



**STATEMENT OF WORK FOR THE STUDY, PROTOTYPING  
AND DESIGN OF AN SKA ELEMENT**

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**ORGANISATION DETAILS**

|                    |   |
|--------------------|---|
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**LIST OF ABBREVIATIONS AND ACRONYMS**

- AIV .....Assembly, Integration & Verification
- PA/QA.....Product Assurance, Quality Assurance
- SEMP.....System engineering management plan
- SKA .....Square Kilometre Array

## 1 Scope

The study, prototyping and design of an SKA Element shall include the final design of the Element and all Sub-Elements, as specified in the applicable technical specification, to the point where construction of the Element can be procured.

The work is being described on the basis that the activity associated with study, prototyping and design covers all instances and if necessary, variants, of the Element required to complete the SKA telescopes on both sites.

Construction of the Element includes production engineering, fabrication, transport and Assembly Integration and Verification (AIV) at Element level. Construction includes all activities and hardware/software procurement starting from the deliverables of the work specified herein.

The work includes but is not limited to the following tasks

1. The generation of the functional and performance requirements for the element.
2. The design and analysis of the Element, with a view not only of meeting the required performance and schedule constraints, but also of taking advantage of the most economic and efficient industrial methodologies and thereby ensuring competitive costs.
3. The detailed design of the Element.
4. Developing and maintaining a schedule for the construction of the Element
5. The calculation of the costs of the Element, including margins, from construction to operation.
6. The production of the technical documentation necessary for procurement, including the manufacturing, packing, transport and AIV of the Element.

## 2 Related Documents

### 2.1 Applicable Documents

|       |   |
|-------|---|
| [AD1] | SKA PA/QA plan                                  |
| [AD2] | Product Assurance and Quality Assurance for SKA |
| [AD3] | SKA Documents requirement descriptions (DRD)    |
| [AD4] | SKA Change Control Procedure                    |

### 2.2 Reference Documents

|       |                                |
|-------|--------------------------------|
| [RD1] | SKA SEMP                       |
| [RD2] | SKA baseline reference design. |
| [RD3] | SKA IP policy                  |

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## 3 Requirements

### 3.1 Project definition

The SKA Observatory is described in the preliminary design document [RD2]. The Elements have been allocated preliminary functionality and performance requirements. The derivation of element functional and performance requirements is based on the SKA community experience with radio telescopes and, guided by the decisions of the SKA Board, forms the core of this work. Non-functional requirements are yet to be derived, and it is part of the work to derive and analyse them in order that they might drive the design in a timely manner.

The work described in this statement of work is to be undertaken by consortia of research institutes/organisations and industrial/commercial entities.

The Functional Requirements are subject to change. A Consortium shall make provision for such change and do so with no additional cost during the design phase for those of a reasonable magnitude and date of occurrence. Such changes will be analysed for impact together with Consortia and the SKA science director. Changes that affect the scope or science will be authorised for implementation by the SKA Director General and SKA Board.

It is part of the work to define collaboratively interfaces between Elements. The interfaces shall be controlled and owned by the SKA office. The definitions of these interfaces are subject to change as the design evolves. The motivation for changes are likely to come from the Element definition work, but the approval of major changes remain the responsibility of the SKA Office. Consortia shall accommodate a reasonable level of change without development cost implication.

#### 3.1.1 Deliverable Item definition

The items covered in this statement of work are

1. The design of the Element as defined in baseline reference design [RD2] and the Work Breakdown structure, up to the point where construction of said Element can be readily procured by the SKA organization.
2. All necessary development, design, analysis and verification documentation
3. All necessary operation, maintenance and safety documentation
4. All necessary specification, drawings, plans and fabrication documentation as may be required to procure, under competitive tendering, the Element specified in the technical specification, including spare parts, dedicated tooling and other needs of maintenance and operations.

The SKA element concepts have been developed by the SKA community and have been incorporated into a framework of a baseline reference design, the analysis and evaluation thereof, leading to a logical architecture definition reflected in the breakdown of the system.

The baseline design [RD2] provides the consortium with a starting point for the work identified in this document.

