



**REPORT ON DELIVERABLE WP2.3
APERTURE ARRAY CONCEPT DESIGN REVIEW**

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 Author A.J.J. van Es
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LIST OF ABBREVIATIONS

AA.....	Aperture Array
ASIC	Application-Specific Integrated Circuit
ASKAP	Australian SKA Pathfinder
ASTRON	Netherlands Foundation for Research in Astronomy
CAD.....	Computer Aided Design
CDR.....	Critical Design Review
CISRO	(Australian) Commonwealth Scientific and Research Organisation
CoDR.....	Conceptual Design Review
DRM	Design Reference Mission
EMC	Electro Magnetic Compatibility
EX.....	Example
FFT.....	Fast Fourier Transform
FoV.....	Field of View
FPGA.....	Field Programmable Gate Array
GNU	GNU's Not Unix
INAF	National Institute for Astrophysics
IP	Intellectual Property
JIVE.....	Joint Institute for VLBI in Europe
JPL	Jet Propulsion Labs
KASI	Korea Astronomy Space-Science Institute

LEMP.....	Logistic Engineering Management Plan
MPIfR	Max Planck Institute for Radio Astronomy
MTBF.....	Mean Time Before Failure
MTTR	Mean Time To Replacement
NCRA	National Centre for Radio Astrophysics
NRC-HIA	National Research Council Herzberg Institute of Astrophysics
NRF	National Research Foundation
OPAR	Observatoire de Paris
OS	Operating System
PAF	Phased Array Feed
PDR.....	Preliminary Design Phase
PSU	Power Supply Voltages
RFI.....	Radio Frequency Interference
RMON	Remote Monitoring
RMP	Risk Management Plan
SEMP	System Engineering Management Plan
SRS	(Sub) Systems Requirement Specification
SRR.....	(Sub) Systems Requirement Review
SKA	Square Kilometre Array
SNMP	Simple Network Management Protocol
SPDO	SKA Program Development Office
TDP	Technology Development Program
TIFR	Tata Institute of Fundamental Research
UCAM.....	University of Cambridge
UMAN.....	University of Manchester
UORL	University of Orleans
UOXF	University of Oxford
VLBI.....	Very Long Baseline Interferometry
WBSPF.....	Wide Band Single Pixel Feed

1 Introduction

1.1 Purpose of the document

This document is submitted as fulfilment of the requirements for Milestone 59 (Deliverable 2.6) of PrepSKA Work Package 2.3 Verification Programs (WP2) following the successful completion of the Aperture Array Concept Design Review (CoDR).

1.2 Scope of the document

The document provides an overview of the Aperture Array Verification Program Concept Design Review, the outcomes and subsequent events and planning.

2 SKA Aperture Array CoDR

2.1 Overview and Context

The Aperture Array CoDR was conducted during the period 19th to 20th April 2011 at the Novotel Hotel at Schiphol Airport. The members of the AAVP Management Team and the SKA Program Development Office AA-domain specialist presented the status of the project to the review panel.

The review panel consisted of four members: two from industry, one from the Radio Astronomy community, plus the SPDO Project Engineer who also chaired the panel.

The review was attended by observers across the SKA community and by representatives from the different pathfinders and demonstrators.

2.2 Review Plan

To facilitate the review a plan was developed setting out:

1. The context of the review,
2. The purpose and expected outcome of the review,
3. The roles and responsibilities of the review participants
4. The logistics behind the review.

The plan was reviewed with the SPDO Project Manager and was updated as and when changes were encountered. The final revision of the plan was available two weeks before the start of the review. The final revision of the plan is attached in Appendix A.

2.3 Purpose and Expected Outcomes of the CoDR

As outlined in the Review Plan the CoDR was conducted to evaluate:

- The overall technical progress,
- Whether the technical adequacy obtained during the concept phase, as defined in the relevant

documentation, is at a sufficient level of maturity to allow the Aperture Array element to move into the next phase,

- Whether all aspects of the Aperture Array element have been covered and where gaps exist, whether adequate measures have been identified to address the shortcomings.

The Review Panel is requested to consider the following questions:

1. Are the requirements complete, and sufficiently defined for this stage of the project?
2. At the concept level, is the element/subsystem presented capable of meeting the requirements?
3. Has interfaces to other aspects of the system have adequately identified and defined at this stage of the program?
4. Are the options proposed to be carried forward credible and are the presented data and information in support of each option credible?
5. Have all the necessary aspects of the specific element/subsystem been considered and addressed during the review or are there gaps and/or shortcomings?
6. Does the risk profile appear reasonably detailed and assessed for this stage of the program?
7. Do the stated risk controls and proposed mitigations appear reasonable and executable?
8. Is the overall plan (including the identification of the tasks, effort, resources, costs, schedule and risk mitigation needed) to complete the subsequent project phases credible?

2.4 Documentation

In support of the review six (6) documents were developed and distributed to the review panel before the review. A set of twenty one (21) reference documents provided by the SPDO program, pathfinders demonstrators and pre-cursor programs was added to the specific review documents. A significant portion of the reviewed documents were developed by the lead and participating institutes.

A list of the documents is part of the AA CoDR Review plan (Appendix A).

The documents were made available to all the SKA liaison engineers, the observers, the SKA Science and Engineering Committee (SSEC), International Engineering Advisory Committee (IEAC) and the WP2 Management Team prior to the review.

Copies of the documents are available on the following sites:

<http://www.astron.nl/AACoDR/>

(note: this is not a permanent site)

and http://www.skatelescope.org/public/2011-04-19_Aperture_Array_CoDR_Documents/

2.5 Review

The agenda followed during the review is shown in the Review Plan in Appendix A.

The review consisted of a number of presentations based on the documents provided to the panel. The presentations covered the science case, the technical concepts for both frequency ranges under consideration, high level system descriptions, requirements, risks and management aspects.

2.6 Review Panel Findings

The panel was unanimous in recommending that the Low Frequency Aperture Array project move to the next stage, leading to the System Requirements Review (SRR). For the Mid Frequency Aperture Array the panel recommended a further feasibility assessment, including work on power and cost.

