Response to the Panel Report

on the

SKA System Concept Design Review

SKA Program Development Office, 24 May 2010

Summary

The Panel's report has had a profound effect on the international SKA Project.

The SKA Science and Engineering Committee (SSEC) has considered the Panel's main conclusion that the combination of scope, timeline and cost of the project is in general over-ambitious and in several areas unrealistic, and its recommendation that the science goals be prioritized to allow the definition of a baseline design, and has taken action. It has appointed a sub-committee to define the science goals and a concept technical baseline for Phase 1 of the project with the aim of stabilizing the requirements on the design as soon as possible. Also in the process of definition is the timeline and process by which enhancements to the baseline design can be incorporated in Phase 2, potentially enabling wider science goals. It is now envisaged that the decision on the mix of receptor technologies in Phase 2 will take place in 2016.

The Panel's conclusion that two years is too short a time for the detailed design, production engineering and tooling phase, has also been acted upon by the SSEC, and an additional year has been incorporated in the schedule. Roll-out of Phase 1 construction is now planned to commence in 2016.

The impact of these decisions on the conduct of the system design for the SKA and the development of the system architecture, as well as the key dates in that process, is currently being analysed by the SPDO and the partner institutes.

The Panel commended the SPDO on its preparations for the review and the degree and professionalism of the SKA systems engineering, but recommended that the SSEC should further empower the SPDO in its central role. In particular, the Panel emphasised that the project structure should be strengthened with institutional accountability formally in place. In response, the SSEC approved the establishment of a WP2 Management Team for the system design work, led by the SPDO Project Manager and including the SPDO Project Engineer and the responsible people at the six Lead Institutes around the world.

1. Introduction

In its report, the CoDR panel summarized its findings and recommendations in a series of 20 points and went into further detail in separate sections on Review Preparation, Overall Impression, Science Goals, Technology, Project Definition Phase, Decision Making, Costing and Resources, Schedule, Site Selection, Project Structure, and Answers to Detailed Questions posed by the SPDO. In the following, we respond to the points made by the Panel.

2. Response to specific points in the Panel Report

2.1 Review Preparation and Overall Impression

1. The Panel was impressed by the preparations for the review and the degree and professionalism of the SKA systems engineering. The Panel appreciates the rapid response to questions submitted shortly before the review. The documentation provided was of a high standard and covered all relevant aspects. This gave a lot of confidence in the SPDO led effort.

2. The SKA team seemed to have recognized about 95% of the problems (but recognizing a problem does not mean it is solved or that it is solvable). The Panel could only identify two possible gaps: security of hardware at remote sites, and export controls.

The SPDO and colleagues around the world put substantial effort into the document set in the knowledge that a formal systems engineering approach is essential for a project of this size and technical and organizational complexity. It is important that the Panel has clearly stated its support for this approach, and has noted (p.8) that "The early introduction of systems engineering as has occurred should be extremely beneficial."

The gaps in the system engineering analysis identified by the Panel concerning security of hardware at the remote sites, and possible export controls on high technology items have been noted by the SPDO and will be rectified.

3. SKA in its present setup tries to push technology limits on pretty much <u>all</u> fronts. Some parameters are pushed orders of magnitude beyond state-of-the-art. Even things that traditionally have been minor problems are now an issue (e.g., power, computing, signal transport & processing, …). Given current time and cost constraints the Panel felt that the combination of scope, timeline, and cost was in general overambitious and in several areas unrealistic.

4. Given current timeframe and assumed funding constraints, the science covers too large a parameter space and includes requirements which imply differing optimal design decisions, e.g. optimizing hardware for survey vs. Single object observations. This hinders further progress in the SKA definition and converging on a conceptual design. It is an important decision for the project to either keep to the proposed timeline and adjust the scope accordingly, or keep the ambitious scope and adjust the timeline (and budget) accordingly.

5. The system engineering team did a great job in trying to satisfy the wide range of science requirements. However, the Panel did not see stable requirements which would allow a stable design for SKA. At this stage, the panel expected a higher degree of refinement regarding the SKA concept.

6. SKA is ready to move into the definition phase. This transition is essential to support the proposed timeline for a construction start (with a redefined scope), to arrive at an SKA concept, and to ensure that additional resources are focused on activities that truly support the SKA schedule.

The Panel's conclusion that the combination of scope, timeline, and cost was in general overambitious and in several areas unrealistic, has been considered by the SSEC. Their resolution of this problem has been to reduce the scope of the SKA in terms of its science for the first phase and define the baseline technology (see next section).The SSEC also extended the timeline for the overall project, while holding to the capital cost target of 1.5 B€ (2007). As summarized in the next section, a sub-set of the SKA science goals have been selected for Phase 1 by the SSEC in order to drive the concept technical baseline in the first phase of development. This will provide a focussed mission statement and enable the project to converge on a realizable and stable set of requirements for the design in the short term.

With the additional resources allocated by the project partners, and the formal global project management structure described in section 2.6, this is expected to result in a stable design at the end of 2011 ready for costing by the end of 2012, as planned.

