COMBINATION OF COLLABORATIVE PROJECT AND COORDINATION AND SUPPORT ACTION

Construction of new infrastructures - preparatory phase

FP7-INFRASTRUCTURES-2007-1

A Preparatory Phase proposal for the Square Kilometre Array

PrepSKA

Date of preparation: 2 May 2007

Participant no. *	Participant organisation name	Part. short name	Country
1 (Coordinator)	Science and Technology Facilities Council	STFC	UK
2	Netherlands Organisation for Scientific Research	NWO	NL
3	Centre National de la Recherche Scientifique	CNRS	FR
4	Istituto Nazionale di Astrofisica	INAF	IT
5	Fundacion General de la Universidad de Alcala Instituto Geografico Nacional	FG-IGN	ES
6	Department of Education Science and Training	DEST	AU
7	National Research Foundation	NRF	ZA
8	National Research Council	NRC	CA
9	The University of Manchester	UMAN	UK
10	Netherlands Foundation for Research in Astronomy	ASTRON	NL
11	Max-Planck Institut fur Radioastronomie	MPIfR	DE
12	Cornell University	Cornell	USA
13	University of Cambridge	UCAM	UK
14	University of Oxford	UOXF	UK
15	Commonwealth Scientific and Industrial Research Organisation	CSIRO	AU
16	Joint Institute for VLBI in Europe	JIVE	EU(NL)
17	Observatoire de Paris	OBSPAR	FR
18	Universite d'Orleans	UORL	FR
19	University of Calgary	UCAL	CA
20	University of Groningen	RUG	NL

Work programme topics addressed:
INFRA-2007-2.2.1.31: Preparatory Phase for research infrastructures in the 2006 ESFRI roadmap.

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Proposal abstract

The Square Kilometre Array (SKA) will be one of the largest scientific projects ever undertaken. It is a machine designed to answer some of the big questions of our time: what is Dark Energy? Was Einstein right about gravity? What is the nature of dark matter? Can we detect gravitational waves? When and how did the first stars and galaxies form? What was the origin of cosmic magnetism? How do Earth-like planets form? Is there life, intelligent or otherwise, elsewhere in the Universe?

There are several issues that need to be addressed before construction of the SKA can begin:

1. What is the design for the SKA?
2. Where will the SKA be located?
3. What is the legal framework and governance structure under which SKA will operate?
4. What is the most cost-effective mechanism for the procurement of the various components of the SKA?
5. How will the SKA be funded?

The purpose of this proposal is to address all of these points. We seek funding to integrate the R&D work from around the globe in order to develop the fully-costed design for Phase 1 of the SKA, and a deployment plan for the full instrument. With active collaboration between funding agencies and scientists, we will investigate all of the options for the policy-related questions. The principal deliverable will be an implementation plan that will form the basis of a funding proposal to governments to start the construction of the SKA.

Table of Contents

Summary Tables

*Table 1a - List of **participants** in the proposal*

Participant no. *	Participant organisation name	Part. short name	Country
1 (Coordinator)	Science and Technology Facilities Council	STFC	UK
2	Netherlands Organisation for Scientific Research	NWO	NL
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6	Department of Education Science and Training	DEST	AU
7	National Research Foundation	NRF	ZA
8	National Research Council	NRC	CA
9	The University of Manchester	UMAN	UK
10	Netherlands Foundation for Research in Astronomy	ASTRON	NL
11	Max-Planck Institut fur Radioastronomie	MPIfR	DE
12	Cornell University	Cornell	USA
13	University of Cambridge	UCAM	UK
14	University of Oxford	UOXF	UK
15	Commonwealth Scientific and Industrial Research Organisation	CSIRO	AU
16	Joint Institute for VLBI in Europe	JIVE	EU(NL)
17	Observatoire de Paris	OBSPAR	FR
18	Universite d'Orleans	UORL	FR
19	University of Calgary	UCAL	CA
20	University of Groningen	RUG	NL

Table 1b - List of **other organisations** involved in the Preparatory Phase

Organisation Name	Country	Description of the Organisation / Specific role or contribution to the preparatory phase
National Science Foundation (NSF)	USA	US funding agency for astronomy and other sciences. In PrepSKA will be involved in all policy-related work-packages.
Associated Universities Inc (AUI)	USA	AUI is a non-profit research management organization that operates the U.S.National Radio Astronomy Observatory (NRAO) under Cooperative Agreement with the National Science Foundation and is the North American executive for the Atacama Large Millimetre Array under construction in Chile. AUI will be involved with the international governance aspects, including financial and procurement models, in PrepSKA.
International SKA Project Office (ISPO)	N/A	The ISPO is an international organisation established by the International SKA Steering Committee (ISSC) to provide the overall leadership and management of the joint development of the SKA design.
National Radio Astronomy Observatory (NRAO)	USA	US organisation responsible for the development and operation of major radio astronomical facilities (e.g. GBT, VLA, VLBA and ALMA. In PrepSKA will be involved in technical activities

Dominion Radio Astronomy Observatory (DRAO)	CA	Canadian organisation that runs the Canadian radio astronomy facility in Penticton; it also has a strong technical group skilled in many aspects of radio astronomy technology. In PrepSKA DRAO will participate in technical activities.
Karoo Array Telescope (MeerKAT)	ZA	MeerKAT is an array telescope being developed and constructed in the Northern Cape province of South Africa. It is funded by the South African national government and is an international collaboration of several SKA-participating countries.
Mileura International Radio Array (MIRA)	AU/CA/ IN/US/ZA	MIRA is an SKA Pathfinder being developed and constructed as an international collaboration of several SKA-participating countries. In PrepSKA specific MIRA work will be associated with technical activities.

Introduction

The Square Kilometre Array (SKA) is a global project to design and build a next generation radio telescope at metre to centimetre wavelengths. Since its genesis in the early 1990s, the SKA has benefited from a distributed development model, in which different aspects of the R&D required to build the SKA are worked upon in different institutes around the world. In 2000, the project become more focused with the establishment of the International SKA Steering Committee (ISSC), a group of senior scientists and engineers from countries with a strong desire to be involved in the SKA. In 2002, the ISSC formed the International SKA Project Office (ISPO) with its own Director, whose job (in part) was to coordinate the global activities to ensure that all aspects of the design were being addressed and that technological risk mitigation schemes were in place.

The time is now ripe to take this relatively informal organisation to a new level. Around €140M has been and is being spent on SKA-related R&D; the level of technological and project maturity is such that we can now enter the last phase required before construction. Therefore, the advent of the Preparatory Phase instrument within FP7 is very welcome. The SKA Preparatory Phase (PrepSKA) offers an unique opportunity to provide the resources required to establish a central coordinating team; this team will have two components:

1. working groups will be established, led by funding agencies, to develop the options required to establish an appropriate financial, governance and legal framework for the SKA;

2. a Central Design Integration Team (CDIT) will be formed, embedded within the ISPO and hosted at one of the PrepSKA institutes (decision expected in May 2007). This team will have as its primary task the goal of integrating all of the diverse strands of technology development from around the around the world to produce a detailed and fully costed design for Phase 1 of the SKA, and to develop a deployment plan for the full SKA.

PrepSKA will be unique in another aspect in that it provides an opportunity for funding agencies, government bodies and scientists to work together to establish the framework and implementation plan to enable what will be one of the largest scientific projects ever attempted on a global scale. PrepSKA will enable significant national and regional R&D funds to be leveraged; it will have the potential of enabling significant industrial involvement (note the supporting letter from IBM appended to this proposal).

PrepSKA is planned to run for 4 years; the policy-related work-packages will run for 3 years. This is a deliberate choice to enable the option papers that emerge from the policy work-packages to be discussed and considered by decision-makers, and the results fully integrated into the implementation plan that is the principal deliverable from PrepSKA. This will ensure the emergence of a focused and coherent plan.

