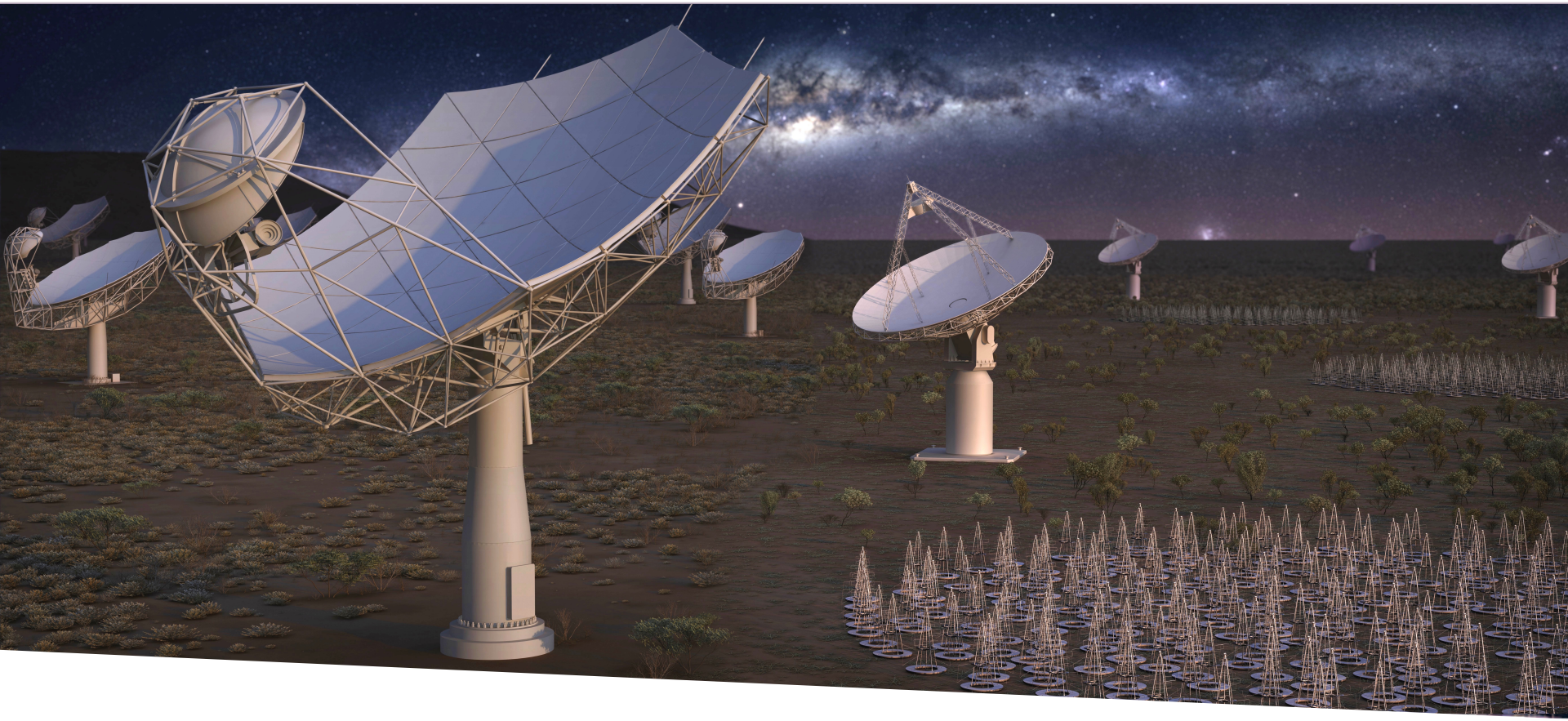
SKA Science Update



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Robert Braun, Science Director

12 June 2017

Science Meeting & KSP Workshop

- Special emphasis on early career researchers in program
- Three days of science: ~60 talks, 54% “early”, and ~60 posters plus 1^{m} “marathon” talks
- One day KSP break-outs
- One day KSP overviews with SKAO Q&A
- ~200 participants

Science Meeting and KSP Workshop

Cost Control Plan

- Sequence of reinstatable (via extra funding) measures to achieve construction Cost Cap
- Ordering of measures (top to bottom) is attempt to reflect science impact
- Some line items represent “competing” options for which a future down-select would occur based on complete technical assessment

How was preliminary CCP order determined?

