**Work Package Title:** SKA System

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Work package number** | WP2.1 | | **Start date or starting event** | | | | | T+0 months | |
| **Work package title** | SKA system | | | | | | | | |
| **Activity Type** | RTD (Research and technological development) | | | | | | | | |
| **Participant id** | 4 | 7 | | 9 | 10 | 11 | 12 | | 13 |
| **Person-months per beneficiary** | 6 | (38) | | (12) | 8 (+24) | (6) | (26) | | (12) |
| **Participant id** | 14 | 15 | | 17 | 18 | 23 | UMAN (SPDO) | | FG-IGN |
| **Person-months per beneficiary** | (12) | (24) | | (16) | 6 | (24) | 102 (+66) | | (2) |

|  |
| --- |
| **Objectives:**  WP2 is the main SKA design activity; it will produce a top-level design for the SKA and a detailed costed system design for Phase 1 of the SKA. |

|  |
| --- |
| **Description of work**:  This project is the over-arching international activity for the engineering design of the SKA and addresses both short and long-term challenges. It is expected that the costed system design will be completed by 2012, to be followed by detailed design, production engineering and tooling in 2013 and 2014, and construction start (Phase 1) in 2015.  The costed system design will be achieved by a process which continues definition and design of the SKA concept within the astronomy and engineering communities, sets and reviews the specifications for the SKA, undertakes cost and performance analysis studies, examines trade-offs, and formulates conceptual SKA and detailed Phase 1 system designs. The adopted designs will reflect inputs from manufacturing, operations, instrument support (including maintenance) and life cycle studies performed as part of the project, as well as from regional Precursors, Pathfinders and Design Studies.  The SKA project has been pursuing technologies for realizing low-cost receptors with the sensitivity required and performance to meet ambitious single-field and survey sensitivity goals. There are different optimum receptor technologies for different frequency bands, with frequencies < 0.3 GHz being the domain of sparse aperture arrays (e.g. LOFAR, MWA and LWA). From 1 to 10 GHz, parabolic dishes with wideband, single-pixel feeds are a feasible technology. Very wideband single-pixel feeds covering the full range are under development and need to show that their sensitivity and performance makes a cost effective solution. The fall-back is to use narrow band feeds with an indexing arrangement. Over the range 0.3 – 1 GHz the single-pixel solution is again likely to be viable but the Aperture Array (AA) and Phased Array Feed (PAF) Wide Field of View (WFoV) technologies promise very significant additional scientific benefits through their enhanced survey speed capability, and could replace single pixel feeds in this range if they can achieve the necessary cost, sensitivity and imaging performance. It should be noted that the pursuit of multiple options increases the likelihood that at least one WFoV feed technology will prove viable on SKA development timescales.  Two major verification programs will be carried out during the course of PrepSKA: the Dish Verification Program (DVP) and the Aperture Array Verification program (AAVP). These are 4 year programs and will be completed at the end of 2012 with post-PrepSKA funding now under consideration.  WP2.1 is divided into the eight tasks set out below, the relatively large number reflecting the complexity of the undertaking. The project will be coordinated by UMAN (SPDO).  WP2.1.1: **SKA definition and design**.  This task will focus on the complete definition and design of the SKA. A system engineering approach will be adopted and various system engineering phases will be executed. Each of the phases will be concluded by a design review at which stage the documentation for the specific phase will be reviewed by both internal and external independent parties.  **SKA Definition**  The work during this phase will be focussed on the development and verification of the complete set of system requirements. The requirements will be gathered from a variety of sources which will include science (via the Design Reference Mission), the life cycle studies and analysis, science operations, support operations, environmental aspects of the sites, health and safety aspects, human factors, to name but a few. Inputs from all these sources will be gathered and disseminated to extract the system requirements. A process of requirements verification will also be performed to ensure the validity and completeness of these requirements.  **SKA Design**  This task produces the major WP2 deliverable which is a costed system design. It draws on many other WP2 activities but is especially tightly coupled with other WP2.1 tasks. Primary design goals include expandability of SKA capability from Phase 1 to the full SKA, and low total cost of ownership.  The system design task will focus on three facets.  (a) Physical design. This will use the outputs from the SKA definition, WP2.1.7 and other results (e.g. from Pathfinders and Design Studies) which set out the proposed sub-system implementation technologies. A hierarchical physical architecture will be developed, one aspect of which is a physical description of the array and its constituents. The architecture will describe major electrical interfaces between physical building blocks for data, control and power distribution. Where applicable, mechanical assemblies and mechanical interfaces will also be described. A mapping of sub-systems to physical components, at module level, will be made.  (b) Behavioural design. This will use information from WP2.1.3 and WP2.1.4 to define the input and output data, and the associated “black box” behaviour of the SKA system. A hierarchy of system functions will be developed to describe the functional design of the system, including aspects such as user interfacing, system control, system monitoring, signal conditioning, signal processing, and data product packaging. Major software components will be identified in association with WP2.6. The behavioural design will include the flow of signal data and control data through the system, and function will be linked to physical design in key areas such as data flow and electrical interfaces  (c) Performance design. This uses links to the outputs from the SKA definition and WP2.1.7 to formulate system-level performance requirements. These requirements will be broken down into element and sub-system requirements via development of system architecture performance models. Performance design will be linked to other design facets by mapping performance to physical components, functions and data interfaces. Cost modelling, including cost allocation to sub-systems in a form suitable for use in WP2.1.7, will also be included.  At the end of the system design task the SKA system architecture will have been described in terms of hardware and software elements and sub-systems, and their costs; the top-level physical composition of elements defined; interfaces between elements specified; and functions and performance mapped to elements and sub-systems. While WP2.1.1 will contain formal risk tracking and management sub-tasks, links to technology prototyping tasks (WP2.2 – WP2.6) and thence to the diverse suite of large-scale SKA Pathfinder and Design Studies, provide a strong practical risk mitigation strategy.  Participants: This central task will be led by UMAN (SPDO) in association with all WP2 participants, including those listed in linked tasks. Recognizing the wide interest in this activity, further links with the wider SKA community will be in place via the UMAN (SPDO) working groups, task forces and design groups.  WP2.1.2: **SKA life cycle studies and analysis**.  It will outline an end-to-end life cycle description of the SKA, and develop a first-order cost model applicable to major stages of the instrument’s life. WP2.1.2 will be closely linked with the SKA system definition and design (WP2.1.1), especially in terms of setting out design precepts in key areas such as telescope expandability and flexibility, design standardization, and documentation requirements. The task has two main parts. First, major aspects of the life cycle of the SKA will be described in terms of stages such as development, construction (including production), commissioning, operation, maintenance, upgrading and de-commissioning. Second, a life cycle support model, with an allied costing model, will be developed. This involves consideration of issues such as reliability, instrument availability, maintainability, and requirements at each SKA facility. Major input to these studies will be obtained from WP2.1.3 (Science operations) and WP 2.1.4 (Support operations). As well as building on the experience of the current SKA Precursors, Pathfinders and Design Studies the task will examine closely the plans and experience of major instruments such as the VLA, MERLIN, WSRT, PdBI, ATCA and ALMA.  The majority of the work in this work package will be performed as part of the system Definition Phase. This will ensure that the life cycle requirements will form part of the SKA System Requirement Specification and the subsequent Preliminary Design.  Participants: This task will be led by UMAN (SPDO). Other contributors include NRF (which is developing a life cycle formalism for the South African Pathfinder), CSIRO (with large array operational experience), ASTRON (with LOFAR experience and background in relevant SKADS studies) and UK (UCAM, UOXF, UMAN) (with experience in SKADS and in the operation of large radio observatories).  WP2.1.3: **SKA science operations**  This task will develop a high-level science operational model for the SKA and a detailed science operational plan for the initial phase of operations. The aim is to ensure that the SKA can be operated in an effective and efficient way, both in terms of operational modes and performance. WP2.1.3 provides key inputs to the WP2.1.1 system definition and design task and the support operations WP2.1.4. The task will incorporate experience gained from existing instruments while analyzing the operational impact of new SKA operating modes (e.g. multiuser access in at least some frequency bands). Inputs from SKA Precursors and Pathfinders will be incorporated as these telescopes become operational.  Initial work for this task will be performed during the Concept Phase but the majority of the work will be performed as part of the system Definition Phase. It is foreseen that a first draft of the science operations plan will be available at system Concept Design Review. This plan will be expanded, refined and finalised during the Definition Phase and will be presented for review at the SRR. In the event of any changes during the preliminary design, the document will be updated and again be presented for review during the PDR.  Participants: This task will be led by ASTRON, which has recent experience in developing operational models for the new-generation LOFAR telescope. Other key contributors are UMAN (SPDO), Cornell (TDP), CSIRO (ASKAP) (each of which brings substantial operational experience from instruments in the USA, Australia and UK), and NRF (MeerKAT) (which has developed an operational formalism for the South African Pathfinder). Wider consultation is also planned via the UMAN (SPDO) working groups.  WP2.1.4: **SKA support operations**.  This task will produce a top-level support model for the SKA, including a maintenance plan for the SKA. It is linked closely with the life-cycle and science operational tasks (WP2.1.2, WP2.1.3) and is a primary input to the system definition and design task (WP2.1.1). SKA maintenance aspects are crucial in realizing the operational goals while simultaneously containing costs. This task will look at issues such as usage (mission) profile, availability and reliability requirements and targets, and required lines of support. Modelling will take into account items such as maintenance and repair schedules and resources, renewal of software and hardware components built using low-cost consumer technologies, equipment operating environment and power consumption, performance-reliability trade-offs, and maintenance and re-investment costs. A comprehensive audit of maintenance experiences at existing telescopes and SKA Precursors and Pathfinders will be made, at the same time studying the SKA as a “complex” system with new possibilities in areas such as expert system based diagnosis, and design for graceful degradation.  