0. Brief description of the new research infrastructure (or major upgrade)

More than 50 institutes in 17 countries are actively involved in the development of the SKA. The telescope will have a collecting area of up to one million square metres spread over at least 3000 km, providing a sensitivity 50 times greater than the Expanded VLA (which will be the world's most powerful radio telescope). In addition, the SKA will deliver an instantaneous field of view (FOV) of up to several tens of square degrees, many times that of existing instruments, and the new possibility of multiple simultaneous users of several large, independent fields-of-view. These capabilities are enabled by a much greater use of information and communications technology than in current designs; the result will be an extremely powerful survey telescope with the capability to follow up individual objects with high angular and time resolution.

The SKA science impact will be widely felt in astro-particle physics and cosmology, fundamental physics, galactic and extragalactic astronomy, solar system science and astrobiology. The range of key science to be tackled by the SKA covers the epoch of re-ionization, galaxy evolution, dark energy, cosmic magnetism, strong field tests of gravity, gravitational wave detection, transients, proto-planetary disks, and the search for extra-terrestrial life. The major increase in performance compared to existing telescopes, and the flexibility inherent in the telescope design, allows us to predict that unexpected discoveries will be made with the SKA.

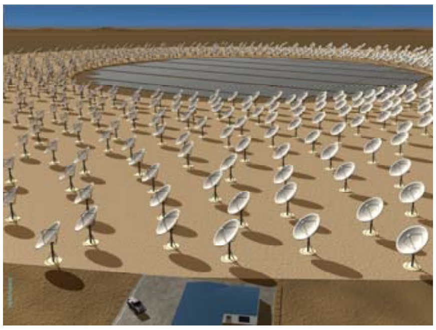


Fig 0.1: Artist's impression of the core of the SKA

The Reference Design for the full SKA is an interferometer array capable of imaging the radio sky at frequencies from ≤100 MHz to 25 GHz, and providing an all-sky monitoring capability at frequencies below 1 GHz. The concept involves parabolic dishes with innovative feeds to maximize a combination of spatial and frequency coverage; at lower frequencies phased arrays can become cost-effective and offer new operational capabilities. Technological innovation, closely paralleling commercial IT developments, is the key to the design concepts under investigation and to the target cost of 1.5 billion Euro. Data transport rates are likely to be in the range of 100 Giga-bits/sec to Tera-bits/sec, with Petaflop capacity required for the central processor. Much of the required technology is currently being developed in the course of specific design studies (including the EC funded FP6 SKA Design Study, SKADS) and the construction of several SKA Pathfinder instruments around the world. The final step of integrating the accumulated R&D knowledge into a detailed system design for the SKA, is planned to take place from 2008 to 2011, and is the subject of this proposal.

A telescope array presents the opportunity for conducting transformational science *as it is being built,* and reaches certain capability milestones at a very early stage of the antenna roll-out process. The SKA is planned to progress from the Pathfinder telescopes to the first 10% of the SKA (designated Phase 1) by 2015 with a restricted frequency range at a cost of about €250M, to the full SKA with the full frequency range in 2020. The Phase 1 stage will initially focus on the mid-band frequencies from several hundred MHz to a few GHz.

Two locations for the telescope, Australia and Southern Africa, have been short-listed by the International SKA Steering Committee as acceptable sites for the SKA. Additional studies of the site characteristics will be carried out as part of this FP7 Preparatory Phase proposal, PrepSKA, and a final choice will be made in accordance with the process and time scales established by the relevant funding agencies based on input from the policy work-packages in this proposal.

Further information on the SKA can be found at http://www.skatelescope.org.

1. Objectives and description of the activities foreseen

1.1 Objectives of the Preparatory Phase

R&D for the SKA has been underway for about a decade, starting in the Netherlands with an emphasis on identifying novel and innovative technologies, and more recently taking advantage of work being undertaken for other projects, e.g. the Allen Telescope Array, MWA and the EVLA in the USA, LOFAR, e-MERLIN and e-EVN in Europe and the GMRT in India. In the last few years these efforts have expanded and become more focused on the SKA. In particular, various regional development programmes have received significant funding: SKADS in Europe; MeerKAT (Karoo Array Telescope) in South Africa; the MIRA project in Australia (with Canadian involvement), APERTIF in the Netherlands and hopefully the US TDP (Technology Development Program), which is awaiting a funding decision by the NSF. In total, an estimated €140M will have been invested by 2010 in R&D which is directly relevant to the technologies that will be required for the SKA.

In parallel, the scientific case for the SKA has been laid down in great detail ("Science with the Square Kilometre Array", eds: C. Carilli, S. Rawlings, New Astronomy Reviews, Vol.48, Elsevier, December 2004), which provides a sound base on which to move forward to the next stage of development, and which is the basis for the design decisions which must be taken.

Also in parallel, a well-developed early governance and scientific advisory structure has evolved to drive the technical and political agendas for the project. The ISSC has become engaged with interested funding agencies and national governments. These organisations now meet informally twice a year to discuss issues related to the SKA, and are beginning to explore how they can set down a framework in which the project can further develop once a coherent proposal is submitted by the scientific community. In particular, one aim for the near future will be the creation of a 'Forum' that will facilitate detailed discussion between the SKA project and associated funding agencies and organisations on all issues of concern.

In Europe, the €38M SKADS project, in concert with efforts elsewhere around the world, has been responsible for the inclusion of the SKA on the roadmap of the European Strategy Forum for Research Infrastructures (ESFRI: http://cordis.europa.eu/esfri). The presence of a project on this roadmap, announced in October 2006, was an essential step in the process of being invited to submit a proposal for a preparatory phase within FP7.

This PrepSKA proposal, conceived and developed by a strong SKA partnership, is a global endeavour; involving funding agencies and scientists working together in an unique fashion to explore the appropriate legal, policy and technical framework required for the SKA. It will use EC funding to facilitate significantly larger levels of matching resources from many countries, and integrate the results of additional work packages not funded by the EC, in order to produce an implementation plan that will lead to the construction of the SKA.

The SKA is a large, complex project requiring significant involvement by industry at all stages, from pre-competitive R&D to operations. In the case of the SKA, two particular aspects drive close collaboration with industrial partners, the large numbers of antenna elements, and the huge signal transport and processing requirements. It is clear that economical mass production and deployment will be a key element of the project. The implementation and operation of the SKA, and probably its ultimate specifications, will be influenced strongly by the imperative to align the project technology with volume (consumer) manufacturing and deployment methods.

The principal objectives of PrepSKA are:

- to produce a deployment plan for the full SKA, and a detailed costed system design for Phase 1 of the SKA;
- to further characterise the two candidate SKA sites in Southern Africa and Australia and to analyse the various risks associated with locating the SKA at each of the sites;
- to develop options for viable models of governance and the legal framework for the SKA during its construction and operational phases;
- to develop options for how the SKA should approach procurement and how it should involve industry in such a global project;
- to investigate all aspects of the financial model required to ensure the construction, operation and, ultimately, the decommissioning of the SKA;
- to integrate all of the activities, reports and outputs of the various working groups to form an SKA implementation plan.

It is proposed the PrepSKA will last for 4 years from 2008 to 2011. The detailed work programme and timeline are outlined in the following sections.

1.2 Work plan

PrepSKA is a complex proposal involving a mixture of technical work-packages, aimed at pulling together the international design efforts, and policy work-packages, aimed at developing the governance and legal framework required for construction. Table 2a below provides a summary of the 7 work-packages supported by this proposal. Table 2b provides a list of other work-packages, all of which are funded or about to be funded, which highlight the design effort currently on-going around the world that is relevant to the SKA. The list demonstrates that SKA is a complex project, with many countries engaged in a coordinated and coherent fashion in addressing the different areas of technology required. This multi-national approach demonstrates the global interest in the project and is a central part of the risk mitigation approach which the SKA is following.

