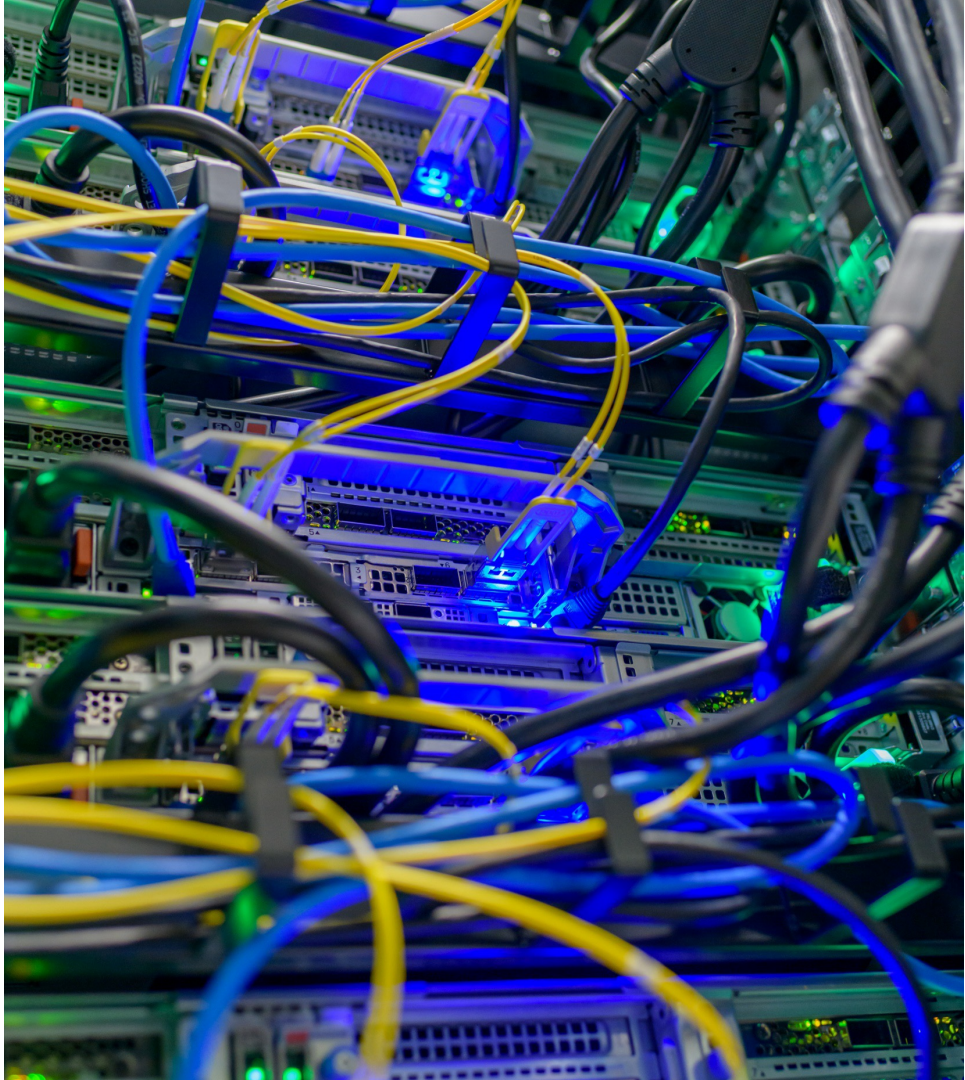
ATUC Open Day Session 3

Making the most of our facilities



Australia’s National Science Agency

Strategy for ATNF R&D

Keith Bannister

Why do technology development?

- To advance the state of the art of radio astronomy
- To maintain and upgrade ATNF facilities
  - keep them at the forefront of science
- To improve collaborations with other institutions:
  - Working jointly on technologies
  - Providing technologies for use on other facilities

Our strengths

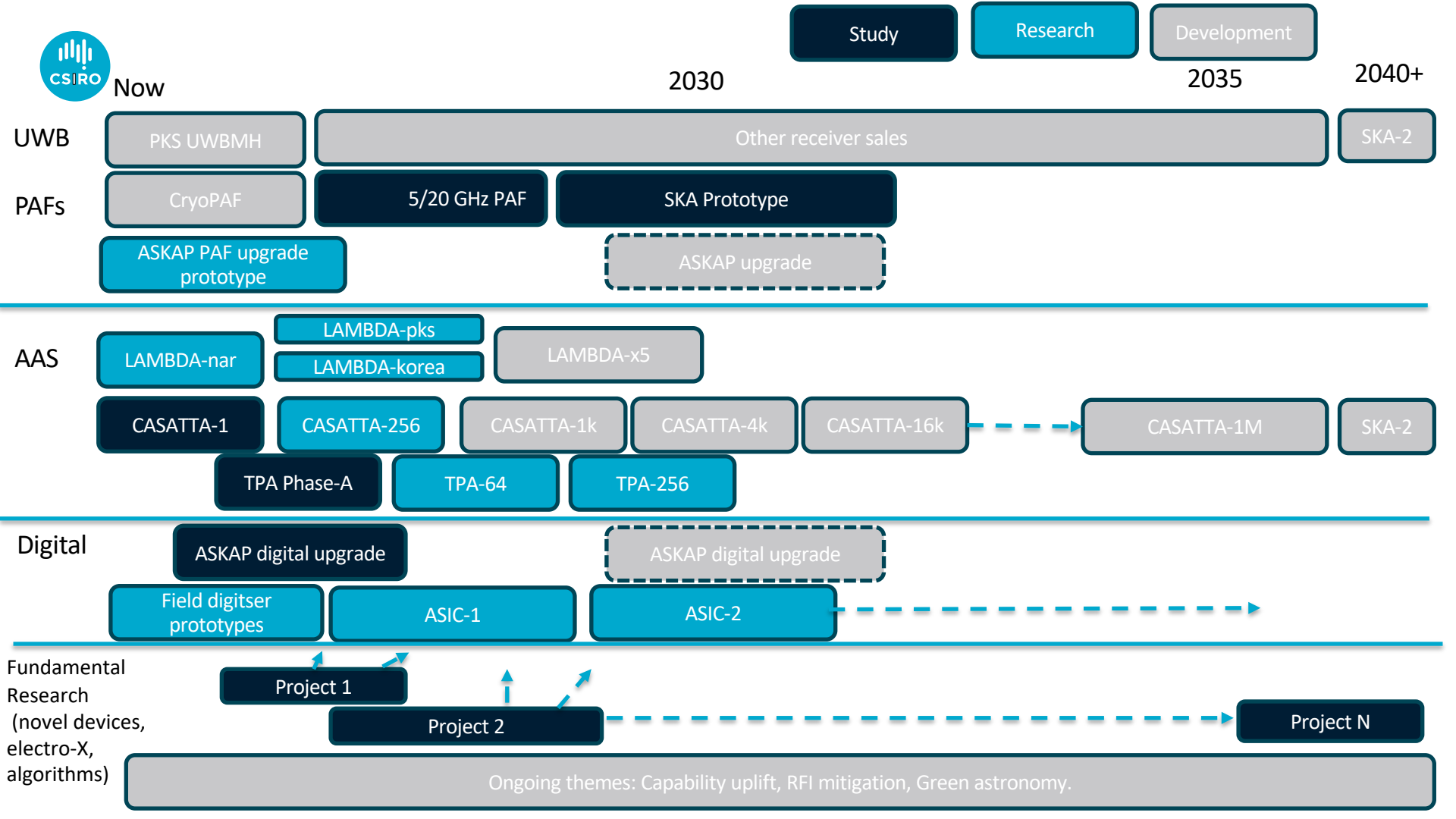
- ATNF can make most high-tech components in the value chain
- Not steel or concrete
- Only a handful institutes around the world can build the end-to-end system in-house.
- In some aspects, ATNF technologies are world-leading.

