STAGE 1 OF THE PRE-CONSTRUCTION PHASE EXPRESSION OF INTEREST

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ORGANISATION DETAILS

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1 Introduction

Following the completion of the Preparatory Phase of the Square Kilometre Array (SKA) in December 2011, the project has progressed to the Pre-Construction phase. With the establishment of a new legal entity, the SKA Organisation, on 14 December 2011, the project has also moved into a different organisational structure.

The work to be executed during the pre-construction phase will be structured and managed as described in the SKA Project Execution Plan (PEP) for this phase. During this phase the SKA Organisation intends to enter into agreements with a small number of consortia who will be responsible for executing large portions of the work, especially at the Element level of the SKA. The process of allocating the work will be formal and consortia will be invited to bid during a formal Request for Proposal process against work packages described in a detailed Work Breakdown Structure (WBS)/Statement of Work (SOW).

The preconstruction phase is subdivided into two stages. The Office of the SKA Organisation, supported by organisations and groups around the world, is in the process of finalising the WBS/SOW for the first stage (Stage 1) and the aim is to issue the formal a Request for Proposals (RFP) for this stage towards the end of June 2012.

In preparation for the formal process the Office of the SKA Organisation has decided to issue an Expression of Interest (EoI) (this document). The aims and rules for participating in the EoI process are set out below.

Organisations and consortia are hereby invited to participate in the EoI process and to provide responses to the Office of the SKA Organisation **no later than 16:00 UT on 14 May 2012**.

2 Scope of Stage 1 of the Pre-construction Phase

The scope of Stage 1 of the Pre-construction Phase includes all of the work at all of the hierarchical levels of the SKA appropriate to progress the project from the end of the Preparatory Phase of the SKA (PrepSKA) to the successful completion of the relevant Requirements Reviews at the System and Element levels of the SKA.

3 Aims of the Expression of Interest

The aims of the EoI process are to:

1) To establish a snapshot of the coverage of the interest to participate/execute the work as defined for the SKA Preconstruction Stage 1 WBS, and
2) To facilitate consortia formation by the gathering and utilisation of the information provided as part of the EoI process.

To achieve this goal the following information provided during the EoI process will be made available to all respondents participating in the process:

- Organisational names and contact information of respondents,
- Type of respondent (whether it is an individual organisation/company or a consortium representative), and

- Summary of areas where respondents expressed interest to lead [1]and/or to participate.

Detailed information with regards to the members of consortia will not be disclosed.

Any other information that an organisation or potential consortia provide as part of this process but would wish to remain confidential should be identified as part of the 'additional information' section on the EoI information page. Such requests will be taken into consideration when disclosing information.

Please take note that a report on the results of the EoI process will be drafted and presented to the Board of the SKA Organisation. All of the information provided by the respondents will be made available to the Board.

4 General Information and Rules

The EoI is not a formal process. Responses will not be evaluated or measured against any criteria. However, guidelines for the completion of the EoI should be adhered to in order to ensure a complete and coherent result.

The summary tables as provided as part of this EoI have been extracted from the latest revision of the fully detailed Stage 1 WBS/SOW which is a still under development. The summary tables do therefore not reflect 100% of the tasks and other information contained in the detailed WBS/SOW, but the information provided in this EoI should be sufficient to enable the reader to develop a very good understanding of the intent and the typical content of each of the WBS elements.

Please note the following important points:

- The EoI does not constitute a formal Request for Proposal from the SKA Organisation.
- The process does not place any obligation on the SKA Organisation to enter into any agreements with any of the respondents.
- Responding to the EoI does not place any obligation on the respondents to deliver a formal proposal, or even to participate, during the formal Request for Proposal process.
- Participation or non participation in the EoI process will not result in automatic inclusion or exclusion from the formal RFP process.
- The SKA hierarchical breakdown represented by the WBS is preliminary, and has been defined as a starting point. Respondents should be aware that Stage 1 includes the work to define the SKA hierarchical breakdown on the basis of requirements capture and analysis; therefore the hierarchical breakdown shown in the WBS may change during Stage 2.

Results from the EoI process will be used to facilitate and/or strengthen the formation of consortia by disclosing the interest shown by respondents in the relevant areas of work within the Elements of the SKA. However, responding to the EoI does not place any obligation on the organisations leading the consortia to include respondents in the consortium.

The EoI is structured around the various SKA1 Elements as defined in the Stage 1 WBS. Respondents are to indicate their interest in participating in the Stage 1 WBS elements by selecting the

[1] A lead organisation is defined as the organisation which has overall leadership of a consortium and therefore has the responsibility for the management of the execution and delivery of the work as allocated to the consortium.

appropriate tick box. Eventual large work packages may not necessarily be extracted and allocated along SKA Elements lines and boundaries.

Industry

Industry is welcome to participate in the EoI even if you are not part of a potential consortium at the moment. Because industry will eventually be required to be part of consortia during the execution of Stage 1, the information gathered during the EoI process will enable industry to identify and enter into discussions/negotiations with potential consortia lead organisations.

Site dependent WBS elements

All Elements of the SKA but especially the Power (SKA.TEL.PWR) and the Site and Infrastructure (SKA.TEL.INFRA) Elements are very site dependent and it is foreseen that differing levels of rework in the finalisation of the WBS/SOW will only be possible once the site decision has been completed. For the Power and the Site and Infrastructure Elements the tables as included in this EoI are therefore generic in nature and aimed at providing an indication of the type of work that can be expected within these two Elements. Organisations/consortia are invited to express their interest in the WBS elements of these two SKA Elements but it must be recognised that the details and scope of work will change once the site decision has been finalised. The information obtained during the current EoI process for these two Elements will not only be disclosed along with the others, it will also serve as input into the possible consortia forming and RFP process for these two Elements following the finalisation of the WBS/SOW in these two areas.

5 How to complete the EoI

For ease of completion, compatibility with different platforms and eventual consolidation, the EoI is presented in the form of a Word 2007 document. Organisations/consortia are requested to use the document and insert text directly into it. However, **please type only in the white sections of the document**.

Expression of interest

To express interest to execute a particular WBS element, insert '**Y**' in the appropriate cell to the right of the heading of the WBS element (see example below).

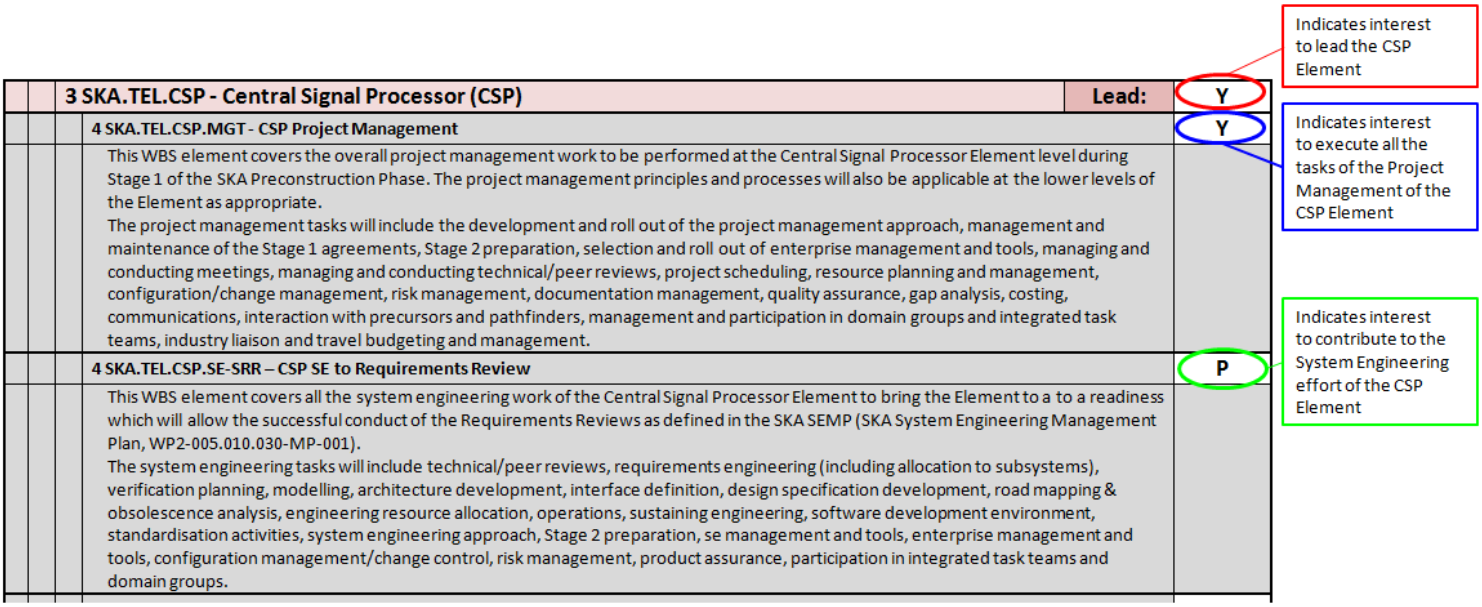
Partial interest

The WBS is broken down to sufficient detail so as not to require partial interest within WBS elements. However, in the event that an organisation/consortia are interested in only contributing/participating in individual WBS elements, please indicate this by inserting '**P**' in the appropriate cell to the right of the heading of the WBS element (see example below). Add any relevant information with regards to the contribution/participation to the 'Notes' section at the end of the Element.

For those consortia that are preparing or are interested to lead the entire effort for a particular SKA Element, insert '**Y**' in the appropriate cell to the right of the heading of the WBS element (see example below).

Each respondent must complete the information page of the EoI. Consortia are requested to provide information on the composition and status of the particular consortium as indicated on the information page. This information will not be publicly disclosed but will be reported to the SKA Board.

In the case of well advanced consortia submissions by the lead organisation on behalf of the consortium are acceptable.



3 SKA.TEL.CSP - Central Signal Processor (CSP)	**Lead:**	**Y**
4 SKA.TEL.CSP.MGT - CSP Project Management		**Y**
This WBS element covers the overall project management work to be performed at the Central Signal Processor Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
4 SKA.TEL.CSP.SE-SRR – CSP SE to Requirements Review		**P**
This WBS element covers all the system engineering work of the Central Signal Processor Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		

Example of completing the SKA Pre-construction Phase Stage 1 EoI

6 Submission of EoIs

Completed EoIs are to be to be e-mailed to Kobus Cloete (cloete@skatelescope.org) **by no later than 16:00 UT on 14 May 2012**.

Confirmation of receipt of the submission will be e-mailed to the respondent by no later than 10:00 UT on Tuesday 15 May 2012.

Format of submissions

Respondents must return the EoI in Word format. It is also recommended that the completed EoI be converted to pdf and sent to the SKA Office alongside the Word document. The pdf will serve as reference of the EoI that was submitted by the respondent.

File name

The current filename is MGT-001.005.015-EOI-001-1_Stage1EoI.docx in accordance with the SKA document handling standards. Please rename the file as follows when replying:

SKA-EoI-2012-***mm-dd-ORG***.docx

Where ***mm*** the month of submission, ***dd*** is is the day of submission, and ***ORG*** is the name of the organisation submitting the EoI. Pdf versions of the submission must please have the same filename as the Word files.

7 Queries

Any queries or questions can be sent to Kobus Cloete (cloete@skatelescope.org).

8 Definitions

A comprehensive list of definitions are available in the WBS/SOW Glossary (document MGT-040.030.015-LST-002, Rev K, dated 2012-04-30).

9 Acronyms

ADD ..... Architectural Design Document
AIP ..... Advanced instrumentation Programme
CDR ..... Critical Design Review
CSP ..... Central Signal Processor
DG ..... Domain Group
EMC ..... Electromagnetic Compatibility
EMI ..... Electromagnetic Interference
EoI ..... Expression of Interest
ICD ..... Interface Control Document
ITT ..... Integrated Task Team
LEMP ..... Logistic Engineering Management Plan
LFAA ..... Low Frequency Aperture Array
MFAA ..... Mid Frequency Aperture Array
NIP ..... Non Imaging Processor
PDR ..... Preliminary Design Review
PEP ..... Project Execution Plan
QA ..... Quality Assurance
RfI ..... Request for Information
RFI ..... Radio Frequency Interference
RFP ..... Request for Proposal
SaDT ..... Signal and Data Transport
SaT ..... Synchronisation and Timing
SDP ..... Science Data Processor
SE ..... System Engineering
SEMP ..... System Engineering Management Plan
SKA ..... Square Kilometre Array
SKA1 ..... Phase 1 of the SKA
SKA2 ..... Phase 2 of the SKA
SOW ..... Statement of Work
SPDO ..... SKA Program Development Office
SRR ..... (Sub)System Requirements Review
TEL ..... Telescope
ToR ..... Terms of Reference
TRA ..... Technology Readiness Assessment
TRL ..... Technology Readiness Level
WBS ..... Work Breakdown Structure
WP ..... Work Package
WPC ..... Work Package Consortium/Consortia