Following these two tables is a Gantt chart (Figure 1.2.1) showing the overall timing of the PrepSKA-supported work-packages and their principal components. Figure 1.2.2 is a diagram that attempts to show the interdependencies of the main work-packages. Not all WPs are included in this diagram since WP1 (management) permeates all WPs; WP4 (governance and legal) is somewhat independent of the others, although it does feed its results into WP7, the implementation plan.

Important note: the overall budget for PrepSKA is shown in Table 2a. This is translated to funding for relevant institutes in the A3.1 and A3.2 budgetary forms. You will see that the budget for the ISPO-CDIT (WP2 and WP3) has been allocated to JIVE. In this instance we are using JIVE as a 'flag of convenience' (with the agreement of the JIVE Director) since the decision as to which institute will host the ISPO has not yet been taken. The plan is that the host will be decided by the ISSC in May 2007. Once that is known, then the budget allocated to JIVE will move to the host institute.

Table 2a - List of Preparatory Phase ***Work Packages foreseen under this proposal***

Work Package No	**Descriptive Title**	**Short description and specific objectives of the task**	**Leading Participant**	**Total budget**	**Requested EC contribution**
WP1	*Management of the contract*		**STFC / UMAN**	**877,181**	**877,181**
WP2	Technical activity: SKA Design	**Will produce a costed, top-level design for the SKA**	**ISPO - CDIT**	**19,375,000**	**4,756,401**

		and a detailed system design for SKA Phase 1			
WP3	Support activity: SKA sites	**Additional studies of the short-listed SKA sites**	**ISPO**	**414,600**	**414,600**
WP4	Support activity: SKA Governance	**A study of options for models of the governance and legal framework for the SKA**	**NWO**	**431,684**	**431,684**
WP5	Support activity: SKA procurement and industrial involvement	**A study of the options for how the SKA should approach procurement and how it should involve industry**	**INAF**	**713,998**	**713,998**
WP6	Support activity: Developing the funding model for the SKA	**A study of the financial model required for the construction, operation and, ultimately, the decommissioning of the SKA.**	**STFC**	**331,620**	**331,620**
WP7	Coordination activity: Production of final report and SKA implementation plan	**The integration of all of the output of the other WPS. Produce an SKA implementation plan. Publish a costed SKA system design**	**UMan**	**60,000**	**60,000**
Totals				**22,210,585**	**7,585,485**

Table 2b - List of ***other*** *Preparatory Phase* ***Work Packages not directly supported by the EC in this proposal***

The Work Packages summarized in the table below, and in section 1.5, will generate R&D knowledge that is directly relevant for the SKA. In the case of the Pathfinder Telescopes (LOFAR, MIRA, MeerKAT, EVLA, e-MERLIN) a major additional goal is the creation of science-capable instruments. Note that all projects, with the current exception of the US Technology Development Program (TDP), are funded. The total R&D work included in Table 2b is budgeted at 106 M€.

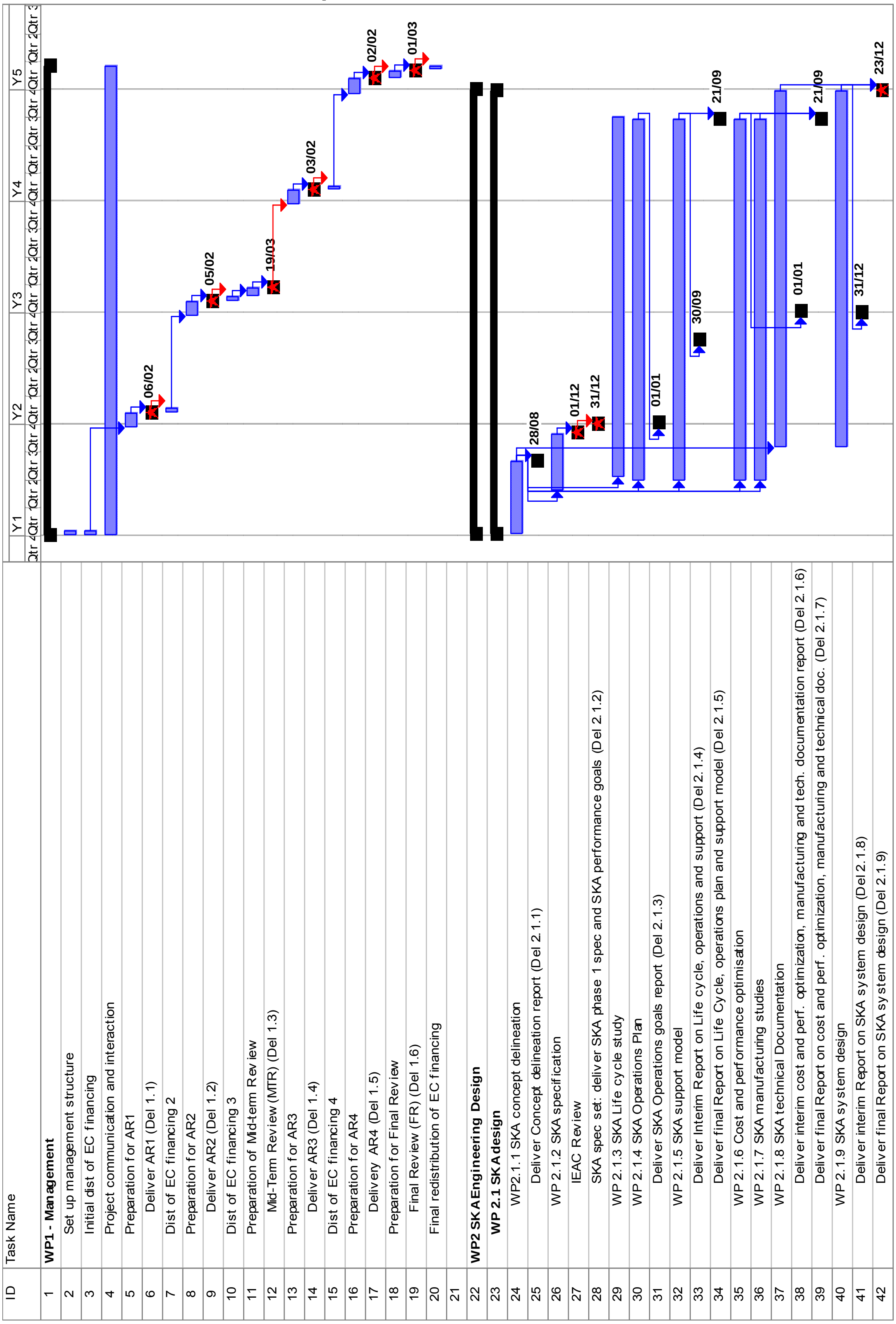
Work Package No	Descriptive Title	Short description and specific objectives of the task	Organisations involved	Approximate budget €1000s
WP8-1	Technical Work: SKA Science and Astronomical Data Simulations	Derive a quantitative set of design specifications for the SKA with emphasis on aperture arrays	FP6-SKADS	3500
WP8-2	Technical Work: Aperture Array	Design, develop and critically assess the performance of a multi-	FP6-SKADS	8500

