



SOFTWARE AND COMPUTING CODR

STRATEGY TO PROCEED PAST CODR

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LIST OF ABBREVIATIONS

CDR	Critical Design Review
CMMI	SEI Capability Maturity Model Integration
CMO	Current Mode of Operations
COTS	Commercial Off The Shelf
CoDR	Concept Design Review
FMO	Future Mode of Operations
HPC	High Performance Computing
MECE.....	Mutually Exclusive, Completely Exhaustive
PDR	Pre-Production Design Review
PrepSKA	Preparatory phase of the SKA
S&C	Software and Computing
SEI	Software Engineering Institute of the Carnegie Mellon University
SKA.....	Square Kilometre Array
SPDO	SKA Program Development Office
SRR.....	System Requirements Review
WBS	Work Breakdown Structure
WP2	PrepSKA Work Package 2

1 Executive Summary

For the Software and Computing Domain, this document details the following areas:

- Phases of development for the SKA
- Identifying and addressing gaps in deliverables from the Concept Phase
- Identifying actions to address risks identified during the Concept Phase
- Deliverables expected from the Definition Phase
- Outline of activities to be undertaken during the definition phase

2 Introduction

This document describes the strategy to move to the next phase of the project defined in the System Engineering Management Plan (SEMP), the Definition Phase for the software and computing (S&C) domain.

2.1 Purpose of the document

For the Software and Computing Domain, this document details the following areas:

- Phases of development for the SKA
- Identifying gaps at the end of the Concept Phase
- Outlining activities needed during the definition phase to begin to address the gaps
- Outlining activities required to begin to address risks identified during the Concept Phase
- Deliverables expected from the Definition Phase
- Proceeding forwards with requirements development from the Concept Phase to the Definition Phase
- Proceeding forwards with architecture development from the Concept Phase to the Definition Phase

3 References

3.1 Applicable Documents

The following documents are applicable to the extent stated herein.

In the event of conflict between the contents of the applicable documents and this document, the **applicable documents** shall take precedence.

- [1] S06: WP2-005.010.030-MP-001 - System Engineering Management Plan (Revision F)
- [2] D4: WP2-050.020.010-RE-001 - Software and Computing Risk Register

3.2 Reference Documents

The following documents are referenced in this document. In the event of conflict between the contents of the referenced documents and this document, **this document** shall take precedence.

- [3] D3: WP2-050.020.010-DD-001 - Software and Computing System Overview
- [4] D2a: WP2-050.020.010-RR-001 - Analysis of requirements derived from the Design Reference Mission
- [5] D3a: WP2-050.020.010-SR-001 - Visibility Processing
- [6] D3B: WP2-050.020.010-SR-002 - Processing for Pulsars and Transients
- [7] D5: WP2-050.020.010-MP-001 - Software Engineering

4 Phases of Development for the SKA

To provide a context for the phases of development for the Software and Computing element domain, a high level overview of the SKA project and its milestones is presented in this section:

- Description of the SKA Project Phases
- Description of top level SKA milestones

Further detail is provided in the SEMP system level documentation [1].

4.1 SKA Project Phases

Figure 1 gives a time line for phases of the project and identifies its top level milestones.

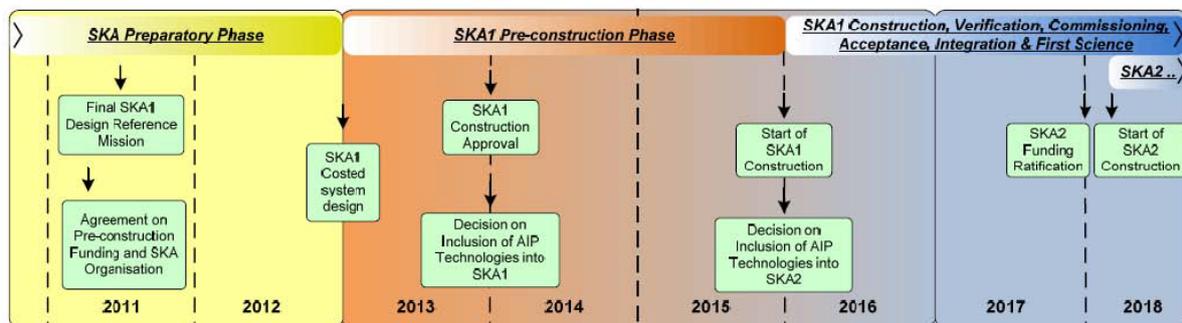


Figure 1: SKA Project Phases

This document is prepared for the Conceptual Design Review at the end of the Concept Phase. Following the CoDR is the Definition Phase leading to a Sub-system Requirements Review (SRR). The Pre-construction phase follows the preparatory phase and is sub-divided into, Preliminary Design, and Detailed Design and Preliminary production phases each ending in a review (PDR, CDR and PRR respectively).