- Minimise negative science impact, using the “High Priority Science Objectives” as indicative measure
  - Wide review and endorsement of the HPSOs
- Maximise straightforward re-instatement potential given additional funding
  - Recognise the anticipated **full** refresh cycle for High Performance Computing and Pulsar Search hardware is 3 – 5 years
  - Recognise ramp up in post-construction phase to full volume of science data products (and hence HPC requirements)
  - Additional feeds (given mature design) are easier to deploy than new dishes
  - Major infrastructure re-instatement work is both costly and disruptive

SKA Science Assessment Teams

1. Impact on EoR/CD of changes to SKA1-Low maximum baseline length
   - **Emma Chapman (ICL, Chair),** Gianni Bernardi (SKA-SA), George Heald (CSIRO), Jack Line (UMelbourne), Bart Pindor (UMelbourne), Cath Trott (CurtinU), Sarod Yatawatta (ASTRON), Jeff Wagg (SKAO Support)
2. Required timing accuracy to enable successful precision pulsar timing science
   - **Andrea Possenti (INAF, Chair),** Adam Deller (SwinbU), Ingrid Stairs (UBC), Ben Stappers (UMan), Scott Ransom (NRAO), Willem van Straten (AUT), Evan Keane (SKAO Support)
3. Impact of SKA-Low antenna optimised frequency coverage
   - **Chiara Ferrari (ObsCoAz, Chair)**, Leon Koopmans (UGroningen), James Aguirre (UPenn), Annalisa Bonafede (INAF), Jason Hessels (UAmsterdam), Divya Oberoi (NCRA), Philippe Zarka (ObsPM), Francesco de Gasperin (ULeiden), Anna Bonaldi (SKAO Support)

SKA Science Working Groups and Focus Groups

SWGs and FGs	Co-Chairs
Extragalactic (non-HI) Spectral Line	Rob Beswick, Francoise Combes
Our Galaxy	Mark Thompson, Grazia Umana
Solar, Heliospheric & Ionospheric Physics	Eduard Kontar, Divya Oberoi
Epoch of Reionization	Jonathan Pritchard, Garrelt Mellema
Cosmology	Mario Santos, Xuelei Chen
Extragalactic Continuum	Rosella Cassano, Minh Huynh
Cradle of Life	Andrew Siemion, Di Li
HI galaxy science	Erwin de Blok, Martin Meyer
Magnetism	Ann Mao, Russ Taylor
Pulsars	Andrea Possenti, Ingrid Stairs
Transients	Michael Rupen, Jean-Pierre Macquart
VLBI	Zsolt Paragi, Cormac Reynolds
High Energy Cosmic Particles	Justin Bray

SKA Science Town Hall Meeting 18 & 19 May

- Preliminary reports from the three Science Assessment Teams
- Preliminary Science Assessments from each SWG / FG which:
  1. Endorse or suggest reordering of items in the cost savings measures list
  2. Affirm or not the transformational science capability of the cost-capped observatory
- Programme for Town Hall
  - Reps provided by each SAT, SWG/FG based on availability (very short lead time between 1st announcement and meeting)
  - Q&A opportunities after each talk and in four Q&A sessions
- Some 70 participants plus live video streaming with e-mail questions available to all 600 SWG/FG members
- Wrap-up discussion: areas of consensus and contention

SKA Science Assessment Teams: Preliminary Conclusions

1. Impact on Epoch of Reionisation / Cosmic Dawn of changes to SKA1-Low maximum baseline length
   - Resources in place for effective assessment
   - Early indications may suggest that distinctions between B_{Max} = 65, 50 and 40 km are not extreme
2. Required timing accuracy to enable successful precision pulsar timing science
   - Clock precision (~4 ns) and redundancy for MID are vital
   - LOW requirements can likely be relaxed
3. Impact of SKA-Low antenna optimised frequency coverage
   - Major capability loss if low performance above 200 MHz
   - Biggest hits to Pulsar surveys (MSP yield), but also EoR tail, Solar, and continuum imaging (particularly in combination with a B_{Max} reduction!)

SWG/FG Preliminary Assessments

- Cosmology
  - Some concerns/questions over HPC reductions
  - Some risk to weak lensing from B_{Max} MID
  - Risk of “red-shift desert” if LOW frequency coverage reduced
- Cradle of Life
  - Concern over high resolution performance from reducing B_{Max} MID
  - Significant concern over double hit to Band 5 (feed number plus BW)
- Epoch of Reionisation
  - Great concern over any reduction in core sensitivity
  - Need for good performance and smooth band-pass over 50 – 240 MHz
- Extragalactic Continuum
  - Concern over B_{Max} LOW, particularly in combination with frequency coverage
  - Significant concern over double hit to Band 5 (feed number plus BW)
  - Desire for clarification around SDP HPC reductions
- Extragalactic Spectral Line
  - Significant concern over double hit to Band 5 (feed number plus BW)
  - Question of how best to distribute a reduced initial Band 5 feed number deployment. Winners and losers with all options.

