SKA
SQUARE KILOMETRE ARRAY

2017 SKA Engineering Meeting

12–16 June 2017

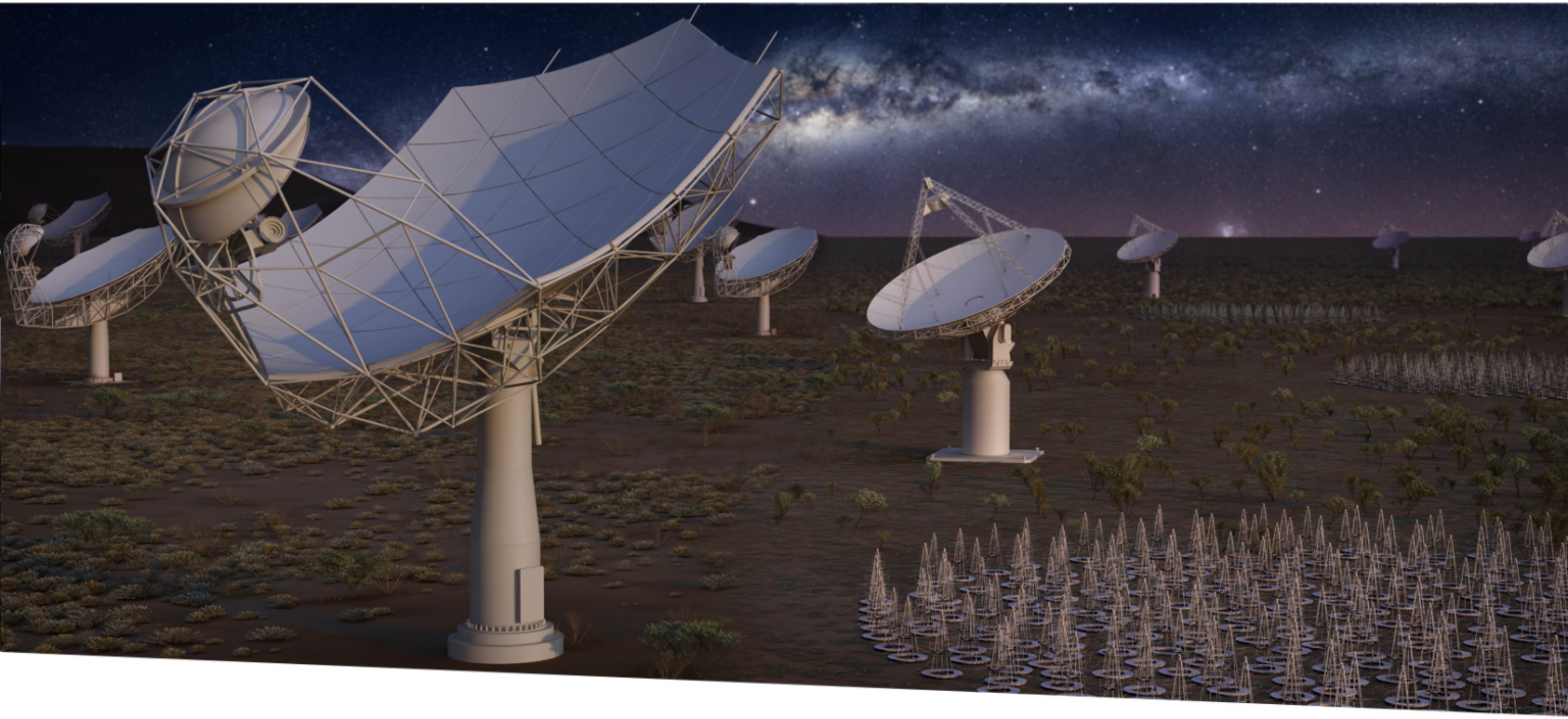
Rotterdam, the Netherlands

#SKAengcon17

NWO Netherlands Organisation for Scientific Research

ASTRON Netherlands Institute for Radio Astronomy

Towards CDR



SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope

Alistair McPherson

12 June 2017

Major events in 2017

- November 4-5: 22nd SKA Board Meeting
- December 6-7: SKA1 System Review, SKA HQ
- January 10-12: SKA-Low Workshop, Astron
- February 2-3: SKA-Mid Workshop, SKAO
- February 16-17: CUS Meeting, SKAO
- March 16-17: SEAC Meeting, Pisa
- March 29-10: 23rd SKA Board Meeting, Perth
- May 11th: MeerKAT Programmatic Workshop
- May 16-17: MeerKAT Integration Review

Staffing

- New Starts
  - Robert Laing – System Scientist
  - Lorenzo Pivetta – HPC Software Engineer
  - Ian Hastings – Head of Procurement Services
  - Fiona Davenport – Head of Human Resources
  - Gerhard Swart – Telescope Engineer (Mid)
  - Peter Shepherd – PM SDP/TM (Interim)
  - Maurizio Miccolis – PM SDP/TM (September)
  - Cristina Garcia Miro – VLBI Scientist (August)
- New Positions
  - Maria Grazia Labate – Telescope Engineer (Low)
  - TBA – System Engineer (Low)
  - TBA – Software Quality Engineer
  - TBA –System Engineer(Verification)
- Current Recruitment
  - RAMS/ILS Engineer
  - RFI/EMC Engineer

