

PrepSKA Program Work

- WP2.1.6 Electromagnetic compatibility
- WP2.1.7 SKA cost analysis
- WP2.3.1 Wide FoV Aperture Array - AAVP (AA-lo work package co-lead)
- WP2.3.2 AAVP signal processing
- WP2.6.2 Computing h/w architecture
- WP2.6.5 Data products, storage, distribⁿ
- WP3.5 SKA configuration
- WP5 Procurement (incl. Phil Crosby)
+ SESC, IEAC, SWG, PITF, ...

A Systems Engineering Tool for the Square Kilometre Array

Curtin University of Technology

How would you spend \$3 billion?

The Square Kilometre Array (SKA) will be the world's largest radio telescope, with an aperture of up to one million square metres, due to be operational by 2022 at a cost estimated at 1.1 billion euros (€1.1) or about 1.1 billion USD. A systems approach to cost and performance management, and subsequent optimisation, is required to realise the radio telescope. Curtin is taking a lead role in this project and 2 grant lines a systems-developed costing tool which has been incorporated into the SKA design process.



Fig. 1. Technology concept aster simulation for the SKA. Aperture array (left) and antenna element (right) are shown. The same aster is shown at a larger scale, although a larger aster. The aster shows the relative positions of the antenna elements and the central core.

2. System Engineering for the SKA

The Costing Tool is an important part of the SKA systems engineering environment. It leads the software in a system where the design space can be specified and the design space can be explored and optimised. The tool uses a framework of interconnected, but independent, concept interdependencies to determine the overall design path (Fig. 2) [4].

1. The SKA Costing Tool

The software is an interactive simulation tool, written in Python. It contains a costing engine which sets up hierarchy design consisting of conceptual sub-systems (Fig. 3) [1].

System features of the tool are:

- generation of a radio system tree
- model incorporation as a GSD environment
- construction of parametric models and hierarchy structures for detailed designs
- trade-off exploration and optimisation
- cost coding (e.g. software, silicon level)
- responsibility for error and other reporting
- model-based simulation
- model-based optimisation
- trade-off analysis
- trade-off analysis

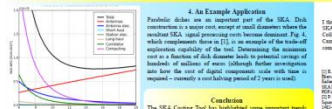


Fig. 2. A schematic representation of the SKA system decomposition into the SKA System. The system is decomposed into sub-systems, which are further decomposed into components. The SKA System is decomposed into the SKA System, the SKA System, and the SKA System.

4. An Example Application

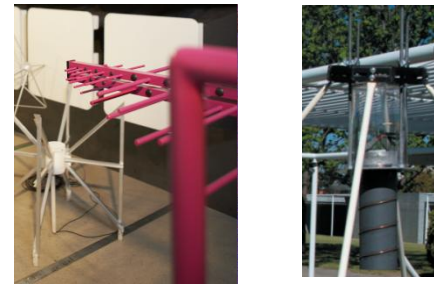
Parallel studies are an important part of the SKA. This construction is a major cost, except at small diameters, where the required SKA signal processing cost becomes dominant. Fig. 4, which compares three SKA [1], is an example of the trade-off exploration capability of the tool. Changing the antenna cost as a function of dish diameter leads to potential savings of hundreds of millions of euros (although further investigations into the cost of digital components will lead to improved – currently a working model of 20 years in cost).

Conclusions

The SKA Costing Tool has highlighted some important results and trade-offs that should be considered in developing a system view of the SKA. Current activities include advanced modelling of cost processing requirements and software performance. With additional optimisation, saving millions of euros, the tool will continue to be a major technology driver making the SKA.

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Progress

- Started ICRAR – 1 September, 2009
- €50M venture; 40+ research staff
- Budgets and programs in place
- More than 200 person-months for PrepSKA
- Hired round-1 EMC, AAVP, data archive personnel
- AAVP collaboration agreement close to signing
- Steady progress on SKACost
 - T. Colegate deployed to SPDO



International Centre for Radio Astronomy Research

Curtin University of Technology

THE UNIVERSITY OF WESTERN AUSTRALIA

ICRAR is a partnership between Curtin University of Technology and The University of Western Australia

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- *Lister Staveley-Smith, ASKAP Wallaby SSP (Mon pm)*
- *J-P Macquart et al., ASKAP CRAFT SSP (poster + 1200 – 1330 mtg Tues)*
- *P Hall et al., PITF (Wed am)*
- *T. Colegate et al.: New improved SKAcost (Wed pm)*
- *S. Tingay, Long baseline science (Thurs pm)*

The Commensal Real-time ASKAP Fast Transients (CRAFT) Survey

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Abstract
The CRAFT team is developing a commensal survey experiment for fast (< 5s) transient radio sources. Our objective is to cover the enormous volume of transient parameter space made available by ASKAP with an unprecedented combination of sensitivity and field-of-view at centimetre wavelengths. Through the CRAFT survey, ASKAP will develop and test many of the key technologies and survey modes proposed for high time resolution science with the SKA.

Why ASKAP?