- **Feeds**: ultra-wideband, phased array, cryogenics, room temperature
- **Electronics**: digital and radio frequency
- **Software**: Embedded and high-performance computing
- **Algorithms**: Imaging, real-time processing, AI
- **Archives**

ASKAP Upgrade	Dish Array (ATWA?)	Aperture Array
Improved PAF Tsys Improved bandwidth: 512 MHz 36 antennas = unchanged 36 beams = unchanged ASIC-based digitizer (Kestrel) Flexible GPU beamformer/correlator architecture	200x6m Dishes on ASKAP site - ~6km baselines Frequency range: 0.7-20 GHz – 3 or 4 receivers. 4 GHz instantaneous bandwidth. ASIC digitizer (Kestrel) Flexible GPU beamformer/correlator architecture	16k elements. Configuration options: - 16k dense packed - 64 stations x 256 elements - Frequency: - Low band: 350-700 MHz - High band: 700-1420 Mhz

Research lines

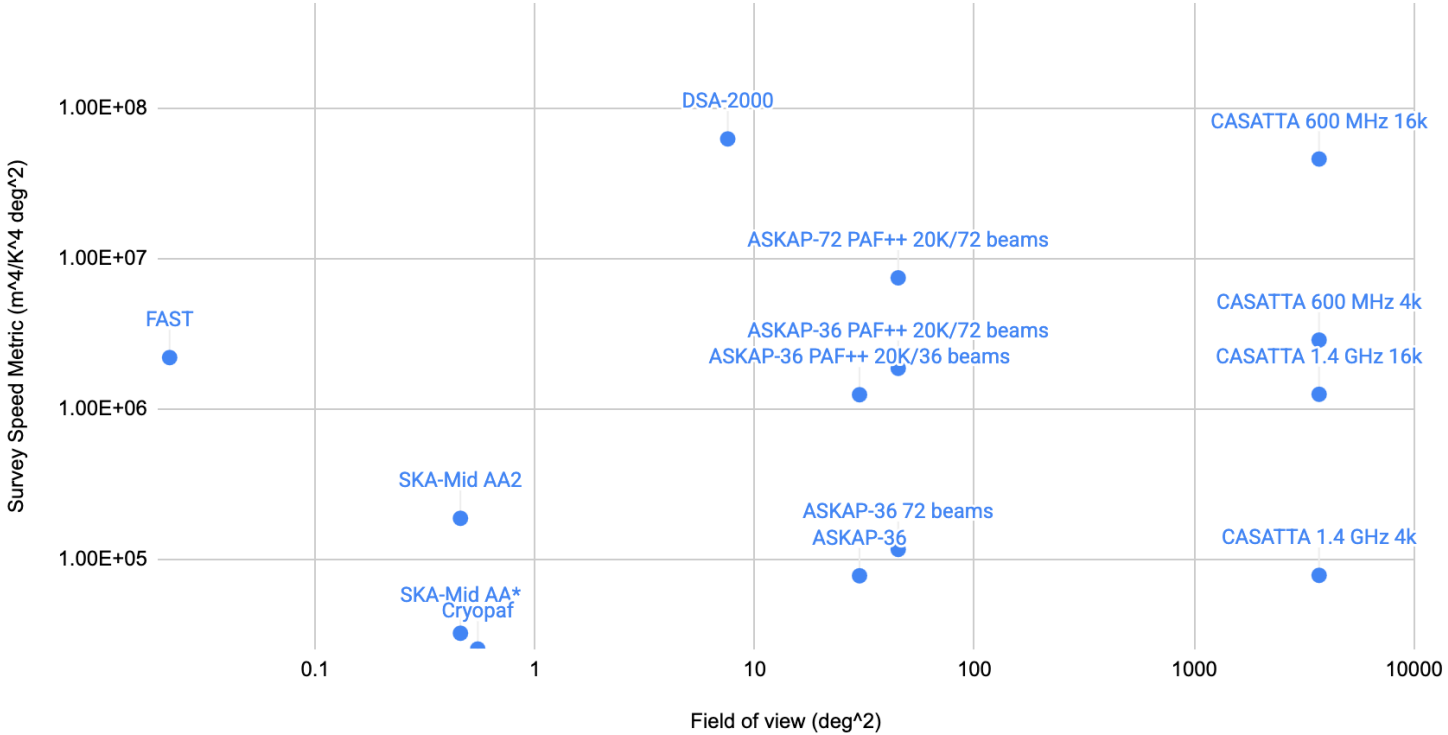
- **Existing technology developments**, +
- **Small Scale & demonstrator telescopes**
  - LAMDA-36 – Low frequency aperture array VLBI demonstrator
  - CASATTA-64 – mid frequency aperture demonstrator
  - GINAN.- Global EOR experiment
  - Terrestrial LunarPAF demonstrator – Low power aperture array
- **Medium term research - 1-2 years**
  - Field-deployable digitization
  - High density RF chain and shielding
  - Mid frequency aperture array antennas
- **Long term research - 3-5 years**
  - Application specific integrated circuits (digital, RF, mixed signal)
  - Custom Low noise amplifiers for all instruments
  - Miniature Microwave integrated circuits (MMICs) for all instruments
  - Electro-optic, electro-acoustic devices and packaging (electro-X)
  - Very Large N (more than 16k elements) digital signal processing
- **Ideas factory**
  - Low power beamforming
  - Digitally tunable filters
  - Optical RFI suppression
  - Total power interferometry
  - THz systems
  - …