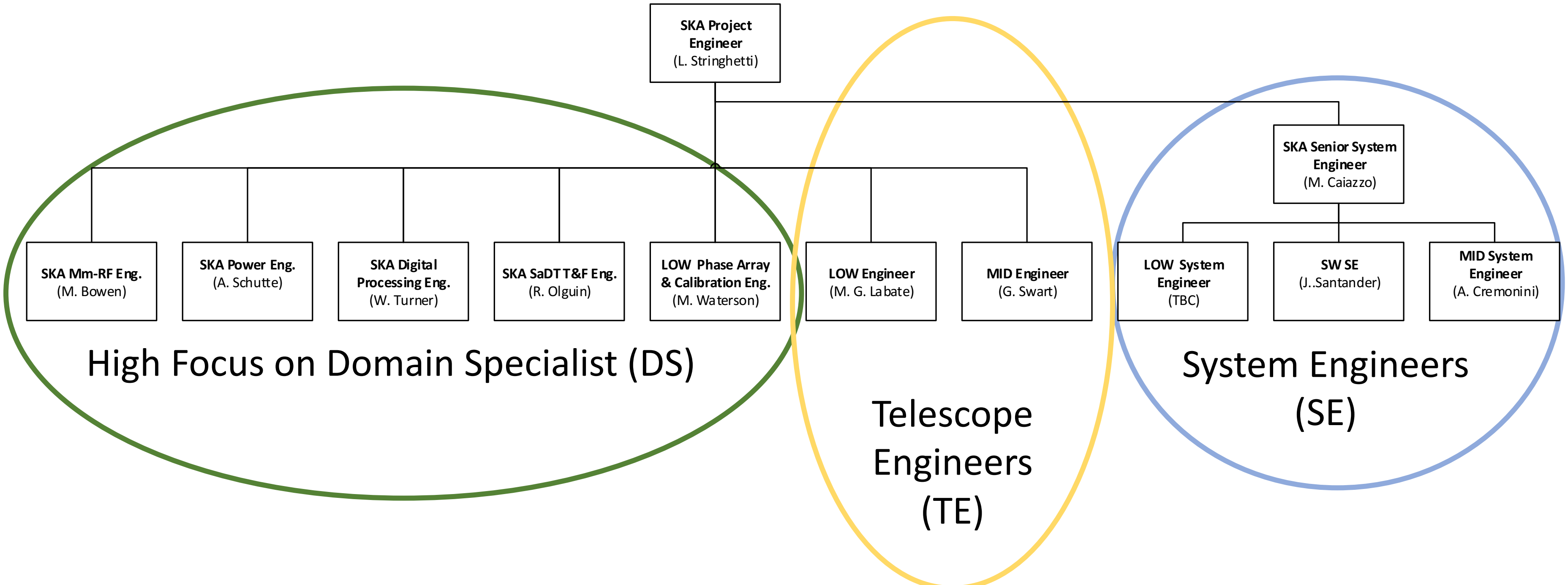
System PDR actions and progress (1)

Ref	Recommendation	SKAO Response
1	Confirm ICD completeness and quality check. The MID & LOW TM-SADT and MID TM-INFRA SA ICDs are completed and released.	Top priority action to complete
2	The technical budgets and initial allocations are completed and released, for example the Timing and Synchronisation budget. Complete calibration requirements/concept and the Error Budgets.	Aim to complete for Pre-CDR
3	The L2 requirements are aligned with the L1 requirements rev 10 and released as planned. The design compliance matrices are worked on to identify the non-compliances that are likely to impact science performance and that plans are developed to address each of them.	Top priority action to complete prior to Pre-CDR: Rev 11 tidy up
4	Complete software architecture	Aim to complete by System CDR
5	Complete end-to-end signal chain analysis	Aim to complete 1st draft for Pre-CDR
6	Elaborate a more detailed and resourced project plan to CDR to allow tracking of progress up to and beyond the CDR. Proactively define a mitigation plan to cover the eventuality that the project is unable to meet the aggressive schedule described to the panel.	Maintaining Gantt and updating roles and responsibilities (eg Telescope Engineer roles) in PMP. Consider showing more explicitly the mitigations that already exist to cope with schedule over-runs (Office business plan, mechanism for Consortium Agreement extensions etc) in PMP or Risk Register.
7	Continue to strive to try find ways to improve the coordination of activities with consortia teams and to ensure the alignment behind a common set of priorities and goals. Daily stand-up reviews with risk owners to remove blockers to progress in closing these actions and to assure progress to this schedule is on track.	Ongoing
8	Perform a specific review of programmatic risk management should be conducted to ensure alignment and to confirm that risk management (rather than risk documenting) is occurring and is driving to closure these priorities.	Risk audit carried out Dec 2016 by external auditor on behalf of Finance Committee. Outcome “Substantial Assurance”

System PDR actions and progress (2)