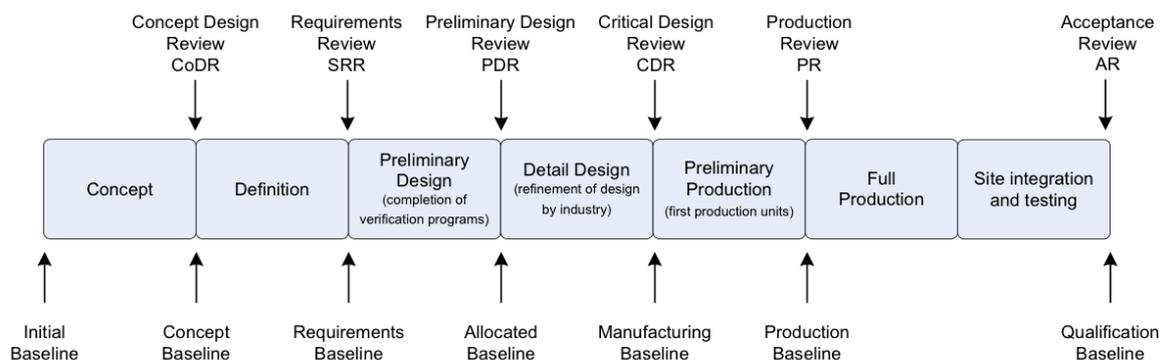


Figure 2: Deliverables by Project Phases

4.2 Software and Computing Definition Phase

The Definition Phase immediately follows the Concept Phase and its associated CoDR. The Definition Phase leads to the Software and Computing Requirements Review, SRR. The following is extracted from the SEMP

[1] “The aim of the Definition Phase is primarily to perform requirements analysis and validation to ensure that the complete set of requirements is understood and is present. Gaps will be identified and actions to address these shortcomings will be initiated. The result of these activities will be captured in the relevant Requirement Specifications to be reviewed at the conclusion of this phase.

In support the technology option(s), as confirmed during the CoDR, will be investigated in more detail. Further prototyping and testing may be done and analyses and simulation work will continue.

Trade-off studies between the possible solutions will be performed with the aim of identification and selection of a preferred solution. The tradeoffs will include aspects and inputs from the levels above and below.

It is recognised that for some elements or subsystems it may not be possible to arrive at a preferred solution during this phase and that more than one solution might be carried forward to the next phase.

Architectural design activities will also be initiated with the aim of producing a first draft design document at the end of the phase.

Interfaces will be refined and finalised as far as possible (especially functional interfaces).

This phase will be concluded by the [Software and Computing] Requirements Review (SRR). The Requirements Baseline is reached upon conclusion of the SRR.”

5 Gaps Identified at the Conclusion of the Concept Phase

The SEMP [1] requires that a main aim of the CoDR is to confirm that the 'problem' has been thoroughly explored and is well understood. This is important to be able to move forward to the next phases of the project where technology options will be investigated and selections being made.

The aim of the Definition Phase is then primarily to perform requirements analysis and validation to ensure that the complete set of requirements is understood and is present. Inevitably gaps will still exist at the end of the concept phase which must be identified and actions taken to address these shortcomings will be initiated in the definition phase. The result of these activities will be captured in the relevant Requirement Specifications to be reviewed at the conclusion of this phase.

We identify the following gaps at the end of the conceptual phase:

1. A multi-tier model for the delivery of data products from the telescope to end users is assumed. Tier-0 is the observatory and Tier-1 regional data centres. Science processing beyond calibration and imaging or core time-series analysis could be performed at the observatory, regional science centres or be the responsibility of science teams. Different models have been adopted for the pathfinders. The observatory responsibility must be defined via a sufficiently detailed operational model, see sections 3.4 and 3.5 of the Software and Computing System Overview [3].
 - a. This must be addressed in the development of the operations plan. Given the significant impact on the cost of the S&C domain for the observatory, interaction between the development of the operations plan and the S&C domain must be close during the definition phase.
2. Detailed aspects of the S&C requirements are not fully defined by the current use cases in the DRM. The analysis of the DRM to derive requirements highlights and discusses these gaps [4].
 - a. During the definition phase the DRM will be iteratively revised. This process needs to converge quite quickly and we suggest very close involvement of the S&C domain expertise in the work to refine the DRM
3. There is an exceptionally strong interaction between the S&C domain and Monitor and Control which goes beyond interfaces and relates to the Layered structure of software. Some aspects of base-tools and core services are shared between the domains, see Section 4.3 of the Software and Computing System Overview [3].
 - a. Work should be initiated in the definition phase between the S&C and M&C work packages to ensure the overlap is properly defined.
4. There is no one place in which an overall data model for the telescope is defined, but is spread across multiple domains (S&C, DSP and networking). There is a need for a single coherent data model to be defined incorporating the cross-domain information.
 - a. Work should be initiated to define a system group with appropriate expertise to define the overall system data model.