The majority of the work in this work package will be performed as part of the system Definition Phase. This will ensure that the life cycle requirements will form part of the SKA System Requirement Specification and the subsequent Preliminary Design.  Participants: WP2.1.4 will be coordinated by UMAN (SPDO) with key contributions from ASTRON, Cornell (TDP), and CSIRO (ASKAP), each of which has operational experience with large arrays. NRF (MeerKAT) will also contribute, principally in helping to define the formal links between WP2.1.4 and the system design task, WP2.1.1.  WP2.1.5: **SKA monitoring and control**  This task will focus on all aspects of the monitoring and control system of the SKA. The work will be performed at various levels of the project and within various domains. Guidance will be provided from the system level to ensure that the monitoring and control system will be coherent and will incorporate the complete set of requirements. Key inputs will be obtained from WP2.1.3 and WP2.1.4 and it will provide key inputs to the WP2.1.1 system definition and design task.  The majority of the work in this work package will be performed as part of the system Definition Phase. This will ensure that the life cycle requirements will form part of the SKA System Requirement Specification and the subsequent Preliminary Design.  Participants: This task will be led by UK (UCAM, UOXF, UMAN) who have extensive experience of telescope control system implementation. Other contributors are Cornell (TDP) (folding in the experience of operational US arrays), NCRA-TIFR , together with partners in India (IUCAA, PSL, TRDDC, and CDAC) who also have extensive experience of telescope control system implementation and NRF (MeerKAT).  WP2.1.6: **SKA electromagnetic compatibility**  The topic of electromagnetic compatibility involves various disciplines and cuts across several of the domains. The work will be performed at various levels of the project with contributions from various domains. Guidance will be provided from the system level to ensure a coherent and complete electromagnetic compatibility effort for the SKA.  The majority of the work in this work package will be performed as part of the system Definition Phase. This will ensure that the life cycle requirements will form part of the SKA System Requirement Specification and the subsequent Preliminary Design.  Participants: This task will be led jointly by OPAR and ASTRON, who will draw heavily on LOFAR and SKADS experience to frame an SKA RFI mitigation strategy in collaboration with UMAN (SPDO) engineers. Other participants will be UORL, INAF, MPG, Cornell (TDP) and ICRAR.  WP2.1.7: **SKA cost analysis**.  This task will continue development of cost analysis work for the SKA, and will illuminate key trade-offs in the design of the instrument. It will collect and distil high integrity cost data from Precursors, Pathfinders, Design Studies and other sources. Detailed SKA Phase 1 optimizations and initial SKA investigations will be completed during PrepSKA, and the tools developed will be used for the life of the SKA project.  Work on this task will be ongoing throughout the project and will culminate in the fully costed system design at the end of the project.  Participants: This task will be led by UMAN (SPDO). ASTRON and UK (UCAM, UOXF, UMAN) will build on the efforts of the SKADS programme to contribute detailed costing information on Aperture Arrays and related systems. Cornell (TDP) will undertake a similar role for dishes and single-pixel feeds. CSIRO (ASKAP) will contribute information for phased array feeds and software. MPG and FG-IGN will contribute component-level Cost & Performance (C&P) data for key data transport and RF systems. ICRAR will contribute expertise in SKA system design and C&P software development areas.  WP2.1.8: **SKA power consumption**.  Because of the complexity, size and physical distribution of the SKA, power provision will also be complex and may include various delivering technologies. Power consumption will therefore be a critical aspect and will influence the long term feasibility and affordability of the SKA. This task will focus on all aspects of the power consumption across all domains. As well as active power consumption, a variety of energy-saving measures will be explored and utilized, where possible, in the design of components. This would include passive cooling techniques, peak power management techniques and possibly the use of phase-change materials for peak-temperature shaving.  Work on this task will be ongoing throughout the project and at all levels of the project. Power consumption issues will be reviewed and scrutinised at every design review to be performed at system, element, subsystem and in some cases, down to assembly levels.  Participants: WP2.1.8 will be coordinated by UMAN (SPDO) together with MPG with key contributions from KASI, SKA task forces and all of the domains. |

|  |
| --- |
| **Deliverables:**  WP2 deliverables will be structured according to a series of standard Design Reviews (DRs), as laid out in the introductory part of this document. The documentation from all Work Plan sub-system tasks will be combined into an integrated document set for the particular review in question. A DR report on each review will be produced by an independent review team. The WP2 deliverable for each DR will be a report written by the UMAN (SPDO) referencing the DR report and all the input documentation. The items below describe the deliverables expected in the PrepSKA period. Subsequent DRs will take place after the end of the PrepSKA period (T+45 months).  1. System Concept Design Review (CoDR).  *Type*: Report. *Delivery:* T+22  2. System Requirements Review (SRR)  *Type*: Report. *Delivery:* T+36  3. System Preliminary Design (not a DR report)  *Type*: Report. *Delivery:* T+45 |