ASKAP Upgrade Pathways

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Motivation and constraints

- Upgrades will be needed to ensure ASKAP's future in the SKA era
  - ASKAP's instrument design (Mk II hardware) is already 10 years old
  - ASKAP has a unique role and much of its potential has yet to be realised

- ASKAP has a dedicated survey mission for the next 5+ years
  - Large scale disruptive upgrades should be avoided during this time
  - Rolling upgrades to specific subsystems may be a good alternative

- The nature of upgrades is changing with technology
  - Software and firmware need continuous improvement during operations
  - Development and testing practices are key to avoiding downtime

Shelved upgrades that could be revisited

- Add another correlator block for 48 MHz of additional bandwidth
  - Difficult or impossible to source new redback boards
  - Increased data rate would add to processing capacity issues
  - Only a minor improvement in sensitivity

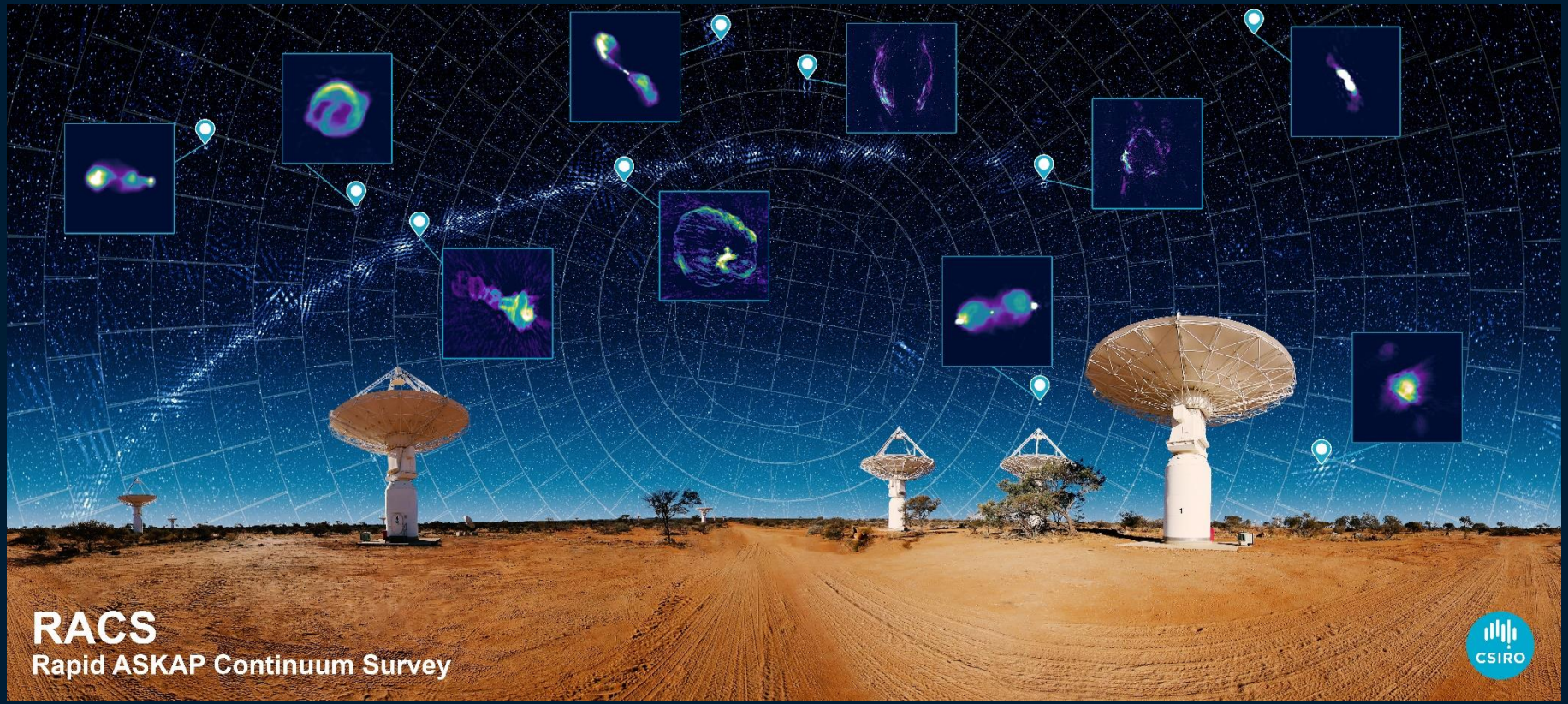
- Implement split band mode in existing control system software
  - Could be used for more efficient spectral line surveys
  - EMU prefers the low band and POSSUM benefits more from EMU+WALLABY
  - Better to get a head-start on integration of next-gen digital systems

What makes ASKAP unique in the SKA era?

