REPORT ON DELIVERABLE WP2.1.1
SYSTEM DELTA CONCEPT DESIGN REVIEW

Document number ................................................................. MGT-005.010.020-MR-002
Revision ........................................................................................................................... A
Author ................................................................................................................. K. Cloete
Date ................................................................................................................. 2011-03-15
Status ................................................................................................................... Released

DOCUMENT HISTORY

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<th>Engineering Change Number</th>
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<td>Submitted to PrepSKA Board Meeting scheduled for 29 March 2011</td>
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LIST OF ABREVIATIONS

CoDR.................................Concept Design Review
dCoDR..............................delta Concept Design Review
PrepSKA........................Preparatory Phase of the SKA
SKA.................................Square Kilometre Array
SPDO ...............................SKA Program Development Office
SSEC...............................SKA Science and Engineering Committee
WP.................................Work Package
1 Introduction

1.1 Purpose of the document

This document is submitted as fulfilment of the requirements for Milestone 7 (Deliverable 2.1) of PrepSKA Work Package 2 (WP2) following the successful completion of the System delta Concept Design Review (dCoDR).

1.2 Scope of the document

The document provides an overview of the System dCoDR process, outcomes and subsequent events and planning.

2 SKA System dCoDR

2.1 Overview and Context

The system level Concept Design Review (CoDR) was conducted during February 2010. The strategic aim presented during the review was to facilitate the narrowing down of options and technologies as the project moved forward from a very wide base. However, the CoDR Review Panel observed that this strategy was not well-supported by the budget and the schedule. The two main recommendations of the panel were that (1) the science goals needed to be prioritised and (2) that a ‘baseline’ SKA be defined with possible future ‘enhancements’.

As a result of the CoDR Review Panel recommendations there has been a review of SKA strategy in so far as;

1. The science goals for the SKA Phase 1 instrument (SKA1) were prioritised, and

2. A supporting set of baseline front end technologies, coupled with an Advanced Instrumentation Programme (AIP), were identified.

Due to these changes the Concept Baseline, as presented and reviewed during the February 2010 CoDR, had to be adapted. The original set of CoDR documents was reworked and presented for a fresh review during the recently concluded system delta CoDR (dCoDR).

The system dCoDR was conducted during the period 23 to 25 February 2011 at the University of Manchester. During this period members of the SKA Program Development Office (SPDO) presented the various aspects of the reworked system concept design to a four member review panel.

The review panel consisted out of a subset of the of the original CoDR Review Panel with four of the original five members of the panel participating in the dCoDR.

The review was also attended by various observers from across the SKA community.
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, and
4. The logistics behind the review.

The plan was reviewed with the chairman of the review panel and was updated as and when changes were encountered. The final revision of the plan was available well 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 dCoDR

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

- The overall system level technical progress,
- Whether the changes made to the project following the CoDR managed to bring more focus and feasibility to the project,
- Whether the technical adequacy obtained during the concept phase, as defined in the relevant SKA documentation, was at a sufficient level of maturity to allow the system to move into the next phase,
- Whether all system aspects of the project had been covered and where gaps exist, whether adequate measures had been identified to address the shortcomings.

The expected outcome of the review was input into the re-establishment of the system concept baseline by inclusion of the changes in the project philosophy and strategy.

More specifically the Review Panel was requested to consider the following questions:

1. Had the strategy adopted by the project following the February 2010 CoDR succeeded in addressing the previous imbalance in focus, scope, cost, risk and schedule?
2. At the concept level, was the Phase 1 system presented capable of meeting the prioritized science requirements for Phase 1?
3. Had sufficient evidence been presented for the Phase 1 candidate technologies to justify further resources being spent on further analysis and refinement, based on current knowledge of feasibility, cost and performance (i.e. meeting science requirements)?
4. Was the strategy adopted to realize Phase 1 while maintaining a view on Phase 2 credible and feasible?
5. Had all the necessary elements been considered or were there gaps and/or shortcomings?

6. Was there a sufficiently accurate estimate of risk at this stage of the project?

7. Were the planned decision-making processes sufficient and reasonable for carrying out the trade-offs needed to arrive at a final system design?

8. Was the plan for proceeding through the subsequent project phases credible?

9. Was the schedule for proceeding to the subsequent project phases credible?

10. Were resources sufficient to carry out work subsequent to the dCoDR, and commensurate with the planned schedule? (People, Budget).

2.4 Documentation

In support of the review twenty one (21) documents and thirteen (13) supporting documents were developed and distributed to the review panel before the review. The documents were developed under the leadership of the SPDO with inputs and contributions also received from other lead and participating institutes.

A list of the documents and the dates the documents were delivered to the review panel are shown in Appendix B.

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

Copies of the documents are available on the following sites:


Prior to the review several questions were received from the review panel members. These questions were recorded and answers were provided back to the panel before the review.

2.5 Review

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

During the review several presentations, based on the documentation, were made. The presentations aimed to represent the detail of the underlying documentation.

Copies of the agenda and presentations are available at:

http://www.skatelescope.org/indico/conferenceDisplay.py?confId=115
During the review the panel requested a change in the sequence of presentations on the Thursday. Sessions 4 and 5 of the original agenda were exchanged and more time was spent on reviewing the strategies going forward.

During Friday (25 February) the review panel spent the majority of the morning in a closed session discussing and drafting the panel report. In parallel the SPDO had a round table discussion with the observers on their views and perceptions of all the aspects of the review.

During the afternoon the panel provided their initial verbal feedback to the SPDO and the observers. The aspects mentioned during this debriefing session are all covered in the panel report and are therefore not repeated here.

2.6 Review Panel Findings and Report

2.6.1 Primary Finding

The finding from the panel was that the milestone was successfully passed.

2.6.2 Review Panel Report

The finalised report from the review panel was received on 4 March 2011. The report highlighted the following eight key findings (as extracted from the panel report):

1) There has been significant progress since the CoDR in February 2010 with the majority of that review’s recommendations having been addressed within the Project. The Panel congratulates the project for the achievement of this progress, both at the SPDO and in the contributing institutes.