*The consortium shall develop the design of the Element and is free to redefine the architecture definition of the Element in consultation with the SKA Office who will in turn consult with the affected interfacing Elements and the scientific and technical advisory bodies. **The information of the***

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*baseline reference design is provided as information to aid the derivation of functional and performance requirements and does not represent a preferred technical solution for the SKA.*

### 3.1.2 Project stages Definition

#### 3.1.2.1 Stage 1 (Requirements generation & Preliminary Design)

The main objectives of stage 1 are to produce a consolidated design, to demonstrate its compliance with the applicable specifications, provide a cost and schedule estimate and document the supporting analysis and plans, provide a risk estimate and produce draft specifications and statements of work for the eventual construction.

**At the start of stage 1, as per the timeline described in 3.1.3 the SKA office will confirm outstanding requirements or specifications. In addition, at that time the SKA office will provide the consortia with a target cost for the Element for SKA1.**

Stage 1 contains

- **Critical analysis of the baseline design and exploration of alternatives**
- **Generation of functional and performance specifications for the element.**
- **Definition of interfaces with other elements of the SKA.**
- Refining the Element concept by the consortium and validating it through thorough study and analysis. This includes hardware development, test and evaluation where already necessary to ascertain compliance with the applicable requirements. Design and analysis shall cover as a minimum:
  - All identified subsystems of the Element
  - All control systems necessary for the operation of the Element
  - All power and infrastructural requirements for the Element.
  - Analysis shall include finite element modelling (for example in relation to the environmental specifications for the site), computational fluid dynamics, control analysis, RFI/EMC analysis, RAMS analysis and safety analysis
- Risk assessment, cost estimation and schedule for construction and retirement of such risks and estimates in parallel with the process of design and analysis

During stage 1 of the study, the technical solution shall be addressed to such a level of detail that:

- a) Technical specifications, development and verification plans are available for all items to be developed within the study (at least two levels below the Element)
- b) Fulfilment of all applicable requirements is demonstrated
- c) All critical areas, in terms of performing this study, are identified and solutions presented.
- d) Within the framework of this study, the development risks (on technical, cost and schedule basis) are evaluated with a high degree of confidence.
- e) All critical areas, in terms of performance, end-to-end cost and schedule of the eventual procurement, integration, verification and operation of the Element are identified and presented.
- f) End-to-end technical, financial and schedule risks associated with the eventual procurement, transport, integration and operation of the Element are evaluated within high degree of confidence. Risk mitigation measures are identified and a draft risk register established.
- g) Production, transport, integration and verification plans are established, down to the lowest level of the product tree the contractor has established.

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- h) End-to-end costs associated with the eventual procurement, transport, integration and operation of the Element are clearly identified and quantified in a draft cost estimate.

The output of stage 1 forms the basis for proceeding with stage 2.

Following the commencement of stage 1 there will be a formal confirmation of the critical requirements placed on the Element, where outstanding specifications are placed, and existing ones are confirmed. Throughout stage 1, SKA will provide updates to environmental specifications and other applicable requirements, regulations and standards within the scope of this work, subject to Change Control [AD3].

Stage 1 starts at T0 with the kick-off meeting for this study and ends with the successful completion of the stage 1 study review (SRR – System Requirements Review; PDR – Preliminary Design Review), acceptance by SKA of the associated documentation and closure of associated actions.

### 3.1.2.2 Stage 2

Stage 2 of this study is the detailed design and engineering phase that prepares for and precedes potential procurement of the Element. Within stage 2 the design is detailed and verified by way of analysis and/or test down to the lowest level selected by the consortium, but no less than 3 levels below that of the Element itself. This includes but is not necessarily limited to

- Carrying out detailed optimization of the Element mechanical, thermal, optical, electro-optical, electronic and electrical subsystems in relation to the environmental specifications.
- **RFI characterisation of critical components.**
- **Developing the construction plans including requirements on the infrastructure (e.g. clearance for stations, access, power, storage, pre-assembly areas).**
- Scheduling for the manufacture, assembly and testing on site and establishing integrated logistics requirements and solutions.
- **Performing the RAMS analyses, including Failure Modes Effects and Criticality Analysis to validate initial maintenance planning.**
- Expanding and consolidating the risk register for construction.

The analysis performed in stage 1 shall be expanded and consolidated. The detailed RFI compliance plan shall be developed and demonstrated.