2.6.1 Primary Finding

The report with the findings of the panel was received on June 7th 2011. The panel expressed appreciation for the considerable effort and the amount of work done for the review and was happy to notice that the AA group adopted procedures commensurate with the overall system design. The most important findings are:

1. For AA-low, the panel is unanimous in recommending that the project move to the next stage, leading to the System Requirements Review (SRR), with recommendations detailed in the report.
2. For AA-mid, the panel recommends further feasibility assessment, including work on power and cost. Work is also needed on draft requirements, based on SKA2 science, in conjunction with similar work at the system level. An independent review process seems appropriate following this work. The timescale on which decisions on the potential adoption of AA-mid technology is currently set by the project as 2016. This is needed to provide feedback on the viability of AA-mid so that work on SKA2 can be adapted accordingly.

Completion of this task, including physical verification and costing, within four years will be a challenge. Also, it is likely that further iteration and clarification between SKA2 System and AA-mid Element levels will be needed. This is not entirely under the control of the AAVP, and will absorb additional time.

Other aspects discussed during the review are mentioned in the report and summarized in a total of 14 recommendations.

A copy of the review panel report is included in Appendix B.

2.7 Response to Review Panel Report

A document is currently being drafted in response to the Review Panel Report which will include input from the Aperture Array Verification Program Management Team.

3 Next Steps

The next steps in the Program will focus on implementation of the findings and recommendations of the panel and will focus on:

- for AA-mid to achieve the Delta Review
- for AA-low to have a SRR before the end of PrepSKA (March 2012)

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APPENDIX A

Review Plan



APERTURE ARRAY CONCEPT DESIGN REVIEW PLAN

Document number..... WP2-010.020.010-PLA-002
 Revision..... E
 Author A. van Es
 Date..... 2011-04-12
 Status Final

Name	Designation	Affiliation	Date	Signature
Released as part of Aperture Array CoDR documents:				
A. van Es	Program Manager	AAVP	2011-04-12	<i>AE</i>
Co Authors and contributors: A. Faulkner, K. Cloete, ..				
Approved for release as part of Aperture Array CoDR documents:				
K. Cloete	Project Manager	SPDO	2011-04-12	<i>K</i>

DOCUMENT HISTORY

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E	2011-04-12		Released

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	Package	Version	Filename
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- Peter Dewdney PE SPDO
- Raf Roovers Dep Head NXP central R&D
- Richard Williams Programme Manager Cambridge Consultants
- Colin Lonsdale Dir. MIT/Haystack

AAVP Arnold van Ardenne, Jan Geralt bij de Vaate, Andrew Faulkner, André van Es, Derek McKay, Ilse van Bommel, Steve Rawlings

SPDO

Richard Schilizzi, Peter Dewdney, Joe Lazio, Minh Huynh, Kobus Cloete, Tim Stevenson, Neil Roddis, Andre Gunst, Roshene McCool, Wallace Turner, Duncan Hall, Georgina Harris, Rob Millenaar, Billy Adams, Lisa Bell, Colin Greenwood, Jo Bowler, Phil Crosby, Greta Collins.

WP2 Management Team

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Liaison Engineers

Jan Geralt bij de Vaate (ASTRON), John Bunton (CSIRO), Gary Hovey (DRAO), Peter Hall (ICRAR), Stelio Montebugnoli (INAF), Domingos Barbosa (IT), Leonid Gurvits (JIVE), Arpad Szomoru (JIVE), Jongsoo Kim (KASI), Reinhard Keller (MPG), Yashwant Gupta (NCRA-TIFR), Anita Loots (NRF), Steve Torchinsky (OBSPAR), Thijs van der Hulst (RUG), Athol Kemball (TDP), Lynn Baker (TDP), Len Bruton (UCAL), Paul Alexander (UCAM), Andy Faulkner (UCAM), Chris Shenton (UMAN), Rodolphe Weber (UORL), Kristian Zarb Adami (UOXF), Mike Jones (UOXF).

SSEC Chairman

M Garret (ASTRON).

IEAC

Jaap Baars (Arcor), Marco de Vos (ASTRON), Wolfgang von Rueden (CERN), Peter Hall (Curtin University), Tony Beasley (National Ecological Observatory Network), Noriyuki Kawaguchi (National Astronomical Observatory), Peter Napier (Chair) (NRAO), André Hoogstrate (TNO).

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LIST OF ABBREVIATIONS

AA.....	Aperture Array
AAVP.....	Aperture Array Verification Programme
COAR.....	Consolidated Action Observation Register
CoDR.....	Concept Design Review
SKA	Square Kilometre Array
SPDO	SKA Program Development Office
SSEC.....	SKA Science and Engineering Committee
UK	United Kingdom
WP.....	Work Package

1 Introduction

1.1 Purpose of the document

This document describes the plan for the Aperture Array Concept Design Review (AA CoDR) for the Square Kilometre Array (SKA) project.

1.2 Scope of the document

This document will describe all matters related to the review itself. It will include logistics surrounding the review as well as a preliminary agenda.

1.3 Date and Place

The AA CoDR will be held on 19 and 20 April 2011 at the Novotel Amsterdam Airport, the Netherlands.

2 Purpose and Expected Outcome of the AA CoDR

The AA CoDR will be conducted at the end of the concept phase. At the AA CoDR concepts will include a range of options. The CoDR review will focus on whether first order solutions have been identified and are appropriate. Work in advancing fundamental technologies known to be critical to the element may also be reported if this is supportive of the concept and its feasibility. Concept Design Reviews are therefore the culmination of the Concept phase of development where the demonstration of feasibility is the objective. In subsequent phases of the project technology options will be investigated and selections will be made.

The concepts presented at an SKA domain CoDR should therefore not be over-defined, nor should they contain any preliminary designs. This is because the requirements have not been fully captured and detailed studies are in danger of being done too early.

The CoDR will be conducted to evaluate:

- The overall technical progress,
- Whether the technical adequacy obtained during the concept phase, as defined in the relevant documentation, is at a sufficient level of maturity to allow the Aperture Array element to move into the next phase,
- Whether all aspects of the Aperture Array element have been covered and where gaps exist, whether adequate measures have been identified to address the shortcomings.

The expected outcome of the review is input to the establishment of the system concept baseline. Following the successful review, the next phase, the AA definition phase, will be initiated.

Questions to the SKA AA CoDR panel:

The Review Panel is requested to consider the following questions:

1. Are the requirements complete, and sufficiently defined for this stage of the project?
2. At the concept level, is the element/subsystem presented capable of meeting the requirements?
3. Has interfaces to other aspects of the system have adequately identified and defined at this stage of the program?