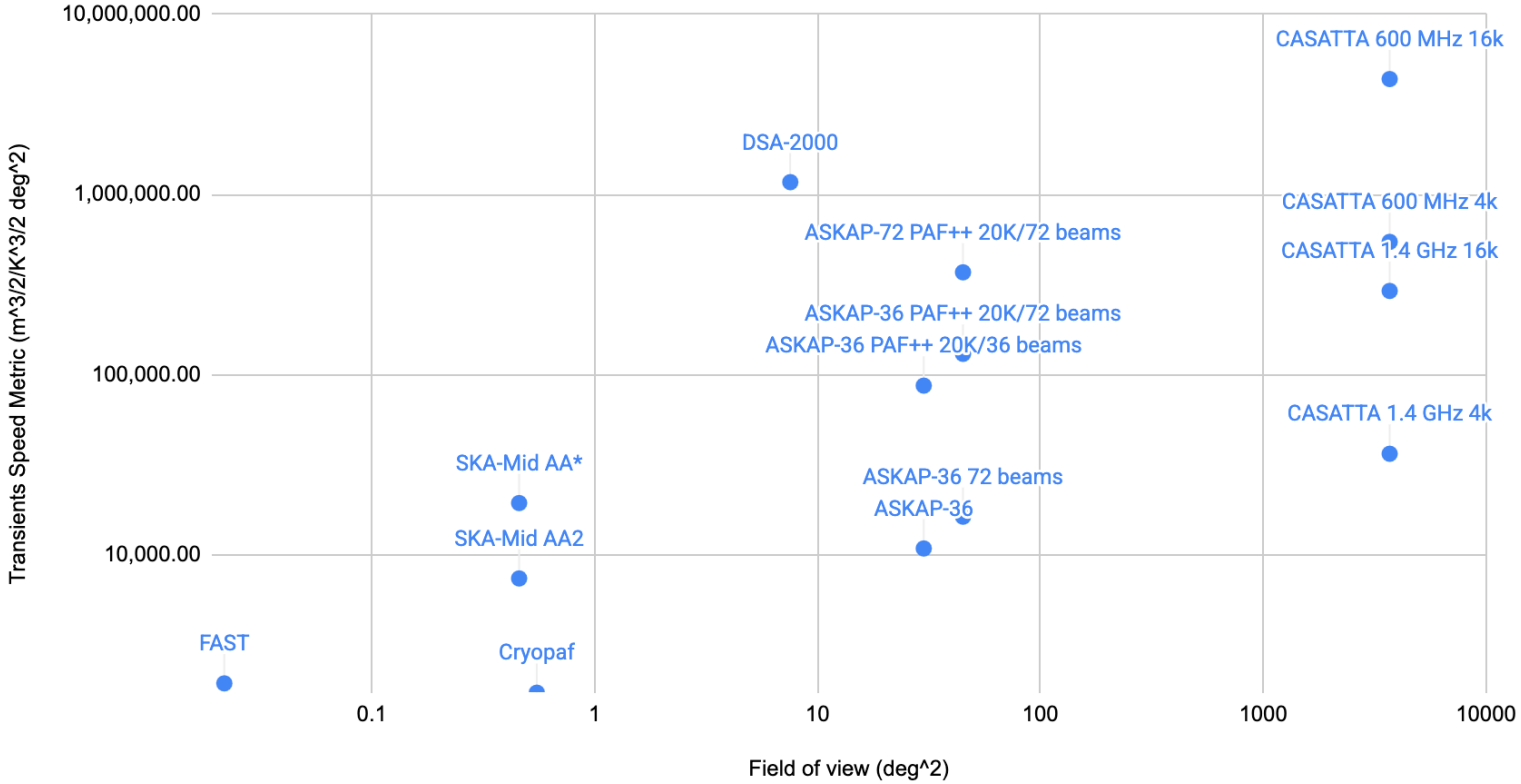

Study
Research
Development
Now
2030
2035
2040+
UWB
PKS UWBMH
Other receiver sales
SKA-2
PAFs
CryoPAF
5/20 GHz PAF
SKA Prototype
ASKAP PAF upgrade prototype
ASKAP upgrade
AAS
LAMBDA-pks
LAMBDA-nar
LAMBDA-korea
LAMBDA-x5
CASATTA-1
CASATTA-256
CASATTA-1k
CASATTA-4k
CASATTA-16k
CASATTA-1M
SKA-2
TPA Phase-A
TPA-64
TPA-256
Digital
ASKAP digital upgrade
ASKAP digital upgrade
Field digitser prototypes
ASIC-1
ASIC-2
Fundamental Research (novel devices, electro-X, algorithms)
Project 1
Project 2
Project N
Ongoing themes: Capability uplift, RFI mitigation, Green astronomy.

Key

- **Study**: At the scale below a CSIRO/ATNF “Project” e.g ~ $100k, 1 FTE for 1 year.
- **Research**: is bigger, but no deployment in the fields.
- **Deployment**: Lots of site works, large visibility outside ATNF. Maybe is or isn’t a “National facility”
- Not included: Facility support takes time from people.

“S


DSA-2000
CASATTA 600 MHz 16k
ASKAP-72 PAF++ 20K/72 beams
CASATTA 600 MHz 4k
FAST
ASKAP-36 PAF++ 20K/72 beams
ASKAP-36 PAF++ 20K/36 beams
CASATTA 1.4 GHz 16k
SKA-Mid AA2
ASKAP-36 72 beams
ASKAP-36
CASATTA 1.4 GHz 4k
SKA-Mid AA*
Cryopaf
1.00E+08
1.00E+07
1.00E+06
1.00E+05
Survey Speed Metric (m^4/K^4 deg^2)
0.1
1
10
100
1000
10000
Field of view (deg^2)


10,000,000.00
1,000,000.00
100,000.00
10,000.00
Transients Speed Metric (m^3/2/K^3/2 deg^2)
0.1
1
10
100
1000
10000
Field of view (deg^2)
CASATTA 600 MHz 16k
DSA-2000
CASATTA 600 MHz 4k
ASKAP-72 PAF++ 20K/72 beams
CASATTA 1.4 GHz 16k
ASKAP-36 PAF++ 20K/72 beams
ASKAP-36 PAF++ 20K/36 beams
CASATTA 1.4 GHz 4k
SKA-Mid AA*
ASKAP-36 72 beams
ASKAP-36
SKA-Mid AA2
FAST
Cryopaf

Thanks

Postgraduate Student Committee Update

Committee Goals

Provide input and feedback to S&A

Establish online communication panel for students

Arrange student forum meetings

Identify student opportunities

Student visits to observatories

Coordinate planning for annual student symposium

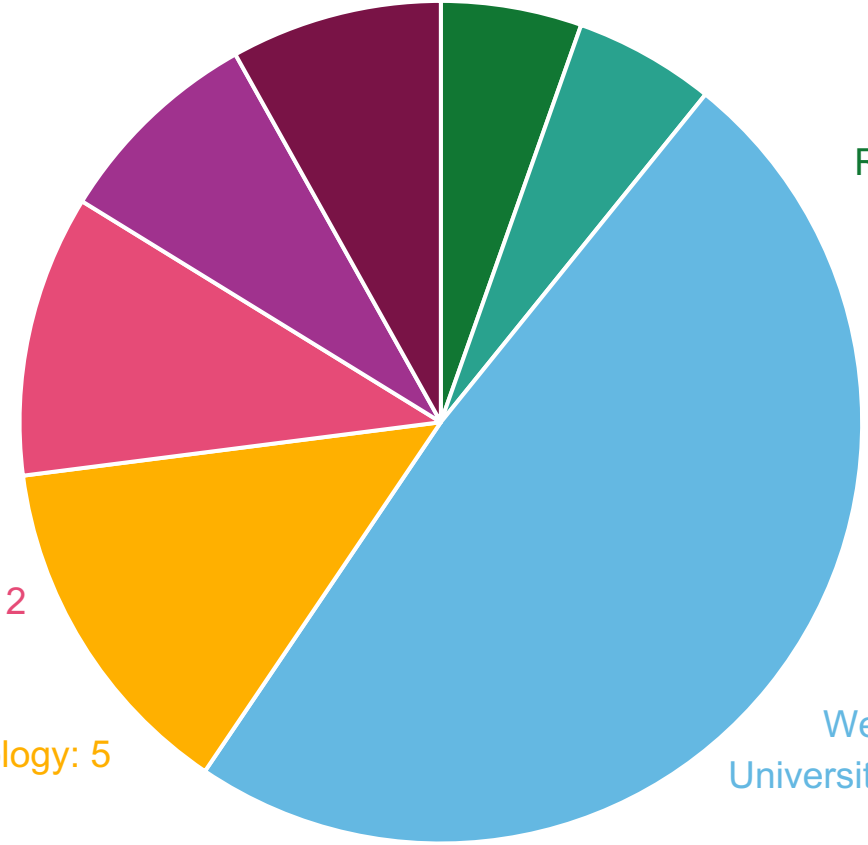
Committee Members

Beth Cappellazzo
Macquarie University

Sanja Lazarevic
Western Sydney University

Sparrow Roch
Swinburne University

Currrent Co-Supervised Students



ACT

Australian National University: 2
University of NSW, Canberra: 1

TAS

University of Tasmania: 3

WA

Curtin University: 2
University of Western Australia: 2

VIC

Swinburne University of Technology: 5

Overseas

Ruhr-Universitat Bochum: 1
Texas A&M University: 1

QLD

Griffith University: 1
James Cook University: 1

NSW

University of Sydney: 8
Macquarie University: 6
Western Sydney University: 3
University of Technology Sydney: 1