Ref	Recommendation	SKAO Response
9	Baseline [design], PBS, PD, WBS: a formal set of these structures and documents be compiled into one SKAO document and routed for approval no later than pre-CDR. This document will describe the project globally, summarising the main features and the parameters of each subsystem and be used as the basis for the CDR.	Ongoing: all exist as drafts and will be updated for Pre-CDR and CDR itself, though probably not as a single document
10	A plan be developed covering the transition of the project from the detailed design phase to the construction including software to ensure the continuity and the transfer of know-how.	A Transitional plan is currently being developed. Support from consortia during this period is being developed as part of the plan.
11	Procurement plan be drafted no later than the pre-CDR.	Not applicable. Development Policy and Procedures being develop through IGO process. Procurement Plan itself will be alongside Construction Proposal after System CDR – not part of CDR.
12	Terms of reference and scope for the System CDR are consistent with standard systems engineering practice to enable the external review panel to assess the readiness in a comprehensive manner. Recommend validating the CDR requirements and review plan with external independent subject matter experts and incorporate any changes to make the review comprehensive and standard.	This is as planned
13	An independent external review be held to evaluate the aspects of a normal System PDR which have not been included in the scope of this review – namely the congruence of the cost, schedule, manpower and scope – as soon as possible to confirm to SKAO senior leadership that the project is indeed at the level needed to proceed successfully in the critical design phase and/or to identify any key and potentially very high risk areas of concern that need to be addressed.	Pre-CDR will cover this
14	Automatic fault detection and diagnosis functionalities are included in the top-level requirements and functional analyses for both LOW and MID telescopes. These should aim to detect and diagnose 95% of failures down to the LRU level.	MID and LOW functional analysis already describe the function as. There are also some requirements in REV10 (which was not part of the PDR) that trace the “fault detection” so the alignment of functional analysis with requirement is part of the normal work.
15	Design Description be revised to include references to lower level documents covering more detailed aspects of the design and thereby together provide a complete and coherent description of the telescopes	Pre-CDR

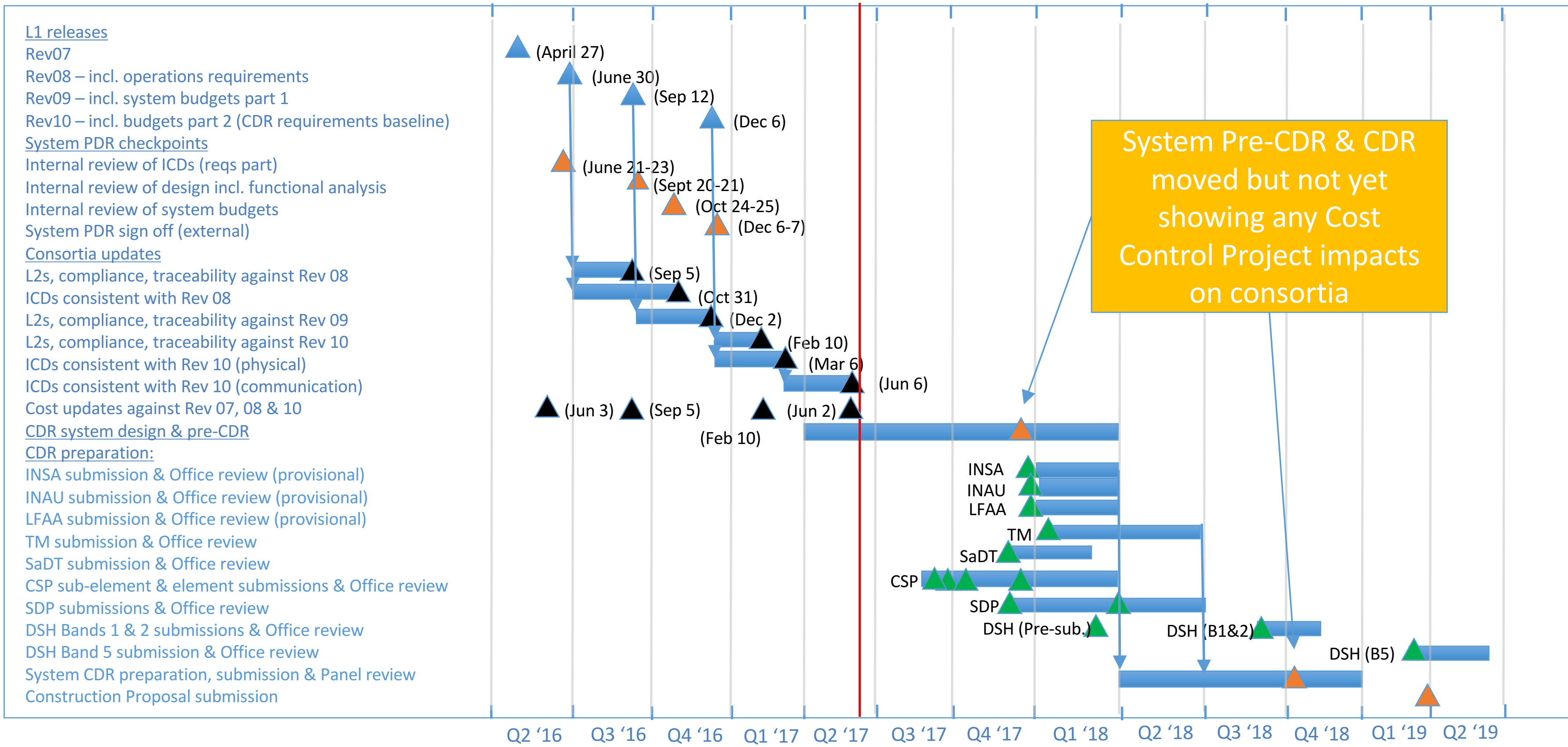
Internal organization SKA Telescope engineering Office



