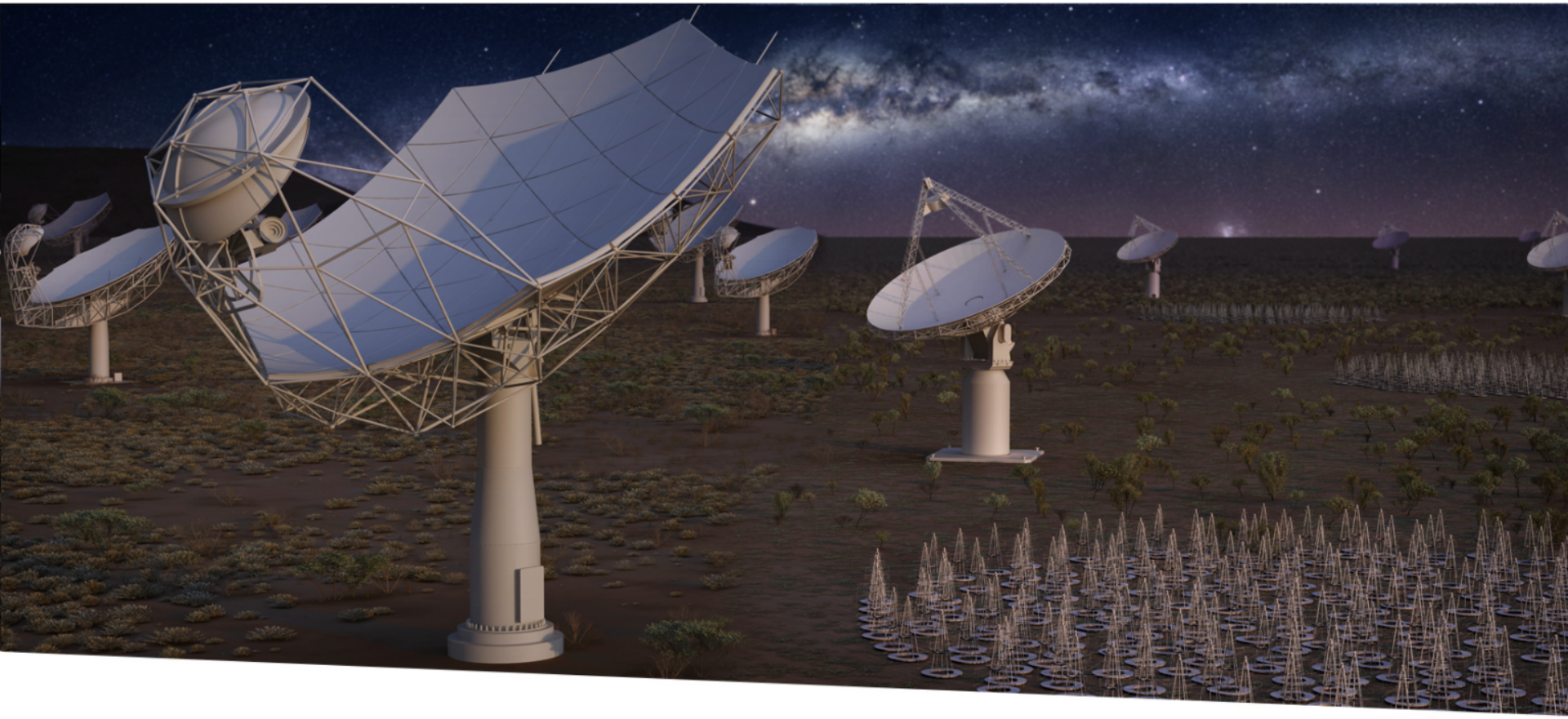
SKA Technology Development

Advanced Instrumentation Program Meeting



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Mark Bowen

15 June 2017

Outline

- SKA Technology Development
- Advanced Instrumentation Program Meeting
- Advanced Instrumentation Program (AIP)
  - Wide Band Single Pixel Feed (WBSPF)
  - Low Frequency Aperture Array (LFAA)
  - Phased Array Feed (PAF)
  - Program challenges
- SKA Observatory Development Program (SODP)
- Recommendations
- The Way Forward

SKA Technology Development

Advanced Instrumentation Program (AIP)