2) The Panel welcomes the organization of SKA into the two phases (SKA1, SKA2), together with the creation of an Advanced Instrumentation Program (AIP). We believe this phasing has introduced more focus and has reduced the overall risks.

3) The Panel (continues to be) impressed by the preparations for the review and the degree and professionalism of the systems engineering.

4) The Panel was impressed by how the Project has been able to focus the science case and to decide on priorities within the Project, particularly when considering that this has been done without the need to involve an external advisory body. This is seen as an indicator of the strong support within the science community towards the success of the SKA.

5) The Panel recognizes the major effort that has been undertaken to produce the Project Execution Plan (PEP) which provides a clear path forward for the next 4 years of the Project.

6) The Panel recognizes that there has been progress on costing but feels that more will need to be achieved on cost reduction in order to meet the target figures for SKA1.

7) The Panel understands that major decisions lie ahead (e.g., SPO location and governance structure, site selection) and that these may result in changes to the PEP.
8) The improved focus in the Project together with the changes implemented over the past year gave the Panel the confidence that the Project is ready to move ahead into the Definition Phase.

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

2.7 Response to Review Panel Report

No major issues were identified in the report and as a result no response will be made.

3 Next Steps

The next system phase, the definition phase, has been initiated. This phase will culminate in the System Requirements Review to be conducted in March 2012.

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APPENDIX A

Review Plan
SKA SYSTEM DELTA CONCEPT DESIGN REVIEW PLAN

Document number: WP2-005.020.010-PLA-002
Revision: D
Author: K. Cloete
Date: 2011-02-07
Status: Released

Released as part of SKA System dCoDR documents:

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<td>K Cloete</td>
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### ORGANISATION DETAILS

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<tr>
<td>Physical/Postal Address</td>
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<tr>
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<td>The University of Manchester</td>
</tr>
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<td>Oxford Road</td>
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<td></td>
<td>Manchester, UK</td>
</tr>
<tr>
<td></td>
<td>M13 9PL</td>
</tr>
<tr>
<td>Fax.</td>
<td>+44 (0)161 275 4049</td>
</tr>
<tr>
<td>Website</td>
<td><a href="http://www.skatelescope.org">www.skatelescope.org</a></td>
</tr>
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</table>
DISTRIBUTION LIST

Review Panel
- Wolfgang Wild (chair)
  - ALMA, European Southern Observatory, Garching bei München, Germany
- John Webber
  - ALMA, National Radio Astronomy Observatory, Charlottesville, USA
- Robin Sharpe
  - External advisor, Ex Philips Semiconductors, Winchester, UK
- Lyndon Evans
  - Large Hadron Collider, CERN, Geneva, Switzerland

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

WP2 Management Team
Andrew Faulkner (AAVP), Athol Kemball (TDP), Carole Jackson (CSIRO), Gary Hovey (DRAO), Lynn Baker (TDP), Paul Alexander (UK), Steve Torchinsky (OBSPAR), Jan Geralt bij de Vaate (ASTRON)

Liaison Engineers
Anita Loots (NRF), Arpad Szomoru (JIVE), Chris Shenton (UMAN), Domingos Barbosa (IT), John Bunton (CSIRO), Kristian Zarb Adami (UOXF), Len Bruton (UCAL), Leonid Gurvits (JIVE), Michael Jones (UOXF), Peter Hall (ICRAR), Reinhard Keller (MPIfR), Rodolphe Weber (UORL), Stelio Montebugnoli (INAF), Thijs van der Hulst (RUG), Yashwant Gupta (NCRA-TIFR)

SSEC Chairman
M Garret (ASTRON)

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

CoDR ....................... Concept Design Review  
dCoDR ....................... delta 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 System delta Concept Design Review (dCoDR) for the Square Kilometre Array (SKA) project.

1.2 Scope of the document

This document will described 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 System dCoDR will be held on 23, 24 and 25 February 2011 at the University of Manchester, Manchester, UK.

2 Purpose and Expected Outcome of the System dCoDR

Following the system Concept Design Review (CoDR) in February 2010, the project reprioritised and refocused the science and engineering especially for the SKA Phase 1 instrument. Due to these changes the baseline as established during the CoDR will be updated and rebaselined during the system delta Concept Design Review (dCoDR).

The dCoDR will be conducted to evaluate:

- The overall system level technical progress,
- Whether the changes made to the project following the CoDR managed to bring more focus and feasibility to the project,
- 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 re-establishment of the system concept baseline by inclusion of the changes in the project philosophy and strategy. Following the successful review, the next phase, the system definition phase, will be initiated.

More specifically the Review Panel is requested to consider the following questions:

1. Has the strategy adopted by the project following the February 2010 CoDR succeeded in addressing the previous imbalance in focus, scope, cost, risk and schedule?
2. At the concept level, is the Phase 1 system presented capable of meeting the prioritized science requirements for Phase 1?
3. Has sufficient evidence been presented for the Phase 1 candidate technologies to justify further resources being spent on further analysis and refinement, based on current knowledge of feasibility, cost and performance (i.e. meeting science requirements)?
4. Is the strategy adopted to realize Phase 1 while maintaining a view on Phase 2 credible and feasible?
5. Have all the necessary elements been considered or are there gaps and/or shortcomings?
6. Is there a sufficiently accurate estimate of risk at this stage of the project?
7. Are the planned decision-making processes sufficient and reasonable for carrying out the trade-offs needed to arrive at a final system design?
8. Is the plan for proceeding through the subsequent project phases credible?
9. Is the schedule for proceeding to the subsequent project phases credible?
10. Are resources sufficient to carry out work subsequent to the dCoDR, and commensurate with the planned schedule? (People, Budget).