The detailed design shall be elaborated such that

- a) A thorough and complete evaluation of the ability of the design to fulfil the requirements is possible.
- b) The development process for hardware and software is well established including manufacturing methods, processing and tooling requirements.
- c) A production plan is developed to the lowest level of the element product tree (as developed by the consortium)
- d) SKA can be assured that the end-to-end costs of the system are well understood. A detailed bottom up allocation of contingency in the cost structure is expected at the end of stage 2.
- e) The procurement documentation for each sub-system of the Element is ready for competitive procurement. This includes technical specifications and statements of work.
- f) The consortium is able to provide the documentation for the supply of the Element.



Stage 2 starts upon successful completion of stage 1 and ends with the successful completion of the stage 2 review (CDR- Critical Design Review).

### 3.1.3 Project Schedule and Key Milestones

The total time span for the design shall not exceed 3 calendar years from the start of the study (kick-off meeting) to the completion of the last milestone.

| Milestone number | Short description  | Latest date  | Location                                 | Comment          |
|------------------|--|--------------|--|------------------|
| 1                | Kick-off meeting   | T0           | Consortium premises                      |                  |
|                  | Progress meetings  | T0+4 weeks   | Telecon or Consortium premises           |                  |
| 2                | Requirements Review - Finalisation of TBC's and TBD's in specification and setting of target cost for element. | T0+12 weeks  | Consortium premises or SKA offices       |                  |
| 3                | Submission of stage 1 (PDR) data package   | T0+52 weeks  | N/A                                      |                  |
| 4                | stage 1 review meeting (SRR & PDR)   | T0+60 weeks  | Office of the SKA or consortium offices. |                  |
| 6                | Closure of stage 1   | T0+68 weeks  | N/A                                      | Start of stage 2 |
| 7                | Submission of stage 2 (CDR) data package   | T0+140 weeks | N/A                                      |                  |
| 8                | Review of stage 2 data package (CDR)   | T0+148 weeks | SKA offices                              |                  |
| 9                | Closure of stage 2   | T0+154 weeks | N/A                                      |                  |
| 10               | Submission of the final documentation package for supply of the Element.                                       | T0+156 weeks | N/A                                      |                  |

### 3.1.3.1 *Kick-off meeting*

The main objective of the kick-off meeting is to confirm the mutual understanding of the scope of work specified herein, including the applicable specifications.

In particular the consortium shall

- Present the project plan, schedule and work breakdown structure
- Introduce the key resources and team members
- Make a technical presentation of the proposed solution.
- Presentation of management plans.

The consortium shall take the minutes of the meeting and record the action items.

### 3.1.3.2 *Progress meetings*

A progress meeting shall be held every 4 weeks during the whole duration of the project. Progress meetings may be held at the consortium premises or over the telephone/video conferencing facilities available.

The consortium shall provide a written progress report at least three working days in advance of the meeting. The progress report shall include an update of the risk register and concerns.

The consortium shall take the minutes of the meeting and record the action items.

### 3.1.3.3 *Stage 1 and Stage 2 reviews.*

The review procedure shall be as follows. The contents of the review data package shall be established as a minimum eight weeks before the review. As a minimum it shall contain design reports and analysis reports for all Sub-Elements and all deliverables as specified herein.

The review shall be organized by the SKA office and will involve members of the SKA office as well as external consultants as members of the review board. The chair of the review board is appointed by SKA Director General. The membership of the board is communicated to the consortium at the earliest possible time.

The review board shall be established by the SKA office and shall review the documentation provided and submit written comments to the consortium no less than 3 working weeks before the review meeting. The consortium shall consolidate the comments and provide written answers to the board no less than 1 working week before the review meeting.

The agenda of the review meeting shall be agreed upon between the consortium and the review chair no less than 1 week before the review meeting. The review meeting may include in depth presentations by the consortium of the work undertaken. No detailed schedule of a review meeting is specified but for planning purposes it can be expected that a review may last 4 working days.

The review board shall report in writing to the SKA Director General with a recommendation to proceed to the next stage, await the closure of action items before proceeding or to declare the review as not passed. The review board is not an executive body and may not issue programmatic actions.

### 3.1.4 Deliverables

Without exception, but within the provisions of the SKA IP Policy, all design information arising from the study will become property of the SKA. Without exception all hardware or prototypes developed as part of the study will remain property of the consortium. The consortium will undertake to keep such prototypes in safe storage for a period not less than 3 calendar years after the completion of the study.