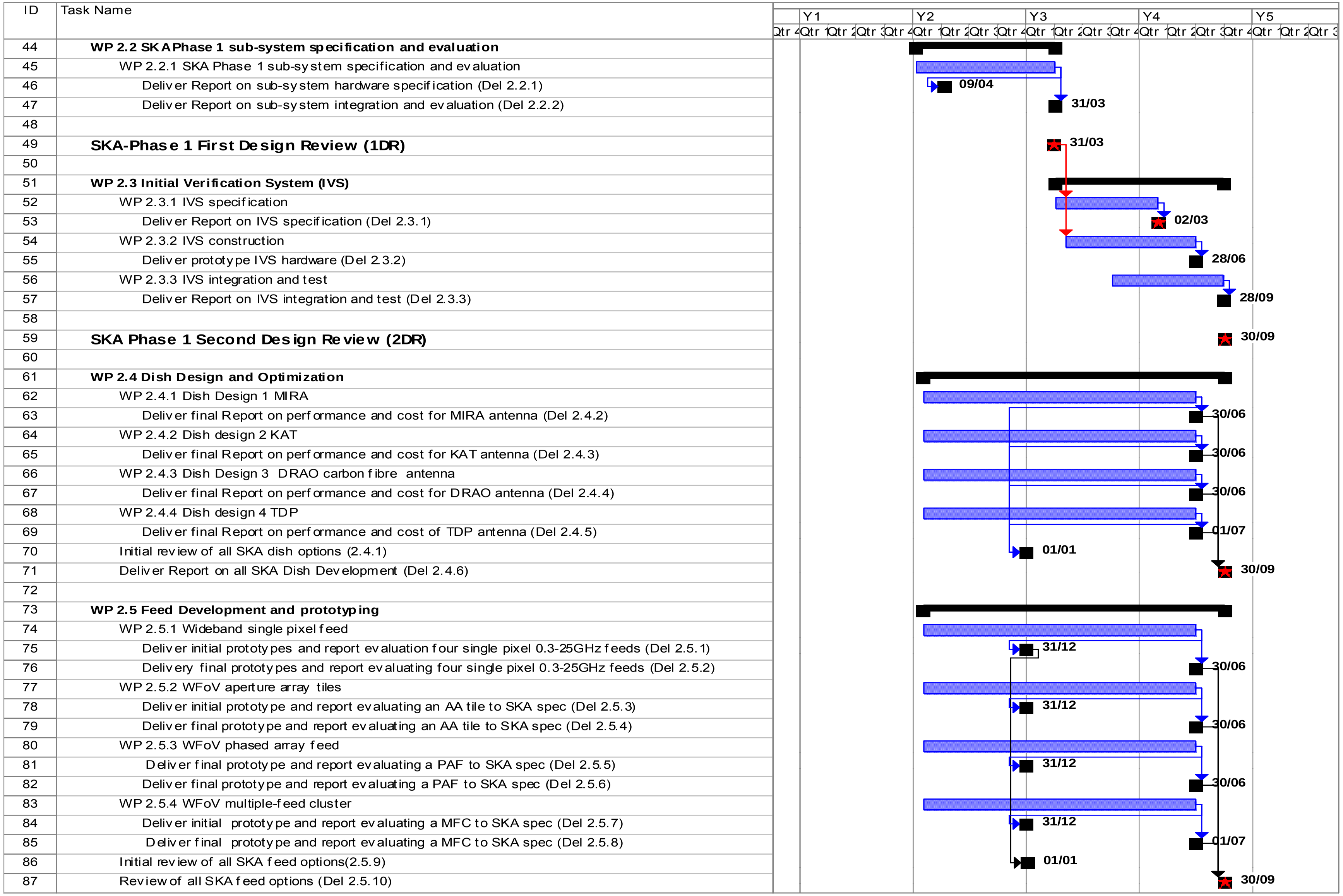
	Demonstrator EMBRACE	field aperture array demonstrator system for high sensitivity, high resolution, SKA observations.		
WP8-3	Technical Work: SKA Technical Foundations and Enabling Technologies	Establish the level of maturity of key technologies for a multi-fielding aperture array; make technology selections	FP6-SKADS	13500
WP8-4	Technical Work: The SKA Data Network and its Output Data	Study the intra- and inter-station signal connection networks, the (central) data handling and the physical infrastructure of the SKA	FP6-SKADS	3700
WP9-1	Technical Work: LOFAR Final R&D phase	Final design of High Band Antenna (120-240MHz), Transient Buffer Board, completion of the streaming processing software in the correlator and system health management software.	ASTRON and industrial partners	5000
WP9-2	Support Activities: LOFAR sites and procurement (final phase)	LOFAR site characterisation. Implement mass-procurement procedures	ASTRON	2000
WP9-3	Technical Work: Calibration & RFI algorithms for LOFAR	Develop and test algorithms for calibrating & imaging of wide-field low frequency data and for removing man-made interference	ASTRON and universities	2200
WP9-4	Technical Work: LOFAR Commissioning	optimization of initial station performance; implement operations plan	ASTRON and universities	6000
WP10	Technical Work: APERTIF	Design, manufacture, and test Phased Array Feeds on the Westerbork Radio Telescope	ASTRON	5500
WP11	Technical Work: e-MERLIN	Design phase and time transfer link over long distances	UMan	400
WP12-1	Technical Work: MIRA System Design	Overall instrument design	CSIRO ATNF (Australia)	1600
WP12-2	Support activity: MIRA Site Characterization	Conduct site specific studies and work programmes for the Mileura Radio Astronomy Park, potential SKA site	CSIRO ATNF, WA-DOIR	200
WP12-3	Technical Work: MIRA Antennas	Design, manufacture and commission high-dynamic range parabolic antennas.	CSIRO ATNF, HIA	600
WP12-4	Technical Work: MIRA Smart Feeds (FPA)	Design, manufacture and commission FPA's.	CSIRO ATNF, HIA	3600
WP12-5	Technical Work: MIRA Digital Systems	Design, manufacture and commission antenna beamformers and correlator.	CSIRO ATNF, ICT	1900
WP12-6	Technical Work: MIRA Receivers	Design, manufacture and commission receivers, LNA's and digitisers.	CSIRO ATNF, HIA	2200

WP12-7	Technical Work: MIRA Computing	Design and coding of control, data path, data reduction software. Design and purchase of computer systems.	CSIRO ATNF, NRF	3600
WP12-8	Technical Work: MIRA Signal Transport	Design, manufacture and commission data transport systems (antenna to core, core to Internet backbone).	CSIRO ATNF	1200
WP13-1	Technical Work: MeerKAT dish design	Design manufacture and commission a prototype dish reflector using composite materials	NRF (South Africa)	3400
WP13-2	Technical Work: MeerKAT feed/receiver design	Design manufacture and commission a prototype wideband single-pixel feed and receiver system	NRF	1700
WP13-3	Technical Work: MeerKAT signal transport and processing	Investigate technologies for the analogue and digital signal paths; develop scalable reconfigurable computing platform necessary for the data processing system.	NRF	6800
WP13-4	Technical Work: MeerKAT software development	Develop software for a distributed control system and software to produce data products.	NRF	3800
WP13-5	Technical Work: MeerKAT costing and systems engineering	Develop costing models that include both capital and operating costs	NRF	1300
WP13-6	Technical Work: MeerKAT configuration	Conduct science simulations on MeerKAT configuration	NRF	1800
WP13-7	Support activity: Establishment of the Karoo Radio Astronomy Reserve	Conduct site specific studies and work programmes for the Karoo Radio Astronomy Reserve, potential SKA site	NRF	3600
WP14-1	Technical Work: Calibration	Develop calibration & imaging algorithms	U. Calgary, Canada	250
WP14-2	Technical Work: LNAs	Develop inexpensive LNAs for SKA mid and high frequencies.	U. Calgary; DRAO/HIA/NRC	1300
WP14-3	Technical Work: SKA Composite Antennas	Design and develop reflector antennas using composite materials	DRAO/HIA/NRC Canada	1550
WP14-4	Technical Work: SKA Phased Array Feeds	Design and develop a Vivaldi-based Phased Array Feed with fully digital back-end	DRAO/HIA/NRC	1250
WP14-5	Technical Work: Software simulation	Simulate wide-field synthesis imaging using phased array feeds.	DRAO/HIA/NRC	325
WP14-6	Technical Work: Correlator	Design and commission the EVLA correlator, an SKA prototype	DRAO/HIA/NRC, NRAO	1650
WP15	Technical Work:	Station to core data link; Intra-antenna data link; LO & timing	NRAO (USA)	5000