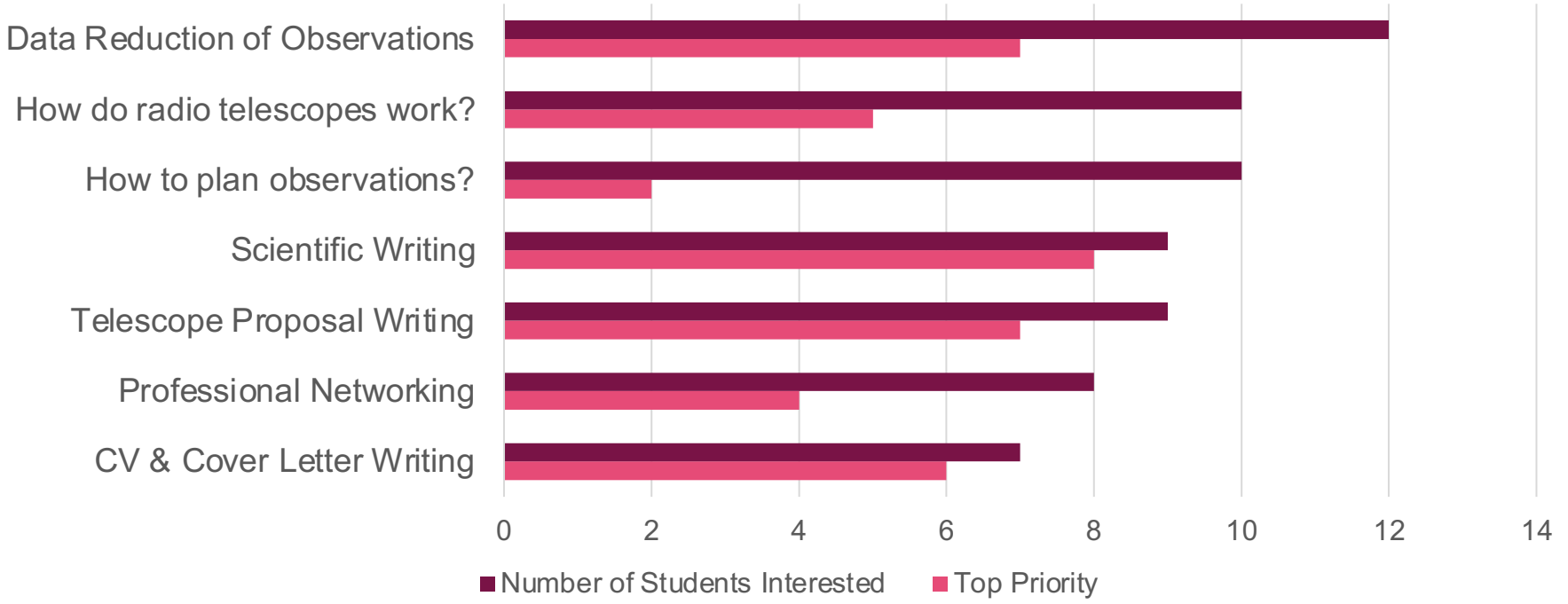
Student Survey

What training would you be interested in receiving?

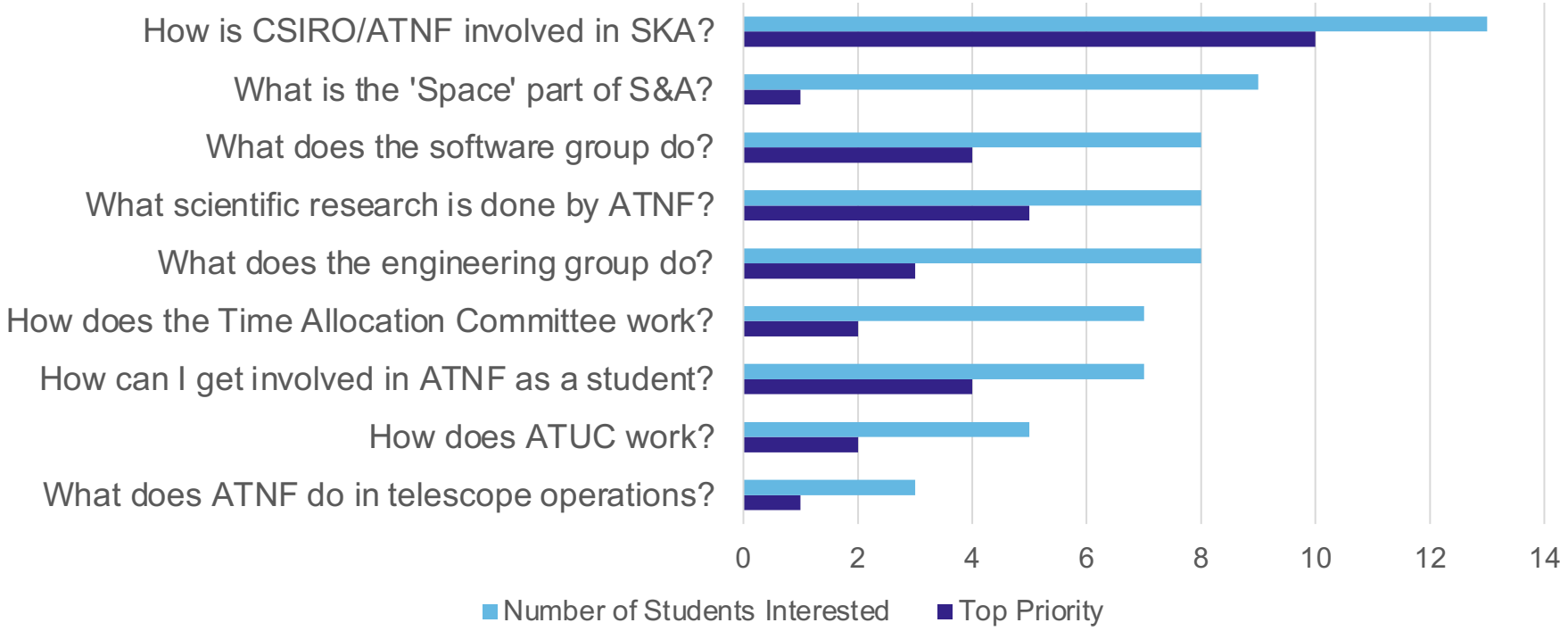
What would you like to learn about ATNF and S&A?

Are you interested in observatory visits?