4. Are the options proposed to be carried forward credible and are the presented data and information in support of each option credible?
5. Have all the necessary aspects of the specific element/subsystem been considered and addressed during the review or are there gaps and/or shortcomings?
6. Does the risk profile appear reasonably detailed and assessed for this stage of the program?
7. Do the stated risk controls and proposed mitigations appear reasonable and executable?
8. Is the overall plan (including the identification of the tasks, effort, resources, costs, schedule and risk mitigation needed) to complete the subsequent project phases credible?

3 Organisation

3.1 Participants

The following groups of review participants have been identified:

- External Review Panel : The four members of the external review panel
- Presenters : Members of the AAVP and staff members of the SPDO
- Observers : Any other attendee (see below)

The External Review Panel is composed of the following members (one being the chair):

- Peter Dewdney (SPDO)
- Raf Roovers (NXP central R&D)
- Richard Williams (Cambridge Consultants Ltd.)
- Colin Lonsdale (MIT/Haystack)

As Presenters, the following people have been identified:

- Arnold van Ardenne (ASTRON) ardenne@astron.nl
- Andrew Faulkner (Univ. of Cambridge) ajf@mrao.cam.ac.uk
- Jan Geralt bij de Vaate (ASTRON) vaate@astron.nl
- Steve Rawlings (Univ. of Oxford) sr@astro.ox.ac.uk
- André Gunst (SPDO) gunst@skatelescope.org
- André van Es (ASTRON) es@astron.nl
- Kobus Cloete (SPDO) cloete@skatelescope.org

Note that the presenters will be doing the presentations on behalf of the international collaboration and contributors.

As Observers, the following people have been invited:

- Liaison engineers
- WP2 Management Team members
- Members of the SSEC (exact numbers and attendance still to be confirmed)
- Members of the International Engineering Advisory Committee (IEAC)
- SPDO staff members

3.2 Review Process

The External Review Panel is expected to review the CoDR documentation prior to the actual Design Review. Any questions, comments or queries sent to the AAVP Programme Manager (André van Es) in advance will be recorded and be dealt with during the review. Questions, comments or queries posed during the review will be recorded and will be attempted to be addressed during the review.

In the event that any issue cannot be dealt with during the review, it will be recorded as such and the AAVP will address these outstanding issues as soon as possible after the review.

3.3 Roles and Responsibilities

The AAVP shall

- Distribute the last of the documentation to the External Reviewers no later than two weeks before the review date;
- Record all questions, comments and queries raised before and during the review;
- Respond to questions, comments and queries before, during and after the review;
- Record the responses to the questions, comments and queries;
- Organise and support the review meeting;
- Provide the necessary facilities for the meeting;
- Respond to agreed Actions within the agreed due dates;
- Compile an overview report to the PrepSKA Board and SSEC after the review.

The External Review Panel Chairman shall

- Organise and lead the External Review Panel;
- Review the documentation;
- Raise questions, comments and queries before and during the review related to any part or aspect of the project;
- Prepare and issue the External Review Panel Report, together with a list of the agreed Actions;

The External Review Panel Members shall

- Review the documentation;
- Raise questions, comments and queries before and during the review related to any part or aspect of the project;
- Support the Chairman in the preparation of the External Review Panel Report;

Observers:

Observers are deemed to have more than a passing familiarity with the work being reviewed and to have had some opportunity to pass comment prior to the Review. In order to capture views that develop during the Review process, but to allow the formal procedure to complete in the time allocated, COARs may be drafted by Observers and an opportunity to present them to the SPDO immediately following the Review is envisaged. As this right is available to Observers, questions or statements from the floor of the Review will be discouraged. Questions from the panel will be handled by the presenter which may, at his/her discretion, call on members of the audience to assist with answering the question.

The Observers are therefore invited to:

- Attend the review;
- Provide written feedback with regards to any aspects of the review, including the documentation, in COAR format after the review;
- Assist with answering questions from the review panel if requested to do so by the presenter.

4 Review Schedule

1. **Weeks up to 31st March 2011** – Produce documents, review, update and finalise documents during this period.
2. **4 April 2011** – 16:00 hrs documents available for Walkthrough
3. **6 April 2011** – Walkthrough of documents
4. **12 April 2011** Distribute last of the documents to external reviewers.
5. **19 April 2011** – Review panel members arrive in Amsterdam
6. **19 and 20 April 2011** – Conduct design review
7. **20 April 2010** – Review panel to draft report and provide initial feedback
8. **Week 20 April to 1 May** – Internal follow-up review, determine and action follow up items.

5 Documentation

Documents

	Document Title	AA-CoDR document	Description & work to be done for AA-CoDR
	Reference Documents		
R1	SKA Science Case	Reference	Describes overall SKA science anticipation
R2	Design Reference Mission	Reference	Breakdown of science requirements and some technical implementation considerations for SKA2
R3	Science for Phase 1	Reference	The DRM for Phase 1. Being prepared for System CoDR.
R4	System Engineering Management Plan (SEMP)	Reference	Description of the overall development process
R5	Costing Strategy	Reference	Description of the Costing Strategy
R6	Technology Roadmap	Reference	Roadmap document for technologies employed within SKA
R7	SKA1: High Level System Description	Reference	
R8	SKA Phase1 System Requirements Specification	Reference	Phase 1 System Requirements
R9	Project Execution Plan Pre-Construction Phase For The Square Kilometre Array (SKA)	Reference	High level plan for the pre-construction phase of the SKA
R10	The Radio Frequency Interference Environment At Candidate SKA Sites	Reference	Measurement data of the RFI Characteristics at the candidate sites
R11	SKA Project Dictionary	Reference	List containing terms and acronyms frequently used within SKA
R12	PREPSKA Documentation Standards, Handling And Control	Reference	Procedure for documentation handling
R13	Risk Management Plan	Reference	Plan describing the Risk Management Strategies
R14	Cost Estimation For The SKA – A 'How To' Manual	Reference	Practical guidelines for the costing of subsystems
R15	Conical Spiral Antenna Analysis	Reference	Analysis of Conical Spiral Antenna Analysis
R16	Vivaldi Antenna Analysis	Reference	Analysis of Vivaldi antenna design