- ASKAP's 30 deg² field-of-view (FoV) and antenna baselines up to 6km should allow the detection and localization of transients to within a fraction of its 7" synthesised beam. Accurate localization is necessary to enable identification of the progenitor objects and to perform optical spectroscopic follow-up.
- The array will contain 36 x 12m antennas operating in the range 700-1700MHz, with an instantaneous bandwidth of up to 300 MHz and a T_r of approximately 50 K.
- ASKAP's interferometric capability and spatially diverse configuration offers the possibility of discriminating between terrestrial and extraterrestrial events, thus imparting credibility to any putative transient signal detection.
- ASKAP probes scientifically interesting parameter space which is largely unexplored, as shown in Figure 1.

Scientific Motivation

- Fast timescale transients open new vistas on the physics of high brightness temperature emission, extreme states of matter and the physics of strong gravitational fields.
- Possible sources range from obvious known targets to more speculative but high-return possibilities, and include pulsar giant pulses, RRATs, magnetars, Lorimer bursts, gravitational wave events (e.g. merging BH-BH systems) and SETI emitters.
- The detection of extragalactic transients would afford us a new probe on the huge reservoir of baryons present in the IGM.

Strategy
CRAFT team members are beginning a series of 'trailblazer' investigations at several major telescopes, including the EVLA, GMRT and Parkes. These are interesting scientific experiments in themselves, and are designed to develop thinking in the areas of algorithms and architectures, and to generate insight in the application of particular technologies (CPU, GPU, FPGA) for processing engines. Outcomes of the trailblazers and associated technology prototyping projects will be evaluated as part of the preparation of a costed design proposal for an ASKAP transients instrumentation suite.

Detection Hardware
Ideally, an ASKAP fast transients detector would monitor the baseband voltage stream from all the ASKAP Phased Array Feed (PAF) beams from all the antennas. However, the computational challenge of processing ASKAP's entire >12Tbps high-resolution data stream in real-time makes this task prohibitive. Our strategy, summarised in Figure 2, aims at exploiting the telescope's capabilities by trading FoV, temporal and spectral resolution, and sensitivity against one another while maintaining a manageable data rate. Our strategies include:

- an incoherent signal processing system fed from the channelised PAF beam auto-correlators;
- a buffer for each of the PAF-beam voltage datastreams and a dump of the data following a trigger from another system for subsequent off-line processing;
- a processor taking coherent data from a number of tied-array beams;
- a system which will coherently search high time resolution visibilities; and
- external processors connecting to each of the PAF beam voltage datastreams.

Initial Hardware

- Our priority is to implement a system which monitors the total powers of the PAF beams summed incoherently across the array to exploit ASKAP's entire 30 deg² FoV from all 36 antennas.
- At 1ms time resolution and 1MHz spectral resolution, the incoherent approach allows a tractable data rate, at the expense of a loss of a factor of 6 in instantaneous sensitivity relative to a full correlation approach.
- A detected transient will trigger a buffer readout, recovering a small portion of the coherent datastream and enabling us to image the event at the full array sensitivity and angular resolution, with high temporal and spectral resolution.

Figure 1: Phase space probed by various current or planned radio facilities operating at 1.4GHz, as depicted by the minimum detectable flux density (S_{min}) at the 5σ level versus instantaneous accessible FoV. For simplicity in presentation, all telescopes are plotted with the same operating bandwidths (0.5GHz) and integration time (1ms). The solid diagonal line refers to single-pixel, single-reflector telescopes having - again for simplicity - the same system temperature (25K) and aperture efficiency (80%). The SKA-SFP point indicates the sensitivity for 2000 single-beam feed 15-m antennas, extended to phased array feeds (SKA-PAF) with a 20 deg² FoV and T_r = 50K. The vertical dashed lines indicate the observation time required to detect an event at the rate of 225 events 'sky⁻¹ day⁻¹'. The horizontal dashed lines show some normal flux densities of transient sources at 1.4GHz. The shading represents the parameter space covered by a correlated ASKAP (green, incoherently summed ASKAP (blue) and the Parkes Multibeam (grey). Adapted from Cordes (2009).

Figure 2: The modular layout of our proposed detection system and its anticipated evolution with time.

Future Hardware and Paths to the SKA: One Contribution
ICRAR/Curtin and JPL colleagues are designing and prototyping fast transient detectors using several processing engines fed from beamformed PAF voltage streams. These engines will initially use incoherent processing techniques but will offer improved temporal and spectral resolution relative to the initial hardware configuration mentioned above. Scalable coherent processor architectures will also be demonstrated, as this approach can be shown to be attractive for large arrays such as the SKA [2]. As part of the trailblazer experiments mentioned previously, a variety of technology approaches will be trialled, including FPGA-based de-dispersers and CPU-based post processors involving machine learning algorithms. The role of new-generation structured ASICs in production ASKAP, and future SKA, systems will also be examined.

For more information:
1. Macquart et al., "The Commensal Real-time ASKAP Fast Transients (CRAFT) Survey", PASA (in press, arXiv:1001.2958)
2. D'Adario, L. Searching for Dispersed pulses with ASKAP, JPL memorandum, March 2010

Acknowledgements
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