2.2 Science Goals, Technology, and Decision-making

7. The project needs to take important decisions on science and technology soon. It is recommended to define very well the process for making choices and make it very visible throughout the project. Entrust decision making to smaller groups wherever possible.

8. The Panel recommends prioritizing the science goals as soon as possible in order to enable the project to move forward with a system concept definition. This is a necessary condition to allow the definition of a SKA baseline design whose implementation would be feasible on the chosen timeline.

9. 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. Ideally this Science Advisory Body would consist of science authorities in astronomy who are independent of technology driven programs for SKA.

10. 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.

11. The Panel recommends a two stage approach by defining a "baseline" SKA project and future "enhancements". The baseline SKA would be based on achieving a few top level science goals resulting from the science prioritization process. It would accommodate a mix of low risk and high risk technology and be feasible within the schedule and cost constraints. 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 and enable wider science goals ("enhancements").

12. 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. The TAB should consist of neutral experts who can assist the project to make initial technology

selections and in the process of road mapping for the introduction of innovative technologies into later stages of deployment.

At its recent meeting in Manchester, the SSEC acted upon these conclusions and recommendations. Reacting to the Panel's observation on the risks in simultaneously pushing the limits in many key technologies for the SKA, it decided to define as quickly as possible the science goals and baseline technology for Phase 1 in order to bring focus to the project.

The SSEC also decided to follow the Panel's recommendation of a two stage technology development program including the baseline (Stage 1) and innovative technologies that need more time to prove their technical maturity and cost feasibility before committing to construction (Stage 2). From the SSEC's point of view, SKA Phase 1 technology will be the Panel's Stage 1 and will continue through into Phase 2, while the Panel's Stage 2 enhanced technology <u>may</u> be a significant fraction of SKA Phase 2 but this is dependent on the outcomes of the current R&D programs.

<u>Science goals</u>

The SSEC did not follow the Panel's recommendation to establish a Science Advisory Board at this time because it decided it was itself competent to carry out the science prioritization on a much shorter timescale. A sub-committee was appointed from among its members and the SPDO Director to make a proposal for the science goals for Phase 1.

The Phase 1 science goals identified by the sub-committee and approved by the SSEC at a recent telecon are a sub-set of the Phase 2 goals. They are as follows:

(i) Understanding the history and role of neutral Hydrogen in the Universe from the dark ages to the present-day, and

(ii) Detecting and timing binary pulsars and spin-stable millisecond pulsars in order to test theories of gravity (including General Relativity and quantum gravity), to discover gravitational waves from cosmological sources, and to determine the equation of state of nuclear matter.

These science goals will remain prime in Phase 2 as well, but will be augmented in the event that any of the enhancement technologies are adopted in Phase 2.

<u>Technology</u>

The SSEC recognised that indeed the engineering and development interests had assumed their own lives within the project, and agreed to simplify the SKA mission statement to return the project to being primarily science-driven.

The SSEC did not follow the Panel's second recommendation to establish a Technical Advisory Board, again because it decided it was itself competent to define the technical baseline SKA project in such a way as to enable the focussed science goals. The existing

International Engineering Advisory Committee will comment on the technology choices at its meeting in June this year.

The baseline design concept for Phase 1 (SKA_1) to enable the science goals above includes the following two elements, both of which are extensions of well-proven technologies:

i) a low-frequency sparse aperture array operating at frequencies between 70 and 450 MHz. The array will be centrally condensed but some of the collecting area will be in stations located out to a maximum baseline length of 100 km from the core, and

ii) a dish array employing a “first-light” instrumentation package that will use single-pixel feeds to provide high sensitivity and excellent polarization characteristics over a frequency range of 0.45-3 GHz. The array will be centrally condensed but some of the collecting area will be co-located with the sparse aperture array stations out to a maximum baseline length of 100 km from the core.

The dish design will be SKA_2 (SKA Phase-2) enabled in terms of its overall performance specification.

<u>Phase 1 → Phase 2</u>

The SSEC sub-committee also conducted a top-level analysis of the steps from the SKA_1 concept design towards the realisation of SKA_2. The need to develop and assess new innovative technologies that will substantially enhance the baseline technical specification of SKA_2 is embedded within SKA_1 via a “second-generation” instrumentation programme.

Examples of possible second generation instrumentation include: (i) the deployment of Phased-Array Feeds (PAFs) at the focus of the SKA_1 dishes, (ii) the deployment of a large Dense Aperture Array (DAA) operating at frequencies < 1.7 GHz, (iii) placing high-frequency feeds on the dishes, and (iv) enhancements of the back-end digital processing hardware.

Given the investment and associated progress expected to be made in all of these areas over the next 5 years, the SSEC now plans a decision on second-generation instrumentation in 2016, at the start of the initial SKA_1 construction phase. This will follow the science-technology-cost trade-off process outlined in the CoDR documentation and set the requirements for the final design for SKA_2. The impact of these decisions on the conduct of the system design for the SKA and the development of the system architecture, as well as the key dates in that process, is currently being analysed by the SPDO and the partner institutes.

