

# Technologies for Radio Astronomy



**CSIRO Astronomy and Space Science**

**Tasso Tzioumis**

**Facilities Program Director – Technologies**

**June 2016**

[www.csiro.au](http://www.csiro.au)



# Directions for ATNF Engineering

(Update since last ATUC meeting)

- **Broad directions largely unchanged (June 2016)**
- **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.



# Available resources & allocations

- **FY 2015-16: ~50 FTEs!! → Current allocations:**
  - ASKAP : ~ 20 FTE → Ongoing commitment
    - ASKAP production → Secondments (2); Terms and casuals (4)
      - Most/all would finish at end of 2016.
  - SKA: ~ 10 FTE → Re-structure after SKA re-baseline → CSP
    - + additional ~3 FTE internal for PAF developments
  - FAST: ~ 6 FTE (deliver system End 2016!!) + Workshop time
  - UWB: ~2-3 FTE (complete 2017)
- **FY 2016-17 Planned: → Similar allocations:**
  - ASKAP: ~ 15 FTE
  - SKA: ~10 FTE ( + 1.5 FTE on PAF internally)
  - FAST: 4 FTE - end in 2016
  - UWB: 5 FTE. Pick-up momentum once FAST ends

# Engineering papers published

Chippendale, A.P.; Hampson, G.A.; Brown, A.J.; Beresford, R.; Barker, S.; Broadhurst, S.; Brothers, M.; Cantrall, C.; Cheng, W.; Doherty, P.; and 7 co-authors. "ASKAP Mk II Phased-Array Feed: From the laboratory to the observatory". *Radio Science Conference (URSI AT-RASC), 2015 1st URSI Atlantic*, Gran Canaria, Spain, 16-24 May, 2015, 1 p (December 2015).

Chippendale, A.; Brown, A.J.; Beresford, R.J.; Hampson, G.A.; Macleod, A.; Shaw, R.D.; Brothers, M.L.; Cantrall, C.; Forsyth, A.R.; Hay, S.G.; Leach, M. "Measured sensitivity of the first mark II phased array feed on an ASKAP antenna". *International Conference on Electromagnetics in Advanced Applications*, Turin, Italy, 7-11 September, 2015, 541-544 (December 2015).

Dunning, A.; Bowen, M.; Bourne, M., Hayman, D.; Smith, S.L. "An ultra-wideband dielectrically loaded quad-ridged feed horn for radio astronomy". *International Conference on Electromagnetics in Advanced Applications*, Turin, Italy, 7-11 September, 2015, 787-790 (December 2015).

Hellbourg, G.; Chippendale, A.P.; Tuthill, J.; Jeffs, B.D. "'Statistical performance of reference antenna based spatial RFI mitigation for radio astronomy". *2015 IEEE International Symposium on Antennas and Propagation and North American Radio Science Meeting*, Vancouver, Canada, 19-24 July, 2015, 1518-1519 (December 2015).