SWG/FG Preliminary Assessments

- HI galaxy Science
  - Concern over deepest HPC cuts
  - Concern over MID core cuts and Band 1 cut
- Magnetism
  - Concern over B_{Max} LOW, in combination with frequency coverage and BW
  - Concern over triple hit to Band 5 (feed number, plus BW, plus core vs arms)
  - Concern over LOW/MID core cuts
  - Concern over HPC and commensality
- Our Galaxy
  - Some concern over deep HPC cuts
  - Concern over triple hit to Band 5 (feed number plus BW, plus core vs arms)
- Pulsars
  - Serious concern over deep PSS cuts for both MID and LOW
  - Concern over Band 5 deployment only in arms
  - Concern over MSP yield for LOW antenna frequency range

SWG/FG Preliminary Assessments

- Solar, Heliospheric, Ionospheric
  - Concern over LOW frequency coverage or BW cuts
- Transients
  - Concern over Band 1 loss (FRB yield), Band 5 loss (high optical depth, angular resolution)
  - Some concern over PSS capabilities (beams, DMs)
  - Some concern over HPC and fast imaging pipeline
- High Energy Cosmic Particles
  - Serious concern over analogue BF
  - Concern over LOW core reduction, BW
- VLBI
  - Serious concern over Band 5 sensitivity for arms vs core deployment

Areas of Consensus/Contention

- Extremely open and constructive discussion of the issues

1. Double hit to MID Band 5 (from feed number and BW) may be excessive
   - Explore methods of mitigation
2. Double hit to LOW θ_{Min} (from B_{Max} and high frequency performance) may be excessive
   - Explore methods of mitigation
3. Need for careful consideration of optimal placement of any partial Band 5 feed deployment
   - Wide consultation needed to insure all issues taken into account
4. Concern regarding deep PSS cuts
   - Explore prospects for mitigation
5. Lack of clarity around implications of HPC cuts

Adjustments to Ordered CCP List (25 May)

- LOW antenna design: Based on the major negative science impact of cuts to both the maximum baseline of SKA1-Low, as well as the higher frequency performance, the intent is to give higher priority to preserving the high frequency performance of the antenna system

- MID Band 5 partial deployment: A wide community consultation will be undertaken to ensure that any partial deployment of the Band 5 feeds takes account of all science constraints

- Reduce CBF-LOW, Reduce PSS-LOW, Reduce PSS-MID, Reduce CBF-MID: All five of these items have been moved down to below the nominal Cost Cap line, since the negative science impact of each is deemed to be too severe in relation to the anticipated cost savings

Updated CCP list (page 1/2)

WS / Origin	Description	LOW / MID / COMMON	Science Implication	Science Impact
5.39	INFRA_SA Renewable energy to outer dishes	MID	None	1
5.3	Maximise use of code produced during Pre-Construction	COMMON	None	1
5.38	Simplify DDBH LOW	LOW	None	1
5.38	Simplify DDBH MID	MID	None	1
5.25.2	Reduce PSS-MID: A, 750 nodes to 500 nodes	MID	Likely none, or small reduction of pulsar search parameter space.	1
5.25.2	Reduce PSS-LOW: A, 250 nodes to 167 nodes	LOW	Likely none, or small reduction of pulsar search parameter space.	1
5.35	Reduce CBF-MID: Freq. Slice variant of CSP design vs. MeerKAT-based design	MID	None	1
5.19	MID Frequency and Timing Standard: SaDT solution vs. MeerKAT-based solution	MID	None	1
5.36	MID SPF Digitisers: DSH solution vs. MeerKAT-based solution	MID	None	1
5.26 / 5.29	LOW RPF: Early Digital Beam Formation vs. Analogue Beam Formation	LOW	None	1
2	LOW Antenna: Log Periodic Design vs. Dipole Design	LOW	None of the current designs meet the L1 requirements	3
8	SDP- HPC: Deploy 200 Pflops (rather than 260 Pflops)	COMMON	Lower allowed duty cycle for HPC-intensive observations.	2
5.24.3	Reduce Bmax MID from 150 to 120 km: Case A, remove 3 dishes, but keep infra to 150km	MID	Reduction of maximum achievable resolution by 20%, although can be partially recovered with data weighting and longer integration times.	2
5.24.2	Reduce Bmax MID from 150 to 120 km: Case B, remove infra, but add dishes to core	MID	Reduction of maximum achievable resolution by 20%, although can be partially recovered with data weighting and longer integration times.	2
5.24.1	Reduce Bmax MID from 150 to 120 km: Case C, remove infra, remove dishes	MID	Reduction of maximum achievable resolution by 20%, although can be partially recovered with data weighting and longer integration times.	2
5.5.2	Reduce MID Band 5 feeds: A, from 130 to 67	MID	Placement to be determined based on full community consultation.	2
5.25.2	Reduce PSS-LOW: B, 167 nodes to 125 nodes	LOW	Likely reduction in processed PSS beam number (1.3x) or pulsar search parameter space	2
5.25.2	Reduce PSS-MID: B, 500 nodes to 375 nodes	MID	Likely reduction in processed PSS beam number (1.3x) or pulsar search parameter space	2