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	Document Title	AA-CoDR document	Description & work to be done for AA-CoDR
R17	BLU and log per Antenna Analysis	Reference	Analysis of two antenna designs
R18	AAVP Collaboration Agreement	Reference	Document that contains the agreements on which the AAVP Collaboration is based
	AA Review Documents		
1	AA strategy to proceed to the next phase (SRR)	New document	New document
			Introduction and Executive summary
			AA requirements for Phase 1, AIP & Phase 2
			Technology discussion and choices to take forward.
			<i>Plans for the next stage:</i> technical schedule and focus management aspects
			Development timeline
			Appendix 1: SKADS report
			Appendices 2 - 4: LOFAR, MWA, PAPER HERA and LWA reports
2	AA concept descriptions	New document	High level description System concept options, specification derivation and definition (Each topic will normally have both AA-low and AA-mid subsections)
			High level system description
			Technical requirements derived from science and trade-off discussion
			Performance parameter calculations
			Block diagrams showing AA system context System concept options
			Technologies Readiness and Roadmap to be taken forward
			Power requirement discussion
			Software requirements, implementation and tracking discussion, calibration (temp)
			Reliability, Availability, Maintainability and Safety (RAMS)
			Appendix: AA Risk register and mitigation approach (snap shot)

3	AA SRS	New document	Detailed system requirement specification (SRS) Detailed line-by-line specifications
			Appendix 1: Draft requirements traceability matrix
4	AA Implementation	New document	Deployment and operation Deployment and operation overview Costing and trade-offs Deployment schedule considerations Projected power requirements Logistic planning MTBF and maintainability issues
5	AA Risk register	New document	Risk register Ongoing active document as a spread-sheet

6 Agenda

Session		Presenter	Starting Time	Time Allocated
Tuesday, 19 April 2011				
	Panel members arrive at Schiphol			
	Lunch		12:00 – 13:00	1 hour
1	Review Panel (closed meeting)	Reviewers	13:00 – 13:30	30 minutes
	Welcome and General Overview of AA	AvA	13:30 -13:45	15 minutes
	Purpose and Context of the AA CoDR	KC	13:45 – 14:00	15 minutes
	AA Science Case	SR	14:00 – 14:30	30 minutes
	AA System Requirements	AG	14:30 – 15:00	30 minutes
	Coffee Break		15:00 – 15:30	30 minutes
2	Engineering: Technical AA Concepts	JGbdV	15:30 – 16:30	60 minutes
	High Level System Description	AF	16:30 – 17:15	45 minutes
	AA Risks and Risk Management	AvE	17:15 – 17:30	15 minutes
	Review Panel (closed meeting)	Reviewers	17:30 – 18:00	30 minutes
	Drinks and Dinner		19:00	
Wednesday, 20 April 2011				
3	Deployment and Operations	AF	09:00 – 09:45	45 minutes
	Strategy to proceed to Next Phase	AF/ AvE	09:45 – 10:15	30 minutes
	Coffee Break		10:15 – 10:45	30 minutes
	Summary of AA for SKA	AvA	10:45 – 11:15	30 minutes
	Review Panel (closed meeting)	Reviewers	11:15 – 12:30	75 minutes
	Lunch		12:30 – 13:30	60 minutes
4	Initial feedback to AA Team	Reviewers	13:30 – 14:30	60 minutes
	Summary and closing of the review	AvA/KC	14:30 – 14:45	15 minutes

AvA Arnold van Ardenne
AF Andy Faulkner
AG André Gunst
AvE André van Es
JGbdV Jan Geralt bij de Vaate
KC Kobus Cloete
SR Steve Rawlings

7 Logistics

7.1 Location

The AA CoDR will take place at the

Novotel Amsterdam Airport
Sloterweg 299
1171 VB Badhoevedorp
Tel: +31 20 658 8118
Fax: +31 20 658 8100
e-mail H5330-SB@accor.com

7.2 Contact Persons

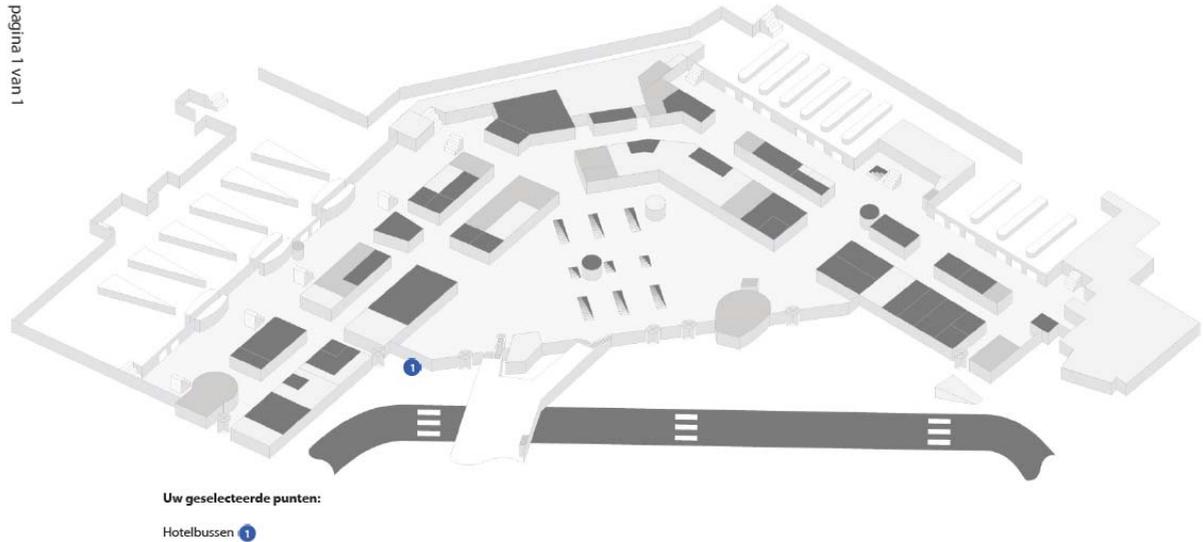
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8 Map + Shuttle Timetable

Map indicating bus location:



SHUTTLE BUS TIMETABLE

Departure from Novotel Amsterdam Airport

4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1
	00	00	10	10	10	00		05				00	00	00	00	12	02	12			00
30	30	15	30	30	25	20	30		22	22	22	20	20	20	17	27	22	32	22	30	30
		35			45			40				40	40	40	37	47	37	47			
		50	50	50		55			52	52					52		57		57		

Departure from Schiphol Airport

4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	0	1
			15	15	10	05	15		00	05	05		00	00	00	10	05	15	05	15	15
	20	20			30	20		25				20	20	20	20	30	20	30			
		35	35	35	45	40			35	35	40	40	40	40	35	45	40		40	45	45
50	50	55	55	55			50								55		55	50			

APPENDIX B
Panel Report

SKA APERTURE ARRAY CONCEPT DESIGN REVIEW

P. Dewdney, C. Lonsdale, R. Roovers, R. Williams

01 June 2010

1 Introduction

The SKA Aperture Array Concept Design Review (AA CoDR) was held at Schiphol in The Netherlands on April 19 and 20, 2011. A detailed agenda is given in Appendix I. The review was conducted by a four-member panel to assess progress to date on the two Aperture Array (AA) receptor technologies proposed for the SKA. The names and positions of the panel members are provided in Appendix II. This is the first in a series of formal reviews outlined in the SKA Engineering Management Plan (SEMP [1]), which are held for each of the top levels of the system. The AAs are one level below the system. As part of the system, their requirements are described in System Requirements Specification [2] and a first iteration of their performance is described in the System High Level Description [3].