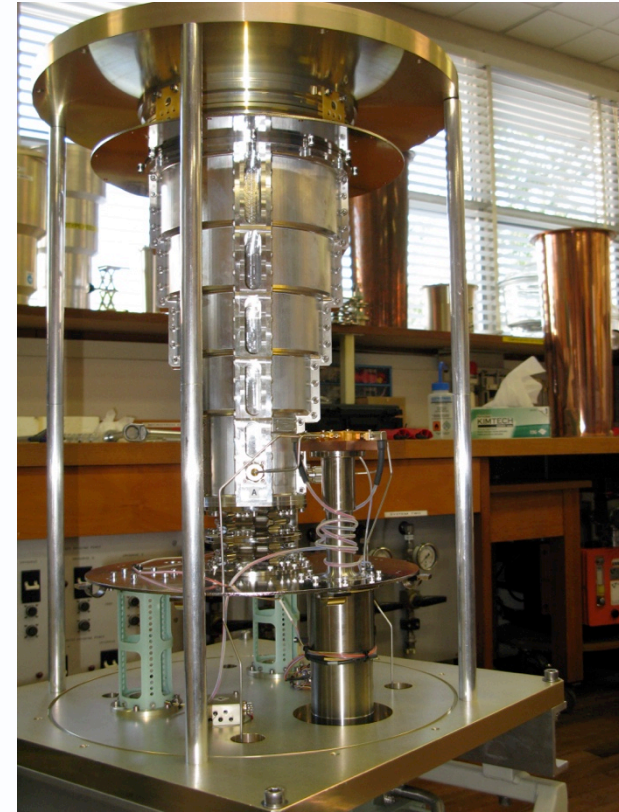
# CABB

- **Formal CSIRO commitment to new functionality ceased Sept 2014**
  - Now ALL tasks covered by post-retirement fellows!!
  - Adequate spares for operations and short-term support.
  - **Unlikely that 16 MHz would be completed!**
- **ATCA CABB upgrade?:** GPU cluster based
  - Leverage on GPU developments at Parkes
    - **Software correlation would allow unlimited zooms?**
  - Digital systems from UWB and SKA developments
  - Hardware: ~\$0.5M for replacing CABB
    - Scalable for more bandwidth.
  - >~\$1M+ for realistic project
  - **External funding!!**



# FAST – 19 beam 1.3 GHz receiver

- **Fully externally funded.**
- Contract with FAST signed Jan 2016!
  - 30% initial payment received in March!
  - Contract delivery ~13 months
  - Prefer by Sept 2016 → Dec 2016?
- Construction well underway
  - New CNC machine in workshop
- Strategic relationship with China!
  - **MUST nurture & develop!?**
- Resource requirements & conflicts
  - Recruitments for FAST
  - Fund ASKAP production team → release key staff for FAST
  - → Planned delays in UWB delivery.



# Ultra-wideband Receiver for Parkes

- Observed band 700 - 4000 MHz;  $T_{\text{sys}} < 20\text{K}$  over most of band
- ARC LIEF grant: \$370k awarded for 2015 ~40% of direct costs
- **Institutions:** CSIRO, Curtin, MPIfR, Melbourne, Monash, NAO/CAS, Swinburne, Sydney, Western Australia
  - Contribute ~ 60% of direct costs
  - CSIRO in-kind ~9 FTE total (over ~2-3 years)
- **Lead Institution is Swinburne. Managing external funds.**
  - Collaboration agreement signed June 2015
  - Project plan in place – October 2015 → Funds available
  - **BUT: Slow-down in delivery due to commitments to ASKAP, SKA, FAST.**

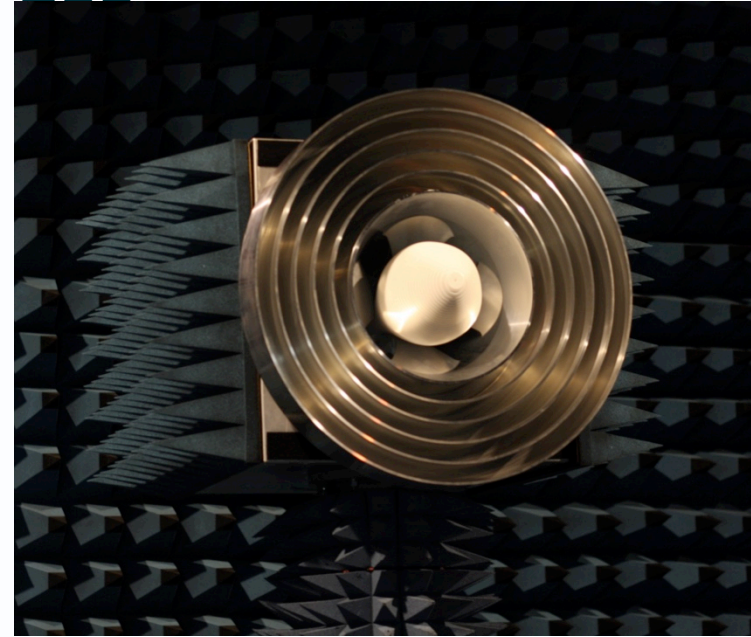
# UWB Project plan summary & Progress

- **Digital systems:** Under development (Paul Roberts)
  - Pre-production system (4 ch) by Nov 2016 @ Parkes
  - Utilise in RFI test/development system.
  - Use as debug and software development platform for full UWB
  - **Explore use as backend for older Receivers & VLBI system.**
- **RF:** LNA design/fabrication/testing – end 2016. Production early 2017
  - Prototype development underway
- **Mechanical:** Design - 2016; Manufacture – early 2017 (Dewar)
- **RF and C/M:** design - late 2016; production – early 2017
- **Computing/software:** Develop by Swinburne in 2016
  - **GPUs and Switch @ Parkes – installed in January 2016**
  - **In use by Bonn PAF. Available for further system development**
- **Integration/Install/Commission:** Mid 2017
  