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: Staff members of the SPDO
- Observers: Any other attendee (see below)

The External Review Panel is composed of the following members:

- Wolfgang Wild (ALMA) (chairman) \texttt{wwild@eso.org}
- John Webber (NRAO) \texttt{jwebber@nrao.edu}
- Robin Sharpe \texttt{robin.sharpe@ntlworld.com}
- Lyndon Evans (Large Hadron Collider) \texttt{Lyn.Evans@cern.ch}

As Presenters, the following people have been identified:

- Richard Schilizzi (SPDO) \texttt{schilizzi@skatelescope.org}
- Peter Dewdney (SPDO) \texttt{dewdney@skatelescope.org}
- Joe Lazio (SPDO) (TBC) \texttt{lazio@skatelescope.org}
- Kobus Cloete (SPDO) \texttt{cloete@skatelescope.org}
- Tim Stevenson (SPDO) \texttt{stevenson@skatelescope.org}
- SPDO Domain Specialists

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 dCoDR documentation prior to the actual Design Review. Any questions, comments or queries sent to the SPDO Project Manager (K. Cloete) 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 SPDO will address these outstanding issues as soon as possible after the review.

3.3 Roles and Responsibilities

The SPDO shall
- Distribute the last of the documentation to the External Reviewers no later than 14 February 2011;
- 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;

The Observers are invited to
- Attend the review;
- Provide written feedback with regards to any of the aspect (including the documentation) of the review after the review.

4 Review Schedule

1. **Weeks up to 14 February 2011** – Produce documents, review, update and finalise documents during this period.
2. **14 Feb 2011** - Distribute last of the documents to external reviewers.
3. **23 Feb 2010** – Review panel members arrive in Manchester
4. **23 and 24 Feb 2010** – Conduct design review
5. **25 Feb 2010** – Review panel to draft report and provide initial feedback
6. **Week 29 Feb to 4 Mar** – Internal follow-up review, determine and action follow up items.
## 5 Documentation

The dCoDR Documentation Package consists of the following documents:

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<td>2</td>
<td>SKA Science Case</td>
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<td>3</td>
<td>SKA Design Reference Mission</td>
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<td>4</td>
<td>SKA1 Design Reference Mission</td>
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<td>5</td>
<td>The SKA Science And Support Operations Plan</td>
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<td>6</td>
<td>High-level System Description</td>
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<td>7</td>
<td>System Requirements Specification (SyRS)</td>
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<tr>
<td>8</td>
<td>SKA strategies and philosophies</td>
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<td>9</td>
<td>SKA Monitoring and Control Strategy</td>
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<td>10</td>
<td>SKA Costing Strategy</td>
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<tr>
<td>11</td>
<td>Risk Register</td>
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<td>12</td>
<td>System Engineering Management Plan (SEMP)</td>
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<td>Logistics Engineering Management Plan (LEMP)</td>
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<td>Risk Management Plan (RMP)</td>
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<td>15</td>
<td>PREPSKA Documentation Standards, Handling And Control</td>
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<td>Project Dictionary</td>
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<td>Strategy to Proceed to the Next Phase</td>
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<td>18</td>
<td>SKA Configurations Design</td>
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<td>The Radio Frequency Interference Environment at Candidate SKA Sites</td>
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<td>Tropospheric Characterisation of SKA Sites</td>
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<td>SKA System Delta Concept Design Review Plan</td>
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<td>22</td>
<td>SKA Science-Technology Trade-Off Process</td>
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<td>Observing Time Performance Factors in Carrying Out SKA Trade-Offs</td>
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<td>24</td>
<td>SKA Site Climate Data</td>
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<td>25</td>
<td>Cost Estimation for the SKA – A ‘How To’ Manual</td>
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<td>Project Execution Plan: Pre-Construction Phase for the Square Kilometre Array (SKA)</td>
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<td>27</td>
<td>PrepSKA FP7 Work Package 2 Project Plan</td>
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Please note this list is close to final. Only minor changes are expected.
## Agenda

Please note that all times are reflected in UT.

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<td>Lunch</td>
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<td>RTS</td>
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<td><strong>Science:</strong> SKA science case, SKA DRM, Memo 125 and Phase 1 DRM</td>
<td>PED</td>
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<td>Engineering: Overview of adopted strategy in view of the changes</td>
<td>PED</td>
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<td>Operations plan(s)</td>
<td>TBC</td>
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<td>17:15 – 17:45</td>
<td>30 minutes</td>
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<tr>
<td>3</td>
<td>High level system description (include presentation of technical risks)</td>
<td>PED</td>
<td>17:45 – 18:45</td>
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<tr>
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<td>Review panel (closed meeting)</td>
<td>Reviewers</td>
<td>18:45 – 19:15</td>
</tr>
<tr>
<td><strong>Thursday, 24 February 2010</strong></td>
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<td>Coffee break</td>
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<td>10:00 – 10:30</td>
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<td>4</td>
<td>Review panel (closed meeting)</td>
<td>Reviewers</td>
<td>10:30 – 11:00</td>
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<td>Trade-off process</td>
<td>PED</td>
<td>11:00 – 11:30</td>
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<tr>
<td></td>
<td>Phase 1 System Requirement Specification</td>
<td>TS</td>
<td>11:30 – 12:15</td>
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<td></td>
<td>Risks and risk management</td>
<td>KC</td>
<td>12:15 – 12:45</td>
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<tr>
<td>Lunch</td>
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<td>12:45 – 13:30</td>
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<td>5</td>
<td>Strategies and philosophies</td>
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<td></td>
<td>• Cost</td>
<td>RMC</td>
<td>13:30 – 14:00</td>
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<td>• Power</td>
<td>GHD</td>
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<td></td>
<td>• Environmental and geotechnical</td>
<td>TS</td>
<td>14:30 – 15:00</td>
</tr>
<tr>
<td></td>
<td>• Other</td>
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<td>15:00 – 15:15</td>
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<td><strong>Coffee break</strong></td>
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<td>15:15 – 15:45</td>
<td>30 minutes</td>
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<td>6</td>
<td>Management plans (SEMP, LEMP, RMP, others)</td>
<td>KC</td>
<td>15:45 – 16:15</td>
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<td>Review panel (closed meeting)</td>
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<td>Dinner (Christies Bistro)</td>
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<td>7</td>
<td>Review panel (closed meeting)</td>
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<tr>
<td></td>
<td>SPDO/Observer discussions (parallel session) (TBC)</td>
<td>KC Facilitate</td>
<td>10:30 – 13:00</td>
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</table>
### 7 Logistics