As context, Figure 1 shows the expected sequence of reviews at this level. The SEMP outlines the expectations for progress in each phase, on which the charge to the panel was based. The charge to the panel was stated in the Review Plan, one of the documents provided. For convenience it is repeated in Appendix III.

Note that a linear process operating in isolation, such as implied by Figure 1, is an over simplification. A much more complex process is expected: simultaneous development of system requirements, element requirements, cost and performance data will necessitate an iterative approach and frequent interaction with the system design.

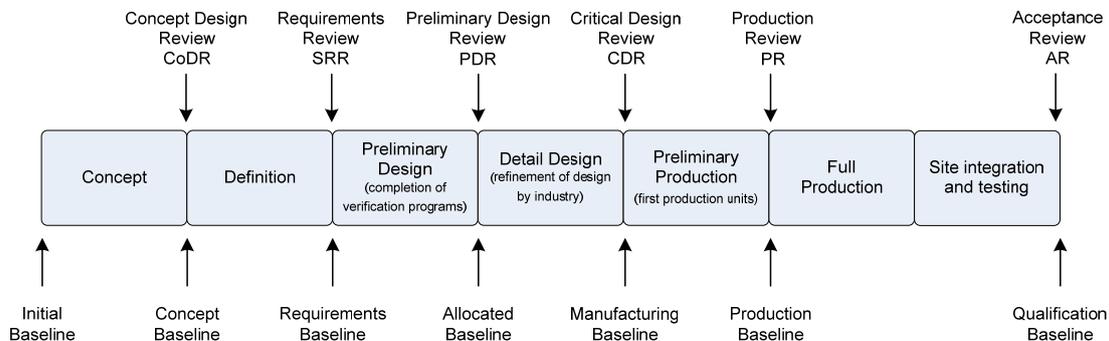


Figure 1 (Figure 9 of SEMP): Reviews, baselines and phases at each Element level of the SKA project.

2 References

- [1] K Cloete, 'System Engineering Management Plan', document number WP2-005.010.030-MP-001, Revision E dated 2011-02-14.
- [2] T Stevenson et al., 'SKA Phase 1 System Requirements Specification', WP2-005.030.000-SRS-002-B, dated 2011-02-14.
- [3] P. E. Dewdney et al., 'SKA1: High Level System Description', Rev. A., WP2-005.030.010-TD-002, 2011-02-14.

3 Overall Summary Findings

The following sub-sections are the summary findings in answer to the overall questions in the charge, and a statement of the panels view on the outcome. More specific comments and recommendations are contained in subsequent sections.

3.1 Overall Progress

The panel is impressed by the considerable effort and the amount of work done for the review, especially the work done leading up to the AA CoDR and that the AA group is adopting procedures commensurate with the overall system design.

Even though there is technical overlap, similar theory, and probably some common components for AA-low and AA-mid, they are sufficiently different parts of the SKA system that the documents should be separated. In particular, these systems occupy very different regimes in terms of required manufacturing and cost control techniques, calibration challenges of various kinds, sky properties and imaging performance requirements, fractional bandwidth targets, and current technical maturity. Commonalities in sub-systems or parts, to the extent that they represent true overlap, can be clearly isolated and documented separately.

This view is commensurate with the agreed SKA project work-flow, in which the AA-low is a sufficiently mature technology to be included in the SKA1 design and AA-mid is on a parallel path to raise its level of maturity before being considered for SKA2. A simplified version of the project workflow is given in Figure 2 for reference. The panel emphasises that a sufficient level of effort on both parts of the AA programme are required for these goals to be realised.

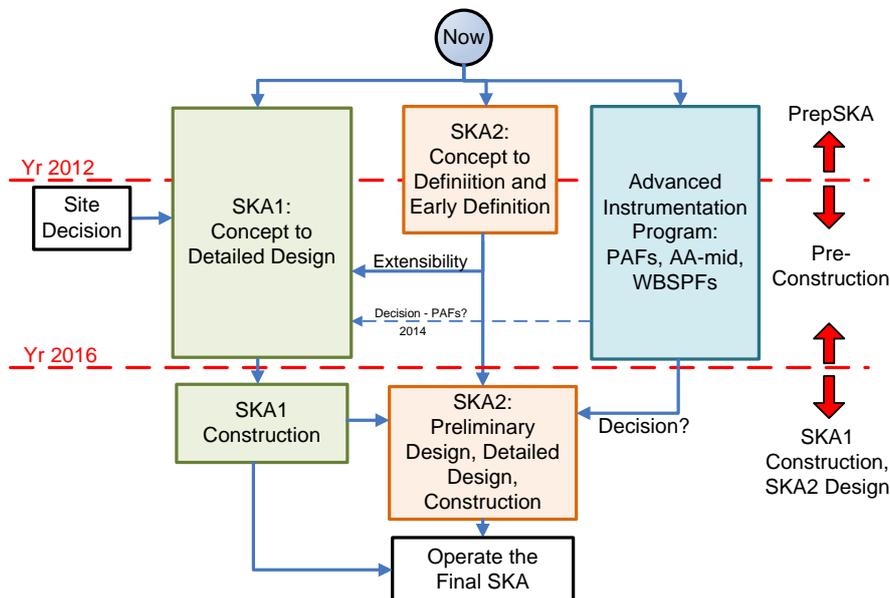


Figure 2: A simplified version of Figure 16 of the System High Level Description [3].

3.2 Technical Adequacy

The panel was asked whether the technical adequacy obtained during the concept phase is at a sufficient level of maturity to allow the Aperture Array Element to move into the next phase. The panel has a two-part answer to this question.

