?
- 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

#### • Delays due to lab issues & Customs clearance!!







#### "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 proposal Tsys < 20K !?</li>
  - Cost: ~\$3M (incl 5 FTE from CASS)
  - LIEF led by UWA Result in Nov 2017.







#### Parkes UltaWideBand system (UWB)

- Band 700 4000 MHz; Tsys < 20K
- Consortium funding + ARC + CASS (labour: 6.5 FTE)
- Novel feed: ridged-horn+rings+dielectric
  - Cooled Rx version Tested on Parkes Aug'17
- LNAs designed & chips fabricated in foundry
  - Not working with cooled Rx!!
  - Different foundry run → Jan 2018
  - Interim L/S LNAs (limited at band edges)
- Sampler/digitiser and timing (Back-end)
  - Full scale construction now!
  - 2-ch test system to Parkes in Nov'17
- Ethernet switch and GPU cluster (2016)
  - Software led by Swinbourne → Testing
- RFI mitigation built-in reference antenna
  - Chinese (XAO) secondment for 1-year
- Construction within 2017
- Integration Jan-Feb 2018; Install Mar 2018
- Shared-risk observing APR2018 semester
- $\rightarrow$  New LNAs; New ADCs; Oversample  $\rightarrow$  mid-2018







#### **New Projects**

- **ASKAP transparent feedlegs:** (1FTE + \$200k) test system
  - Improve ASKAP Tsys by 10-20K ( $\rightarrow$  achieve original ASKAP spec)
  - Test feasibility on 1 antenna; "Proof-of-concept" system
    - Ordered!! Due end'17; Test 1<sup>st</sup> quarter 2018
  - Full ASKAP conversion >\$2M in parts + \$1M in labour effort. Funding?
  - Maximum benefit if done within ~2 years.
- **GPU upgrade of ATCA:** Update CABB and double BW (sensitivity increase) (*details: Chris Phillips ATUC talk Jun 2017*)
  - Versatile; flexible; fast transients; maintainability; unattended observing; support
  - SIEF proposal for ~\$3M ; ~\$2M external funding and ~\$1M from CASS
  - Did not get funded!! (did not fit SIEF guidelines!)
  - CASS continues R&D; Both ADCs and GPUs (4 GPU test system now)
  - → Full system needs external funds! LIEF proposal?? University to lead?



## 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 UWB-H first
- Cost: ~\$0.5M h/w; + 5 FTE Labour.
- Needs funding. LIEF??



#### **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 early 2018)
  - Ultra Wideband High (4 -24 GHz) unfunded; incremental cost ~\$0.5M+5FTE
  - 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 LIEF proposal ??
  - Now vulnerable to CABB failures  $\rightarrow$  GPUs for maintainibility
    - Versatility and New Modes (Zooms; transients,...)
  - \*\* Strategic development of GPU capabilities



#### **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
- $\rightarrow$  Overall Strategy endorsed by ATSC



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