#### 7.1 Location

The SPDO office is located at:

Jodrell Bank Centre for Astrophysics (Room 3.136)  
Alan Turing Building (Building 46) (53°28'4.58"N 2°13'53.27"W)  
University of Manchester  
Manchester  
M13 9PL  
UK

The meeting room for the review is:

- Lovell Seminar Room, Room 3.225, Alan Turing Building (Building 46)  
  (53°28'4.58"N 2°13'53.27"W)

#### 7.2 Contact Persons

For support please contact any of the following SPDO representatives:

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Phone</th>
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<tbody>
<tr>
<td>Kobus Cloete</td>
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<td>+44 161 275 4081</td>
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<tr>
<td></td>
<td>Fax</td>
<td>+44 (0)161 275 4049</td>
</tr>
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</table>

### 8 Campus Map

Campus map attached on next page.  
For more maps of the campus please see [http://www.manchester.ac.uk/visitors/travel/maps/](http://www.manchester.ac.uk/visitors/travel/maps/).
APPENDIX B

List of Documents
# Delivery Status of System Delta CoDR Documents

All documents are available from the following url:


<table>
<thead>
<tr>
<th>Document Title</th>
<th>Document reference</th>
<th>Distribution Date</th>
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<tr>
<td></td>
<td>WP2-005.010.030-MR-001, Rev D, dated 2011-02-07</td>
<td></td>
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<tr>
<td></td>
<td><em>(File: 01-WP2-005.010.030-MR-001-D_coDRContext.pdf)</em></td>
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<tr>
<td><strong>2</strong> SKA Science Case</td>
<td>Please visit the following url.</td>
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</tr>
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<td></td>
<td>All the chapters of the Science Case are available on this page.</td>
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<tr>
<td></td>
<td>SKA-mid and SKA-lo”, report, v.1.0.</td>
<td></td>
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<tr>
<td></td>
<td><em>(File: 03-RSM-v1.0-Word.pdf)</em></td>
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<td>(Same document as for Feb 2010 CoDR, can be downloaded from url)</td>
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<tr>
<td></td>
<td>SKA Phase 1’, PHASE1-DRM-V1.3 (DRAFT), 2011-01-17.</td>
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<td><em>(File: 06-WP2-005.030.010-TD-002-A_HighLevelSysDescription.pdf)</em></td>
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<tr>
<td><strong>7</strong> SKA1 System Requirements Specification (SRS) (First draft)</td>
<td>T.J. Stevenson et al, ‘SKA Phase 1 System Requirements Specification’, document</td>
<td>2011-02-15</td>
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<td>WP2-005.030.000-SRS-002, Rev B, dated 2011-02-14.</td>
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(File: 17-WP2-005.010.030-PLA-002-B_NextPhase.pdf) | 2011-02-15 |

**WP3 Documents**

(File: 18-WP3-050.020.000-R-002-A_SKAConfigurations.pdf) | 2011-02-18 |
(File: 18-WP3-010.020.000-R-001-1.3_SitesRFIEnv.pdf) | 2011-02-11 |
(File: 20-WP3-040.020.000-R-001-2_TropoCharac.pdf) | 2011-02-11 |
(File: 21-WP2-005.020.010-PLA-002-C_dCoDRPlan.pdf) | 2011-02-03 |

**Supporting documents**

(File: 22-WP2-005.010.030-MP-004-1.2_ScienceEngTradeoff.pdf)  
(Same document as for Feb 2010 CoDR, can be downloaded from url) | 2011-02-09 |
(File: WP2-005.010.030-PR-001-B_ScienceEngTradeoff_OTPF.pdf) | 2011-02-09 |
| 24 SKA Site Climate Data | R.P. Millenaar, ‘SKA Site Climate Data’, Version: 0.2 (draft), dated 30-9-2008  
(File: 22-SKA_Site_Climate_Data_v2.pdf)  
(Same document as for Feb 2010 CoDR, can be downloaded from url) | 2011-02-09 |
(File: 25-MGT-040.070.000-MP-002-B_Shortformcosting.pdf) | 2011-02-09 |
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  *(File: 29-Memo130_Dewdney_SKA1 Preliminary System Description.pdf)* | 2011-02-09 |
| 30 | Technical Note: SKA lower frequency limit                                      | T.J. Stevenson et al, ‘Issues to be Considered in Moving the Lower Operating Limit of SKA from 70MHz to 50MHz’, document WP2-005.035.001-TN-001, Rev B, dated 2011-02-15  
  
  *(File: 30-WP2-005.035.001-TN-001-B_70to50MHzLowerLimit.pdf)* | 2011-02-16 |
| 31 | Use Case Template                                                              | T.J. Stevenson, ‘Use Case Template’, document WP2-005.045.000-UC-001, Rev A, dated 2011-02-15  
  
  *(File: 31-WP2-005.045.000-UC-001-A_UseCaseTemplate.pdf)* | 2011-02-16 |
| 32 | Previous questions and answers from panel                                      | *(File: 32-CoDR_COAR_RevD.pdf)*  
  
  *(Same document as for Feb 2010 CoDR, can be downloaded from url)* | 2011-02-09 |
  
  *(Same document as for Feb 2010 CoDR, can be downloaded from url)* | 2011-02-09 |
  
  *(Same document as for Feb 2010 CoDR, can be downloaded from url)* | 2011-02-09 |
APPENDIX C

Review Panel Report
SKA Delta System Concept Design Review

(dCoDR)

23rd to 25th February 2011

Report of the Review Panel

Wolfgang Wild (ESO-ALMA)
John Webber (NRAO-ALMA)
Robin Sharpe (Semiconductor Industry)
Lyndon Evans (Large Hadron Collider)
Summary

The key findings and recommendations of the Review Panel are summarized below:

1. There has been significant progress since the CoDR in February 2010 with the majority of that review’s recommendations having been addressed within the Project. The Panel congratulates the project for the achievement of this progress, both at the SPDO and in the contributing institutes.