The main changes respect previous organization charts are:

- There are two Telescope Engineers (one for each telescope)
- There are three System Engineers (one for each Telescope and one for SW)

High-level Pre-Construction Schedule

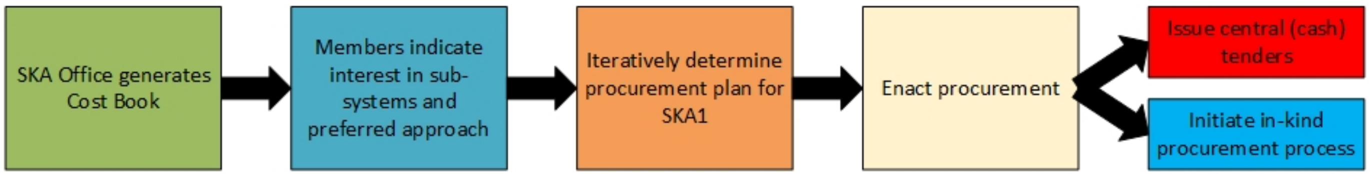


Andrea Casson, June 2017

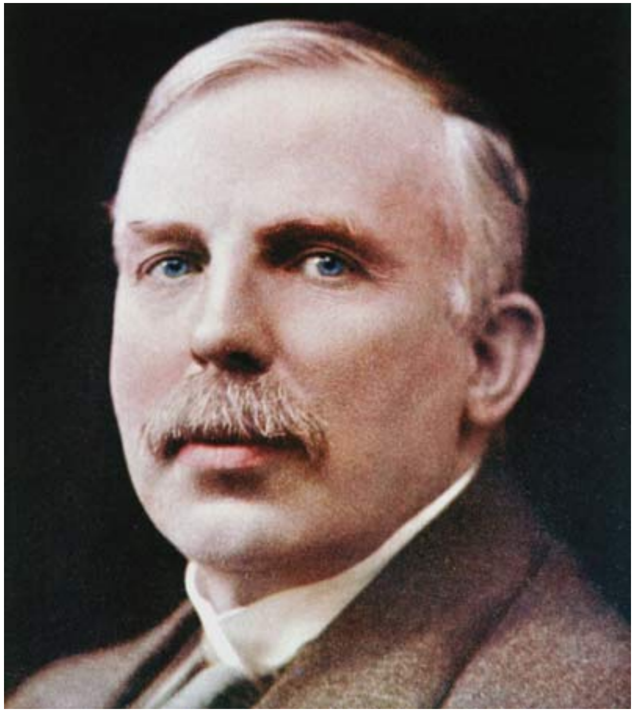
SKA1 Construction Programme

- **Scope:** draft WBS and Cost Book released Q2 2016 for initial Expression of Interest process
  - next draft release Q4 2017 to include consortia input received over the summer plus Observatory level WPs
- **Costs:** 5 sets of construction and operations cost estimates received from consortia to date
  - Increasing level of maturity
  - Still exceeding the construction cost cap
  - Cost Control Measures being developed
- **Schedule:** draft being developed for the November Board of Directors meeting
- **Support & facilities:** definition/negotiations proceeding ON ITFs and Construction Support Centres
- **Transition:** Transition Plan from Pre-Construction to Construction under development

Process steps and WBS development



- Cost Book
  - Developed ‘intelligently’ with appropriate granularity and structure
- Negotiating parties want to understand potential for a fair work return
  - Some steps in discussion on a potential procurement plan, optimising approach to help to facilitate work return ambitions while minimising project risk
- A Construction WBS (leading to Cost Book) has been drafted, which reflects the need to build up the Telescopes hierarchically



“Gentlemen, we have run out of money. It's time to start thinking.”