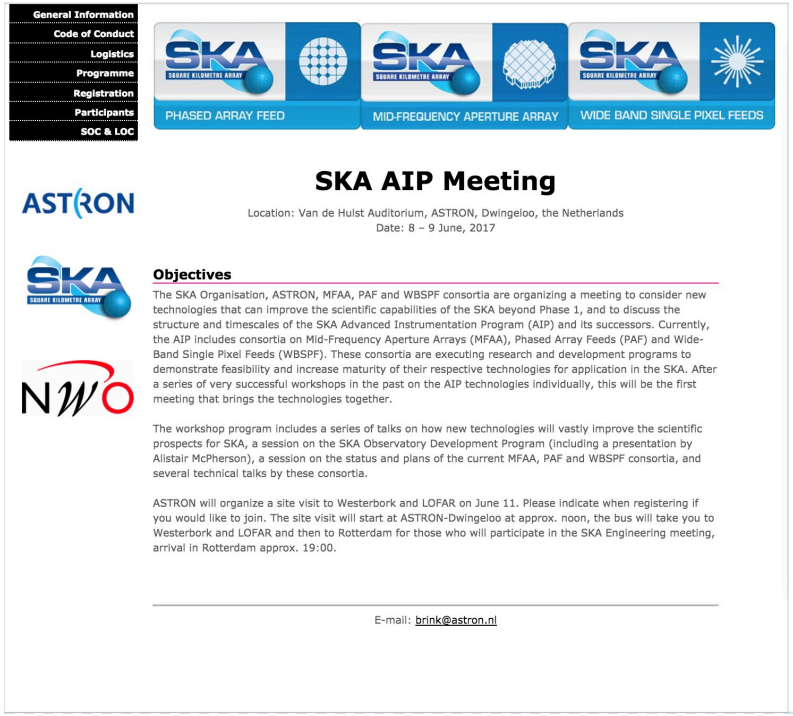
- SKA pre-construction
- Develop technology for SKA1 and SKA2
  - Wideband Single Pixel Feeds (WBSPF) – SKA1
  - Mid Frequency Aperture Array (MFAA) – SKA2
  - Phased Array Feeds (PAF) – SKA Survey now SKA1/SKA2

SKA Observatory Development Program (SODP)

- SKA1 construction and beyond to SKA2
- Enhance the scientific capability of the SKA
- Develop technology for SKA1 and SKA2
- Industrial engagement/partnership
- SKAO funded – partial/full

AIP Meeting

- ASTRON, The Netherlands (08 – 09 June 2017)
- To consider new technologies that can improve the scientific capabilities of the SKA beyond Phase 1, and to discuss the structure and timescales of the SKA Advanced Instrumentation Program (AIP) and its successors.
- Meeting website: http://www.astron.nl/ska-aip2017/

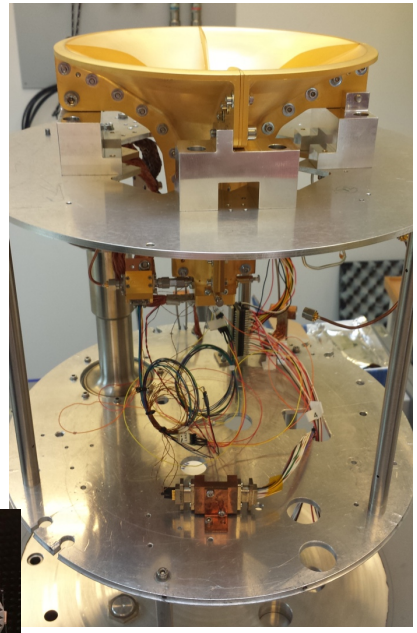


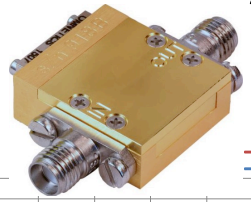
Advanced Instrumentation Program

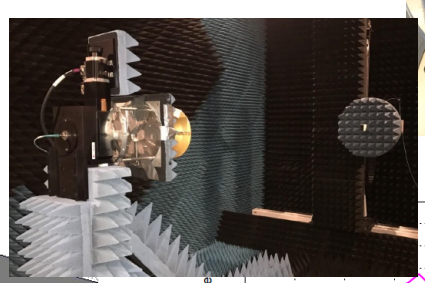
WIDE BAND SINGLE PIXEL FEEDS

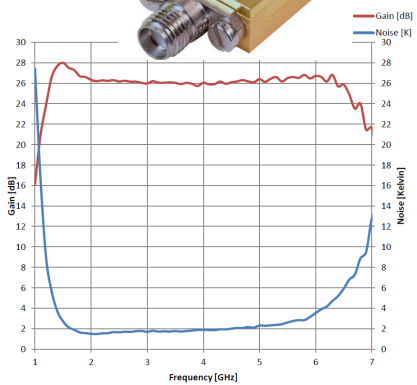
Wide Band Single Pixel Feed (WBSPF)