- **→ Towards a single digital back-end for ALL Parkes systems!**
  - **GPUs and Switch already available!!**



# Prototype UWB Feed Progress

- Prototype feed developed at CSIRO
- Feed tested in June 2015
  - – Room temperature only
- → Paper published! Patents by CSIRO.
- Next steps: Cryo testing.
  - Waiting for available workshop time.



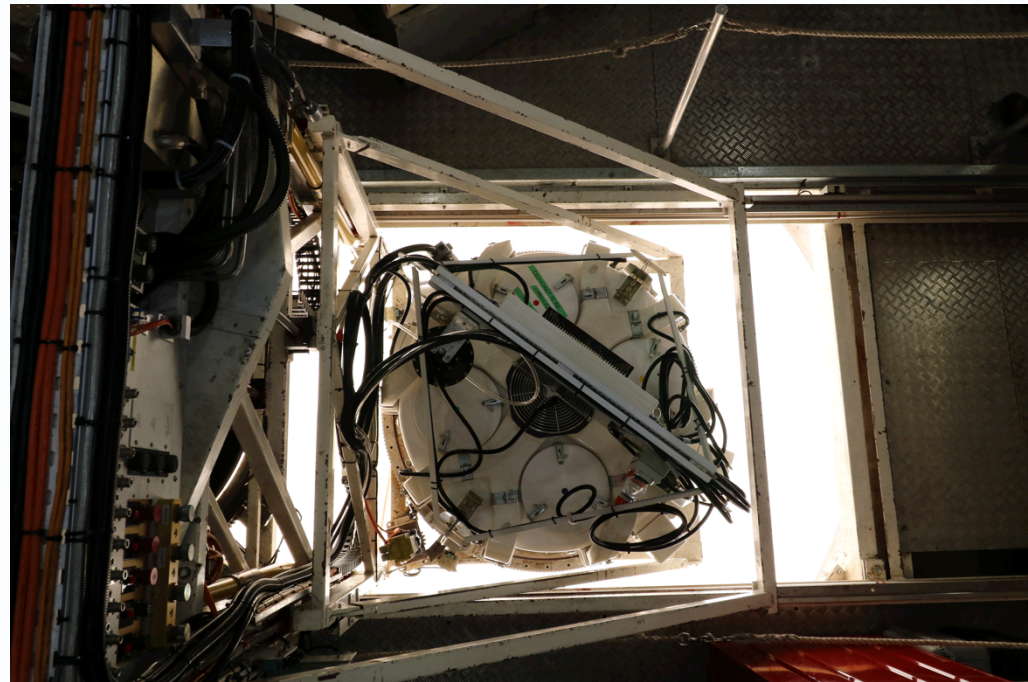
UWB Feed Installed in Antenna Test Range  
Credit: Alex Dunning

## Technological Challenges for UWB system

- Cryogenic cooling - Materials
- Vacuum window
- Wideband LNA development – fab run in July
- System integration – in 2017
  - Mitigate delays by early digital and software developments in 2016.

# ADE PAF system for MPIfR → Parkes

- Contract for standard ASKAP PAF for Effelsberg telescope.
- RFI environment at Effelsberg & Parkes → mods to PAF filtering
  - Funded by MPIfR
- Modified beamformer outputs → Ethernet output
- Strategic use of PAF. Single-dish demonstration → **Bonn PAF at Parkes**
- **Commissioning/Early science**
- **Collaborative Project:**
  - CASS- MPIfR
  - Open to community. NOT NF
  - Proposals Dec15 for APR2016
    - Must bring resources
  - FRBs – primary targets
  - PAF to Bonn in Oct 2016