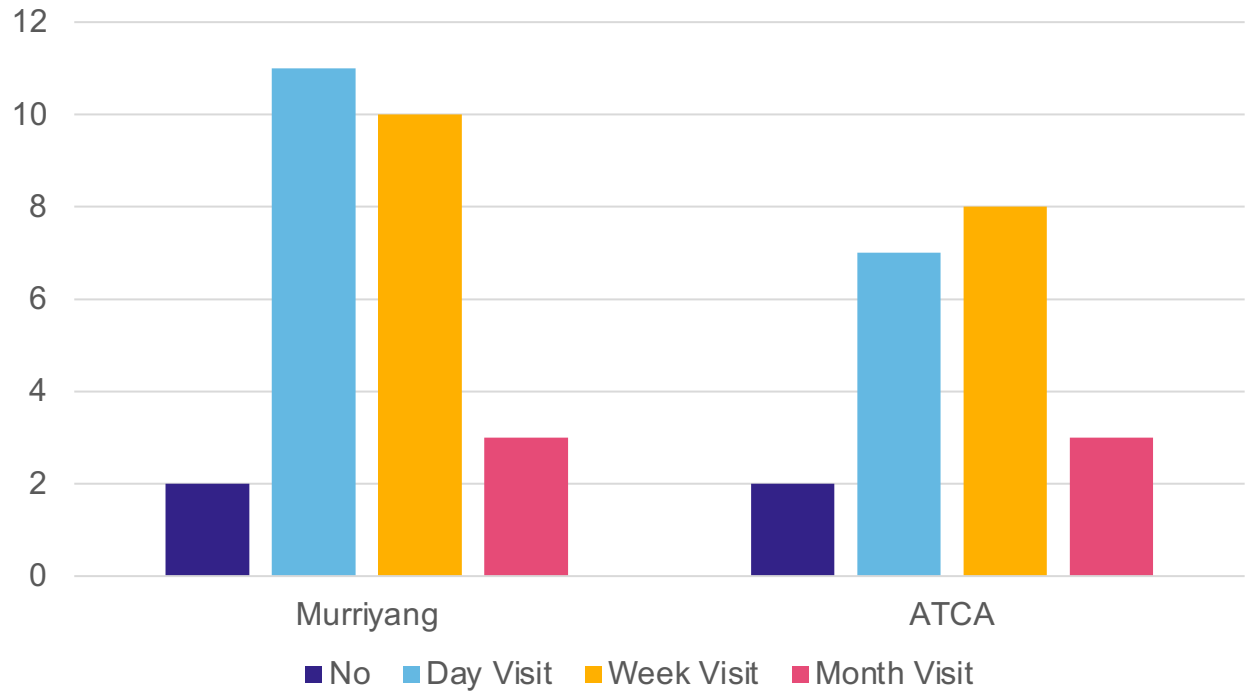
What training would you be interested in receiving?



What would you like to learn about the ATNF and S&A?



Would you be interested in visiting Murriyang and ATCA?



Survey Summary

Students are eager to learn,

want to be involved in community,

and are seeking unique opportunities.

The Committee So Far…

- Student Survey
- Student Symposium
- Discussing workshop & talk ideas
- Slack channel
- Monthly postgrad catch-ups, hosted by Kelly

What's Next?

Visit Parkes before EOFY

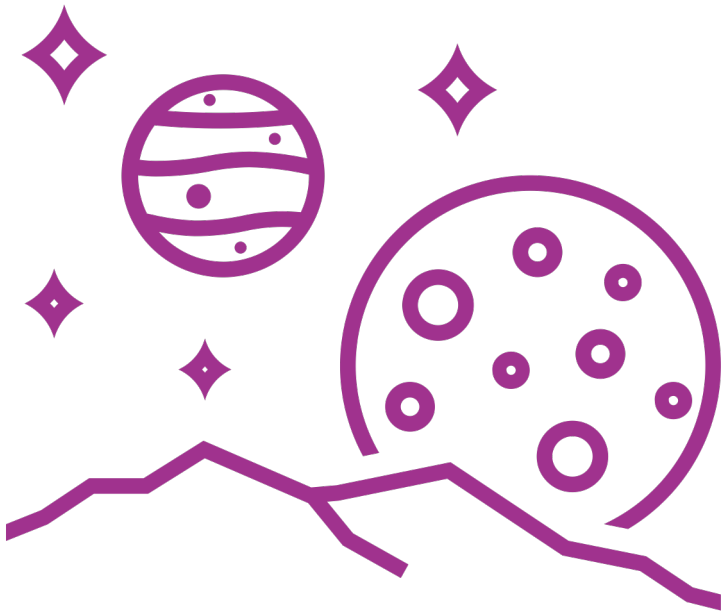
- But we'll visit ATCA another time! ☺

Organize workshops & talks

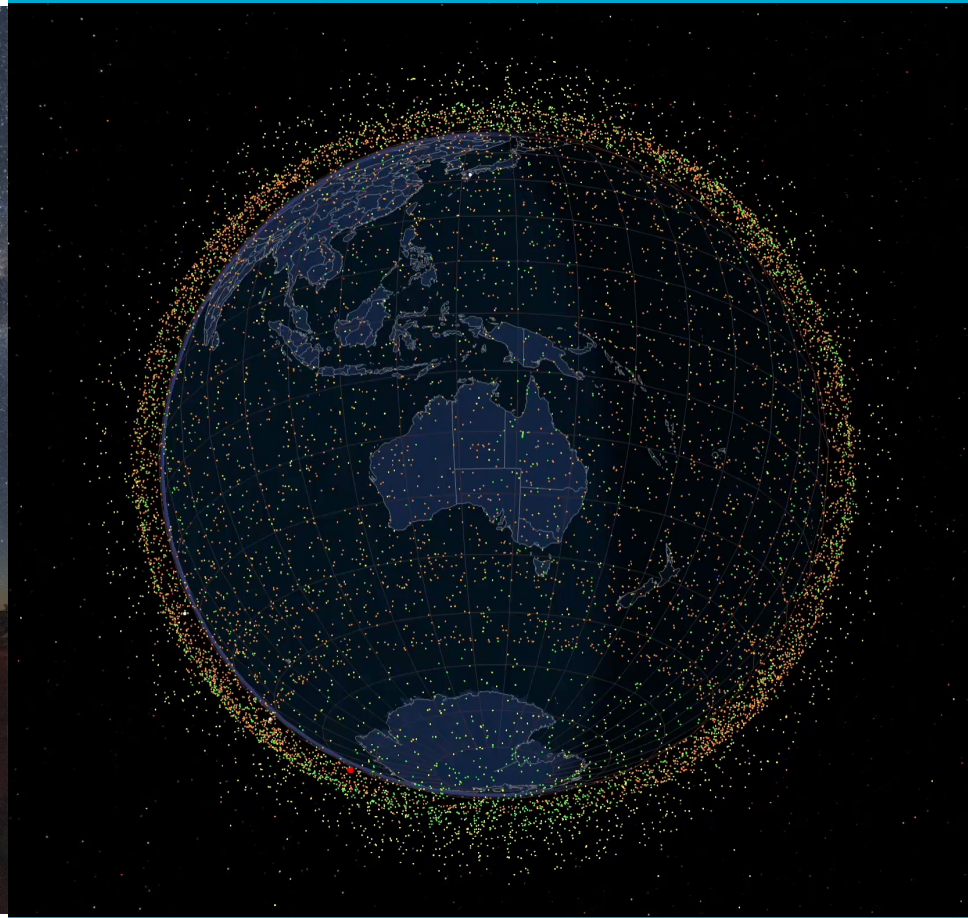
- Student involvement with ATNF
- ASKAP trainings

Last Notes

- Looking for more committee members!
- Join the postgrad student Slack
- Planning focus: observatory visit & workshops/talks
- Please reach out with any comments, suggestions, etc.