- Field of view and low RFI at 20cm radio wavelengths
- Integrated supercomputing and science-ready data products
- Highly efficient autonomous end-to-end operations model

- The above combine to maximise all-sky survey capabilities
  - Multiplies theoretical survey speed beyond collecting area and field of view
  - Demonstrated as a unique role with the Rapid ASKAP Continuum Survey

Transient & synoptic science, multi-messenger, rapid response, radio sky model, finding rare objects & the unknown



S. Weinreb and J. Shi, "Low Noise Amplifier With 7-K Noise at 1.4 GHz and 25 °C," in IEEE Transactions on Microwave Theory and Techniques, vol. 69, no. 4, pp. 2345-2351, April 2021, doi: 10.1109/TMTT.2021.3061459.

Phase 1: Improve ASKAP's sensitivity

- Upgrade PAF low-noise amplifiers (by far the best option)
  - High impact, relatively low cost and complexity
  - 12K LNA + 15K practical penalties = 27K Tsys (c.f. 75K for ADE hardware)
  - **2.8x survey speed increase**
  - Overall cost of approximately $2M
  - Minimises the sensitivity gap to SKA-mid with no additional data rate

- Install transparent feed legs (probably not worth the cost)
  - Low impact, high cost, medium complexity
- Increase antenna diameter (probably not worth the complexity)
  - High impact, high cost, high complexity

Current generation ASKAP LNA board

Phase 1: Rolling upgrades during surveys

- Develop and test upgraded LNA board for existing PAF/domino
  - Take one antenna out of the array and isolate for single-dish field tests
  - 2 years of R&D to develop and test a new LNA board?
- Refurbish one antenna at a time during ongoing surveys
  - Bring PAF to workshop, replace all LNA boards
  - Upgrade TEC cooling system to maintain temperature/gain stability
  - Replace any degrading components e.g. RFoF laser diodes
  - Inspect and replace chequerboard conformal coating
  - Upgrade antenna drive systems, replace degraded panels
- 3 to 4 years at a rate of one antenna per month, but no deadline

Rolling upgrade

- Bring ASKAP up to the performance that surveys were originally planned around (50K Tsys or better)
- Start with inner or outer antennas depending on science goals
- Sensitivity and baseline weighting will change during the surveys, but we can adjust the observing strategy to compensate
  - e.g. progressively drop integration time and use the saving to cover more area

Phase 2: Upgrade ASKAP's digital systems

- Full digital hardware upgrade after the first surveys finish
  - Necessary to replace aging components in the existing system
  - Ensures cross-compatibility and shared effort across ATNF engineering
  - Easier to control, manage and maintain than a hybrid of new and old
- Include flexibility and power to implement advanced modes
  - Adaptive beamforming, split bands, fast transients, tied array, etc.
- Match bandwidth to existing PAF front-end filters (600 MHz)
  - Throttle output bandwidth until computing capacity is available

- More expensive (tens of millions?) and more disruptive

Phase 3: Upgrade ingest, processing & archiving

- Replace ingest cluster and upgrade to match increased correlator output
- Expand dedicated supercomputing capacity for ops and post-processing
- Expand and secure archive capacity for current and new surveys
- Implement new data formats to replace MS & FITS if appropriate

- Review service provider arrangements to reduce risk?
  - Currently not under direct control of timelines, procurement etc.
- Not strongly coupled to other phases if we design carefully
- At least 5 years away given Setonix is being commissioned now

Large scale future expansion options

- Adding more antennas would improve image quality and sensitivity while maintaining field of view
  - Requires analysis of existing infrastructure (roads, power, fibre, etc.) to see what could be done and at what cost
  - Could increase diameter of existing antennas as part of this upgrade
- Cryogenic PAFs
  - Perhaps not needed if we can get to 27K uncooled?

Continuous improvement is essential

- Meet our initial goals before increasing system complexity
  - Make all required modes available - joint deconvolution, fast imaging, etc.
  - Improve image quality - sky model, advanced processing and calibration
- Develop new features and improvements
  - Deploy an upgraded processing pipeline framework with more feedback
  - Integrate CINTEL into the operations workflow to maximise efficiency
  - Investigate advanced beamforming, holography and improved pointing correction
  - Deploy CP-view, CARTA, new archive services based on science needs
- Adapt to changing software/hardware ecosystems
  - Upgrade code and libraries, servers, operating systems, build & deployment methods
  - Maintain and expand ASKAPsoft's parallel performance, extend to GPU hardware

Key points and priorities

- Meet all outstanding requirements and secure archive space to complete the first full survey campaign
  - Support ongoing development and operations
- Improve sensitivity with rolling PAF upgrades
  - Reach or exceed the original survey specifications
- Plan more disruptive upgrades and future surveys according to emerging results, starting with digital signal processing