5. Time-series processing for pulsars and transients may involve a hardware or firmware solution for part of the processing, see Processing for Pulsars and Transients [6]. A clear route to determining the detailed architecture for this aspect of the system needs to be identified.
 - a. Cross WP analysis of the optimum solution for the processing requirement for the relevant use cases from the DRM should be undertaken including relevant expertise from each domain.

6 Addressing Risks Identified During the Concept Phase

Software and Computing risks are presented in [2].

In this section we discuss the approach that needs to be taken during the definition phase and through to detailed design / construction in order to manage the risk.

Risks fall into two broad areas, those associated with the programmatic issues of direct relevance to the S&C domain and risks concerned with our inability to fully achieve the requirements.

The top level programmatic risks are that the scope of the work exceeds the available resources (see risks in Section 2 of [2]). Coupled to these are risks associated in not taking actions associated with the Gaps identified above in Section 5 of [2]. These programmatic risks can most sensibly be mitigated by adopting an appropriate development model which we discuss below.

The second set of risks is concerned with not fully meeting the requirements on the S&C domain. Examples will be that the software system does not deliver the highest-fidelity data products required by the science use cases. Experience of all existing facilities indicate that there will be continued evolution of data analysis algorithms beyond the formal construction phase and that these will in many cases go hand-in-hand with improved scientific return from the facility. We also note that we are not starting from a zero base level. The Pathfinder and Precursors will provide not only valuable insight and experience, but also a code-base on which to begin the development of the SKA1 software system. While SKA1 will be a major processing challenge for astronomy, it will not push the boundaries of the available processing power in the way the SKA2 is expected to. Again by adopting an appropriate design and development approach within the overall system engineering methodology the risks can be significantly mitigated. As a practical example, delivery of a software system at the start of operations including an imaging pipeline which delivered routinely 60 dB dynamic range, thus failing to achieve the require of >65 dB, is preferable to very late delivery of a pipeline which has the potential to achieve the requirement.

With these considerations in mind the approach to the design and development work should:

1. During definition phase:
 - a. Match the scope of work beyond the required deliverables very carefully to the available expert resource.
 - b. Develop a WBS for the detailed design phase which embodies a development model which mitigates risk by ensuring a working S&C system is delivered in an incremental evolving manner (see below).
 - c. Provide the necessary resource to address the high priority issues identified in the analysis of gaps in the previous section to ensure that a stable system-architecture is defined at the end of the definition phase.
2. For the detailed design, a development model should be adopted in which we:
 - a. Follow the structuring of the sub-system as discussed in Section 4.1 “Architecture Goals” in the Software and Computing System Overview [3]

- b. Ensure a well-defined software-engineering approach is enforced throughout the project as outlined in the Software Engineering document [7]
- c. Adopt a deploy-early approach.
- d. Develop a comprehensive test suite which is rigorously applied and required to evolve with the code base
- e. Follow a continuous, develop-deploy-test approach
- f. Follow a co-design approach to allow for algorithm/implementation design to keep in step with hardware evolution
- g. Design for successful deployment. For example until single-pass calibration algorithms are proven design for a multi-pass approach to calibration, see the Visibility Processing document [5].

7 Deliverables for the Software and Computing Definition Phase

The Software and Computing SRR, conducted at the end of the Definition Phase, will review the definition of items in the Software and Computing Requirements Specification.

Documents to be reviewed during the Software and Computing SRR will include:

1. Requirement specifications developed during the Definition Phase, including definition of verification tests to be performed against each of the requirements
2. First draft high level architecture description documents including:
 - a. Top level block diagrams, and
 - b. Descriptions of interfaces between components in the architectures
3. Updated risk register including relevant mitigation strategies
4. A requirements traceability matrix, from and to system level requirements
5. Reports outlining the findings of the investigations into candidate high level architecture options and justifications of the selected architectures to be carried forward
6. Strategy and plans for proceeding to the next phase
7. Updated cost, schedule, power and RAM estimates
8. Input as required into system level documents such as a draft health and safety plan

As part of the work leading to the Software and Computing SRR, it will be necessary to develop insights into two categories of need for further development:

- A. Required development that may extend research into areas that require further exploration to elicit further concepts and options
- B. More mainstream development of established concepts and options

Work on the former category will by its nature be distinguished from and have a higher risk profile than work on the latter category.

8 Activities in the Definition Phase

In this section we outline the activities which are required in the definition phase of the project. This is not intended to be a comprehensive Work Breakdown Structure (WBS) – this document will form one input to the definition of the WBS for the next phase: the WBS will be refined via an SPO process following successful CoDR.