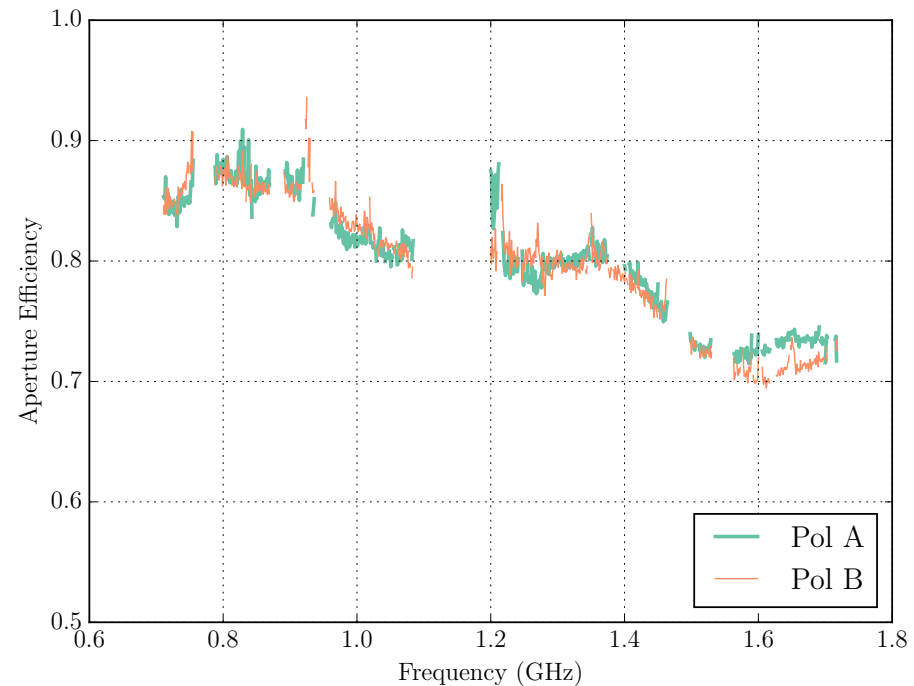
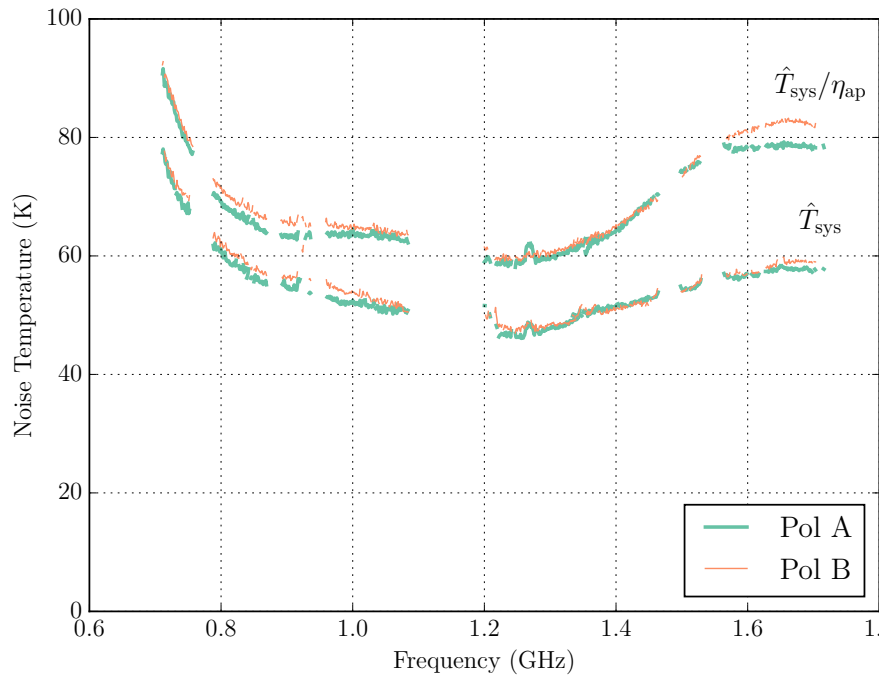