Thank you! ☺



RFI mitigation efforts at ATNF

Dr Liroy Lourenço |ATNF Futures 2030 Workshop

Australia’s National Science Agency

Four Categories of Satellite RFI

Intended emissions

- Not technically RFI, but very strong emission we must deal with

Unwanted emissions (Spurious+OOBE)

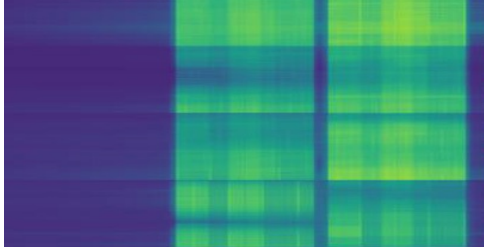
- Every transmitter creates intermodulation products and harmonics. Problematic for RAS due to sensitivity

Unintended radiation / UEMR

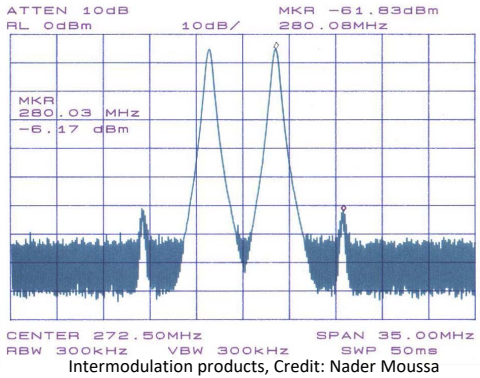
- Satellite platforms radiate from power inverters, computers, networking equipment, inadequately shielded LOs/transmitters. Exist from 30 MHz to K band, shown to be a problem for RAS by Di Vruno et al, Bassa et al, Grigg et al, Indermuehle et al.
- Also a problem at Optical/IR, thermal signatures found with SPT

Reflections

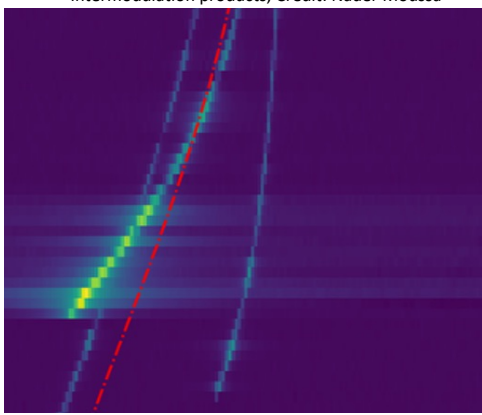
- With increasing orbital density and large RCS satellites, reflecting terrestrial emissions are increasingly detected in RAS observations, undermining RQZ protections



Intended Emission (DTC), Credit: B. Indermuehle/ATNF



Intermodulation products, Credit: Nader Moussa



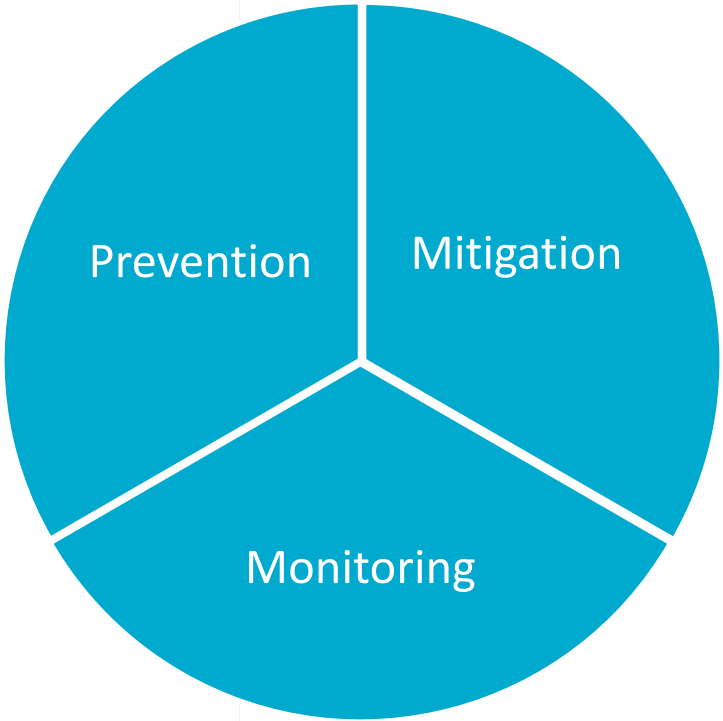
Leaking DTC LOs on Starlink satellites, Credit: B. Indermuehle/ATNF

RFI: Key Themes & Outcomes — ATNF Futures 2030 Workshop

- Growing Threat Landscape
- Satellite constellation (LEO) RFI rapidly worsening; unavoidable at many frequencies
- GNSS satellites contaminate 1.2–1.3 GHz — wiped out half of ASKAP Band 2 HI coverage
    - Redshifted HI most impacted: frequency-specific RFI blocks science at given redshifts
- D2D comms, add complexity to an already difficult problem

- Resourcing & People

- Multiple techniques explored but none yet deployed operationally
- Mitigation 'falls off the to-do list' — must be non-negotiable from instrument design stage
- ASKAP beam weights too slow for real-time adaptive nulling in current system
- RFI-aware smart scheduling: near-term, achievable low-hanging-fruit opportunity?



Need a holistic RFI Management Framework with a suite of mitigation tools throughout the ATNF, system(s) & signal chain.

- Spectrum Management
- Site Selection
- Co-Ordination

Prevention

Mitigation

Monitoring

on-site monitoring

Commensal

Dedicated/ Targeted

Operations

- Site Entity
  - Emissions mgmt
  - Outreach
- Co-Ordination
- Avoidance
  - **Boresight Avoidance**
  - **Smart Scheduling**
  - **Prediction**
  - SSA*
  - Ducting

Instrumentation

- Shielding
- Filters*
- Resilient Receivers
- *Photonic Limiter*

- PFB
- Dynamic Range
- *Blanking*/masks**
  - MAD
  - Spectral Kurtosis
  - Sample clipping
- Ref. Antennas
- *Adaptive Beamforming*

Scientific Computing

- Flagging* (detection)
  - AOFlagger, cFlagger etc.
  - Gridflag? UV domain
  - ML (SNN)(compute…)
- Anti-coincidence
- Spatial Filtering

You!

Level 4: equipment damage

Level 3: saturation, no data recovery

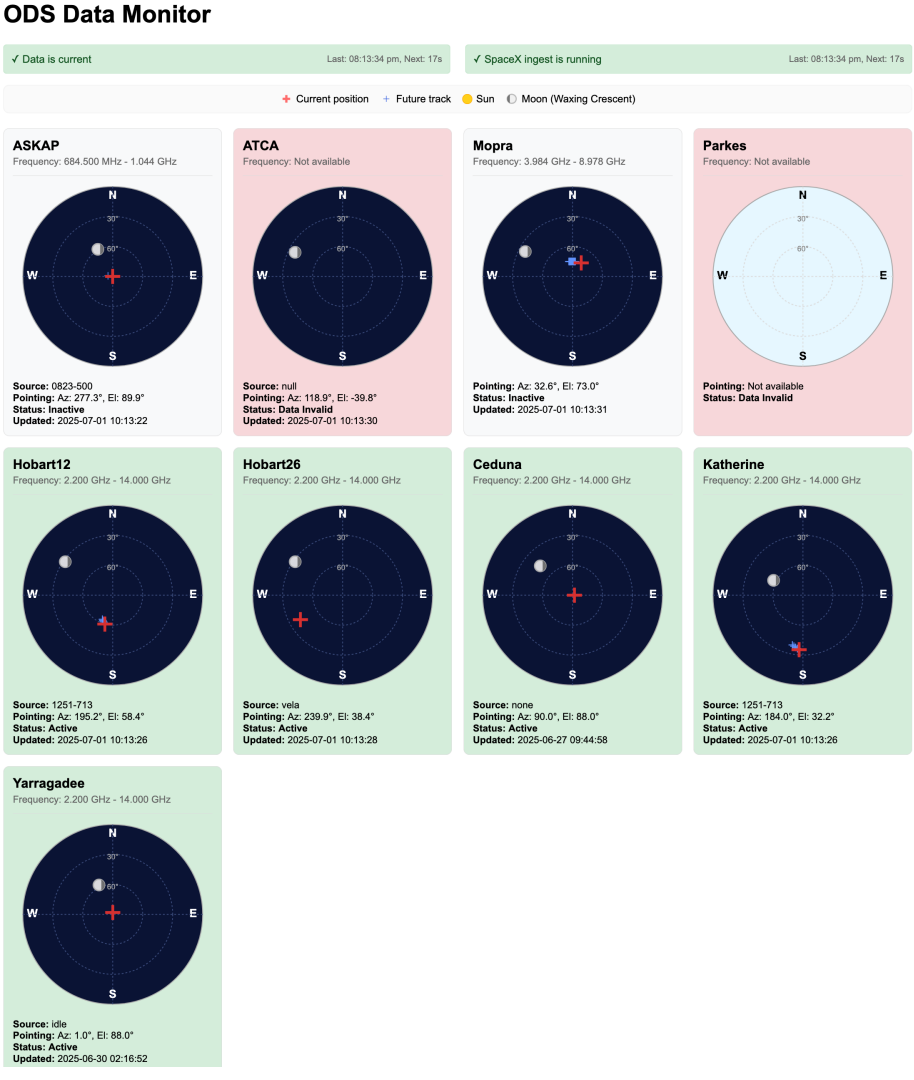
Level 2: non-linearity, RFI + harmonics + InterMod require excision