Updated CCP list (page 2/2)

8	SDP- HPC: Deploy 150 Pflops (from 200 Pflops)	COMMON	Lower allowed duty cycle for HPC-intensive observations.	3
5.30.0	Reduce Bmax LOW to 50km: A, remove infra, add 18 stations to core	LOW	Science Risk to EoR: Bmax.	3
5.30.0	Reduce Bmax LOW to 50km: B, remove 18 stations	LOW	Science Risk to EoR: Bmax	3
5.30a	Reduce Bmax LOW to 40km: C, remove next 18 stations	LOW	Science Risk to EoR: Bmax	3
8	SDP- HPC: Deploy 100 Pflops (from 150 Pflops)	COMMON	Lower allowed duty cycle for HPC-intensive observations.	4
8	SDP- HPC: Deploy 50 Pflops (from 100 Pflops)	COMMON	Lower allowed duty cycle for HPC-intensive observations.	4
5.31	Reduce CBF-LOW BW: A, 300 to 200 MHz	LOW	Longer observing times for continuum applications (1.5x)	4
5.25.2 / Deeper Savings	Reduce PSS-LOW: C, 125 nodes to 83 nodes	LOW	Likely reduction in processed PSS beam number (2x) or pulsar search parameter space	4
5.25.2 / Deeper Savings	Reduce PSS-MID: B, 375 nodes to 250 nodes	MID	Likely reduction in processed PSS beam number (2x) or pulsar search parameter space	4
5.13.2	Reduce Bandwidth output of band 5 to 2.5GHz	MID	Longer Band 5 observing times for some applications (2x)	4
5.35	Reduce MID CBF and DSH BW: 5 to 1.4 GHz	MID	Longer observing times to achieve continuum sensitivity in Band 5 (3.6x)	4
5.24 / Deeper Savings	Remove 11 MID Dishes from core	MID	10% Array sensitivity loss in core	4
5.30 / Deeper Savings	Remove 54 LOW stations from core	LOW	10% Array sensitivity loss in core	4
5.24 / Deeper Savings	Remove additional 11 MID Dishes from core	MID	20% Array sensitivity loss in core	4
5.30 / Deeper Savings	Remove additional 54 LOW stations from core	LOW	20% Array sensitivity loss in core	4
5.24.2	Reduce Bmax MID from 120 to 100 km: D, remove infra, remove next 3 dishes	MID	Lose Science (Planetary disks, High resolution Star Formation)	4
5.5.1	Remove MID Band 1 feeds: 105 to 0	MID	Lose Science (Cosmology, Galaxy Evolution)	4
5.5.2	Reduce MID Band 5 feeds: B, from 67 to 0	MID	Lose Science (Planetary disks, Star Formation)	4