— **Ernest Rutherford**

Cost Control Project

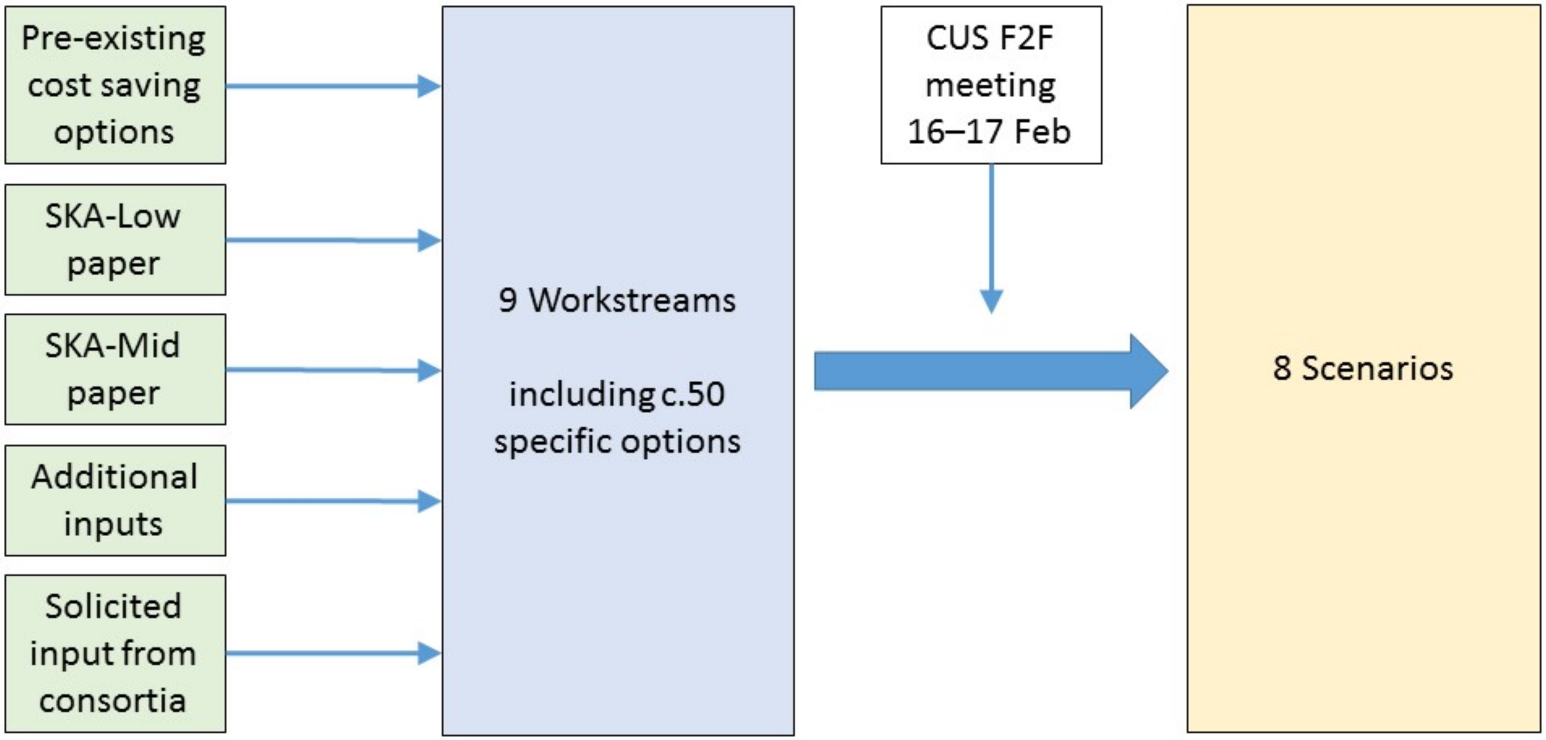
BD-22 Decision

"The Board directs the SKA Office to commence a review of the existing telescope design, guided by a sub-committee of the Board, with a view to reducing construction and operational costs. Such a review will provide revised design options against the cost cap (€674m, 2016 €). In providing the options the SKA Office will:

- Draw on the papers developing alternative options for SKA Mid (provided by RSA) and SKA Low (to be co-ordinated by Australia);
- Optimise the use of pre-cursor and pathfinder technology where it provides cost savings and/or reduces risk;
- Draw on cost reduction options already identified by consortia and the SKA Office;
- As far as possible, preserve the existing schedule and science goals;
- Allow for the expansion of the design as additional funding becomes available.

The SKA Office will present preliminary recommendations at the March Board meeting."

Process – Phase 1



Development of Scenarios

- Scenario 1 – Minimum Science Impact
- Scenario 2 – Partial Impact on Science
- Scenario 3 – Sequential saving to cost cap
- Scenario 4 – SA Paper plus minimum science impact on SKA-Low
- Scenario 5 – SA Paper plus maximum savings on SKA-Low
- Scenario 6 – deleted
- Scenario 7 – Minimum impact on current pre-construction schedule
- Scenario 8 – SKA-SA Paper and SKA-Low Paper

Recommendation – Further develop Scenarios 3 & 8 design space

- Minimum impact on scientific capability
- Moderate technical risk with mitigation
- Controlled schedule slip
- Includes ~16% contingency
- Most options can be re-instated if additional funding is available; exploits inherent scalability of interferometers
- Minimal changes to the baseline design

Design Space

- Design Space:
  - A group of options which provides a space from which a scenario can be selected. When a scenario is selected, some options will be chosen and some discarded.

- Phase 2 Design Space comprises:
  - CCP Phase 1 Scenario 3 – Ordered by Science Impact
  - CCP Phase 1 Scenario 8 – SKA- Mid and SKA- Low papers