2. The Panel welcomes the organization of SKA into the two phases (SKA1, SKA2), together with the creation of an Advanced Instrumentation Program (AIP). We believe this phasing has introduced more focus and has reduced the overall risks.

3. The Panel (continues to be) impressed by the preparations for the review and the degree and professionalism of the systems engineering.

4. The Panel was impressed by how the Project has been able to focus the science case and to decide on priorities within the Project, particularly when considering that this has been done without the need to involve an external advisory body. This is seen as an indicator of the strong support within the science community towards the success of the SKA.

5. The Panel recognizes the major effort that has been undertaken to produce the Project Execution Plan (PEP) which provides a clear path forward for the next 4 years of the Project.

6. The Panel recognizes that there has been progress on costing but feels that more will need to be achieved on cost reduction in order to meet the target figures for SKA1.

7. The Panel understands that major decisions lie ahead (e.g., SPO location and governance structure, site selection) and that these may result in changes to the PEP.

8. The improved focus in the Project together with the changes implemented over the past year gave the Panel the confidence that the Project is ready to move ahead into the Definition Phase.
Introduction

The SKA Delta System Concept Design Review (dCoDR) was convened by the Director of the SKA Program Development Office (SPDO) and was held from February 23rd to 25th, 2011, at the University of Manchester, Manchester, UK.

The Delta review was aimed at reviewing the progress since the original System Concept Design Review (CoDR) which took place in February, 2010, and specifically in respect of actions taken in the project subsequently to that review.

The dCoDR Panel consisted of four of the members of the original CoDR Panel, an external team with broad experience from the fields of Radio Astronomy, Particle Physics, large international project collaborations, and Consumer Electronics and Semiconductors. The Panel membership is given in Appendix 1, and the Panel’s charter in Appendix 2.

This report outlines the observations and recommendations made by the Panel which were fed back to the SKA Director, the SPDO and observers on February 25th, 2011. The feedback in this report concentrates predominantly on changes in the project over the past 12 month period and as such it should be read in conjunction with the earlier CoDR report.

The Panel was unanimous in their assessment of the Project together with the comments listed in this report.

Review Preparation

The panel was once again impressed by the thoroughness of the preparation for this review. The document set has been thoroughly revised and updated since the February 2010 CoDR to reflect changes in the plans following that review. Several new documents have also been created; notable among these is the Project Execution Plan which has clearly been a major effort by a larger group of authors and collaborators.

Appendix 3 lists the documentation provided together with a comparison to those of the previous review.

As before the preparatory information was felt to be at a high level of maturity when considering the early phase of the project and this further reinforced the confidence felt by the Panel in the SPDO-led effort.

The review Panel acknowledges and thanks the staff in the SPDO and the contributing organizations for the standard of preparation as well as for the open discussions and sharing of information.

Overall Impression

As with the 2010 System Concept Design Review the professionalism of the SKA system engineering was of a very high standard. There were no significant gaps that could be identified and the documentation had been further improved since last year, now amounting to around 1,000 pages.
As a minor observation, there are some areas of duplication in the documents which if they could be reduced will help future maintenance.

**Post CoDR Actions**

The major points of feedback at the original CoDR were that the Panel felt that the project as presented then was too ambitious for the planned timeline and budget, that the requirements were not sufficiently stable, and also that a (too large) number of technologies under consideration were not sufficiently proven for the envisaged timeline. Over the past year the Project has made significant changes to address these and other points.

The most significant changes have been: (1) reaching agreement across the science community on priorities for the initial deployment of the instrument; (2) adopting a phased approach towards deployment of the SKA; and (3) including a parallel path for the development of innovative technologies. These changes address many of the earlier issues by facilitating the construction of a phase 1 instrument (called SKA1) which still provides a significant step in science capability (e.g., ~100 times in survey speed, ~4 times in sensitivity of existing facilities) while being able to be built with more proven technology, and with breakpoints in the planning to allow new technologies to be adopted as they become sufficiently mature for incorporation into the full SKA. The overall ambition for the full SKA (called SKA2) has not been reduced but the introduction of the more focused initial phase means that the Project will be able to move forwards rather than being overwhelmed with too many initial requirements.

The Panel acknowledges these steps as significant progress. The Panel also congratulates the Project for the way in which it has been able to achieve agreement across the science community on the initial science goals, particularly when considering the large number of stakeholders and that this has been achieved without installing any kind of independent advisory bodies. The Panel sees this as an indicator of the strong support within the science community towards the success of the SKA which is an encouraging sign.

In summary, there has been a breakthrough in focusing the science goals since the CoDR. The Project has clearly seen the need to prioritize and has been able to converge on a preliminary set of science goals which has led to a much more realizable set of requirements for the initial deployment of the SKA.

Based on the foregoing the Panel agrees that **SKA1 is ready to move into the definition phase**.

**Project Execution Plan**

The Panel recognizes the major effort that has been undertaken to produce the Project Execution Plan (PEP) which has involved 18 people over a four month period. The PEP details the path forward for the next 4 years of the Project. The top down planning looks reasonable and well thought out in terms of the technical and budgetary detail. It should be noted that the project faces a major transition from the current SPDO (SKA Program Development Office) located in Manchester to a new legal entity, the SPO (SKA Project Office) with a yet to be decided location and governance structure.
Some system milestones and decision points appear quite early in the schedule when considering the critical relationship between the sub-system performance and that of the overall system. For example, the SRR (finalized requirements) for Software and Computing is almost two years after the SRR for the whole SKA1, yet it is already anticipated that the computing requirements will be very challenging to meet so it could be expected that this may lead to some changes to the overall system. Hence, the overall system SRR appears quite early in this respect.