All deliverable documents shall be provided in electronic and paper format to the SKA project office.

#### 3.1.4.1 Progress reports

In addition to the compliance with the applicable Document requirements description, the progress report shall address

- Any assumptions used in the design that are not part of the baseline design or agreed upon technical specification.
- Advances made in the design of the Element and its Sub-Elements
- Problems found and corrective actions
- Non-conformities identified and possible remedies
- The project planning and updates on progress

Progress reports shall include a draft agenda for the meeting and the action items being tracked.

Progress reports shall include clear indications (e.g. red flag reports) of problems that may jeopardise the study or the eventual procurement of the Element.

***The consortium is required at the earliest possible moment to alert SKA in case of problems that may cause the Element to fail to meet its specification. This shall be done, wherever possible, in advance of the submission of any Non Compliance Report.***

#### 3.1.4.2 Stage 1 data package

The stage 1 data package shall cover all activities undertaken during stage 1. The data package shall document the baseline design and the trade offs that lead to this definition. The data package shall demonstrate compliance with the applicable requirements and establish verification plans. The data package shall provide a robust cost and schedule estimate for construction, assess and document risks, establish the statement of work for construction and provide a sound basis for stage 2.

The data package shall include but not be limited to:

- 
1. The Element overall design report providing the critical characteristics that provide the required functionality and performance.
  2. Specific design reports for all second tier subsystems (the Element being the first tier). The design reports shall include the manufacturing/procurement approach, transport, installation and verification, support equipment for operations.
  3. Finite element models where relied upon to demonstrate compliance
  4. Software architecture models and use cases
  5. Parametric models used for the optimization of the design.
  6. Analysis reports: Finite element modelling (including all mechanical and thermal load cases), thermal analysis, fluid dynamics, RFI/EMC analysis, safety analysis, hazard analysis. In cases where specific construction or assembly equipment is required. The analysis shall cover these and their operation.
  7. Cost analysis for development, construction, verification, commissioning and steady state operations
  8. Preliminary construction plans
  9. Configuration items list
  10. Compliance matrix
  11. Preliminary maintenance plan
  12. Preliminary verification plan
  13. Schedule estimate for construction
  14. High level risk register
  15. Draft Statement of work for the construction of the Element
  16. Draft technical specifications for the construction of the Element.

#### 3.1.4.3 Stage 2 data package

The stage 2 data package shall document the detailed design of the Element, including the design and operation documentation for all the equipment (software and hardware) that are necessary for handling, transport, storage, installation, maintenance and operation thereof.

The stage 2 data package shall provide in-depth evidence that the design meets all applicable requirements.

The stage 2 data package shall contain all documentation required for SKA to initiate a competitive tender for the procurement of the Element.

The stage 2 data package shall include but not necessarily be limited to:

1. A formal statement of compliance with the specifications
2. A complete documentation package for the procurement of the Element including as a minimum:
  - a. The statement of work, including all applicable and reference documentation
  - b. Technical specifications for the system and subsystems, including all applicable and reference documentation
  - c. Detailed engineering drawings and interface control documentation.
3. Specific design reports for all subsystems down to at least the third tier (the Element being first tier). Design reports shall include transport, integration and verification.
4. All finite element models
5. Software architecture models and use cases
6. Software libraries required to demonstrate compliance

7. Software configuration information (operating system, libraries, compilers etc.) for demonstration of compliance.
8. Parametric models used for the optimization of the design.
9. Analysis report: Finite element modelling including all mechanical and thermal load cases), thermal analysis, fluid dynamics, EMC analysis, safety analysis, hazard analysis. In case that specific construction or assembly equipment is required the analysis shall cover these and their operation as well.
10. Integrated Logistics (RAMS/FMECA) report
11. End-to-end detailed cost breakdown. Itemized costs for standard procurements shall be backed by market surveys and/or offers for supply (e.g. steel costs, lines of code)
12. Construction plan, including an acceptance test plan and acceptance test procedures.
13. Operations plan including maintenance plan
14. Logistics requirements for construction, training requirements
15. Configuration items list
16. Schedule for construction
17. Detailed risk register.

#### 3.1.4.4 *Documentation package for supply*

The consortium shall submit, at the end of stage 2, to SKA a complete documentation package allowing the SKA office to tender for the construction of the Element including delivery on site and re-integration and verification on site.