Design Space

ECP#	WS	Description	Alternate Design Description	Science Impact	Re-instatement	Construction saving estimate (Euro M)	Cons. saving confidence	Pre-C schedule impact (weeks)	TMT risk	Operations cost impact (Euro M)	Con schedule impact (wks)	Cumulative cost saving (Euro M)	Total cost estimate (Euro M)
170006	5.39	INFRA_SA Renewable energy to outer dishes		1	NA	2.5	M	20	8		-8	2.5	826.5
170012	5.3	Maximise use of code produced during Pre-Construction		1	NA	0	L	0			0	2.5	826.5
170010	5.38	Simplify DDBH LOW		1	NA	5.4	M	3	8		-4	7.9	821.1
170007	5.38	Simplify DDBH MID		1	NA	3	M	8	8			10.9	818.1
170013	5.25.2	Reduce PSS-MID: A, 750 nodes to 500 nodes		1	NA	2.8	H	4	10	1	0	13.7	815.3
170014	5.25.2	Reduce PSS-LOW: A, 250 nodes to 167 nodes		1	NA	1	H	4	10		0	14.7	814.3
w/s 2	5.35	Reduce CBF-MID: Frequency Slice variant of CSP design		1	NA	18.5	M	13	6		0	33.2	795.8
w/s 5			Reduce CBF-MID: MeerKAT-based design			0	L					33.2	795.8
w/s 4	5.19	MID Frequency and Timing Standard (SaDT solution)		1	NA	0	H	0			0	33.2	795.8
w/s 4			MID Frequency and Timing Standard (MeerKAT-based solution)			0	L					33.2	795.8
NONE	5.19	MID SPF Digitisers (DSH solution)		1	NA	0	H	0			0	33.2	795.8
w/s 5			MID SPF Digitisers (MeerKAT-based solution)			0	L	52	4		0	33.2	795.8
w/s 1	5.26/5.29	LOW RPF: Early Digital Beam Formation		1	NA	0	L					33.2	795.8
w/s 1			LOW RPF: Analogue Beam Formation			20	L					53.2	775.8
w/s 3	2	LOW: Log Periodic Antenna Design		3	NA	0	H	0			0	53.2	775.8
w/s 3			LOW: Dipole Antenna Design			0	L					53.2	775.8
170011	8	SDP- HPC: Deploy 200 Pflops (rather than 260 Pflops)		2	Easy	11	H	0	1	2	0	64.2	764.8
170008	5.24.3	Reduce Bmax MID to 120 km: A, remove 3 dishes, but keep infra to 150km		2	Easy	4.1	M	2	8		-8	68.3	760.7
170008	5.24.2	Reduce Bmax MID to 120 km: B, remove infra, but add dishes to core		2	Hard	6.2	M	8	8		-8	74.5	754.5
170008	5.24.1	Reduce Bmax MID to 120 km: C, remove infra, remove dishes		2	Hard	6.2	M	2	8		-8	80.7	748.3
170004	5.13.2	Reduce Bandwidth output of band 5 to 2.5GHz		2	Easy	1	H	0	2		0	81.7	747.3
170003	5.13.2.1	Reduce MID Band 5 feeds: A, from 130 to 67		2	Easy	9.6	M	0	0		0	91.3	737.7
170014	5.25.2	Reduce PSS-LOW: B, 167 nodes to 125 nodes		2	Easy	0.7	M	26	10		0	92.0	737.0
170013	5.25.2	Reduce PSS-MID: B, 500 nodes to 375 nodes		2	Easy	2	M	26	10	1	0	94.0	735.0
170015	5.35	Reduce MID CBF BW: 5 to 1.4 GHz (1.4 GHz imaging all bands, 1500 beams Pulsar 300MHz, 16 beams PST 1.4 GHz, zoom windows)		2	Easy	0						94.0	735.0
170016	5.31	Reduce CBF-LOW BW: A, 300 to 200 MHz		2	Easy	1.5	H	0	2	0	0	95.5	733.5
170011	8	SDP- HPC: Deploy 150 Pflops (from 200 Pflops)		3	Easy	10	H	0	1	1	0	105.5	723.5
170005	5.30.0	Reduce Bmax LOW to 50km: A, remove infra, add 18 stations to core		3	Hard	10.2	M	4	3		0	115.7	713.3
170005	5.30.0	Reduce Bmax LOW to 50km: B, remove 18 stations		3	Hard	4	M	4	3		-10	119.7	709.3
170014	5.25.2	Reduce PSS-LOW: B, 125 nodes to 83 nodes		3	Easy	0.4	L	52	10	0	0	120.1	708.9
170013	5.25.2	Reduce PSS-MID: B, 375 nodes to 250 nodes		3	Easy	1.7	L	52	10	1	0	121.8	707.2
170005	5.30a	Reduce Bmax LOW to 40km: B, remove next 18 stations		3	Hard	14.3	M	10	3		-20	136.1	692.9
170011	8	SDP- HPC: Deploy 100 Pflops (from 150 Pflops)		4	Easy	9	H	0	1	1	0	145.1	683.9
170011	8	SDP- HPC: Deploy 50 Pflops (from 100 Pflops)		4	Easy	10	H	0	1	1	0	155.1	673.9
170009	5.24	Remove 11 MID Dishes from core		4	Hard	17.1	M	8	4		-9	172.2	656.8
170005	5.30	Remove 54 LOW stations from core		4	Hard	12	M	10	3		-30	184.2	644.8
170009	5.24	Remove additional 11 MID Dishes from core		4	Hard	19.3	M	8	4		-17	203.5	625.5
170005	5.30	Remove additional 54 LOW stations from core		4	Hard	13.1	M	10	3		-30	216.6	612.4
170008	5.24.a	Reduce Bmax MID to 100 km: D, remove infra, remove next 3 dishes		4	Hard	12.7	M	8	8		-8	229.3	599.7
170003	5.5.1	Remove MID Band 1 feeds: 108 to 0		4	Easy	10.2	M	0	0		-13	239.5	589.5
170003	5.5.2	Reduce MID Band 5 feeds: B, from 67 to 0		4	Easy	10	M	0	0		-13	249.5	579.5