1. For AA-low, the panel is unanimous in recommending that the project move to the next stage, leading to the System Requirements Review (SRR), with recommendations detailed in subsequent pages.
2. For AA-mid, the panel recommends further feasibility assessment, including work on power and cost. Work is also needed on draft requirements, based on SKA2 science, in conjunction with similar work at the system level. An independent review process seems appropriate following this work (See Section 3.1 and Figure 2. Note also that Figure 2 is a simplified version of a more comprehensive diagram in [3].) The timescale on which decisions on the potential adoption of AA-mid technology is currently set by the project as 2016. This is needed to provide feedback on the viability of AA-mid so that work on SKA2 can be adapted accordingly.

Completion of this task, including physical verification and costing, within four years will be a challenge. Also, it is likely that further iteration and clarification between SKA2 System and AA-mid Element levels will be needed. This is not entirely under the control of the AAVP, and will absorb additional time.

Recommendation 1: Work with the System level on establishing at least a first pass on obtaining sound requirements and clear concept-level options for AA-mid, within SKA2. Put together the AA-mid specific documentation and organise a CoDR-style review as soon as possible thereafter.

3.3 Coverage and Gaps

The panel was asked whether all aspects of the Aperture Array Element level have been covered, and where gaps exist, whether adequate measures have been identified to address the shortcomings.

Some gaps have been identified, but for AA-low they are not sufficiently serious to prevent the project from proceeding to the next phase. Nevertheless, a few important aspects should receive more emphasis in the near future (e.g. power consumption).

The panel emphasizes that more analytic detail must be presented at the next review, yielding evidence through results that the management of the program is efficient and thorough. The material presented at this review reveals a degree of disparity between the efforts in different areas that suggests immaturity of the management structure and a lack of adequate coordination.

3.4 Expected Outcome

The panel believes the expected goal has been reached: a concept baseline has now been established for AA-low, using the project accepted definitions (see Figure 1 and [1]). However, more work is needed in the near term to bring different aspects of this baseline up to a common level of maturity, which is necessary for a balanced assessment and robust analysis supporting elimination of options in the next phase.

As noted above, more investigation is necessary for AA-mid before a concept baseline can be established.

4 Comments and Recommendations

4.1 AA Requirements

While the panel is aware that system and science requirements are still in flux, it is important that AA requirements be developed in parallel with science/system requirements. Much more effort in this area is urgently needed. The uncertainty in requirements will prevent the range of AA options currently being considered from being reduced in a systematic and properly justified manner. For example, the presentation on AA Implementation contains many implicit requirements, and it is essential to coordinate these bottom-up requirements with the higher level requirements inherited from the system level, and to merge them into a consistent set.

Development of AA-mid requirements will require further investigation of SKA2 science and system requirements. This investigation is commensurate with the SKA project workflow illustrated in Figure 2.

The requirements document, itself, is a good start in terms of organization, but content needs urgent work. Also, the approach to requirements described in the presentations was in line with good practice.

Recommendation 2: Accelerate the establishment of agreed and reviewed requirements, particularly for SKA1. Work with the Science and System teams to inform and encourage the development of stable science goals and system requirements. Then derive the AA requirements accordingly. This could mean a temporary re-assignment of resources to help achieve this goal, although the panel notes that the newly appointed AA-Verification Scientist could help progress this task. **The AA project should inform and iterate with the Science Project on capability and relevant trade-offs.** SKA1 requirements and SKA2 requirements should be in separate documents. This will also separate AA-low requirements from AA-mid requirements. However, **SKA1 requirements should include consideration of applicability of solutions to SKA2 (i.e. extensibility requirements).**

4.2 AA Options

The panel found it difficult to understand how the technical options are organised and bounded. Neither the documentation nor the presentations were clear on this point. This concern is part management and part technical. Many potential options were noted, but the number of combinations could build up to an impossible level if this is not managed. Further delineation of options will be needed if the AA project is to remain “finite”.

The top level option choice for AA-low appears to be the frequency banding (one band or two). Within each option are the choices of element and array designs. There was only a brief mention of the two-band option and no technical information was presented. There are, of course, additional sub-options to be considered. A useful tool might be a hierarchical options structure or decision tree. If the option tree is not clear soon, it may be very difficult to decide on a design for AAVS1.

For AA-mid, several array element designs are still in play, although one (Vivaldi) is receiving much more attention than the others. Does this mean that only one is actually viable?

Recommendation 3: Clarify a set of options now. Set up selection criteria and methods to objectively compare options. Establish a process to progressively reduce the number of options being considered. Specify and develop the AAVS demonstrators and engineering models to enable the key selecting performance and other parameters to be measured. Other parameters should include information on environmental protection, performance over temperature ranges, and other “non-functional” data. We emphasize that establishing a clear, appropriate and well justified set of

requirements at both the system and subsystem levels (recommendation 2 above) is a prerequisite, otherwise the process of reducing the number of options will lack essential guidance.

4.3 AA Project Streams

As noted above, the AA aspects of SKA1, SKA2 and the AIP program are quite different. They have different risk profiles, schedules and levels of technical maturity.

Recommendation 4: Separate the SKA1, SKA2 and AIP in the AA Element. This should be done from a specification, technology/design, documentation and project management perspective.

4.4 AA Management

The AAVP has been in an exploratory phase and is now transitioning into a design phase. Without active project management processes in place there is considerable risk that progress will stall while the new organisational structure is established. This is all the more challenging because the AAVP has a geographically separated team. For example, in the two slides on the management structure in the presentation on Strategy to Proceed to the Next Phase, it is not clear who is responsible for which aspects, even at the top level. There are boxes in the diagram on Program Structure for project managers, but these people did not play an active role in the review. What are the roles of all the project managers?

Recommendation 5: As a matter of urgency, build on the risk management, planning, scheduling, population of the organisational chart, allocation of tasks and responsibilities, progress monitoring, and document control that has already been started.

4.5 Demonstrators, Test Platforms, and Engineering Models

The AAVP project will be investing in several large engineering models for the AAs. The panel certainly understands the general need for physical testing of the AA stations, but had difficulty in ascertaining the engineering purposes or the results expected in these cases. At least an outline of a test plan should have been presented at this review.