## **4 Tasks applicable to all project stages**

### **4.1 Project management and control**

1. The consortium shall implement a centralized project management system.
2. The consortium project manager shall be the principal point of contact and have full authority to deal with all matters arising during the study, including but not limited to technical matters.
3. The consortium shall implement a work breakdown structure that reflects the subsystem architecture and is based on the final system product tree. Work package managers shall be identified and changes to the assignments shall be communicated to SKA no later than the earliest progress meeting.
4. The consortium shall implement a project plan and schedule following the work breakdown structure.
5. The consortium shall communicate to SKA any deviations from the project plan.
6. The project plan shall be updated according to the work done as a minimum at each progress report.

### **4.2 Configuration management**

The consortium shall follow the principles of configuration management as laid down in the SKA SEMP [RD1], or equivalent best practices. In particular,

1. The consortium shall identify each document, drawing, subsystem or part, establishing the item configuration and relation to the hardware and software at any time in the study
2. The consortium shall establish a configuration control process, in agreement with best practices.
3. The consortium shall ensure that all personnel that use or generate information can easily access and have appropriate training in the tools implemented to ensure configuration control.
4. The consortium shall provide a central repository for all information and that this repository is properly backed up.
5. The configuration item data list shall, as a minimum, list all documents that define or describe the Element. The configuration item data list shall be updated with each progress report.

### **4.3 Change requests and waivers**

Change management is described in 5. Once a baseline has been established and investment in further development of the baseline is planned, configuration management shall be employed. Changes are inevitable and shall be actively managed.

Proposed changes are of two broad classes based upon their impact on the system as a whole. If a proposed change affects the SKA budget or overall schedule, or affects more than one Element, or changes external interfaces, it is classed as Major. All other change proposals are classed as Minor. This Statement of Work is concerned solely with Major change requests.

Change requests are here defined as formal requests for a change to the requirements of the study or the terms of the study (e.g. dates etc). A change request is formally issued by the consortium or SKA and requires agreement of the other party to take effect.

A change request shall be addressed within one calendar month of receipt. Absence of response shall be assumed to be a rejection of the change request. A change request shall, as a minimum, include a rationale, technical feasibility of proposed changes, backed by analysis, and a list of the affected subsystems, including performance impacts. Schedule and cost impacts must be addressed.

A waiver is defined as permission, granted by the SKA Office to the consortium to deviate from the specification or a particular clause in the statement of work. It does not imply a change to the specification nor to the statement of work.

Waivers shall be addressed within one calendar month of receipt by the SKA Office. The absence of a response shall be assumed to be a rejection of the waiver request. A waiver request shall, as a minimum, include a rationale, the technical feasibility of proposed changes backed by analysis, and a list of the affected subsystems, including performance impacts. Schedule and cost impacts must be addressed.

### **4.4 Red flag reports**

A red flag report shall be issued by the consortium within 24 hours of the occurrence of a major problem jeopardising the timely delivery, achievement of the milestones, or the achievement of the

technical or cost performance and requiring the immediate attention of SKA. This reporting shall apply at all project levels.

#### **4.5 Product & Quality assurance and safety**

The consortium shall implement and maintain throughout the study a quality assurance and safety approach that covers all aspects of ISO9001 and all specified reliability, quality assurance and safety requirements.

All national safety laws and legislation applicable to the design, development, manufacturing, installation and operation of the supply shall be followed and fulfilled.

### **5 Documentation**

All documentation and correspondence shall be in English.

All deliverable documentation shall follow the SKA numbering system.

All original documentation shall be delivered in PDF format and MS-WORD. All secondary (e.g. scanned) documentation shall be delivered in PDF format. In case of conflict the signed PDF format document shall always be considered the master document.

All deliverable documentation shall be signed as a minimum by the author and the consortium project manager or delegate. In case of delegation, the consortium shall provide a clear delegation authority chain that does not extend beyond one level (i.e. no further delegation is allowed).

Electronic drawings, finite element models or other modelling shall be delivered in widely acceptable portable data formats as well as their original. The use of ANSYS for FEM, SolidWorks for CAD, MATLAB/SYSML for control modelling and UML for computer modelling is encouraged but not required.

### **6 Delivery**

All deliverables shall be sent to the SKA office.