# Bonn PAF at Parkes –Timelines

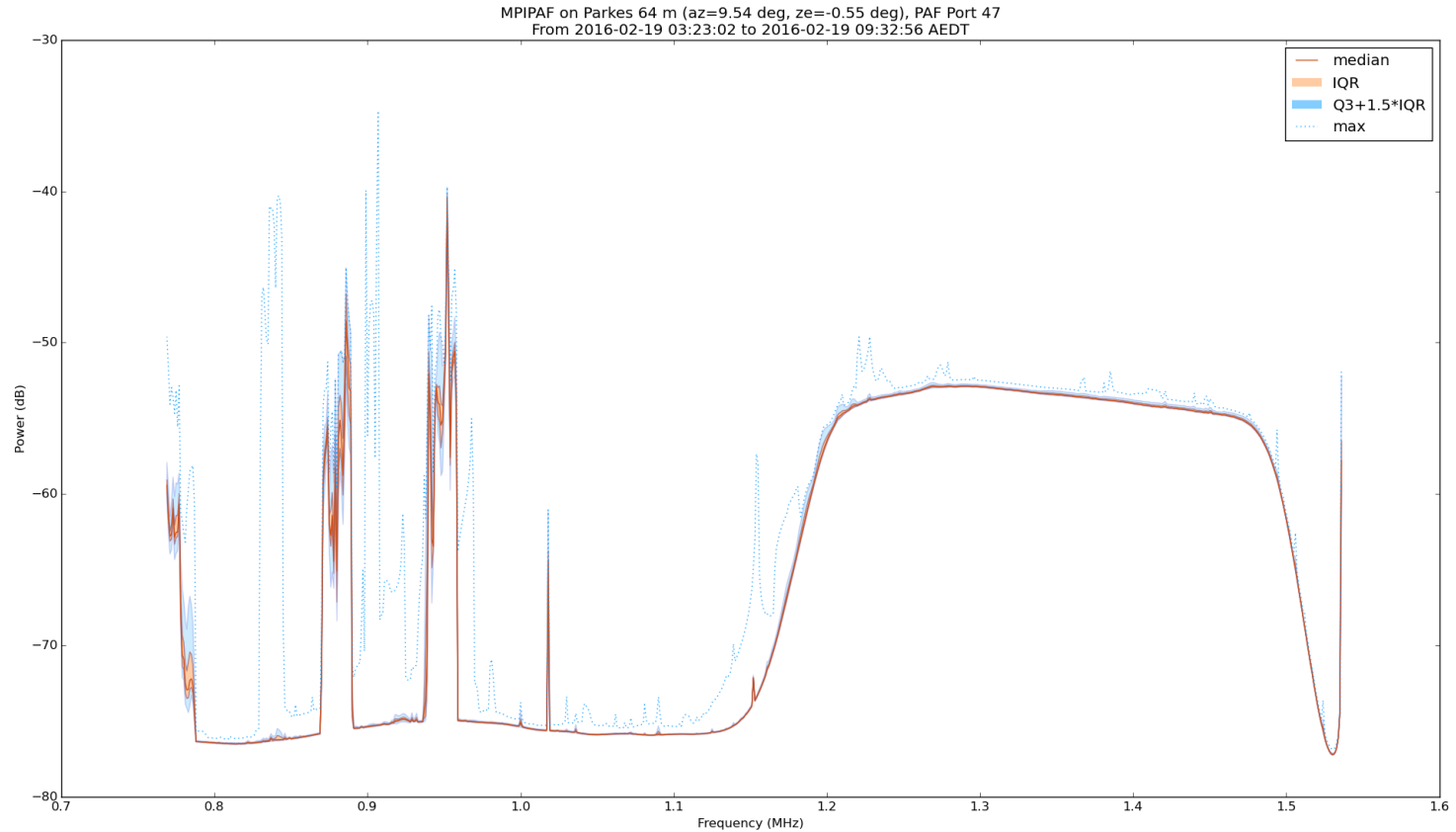
- Install/Commission: Planned for **OCT2015 semester**
  - Bonn PAF filter modifications – Dec 2015 → Done in Jan 2016
  - Test digital/GPU system in Sydney – Dec 2015 ✓
- Parkes preparations: Early in semester
  - Fibre wiring ~ 2 week shutdown: Started 23/11/15!! ✓
  - Racks mods; Install GPUs and Back-end – Jan 2016 ✓ (end)
  - PAF Install: 8-17 Feb 2016. Replace MB system for 8 months.
  - Control computer via TOSS. Jan 2016 ✓
  - Engineering Commissioning: Feb-Mar 2016 ✓
    - Extensive beamforming tests and developments.
- 2-3 engineers/scientists external support
  - Germany and Jodrell Bank – 3 MPIfR engineer visit – Dec & Feb ✓
  - Joint CSIRO/MPIfR post-doc – Started 1 Nov 2015 (full time) ✓
- Science Commission & Scientific Observations: **APR2016 semester**
  - Ethernet Firmware mods – end March (harder than hoped)
  - Software by Bonn & Jodrell Bank: Still Commissioning!
  - First results on pulsars.
- **PAF to Bonn after Sept 2016**