8.1 Participation in Definition of the Operations Plan

The operations plan is critical to define the scope and other requirements of the S&C domain (see section 5). This is a system-level task, but in the planning for the S&C domain resource should be made available to this system-level task to ensure the during formulation of the operations plan appropriate S&C expertise is available.

8.2 Participate in Definition of the overall Data Model

An overall data model including data flow, data rates, monitor and control and persistency requirements should be developed at system level. The model will ensure consistency in the flow of data, information and control aspects through the telescope system. Appropriate expertise from the S&C domain should be made available to this task.

8.3 Further Development of Software and Computing Requirements

This work is based on that described in the SEMP [1], but with some tailoring for the Software and Computing domain.

Activities that address developing and managing requirements include:

- Further definition and development of software functional and performance requirements
- Further definition and development of hardware performance requirements to meet software functional and performance requirements
- Further definition and development of interface requirements
- Integration and prioritisation of software and computing requirements

These activities will be carried out in several iterations concurrently with the other activities during the Definition Phase.

To ensure convergence with the DRM where gaps have been identified (Section 5) appropriate S&C expertise should be made available during the detailed work to revise DRM-level requirements to ensure they are complete from an S&C perspective.

Specific sub-tasks will include:

- Production the traceability matrix and documentation of the requirements
 - Document set giving complete analysis leading to requirements
- Definition of tests

8.4 Developing the Software and Computing Architectures

The processes for architecture development during the Definition Phase can be summarised as:

Develop candidate architecture solutions and select a preferred solution:

- Develop alternative architecture solutions and selection criteria
- Based on the selection decision criteria, select the architecture solutions to be developed in more detail

Development of selected architectures:

- Develop the selected architectures
- Establish and maintain technical data packages
- Specify interfaces

The architecture will be informed not only by the requirements, but also by the experience and results of the pathfinders and precursors.

Attention must be paid to the evolution of potential hardware solutions during the design phase and the need for co-design. Architectural alternatives must encompass a range of achievable solutions providing low-risk (likely high cost) and high-risk (likely lower cost) detailed design options to be retained through to PDR.

Tests to analyse potential solutions against the decision criteria will be conducted. The tests, decision rationale and outcomes will be documented. For example:

- Performance modelling for algorithms running on HPC parallel architectures is likely to provide significant insight
- The existence of codes from the precursors and pathfinders that provide some elements of required functionalities may influence the architectural design; criteria for evaluating existing alternative codes may include:
 - Functionality, Reliability, Cost, Ease of adoption and reuse, Vendor reputation for proprietary solutions, Ease of customisation, Ease of implementation
 - Proven solutions from the precursors and pathfinders leading to the early adoption of the software base from these projects.

Preliminary interface definitions for software and computing sub-system components will be defined. These will focus on user, software, and hardware interfaces. The interface descriptions will

be consolidated into the architectural design document. Considerations for interface definitions may include:

- Preferably use open – i.e. non-proprietary – interface standards between applications
- Preferably use open – i.e. non-proprietary – computing infrastructures
- As a preference, applications that users interface with shall be capable of externalising these interactions to independent Web-based interfaces
- Each user shall be uniquely identified and authenticated using a single sign-on digital identity

Input to – and maintenance of – entries in the Software and Computing Risk Register [2] will continue.

Preferred solutions and select alternative options will be identified. An estimate of total costs of ownership will be generated, decomposed into:

- Initial acquisition
- Subsequent development and maintenance
- Possible costs of decommissioning with transition to future solutions

Sub-tasks will include:

- Assessment and definition of interfaces
- Participation in inter WP work to define interfaces and common software layer components with the M&C domain.
- Participation in inter WP work to determine architectural options to be followed for time-series analysis.

8.5 Continued analysis, development and implementation of pipeline solutions

This activity will allow the on-going development work to continue within the framework of the SKA1 definition phase. The work will be documented in reports which will inform the architectural decisions.

8.6 Continued analysis, development and implementation of streaming data solutions

This activity will allow the on-going development work to continue within the framework of the SKA1 definition phase. The work will be documented in reports which will inform the architectural decisions.

8.7 Continued development of software engineering plan

This activity will formalise the continuing development of the software engineering plan.

8.8 Continued analysis, development and definition of software components

This activity will allow the on-going development work to continue within the framework of the SKA1 definition phase. The work will be documented in reports which will inform the architectural decisions.

8.9 Coordinated activity to update risk register

This task will be a coordination activity to ensure coordinated updating of the risk register.

8.10 Development of strategy of how to proceed to the next phase

This activity will be a coordination activity to bring together all elements of work to provide a description of how to proceed to the next phase.

8.11 Development of cost and power requirements

This activity will be a coordination activity to bring together all elements of work to provide a description of cost and power requirements, how these have been obtained and how they relate to the architectural decisions and the way forward.

8.12 Contribution to system-level requirements

This activity will provide input to all other system-level activities as required from the S&C domain.