The
Square Kilometre Array
Stage 1 of the Pre-construction Phase

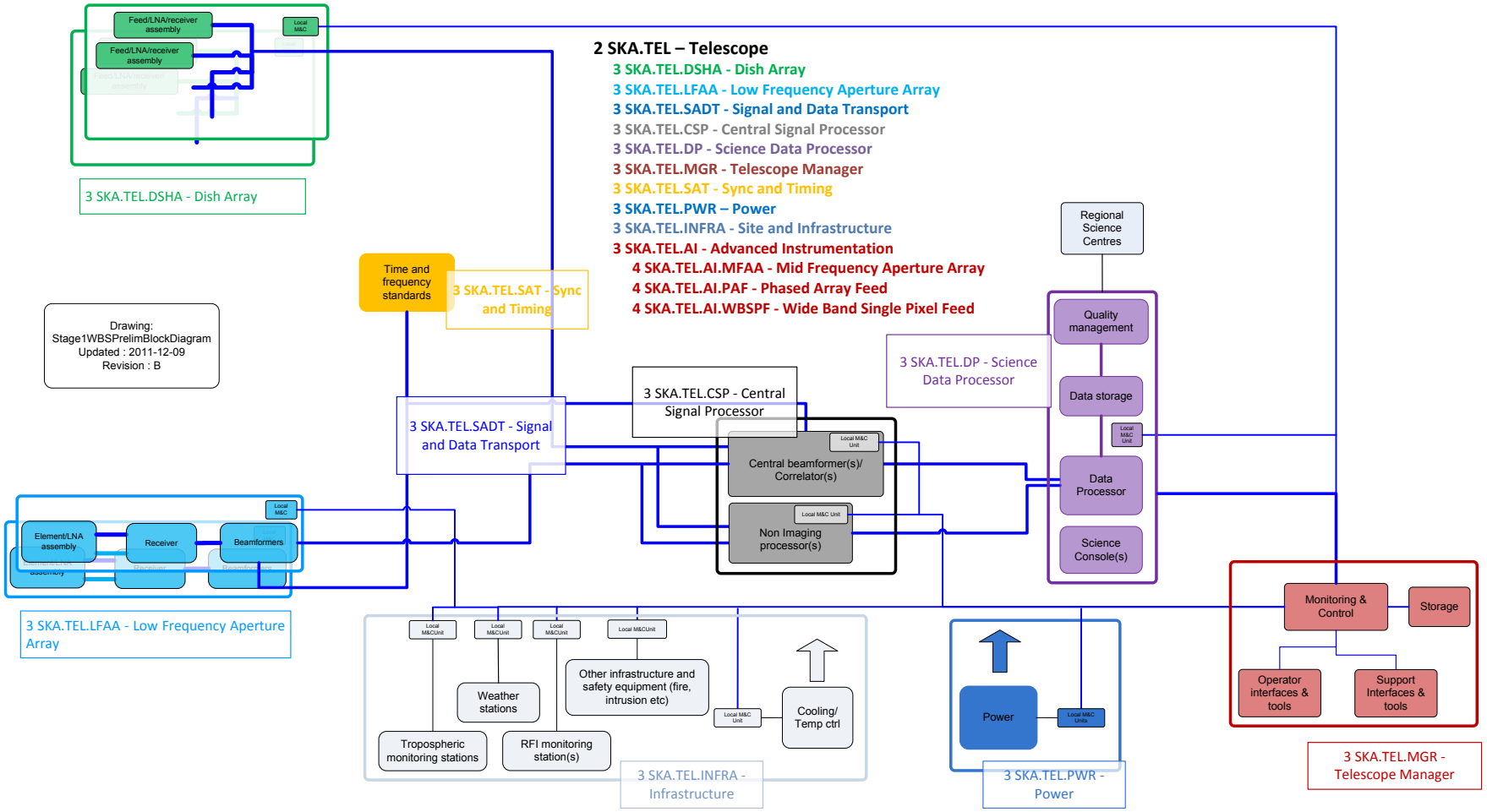
EXPRESSION OF INTEREST

Information Page

To be completed by all respondents

1	Name of organisation		
2	Address of organisation		
3	Contact details of organisation representative	Name:	
		Telephone:	
		E-mail:	
4	Is the organisation representing a consortium? (Y/N)		
5	If Yes to 6, provide the following details of the consortium:		
a	What is the status of the consortium (newly formed, preliminary discussions only, fairly well advanced)		
b	List of members/potential members		
c	Are the members supporting the submission (Y/N)?		
6	Additional information		

SKA Elements



Integrated Task Teams

SKA Integrated Task Teams are defined as (see WBS/SOW Glossary): *A group, drawn from Consortia, with relevant expertise and design responsibility, brought together under SKA Organisation oversight, to make architecture, design, analysis, planning or other recommendations. These recommendations are intended to be used by the SKA Organisation to inform decisions which will apply Project wide. Membership of an ITT implies that the participating individual, organisation or Consortium agrees to be bound by any decision following from a collective recommendation.*

The purpose of Integrated Tasks is to carry out work that cuts across Element boundaries. The tasks are initiated, organised and coordinated by the SKA Office, and resourced by the Element consortia and the SKA Office. The outputs/deliverables of Integrated Tasks are documented as specific engineering results, methods, and/or recommendations to the System Level.

Current ITTs are summarised in the table below.

Integrated Task Team	Description
4 SKA.TEL.ITT.SSP – System Science Performance	This ITT will be responsible to perform work in support of technical questions, decisions and choices, which affect the overall SKA System Science performance and/or cost. More than one Element will typically be involved, and a trade-off may be necessary between Elements.
4 SKA.TEL.ITT.TRD – System Trades	This ITT will evaluate potential System implementation options against current science goals and cost, on the basis of science performance, risk and cost. The trade space will be provided as a result of external investigations to this ITT at the System and Element Levels, resulting in well-formed trade options.
4 SKA.TEL.ITT.OPS – Observatory Operations	This ITT will be responsible for the development of the complete Concept of Operations (ConOps) for the SKA1, including science and support aspects.
4.SKA.TEL.ITT.CONF - SKA Array Configuration & Topology	This ITT will generate optimised topology designs for infrastructure and network services associated with the Array, and will centralises the work necessary to efficiently analyse Array Configuration change proposals.
4 SKA.TEL.ITT. SWD – Software Development Policies	The goal of this ITT is to is develop a standardized approach to similar problems across the project wherever software is being developed or utilized, and to identify opportunities to re-use software, either across the project or from outside the project.
4.SKA.TEL.ITT.RFI – Development of Policies and standards on EMI, RFI, and shielding	This ITT will develop policies, frameworks and standards to protect the SKA site and the telescope from harmful radio interference during construction and operation of the SKA, and to serve as input requirements into the development and design of equipment.

SKA Elements WBS/SOW Summary Tables

SKA.TEL.DSH – Dishes

		3 SKA.TEL.DSH – Dishes		**LEAD:**	
			4 SKA.TEL.DSH.MGT - Dishes Project Management		
			This WBS element covers the overall project management work to be performed at the Dish Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.	
			4 SKA.TEL.DSH.SE-SRR – Dishes SE to Requirements Review		
			This WBS element covers all the system engineering work of the Dish Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		
			4 SKA.TEL.DSH.SE-VSYS - System Engineering for Verification Systems		
			This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		

			4 SKA.TEL.DSH.INFRA – Dishes Infrastructure Requirements	
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the Dish Element to the Site and Infrastructure Element (SKA.TEL.INFRA).	
			4 SKA.TEL.DSH.PWR – Dishes Power Requirements	
			These are a set of tasks required to support the development and delivery of the power requirements by the Dish Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.	
			4 SKA.TEL.DSH.OPTIC – Optical Design	
			This WBS element provides for the design of the reflective optics for the dish receptor of astronomical signal for frequencies from 450 MHz to 10 GHz. Tasks will include: Analysis of requirements allocated from the Dish Element level, development of a verification plan, development of an architectural design, development of a set of implementation options, and the development of parameterised performance models for each optical design option.	
			4 SKA.TEL.DSH.STRUC – Structure	
			This WBS element provides for the development and analysis of the requirements and models for the structural components needed to support the optical components and all the other physical components of the dish contained above (but not including) the foundation. Tasks will include: Analysis of requirements allocated from the Dish Element level to the dish structure, development of a verification plan, development of an architectural design, development of a set of implementation options, development of parameterised performance and cost models for each option, participate in trade studies, and the identification and definition of interfaces for the structure.	
			4 SKA.TEL.DSH.FEED – Feeds and LNAs	
			There will be two types of dual polarization feeds that needs consideration: Single Pixel Feeds (SPFs) (part of the SKA1 baseline) and Phase Array Feeds (PAFs) (part of the SKA advanced instrumentation). Feeds in general are closely coupled both with the optical design and with the Low Noise Amplifiers (LNAs). Tasks will include: Analysis of requirements allocated from the Dish Element level to the Feeds and LNAs subsystems, development of a verification plan, development of an architectural design(s), development of a set of implementation options, development of parameterised performance and cost models for each option, participate in trade studies, and the identification and definition of interfaces for feeds.	
			4 SKA.TEL.DSH.RCVR – Receivers	
			These are either single pixel feed receivers or phased array feed receivers, both of which receive amplified RF from the feed/LNAs. This WBS element provides for the analysis of requirements allocated from the Dish Element level to the Receiver subsystem, development of a verification plan, development of architectural design(s), development of a set of implementation options, development of parameterised performance and cost models for each option, participate in trade studies, and the identification and definition of interfaces for feeds.	

			4 SKA.TEL.DSH.LMC – Local Monitor and Control		
			The Dish local monitor and control provides computer control of the dish, responds to commands from the central array controller and provides appropriate data on the state of the dish. It interfaces to the telescope manager at the system level. This WBS element provides for the definition of the Local Monitoring and Control assembly aspects for the dishes. Tasks will include the analysis of requirements allocated from the Dish Element level to the Local Monitoring and Control subsystem, development of a verification plan, development of an architectural design(s), development of a set of implementation options, development of parameterised performance and cost models for each option, participate in trade studies, and the identification and definition of interfaces for the dishes Local Monitoring and Control.	
			4 SKA.TEL.DSH.LINFRA – Local Infrastructure		
			Local infrastructure includes the local signal transport, local power distribution, time and frequency (if present), and miscellaneous infrastructure facilities. Tasks include the analysis of requirements allocated from the Dish Element level to the local infrastructure subsystem, development of a verification plan, development of an architectural design(s), development of a set of implementation options, development of parameterised performance and cost models for each option, participate in trade studies, and the identification and definition of interfaces for the dishes local infrastructure.		
			4 SKA.TEL.DSH.VSYS-DVA1 - DVA1 Dish Verification System		
			This WBS element covers all the tasks and activities during Stage 1 for the development and construction of the DVA1 dish verification system. Tasks to be performed as part of the dish verification system include: Management, System Engineering and Design and Development.		
				5 SKA.TEL.DSH.VSYS-DVA1.MGT - DVA1 Verification System: Management	
				Management of the DVA1 Verification System Activity. This is an umbrella task for the management of the DVA1 dish prototype. A subset of the management tasks defined in the Management for the SKA.TEL.DSH tasks will be utilised to manage the execution of the DVA1 Verification System activity, recognizing the size of the task of planning, building and testing prototype dishes. The SKA.TEL.DSH.VSYS DVA1.MGT tasks remain under the overall umbrella of SKA.TEL.DSH.MGT, wherein all of these tasks will be supported. A separately tailored series of meetings, reviews, schedule, change management, risk management, and costing will be needed for the Verification Systems.	
				5 SKA.TEL.DSH.VSYS-DVA1.SE - DVA1 Verification System: System Engineering	
				This WBS element provides System Engineering underpinnings for the DVA1 Verification System development and the necessary links to SKA development. This WBS element encompasses mainly the planning aspects, and SKA.TEL.DSH.VSYS DVA1.D&D encompasses the build, test and reporting aspects of the DVA1 Verification System program. The general purpose is to extract maximum value from the prototyping programs. As closely as possible, the SKA.TEL.DSH.VSYS-DVA1 tasks should proceed in parallel with and support the SKA.TEL.DSH tasks.	

				5 SKA.TEL.DSH.VSYS-DVA1.D&D – DVA1 Verification System: Design and Development	
				First version Verification System Dish: Design, Construct and Test. This WBS element is directed specifically at DVA1. The primary deliverable is a verified behavioural model of DVA1, containing all parameters that materially affect System performance or which must be calibrated. Particular emphasis is to be placed on time-variable behaviour and the associated time scales. This task has begun and will carry on past the Dish Array SRR. Reports on the status of deliverables should be put forward at the Dish Array SRR. Tasks will include the physical design, construction and test of the DVA1, DVA1 definition and design, DVA1 subsystem definition and design, DVA1 sub-system detailed design/build, definition and execution of the DVA1 test program, refined DVA1 cost modelling, a preliminary dish array production cost model, and a DVA1 dish array design impact report.	
			4 SKA.TEL.DSH.VSYS-DVAX - DVAX Dish Verification System		
			This WBS element covers all the tasks and activities during Stage 1 for the development and construction of dish verification system(s) where 'X' is the designator for yet to be determined number of prototypes or engineering models. Tasks to be performed as part of the dish verification system include: Management, System Engineering and Design and Development. Note that all the WBS elements will be applicable to each verification system proposed.		
				5 SKA.TEL.DSH.VSYS-DVAX.MGT - DVAX Verification System: Management	
				Management of the DVAX Verification System Activity. This is an umbrella task for management of one or more dish prototypes or engineering models. A subset of the management tasks defined in the Management for the SKA.TEL.DSH tasks will be utilised to manage the execution of the DVAX Verification System activity, recognizing the size of the task of planning, building and testing prototype dishes. The SKA.TEL.DSH.VSYS-DVAX.MGT tasks remain under the overall umbrella of SKA.TEL.DSH.MGT, wherein all of these tasks will be supported. A separately tailored series of meetings, reviews, schedule, change management, risk management, and costing will be needed for the Verification Systems.	
				5 SKA.TEL.DSH.VSYS-DVAX.SE - DVAX Dish Verification System: System Engineering	
				This WBS element provides System Engineering underpinnings for the DVAX Verification System development and the necessary links to SKA development. This may encompass management of several prototype/engineering-model antennas. This is an umbrella system engineering task one or more dish prototypes or engineering models. This task encompasses mainly the planning aspects, and SKA.TEL.DSH.VSYS DVAX.D&D encompasses the build, test and reporting aspects of the DVAX Verification System program. The general purpose is to extract maximum value from the prototyping programs. As closely as possible, the SKA.TEL.DSH.VSYS-DVAX tasks should proceed in parallel with and support the SKA.TEL.DSH tasks.	
				5 SKA.TEL.DSH.VSYS-DVAX.D&D – DVAX Dish Verification System: Design and Development.	
				First version Verification System Dish: Design, Construct and Test. The primary deliverable is a verified behavioural model of DVAX, containing all parameters that materially affect System performance or which must be calibrated. Particular emphasis is to be placed on time-variable behaviour and the associated time scales. This task has begun and will carry on past the Dish Array SRR. Reports on	

				the status of deliverables should be put forward at the Dish Array SRR. Tasks will include the physical design, construction and test of the DVAX, DVAX definition and design, DVAX subsystem definition and design, DVAX sub-system detailed design/build, definition and execution of the DVAX test program, refined DVAX cost modelling, a preliminary dish array production cost model, and a DVAX dish array design impact report.	
Notes:					

SKA.TEL.LFAA - Low Frequency Aperture Array (LFAA)