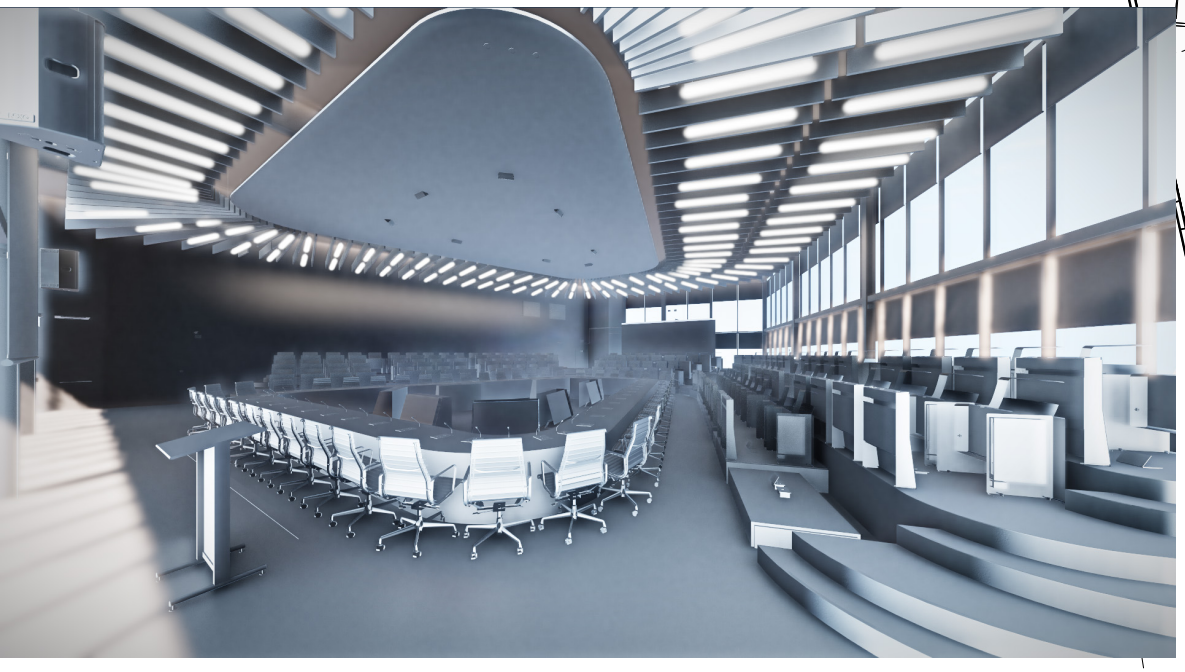
Adjustments to Ordered CCP List (25 May)

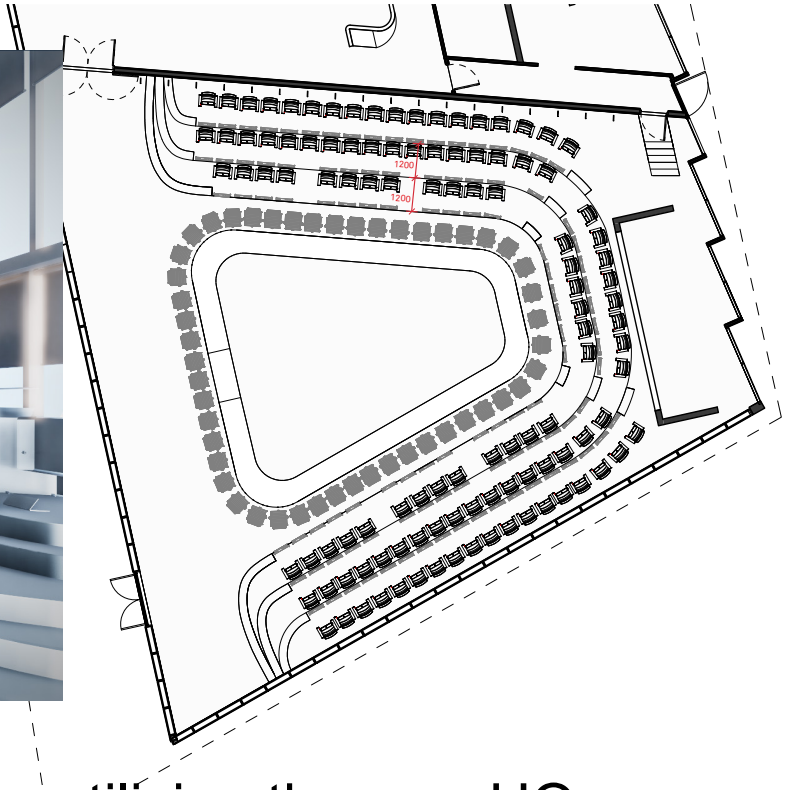
- Preserve **full ν coverage, BW and commensality** on both LOW (300 MHz) and MID (5 GHz)
- Keep PSS cuts down to only a 30% hit in search speed
- Full community consultation to optimise any partial deployment of SPF5
- Based on updated CCP list:
  - Overall consensus around ordering of measures
  - Transformational science is retained in essentially all areas

Next CCP Steps

- Science & Engineering Advisory Committee review (23 June)
- Final written reports from all SATs and SWG/FGs due 1 July
- Recommendation to SKA Board (18 & 19 July)

SKA Science Meeting for 2018





- Possible inaugural Science conference utilising the new HQ meeting room:

  “Science with the SKA Precursors and Prospects for the SKA”

- Possible dates: Q3/4 of 2018

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www.skatelescope.org