# PAF Performance measurements on Parkes

- Results yet to be published.... (Aaron Chippendale et al)



# PAF spectrum at Parkes



# PAF R & D the “Rocket” PAF

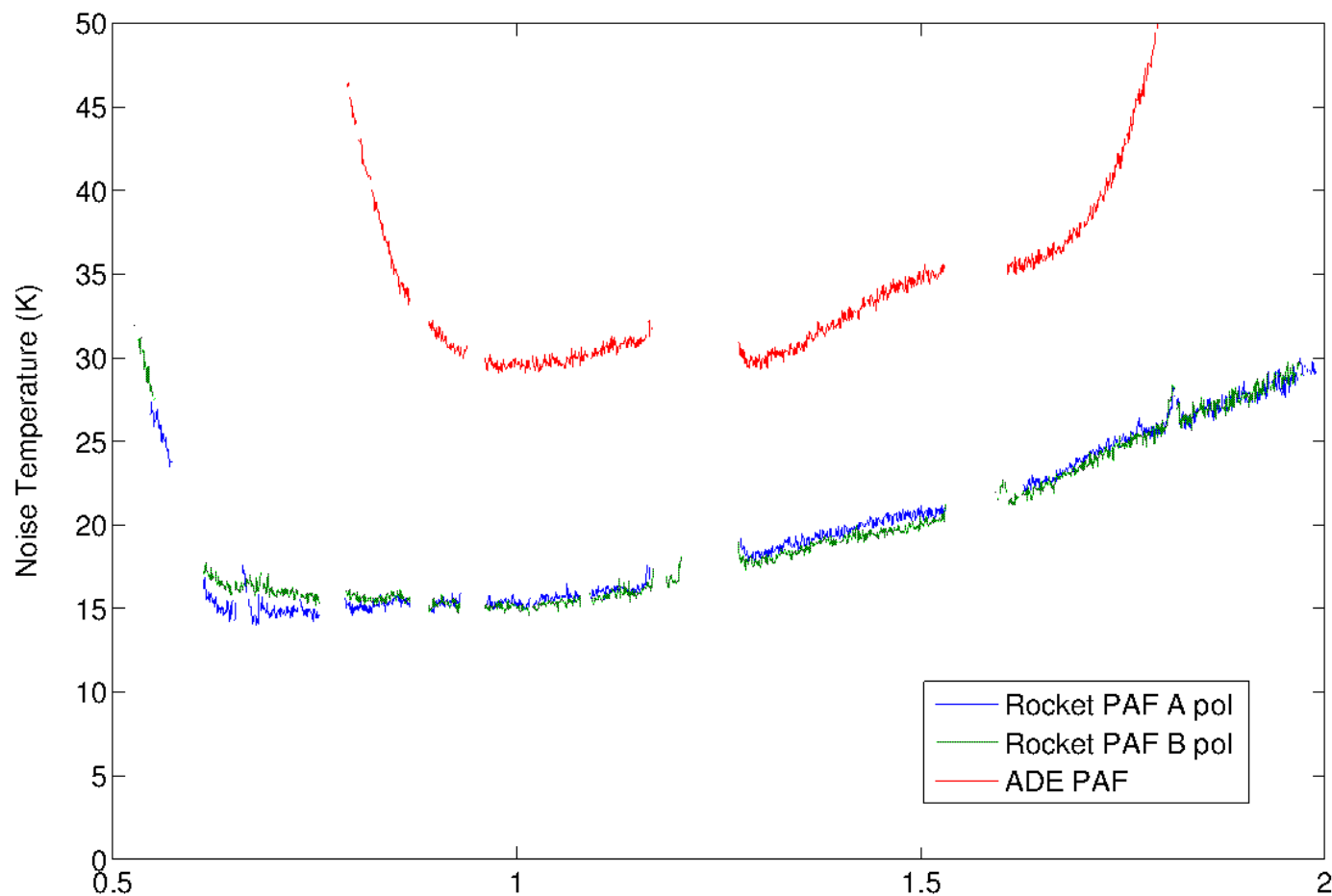
- PAF R&D under SKA-survey
  - Continues as an Advanced Instrumentation Program (AIP)
    - Pre-construction AIP consortium at next SKA Board meeting
    - As Observatory Development Program (ODP) in SKA construction phase
- Key technology for CASS – world leader! → “Rocket” PAF (Alex Dunning)