41 options in total:

10 of these comprise 5 design alternatives (yellow shaded rows) which are being assessed via workstreams 1 to 6

Remaining 31 options were grouped into 14 ECPs (170003-170016) and are being evaluated by consortia in workstream 8

Workstream 7 examines the design space ordering and 3 specific scientific questions

CCP Phase 2 Workstreams

1. SKA-Low Beamforming Resolution Team
2. SKA-Mid CBF review of improved design by CSP
3. SKA-Low Antenna – evaluate potential alternatives
4. SKA-Mid Frequency Reference and Timing – Review SKA-SA solution
5. Data Capture Engine – Review SKA-SA option and compare with baseline solution
6. SDP Execution Framework- Review SKA-SA execution framework against SKA requirements
7. Science Assessments:
   - Impact on EoR/CD of changes to SKA1-Low maximum baseline length
   - Required timing accuracy to enable successful precision pulsar timing science
   - Impact of SKA-Low antenna design
8. Programmatic Assessment

Programmatic Assessment

- Aim is to improve confidence in the cost, schedule and risk estimates made in CCP Phase 1, and to extend these where possible
- Design Space items (with the exception of those covered under workstreams 1-6) are being assessed by the consortia using the ECP process
  - Additional questions included impacts on the Construction schedule, operational cost drivers and interfaces
  - A separate construction risk assessment is being carried out by evaluating each Design Space item against the current risk profile in the Risk Register
- A summary of the results to date is given in the updated Design Space table in the report and full details are here: https://confluence.skatelescope.org/display/CCP/8.+Programmatic+Assessment+page
- Continued movement within savings, but on average as anticipated
  - Uncertainties reduced
  - Issue on TM Savings not being realised (€10M)
- Cost Cap is achievable by controlling reductions chosen

Key Criteria

- Cost saving and confidence in estimates
- Science Impact
- Affect on Operations Costs
- Schedule Impact to Pre-Construction and Construction
- Risk in both Pre-Construction and Construction
- Ability to Re-Instate

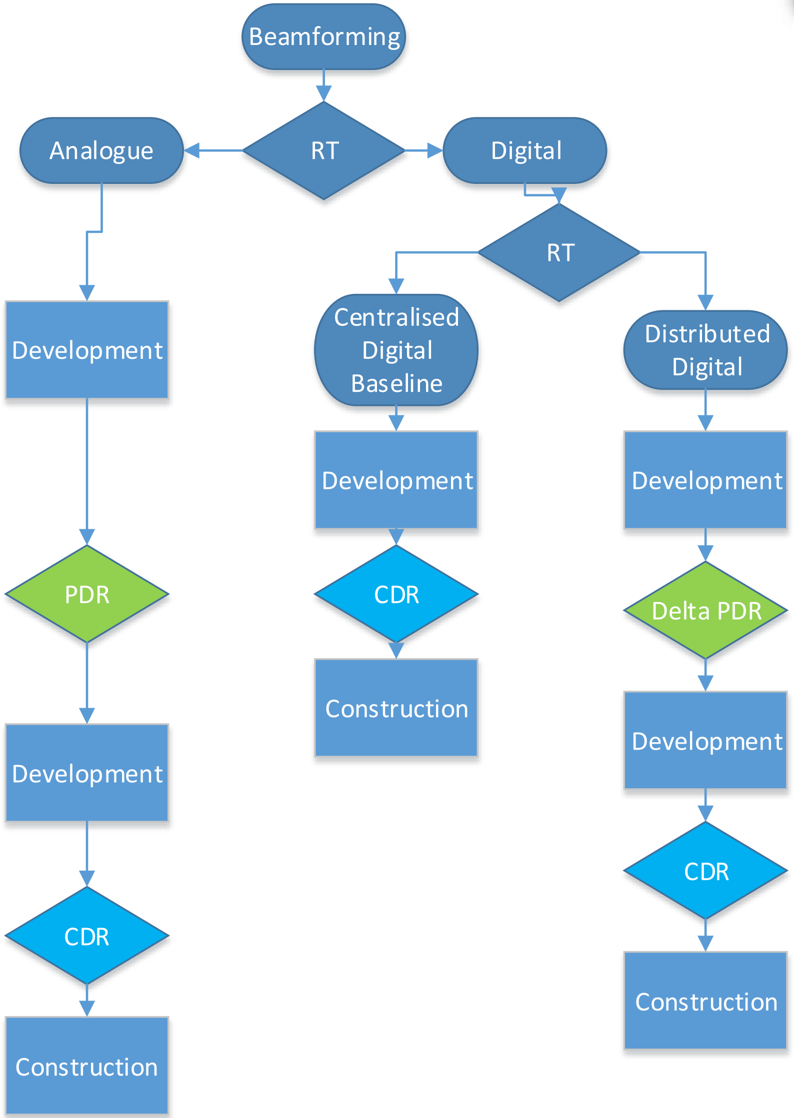
Interim Conclusions

- Options in three groups:
  - Those that affect procurement quantities such as number of Feeds, size of SDP, baselines and numbers of Dish and stations
  - Those that will take some time to evaluate and a decision can be taken when relevant information is available to be implemented in construction such as DCE
  - Those which are intrusive to the design and whilst they require investigation, will cause delay, such as Low Beamforming