		3 SKA.TEL.LFAA - Low Frequency Aperture Array	**LEAD:**	
			4 SKA.TEL.LFAA.MGT – Low Frequency Aperture Array Project Management	
			This WBS element covers the overall project management work to be performed at the Low Frequency Aperture Array Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.	
			4 SKA.TEL.LFAA.SE-SRR – LFAA SE to Requirements Review	
			This WBS element covers all the system engineering work of the Low Frequency Aperture Array Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.	
			4 SKA.TEL.LFAA.SE-VSYS - System Engineering for Verification Systems	
			This WBS element provides System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.	
			4 SKA.TEL.LFAA.CNF – Configuration	
			This WBS element covers all the work required for investigations into the configuration of the aperture array at the intra- and inter-station level. Tasks will include the analysis of the requirements, study of calibration requirements from the LFAA calibration, study of the configurations of all low frequency pathfinders, investigation of the performance of possible LFAA configurations utilising the appropriate	

			simulation tools, and reporting on the results.				
			4 SKA.TEL.LFAA.CAL – Calibration				
			This WBS element contains the activities to be performed to move the calibration for SKA LFAAs from CoDR to SRR level. Tasks will include the analysis of the calibration requirements, verification that the configuration options can meet the requirements, development of station calibration strategy, and plans to verify the calibration strategy theoretically and practically.				
			4 SKA.TEL.LFAA.VSYS – Verification Systems				
			This WBS is a combination of all the LFAA verification systems planned to prepare or build for Stage 1: AAVS0 and AAVS1. These are major design, construction and test projects in their own right. Hence appropriate project management and system engineering is required. It is necessary to design these systems to demonstrate and verify the performance of the SKA LFAA implementation. This will be justified as part of the LFAA.SE-VSYS deliverables.				
				5 SKA.TEL.LFAA.VSYS.MGT - Management			
				This is a grouping of management tasks required to support the delivery of the verification systems for the LFAA. The appropriate tasks from the overall LFAA project management (LFAA.MGT) are inherited.			
				5 SKA.TEL.LFAA.VSYS.SE - System Engineering			
				This is a grouping of system engineering tasks required to support the delivery of the verification systems for the LFAA. The appropriate tasks from the overall LFAA system engineering are inherited. This is complementary to the LFAA.SE-VSYS tasks.			
				5 SKA.TEL.LFAA.VSYS.AAVS0 – Verification System AAVS0			
				This WBS element is the high level combination of the seven individual sub-system work packages to build the LFAA verification system AAVS0. The detail of the tasks is provided in the level 6 WBS elements below.			
					6 SKA.TEL.LFAA.VSYS.AAVS0.SDD – System Definition & Design		
					This WBS element provides for the word to define and to design the AAVS0 verification system. The goal of this verification system is to demonstrate and compare the single element performance of the antenna concepts which were presented during the LFAA CoDR. Tasks will include the development and documentation of the architecture of AAVS0.		
					6 SKA.TEL.LFAA.VSYS.AAVS0.PR – Production		
					This WBS element contains all work related to the investigations towards the production of the AAVS0 verification system. Since the amount of hardware is limited this work package is focusing on the intellectual property matters primarily.		
					6 SKA.TEL.LFAA.VSYS.AAVS0.INS – Installation		
					This WBS element contains all the planning work required to eventually install the delivered AAVS0 components on a site. Tasks will include the derivation of the installation requirements for AAVS0.		

					6 SKA.TEL.LFAA.VSYS.AAVS0.TLG – Tooling	
					This WBS element contains the identification, specification, production and deployment plan for equipment (tools) required for the installation of the AAVS0 system. Tasks will include the identification and definition of the required tools.	
					6 SKA.TEL.LFAA.VSYS.AAVS0.INT – Integration	
					This WBS element contains all work required in defining the integration of all the components of the verification system. It also contains all work similarly required for the integration of the LFAA system into the overall SKA telescope. Tasks will include the development of an integration plan and establishing a preliminary list of all components required in the verification system.	
					6 SKA.TEL.LFAA.VSYS.AAVS0.VF – Verification	
					This WBS element contains all work required for the actual verification tests of AAVS0. Note that this is distinct from the overall strategy, planning and scheduling task of all verification items (SKA.TEL.LFAA.SE.VSYS). Tasks will include the development of component-level test plans and organising of the component-level testing hierarchically to match to the next level.	
					6 SKA.TEL.LFAA.VSYS.AAVS0.TAR – Test Assessment & Reporting	
					This WBS element covers all activities related to the test assessment of the AAVS0 verification system. Tasks include the performance of the verification of the integrated verification system as written in the test & verification plan for AAVS0. Several verification methods exist like inspection, test, demonstration, analysis and simulation. All these results will be wrapped up and written down in this task.	
				5 SKA.TEL.LFAA.VSYS.AAVS1 – Verification System AAVS1		
				This WBS is a combination of seven individual sub-system work packages to build the LFAA verification system AAVS1. These are major design, construction and test projects in their own right. It is necessary to design these systems to demonstrate and verify the performance of the SKA LFAA implementation. As part of the programme the work associated with production and installation is essential prior to verification. The actual production and build of AAVS1 is work defined is in Stage 2. The detail of the tasks is provided in the level 6 WBS elements below.		
					6 SKA.TEL.LFAA.VSYS.AAVS1.SDD – System Definition & Design	
					This WBS element is to define the AAVS1 verification system and to design AAVS1. The goal of the verification systems is to demonstrate the performance of the evolving design of the AA for SKA Phase 1 and to provide information for the selection of sub-systems for alternative designs. Tasks include the definition of the results required from the demonstrator AAVS1, and the definition of the architecture roadmap from AAVS0 to SKA1 and SKA2.	
					6 SKA.TEL.LFAA.VSYS.AAVS1.PR – Production	
					This WBS element contains all work related to the definition of production requirements of the AAVS1 verification system. Tasks will include the preparation of plans for production tendering and definition of the documentation set required for this including	

					assembly test plans, establishing relevant links with industry and evaluate proposed options, and the communication of opportunities for the pre-construction phase.	
					6 SKA.TEL.LFAA.VSYS.AAVS1.INS – Installation	
					This WBS element contains all planning of the work that will be required to install the delivered components on the site. This includes site assembly, deployment and commissioning. Tasks will include coordination meetings with the Site and Infrastructure element, derivation of installation requirements, and the planning of work to be carried out in the next phase of the project.	
					6 SKA.TEL.LFAA.VSYS.AAVS1.TLG – Tooling	
					This WBS element contains the identification, specification, production and deployment plan for equipment (tools) required for the installation of the AAVS1 system. Tasks will include the identification and definition of the required tools.	
					6 SKA.TEL.LFAA.VSYS.AAVS1.INT – Integration	
					This WBS element contains all work required in defining the integration of all AAVS1 components in the verification system. It also contains all work similarly required for the integration of the LFAA system into the overall SKA telescope. Tasks will include the development of an integration plan for LFAA, establishing a list of all components required in the verification system, and the planning of the work to be carried out in the next phase of the project (PDR).	
					6 SKA.TEL.LFAA.VSYS.AAVS1.VF – Verification	
					This WBS element contains all work required for to plan the actual verification tests of AAVS1. Note that this is distinct from the overall strategy, planning and scheduling task of all verification items (SKA.TEL.LFAA.SE.VSYS). Tasks will include the development of component-level test plans, organise component-level testing hierarchically and match to next level, and planning of the work to be carried out in the next phase of the project (PDR).	
					6 SKA.TEL.LFAA.VSYS.AAVS1.TAR – Test Assessment & Reporting	
					This WBS element covers all activities related to the test assessment of the verification systems. All tests as specified in the test and verification plan are executed in this SOW. Hence this task will be carried out for AAVS1 in Stage 2 of the Pre-Construction phase. Tasks include the assessment of the performance of the verification of the integrated verification system as written in the test & verification plan. Several verification methods exist like inspection, test, demonstration, analysis and simulation.	
			4 SKA.TEL.LFAA.LMC – Local Monitoring & Control			
			This WBS element provides for the definition of the Local Monitoring and Control assembly aspects for the LFAA system that is necessary for local monitoring and control of the LFAA system components. These elements will form part of the overall SKA control and monitoring hierarchy and so will be developed in consultation with system-wide control and monitoring. Tasks will include the analysis of requirements allocated from the LFAA Element level to the Local Monitoring and Control subsystem, definition of the Local Monitoring and Control, development of a set of implementation options, and the identification and definition of interfaces for the LFAA Local Monitoring and Control.				

			4 SKA.TEL.LFAA.LINFRA – Local Infrastructure		
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements and solution options for the LFAA local infrastructure.		
				5 SKA.TEL.LFAA.LINFRA.SHH – Station Hardware Housing	
				This WBS defines the requirements for the electronic enclosures associated with the LFAA. This will depend strongly on the final station architecture; hence some alternatives will be considered at this stage. Tasks will include the preparation of specifications of the housings in terms of RFI, environmental etc., design of the mechanical requirements of the power filters, fibre input, cooling ports and door of the main beamformer housing, and costing of the solutions.	
				5 SKA.TEL.LFAA.LINFRA.CL – Cooling	
				This WBS is closely associated with the station hardware housing. Due to the power requirements of the LFAA beamforming there will be a significant cooling requirement. The cooling needs will be wherever there is heat dissipating electronics. For the LFAA station this will be at the antenna element, possibly at the “digitisation boxes” if installed and particularly at the main beamformer enclosure. At this early stage the work will mostly be identifying the scale of the problem and considering alternative solutions for future investigation. Tasks will include a survey of cooling techniques used on existing instruments and comment on their effectiveness, calculation of the cooling ability of the digitisation box, calculation of the cooling ability at the antenna element level, and the definition of the plan for Stage 2 concerning cooling	
				5 SKA.TEL.LFAA.LINFRA.PWR – Power	
				The purpose of this activity, which will likely run during Stage 1 and Stage 2 pre-construction phases, is to assess and document LFAA specific power requirements and distribution, and to pass them to the higher-level SKA pre-construction work packages dealing with telescope power demand and supply. Tasks will include the initial power distribution requirements and design for the AAVS1 verification system, and the power distribution planning for Stage 2.	
				5 SKA.TEL.LFAA.LINFRA.TFD – Time/Freq. Distribution	
				This WBS element covers all the activities to be performed for definition of the Time/Frequency distribution within a low frequency AA station. Tasks will include the study of the sync and timing requirements from the Design Reference Mission, the analysis of the impact and effects of the time/freq distribution network on the overall station architecture and cost, definition of the selection criteria for time/freq distribution, definition of the interface with the wide area Time/Frequency network distribution and/or Time/Frequency local generation, and the comparison between COTS and ad hoc solutions	
			4 SKA.TEL.LFAA.AL – Antenna & LNA		
			This WBS element covers the activities to be performed related to the comparison of the Antennas and LNA designs for the Single and Dual Band options.		

				5 SKA.TEL.LFAA.AL.SB – Single Band	
				This WBS element covers all the activities related to the antennas and LNA for the low frequency single band option. Tasks will include the design of integrated single band antenna(s) & LNA(s), for each possibility undertake verification of radiation pattern and noise temperature measurements of a single antenna and a small array of such antennas, analysis of the effects on sensitivity versus scan angle within typical LFAA configurations, studies of manufacturability and element production cost estimates, and the manufacturing and testing of pre-production prototypes of integrated antenna/LNA.	
				5 SKA.TEL.LFAA.AL.DB – Dual Band	
				This WBS element covers all the activities related to the antennas and LNAs for the low frequency dual band option. Tasks will include array configuration performance studies, assessing by measurement and calculation likely effects of mutual coupling, analysis of the effects on sensitivity versus scan angle, and the manufacturing and test of a pre-production prototypes of integrated antennas/LNA.	
			4 SKA.TEL.LFAA.RCV – Receiver		
			This WBS element covers all the activities to be performed for the design and realization of the LFAA receiver. The receiver is defined as the block from the output of LNA to the output of the ADC.		
				5 SKA.TEL.LFAA.RCV.DNA – Receiver Near the Antenna	
				This WBS element covers all the activities related to the architecture of the receivers including the A/D conversion near the antenna. The task also considers all the aspects related to designing the receiver and to enable digitisation close to the receptor. Tasks will include investigation of the implications of the digitisation close to the antenna in terms of self generated RFI, determination of the cost and power consumption of such an architecture, development of cost and performance models, and the design of a mechanical solution.	
				5 SKA.TEL.LFAA.RCV.DCH – Receiver Central Housing	
				This WBS element covers all the activities related to the Receiver Central Housing. The RCV.DCH task considers all the aspects related to the design of the receiver far away from the receptor. Tasks will include the design of a LFAA architecture based on the fact that the ADCs are in a central housing, the determination of the cost and power consumption of such an architecture, and the development of cost and performance models.	
				5 SKA.TEL.LFAA.RCV.ABF – Analogue Beamformer	
				This WBS element covers all the activities related to the Analogue Beamformer. Task will include the investigation into the use of an analogue beamformer in terms of cost, power, performance, system complexity and system reliability, the analysis of the number of antenna elements which should be combined in an analogue beamformer, identification of beamformer technology concepts, identification of physical concepts of physical architectures, and the development of cost and performance models.	

				5 SKA.TEL.LFAA.RCV.AST – Analogue Signal Transport	
				This WBS element covers all the activities related to Analogue Signal Transport (AST). For AST we consider the connection between receptor to the ADC. Tasks will include the evaluation of the best performing and affordable RF over fibre (RoF) system in the lab, performing of field tests, continuation of the development of VCSEL-based options, trade off studies, identification of specifications and selection criteria, and definition of a the plan for Stage 2.	
			4 SKA.TEL.LFAA.SP – Signal Processing		
			This WBS element contains all activities related to the signal processing for LFAA required for Stage 1 of the pre-construction phase.		
				5 SKA.TEL.LFAA.SP.AR – Algorithm	
				This WBS element is concerned with the necessary algorithms required for the AA stations in software. It covers both calibration algorithms and software necessary to control the AA station. Tasks will include the analysis of the LFAA calibration requirements from the LFAA calibration document and analyse the required algorithms for this, analysis of the resources required for the calibration algorithms and control, analysis of implementation options, and the definition of the additional work for the algorithms required in Stage 2.	
				5 SKA.TEL.LFAA.SP.ARC – Architecture	
				This WBS element is concerned with the beamforming architecture for LFAA in Stage 1 of the pre-construction phase. Tasks will include the analysis and comparison of various beamforming architectures, study of the realisations of these architecture(s), specification for the station beamforming algorithms, and the study of realisation of these algorithms.	
				5 SKA.TEL.LFAA.SP.FB – Filterbank	
				This WBS element is concerned with the design of the digital filterbank immediately after the Analogue-to-Digital Conversion (ADC). Tasks will include study of the spectral dynamic range and channel width requirements, specification for digital filterbank that meets requirements, design and and simulation of the filterbank, and implementation and testing of the filterbank in an FPGA structure.	
				5 SKA.TEL.LFAA.SP.DBF – Digital Beamformer	
				This WBS element is concerned with the design of the digital beamformer in the first and second stage processing. Tasks will include study of spatial dynamic range and sky coverage requirements, specification of the digital beamformer that meets requirements, study of realisations of the beamformer, design, simulation, implementation into and FPGA structure and the testing of the filterbank.	
				5 SKA.TEL.LFAA.SP.COR – Station Correlator	
				This WBS element is concerned with the Aperture Array Station correlator possibly required for calibrating the individual antenna element analogue chains. Tasks will include study of calibration requirements from the LFAA calibration document, specification for the station correlator that meets requirements, design and implement a correlator structure, and the analysis of the costs and power implications of station correlator.	