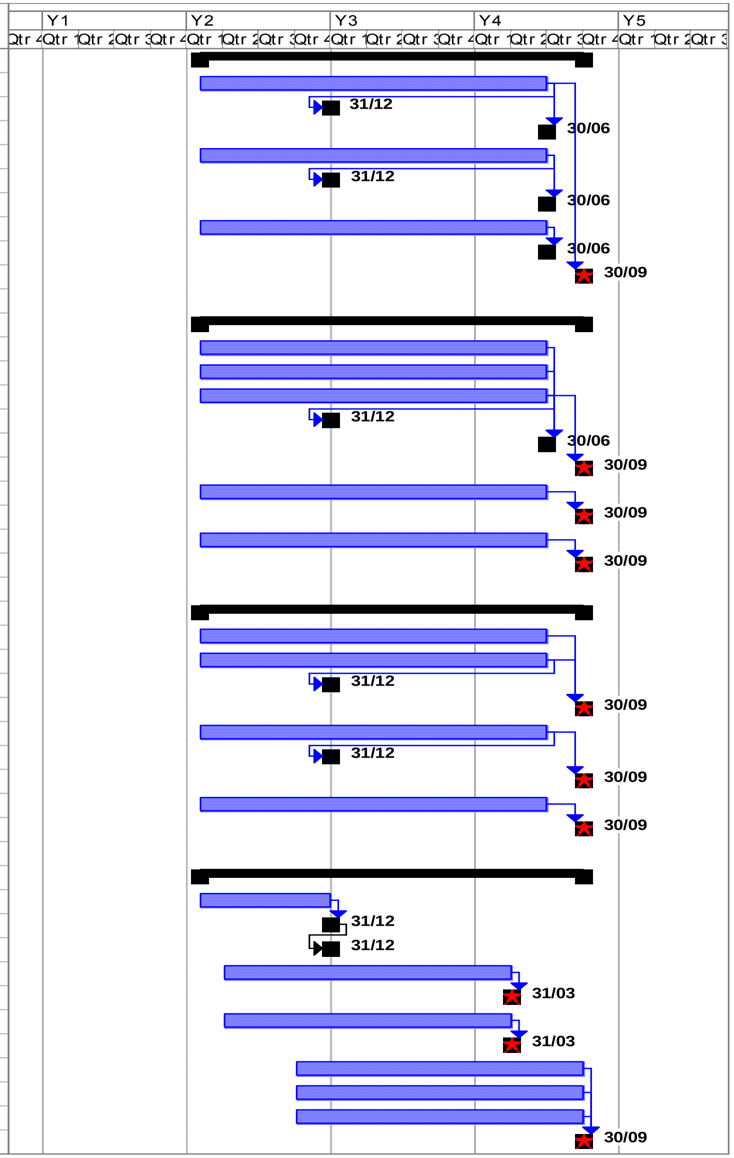
	EVLA	distribution; System design and operations plan; Data products and Virtual Observatory;		
WP16-1	Technical Work: TDP antenna mounts, feeds and receivers	Investigate manufacturing methods, identify optimized designs, prototype wideband single-pixel feeds and receivers, deliver an optimized antenna	Cornell (USA), US SKA Consortium, DRAO/HIA/NRC et al.	4300
WP16-2	Technical Work: TDP system analysis and design	Investigate signal transport, correlator designs, calibration and imaging, RFI mitigation, survey design, radar capability and data management	Cornell (USA), US SKA Consortium et al.	3200
WP16-3	Technical Work: TDP cost function analysis	Consolidate SKA technical developments into assessment of costs with tradeoffs	Cornell (USA), US SKA Consortium et al.	100
WP16-4	Technical Work: TDP SKA design	Contribute to the design of the SKA at all levels (subsystems, connectivity, operations)	Cornell (USA), US SKA Consortium et al.	525
WP17	Technical Work: ATA	Highly programmable digital signal processing engines; RFI mitigation; calibration and imaging; operations	UC Berkeley; SETI Institute	375