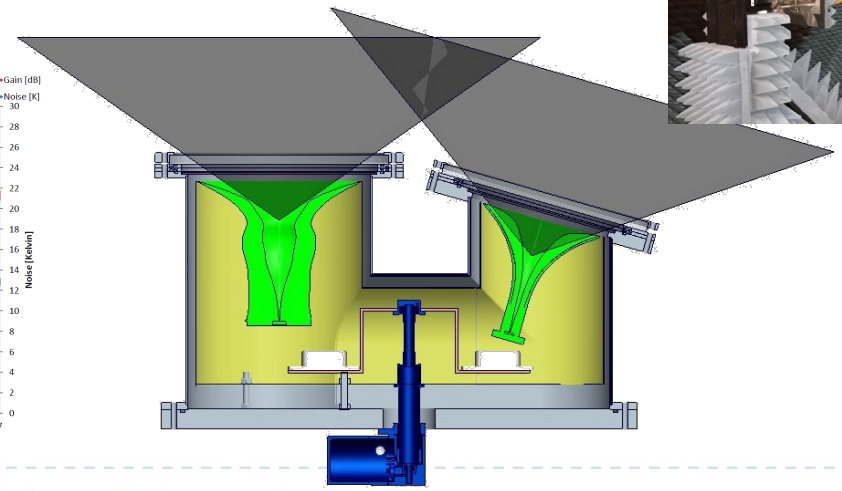
- SKA pre-construction AIP
- Possible alternative technology for SKA1
  - Band A (1.6 - 5.2GHz) – SKA-Mid Bands 3 & 4
  - Band B (4.6 – 24GHz) – SKA-Mid Bands 5a & 5b
- Band A LNA developed – feed being optimised
- Prototype Band B feed and LNA demonstrated
- Delivery of prototype design – PDR