The key aspect to be defined for SKA_2 is the proportions of dishes, dense aperture arrays and sparse aperture arrays in the final system. The receptor specifications for SKA_1 will be developed as result of analysing requirements for SKA_2, taking into account a plausible range of top-level system parameters, aligned with the relevant components of the Design Reference Mission (DRM). During the Phase 1 design process, components of receptors used in SKA_1 that are difficult or impossible to change will be designed and reviewed against the requirements of the full SKA (SKA_2 compliant). In other parts of the system there will be an analysis of the requirements of SKA_1 vs SKA_2 which may result in some parts of the system being replaced in the SKA_2 system. Other aspects of the SKA_1 system, such as delivery of power, will require a cost-based analysis as to whether extensibility to SKA_2 is feasible.

2.3 Project Definition Phase and Schedule

13. 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.

The contracted deliverables to the European Commission are reports referencing the system and sub-system Design Review reports and the input documentation. As far as hardware is concerned these reports will be based on prototypes and measurements of their performance etc. Substantial well-funded Verification Programs are underway for dishes, aperture arrays and phased array feeds and these will produce, or are already producing, prototypes. For software, reports on software engineering and the SKA software architecture as well as developments in the precursor and pathfinder projects and their scalability to the SKA, are planned over the next three years. The Panel's recommendation (answer to Question 11 (p.15)) to run the software work stream more in parallel with the other work streams will be taken into consideration by the SPDO.

14. 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 production 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.

The Panel's conclusion that two years is too short a time for the detailed design, production engineering and tooling phase, has been acted upon by the SSEC, and an additional year has been incorporated in the schedule. Resource planning is now taking place to permit the planned activities to complete within the three years allocated. Roll-out of Phase 1 construction is now planned to commence in 2016.

18. 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.

This will be prepared by the SPDO in conjunction with the Lead Institutes as part of the work of the WP2 Management Team described briefly in section 2.6.

2.4 Costing and Resources

15. A framework for doing lifetime SKA costing seems in place. However, a detailed costing was not given, and the panel expected a more advanced costing at this stage. Stabilising requirements and producing a credible costing are quite urgent at this stage of the project. The project should not underestimate or understate the cost.

Credible costing of the SKA has a high priority in the SPDO, and one of our Domain Specialists has been tasked with coordinating this activity.

16. 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.

The science-technology-cost trade-off process described in the system CoDR documentation provides a framework for accomplishing this goal.

17. 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.

A resource plan is in preparation for the pre-construction phase from 2011-2015. If funded, this will provide the financial resources to complete the R&D for the baseline design and enhancements and to fund the staff of the SKA Organisation needed to manage the detailed design phase prior to construction, and handle procurement issues related to construction. In this pre-construction period, funding is to be channelled through the SKA Organisation to the institutes for prototyping and detailed design work, replacing the separate national and regional funding streams now in place.

One of the specific goals of WP2 in PrepSKA is the preparation by the end of 2012 of a credible construction plan for the SKA including site infrastructure, and a statement on the construction and operations costs.

2.5 Site selection

The SSEC agrees with the Panel that the SKA site decision is important to the long term future of radio astronomy as a whole, and that it may represent the last opportunity to select a relatively well protected site on this planet.

2.6 Project Structure

19. In order to achieve the schedule and resource planning goals outlined above, the project structure needs to be strengthened. The SSEC should further empower the SPDO to carry out the SKA central management, integration, and project administration functions. Success depends on the participating organizations acknowledging and supporting the central role of the SPDO. The project should 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.

The SSEC is fully aware of the need for a strong global structure to coordinate the SKA R&D activities. The SPDO already has a strong central role in the SKA as the coordinating entity for the science case, engineering development, and site characterization of the SKA. This has been recently enhanced by the SSEC's approval of a proposal to establish a WP2 Management Team for the system design work. Support in the participating institutes has increased significantly in the last few months with the identification of dedicated resources in the Lead and Contributing Institutes around the world. The Panel recommended concluding separate MoAs with the institutes as a means of achieving institutional accountability. However, most of the partner institutes around the world have signed the PrepSKA contract with the European Commission to carry out work on the system design, and have accepted specific responsibilities in the Description of Work. So there seems little point in additional MoAs.

The WP2 Management Team will be led by the SPDO Project Manager and include the SPDO Project Engineer and the responsible people at the six Lead Institutes around the world. The SPDO and Lead Institutes are responsible for organizing and managing work by themselves and the Contributing Institutes on the various specific tasks and sub-tasks in WP2. Progress will be tracked on a regular basis by the Management Team using standard project management tools, and risks identified and mitigated.

As noted by the Panel on p11, there is no doubt that additional resources will be required in the SPDO in order to maintain a high frequency of communication with the distributed SKA resources. Steps are being prepared in that direction as part of the proposal for pre-construction funding mentioned in section 2.4.

20. Technical effort should continue in all relevant areas: receptor design and construction of pathfinder/conceptual prototypes; site studies; systems engineering; signal transport and processing; and computing. These activities should emphasize understanding of the performance/cost implications in relation to the science goals.

The technical effort in all these areas is continuing with the aim of delivering designs, performance data where possible, and costs.

2.7 Answers to detailed questions from the SPDO

Responses to the Panel's answers to these questions have been made in the foregoing sections.