Level 1: science affected RFI requires excision

Level 0: negligible impact

ODS

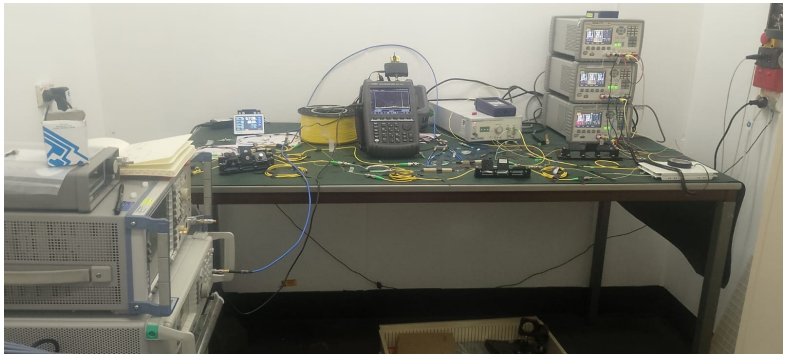
- Observational Data Sharing (ODS) platform is active
- Boresight avoidance (BA) proves effective to mitigate the highest in-band impacts. No panacea (about 10% band-loss improvement @ D2D frequencies, much better at Starlink DL 11.25-12.5 GHz – quantitative measurements soon with BIGCAT)
  - SpaceX implemented for both Starlink and D2D
  - Kuiper in discussions
- LIPD Band coordination (915-928 MHz)
  - Lacuna and Plan-S coordination agreement in progress
- www.narrabri.atnf.csiro.au/ods

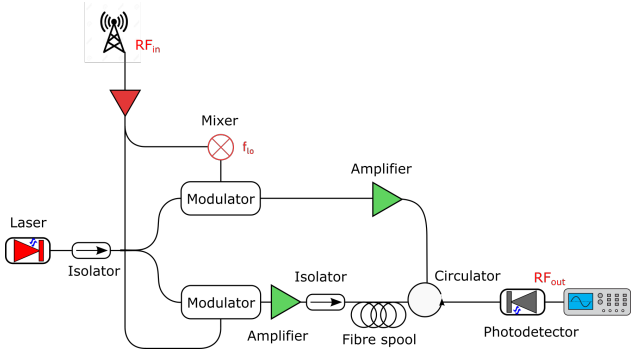


Slide courtesy of Balthasar Indermuehle

Photonic Limiter

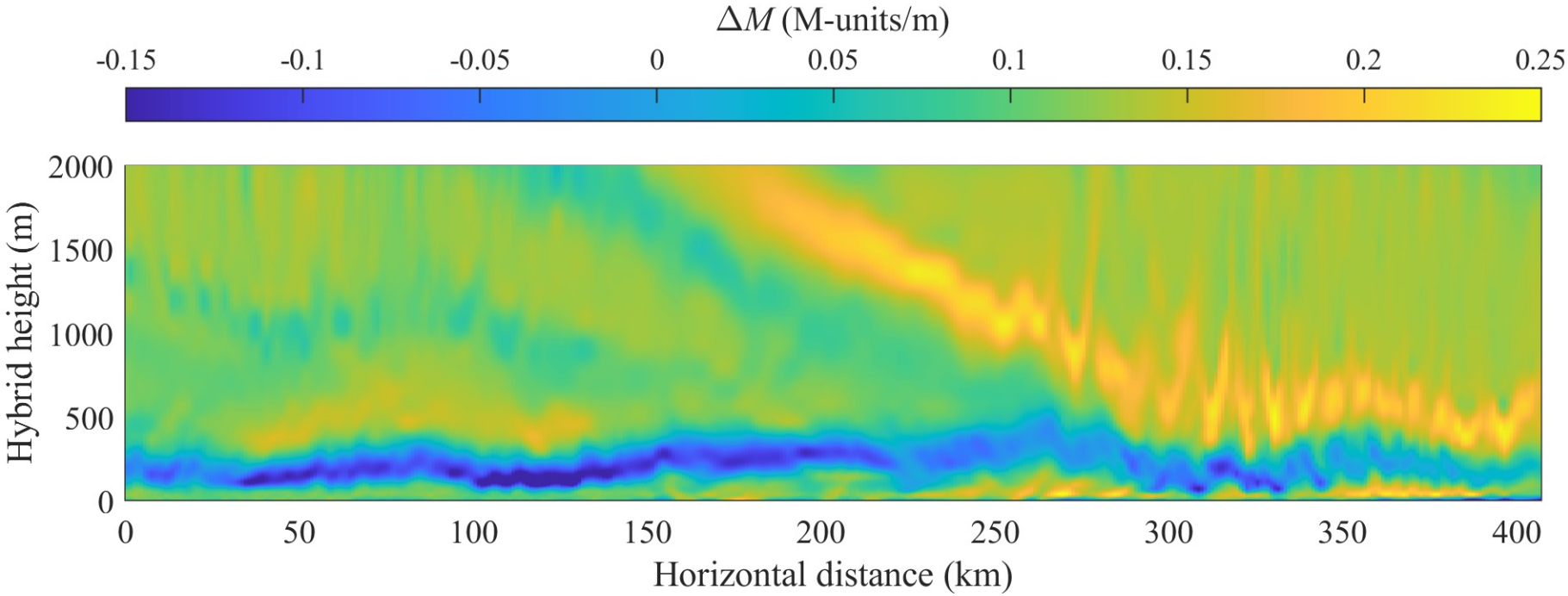
- Microwave photonics
- Removes RFI with adaptive notch filter
- Programmable threshold
- Works over entire band simultaneously
- Prevents saturation and nonlinear effects
- Narrow and broad band
- 6ns ramp up/down time
- Removes multiple tones
- Working simulation + prototype