The construction timing for AAVS1 does not appear to mesh with the overall plan, unless assumptions about the system requirements and the AA-low requirements are made. For example, a schedule was presented in the presentation on Strategy to Proceed to the Next Phase. This schedule shows an AAVS1 CDR (approval of AAVS1) in Dec. 2011. This is not only slightly before the System SRR, it is also well before the AA-low SRR (as shown in the same presentation). It is difficult to understand how a CDR can be carried out to build an engineering model before the requirements are known. However, if the assumptions are specifically documented for AAVS1, and a plan is made in advance for what AAVS1 is designed to accomplish, then the overall process appears more viable.

Recommendation 6: Review the schedule of key events, particularly with respect to the definition of large, expensive test-and-verification work.

As part of the planning of AAVS0, AAVS1 and subsequent test systems, it is essential to understand what is expected from them, how they will be tested, and how the results will influence the subsequent design.

Recommendation 7: Invest effort in developing a test and verification plan for the engineering models, including a plan to obtain or develop associated test equipment. This can be reused through the project and will establish confidence in the solution prior to its deployment on the final site. See also *Recommendation 3*.

4.6 Pathfinder and Precursor Projects

The panel observes that a very large amount of information is being generated in the pathfinder/precursor projects. The panel also understands that unfiltered information from other projects is difficult or impossible to assimilate. Getting information into a useable form can be done on the sending side or the receiving side, but either case requires considerable effort as well as a good understanding of what is relevant. Thus formal mechanisms, such as Memoranda of Understanding, for obtaining and filtering the relevant information are required.

The case for such a mechanism is particularly good for AA-low in the frequency range where the primary science goal is detecting and mapping the EoR signature.

Recommendation 8: The AA project (and possibly the overall project) should seek mutually beneficial, formal relationships with each of the pathfinders, so that SKA relevant information can be delivered to the SKA in the most efficient manner. Establish formal agreements where necessary and assign an appropriate level of effort.

4.7 Science Presentations at the Element Level Reviews

The panel views the role of a science presentation at these reviews as accomplishing two distinct goals: 1) putting the review into a science context, especially for reviewers who are not familiar with the science motivation for overall project; 2) highlighting the motivations for key selected requirements at the specific Element level and their traceability back to science. At this review, the first item was carried out very effectively, but the second item was not attempted.

Recommendation 9: In future reviews at this level use the science presentation to link technology under review to science, especially in the sense of motivating requirements and highlighting traceability.

4.8 Selected Technical Points

The following are selected technical points of major interest. By the SRR, the panel expects more technical content, while the need for procedural and management content will be reduced.

4.8.1 Analogue beam-forming

The panel considers analogue beam-forming as a technique with limited long-term future, although it may be much less expensive today. Carrying forward analogue beam forming for AA-low should be reviewed in this context. It will most likely limit SKA capabilities in the future (for SKA2). The optimum solution could be an explicit AA-low station design to permit convenient and cost-effective conversion from analogue to digital beam-forming.

Recommendation 10: Carry out a review of beam-forming with a view to “future-proofing” the SKA. If analogue beam-forming is continued, a mechanism for smoothly replacing it in the system with a digital version should be created.

4.8.2 Dual Band Option

The dual-band option has much to recommend it and should be on equal footing with the single-receptor option. This does not appear to be the case now. Among other things, the sparseness that

is forced on the station array at the high end of the single-receptor array is a serious scientific capability issue.

Recommendation 11: Ensure that the dual band option is thoroughly researched, and carried forward at least to the SRR stage. Its impact on the system design should also be considered. Some versions of this option may have a major impact on the system design.

4.8.3 Array Element Characteristics

The panel notes the considerable effort going into the array element design. This is well warranted, considering the impact of element performance in the overall performance of an array, especially operating in “sparse mode”. The panel urges continued effort in this area. There are two important aspects that are worth attention: 1) The performance of the element as an antenna is difficult to separate from the performance of the LNA, and the associated matching between them. This is particularly important at the high end of the band, where sky-noise does not dominate. 2) The gain of the element will reduce the available scan angle if it is too high. On the other hand it is also advantageous to increase the effective area by using higher gain antennas. These two effects must be carefully balanced, using the operational requirements as a guide (“How is the array going to be used? Will it be mostly used at transit? What is the maximum required Declination range?). Some of the potential element designs have quite high gain. Has the project analysed the impact on scan angle?

Recommendation 12: All final tests of proposed array elements should include an attached LNA. Test reports on antennas without an LNA must be considered preliminary.

Recommendation 13: A preliminary view on operational requirements for the AA-low array should be obtained from the system level, so as to inform the scan angle requirement and hence maximum design gain for the array elements.

5 Panel Responses to Questions in the Charge

The panel was asked to consider specific questions, which are listed in Appendix III. Where responses to some of the questions are already covered above, only a cross-reference will be given. In some cases additional recommendations have been spawned.

Shortened versions of the questions form the section sub-titles below.

5.1 Q1: Requirements Complete and Sufficiently Defined for this Stage?

Requirements are still at a preliminary stage. The science and system requirements from which the AA requirements are derived have significant parts to be finalised. See *Recommendation 2*.

AA-low constraints need to be accommodated at the system level. The feedback mechanism must be effective in achieving this. For example if the AA array configuration is well matched to the science at low frequencies, it may not be optimum for the science at higher frequencies, especially for the single wide-band option.

5.2 Q2: Is the Element Presented Capable of Meeting Requirements?

Several options were presented, although not well delineated. These should be sufficient to fulfill requirements as they currently exist. However, after requirements have firmed, this may no longer be true. Careful traceability linking will be needed to ensure that this does not occur.

Key decision criteria should be made explicit in the next phase (to the SRR). Especially emphasise engineering choices that have major impact on science cases/cost/power for the options considered (e.g. single/dual band, analogue/digital beam-forming, bit depth). See *Recommendation 3*.

5.3 Q3: Are Interfaces Adequately Identified?

This has been done only at the context level and top level system engineering. While it is likely adequate for now, it is an on-going task. It is particularly important to concentrate on key interfaces early, such as the analogue to digital interface.

5.4 Q4: Are Options to be Carried Forward Credible?

Options were not clearly identified in the review documentation. Where options could be identified, there was limited information available describing them. However, the presentations did provide additional information which was very helpful to the panel.

No criteria for selecting the options have been identified. A more careful analysis may even indicate that some options can already be eliminated. See *Recommendation 3*.

Building and testing engineering models is an important part of evaluating options. These should be specified to expose the performance characteristics which distinguish the options. See *Recommendation 7*.