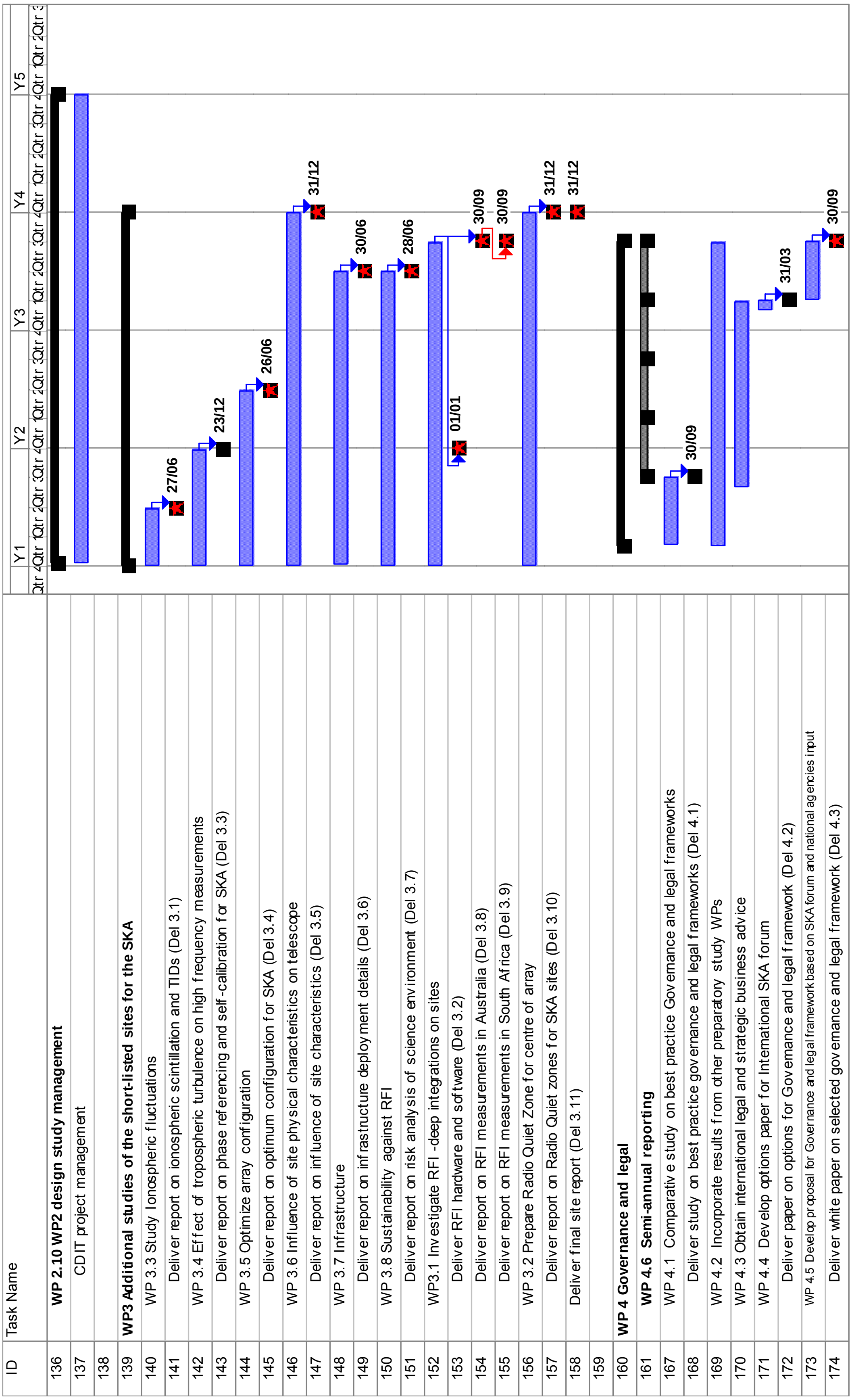
Master Schedule for all PrepSKA tasks



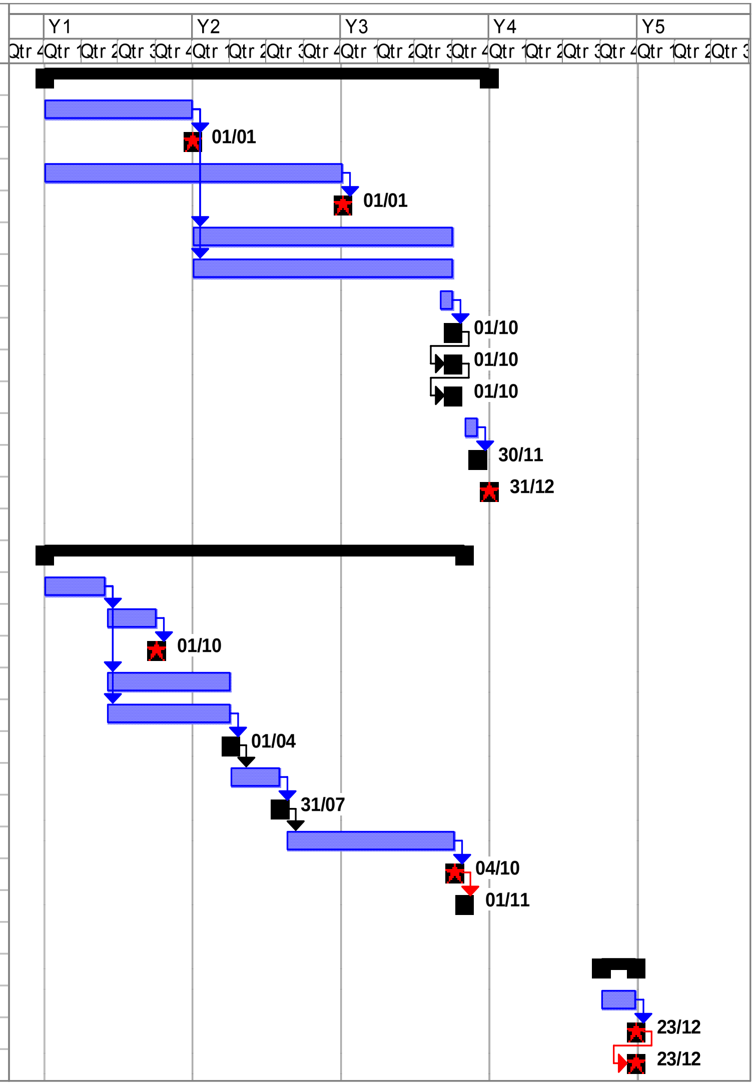

ID
Task Name
Y1
Y2
Y3
Y4
Y5
44 WP 2.2 SKA Phase 1 sub-system specification and evaluation
45 WP 2.2.1 SKA Phase 1 sub-system specification and evaluation
46 Deliver Report on sub-system hardware specification (Del 2.2.1)
09/04
47 Deliver Report on sub-system integration and evaluation (Del 2.2.2)
31/03
48
49 SKA-Phase 1 First Design Review (1DR)
31/03
50
51 WP 2.3 Initial Verification System (IVS)
52 WP 2.3.1 IVS specification
53 Deliver Report on IVS specification (Del 2.3.1)
02/03
54 WP 2.3.2 IVS construction
55 Deliver prototype IVS hardware (Del 2.3.2)
28/06
56 WP 2.3.3 IVS integration and test
57 Deliver Report on IVS integration and test (Del 2.3.3)
28/09
58
59 SKA Phase 1 Second Design Review (2DR)
30/09
60
61 WP 2.4 Dish Design and Optimization
62 WP 2.4.1 Dish Design 1 MIRA
63 Deliver final Report on performance and cost for MIRA antenna (Del 2.4.2)
30/06
64 WP 2.4.2 Dish design 2 KAT
65 Deliver final Report on performance and cost for KAT antenna (Del 2.4.3)
30/06
66 WP 2.4.3 Dish Design 3 DRAO carbon fibre antenna
67 Deliver final Report on performance and cost for DRAO antenna (Del 2.4.4)
30/06
68 WP 2.4.4 Dish design 4 TDP
69 Deliver final Report on performance and cost of TDP antenna (Del 2.4.5)
01/07
70 Initial review of all SKA dish options (2.4.1)
01/01
71 Deliver Report on all SKA Dish Development (Del 2.4.6)
30/09
72
73 WP 2.5 Feed Development and prototyping
74 WP 2.5.1 Wideband single pixel feed
75 Deliver initial prototypes and report evaluation four single pixel 0.3-25GHz feeds (Del 2.5.1)
31/12
76 Delivery final prototypes and report evaluating four single pixel 0.3-25GHz feeds (Del 2.5.2)
30/06
77 WP 2.5.2 WFoV aperture array tiles
78 Deliver initial prototype and report evaluating an AA tile to SKA spec (Del 2.5.3)
31/12
79 Deliver final prototype and report evaluating an AA tile to SKA spec (Del 2.5.4)
30/06
80 WP 2.5.3 WFoV phased array feed
81 Deliver final prototype and report evaluating a PAF to SKA spec (Del 2.5.5)
31/12
82 Deliver final prototype and report evaluating a PAF to SKA spec (Del 2.5.6)
30/06
83 WP 2.5.4 WFoV multiple-feed cluster
84 Deliver initial prototype and report evaluating a MFC to SKA spec (Del 2.5.7)
31/12
85 Deliver final prototype and report evaluating a MFC to SKA spec (Del 2.5.8)
01/07
86 Initial review of all SKA feed options(2.5.9)
01/01
87 Review of all SKA feed options (Del 2.5.10)
30/09

ID	Task Name
89	**WP 2.6 Receiver Development and prototyping**
90	WP2.6.1 Low noise amplifiers
91	Deliver initial 1 or more LNA prototype per band to SKA spec (Del 2.6.1)
92	Deliver final 1 or more LNA prototype per band to SKA spec (Del 2.6.2)
93	WP 2.6.2 Integrated receivers
94	Deliver initial prototype integrated receivers for all SKA bands to SKA spec (Del 2.6.3)
95	Deliver final prototype integrated receivers for all SKA bands to SKA spec (Del 2.6.4)
96	WP2.6.3 New-generation cryogenics
97	Deliver final report on cryo-coolers and protptype if applicable (Del 2.6.5)
98	Deliver final Report on SKA receiver development (Del 2.6.6)
99	
100	**WP 2.7 Signal transport specification and prototyping**
101	WP 2.7.1 Intra-antenna data link
102	WP 2.7.2 Intra-station data link
103	WP 2.7.3 Station to core data link
104	Deliver initial prototype and performance report on antenna to central processing link (Del 2.7.1)
105	Deliver final prototype and performance report on antenna to central processing link (Del 2.7.2)
106	Deliver report on options for SKA Phase 1 station to core links (Del 2.7.3)
107	WP 2.7.4 LO and timing distribution
108	Deliver report on strategy for LO and Timing distribution (Del 2.7.4)
109	WP 2.7.5 SKA control and monitoring
110	Deliver report on implementation approach for array monitoring and control (Del 2.7.5)
111	
112	**WP 2.8 Signal processing development and prototyping**
113	WP 2.8.1 Station signal digital processing
114	WP 2.8.2 Correlator
115	Deliver initial report on costed DSP and correlator design proposals (Del 2.8.1)
116	Deliver final report on costed DSP and correlator design optionss (Del 2.8.2)
117	WP 2.8.3 Radio Frequency Interference mitigation
118	Deliver initial report on SKA RFI mitigation strategy (Del 2.8.3)
119	Deliver final report on SKA RFI mitigation strategy (Del 2.8.4)
120	WP 2.8.4 Non-imaging processors
121	Deliver report on implementation and algorithms for non-imaging processing (Del 2.8.5)
122	
123	**WP 2.9 Software/computing specification and prototyping**
124	WP 2.9.1 Computing and software specification
125	Deliver draft report on SKA computing and s/ware spec, h/ware and cal strategy (Del 2.9.1)
126	Deliver draft report on s/ware syst. architecture, data products & sci. post-proc. strategy (Del 2.9.2)
127	WP 2.9.2 Computing hardware
128	Deliver Prototype of IVS computing hardware (Del 2.9.3)
129	WP 2.9.3 Software engineering
130	Deliver prototype of IVS software (Del 2.9.4)
131	WP 2.9.4 Data products and virtual observatory
132	WP 2.9.5 Calibration
133	WP 2.9.6 Science post-processing
134	Deliver report on final SKA computing and software specs and strategies (Del 2.9.5)