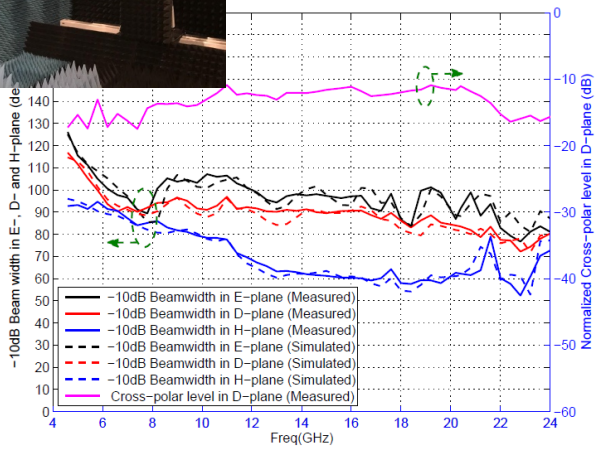








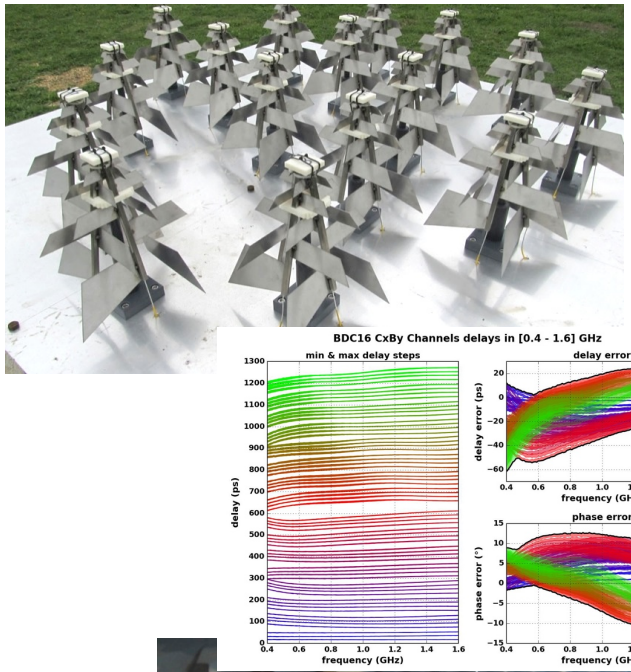


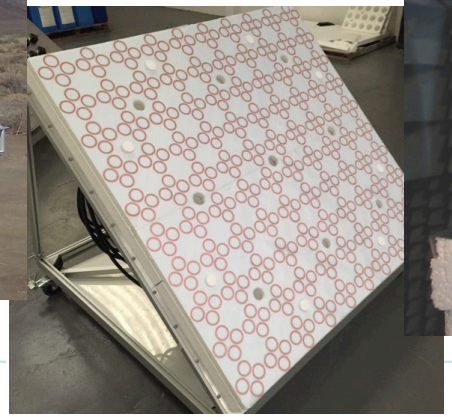


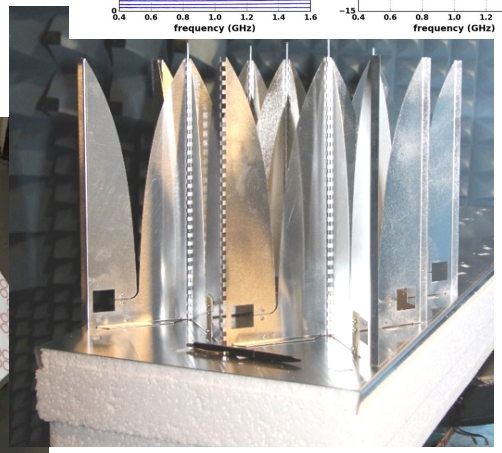
Advanced Instrumentation Program

Mid Frequency Aperture Array (MFAA)

- SKA pre-construction AIP
- Technology development for SKA2
  - Antennas – CORA, Vivaldi, Log periodic
  - MMIC beamformer
  - Prototype Tile Processor Module (CTPM)
  - System trade-off studies (dense vs. sparse)
- System requirements development – SRR
- Whitepaper on an MFAA demonstrator