Low Beamforming

Issues:
Architecture
Interface Control Documents
Technical Developments
Resources

Analogue Beamforming
24 months delay, costs
€30M to save €20M (see
recommendation)



Issues

- Consortia Resources
  - Issues are arising of consortia resources being restricted by funding from Members
  - Subsequent issues in extending some parts of some consortia
- Consortia CDRs/System CDR
  - Consortia plans currently on L1 Requirements Rev 10+
  - Additional delay or delta CDR for any changes to L1
- Cost of extensions of Pre-construction phase is approximately €3.16M/Month
- Maintenance of Momentum of Project

Emerging Recommendations

- The investigation on the DCE continues and the Office will come back to the Board of Directors with updates and will present a recommendation at the appropriate time.

- That investigations continue on Distributed Digital Beamforming, but that Analogue Beamforming be discarded due to additional Pre-Construction costs which outweigh any financial advantage in Construction.

- The remaining options are absorbed into normal work and that they will be managed as cost control mechanisms which can be applied at the time of procurement once funding is understood.

Definition of CDR

- Information Note on ‘Definition of CDR’ drafted to help Consortia in understanding
  - Accompanying document ‘Technical Preparation for Procurement’ has also been drafted
  - These documents improve upon and add to the definition of CDR deliverables in the SoWs
- Lays down the necessary status and documentation of the design at CDR
  - First step to full industrialisation
- Discusses the support of the transition from CDR to Procurement by key personnel through Construction Support Centres (CSCs)
  - CSCs succeed the Pre-Construction phase Consortia

CDR Output

- Design:
  - Validated by analysis and prototypes
  - Information available for manufacturing
  - Operational and maintenance aspects have been analysed and taken into account
- Design Pack Includes
  - All analytical evaluation
  - Definition of processes required for manufacture, verification and installation
  - Analysis of operational and maintenance aspects
  - As-designed documentation pack

CDR to Construction

- Consortium CDRs
- System CDR
- External Cost Review
- Construction Proposal
- Permission to Construct
- Implement Procurement Plan
- Agree Contracts/Agreements
    - Specifications
    - Statements f Work
    - Reference Designs
    - Interface Control Documents
    - Standards

Consortia Role in Construction

- Pre-Construction Role
  - Design Consortia
    - Funded by nations
    - Systems engineering from SKAO
- Construction
  - Preserving knowledge of design
  - Support of SKA Office
  - Support to Contractors/Suppliers

Preserving SKA knowhow

- IP and knowhow created during pre-construction, and world class expertise, will be utilised to the maximum extent possible during Construction and beyond
  - Key personnel will be critical to this
- Pre-Construction Consortia will cease to exist, however:
  - Key personnel will be involved in Construction
  - Key personnel will be engaged via Construction Support Centres which may be existing institutions or collaborations between institutions

How to do this? (I)

- Key personnel and institutions, through the Construction Support Centres mechanism could be involved, optionally, in two ways:
  - By joining Construction consortia to provide hardware and software
  - By obtaining consultancy contracts with the SKA Observatory

Implementation

- The Construction WBS does not presently reflect either scenario
- Careful consideration would need to be given to meshing academia/R&D cultures with industry cultures
- Consultancy would not involve supply of hardware or software
  - It would be time only
- The choice of scenario would depend upon the outcomes of procurement activity and cannot be predicted with full confidence
- Consultancy would be a contribution to Construction, could be in-kind, and would receive valuation

Plan

- Agreement on Fair Work Return Definitions Develop
- Refinement of PBS & WBS
- Call for revised EoI
- Further develop of Procurement Plan
- Gain agreement with Procurement Plan with Members

Towards Construction

Project Safety Management Plan rev 1

SKA-TEL-SKO-0000740

SKA PROJECT SAFETY MANAGEMENT PLAN

Document Number SKA-TEL-SKO-0000740
Document Type .... PLAN
Revision 01
Author .... John Kerr
Date 2017-03-21
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Name	Designation	Affiliation	Signature	
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Designers, from concept to detail, are required to identify hazards which may create significant risks for contractors, users and maintenance personnel and seek to reduce them.

Project Safety Management Plan rev 1

SKA-TEL-SKO-0000740

SKA PROJECT SAFETY MANAGEMENT PLAN

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Author .... John Kerr
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All designers, contractors and other team members that organisations propose to engage are must be competent (or work under the supervision of a competent person), adequately resourced and appointed early enough for the work they have to do.

Collaborative Engineering in Megaprojects

- Open session at 8.30AM on Thursday 15th June in the van Weelde auditorium. Chaired by Tim Stevenson.

- The session is designed to foster exchange of ideas, experiences, and lessons learned in the area of Collaborative Engineering.

- Invited speakers will discuss projects conducted at the following 5 organisations:

Advanced Virgo

AIRBUS SAFRAN LAUNCHERS

ESO

EUROPEAN SPALLATION SOURCE

esa

SQUARE KILOMETRE ARRAY

Exploring the Universe with the world's largest radio telescope