**Work Package Title:** Software and Computing

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| **Work package number**  | WP2.6 | **Start date or starting event** | T+13 months |
| **Work package title** | Software and computing |
| **Activity Type** | RTD |
| **Participant id** | 4 | 7 | 9 | 10 | 11 | 12 | 13 | 14 |
| **Person-months per beneficiary** | 10 | (4) | (24) | (42) | (0) | (12) | (24) | (24) |
| **Participant id** | 15 | 16 | 19 | 20 | 23 | 24 | UMAN (SPDO) |  |
| **Person-months per beneficiary** | (24) | (4) | (4) | (18) | (90) | (5) | 59 (+30) |  |

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| **Objectives:**To formulate and document strategies for the implementation of SKA software and computing hardware, including calibration and imaging techniques, non-imaging data processing, post processing, data storage distribution of science results, and development of interfaces for users and operators. |

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| **Description of Work:** The SKA requires computing and allied topics to be primary inputs to the SKA system design process. Software in particular has proved challenging to radio astronomy projects in the past. WP2.6 adopts formal, top-down design processes as well as incorporating lessons learned from work on contemporary array, Pathfinder and Precursor projects. Risk is addressed via the up-front formulation of plans to evolve the software and computing architectures over time to meet the emergent needs of SKA users and operators.WP2.6 is divided into the six tasks set out below. All tasks are to be coordinated by UMAN (SPDO). The UMAN (SPDO) Software and Computing domain specialist is the WP2.6 project leader.WP2.6.1: **Software Engineering and Architecture Development**This task will establish appropriate software engineering processes and tools based on good industrial practices and international standards, and develop a highlevel software architecture for the SKA. This will focus on flexible development of the overall SKA software base with maximum reuse of existing developments and packages. Specifically, it will:(1) Define software engineering “good practices”, standards and procedures for the SKA, taking into account the global nature of the project and the working cultures of the organisations involved.(2) Set up common tools for the SKA collaborative software development environment, maximally reusing resources already used in astronomical projects and mature tools available from other sources – either open source or commercial;(3) Define a high level software architecture for the SKA, covering the components described elsewhere in this Work Package.(4) Establish a high level software development plan for the SKA, including overall costing and identifying and addressing risks and issues.WP2.6.1 is closely coupled to the WP2.1.1 system definition and design task, and will build on insight gained from Pathfinder and Precursor projects.Participants: This task will be led by ASTRON with contributions from the Indian National Centre for Radio Astrophysics (NCRA), Inter-University Centre for Astronomy and Astrophysics (IUCAA) and Centre for Development of Advanced Computing (C-DAC). Other contributors to (4) above are UK (UCAM, UOXF, UMAN) and Cornell (TDP), the latter also contributing to (1) via experience with contemporary US instruments.WP2.6.2: **Computing Hardware Architecture Development**This task will elicit and document requirements – and investigate hardware options including feasibility, estimated implementation costs, and addressing risks and issues – for SKA computing at all points in the instrument’s data path. It will consider primarily commercial off-the-shelf (COTS) solutions, and will compare the likely demands of SKA and Phase 1 with forecasts of the evolving capability of COTS computing.With its large number of antennas; baselines to at least 3,000 km; required wide Fields of View and very high dynamic range, the SKA will require a formidably large processing system. It is clear that the final required throughput will be ranked high in the list of the world’s most powerful computers.The scalability and power requirements of possible solutions will be examined and one or more possible architectures will be investigated. WP2.6.2 is closely coupled to the WP2.1.8 SKA power consumption task, and will build on insight gained from Pathfinder and Precursor projects.Non-imaging applications are likely to require special-purpose hardware processors, and the throughput required for imaging applications may also require use of High Performance Reconfigurable Computing architectures. WP2.6.2 is potentially closely coupled to WP2.5 Digital Signal Processing task.Participants: This task will be led by UMAN (SPDO), with contributions from ASTRON, Cornell (TDP), CSIRO (ASKAP), ICRAR, UCAL, UK (UCAM, UOXF, UMAN) and KASI, all of which have industry links in relevant areas. Additional input is expected from the UMAN (SPDO) Digital Signal Processing domain specialist and UMAN (SPDO) working groups.WP2.6.3: **Calibration and Imaging Techniques**This task will elicit and document requirements – and formulate and document the overall strategy, estimated implementation costs, and addressing risks and issues – for calibration and imaging for the SKA. It will also develop the software architecture and estimated implementation costs for implementing algorithms developed within the radio astronomy community for the SKA calibration and imaging sub-system.New algorithms – and re-casting of existing algorithms – will be required to ensure that high performance computer architectures are used effectively. It is likely that an important part of this work will be the real-time extraction of at least a sub-set of imaging data to drive array-wide calibration schemes.WP2.6.3 will:(1) Extend the work in the Pathfinder and Precursor projects, and set out the requirements for calibration and imaging (performance, dynamic range, etc.) given operating models developed in WP2.1.1 system definition for the SKA telescope, environment and sky.