ID
Task Name
Y1
Y2
Y3
Y4
Y5
136 WP 2.10 WP2 design study management
137 CDIT project management
138
139 WP3 Additional studies of the short-listed sites for the SKA
140 WP 3.3 Study Ionospheric fluctuations
141 Deliver report on ionospheric scintillation and TIDs (Del 3.1)
142 WP 3.4 Effect of tropospheric turbulence on high frequency measurements
143 Deliver report on phase referencing and self-calibration for SKA (Del 3.3)
144 WP 3.5 Optimize array configuration
145 Deliver report on optimum configuration for SKA (Del 3.4)
146 WP 3.6 Influence of site physical characteristics on telescope
147 Deliver report on influence of site characteristics (Del 3.5)
148 WP 3.7 Infrastructure
149 Deliver report on infrastructure deployment details (Del 3.6)
150 WP 3.8 Sustainability against RFI
151 Deliver report on risk analysis of science environment (Del 3.7)
152 WP3.1 Investigate RFI -deep integrations on sites
153 Deliver RFI hardware and software (Del 3.2)
154 Deliver report on RFI measurements in Australia (Del 3.8)
155 Deliver report on RFI measurements in South Africa (Del 3.9)
156 WP 3.2 Prepare Radio Quiet Zone for centre of array
157 Deliver report on Radio Quiet zones for SKA sites (Del 3.10)
158 Deliver final site report (Del 3.11)
159
160 WP 4 Governance and legal
161 WP 4.6 Semi-annual reporting
167 WP 4.1 Comparative study on best practice Governance and legal frameworks
168 Deliver study on best practice governance and legal frameworks (Del 4.1)
169 WP 4.2 Incorporate results from other preparatory study WPs
170 WP 4.3 Obtain international legal and strategic business advice
171 WP 4.4 Develop options paper for International SKA forum
172 Deliver paper on options for Governance and legal framework (Del 4.2)
173 WP 4.5 Develop proposal for Governance and legal framework based on SKA forum and national agencies input
174 Deliver white paper on selected governance and legal framework (Del 4.3)
27/06
23/12
26/06
31/12
30/06
28/06
01/01
30/09
30/09
31/12
31/12
30/09
31/03
30/09

ID	Task Name
176	**WP 5 SKA procurement and industrial involvment**
177	WP 5.1 Develop working guidelines for procurement for WP2
178	Deliver guidelines for procurement for WP2 (Del 5.1)
179	WP 5.2 Investigate whether industry can contribute to SKA
180	Deliver report on inventory of relevant industries (Del 5.2)
181	WP 5.3 Analyse models for procurement
182	WP 5.4 Risk analyses of procurement models
183	WP 5.5 Develop options paper on procurement for SKA Forum
184	Deliver report on procurement models (Del 5.3)
185	Deliver draft options paper on procurement (Del 5.4)
186	Deliver inventory of policies and goals for Del 5.4 (Del 5.5)
187	WP 5.6 Develop options for procurement for SKA funding agencies
188	Deliver White Paper on final procurement options (Del 5.6)
189	Incorporate white paper on final procurement model in PrepSKA report (Del 5.7)
190	
191	**WP 6 Develop funding model for SKA**
192	WP 6.1 Develop comprehensive cost outline for SKA
193	WP 6.2 Survey of national funding agencies
194	Deliver report on national funding (Del 6.1)
195	WP 6.3 , WP 6.4 Investigate possibility of European Investment Bank loan
196	WP 6.5 Investigate private or corporate funding
197	Deliver report on investigation of funding alternatives (Del 6.2)
198	WP 6.6 Develop detailed options paper on SKA funding model
199	Deliver options paper on SKA funding model (Del 6.3)
200	WP 6.7 Develop options for full funding model
201	Deliver White paper on full funding model for SKA (Del 6.4)
202	Incorporate White paper on financial model for SKA in PrepSKA final report (Del 6.5)
203	
204	**WP 7 Implementation Plan leading to SKA construction**
205	Develop PrepSKA final report and Implementation plan
206	Deliver costed SKA system design (Del 7.1)
207	Deliver SKA implementation Plan (Del 7.2)



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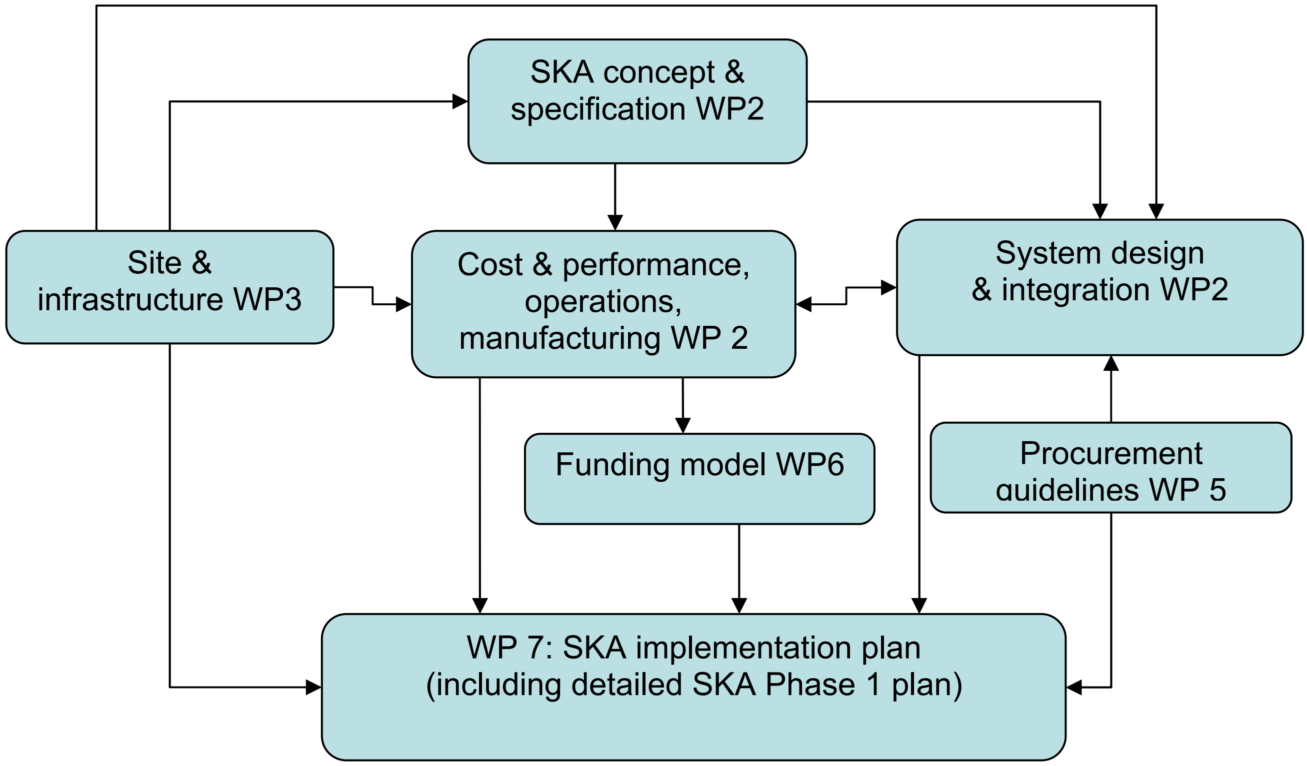


Figure 1.2.2: a diagram that attempts to show the interdependencies of the main work-packages. Not all WPs are included in this diagram since WP1 (management) permeates all WPs; WP4 (governance and legal framework) is also connected, in some manner, to all WPs and feeds its results into WP7, the implementation plan.