The PEP could be further improved by detailing specific hardware and software deliverables associated with the work packages. All the deliverables itemized in the PEP are reports and yet it could be expected that some quantity of prototype sub-systems could be a required deliverable to facilitate the further downstream work packages. These more tangible deliverables can then form the basis of MOUs etc with the work package suppliers.

The Panel also understands that major decisions lie ahead in the near term (e.g., SPO location and governance structure, site selection) and that these may result in necessary changes to the PEP.

**Detailed Project Planning**

At this stage the PEP describes the necessary work packages and quantification of the resource requirements. However, in the view of the Panel in order to successfully manage the project through to the end of the Pre-Construction Phase it will also be necessary to prepare a more detailed project and resource plan. This plan should detail the tasks, resources (by name ideally) and costs, intermediate milestones and deliverables and the interdependencies for completing the detailed design work, prototyping, etc. This plan should be centrally managed and available to all the main contributors in the Project as a means to check progress and communicate changes. This plan should probably have a weekly resolution and be updated with the same frequency to properly track progress and manage changes.

The Panel further recommend that the project status be maintained in formal schedule format, using planning software such as Microsoft Project or a more advanced application, for ease of visibility and compatibility with work package planning documentation. It may be useful to add a professional scheduler to the central management team to coordinate this process.

**Technology**

**Sensor Technologies**

The adoption of a baseline set of receptor technologies coupled with the concurrent development of the less mature technologies significantly de-risks the first phase of the project. This approach also facilitates the later incorporation of newer technologies into the second phase of the project assuming they are able to demonstrate the necessary performance and maturity.

**Signal Processing**

A much greater understanding of requirements appears to exists now. These requirements are understood to be well within the capabilities of current ASIC technology. Several solutions appear available from which to select, so this area seems in good shape.
Computing

Even for SKA1 High Power Computing (HPC) solutions are needed that are beyond the current state of the art in terms of performance. These aspects of the system appear less well quantified than other parts of the system. HPC appears very high risk for SKA2 based on current technology trends. If the required performance cannot be reached then the data analysis will have to be more selective. The SPDO experts say there are ways of working with less powerful computing which would not fundamentally compromise the science that can be done.

Power

There is good confidence since the last review that the requirements for power can be met technically. However, distribution of power to remote stations may be a (cost) issue. The question translates more into one of construction and operations cost and is also an issue for SKA1 when taking the HPC power requirements into account (currently estimated at 30 MW). For SKA2 the overall power estimate is 74 MW for the array and 40 MW for HPC.

Costing and Resources

The cost models which have been presented appear well developed and the major costs drivers are well understood. Some contingency planning is also included in the overall cost. However, large uncertainties still exist in some areas e.g. computing and infrastructure. Limited information was presented on detailed costs but it is clear to the Panel that building SKA1 within the forecast 350M Euro will be very challenging and that more work will be needed on cost reduction. Whether cost reductions alone will be sufficient or if further adjustments to scope, timeframe and/or science goals are required is unclear at this stage.

As mentioned in the earlier review, closure on a construction plan will require that cost reduction options are pursued vigorously so that all stakeholders are convinced that the final construction plan represents the best science value for the money.

In summary, the Panel recognizes that there has been progress on costing but feels that more effort needs to be made in the design phase in order to reduce cost.

Systems Engineering

As observed at the CoDR there is a first class set of engineering processes in place. There is good evidence that the processes are adopted and starting to run. SPDO has added some more staff over the recent months and clear progress has been demonstrated since the CoDR.

Risk Management

Good progress has been made in compiling a risk register which identifies the major risk elements for both phases of the project. Most of these risks have been quantified and potential mitigation actions have been identified in many cases. This is considered to be well on track for this phase of the project. The key risks should all be assigned a clear owner. As the project moves into the next phase each risk should be assigned a probability weighted cost.
The panel believes the major existing risks are in the areas of High Power Computing (HPC), the cost of power, component reliability and continuing to attract and retain the necessary highly skilled staff to run the Project. The Project itself has recognized these but it may prove to be very challenging to retire these risks.

**SKA1 to SKA2 extension**

The major challenges in scaling to the full SKA (SKA2) appear to be linked to provision of power and HPC computing as well as the large number of components required, all of which will be very demanding. Due to the phasing of the plan these don’t need to be resolved until later in the program which gives more time for further technology advances and innovations to be utilised. However, given the scale of the challenge there may be a need to reconsider the scope and/or timelines for the full SKA at a future point. The current plans do incorporate a further concept review prior to the start of the SKA2 phase which gives an opportunity for the lessons learnt from SKA1 to be absorbed into a revised system concept.

**Project structure**

**Management Structure/Governance**

Although this is not a critical point for the dCoDR milestone, the Panel have made the observation that in their experience a strong central management and technical team will be required to lead and coordinate the various contributions to SKA. Several schemes can be envisaged to achieve this including, for instance, central management of funds. Another approach would be to use “Value” contributions funded by different parties.

The Panel felt that there is a chance that management costs may exceed current estimates due to the complexity and distributed (world wide) nature of the Project.

**Legal Entity**

The experience of Panel members is that early attention needs to be given to the structure of the legal entity and that a single country structure may not suffice. This is because there will be a need to attract and employ international staff who may have differing needs in terms of conditions of employment such as contract terms and visas.

Legal issues of import and export will also be a factor to be managed.

**Contracts and MOUs**

In line with our comments from the CoDR report, the Panel is of the opinion that setting up the framework for institutional accountability will be an important step in solidifying the plans. We recommend establishing MOU’s or supplier contracts with high-level authorities such as Institute Directors, Division Heads, or Department Chairs as early as possible.

**SPDO to SPO transition**

The SKA Program Development Office (SPDO) is currently located at the University of Manchester in the UK. The SPDO has been growing a critical mass of capability over the past few years and has
been successful in setting up the necessary systems engineering framework and domain expertise necessary to bring the Project to its current status as well to create the planning to go forward into the Pre-Construction Phase. It has clearly taken some time to build up the now strong team in SPDO.