- Complete picture of the 5×4 test PAF array with the new “rocket” design, where the new central and edge element designs are visible.
- May be more amenable to cryo cooling
  - → Cryo PAF system with  $<20\text{K}$   $T_{\text{sys}}$ !!
  - Superb for single-dish large telescopes!
  - Cooled PAF for Parkes??
    - ~\$2M+. Funding??



# Rocket PAF performance (5x4 prototype)



# Future technical Projects (2018+)

## SKA & ASKAP

- **SKA** Construction/Verification/Commissioning. **Start??**
  - Expect key Australian role. CASS in CSP-Low – follow-up
- **ASKAP enhancements**
  - **Tied-array**: In ASKAP specs but NOT funded!
    - Expert group report. ~\$400k + 5.5 FTE (Firmware+Software)
  - **Transients**: (Cf CRAFT)
    - Add transient mode. Firmware only. ~5FTE effort. NOT Commensal.
- **ASKAP upgrades**. (mainly sensitivity improvements)
  - **“Transparent”** legs. Reduce scatter. Improve Tsys by 10-20K.
    - Initial investigations now.
    - Estimated cost ~\$1.5M h/w + Labour!! **Funding?**
  - **“Skirts”**: Reduce spillover. Better illumination. ~10K to Tsys?
  - **New PAFs** (keep back-end) e.g. “Rocket” PAF.
    - ~15K in Tsys + Better illumination. BUT many \$\$M?
- **Air shower detection by ASKAP (Ekers proposal..)**

# Future Projects & External Contracts

- **NOTE:** Most single-dish cryo systems cost >\$2M!!
- **UWB high** (4-25 GHz) for Parkes. Considered in ATUC before.
  - Leverage on SKA & UWB(low); use UWB GPU cluster & software
  - ~\$1.5-2M; timeline ~2-3 years
  - External funds – AAL; LIEF; Collaborators
- **External contracts:** Maintain/develop capabilities. Strategic.
  - Present **UWB** systems. Strong interest from collaborators!
    - 2-3 contracts in 2017+ timescale?
  - **PAFs**
    - Current generation to Jodrell Bank. NOW
    - Cryo PAFs for large single-dishes. ~20K Tsys
      - 1st system for Parkes. Collaborative funding. Start in 2017-18?
      - Good external candidates (MPIfR; JB; FAST; ....)

# Future technical Projects (2018+)

## PAFs & Others

- **SKA PAF R&D**
  - SKA PAF test array. Up to 4 antennas. Under ODP?
  - Rocket PAF → Cryo PAF systems . <20K Tsys
  - Higher frequency PAFs: SKA; Arrays; Single-dish
  - mm PAFs e.g. for ALMA (cf NRAO)
  - Dual band PAFs
  - MMIC packaging
- **16-25 GHz PAF on ATCA.** Transformative for surveys!
- **Aperture** array applications:
  - SETI; Array of PAFs; Needs Massive digital and GPU resources.
  - Filled aperture array at ~100 MHz. All sky coverage.
- **Other technologies**
  - RF-over-fiber developments
  - UWB in other bands
  - Signal processing FPGA platforms

# Summary (from ATSC presentation)

## 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

# Thank you

**Astronomy & Space Science**  
Tasso Tzioumis

**t** +61 2 9372 4350

**E** Tasso.Tzioumis@csiro.au

**w** [www.csiro.au/cass](http://www.csiro.au/cass)

[www.csiro.au](http://www.csiro.au)