				5 SKA.TEL.LFAA.SP.DST – Digital Signal Transport	
				This WBS element is concerned with the Digital Signal Transport within an Aperture Array station. Tasks will include the study of signal transport requirements, specification for the signal transport system that meets requirements, design of the digital signal transport system for the verification systems, and the plan for Stage 2 for the digital signal transport within the AA station.	
				4 SKA.TEL.LFAA.INFRA – LFAA Infrastructure Requirements	
				This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the LFAA Element to the Site and Infrastructure Element (SKA.TEL.INFRA).	
				4 SKA.TEL.LFAA.PWR – LFAA Power Requirements	
				These are a set of tasks required to support the development and delivery of the power requirements by the LFAA Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.	
Notes:					

SKA.TEL.SADT - Signal and Data Transport (SaDT)

		3 SKA.TEL.SADT - Signal and Data Transport (SaDT)		**LEAD:**	
			4 SKA.TEL.SADT.MGT – SADT Project Management		
			This WBS element covers the overall project management work to be performed at the Signal and Data Transport Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
			4 SKA.TEL.SADT.SE-SRR – SADT SE to Requirements Review		
			This WBS element covers all the system engineering work of the Signal and Data Transport Element to bring the Element to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		
			4 SKA.TEL.SADT.SE-VSYS - System Engineering for Verification Systems		
			This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		
			4 SKA.TEL.SADT.NWA – Network Architecture		
			This WBS element contains those co-ordination and technical management tasks required in order to establish a network architecture and preliminary design for the combined SKA network entity carrying Synchronisation, Telescope Manager and Digital Data Back Haul Signals. The analysis tasks required in order to support the delivery of cost optimised network topologies for the SaDT Element Requirements		

			Review are included here.		
				5 SKA.TEL.SADT.NWA.TOP – Topology Design	
				This WBS element combines all the models from • SKA.TEL.SADT.SAT - Synchronisation and Timing • SKA.TEL.SADT.TM - Telescope Manager • SKA.TEL.SADT.DDBH - Digital Data Back haul into one combined model that can be used in trade studies at the System Level concerned with optimised array configurations and optimised topology layouts. Tasks will include the analysis of link length by distance bin,the derivation of physical layer topology models for the analysis of array configurations, and the development of an optimised node and link and design for physical layer networks.	
				5 SKA.TEL.SADT.NWA.OTD – Optical Transmission Design	
				This WBS element includes all those analysis activities that form a complete optical design model for the SKA and will produce recommendations on the integration (or not) of a combined optical transmission system for SaDT and TM links. Tasks will include the assessment of commercial software modelling packages, and performance analysis modelling.	
			4 SKA.TEL.SADT.NMGR – Network Manager		
			This WBS element includes all those analysis activities in order to establish a strategy and preliminary design for the management of the SKA network entities. Tasks will include requirements analysis for network management, development of a verification plan, review of the options including vendor survey, architecture descriptions including behavioural and structural models, and the development of cost & parametric models.		
			4 SKA.TEL.SADT.DDBH – Digital Data Back Haul		
			This WBS element contains those co-ordination and technical management tasks required to support the delivery of cost optimised network topologies for the SaDT Element Requirements Review. It will address specifically the transport of digital signals from the receptor technologies to a central processing facility.		
				5 SKA.TEL.SADT.DDBH.PKT – Packetisation	
				This WBS element includes all those analysis activities in order to derive; frames packets, synch and syntax in the data exchange mechanisms of the digital data backhaul. Tasks will include requirements analysis, development of a verification plan, identification of applicable transmission protocols, establishing any additional frame metadata requirements and the determination of data alignment methodologies.	
				5 SKA.TEL.SADT.DDBH.DT – Data Transmission	
				This WBS element includes all those analysis tasks required to derive a preliminary design based on requirements. Tasks will include requirements analysis, development of a verification plan, the review of the options, and an optical design based on options.	

				5 SKA.TEL.SADT.DDBH.FLC – Fibre Link Components	
				This WBS element includes all those analysis activities in order to establish a technology roadmap for the Element. Tasks will include the review of fibre link components including suppliers, technology roadmaps by component, state of the art devices, commodity devices price points and performance.	
				5 SKA.TEL.SADT.DDBH.IMGR – Interface Management	
				This WBS element includes all those analysis activities in order to derive interface descriptions for the Element. Tasks will include scoping of the boundaries, identification and definition of internal and external interfaces.	
				5 SKA.TEL.SADT.DDBH.NWA – Network Architecture	
				This WBS element includes all those activities involved with participation in the design of optimised combined physical layer networks for SaDT. Tasks will include the analysis of optimised Link and node layouts based on preliminary designs, and the assembly of appropriate models.	
			4 SKA.TEL.SADT.TM – Telescope Management SaDT		
			This WBS element contains those co-ordination and technical management tasks required to support the delivery of the needs of the telescope management network		
				5 SKA.TEL.SADT.TM.PNET – Production Network	
				This WBS element includes all those analysis activities in order to develop preliminary designs for SRR for the Telescope Manager (SKA.TEL.MGR) Production Network. Tasks will include requirements analysis, development of a verification plan, review of options, development of architectural descriptions, cost and parametric models, and physical design.	
				5 SKA.TEL.SADT.TM.ENET – Engineering Network	
				This WBS element includes all those analysis activities in order to develop preliminary designs for SRR for the Telescope Manager Commissioning Network, used for engineering purposes. Tasks will include requirements analysis, development of a verification plan, review of options, development of architectural descriptions, cost and parametric models, physical design, and installation and operational planning.	
				5 SKA.TEL.SADT.TM.SNET – Safety Critical Functions	
				This WBS element includes all those analysis activities in order to ensure designs include Telescope Manager Safety Critical Functionality. Tasks will include requirements analysis, development of a verification plan, review of options, development of architectural descriptions, cost and parametric models, and physical design.	
				5 SKA.TEL.SADT.TM.IMGR – Interface Management	
				This WBS element includes all those analysis activities in order to derive interface descriptions for the Element. Tasks will include the scoping of the boundaries, and the identification and definition of external and internal interfaces.	

				5 SKA.TEL.SADT.TM.NWA – Network Architecture	
				This WBS element task includes all those activities involved with participation in the design of optimised combined physical layer networks for SaDT. Tasks will include collaboration in the design of optimised physical layer networks, assembly of appropriate models, and establishing of redundant links.	
			4 SKA.TEL.SADT.CSP - Central Processor Data Transmission		
			This WBS element contains those co-ordination and technical management tasks required to support the delivery of cost optimised architectures for the SaDT Element Requirements Review. It will address, specifically, the needs of the central processor data transmission which is the connection between the central processing facility and the High Performance computing facility.		
				5 SKA.TEL.SADT.CSP.DT – Data Transmission	
				This WBS element includes all those analysis tasks required to derive a preliminary design based on requirements. Tasks will include requirements analysis, development of a verification plan, review of options, development of architectural descriptions, cost and parametric models, and contributing to protocol standard activities.	
				5 SKA.TEL.SADT.CSP.FI – Facility Interconnect	
				This WBS element includes all those analysis tasks required to derive a preliminary design based on requirements. Tasks will include requirements analysis, development of a verification plan, review of options, review of facility interconnect components and services, development of architectural descriptions, and cost and parametric models.	
			4 SKA.TEL.SADT.DP - Data Processor Data Transmission		
			This WBS element contains those co-ordination and technical management tasks required to support the delivery of cost optimised network topologies for the SaDT Element Requirements Review. It will address, specifically, the needs of the High Performance computing data transmission which is the connection between the High Performance computing facility and the wider world		
				5 SKA.TEL.SADT.SDP.DT – Data Transmission	
				This WBS element includes all those analysis tasks required to derive a preliminary design based on requirements. Tasks will include requirements analysis, development of a verification plan, review of options, development of architectural descriptions, cost and parametric models, and contributing to protocol standard activities.	
				5 SKA.TEL.SADT.SDP.FI – Facility Interconnect	
				This WBS element includes all those analysis tasks required to derive a preliminary design based on requirements. Tasks will include requirements analysis, development of a verification plan, review of options, review of facility interconnect components and services, development of architectural descriptions, and cost and parametric models.	
			4 SKA.TEL.SADT.RET – Reticulation		
			This WBS element includes all those activities required to deliver the fibre optic cable part of the physical layer network that will serve all		

			parts of the telescope. It will also consider design, installation and operational questions related to the cabled network.		
				5 SKA.TEL.SADT.RET.IMGT – Interface Management	
				This WBS element includes all those analysis activities in order to derive interface descriptions for the Element. Tasks will include the identification, definition and categorisation of external and internal interfaces.	
				5 SKA.TEL.SADT.RET.INSR – Installation Planning	
				This WBS element includes all those analysis activities required to establish recommendations on standards in the Physical layer networks. Tasks will include the review of installation techniques, best practice recommendations, drafts of installation procedures, supplies handling plan, and a procurement plan.	
				5 SKA.TEL.SADT.RET.OPS – Operations Planning	
				This WBS element includes all those analysis activities required to establish recommendations on operations strategies in the Physical layer networks and their impact on the design. Tasks will include maintenance and RAM analysis.	
				5 SKA.TEL.SADT.RET.CABE – Cable Equipment and Components	
				This WBS element includes all those analysis activities required to establish recommendations on equipment, components and services for Physical layer networks. Tasks will include review of physical layer components, and the development of the verification and assessment of the cable infrastructure.	
				5 SKA.TEL.SADT.RET.RH – Record Handling	
				This WBS element involves the development of concepts for the capturing of design records, as-built records and the maintenance of accurate network asset registers for inventory and maintenance during operation. Tasks will include the investigation and cost the implementation of asset management databases, development of practices and procedures required during design, installation and operation, and support standardisation activities.	
			4 SKA.TEL.SADT.INFRA – SADT Infrastructure Requirements		
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the SaDT Element to the Site and Infrastructure Element (SKA.TEL.INFRA).		
			4 SKA.TEL.SADT.PWR – SADT Power Requirements		
			These are a set of tasks required to support the development and delivery of the power requirements by the SaDT Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.		
Notes:					

SKA.TEL.CSP - Central Signal Processor (CSP)

		3 SKA.TEL.CSP - Central Signal Processor (CSP)	**Lead:**	
			4 SKA.TEL.CSP.MGT - CSP Project Management	
			This WBS element covers the overall project management work to be performed at the Central Signal Processor Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.	
			4 SKA.TEL.CSP.SE-SRR – CSP SE to Requirements Review	
			This WBS element covers all the system engineering work of the Central Signal Processor Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.	
			4 SKA.TEL.CSP.SE-VSYS – System Engineering for Verification Systems	
			This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.	
			4 SKA.TEL.CSP.INFRA - CSP Infrastructure Requirements	
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the CSP Element to the Site and Infrastructure Element (SKA.TEL.INFRA).	

			4 SKA.TEL.CSP.PWR – CSP Power Requirements			
			These are a set of tasks required to support the development and delivery of the power requirements by the CSP Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.			
			4 SKA.TEL.CSP.CBF – Correlator and Central Beamformer			
			This WBS element provides for is the generation of the first draft document sets describing the Architecture of the Correlator and Central Beamformer sub-system within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of architecture design documents, physical model for the sub-system, interface control documents applicable at the sub-system level, design specifications and/or procurement specifications, and verification and/ or acceptance plans.			
				5 SKA.TEL.CSP.CBF.MGT – CBF Management		
				This WBS element provides for the Management Control Activity for the Correlator and Central Beam-Former –this is a subset of the management control tasks applied to the Correlator and Central Beamformer assemblies in support of the CSP SRR. Tasks will include project planning, reporting, control, and resource management.		
				5 SKA.TEL.CSP.CBF.SE – CBF System Engineering		
				This WBS element provides for the System Engineering Control Activity – this is a subset of the system engineering tasks applied to the Correlator and Central Beamformer assemblies in support of the CSP SRR. Tasks will include the development of the documents to support the CSP SRR including first draft architecture descriptions, interfaces, costs of options, and requirements.		
					6 SKA.TEL.CSP.CBF.SE.DSH – Dish Correlator and Central Beamformer	
					This WBS element provides for the generation of the first draft document sets describing the Functional and Physical Architecture of the Dish Correlator and Central Beamformer assembly within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of architecture design documents, physical models for the assembly, interface control documents applicable at the assembly level, design specifications and/or procurement specifications, and verification and/ or acceptance specifications. It is anticipated that different physical architectures based on different technology types (potentially including but not limited to ASIC, FPGA, GPU) can be described within different but parallel document sets. Selection criteria will eventually be applied to these to determine which are suitable to progress beyond the CSP SRR.	
					6 SKA.TEL.CSP.CBF.SE.AA – Aperture Array Correlator and Central Beamformer	
					This WBS element provides for the generation of the first draft document sets describing the Functional and Physical Architecture of the AA Correlator and Central Beamformer assembly within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of architecture design documents, physical model for the assembly, interface control documents applicable at the assembly level, design specifications and/or procurement specifications, and verification	