Slide courtesy of Luke McKay

Machine learning to predict RFI from NWP model



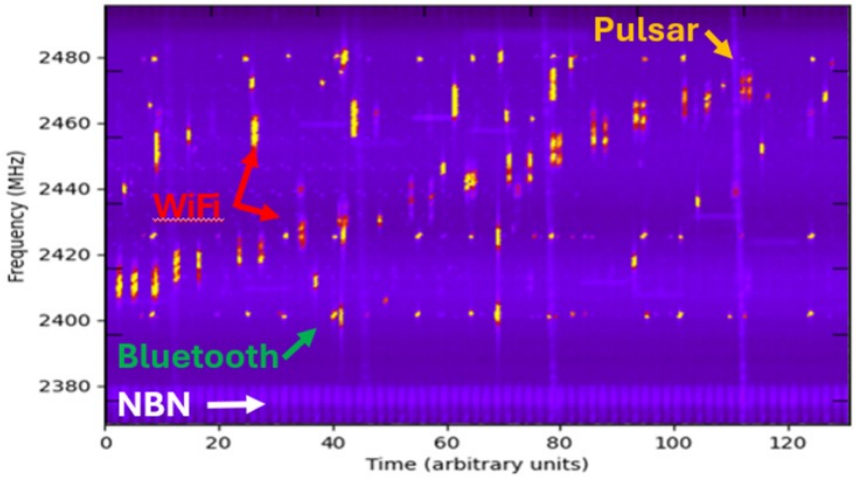
Example duct profile between broadcasting tower (0 km) and CSIRO MRO site (440 km)

 Slide courtesy of Hajime Suzuki

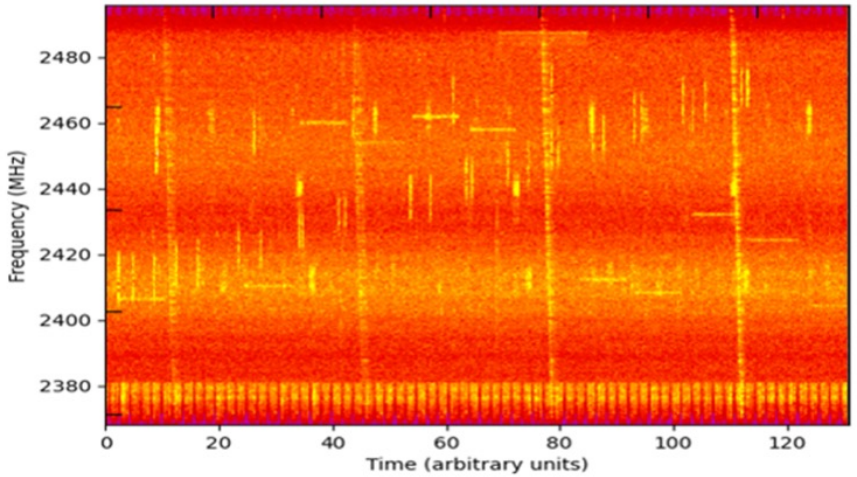
Blanking/Excision

A real time implementation, in the software, would allow the scientific use of this 128 MHz (2368 – 2496 MHz) UWL observing band to increase it from almost 70% of this band being completely unusable all the time to over 90% of this frequency coverage becoming accessible for scientific study.

Before applying Voltage threshold



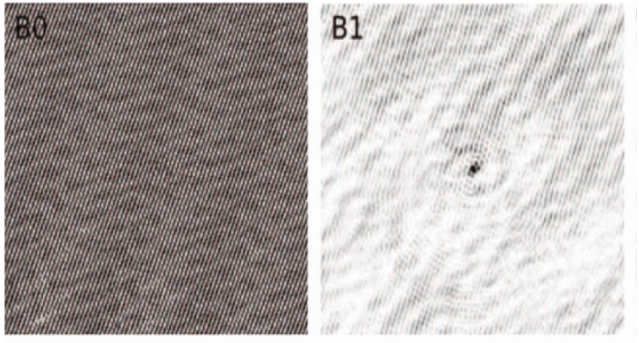
After applying Voltage threshold



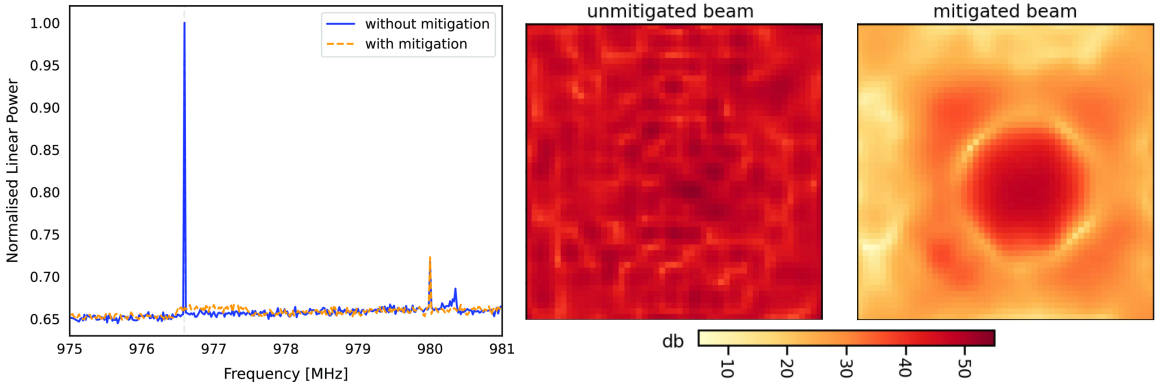
Slide courtesy of Tommy Marshman

Adaptive Beamforming, Spatial filtering via oblique projector

https://doi.org/10.1109/RFINT.2016.7833528



https://doi.org/10.1017/pasa.2024.51



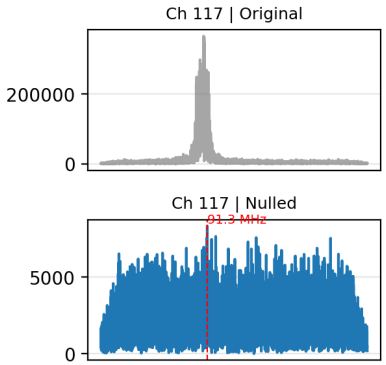
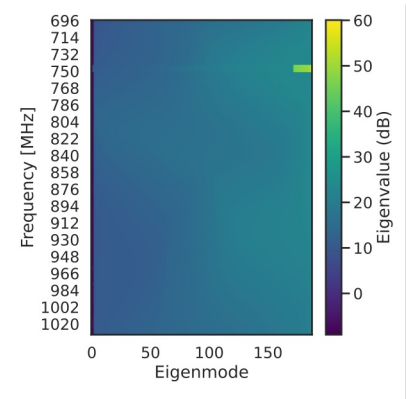
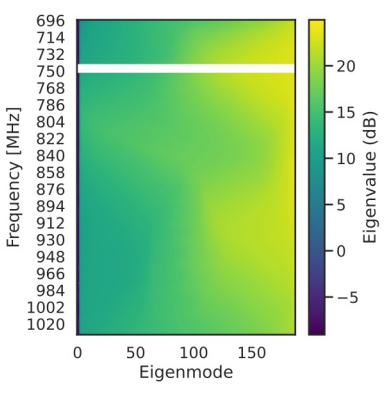


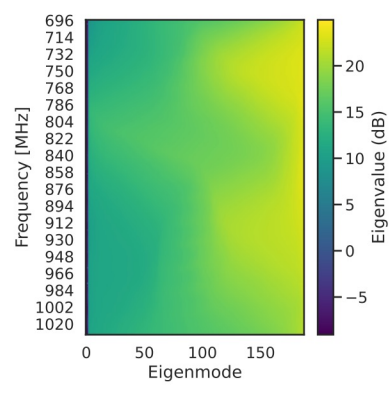
Image courtesy of Jay Smallwood



(a) blank sky eigenvalue spectrogram with RFI



(b) Masked eigenvalue spectrogram



(c) Interpolated spectrogram

https://hdl.handle.net/2123/33225

Thank you

Questions?

CSIRO Space & Astronomy
Dr Liroy Lourenço
Engineer: RFI Mitigation & Spectrum Manager

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https://people.csiro.au/I/L/Liroy-Lourenco

ATUC Open Day Session 3

Making the most of our facilities