As the project moves beyond 2012 a new central organization, the SPO (SKA Project Office) is planned to take over the leadership role. As the Project transitions to the new organization of the SPO careful attention needs to be given to retention of key staff and/or know-how as well as continuity of the program through the transition. Without the participation of those already experienced with SKA, it is difficult to see how the project could be successfully carried through.

**Industry engagement**

An active program of industrial engagement has been started and an international “Informal Industry Group” has been established. Contacts are being developed with for example ASIC vendors, software suppliers, solar power providers and dish manufacturers. These contacts will help the Project with firming up detailed requirements for sub-systems and building up realistic cost estimates.
**Answers to detailed questions**

The Panel was asked to evaluate the overall progress in the project against four areas. These are listed below together with the Panel’s observations.

- **The overall system level technical progress,**

  The Panel recognizes that good progress has been achieved with the system level technical definition and that the adoption of the baseline science goals (DRM1) and introduction of the SKA1, SKA2 and AIP planning phases has been an important step forwards. The adoption of the proven technologies of dipole arrays and single-pixel-feed dishes for SKA1 makes schedule and cost estimation a manageable task, as it sharply defines the requirements for infrastructure, electronics, and software.

- **Whether the changes made to the project following the CoDR managed to bring more focus and feasibility to the project,**

  Referring to the answer above the Panel observes that there is definitely more focus since the CoDR due to the focused science case for SKA1, and phasing of project. The feasibility appears to be increased due to the way that the phasing allows the handling of risks. However, some details are difficult to assess due to the uncertainties in costing. The Panel believes this will improve as design studies continue. The balance between SKA1 construction and the AIP investment aimed at SKA2 must be carefully weighed.

- **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,**

  Based on the information presented and the evident progress of the past 12 months, the Panel is confident that the project is ready to move into the definition 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,**

  No gaps could be identified other than the ones mentioned in the SKA CoDR. These have been recognized and being dealt with.

**Detailed questions**

In forming its view of the status of the project, the Review Panel was specifically requested to consider the 10 questions which are reproduced below. Each question is followed by a summary of the Panel’s comments or observations.

1. **Has the strategy adopted by the project following the February 2010 CoDR succeeded in addressing the previous imbalance in focus, scope, cost, risk and schedule?**

   The new strategy has succeeded in addressing the previous imbalance. The panel very much welcomes the phasing with associated science goals and the AIP. The phasing into SKA1, SKA2 (and possibly SKA3) allows the project to move forwards with the planning, design and construction of SKA1 while still enabling the longer range goal of SKA2. The extension from SKA1 to SKA2 seems well thought out with corresponding decision points. However, cost and schedule will need further attention and may have to be readjusted as the project moves forward.
2 At the concept level, is the Phase 1 system presented capable of meeting the prioritized science requirements for Phase 1?

Yes, the Phase 1 system does appear capable of meeting the prioritized science requirements for SKA1. In the panel’s view, the largest challenge lies in the being able to realize SKA1 within the envisaged cost frame of 350M EUR. The project seems to have a good framework for doing the detailed costing and adapting the scope to the available funding if necessary. Successfully developing the means of building SKA1 at the envisaged performance level while keeping the cost within the overall budget so that the system can be well defined by the end of 2012 (the end of the Preparatory Phase) seems very ambitious.

3 Has sufficient evidence been presented for the Phase 1 candidate technologies to justify further resources being spent on further analysis and refinement, based on current knowledge of feasibility, cost and performance (i.e. meeting science requirements)?

Yes. Candidate technologies for Phase 1 should be further pursued.

4 Is the strategy adopted to realize Phase 1 while maintaining a view on Phase 2 credible and feasible?

Yes, we regard the strategy as credible and reasonable. However, details of Phase 2 may have to be refined once SKA1 is in construction and the results of the AIP become available.

5 Have all the necessary elements been considered or are there gaps and/or shortcomings?

The panel could not see any further gaps or shortcomings.

6 Is there a sufficiently accurate estimate of risk at this stage of the project?

There is a methodology in place for the assessment and quantification of the level of risk. There is now a good risk register covering the fundamental points evident at this point in the project’s lifecycle. However, as the project moves forward the list can be expected to expand, and the panel recommends assigning each risk to an individual owner to ensure that risks are kept in focus and well managed. Tracking the associated probability weighted costs per risk in the register is also recommended.

7 Are the planned decision-making processes sufficient and reasonable for carrying out the trade-offs needed to arrive at a final system design?

The Panel regards the systems engineering approach as high quality and, providing the various contributing parties follow the processes as defined there should be no problems.

The Panel’s proposals to set up more focused “Boards” to steer the project was not taken up last year. Never-the-less the Project has been able to take key and timely decisions as can be seen by the progress of the past year. The Panel still feels that larger decision making structures are less desirable when is comes to making timely decisions and recommends keeping an open eye on this point as the Project moves into more mature phases.

As mentioned last year, a clear and transparent process for capturing, communicating, and enforcing decisions is a requirement in large projects.

8 Is the plan for proceeding through the subsequent project phases credible?
The planning for SKA1 seems credible and detailed (whilst noting the other comments in this report). The timing for SKA2 seems rather ambitious given the global funding situation and current priorities for large science projects.

As mentioned last year all deliverables are currently defined as documents. The Panel believes that the outputs of such a program should also be defined in terms of software and hardware deliverables, e.g. detector prototypes with demonstrated performance, reliability, cost etc., rather than reports alone.

9 Is the schedule for proceeding to the subsequent project phases credible?

The near term planning appears credible. The phases further in the future obviously have more attached risks. It appears to the Panel that the schedule for the later phases is rather optimistic.

10 Are resources sufficient to carry out work subsequent to the dCoDR, and commensurate with the planned schedule? (People, Budget).