5.5 Q5: Are there Gaps or Shortcomings?

Three specific potential gaps have been noted by the panel. These can be addressed in the next phase, but it would have been better to have started them as part of the concept phase.

1. Test & Verification plans for AAVSs.
2. Power consumption (e.g. no mention of this as a risk).
3. Planning for Industrialisation. Later in the project this will have to take into account such things as tolerances, margins and yields.

5.6 Q6: Is the Risk Profile Sufficiently Detailed?

An initial risk profile is provided, but it is still primitive. For example, only two technical risks are listed for AA-low. AA-mid risks should be in a separate document as noted above.

Risks should be extended in next phase to include subsystem technical risks so that they can be subsequently reduced during the execution of project.

5.7 Q7: Are Risk Controls and Mitigations Adequate?

There was no mention in the documentation of how risks would be controlled or on mitigation actions. However, there was a presentation on risks at the review, which did address some of these issues. The mitigation actions have at least started to be catalogued in the presentation.

Recommendation 14: Continue to develop the mitigation plan contained in the risk presentation. Much more follow-up attention should be paid to understanding, registering and mitigating risks.

5.8 Q8: Is the Overall Plan to Complete Subsequent Project Phases Credible?

The panel believes that it is possible, but challenging, to move into the next phase for AA-low. Improving some key areas, especially management, will be the greatest challenge. The panel recognises that the project is “funded” from a variety of sources, and that this creates incredibly difficult challenges. This is all the more reason to follow tried-and-true system engineering and project management practices.

The parallel activity of defining requirements and work on technology demonstrators creates tension. This also needs to be managed well, hence the recommendation to have separate streams for AA-low and AA-mid.

Appendices

Appendix I: AA CoDR Agenda

Session		Presenter	Starting Time	Time Allocated
	Tuesday, 19 April 2011			
	Panel members arrive at Schiphol			
	Lunch		12:00 – 13:00	1 hour
1	Review Panel (closed meeting)	Reviewers	13:00 – 13:30	30 minutes
	Welcome and General Overview of AA	AvA	13:30 -13:45	15 minutes
	Purpose and Context of the AA CoDR	KC	13:45 – 14:00	15 minutes
	AA Science Case	SR	14:00 – 14:30	30 minutes
	AA System Requirements	AG	14:30 – 15:00	30 minutes
	Coffee Break		15:00 – 15:30	30 minutes
2	Engineering: Technical AA Concepts	JGbdV	15:30 – 16:30	60 minutes
	High Level System Description	AF	16:30 – 17:15	45 minutes
	AA Risks and Risk Management	AvE	17:15 – 17:30	15 minutes
	Review Panel (closed meeting)	Reviewers	17:30 – 18:00	30 minutes
	Drinks and Dinner		19:00	
	Wednesday, 20 April 2011			
3	Deployment and Operations	AF	09:00 – 09:45	45 minutes
	Strategy to proceed to Next Phase	AF/ AvE	09:45 – 10:15	30 minutes
	Coffee Break		10:15 – 10:45	30 minutes
	Summary of AA for SKA	AvA	10:45 – 11:15	30 minutes
	Review Panel (closed meeting)	Reviewers	11:15 – 12:30	75 minutes
	Lunch		12:30 – 13:30	60 minutes
4	Initial feedback to AA Team	Reviewers	13:30 – 14:30	60 minutes
	Summary and closing of the review	AvA/KC	14:30 – 14:45	15 minutes

AvA Arnold van Ardenne
 AF Andy Faulkner
 AG André Gunst
 AvE André van Es
 JGbdV Jan Geralt bij de Vaate
 KC Kobus Cloete
 SR Steve Rawlings (unavailable): Ilse van Bommel as substitute.

Appendix II: Panel Members

Prof. Peter Dewdney (chair),
SKA International Project Engineer,
The University of Manchester,
Manchester, UK.

Dr. Colin Lonsdale,
Director, Haystack Observatory,
Massachusetts Institute of Technology,
Westford, Massachusetts, USA.

Dr. Raf Roovers,
Head of Integrated RF Solutions,
NXP Semiconductors,
Eindhoven, The Netherlands

Richard Williams,
Programme Manager, Products and Systems,
Cambridge Consultants,
Cambridge, UK.

Appendix III: Charge to the Panel

The CoDR will be conducted to evaluate:

- The overall system level technical progress,
- Whether the technical adequacy obtained during the concept phase, as defined in the relevant SKA documentation, is at a sufficient level of maturity to allow the system to move into the next phase,
- Whether all system aspects of the project have been covered and where gaps exist, whether adequate measures have been identified to address the shortcomings.

The expected outcome of the review is input to the establishment of the system concept baseline. Following the successful review, the next phase, the system definition phase, will be initiated.

The Review Panel is also requested to consider the following questions:

1. Are the requirements complete, and sufficiently defined for this stage of the project?
2. At the concept level, is the element/subsystem presented capable of meeting the requirements?
3. Has interfaces to other aspects of the system have adequately identified and defined at this stage of the program?
4. Are the options proposed to be carried forward credible and are the presented data and information in support of each option credible?
5. Have all the necessary aspects of the specific element/subsystem been considered and addressed during the review or are there gaps and/or shortcomings?
6. Does the risk profile appear reasonably detailed and assessed for this stage of the program?
7. Do the stated risk controls and proposed mitigations appear reasonable and executable?
8. Is the overall plan (including the identification of the tasks, effort, resources, costs, schedule and risk mitigation needed) to complete the subsequent project phases credible?

Appendix IV: Review Document Set

Review Documents for the SKA AA CoDR, April 19-20, 2011		
	Document Title	Document File Name
1	AA STRATEGY TO PROCEED TO THE NEXT PHASE	01-WP2-010.020.010-PLA-001-F-AANextPhase.pdf
2	AA CONCEPT DESCRIPTIONS	02-WP2-010.020.010-TD-001-E-AAConceptDescription.pdf
3	SKA AA SYSTEM REQUIREMENT SPECIFICATIONS	03-WP2-010.020.010-SRS-001-H_AA SysReq_1.pdf
4	AA DEPLOYMENT AND OPERATION	04-WP2-010.020.010-TR-001-F_AAImplementation.pdf
5	APERTURE ARRAY RISK REGISTER	05-WP2-010.020.010-RE-001-C-AARiskRegister.pdf
6	APERTURE ARRAY CONCEPT DESIGN REVIEW PLAN	06-WP2-010.020.010-PLA-002-E_AACodrReviewPlan.pdf