					and/ or acceptance specifications. It is anticipated that different physical architectures based on different technology types (potentially including but not limited to ASIC, FPGA, GPU) can be described within different but parallel document sets. Selection criteria will eventually be applied to these to determine which are suitable to progress beyond the SRR.	
			4 SKA.TEL.CSP.NIP – Non-Imaging Processor (NIP)			
			This WBS element provides for the generation of the first draft document sets describing the Architecture of the Non-Imaging sub-system within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of architecture design documents, physical model for the sub-system, interface control documents applicable at the sub-system level, design specifications and/or procurement specifications, and verification and/ or acceptance plans. This work package is the generation of the documentation of all the Non-Imaging Aspects of the Central Signal Processor with the exception of Data archiving and data bases.			
				5 SKA.TEL.CSP.NIP.MGT – NIP Management		
				This WBS element provides for the NIP Management Control Activity –This is a subset of the management control tasks applied to the Non-Imaging Processor assemblies in support of the CSP SRR. Tasks will include project planning, reporting, control, and resource management.		
				5 SKA.TEL.CSP.NIP.SE – NIP System Engineering		
				This WBS element provides for the NIP System Engineering Control Activity – this is a subset of the system engineering tasks applied to the NIP subsystem in support of the CSP SRR. Tasks will include first draft document of assembly level requirements, first draft physical model documents, draft design specifications, interface documents, and procurement specifications.		
					6 SKA.TEL.CSP.NIP.SE.SEARCH – Pulsar Search	
					This WBS element provides for the generation of the first draft document sets describing the Physical Architecture of the Pulsar Search sub-system within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of architecture design documents, physical model for the assembly, interface control documents applicable at the assembly level, design specifications and/or procurement specifications, and verification and/ or acceptance specifications. It is anticipated that different physical architectures based on different technology types can be described within different but parallel document sets. Selection criteria will eventually be applied to these to determine which are suitable to progress beyond the CSP SRR.	
					6 SKA.TEL.CSP.NIP.SE.TIMING – Pulsar Timing	
					This WBS element provides for the generation of the first draft document sets describing the Physical Architecture of the Pulsar Timing sub-system within the context of the Pre-Construction Phase stage 1 Central Signal Processor SRR. Tasks will include the development of Architecture design descriptions, physical model for the sub-system, interface control documents applicable at the	

					sub-system level, design specifications and/or procurement specifications, and verification and/ or acceptance specifications. It is anticipated that different physical architectures based on different technology types can be described within different but parallel document sets. Selection criteria will eventually be applied to these to determine which are suitable to progress beyond the SRR.	
			4 SKA.TEL.CSP.CLK – Clock and Timing Distribution			
			This WBS element provides for the definition of the distribution of common clocks within the CSP Element, synchronisation and time reference to the sub systems that constitute the Central Signal Processor Infrastructure Clock and Timing assembly and its interface to the SKA timing defined as part of the Synchronisation and timing group. Tasks will include analysis of functional aspects of Clock and Timing Distribution, development of functional and non-functional requirements, and first pass of one or more physical implementations.			
			4 SKA.TEL.CSP.LMC - Local Monitoring and Control			
			This WBS element provides for the definition of the Local Monitoring and Control assembly aspects of the CSP. Tasks will include development of architecture description document, requirements document, physical model descriptions, and interface and verification plans.			
			4 SKA.TEL.CSP.DRSK – Central Signal Processor De-Risking			
			This WBS element is a place holder for de-risking activities that involve design studies based on physical items including hardware and software. Multiple instances of this work package can be invoked. Tasks will include the identification of the risk the activity will mitigate, development of design specifications, performing the activity and recording of results.			
Notes:						

SKA.TEL.SDP Science Data Processor (SDP)

		3 SKA.TEL.SDP Science Data Processor (SDP)		**LEAD:**	
			4 SKA.TEL.SDP.MGT - SDP Project Management		
			This WBS element covers the overall project management work to be performed at the Science Data Processor Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
			4 SKA.TEL.SDP.SE-SRR – SDP SE to Requirements Review		
			This WBS element covers all the system engineering work of the Science Data Processor Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, resource modelling, operations, sustaining engineering, software development environment, standardisation activities , system engineering approach, stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		
			4 SKA.TEL.SDP.SE-VSYS – System Engineering for Verification Systems		
			This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		
			4 SKA.TEL.SDP.SSUP – Science Support and Simulation		
			This WBS element covers all the activities within the system engineering environment to support interaction with science teams through strengthening shared understandings of the implications of science requirements and science data processor constraints. Tasks will include support for system level simulations, development of plan for SDP simulation and verification, analysis of data challenges.		

			4 SKA.TEL.SDP.DATA – SDP Data Layer		
			This WBS element covers all the activities to collect requirements and architectural elements about data related services to be provided by the SDP internally, to other SKA elements and the outside world. This includes the SKA wide development and definition of data models, the identification of data flow and data life-cycle requirements, as well as the collection of SDP wide database requirements and the meta data exchange with TM. A number of the tasks will require prototyping and large scale testing of available solutions or proposed new solutions. All of the sub-elements have to capture requirements for the development, roll-out, commissioning and full operations phases of the SKA and a mixture of those phases		
				5 SKA.TEL.SDP.DATA.FLOW – Data Flow	
				This WBS element covers all the activities for the definition of resource requirements to temporarily or persistently keep the various data product levels and other auxiliary data. This element is closely related to the data life-cycle modelling element, but deals with the questions of what has to be transferred to where, how fast and for which users. The impact of RFI mitigation strategies must be considered. Tasks will include requirements analysis, analysis of data paths, and analysis of networks requirements.	
				5 SKA.TEL.SDP.DATA.LIFE – Data Life-Cycle	
				This WBS element covers all the activities for the collection of requirements to temporarily or persistently keep the various data product levels and other auxiliary data. This element is closely related to the data-flow modelling element, but deals with the questions of what has to be kept where, for how long and for which users. Tasks will include requirements analysis and documentation.	
				5 SKA.TEL.SDP.RES.DB – Data Base	
				This WBS element covers all the activities for the collection of requirements for database services within and outside the SDP. Analysis of commonalities and differences and impact of design and implementation choices on development and operational resources. Tasks will include requirements analysis and documentation.	
				5 SKA.TEL.SDP.DATA.MODEL – Data Modelling	
				This WBS element covers all the activities for the collection of requirements for data models within the SKA. This includes data models for all data products, but also data models to support the data flow and data life cycle management across the whole SKA, the regional centres and the users. The most visible of these data models is the science data archive data model, which also implements the main query capabilities for the SKA archive. The data modelling element also includes investigation on storage and serialisation/interface data formats.	
				5 SKA.TEL.SDP.DATA.TM – Data Interfaces to Telescope Manager (TM)	
				This WBS element covers all the activities to define the data interfaces between SDP and TM. The SDP and TM will share substantial amounts of data and meta-data as well as functions. This element is responsible for defining the data interfaces between SDP and TM in terms of interface functionality and data content. Essentially this element should answer the questions what data is required by which user, where, when, how often and what is the maximum allowed latency. The impact of RFI mitigation strategies must be considered.	

					Tasks will include requirements analysis and capture, and development of interface descriptions and documentation.	
			4 SKA.TEL.SDP.PIP – Processing Pipelines			
			Pipelines are algorithms implemented in software running in quasi-real time on computer hardware. They are components of, and when taken together form the software system. There are at least four families of pipeline which will be required - calibration, imaging, time-series, and science data processing. In addition an Aperture-Array (AA) specific pipeline dealing with AA specific algorithmic considerations will be considered. Tasks include continuation of the development, analysis and scoping of these algorithms considering in particular scalability to SKA and provides input to inform Architectural and Requirements analysis.			
				5 SKA.TEL.SDP.PIP.IM – Imaging Pipelines		
				Pipelines are algorithms implemented in software running in quasi-real time on computer hardware. Imaging pipelines transform interferometric visibility data (also termed u-v data) produced by correlation and time and frequency integration into voxels in calibrated image cubes, astrometric data relating to the sky distribution of sources, or statistical data relating to the sky distribution of sources. Tasks will focus on the definition of requirements for imaging pipelines for the SKA Phase 1 Science Data Processor.		
					6 SKA.TEL.SDP.PIP.IM.ALG – Algorithm development for imaging pipelines	
					This WBS element focuses on algorithm development for the SKA Phase 1 Science Data Processor software that will process visibility data in quasi-real time pipeline mode. Each algorithm must be accompanied by a cost model. Tasks will include gap analysis, investigation into existing algorithms, estimation of deployment in SKA1, and development of cost model.	
				5 SKA.TEL.SDP.PIP.CAL - Calibration Pipelines		
				Pipelines are algorithms implemented in software running in quasi-real time on computer hardware. Calibration pipelines derive calibration parameters needed to correct the visibility data back to ideal values. Tasks will focus on the definition of requirements for calibration pipelines for the SKA Phase 1 Science Data Processor.		
					6 SKA.TEL.SDP.PIP.CAL.ALG – Algorithm development for calibration pipelines	
					This WBS element focuses on algorithm development for the SKA Phase 1 Science Data Processor software that will process visibility data in quasi-real time pipeline mode. Each algorithm must be accompanied by a cost model. Tasks will include gap analysis, investigation into existing algorithms, estimation of deployment in SKA1, and development of cost model.	
				5 SKA.TEL.SDP.PIP.AA – Aperture Array Pipelines		
				Pipelines are algorithms implemented in software running in quasi-real time on computer hardware. This task considers Aperture-Array specific pipelines which relate directly to the unique character of these collector types. Tasks will focus on the definition of requirements for calibration pipelines for the SKA Phase 1 Science Data Processor.		
					6 SKA.TEL.SDP.PIP.AA.ALG – Algorithm development for Aperture-array pipelines	
					This WBS element focuses on algorithm development for the SKA Phase 1 Science Data Processor software that will process visibility data in quasi-real time pipeline mode. Each algorithm must be accompanied by a cost model. Tasks will include gap analysis,	

					investigation into existing algorithms, estimation of deployment in SKA1, and development of cost model.	
				5 SKA.TEL.SDP.PIP.TD – Time Domain Observation Pipelines		
				Pipelines are algorithms implemented in software running in quasi-real time on computer hardware. Time domain observation pipelines operate on time domain data produced by beam formation and time and frequency integration to search for previously unidentified pulsars; or Search for transient phenomena; or Accurately time the characteristics of previously identified pulsars. Tasks will focus on the definition of requirements for time domain observation pipelines and databases for the SKA Phase 1 Science Data Processor.	
					6 SKA.TEL.SDP.PIP.TD.ALG – Algorithm development for time domain observations	
					This WBS element focuses on algorithm development for the SKA Phase 1 Science Data Processor software to process data for candidate detections and timing in quasi-real time pipeline mode. Tasks will include gap analysis, investigation into existing algorithms, estimation of deployment in SKA1, and development of cost model.	
				5 SKA.TEL.SDP.PIP.SD – Processing of Science Data		
				This WBS element focuses on the definition of requirements for the SKA Phase 1 Science Data Processor software to process science data products that have been delivered by the imaging and time domain observation pipelines. Tasks will include the analysis of use cases, and the definition of validation and verification testing.		
					6 SKA.TEL.SDP.PIP.SD.ALG – Algorithm development for processing science data	
					This WBS element focuses on algorithm development for the SKA Phase 1 Science Data Processor software to process science data products. Tasks will include gap analysis, investigation into existing algorithms, estimation of deployment in SKA1, and development of cost model.	
			4 SKA.TEL.SDP.COMP – Computing Platform			
			This WBS element covers all the activities to provide input in the form of roadmaps and analysis of applicable technologies to inform architectural development, resource modelling and pipeline analysis and development. There is overlap with other elements in which similar technologies are required or developed. This task will concentrate on the availability and roadmapping of relevant technologies which will form COTS components of the SDP architecture.			
				5 SKA.TEL.SDP.COMP.PLT – Compute Platforms		
				The SKA will need to analyse very large streamed data resources as well as perform highly compute intensive analysis. Tasks will include the analysis of the detailed requirements for compute platforms for all different stages of the processing pipeline.		
				5 SKA.TEL.SDP.COMP.STRM – Data Streaming, Distributed Data and Data Buffer		
				The SKA will need to handle very large streamed data resources. This WBS element provides for the tasks to analyse the detailed requirements for solutions and consider the industry standard roadmap for appropriate technologies in the context of the SKA.		

				5 SKA.TEL.SDP.COMP.ROUTE – Routing Technologies	
				The SKA will need to handle very large streamed data resources which will require careful routing through the processing system. This WBS element provides for the tasks to analyse the detailed requirements for solutions and consider the industry standard roadmap for appropriate technologies in the context of the SKA.	
			4 SKA.TEL.SDP.ESCI – E-Science and Grid Computing		
			This WBS element provides for the tasks to analyse the role of E-science and grid computing in a tiered analysis model for the SKA and possible modes of interaction with regional data centres. The task will inform the boundary analysis for the observatory and define requirements for grid E-science, grid-computing and the interaction of the observatory with those elements beyond the observatory boundary.		
			4 SKA.TEL.SDP.SOA – System Operations and Administration		
			This WBS element provides for the tasks to analyse and determine requirements for the 'back office' support functions required to keep the SKA Phase 1 Science Data Processor system running. Tasks will include requirements analysis and capturing, identification of reliability requirements, cost-sensitivity analysis, and the establishment of a security policy.		
			4 SKA.TEL.SDP.LMC - Local Monitoring and Control		
			This WBS element provides for the definition of requirements for the SKA Phase 1 Science Data Processor local monitoring and control and system to be acquired or developed during the subsequent Phases. Tasks will include requirements analysis, analysis of physical implementations, and the development of cost and performance models.		
			4 SKA.TEL.SDP.INFRA – SDP Infrastructure Requirements		
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the Science Data Processor Element to the Site and Infrastructure Element (SKA.TEL.INFRA).		
			4 SKA.TEL.SDP.PWR – SDP Power Requirements		
			These are a set of tasks required to support the development and delivery of the power requirements by the Science Data Processor Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.		

Notes:

SKA.TEL.MGR - Telescope Manager (TM)

		3. SKA.TEL.MGR - Telescope Manager (TM)		**LEAD:**	
			4. SKA.TEL.MGR.MGT - Telescope Manager Project Management		
			This WBS element covers the overall project management work to be performed at the Telescope Manager Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
			4 SKA.TEL.MGR.SE-SRR – Telescope Manager SE to System Requirements Review		
			This WBS element covers all the system engineering work of the Telescope Manager Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		
			4 SKA.TEL.MGR.INFRA – TM Infrastructure Requirements		
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the Telescope Manager Element to the Site and Infrastructure Element (SKA.TEL.INFRA).		
			4 SKA.TEL.MGR.PWR – TM Power Requirements		
			These are a set of tasks required to support the development and delivery of the power requirements by the Telescope Manager Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.		