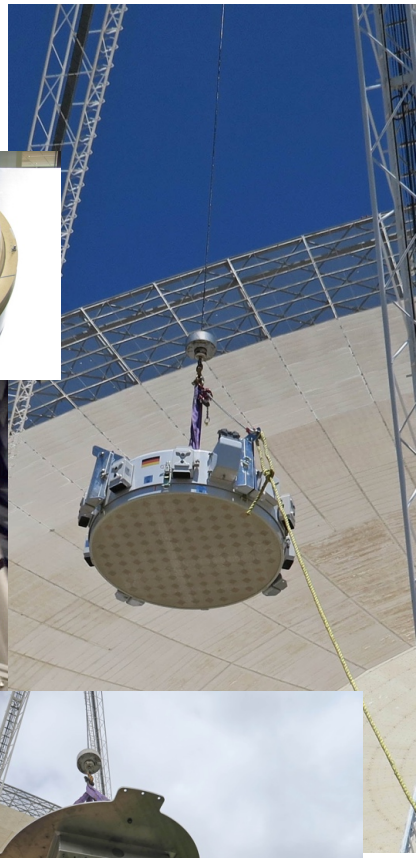


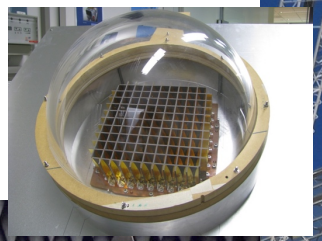
Advanced Instrumentation Program

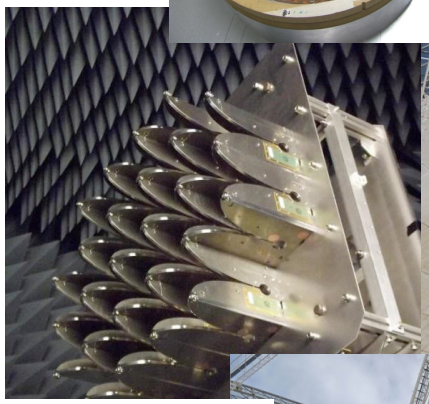
PHASED ARRAY FEED

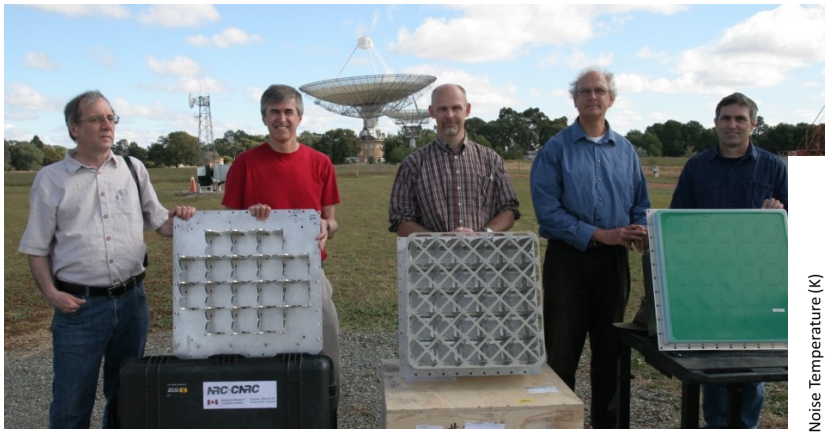
Phased Array Feed (PAF)

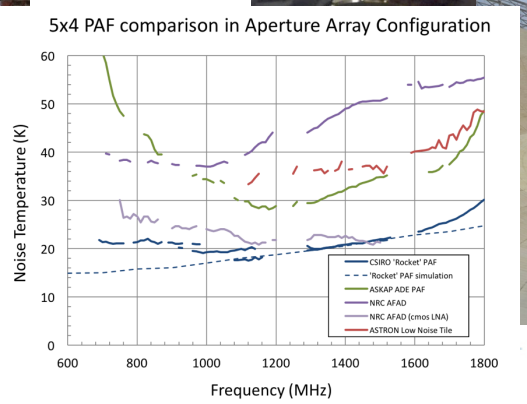
- SKA re-baselining – PAF development moved into the AIP
- Array designs for SKA1-Mid antenna
  - Array Elements - Vivaldi, Chequerboard, Rocket
  - LNA Development - AFAD, PHAROS2, LNT
  - Beamforming, calibration – ASKAP, APERTIF
- Collaborative measurement program











Advanced Instrumentation Program

Program Challenges

- SKA1 pre-construction delayed
- Project focus is on SKA1 construction
- Meeting the SKA1 cost cap – Cost Control Project (CCP)
- Limited resources and project delays mean that institutions involved in both SKA1 and the AIP are prioritising the SKA1 work
  - Institutions reconsidering investment in the AIP
- SODP will fund building SKA1 out to original design baseline
- SKA2 construction delayed – after SKA1 construction (2025 - 2030)
  - Existing AIP milestones of limited relevance
  - R&D towards SKA2 is considered less urgent
  - Lack of clarity on SODP – structure, project selection, …
  - Maintaining momentum and expertise during the transition to SODP

The SKA Observatory

- The SKA Observatory has a 50 year lifetime and will offer world's biggest radio telescope in an international partnership
- Continuous upgrades and expansions, enabling new capabilities, are essential for the future of the SKA
- The SKA science case indicates that there is a large scientific interest in science that can *only* be done with an SKA that includes advanced technologies (hardware and software)
- New technologies are essential for SKA2
- Engagement of young engineers is essential to ensure long-term R&D for the SKA. Observatory development is an ideal vehicle for the SKA to foster and inspire talented engineers and technologists

SKA Observatory Development Program

Current Status

- Initial ODP Paper “noted” by the SKA Board
- Distinct budget line within the scope of SKA
  - Not within operations budget
  - Starts with commencement of construction
  - Ramp up to a constant value of €20M/year
- Initially for continuation of AIP activities
  - WBSPF, LFAA and PAF
- Then open to competition
  - Guided by an observatory roadmap

SKA OBSERVATORY DEVELOPMENT PROGRAMME POLICY

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SKA Observatory Development Program