(2) Verify and undertake improvements for calibration and imaging algorithms, demonstrating them through simulations and real observations with Pathfinders and existing facilities.(3) Assess processing requirements for on-site and distributed processing, given the phased roll-out of the SKA.(4) Determine the optimum use of real-time data from the SKA’s monitoring and control sub-system in the implementation of calibration and imaging.Three distinct categories of calibration requirements will be considered:WP2.6.3.1 Arrays of dishes equipped with Single Pixel Feeds.WP2.6.3.2 Arrays of dishes equipped with Phased Array Feed systems.WP2.6.3.3 Aperture Arrays, which have different calibration requirements from dish-based antennas.All three categories require work in all four of the above areas.Participants: WP2.6.3.1 (Dish Arrays) will be led by Cornell (TDP). UCAL, JIVE and INAF will contribute to (1) and (2), above. NRF (MeerKAT), UK (UCAM, UOXF, UMAN) will contribute to (3) and (4). CSIRO (ASKAP) will contribute to (2), (3) and (4).WP2.6.3.2 (Dishes with PAFs) will be led by CSIRO, which is developing a calibration approach for ASKAP. Additional contributions from ASTRON (APERTIF) and NRC-HIA (PHAD) are expected.WP2.6.3.3 (Aperture Arrays) will be led by ASTRON, which is developing a new calibration approach for LOFAR. WP2.6.4: **Non-Imaging Data Processing**This task addresses the final processing required for non-imaging observations, such as those required to process time varying data from pulsars – both known and those discovered as a result of searching using the SKA. In addition, it is expected that data searches for other transient time varying phenomena will be required.WP2.6.4 will elicit and document requirements – and formulate and document the overall strategy, estimated implementation costs, and address risks and issues – for delivering algorithms for – and demonstrations of – non-imaging data-processing solutions, together with strategies for scaling from Phase 1 to SKA implementations.WP2.6.4 is closely coupled to WP2.5.3 Digital Signal Processing task.Participants: This task will be led by CSIRO (ASKAP), with contributions from UK (UCAM, UOXF, UMAN), ASTRON, INAF, JIVE, Cornell (TDP), NRF (MeerKAT) and UCAL.WP2.6.5: **Data Products, Data Storage and Data Distribution**This task will elicit and document requirements – and formulate and document the overall strategy, estimated implementation costs, and address risks and issues – for delivering the full SKA and SKA Phase 1 data products to the end user astronomer. The SKA is expected to produce massive data sets; the planning for their management is part of this task.Data Products: The data products including data visualisation for each of the key science areas of the SKA will be considered, along with more generic products to be delivered into a virtual observatory environment. A key requirement is that the astronomer is presented with data in a form which maximises the scientific utility of the instrument.Data Storage: The emphasis here is to examine ways in which the maximum amount of scientifically valuable data can be stored, recognising the prodigious rate at which data will be produced. This task is closely related to WP2.6.2 (computer hardware) as well as the data processing tasks.Data Distribution: The overall design of a data distribution pipeline – and the quality of the products from a fully automated pipeline – will be specified, keeping in mind the SKA observing model.Participants: This task will be led by UK (UCAM, UOXF, UMAN), which will draw on experience from both radio telescopes and instruments operating in other wave-bands. ICRAR and UCAL will contribute to all tasks, contribute to the area of data storage. RuG (AstroWise) will contribute in the area of managing complex astronomical data bases and general information systems; Cornell (TDP) and ASTRON will also contribute, bringing in experience from operational US and European radio arrays. MPG will contribute with their ongoing attempts to find an adequate solution for sustainable storage of large amounts of data in a national and European context.WP2.6.6: **Interfaces for Users and Operators**This task will elicit and document requirements – and formulate and document the overall strategy, estimated implementation costs, and address risks and issues – for the development of interfaces to both software and hardware sub-systems for users and operators of the SKA.WP2.6.6 is closely related to WP2.1.3, WP2.1.4 and WP2.1.5.Participants: WP2.6.6 will be coordinated by UMAN (SPDO) with key contributions from ASTRON –, which has recent experience in developing operational models for the new-generation LOFAR telescope – Cornell (TDP), and CSIRO (ASKAP), which have operational experience with large arrays.WP2.6.7: **Exascale Computing and Hardware**The SKA will require very high computing and data-storage capacity for two main reasons: i) data rate – a direct consequence of the large number of antennas required for the SKA; and ii) the target imaging dynamic range, given the high intrinsic sensitivity of the array. Effective utilization of computing at extreme scales requires significant targeted investment in scalable, parallelized algorithms and their efficient mapping to underlying high-performance computing architectures, which are not static over time. Experience indicates clearly that this investment is needed if the transformational science enabled by these levels of computing performance is to be achieved in practice. Extensive research, development and planning will be carried out in these areas to address the relatively low technical maturity. We include the demonstration of these technologies at SKA scale as an issue of technological readiness.Participants: This task will be coordinated by Cornell (TDP).  |

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| **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. CoDR Report for Software & Computing.*Type*: Report. *Delivery*: T+332. Final PrepSKA Wrap-up Progress Report (not a DR report).*Type*: Report. *Delivery*: T+45 |