			4 SKA.TEL.MGR.TELMGT - Telescope Management		
			This is a group of tasks to establish requirements in the area of Telescope Management. This covers the machine control aspects of integrating the various system devices into a single instrument.		
				5 SKA.TEL.MGR.TELMGT.MON - Monitoring data acquisition and handling	
				This WBS element covers the work to establish requirements in the area of acquisition of data (other than science data), processing, aggregation and abstraction, and making data available for access and presentation. Tasks will include requirements analysis and capturing, development of use cases, development of architecture(s), and the definition of the verification strategy.	
				5 SKA.TEL.MGR.TELMGT.CTRL - Control	
				This WBS element covers the work to establish requirements in the area of control of the telescope operation. Tasks will include requirements development and analysis to facilitate interactive and non-interactive control of the system, development of preliminary architecture(s), and cost estimates,	
				5 SKA.TEL.MGR.TELMGT.DTM - Data Model support	
				This WBS element covers the work to provide a contribution to decision making regarding common data models. Tasks will include requirements analysis, proposing data models, and participation in integrated task teams.	
				5 SKA.TEL.MGR.TELMGT.UIS - Operator and Engineer interfaces	
				This WBS element covers the work to establish requirements in the area of user interfaces for operators and engineers. Tasks will include requirements development and analysis, development of use cases, perform trade studies, development of architectures and implementation options, and the verification strategy.	
				5 SKA.TEL.MGR.TELMGT.LMC - Local M&C Interface standardisation	
				This WBS element covers the work to establish requirements in the area of standardising interfaces for Local M&C, including definition of associated constraints. Tasks will include review of relevant existing documentation, requirements extraction, development and analysis, development of use cases, perform trade studies, development of architectures and implementation options, and the verification strategy.	
				5 SKA.TEL.MGR.TELMGT.IFS - Specific Interfaces scoping	
				This WBS element covers the work to establish standard interfaces and touch points with other Elements. Tasks will include interaction with other SKA Elements to determine interface requirements, and to document and review all of these.	
				5 SKA.TEL.MGR.TELMGT.OPDBS - Operations Support databases	
				This WBS element covers the work to establish requirements in the area of databases needed to support operations, such as configuration and status database, observatory calendar and context information database. Tasks will include review of relevant existing documents, requirements development and analysis, development of use cases, perform trade studies, development of	

				architectures and implementation options, and the verification strategy.	
				5 SKA.TEL.MGR.TELMGT.OPSUPP - Operations Support	
				This WBS element covers all the work to establish requirements for TM features to support operations, including maintenance activities. Tasks will include review of relevant existing documents, requirements development and analysis, development of use cases, development of architectures and implementation options, and the verification strategy.	
				5 SKA.TEL.MGR.TELMGT.ARCH - Monitoring data archive	
				This WBS element covers the work to establish requirements in the area of engineering data archive. Tasks will include requirements development and analysis, development of use cases, and the development of architectures and implementation options.	
				5 SKA.TEL.MGR.TELMGT.FAULT - Fault detection and management	
				This WBS element covers all the work to establish requirements in the area of fault detection and management. Tasks will include requirements development and analysis, development of use cases, development of architectures and implementation options, and the study of existing standards and implementations of fault management systems.	
				5 SKA.TEL.MGR.TELMGT.SAFE - Safety and asset protection	
				This WBS element covers all the work to establish requirements in the area of TM support for system safety functions and asset protection. Tasks will include requirements development, analysis of system safety functions, identification of equipment protection scenarios, development of use cases, and the development of architectures and implementation options.	
				5 SKA.TEL.MGR.TELMGT.SEC - Security	
				This WBS element covers the work to establish requirements in the area of security, including physical, data, network and people. Tasks will include development and analysis, development of use cases, development of architectures and implementation options, and development of a verification plan.	
				5 SKA.TEL.MGR.TELMGT.REL - Reliability, availability and integrity	
				This WBS element covers all the work to establish requirements in the area of reliability, availability and integrity maintenance. Tasks will include requirements development and analysis, development of architectures, and development of a verification plan.	
				5 SKA.TEL.MGR.TELMGT.ENGSIM - Engineering device simulators	
				This WBS element covers all the work to establish requirements in the area of engineering device simulators to enable M&C development and verification. Tasks will include requirements development and analysis, development of use cases, development of architectures, and development of a verification plan.	
				5 SKA.TEL.MGR.TELMGT.PLAT - Platform Specification	
				This WBS element covers all the work to collect together the requirements on the computing hardware and operating system(s) of the Telescope Manager. Tasks will include investigation into hardware solutions, costs, and provision of infrastructure requirements.	

			4 SKA.TEL.MGR.OBSMGT - Observation management		
			This WBS element contains all the Observation Management wide high-level activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Observations Management requirements and interfaces.		
				5 SKA.TEL.MGR.OBSMGT.PROPSUB - Proposal Submission	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Proposal Submission requirements and interfaces. Tasks will include requirements development and analysis, interface definition, candidate list of available applications that should be evaluated for expanding to meet the SKA requirements, and development of a verification strategy.	
				5 SKA.TEL.MGR.OBSMGT.OBSPREP - Observation preparation	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Observation Preparation requirements and interfaces. Tasks will include requirements development and analysis, interface definition, candidate list of available applications, and development of a verification strategy.	
				5 SKA.TEL.MGR.OBSMGT.SCHED - Scheduling	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Scheduling requirements and interfaces. Tasks will include requirements development and analysis, interface definition, and development of a verification strategy.	
				5 SKA.TEL.MGR.OBSMGT.CFG - Instrument configuration	
				This WBS element addresses configuration requirements for the observation management; additional set of the configuration requirements may be derived for the telescope operations. In this context, to configure the instrument (entire telescope or a subset) means to set configuration parameters of the instrument in order to collect, process and store observed astronomical data, meta-data, configuration data, relevant engineering data. Tasks will include requirements development and analysis, interface definition, estimation of amount of data, and identification and evaluation of candidate technologies.	
				5 SKA.TEL.MGR.OBSMGT.EXEC - Observation execution	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Observation Execution requirements and interfaces. Tasks will include requirements development and analysis, interface definition, and development of a verification strategy.	
				5 SKA.TEL.MGR.OBSMGT.ARCH - Observation management data archive	
				This WBS element covers all the work to determine requirements for the archive where all information related to observation management will be stored. Tasks will include identification of users, estimation of the type and amount of data, and the identification and evaluation of candidate implementation technologies.	

				5 SKA.TEL.MGR.OBSMGT.UI - User interface	
				This WBS element covers all the work to determine requirements for the user interface for Observation Manager. Tasks will include identification of classes of users, requirements development and analysis, and identification of candidate implementation technologies.	
				5 SKA.TEL.MGR.OBSMGT.SIM - Simulation	
				This WBS element covers the work to define \ simulator to support telescope operations. The simulator will focus on the data compute requirements and data throughput aspects of the pipeline. Tasks will include requirements development and analysis, and costs.	
				5 SKA.TEL.MGR.OBSMGT.PLAT - Platform Specification	
				This WBS element covers the work to collect requirements on the hardware and operating system(s) of the Observation Manager. Tasks will include investigations into hardware solution options, costs, and the power and infrastructure requirements of the potential solutions.	
			4 SKA.TEL.MGR.CSF - Common Software Framework		
			This WBS element contains all the Common Software Framework wide high-level activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Common Software Framework requirements and interfaces Roll up.		
				5 SKA.TEL.MGR.CSF.CDM - Common Data Models	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Common Data Model requirements and interfaces. Tasks will include requirements development and analysis, interaction with other Elements, analysis of existing common data models, and the estimation of costs and effort.	
				5 SKA.TEL.MGR.CSF.PROTO - Common Protocols and Runtime	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the requirements and specification of common protocols and runtime needed by Telescope Manager applications. Tasks will include definition of runtime environment, identification of functional and non-functional requirements of the communication transport layer, analysis of candidate implementation technologies, and definition of a verification strategy.	
				5 SKA.TEL.MGR.CSF.DEVT - Common tools	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Software Development Tools requirements. Tasks will include the determination of common set of software development tools, close interaction with other Elements, and definition of a verification strategy.	
				5 SKA.TELMGR.CSF.TEST - Common Testing Framework	
				This WBS element contains all the activities needed during Stage 1 of the SKA Pre-Construction phase to establish the Common Testing Framework requirements. Tasks will include requirements development and analysis, determining common testing functionality	

				required by Telescope Manager software applications, analysis of current technology options, and costing.	

Notes:

SKA.TEL.SAT - Synchronisation and Timing (SaT)

		3 SKA.TEL.SAT - Synchronisation and Timing (SaT)		**LEAD:**	
			4 SKA.TEL.SAT.MGT – SAT Project Management		
			This WBS element covers the overall project management work to be performed at the Synchronisation and Timing Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
			4 SKA.TEL.SAT.SE-SRR – SAT SE to Requirements Review		
			This WBS element covers all the system engineering work of the Synchronisation and Timing Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.		
			4 SKA.TEL.SAT.SE-VSYS - System Engineering for Verification Systems		
			This WBS element provides the System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		
			4 SKA.TEL.SAT .UTCR - Central Timing and Frequency Reference		
			The central timing and frequency reference provides the fundamental frequency standard for the SKA and provides a long-term stable clock which can be tied to international time standards. This is likely to be one or more high quality active hydrogen masers, possibly used as an ensemble to provide a more stable synthesised timescale.		

				5 SKA.TEL.SAT.UTCR.SCI - Central Timing Science Requirements	
				This WBS element covers all the work to analyse science requirements in terms of long term stability of SKA timescale and its relation to other international timescales, especially for pulsar timing. Also analysis of science requirements for central and common SKA frequency standard for 'VLBI' operations of SKA dishes as part of global VLBI arrays. Tasks will include requirements development and analysis.	
				5 SKA.TEL.SAT.UTCR.CLKS - Clock	
				This WBS element covers all the work to survey/technology roadmap of available 'clocks': active hydrogen masers, and alternatives. Tasks will include survey of existing technology options, investigation of the performance of these options, and costs.	
				5 SKA.TEL.SAT.UTCR.ENSB - Central clock ensemble	
				This WBS element covers all the work for preliminary designs for operation of the central SKA time standard and frequency reference, including options for redundant operation of multiple hydrogen masers (or equivalent), synthesising timescales from multiple hydrogen masers, fall back to secondary clocks, generation of all required time signals, clock messages, standard frequencies and comparisons of these with local GPS measurements and potentially other time standards laboratories. Tasks will include requirements analysis, architectural descriptions, generation of concepts, development of a physical model, and costing.	
			4 SKA.TEL.SAT.STFR - Station Frequency Reference		
			This WBS element covers all the work for SAT and concerns the provision of the local frequency standard to each dish (clump) and AA station.		
				5 SKA.TEL.SAT.STFR.SCI - Frequency Reference Science Requirements	
				This WBS element covers the work to analyse the coherence and relative timing performance for AA stations and dish (clump) elements. Tasks will include requirements development and analysis, and consideration of impact of medium and long term phase stability on calibration strategies, algorithms and data processing.	
				5 SKA.TEL.SAT.STFR.PERF - Performance Models	
				This WBS element covers the work to develop phase variation performance models for optical fibre links. Tasks will include the development of general models for phase variation in optical fibre links including cable types, effects of burial depth, exposed sections, bending, connectors, and the identification of verification activities.	
				5 SKA.TEL.SAT.STFR.DD - Direct distribution of frequency standards	
				This WBS element covers the work to design direct distribution of frequency standards. Tasks will include development of architecture descriptions, development of physical models, development of cost models, and development of power budget.	
				5 SKA.TEL.SAT.STFR.RL - Remote locking of frequency standards	
				This WBS element covers the work to develop remotely locked station frequency standards. Tasks will include development of	

				architecture descriptions, parametric models, and concepts, interface definition, and the development of a verification plan.	
			4 SKA.TEL.SAT.RTS - Remote Timer Server		
			This WBS element covers all the work to define the provision of time services, freq standards at remote AA station and dishes (clump). Tasks will include requirements development and analysis, development of costed architectures, and the development of a verification plan.		
			4 SKA.TEL.SAT.NTW - Network Architecture		
			This WBS element includes all those activities involved with participation in the design of optimised combined physical layer networks for SaT and other SKA networked services. Tasks will include analysis of optimised Link and node layouts based on preliminary designs, assembly of models, and analysis of redundant links.		
			4 SKA.TEL.SAT.LMC - Local Monitoring and Control		
			This WBS element includes all those analysis activities in order to establish a strategy and preliminary design for the management of the SKA SAT systems. Tasks will include development of requirements, development of architectures and the analysis of implementation options.		
			4 SKA.TEL.SAT.INFRA – SAT Infrastructure Requirements		
			This is a grouping of tasks required to support the identification, development and delivery of all the relevant infrastructure requirements by the Synchronisation and Timing Element to the Site and Infrastructure Element (SKA.TEL.INFRA).		
			4 SKA.TEL.SAT.PWR – SAT Power Requirements		
			These are a set of tasks required to support the development and delivery of the power requirements by the Synchronisation and Timing Element to the Power Element (SKA.TEL.PWR). The information provided by this work breakdown structure element will be used in accordance with the Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database.		

Notes:

SKA.TEL.PWR – Power

		3 SKA.TEL.PWR – Power			**LEAD:**	
			4 SKA.TEL.PWR.MGT – Project Management			
			This WBS element covers the overall project management work to be performed at the Power Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.		
			4 SKA.TEL.PWR.SE-SRR - Power SE to Requirements Review			
			This WBS element covers all the system engineering work of the Power Element to bring the Element to a to a readiness which will allow the successful conduct of the Requirements Reviews as defined in the SKA SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment, standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.			
				5 SKA.TEL.PWR.SE-SRR.PUM - Power Utilisation Management		
				This WBS element will be to determine availability levels for all parts of the SKA. In order to minimise power costs, the SKA will need to set required power availability levels as low as possible as well as minimising SKA electrical power consumption. 100% availability, whilst desirable, would mean the construction of redundant power systems which would dramatically increase the cost of the power infrastructure as well as the cost per kilowatt hour, and to harmonise design solutions that affect power requirements. Tasks will include development of System and Element models for power availability analyses, power availability analyses, confirmation of reference and applicable standards for power availability, and development of power design guideline document.		