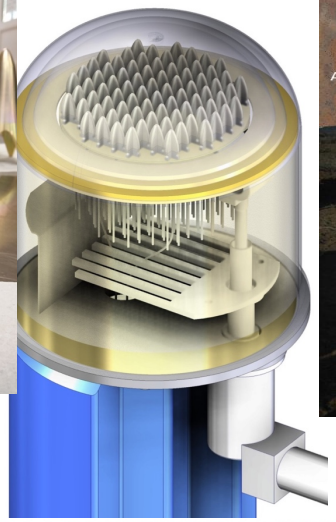
SODP Principles

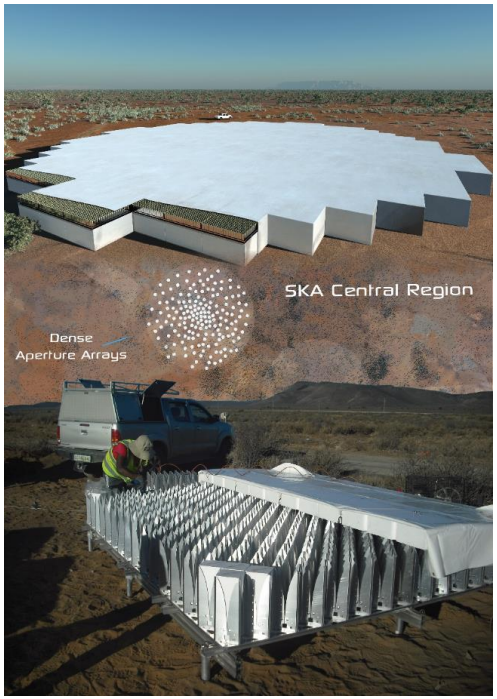
- Offer significant enhancements to the scientific capability
- A clear path to deployment on or for the SKA
- Undertaken by international teams led by an organisation from one of the SKAO Full Members
- SKAO funding limited to institutes from SKAO Full Members
- Organisations from non-member countries may participate but via their own resources
- When appropriate, industry participation should be integral to the proposal

SODP - Activities

Categories of development

1. Blue sky or strategic long term technology development
2. Initial development/technology demonstration
3. Detailed design/prototype development





SODP - Projects

Development for SKA1 and SKA2

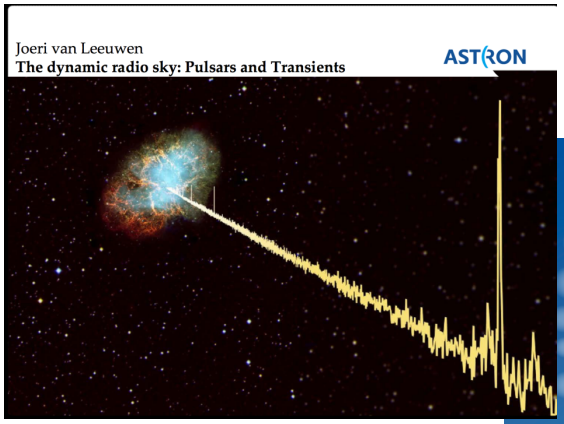
- Building out SKA1 to full scope – SKA1 baseline design
- Developing new capabilities/systems for SKA1 and SKA2
- Development of systems or components for SKA2
- Research and Development – Technology development

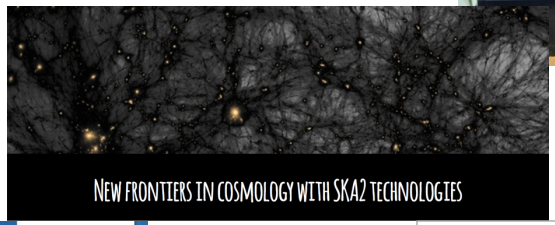
Maintaining the SKA observatory

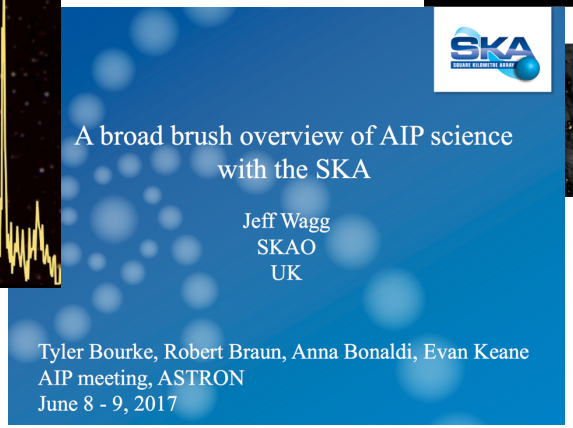
- Equipment refresh e.g. obsolescence – Operations
- Small-scale upgrade – Operations/SODP
- Large-scale upgrade – SODP/Operations
- Replacement of systems – SODP