The resources in the project appear to be continuing to ramp up. Based on experience elsewhere the current central staffing seems on the low side. For the next phase it is essential to secure sufficient staff as proposed in the PEP. The specifics of the budget are difficult to judge for the Panel.

Software milestones still appear to lag within the overall planning. As mentioned last year, given the size of the software challenge (10-30% of total effort), starting earlier than currently planned is advisable.

As mentioned elsewhere cost estimating has made progress over the past year. However, producing a detailed cost plan that can meet the budget target is still required.
Appendix 1 – Panel Membership

Wolfgang Wild (chair)
ALMA
European Southern Observatory
Garching bei München, Germany

John Webber
ALMA
National Radio Astronomy Observatory
Charlottesville, USA

Robin Sharpe
External advisor
Ex Philips Semiconductors
Winchester, UK

Lyndon Evans
Large Hadron Collider
CERN
Geneva, Switzerland
Appendix 2 – Panel Charter

The dCoDR will be conducted to evaluate:

- The overall system level technical progress,
- Whether the changes made to the project following the CoDR managed to bring more focus and feasibility to the project,
- 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 re-establishment of the system concept baseline by inclusion of the changes in the project philosophy and strategy. Following the successful review, the next phase, the system definition phase, will be initiated.

More specifically the Review Panel is requested to consider the following questions:

1. Has the strategy adopted by the project following the February 2010 CoDR succeeded in addressing the previous imbalance in focus, scope, cost, risk and schedule?
2. At the concept level, is the Phase 1 system presented capable of meeting the prioritized science requirements for Phase 1?
3. Has sufficient evidence been presented for the Phase 1 candidate technologies to justify further resources being spent on further analysis and refinement, based on current knowledge of feasibility, cost and performance (i.e. meeting science requirements)?
4. Is the strategy adopted to realize Phase 1 while maintaining a view on Phase 2 credible and feasible?
5. Have all the necessary elements been considered or are there gaps and/or shortcomings?
6. Is there a sufficiently accurate estimate of risk at this stage of the project?
7. Are the planned decision-making processes sufficient and reasonable for carrying out the trade-offs needed to arrive at a final system design?
8. Is the plan for proceeding through the subsequent project phases credible?
9. Is the schedule for proceeding to the subsequent project phases credible?
10. Are resources sufficient to carry out work subsequent to the dCoDR, and commensurate with the planned schedule? (People, Budget).
Appendix 3 – Review Documentation

The dCoDR Documentation Package consisted of the documents listed below. The original CoDR document numbers are shown for reference.

<table>
<thead>
<tr>
<th>CoDR Doc no</th>
<th>dCoDR Doc no</th>
<th>Document Title</th>
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Appendix C to Document MGT-005.010.020-MR-002
Appendix 4 – Key Recommendations of 2010 CoDR Panel

Science Goals

1. The Panel recommends prioritizing the science goals in order to enable the project to move forward with a system concept definition. Also, a simplified SKA mission statement emphasizing a few top-level science goals will help the communication process with funding agencies, the public and other parties.

2. In order to enable the necessary prioritization, the Panel recommends that a suitably empowered and trusted independent Science Advisory Body should be established as soon as possible.

3. It is the Panel’s impression that, in SKA, engineering and development goals and interests have been weighted at least equally with science goals. The Panel recommends changing this situation and making sure that the SKA be a primarily science driven project.

Technology

4. The Panel recommends defining a baseline SKA project - based on a few top level science goals resulting from the prioritization process mentioned above - which enables those goals, accommodates a mix of low risk and high risk technology, and is feasible within the schedule and cost constraints.

5. At the same time, and in view of more ambitious long-term goals, a roadmap should be planned for the introduction of innovative (higher risk) technologies which will become available at a later stage.

6. The Panel recommends that a Technology Advisory Body be established to assist in reaching the appropriate technology choices versus time in the process outline above.

7. The Panel believes that - in order to enable forward planning - the output of the R&D program should be generally defined more in terms of software and hardware deliverables, e.g. detector prototypes with demonstrated performance, reliability, cost etc., rather than reports alone.

Project Definition Phase

8. The Panel recommends defining realistic expectations for deliverables, performance parameters, schedule, cost, contingency, etc during the project definition phase.

9. The project should not underestimate or understate the cost.

10. The SPDO should prepare a list of key planning assumptions that can serve as a reference for the development of cost and schedule estimates during the project definition phase.

Decision making

11. Take important decisions on science and technology soon. Define very well the process for making choices and make it very visible throughout the project.

12. Entrust decision making to smaller groups wherever possible.

13. Decisions on both science and technology need to be informed by independent advisory bodies, e.g. a Science Advisory Committee and a Technology Advisory Committee.

Costing and Resources

14. Stabilising requirements and producing a credible costing are quite urgent at this stage of the project.
15. SKA should ensure that the SKA R&D, design work, and alternatives analysis during the project definition phase is driven by achieving cost reduction and satisfying the target total cost goals as well as the science goals.

16. The Project Director should prepare a resource plan for completing the R&D and conceptual design work needed to produce a high quality set of requirements and conceptual design report. The resource plan needs to be adequate to establish a credible construction plan for SKA including the total construction cost and sufficient information on operating costs to inform the funding agencies of the long-term commitments needed to meet the science goals.

Schedule

17. The schedule for the next two years, including the preparation of a Conceptual Design Report, should include a couple of dozen milestones with clear definitions of what it means to satisfy the milestone and the exact dates that the milestones are expected to be complete.

18. The Panel recommends not to underestimate the effort it will take to get from a working prototype to industrial large scale production based on the Panel’s experience with smaller quantities for ALMA and the LHC, and large quantities in industrial production. The planned time for achieving this step, currently two years for “Detailed Design, Production Engineering and Tooling” is too short in the Panel’s assessment.

Project structure

19. Start setting up the framework for institutional accountability now, e.g., MOU’s with high-level authorities such as Institute Directors, Division Heads, or Department Chairs.

20. The SSEC should further empower the SPDO to carry out the SKA central management, integration, and project administration functions.