			4 SKA.TEL.PWR.SUP – Power Supply to SKA		
			Depending on the outcome of the site decision, it may be necessary for the SKA to be involved in and support the effort to provide power to the site. This WBS element therefore covers the potential work to co-ordinate and manage tasks required to support the delivery of cost and performance optimised designs for the power delivery systems. The task will obtain inputs from, amongst others, design activities and data generated by power consultants (commissioned by the SKA Organisation and SKA host nation), and provision partners.		
				5 SKA.TEL.PWR.SUP.ECO – Analysis of power generation options	
				In order to best inform the SKA Organisation about its options for power provision for the SKA, this WBS element is to carry out an economic analysis of generation options (investigated in SKA.TEL.PWR.SUP) for the lifetime of SKA. Tasks will include the economic analysis of generation options, and contribution to the system integrated task teams.	
				5 SKA.TEL.PWR.SUP.SIT – Potential Siting of Generation Systems in Relation to SKA	
				This WBS element is to investigate the potential EMI / RFI impact of the geographical siting of potential power generation facilities in relation to the SKA. Tasks will include invstigation of WMI/RFI emissions from power generation systems, and the participation in the applicable integrated task teams.	
			4 SKA.TEL.PWR.EMM – RFI and other low emission investigations		
			Each of the Elements of the SKA will be subjected to very stringent and low RFI and emission requirements. This umbrella task covers the work to be performed to investigate technology options and other techniques to ensure that the power element will be able to comply to the overall SKA requirements.		
				5 SKA.TEL.PWR.EMM.RFI – Radio Frequency Interference Requirements	
				This WBS element provides for the identification and assessment of RFI technologies and techniques for the SKA-owned power grid. Tasks will include investigations into RFI mitigation technologies and techniques, the assessment of their capability, identification of possible new technologies and techniques, and the participation on the integrated task teams.	
				5 SKA.TEL.PWR.EMM.LEMI – Low EMI Transmission	
				This WBS element provides for the identification and assessment of technologies and techniques for the transmission of power from a non-SKA power source(s) to the point of distribution in the SKA. Tasks will include the identification of technologies and techniques for the transmission of power and assessment of their capabilities, and the participation in integrated task teams.	
				5 SKA.TEL.PWR.EMM.GROU – Grounding / Earthing	
				This WBS element provides for the investigation of best practice for grounding and lightning protection of the SKA-owned grid and power network. This work package is to support “SKA.TEL.INFRA.GND - Infrastructure Grounding and Lightning Protection Standards and Methods”. Tasks will include the assessment of local and international standards, and the contribution of this knowledge to the relevant integrated task teams.	

			4 SKA.TEL.PWR.GRID – SKA Grid and Distribution Network		
			This umbrella WBS element contains those co-ordination and technical management tasks required to develop the requirements for the SKA-owned grid and to perform first pass modelling, design and costing of the system. Some of the tasks may overlap with the system engineering effort and reconciliation will be done during the foreseen rework and update of the power element WBS/SOW following the finalisation of the SKA site decision.		
				5 SKA.TEL.PWR.GRID.REQ – Collect supply requirements for elements	
				This WBS element is to ensure the delivery of power requirements for each of the SKA elements. The data is to be formatted and stored as the “Power Requirements” part of the “Engineering Resource Requirements and Allocation Database”. Tasks will include the collection of the requirements from the Elements, the analysis of this data, and the population of the database.	
				5 SKA.TEL.PWR.GRID.BDG - Key building power requirements	
				This WBS element is to develop the power requirements for each of the buildings for the SKA. The data is to be formatted and stored as the “Power Requirements” part of the “Engineering Resource Requirements and Allocation Database”. Tasks will include the collaboration with the Site and Infrastructure Element in the identification of the key buildings, the development of power requirements for these facilities, and the population of the database.	
				5 SKA.TEL.PWR.GRID.SGT – Smart Grid Technology	
				Smart grid technology is becoming a popular method of controlling power supply systems to optimise for power efficiency. These systems make use of known patterns and data collected from the grid in order to make best use of the available power. In this case, smart grid technology may also provide an additional mechanism of minimising the radio frequency emissions from the grid by cutting power to systems while they are not in use. This WBS element provides for the potential use of these systems is to be investigated for use in the SKA grid. Tasks will include the review of state of the art technologies for possible use in the SKA owned grid, and the reporting of the findings and requirements.	
				5 SKA.TEL.PWR.GRID.DEV – Development of Power Budget for SKA elements	
				The development of power budgets for elements of the SKA. These budgets are to be set at level 3 or level 4 elements. These budgets will enable the consortia working on the elements to review their power consumption and optimise their designs to minimise power consumption after SRR. Tasks will include the development of the power budgets for level 3 and level 4 elements by combining the consumption estimates and the total power provision plan, the maintenance of the budget, and the top down analysis and allocation of budgets.	
				5 SKA.TEL.PWR.GRID.NETT – Network Topology	
				This WBS element provides for the development of a model of the power distribution network for the SKA. This model can then be used in trade studies at the System Level concerned with optimised array configurations and optimised topology layouts. Tasks will include development of power distribution network parametric and costing models, and the derivation of physical layer topology	

				models for analysis of the array configurations.	
			4 SKA.TEL.PWR.LOC – Locally Powered Remote Station Power Block		
			This WBS element provides for the investigation of the range of options available to the SKA for the generation of power to supply the telescope and its systems in geographic areas where it is not possible to connect to external power providers. Tasks will include a complete review of power generation options, a review of the current state-of-the-art in low RFI conversion and regulation, investigation into power storage, the RAM characteristics, scaling tradeoffs, and the economic analysis of remote power generation.		
			4 SKA.TEL.PWR.PMC - Power Monitoring and Control		
			This WBS element includes all those analysis activities in order to establish a strategy and preliminary design for the monitoring and control of the SKA power systems. Tasks will include the development and analysis of the requirements, identification and definition of interfaces, and the analysis op potential implementation options and costings.		
			4 SKA.TEL.PWR.ENV – Environmental / Ecological Impact of Power Provision		
			The installation of power generation and distribution systems can have an environmental impact, may affect the surrounding ecosystem (flora and fauna) and the population who live in the surrounding area. This work package will study and evaluate the possible environmental impact of these systems. Tasks will include the identification of the most suitable strategy to minimise the impact on the environment and ecosystem of the SKA site, analysis of the SKA site, and the assessment of the potential impact of the SKA power generation and distribution systems on the following environmental.		
			4 SKA.TEL.PWR.ENV – Power Infrastructure Requirements		
			This is a grouping of tasks required to support the delivery of the infrastructure that will be required by the power Element to the Site and Infrastructure level 3 Element, 3 SKA.TEL.INFRA.		

Notes:

SKA.TEL.INFRA - Site and Infrastructure

		3 SKA.TEL.INFRA - Site and Infrastructure				**LEAD:**	
			4 SKA.TEL.INFRA.MGT – Project Management				
			This WBS element covers the overall project management work to be performed at the Site and Infrastructure Element level during Stage 1 of the SKA Preconstruction Phase. The project management principles and processes will also be applicable at the lower levels of the Element as appropriate. The project management tasks will include the development and roll out of the project management approach, management and maintenance of the Stage 1 agreements, Stage 2 preparation, selection and roll out of enterprise management and tools, managing and conducting meetings, managing and conducting technical/peer reviews, project scheduling, resource planning and management, configuration/change management, risk management, documentation management, quality assurance, gap analysis, costing, communications, interaction with precursors and pathfinders, management and participation in domain groups and integrated task teams, industry liaison and travel budgeting and management.			
				5 SKA.TEL.INFRA.MGT.GOV – Interaction with government			
				This WBS element covers the tasks and activities to support the project in consulting with all appropriate levels of government on issues concerning the site of the SKA, the core and intermediate and remote regions. The local host and SKA Office will work in close cooperation to firm up agreements, licences, and permissions.			
				5 SKA.TEL.INFRA.MGT.RQZ – Radio Quiet Zone Matters			
				This WBS element covers the tasks and activities to support the project in consulting with all appropriate levels of government, spectrum management administrations and other spectrum users on issues concerning the Radio Quiet Zone.			
				5 SKA.TEL.INFRA.MGT.MAN – Site Management			
				This WBS element covers the tasks and activities to support the project in organising and developing of the management of site-related issues during Preconstruction and Construction Phase.			
			4 SKA.TEL.INFRA.SE-SRR – System Engineering to System Requirements Review				
			This WBS element covers all the system engineering work to be performed within the Site and Infrastructure element during Stage 1 of the SKA Preconstruction Phase to bring the element to a readiness which will allow the successful conduct of Requirements Reviews as defined in the SEMP (SKA System Engineering Management Plan, WP2-005.010.030-MP-001). The system engineering tasks will include technical/peer reviews, requirements engineering (including allocation to subsystems), verification planning, modelling, architecture development, interface definition, design specification development, road mapping & obsolescence analysis, engineering resource allocation, operations, sustaining engineering, software development environment,					

					standardisation activities, system engineering approach, Stage 2 preparation, se management and tools, enterprise management and tools, configuration management/change control, risk management, product assurance, participation in integrated task teams and domain groups.	
					4 SKA.TEL.INFRA.ENV – Site Environment Engineering	
					This WBS element covers the set of tasks and activities to support the project in investigating the physical environment at locations of infrastructure and report on these and the collection of environmental requirements set by other Elements and derive the infrastructure provisions required to allow these requirements to be met considering the physical environmental conditions.	
					5 SKA.TEL.INFRA.ENV.CLI – Climate, Weather, Environmental Hazards	
					This WBS element provides for the collection and analysis of climate and weather conditions derived from meteorological stations data operated by national authorities and owned weather stations data. The work will apply to all relevant geographical locations for the SKA. Results will inform SE at next higher level.	
					5 SKA.TEL.INFRA.ENV.GEO – Geophysical data	
					This WBS element provides for the collection and analysis of available geophysical and geotechnical information and conditions. It will apply to all relevant geographical locations for the SKA and may eventually involve physical collections and analysis of samples for areas not yet addressed.	
					5 SKA.TEL.INFRA.ENV.RFI – Radio Frequency Interference	
					This WBS element provides for the collection and analysis of available information on the RFI environment. **This will apply** to all relevant geographical locations for the SKA. This is the data collection and reporting counterpart of the technical WBS "**5 SKA.TEL.INFRA.SINS.STI – Site RFI Monitoring**". The task may eventually involve the continued collection and analysis of RFI data on the SKA site.	
					4 SKA.TEL.INFRA.GND –Grounding and Lightning Protection	
					This WBS element covers the set of tasks and activities to support the project in investigating best practice grounding and lightning protection for SKA infrastructure and to support the development of a set of requirements for buildings, structures such as dishes and interconnects and power reticulation. The results will inform SE at next higher level.	
					4 SKA.TEL.INFRA.BCOD – Building Codes	
					This WBS element covers the set of tasks and activities to support the project in investigating and collating relevant building code information. Tasks will include collecting and analysis of the relevant building codes applicable to the SKA site.	
					4 SKA.TEL.INFRA.BLDS – Buildings	
					Top WBS element provides for the investigating of requirements, planning and preparations for the design and construction of buildings for the SKA at various relevant locations, for SKA Phase 1, with a view for extensibility to Phase 2. Tasks will include the establishment 0f a	

			construction time-line for completing building infrastructure required before the end of the Pre-Construction Phase of SKA1. Tasks will include plans, provisional designs and cost assessment for on-site and off-site buildings.	
			4 SKA.TEL.INFRA.ROAD – Roads	
			This WBS element provides for the investigation and collation of the requirements for constructing the road infrastructure for SKA Phase 1, with a view for extensibility to Phase 2. Tasks will include the establishing the construction time-line for completing building the required roads before the end of the Pre-Construction Phase of SKA1, provisional design and the costing of the roads.	
			4 SKA.TEL.INFRA.AIR – Airstrip	
			This WBS element provides for the development and analysis of the requirements for constructing the airstrip infrastructure for SKA Phase 1 (if applicable). Tasks will include the provisional design and costing of the airstrip.	
			4 SKA.TEL.INFRA.WAS – Water and Sanitation	
			This WBS element provides for the development and analysis of the requirements for the provision of water and sanitation infrastructure for SKA Phase 1, with a view for extensibility to Phase 2. Tasks will include the development of a construction time-line, and provisional design and costing.	
			4 SKA.TEL.INFRA.FND – Dish Foundation and other related infrastructure	
			This WBS element provides for the collection of the relevant information for each of the regions where dish foundations must be constructed, and the investigation of implementation options that meet requirements set by the Dish Element. Tasks will include the analysis of other Dish Element infrastructure requirements, the development of a construction time-line, and provisional designs and costing.	
			4 SKA.TEL.INFRA.LFAAS – Low Frequency AA Site	
			This WBS element provides for the collection of the relevant information for each of the regions where LFAA stations will be constructed, and the investigation of implementation options that meet requirements set by the LFAA Element. Tasks will include the analysis of other LFAA Element infrastructure requirements, the development of a construction time-line, and provisional designs and costing.	
			4 SKA.TEL.INFRA.MFAAS – Mid Frequency AA Site	
			This WBS element provides for the collection of the very preliminary information for each of the regions where MFAA stations may be constructed, and the investigation of implementation options that meet requirements set by the MFAA Element. Tasks will include provisional designs and costing.	
			4 SKA.TEL.INFRA.RRET – Routing and Reticulation	
			This WBS element provides for the investigations of options and cost for the implementation of a routing plan for power and fibre networks for the areas where such infrastructure must be established for SKA Phase 1, with attention for further development into Phase 2. Tasks will include the development of a construction time-line, and provisional designs and costing.	