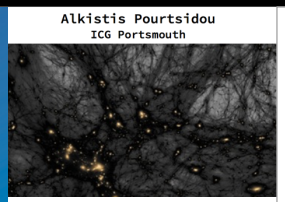
SKA ODP - Science

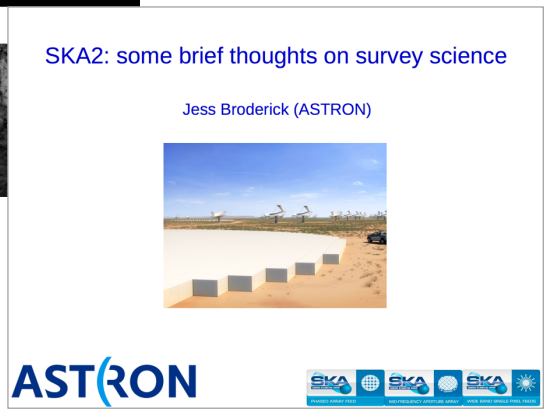
- AIP/SODP Technologies will enable cutting edge science
  - Transient science – *Number scales linearly with FoV*
  - Pulsar science – *Gravity Waves, Black Holes*
  - Survey science – *Entire population of pulsars*
  - Cosmology – *Wide fields (100s to 1000s sq. deg)*
- Sensitivity, FoV, BW, Frequency coverage
- SKA Science Book











Recommendations - General

1. The SKAO should firmly anchor the SODP in its organisation and demonstrate a strong commitment towards observatory development. Such visible and genuine commitment of the SKAO is a necessary condition for partners to successfully acquire national R&D funding
2. A dedicated budget for observatory development, with a significant fraction focused on R&D activities, is an essential part of this commitment
3. Clarification of the return to those who have (or have not) invested in the cost of technology developments
4. The AIP meeting was received and should be a regular occurrence (1 - 2 years). The meeting should remain open for people outside of the SODP and SKA
5. The definition of a CTO (technology development 'visionary') role responsible for monitoring and guiding observatory development would be a very valuable addition to the SKAO – assist in transition to SODP. The CTO should also seek synergy in a broader context, such as with other large research infrastructure projects

Recommendations - Programmatic

6. The SODP be flexible enough to support projects in various stages of the design (e.g. conceptual, preliminary, detailed design)
7. The programmatic overhead and deliverables (e.g. reporting, management, reviews) should be appropriate for the nature of the development
8. At some point a selections will need to be made between competing proposals. Greater clarity on these selection processes, program structure, etc. is necessary for medium-long term planning
9. Particularly during the transition phase – The SKAO support collaborative R&D partnerships, seek to establish/maintain a community of scientists and engineers, and be ready to include them into the SODP once it is properly defined.

Recommendations - Technical

10. The current AIP activities are primarily focused on front-end technologies. The SODP will need to be broad enough to support innovation in all areas e.g. calibration and imaging algorithms, processing platforms and signal processing
11. To successfully evaluate advanced technologies access to a range of SKA facilities will be needed, including (part of) SKA Low and Mid (+local support) and/or an end-to-end test facility.
12. The SODP should support and stimulate collaboration through comparative testing or benchmarking – this has already proven extremely valuable (PAF)

Recommendations - Roadmapping

13. Roadmaps (science, instrumentation, technology) should be established ASAP to underpin observatory development, R&D activities, and industry engagement
14. The roadmap(s) should be established and maintained by the SKAO, in consultation with the teams active in SKA technology development.
15. The roadmap(s) should include realistic timelines to appropriately target and organise development and manage expectations
16. Regular reviews of technology progress should be conducted by an expert panel which includes industry

SODP – The Way Forward

- The existing AIPs have made significant progress:
  - MFAA – Science requirements analysis, system design and front-end technology
  - PAF – Significant improvements in system noise have been achieved. The PAF collaborative testing program has proven extremely valuable.
  - WBSPF is delivering prototypes for band A and B, and will continue to PDR. The consortium is considering broadening their R&D into advanced SPF technologies
- An active development program is an essential in ensuring the long term viability of the SKA – 50 years
- Development roadmaps should be established as a priority to guide the SODP
- The current AIP consortia are ready to assist the SKAO in the work required to establish the SODP

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