			4 SKA.TEL.INFRA.CON – Construction Provisions		
			This WBS element provides for the development of plans for setting up and running of Provisions for the Construction of SKA Infrastructure, including the construction camp. Tasks will include the development of a construction time-line, and provisional designs and costing.		
			4 SKA.TEL.INFRA.SINS – Site Instrumentation		
			This WBS element provides for the maintenance and/or further development/upgrade of on-site instrumentation.		
				5 SKA.TEL.INFRA.SINS.MET – Site Meteo Stations	
				This WBS element provides for the investigations of the existing facilities and identification of possible maintenance or upgrades. Tasks will also include eventual utilisation of the equipment and the recording and analysis of the data.	
				5 SKA.TEL.INFRA.SINS.STI – Site Troposphere Interferometer Facility	
				This WBS element provides for the investigations of the existing facilities and identification of possible maintenance or upgrades. Tasks will also include eventual utilisation of the equipment and the recording and analysis of the data.	
				5 SKA.TEL.INFRA.SINS.RFI – Site RFI Monitoring	
				This WBS element provides for the investigations of the existing facilities and identification of possible maintenance or upgrades. Tasks will also include eventual utilisation of the equipment and the recording and analysis of the data for both fixed and mobile facilities.	
			4 SKA.TEL.INFRA.VER On-site Verification facilities		
			This WBS element provides for the collation of information and requirements for possible early deployment of SKA verification system on the site. Tasks will include the investigation of the infrastructure and support requirements, as well as the time-line and costs for implementation.		
			4 SKA.TEL.INFRA.SEC – Security		
			This WBS element provides for (further) on-site and off-site security of SKA installations, facilities and personnel.		
			4 SKA.TEL.INFRA.OES – Operations Equipment and Support		
			This WBS element provides for the development of plans on aspects of on-site and off-site operations and support activities.		
				5 SKA.TEL.INFRA.OES.LOG – Operations Logistics	
				This WBS element provides for the development and analysis of requirements for on-site and off-site materials and supplies, support for operations. Tasks will include requirements development for materials and supplies, system support and people movement.	
				5 SKA.TEL.INFRA.OES.EQPT – Operations Equipment	
				This WBS element provides for the development and analysis of requirements for on-site operations equipment, including supplies	

				required to operate, maintain and house/store this equipment. Tasks will include possible solutions to the requirements and costing.	
			4 SKA.TEL.INFRA.SAF – Safety		
			This WBS element provides for the development of plans for an SKA on-site and off-site Safety Plan and Code of Conduct. Tasks will include plans for emergency procedures, and training.		
			4 SKA.TEL.INFRA.PWR – Site and Infrastructure Power Requirements		
			These are the tasks required to support the delivery of requirements by the Elements to the Power Element; 3 SKA.TEL.PWR. The information provided by this work breakdown structure element will be used in accordance with TEL.SE.ERA – Engineering Resource Allocation and will populate the power part of the Engineering Resource Requirements and Allocation Database		

Notes:

SKA.AI.MFAA - Mid Frequency Aperture Array (MFAA)

		3 SKA.AI.MFAA - Mid Frequency Aperture Array (MFAA)		**LEAD:**	
			4 SKA.AI.MFAA.MGT - Management		
			This is a grouping of management tasks required to support the delivery for MFAA to bring this technology to TRL4. The appropriate tasks from the SKA project management philosophy for SKA Elements are inherited. Tasks will include Stage 2 preparation, progress meetings, technical and management reviews, configuration/change management, documentation management, scheduling, risk management, gap analysis, management and participation in domain groups and integrated task teams, and costing.		
			4 SKA.AI.MFAA.SE - System Engineering		
			This is a grouping of system engineering tasks required to support the delivery of the verification systems for the MFAA. The appropriate tasks from the SKA system engineering philosophy for SKA Elements are inherited. This is complementary to the MFAA.SE-VSYS tasks. Tasks will include requirements engineering, modelling, trade studies, participation in the integrated task teams, and risk management.		
			4 SKA.AI.MFAA.R&D – MFAA Research & Development		
			This WBS element contains all the activity directed towards establishing candidate MFAA designs in the SKA context. Tasks will include boundary analysis and definition, assemble and maintain inputs to parametric modelling activity, and using derived requirements from a Requirements Look Ahead analysis narrow down the field of designs, identify key performance parameters, set performance targets, determine development needs of each MFAA technology option in order to achieve the required TRL, analyse and report on SKA MFAA requirements and impacts on SKA design, and create a roadmap.		
			4 SKA.AI.MFAA.PA – Pathfinder Analysis		
			This WBS element contains the activities to analyse the tests and demonstrations already performed with the SKA precursors/pathfinders. Tasks include the analysis of the results, the identification of gaps, and the development of a plan to perform more extensive testing with the MFAA.		
			4 SKA.AI.MFAA.SE-VSYS - System Engineering for Verification Systems		
			This WBS element provides System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		
			4 SKA.AI.MFAA.TRA - Technology Readiness Assessment		
			The WBS elements contain all the work to be done to deliver a Technology Readiness Report which proves that the MFAA is at required technology Readiness level. Tasks will include the development of the report itself as well as conducting formal TRA reviews.		

			4 SKA.AI.MFAA.VSYS – Verification Systems		
			This WBS is a combination of all the verification systems planned to prepare or build during Stage 1. Verification systems are seen as major design, construction and test projects in their own right. Therefore, before the project embarks on the development of these systems, clear justification will be developed, reviewed and approved as part of the MFAA.SE-VSYS deliverables. Appropriate project management and system engineering for the verification system will also be required. In the event that an MFAA verification system is developed as part of Stage 1, the details of the work are provided in the WBS elements below.		
				5 SKA.AI.MFAA.VSYS.MGT - Management	
				This is a grouping of management tasks required to support the delivery of the verification systems for the MFAA. The appropriate tasks from SKA.AI.MFAA.MGT WBS element are inherited. Tasks will include progress meetings, technical and management reviews, configuration/change management, documentation management, scheduling, resource management and costing.	
				5 SKA.AI.MFAA.VSYS.SE - System Engineering	
				This is a grouping of system engineering tasks required to support the delivery of the verification systems for the MFAA. The appropriate tasks from the SKA.AI.MFAA.SE WBS element are inherited. This is complementary to the MFAA.SE-VSYS tasks. Tasks will include development of specifications, architectures, and interfaces.	
				5 SKA.AI.MFAA.VSYS.SDD – System Definition & Design	
				These WBS element provides for the definition and design the MFAA verification system. The goal of the verification system is to demonstrate the performance of the evolving design of the MFAA for SKA Phase 2 and to provide information for the selection of sub-systems when there are alternative designs.	
				5 SKA.AI.MFAA.VSYS.PR – Production	
				This WBS element contains all work related to the preparation for production of the verification system. Tasks include the development of plans and test plans.	
				5 SKA.AI.MFAA.VSYS.INS – Installation	
				This WBS element contains all work required to plan installation of the delivered components on the site. This includes site assembly and deployment and tasks include the planning, and derivation of installation requirements.	
				5 SKA.AI.MFAA.VSYS.TLG – Tooling	
				This WBS element contains the identification, specification and the production and deployment plan for equipment required for the installation of the MFAA system. Tasks will include the identification of the requirements, the tools themselves and finalising the list of tools.	
				5 SKA.AI.MFAA.VSYS.INT – Integration	
				This WBS element contains all the work required in defining the integration of all MFAA components in the verification system. Tasks	

				will include the development of the integration plan, and the identification of support equipment for installation.	
				5 SKA.AI.MFAA.VSYS.VF – Verification	
				This WBS element contains all work required for the identification and definition of the verification tests to be performed with the verification system. Tasks will include the development of the test plans.	
				5 SKA.AI.MFAA.VSYS.TAR – Test Assessment & Reporting	
				This WBS element covers all activities related to the test assessment of the verification systems. Tasks include the definition test assessments and the reporting thereof.	
			4 SKA.AI.MFAA.CAL – Calibration		
			This WBS element contains the activities to progress the calibration for MFAAs. Tasks will include requirements development and analysis, derivation of lower level requirements, development of a calibration strategy, and verification of the strategy.		
			4 SKA.AI.MFAA.AL – Antenna & LNA		
			This WBS element covers the activities to be performed related to the comparison of the antennas and LNA designs for the two identified options: the ORA antenna and the Vivaldi antenna.		
				5 SKA.AI.MFAA.AL.ORA – ORA element	
				This WBS element covers the activities to be performed related to a ORA-based array with integrated LNA used for the mid frequency aperture array. Tasks will include refining of the design. Manufacturing of antennas, testing, environmental impact studies, manufacturing studies, and the development of test plans and costing.	
				5 SKA.AI.MFAA.AL.VIV – Vivaldi element	
				This WBS element covers the activities to be performed related to a Vivaldi-based array with integrated LNA used for the mid frequency aperture array. Tasks will include refining of the design. Manufacturing of antennas, testing, environmental impact studies, manufacturing studies, and the development of test plans and costing.	
			4 SKA.AI.MFAA.RCV – Beamformer		
			This WBS element covers all the activities to be performed for the Stage 1 of the SKA Pre-Construction Phase for the MFAA related to the tile beam former. All concepts for the tile beam former shall be compared and a narrow down of the possible concepts will be made. Tasks will include requirements development and analysis, identification of solution options, comparison of options, and development of a verification plan.		
			4 SKA.AI.MFAA.RCV – Receiver		
			This WBS element covers all the activities to be performed for the Stage 1 of the SKA Pre-Construction Phase for the MFAA related to the design and realization of the MFAA receiver. Tasks will include requirements development and analysis, identification of solution options, comparison of options, and development of a verification plan.		

Notes:

SKA.AI.PAF - Phased Array Feed (PAF)

		3 SKA.AI.PAF - Phased Array Feed (PAF)		**LEAD:**	
			4 SKA.AI.PAF.MGT - Management		
			This is a grouping of management tasks required to support the delivery of a maturing PAF developed with the SKA in mind and to bring this technology to TRL4 in the context of the SKA. The appropriate tasks from the SKA project management philosophy for SKA Elements are inherited. Tasks will include Stage 2 preparation, progress meetings, technical and management reviews, configuration/change management, documentation management, scheduling, risk management, gap analysis, management and participation in domain groups and integrated task teams, and costing.		
			4 SKA.AI.PAF.SE - System Engineering		
			This is a grouping of system engineering tasks required to support the delivery of a maturing PAF developed with the SKA in mind. The appropriate tasks from the SKA system engineering philosophy for SKA Elements are inherited. Tasks will include requirements engineering, modelling, trade studies, participation in the integrated task teams, and risk management.		
			4 SKA.AI.PAF.R&D – Phased Array Feeds Research & Development		
			This WBS element contains all the activity directed towards establishing candidate PAF designs in the SKA context ('SKA PAFs'). Tasks will include boundary analysis and definition, assemble and maintain inputs to parametric modelling activity, and using derived requirements from a Requirements Look Ahead analysis narrow down the field of designs, identify key performance parameters, set performance targets, determine development needs of each SKA PAF technology option in order to achieve TRL5, analyse and report on SKA PAF requirements and impacts on Dish design, and create a roadmap.		
			4 SKA.AI.PAF.PA – Pathfinder Analysis		
			This WBS element contains the activities to analyse the tests and demonstrations already performed with the SKA precursors/pathfinders. Tasks include the analysis of the results, the identification of gaps, and the development of a plan to perform more extensive testing with PAFs.		
			4 SKA.AI.PAF.SE-VSYS - System Engineering for Verification Systems		
			This WBS element provides System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.		
			4.SKA.AI.PAF.TRA – Technology Readiness Assessment		
			The WBS elements contain all the work to be done to formally assess the Technology Readiness of PAF designs. Tasks will include the development of a technology readiness report and conducting TRA reviews.		

			4 SKA.AI.PAF.VSYS – Verification Systems		
			This WBS is a combination of all the verification systems planned to prepare or build during Stage 1. This may be a major design, construction and test project in it's own right. Therefore, before the project embarks on the development of a verification system, clear justification will be developed, reviewed and approved as part of the PAF.SE-VSYS deliverables. Appropriate project management and system engineering for the verification system will also be required. In the event that the PAF verification system is developed as part of Stage 1, the details of the work are provided in the WBS elements below.		
				5 SKA.AI.PAF.VSYS.MGT - Management	
				This is a grouping of management tasks required to support the delivery of the verification systems for the PAF. The appropriate tasks from SKA.AI.PAF.MGT WBS element are inherited. Tasks will include progress meetings, technical and management reviews, configuration/change management, documentation management, scheduling, resource management and costing.	
				5 SKA.AI.PAF.VSYS.SE - System Engineering	
				This is a grouping of system engineering tasks required to support the delivery of the verification systems for the PAF. The appropriate tasks from the SKA.AI.PAF.SE WBS element are inherited. This is complementary to the PAF.SE-VSYS tasks. Tasks will include development of specifications, architectures, and interfaces.	
				5 SKA.AI.PAF.VSYS.D&D - Design and Development	
				First version Verification System PAF: Design, Construct and Test. The primary deliverable is a verified behavioural model of an SKA PAF, containing all parameters that materially affect System performance or which must be calibrated. This task may carry on past the end of Stage 1. Tasks will include the physical design, construction and test of the SKA PAF, definition and design, subsystem definition and design, sub-system detailed design/build, definition and execution of the test program, refined SKA PAF cost modelling, a preliminary dish array production cost model, and a design impact report.	
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SKA.AI.WBSPF - Wide Band Single Pixel Feed (WBSPF)

		3 SKA.AI.WBSPF - Wide Band Single Pixel Feed (WBSPF)	**LEAD:**	
			4 SKA.AI.WBSPF.MGT - Management	
			This is a grouping of management tasks required to support the delivery for WSPF to bring this technology to TRL4. The appropriate tasks from the SKA project management philosophy for SKA Elements are inherited. Tasks will include Stage 2 preparation, progress meetings, technical and management reviews, configuration/change management, documentation management, scheduling, risk management, gap analysis, management and participation in domain groups and integrated task teams and costing.	
			4 SKA.AI.WBSPF.SE - System Engineering	
			This is a grouping of system engineering tasks required to support the delivery of a maturing WSPF developed with the SKA in mind. The appropriate tasks from the SKA system engineering philosophy for SKA Elements are inherited. Tasks will include requirements engineering, modelling, trade studies, participation in the integrated task teams, and risk management.	
			4 SKA.AI.WBSPF.R&D – Wideband Single Pixel Feeds Research & Development	
			This work element contains all the activity directed towards establishing candidate WBSPF designs in the SKA context. Tasks will include analysis and review of existing design material, boundary analysis, requirements derivation and analysis, EM modelling, mechanical/thermal FE modelling, passband ripple analysis, TRL review, the analysis and report on WBSPFs impacts on Dish design, and the development of a roadmap.	
			4 SKA.AI.WBSPF.PA – Pathfinder Analysis	
			This WBS element contains the activities to analyse the tests and demonstrations already performed with the SKA precursors/pathfinders. Tasks include the analysis of the results, the identification of gaps, and the development of a plan to perform more extensive testing with the WBSPFs.	
			4 SKA.AI.WBSPF.SE-VSYS - System Engineering for Verification Systems	
			This WBS element provides System Engineering underpinnings for Verification Systems development and the necessary links to SKA development. The main outcome of this work will be a Verification System Development Plan.	
			4.SKA.AI.WBSPF.TRA – Technology Readiness Assessment	
			The WBS elements contain all the work to be done to formally assess the Technology Readiness of WBSPF designs. Tasks will include the development of a technology readiness report and conducting TRA reviews.	
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