1.3 Deliverables, milestones and staff effort

*Table 3a - **Deliverables** List*

Del. no. [1]	**Deliverable name**	**WP no.**	**Nature** [2]	**Dissemi-nation level** [3]	**Delivery date** [4]
3.1	Report on ionospheric scintillation and TIDs for Australia and Southern Africa	3.3	Report	CO	T+6 months
2.1.1	SKA concept delineation	2.1	Report	PU	T+8 months.
4.1	Deliver study on best practice governance and legal frameworks	4.1	Report	PP	T+9 months

1 Deliverable numbers in order of delivery dates. The numbering convention is <WP number>.<number of deliverable within that WP>. For example, deliverable 4.2 would be the second deliverable from work package 4. Deliverables are listed by date order, then by deliverable number within that date.

2 Please indicate the nature of the deliverable using one of the following codes:
R = Report, **P** = Prototype, **D** = Demonstrator, **O** = Other

3 Please indicate the dissemination level using one of the following codes:
PU = Public
PP = Restricted to other programme participants (including the Commission Services).
RE = Restricted to a group specified by the consortium (including the Commission Services).
CO = Confidential, only for members of the consortium (including the Commission Services).

4 Measured in months from the project start date (month 1).

6.1	Summary of the survey of national funding opportunities, processes and timescales presented to the International SKA Forum	6	Report	PP	T+ 9 months
2.1.2	SKA Phase 1 specifications and SKA performance goals .	2.1	Report	PU	T+11 months.
2.1.3	SKA operations concept	2.1	Report	PP	T+12 months
3.2	Deliver RFI hardware and software	3.1	Other	-	T+12 months
3.3	Report on phase referencing and self-calibration for SKA measurements at high frequencies	3.4	Report	PU	T+12months
5.1	Working guidelines for procurement in the course of the WP2 SKA design project		Report	PP	T+12 months
1.1	Annual Report, AR1	1	Report	PU	T+13 months
2.2.1	Sub-system hardware specifications	2.2.1	Report	PU	T+15 months
6.2	Summary of initial investigations on options for alternative (eg private and/or corporate) funding of the SKA.	6	Report	PP	T+15 months
3.4	Report on the optimum configuration for the SKA	3.5	Report	CO	T+18 months
6.3	Draft options paper on the SKA funding model provided to the International SKA Forum		Report	PP	T+19 months
2.1.4	Composite volume incorporating SKA life cycle study, operations plan and support model documents – interim report	2.1.3, 2.1.4, 2.1.5	Report	PP	T+21 months;
2.1.6	Composite volume incorporating SKA cost and performance optimization, manufacturing studies and technical documentation reports – interim report	2.1.6, 2.1.7, 2.1.8	Report	PP	T+24 months
2.1.8	SKA system design – interim report	2.1.9	Report	PP	T+24 months
2.4.1	Initial review of all SKA dish options	2.4	Report	PP	T+24 months
2.5.1	Delivery of initial prototypes and report evaluating four single pixel 0.3-25GHz feeds	2.5.1	Report	PP	T+24 months
2.5.3	Delivery of initial prototypes and report evaluating an AA tile to SKA spec	2.5.2	Report	PP	T+24 months
2.5.5	Delivery of initial prototypes and report evaluating a PAF to SKA spec	2.5.3	Report	PP	T+24 months
2.5.7	Delivery of initial prototypes and report evaluating an MFC to SKA spec	2.5.4	Report	PP	T+24 months
2.5.9	Initial Review of all SKA feed options	2.5	Report	PP	T+24 months
2.6.1	Initial delivery: At least one functional low-noise amplifier per SKA band, packaged or suitable for direct feed connection according to the SKA Phase 1 sub-system specification, and complying with noise temperature, bandwidth and other key specifications	2.6.1	Prototype	-	T+24 months
2.6.3	Initial prototype integrated receivers suitable for operation in all SKA bands, demonstrating both monolithic and packaged solutions, and complying with	2.6.2	Prototype	-	T+24 months

	key specifications				
2.7.1	Initial demonstration of complete low-cost antenna-to-central processing link, with performance report	2.7.1, 2.7.2, 2.7.3	Prototype and report	PP	T+24 months
2.8.1	Deliver initial report on costed DSP and correlator design proposals	2.8.2	Report	PP	T+24 months
2.8.3	Deliver initial report on SKA RFI mitigation strategy	2.8.3	Report	PP	T+24 months
2.9.1	Composite volume incorporating (draft) SKA computing and software specification, computing hardware strategy, and calibration strategy, all with SKA Phase 1 focus	2.9.1, 2.9.2, 2.9.5	Report	PU	T+24 months
2.9.2	Composite volume incorporating (draft) software systems architecture, SKA data products strategy and science post-processing strategy, all with SKA Phase 1 focus	2.9.3, 2.9.4, 2.9.6	Report	PU	T+24 months
5.2	An inventory of the relevant industries in participating countries able to contribute to SKA, and statements of potential willingness to share development costs and risks		Report	RE	T+24 months
1.2	Annual Report, AR2	1	Report	PU	T+25 months
1.3	Mid-Term Review	1	Report	PU	T+27 months
2.2.2	Sub-system integration and evaluation summary	2.2.1	Report	PP	T+27 months
2.5.5	Review of all SKA feed options	2.5.5	Prototypes and report	PP	T+27 months
4.2	Options paper for Governance and legal framework, delivered to Intenational SKA forum	4.2	Report	CO	T+27 months
3.6	Report on the infrastructure deployment timescales, costs and operational models	3.7	Report	CO	T+30 months
3.7	Report on the risk analysis of the science environment	3.8	Report	CO	T+30 months
3.8	Report on RFI measurements in Australia	3.1	Other	CO	T+33 months
3.9	Report on RFI measurements in South Africa	3.1	Other	CO	T+33 months
5.3	A report in which procurement models are analyzed, the analyses to include cost-benefit estimates based on experience at national and international laboratories (e.g. CERN, NASA, ITER), and taking comparative risk into account		Report	RE	T+33 months
5.4	Draft options paper on procurement that will meet technical, policy and geographic distribution goals, for the International SKA Forum		Report	RE	T+33 months
5.5	An inventory of national standpoints, general policies and specific goals to accompany each option in (5.4).		Report	RE	T+33 months
6.4	Final version of options paper, with full funding model for the SKA presented to the interested SKA Funding Agencies		Report	CO	T+33 months
5.6	White paper on options for SKA procurement, for the Plenary Funding Agencies Group.		Report	CO	T+35 months

6.5	Proposed financial model for the SKA incorporated into the PrepSKA Preparatory Report.		Report	PP	T+35 months
3.5	Report on the influence of the physical characteristics of the sites on telescope design, operations, and costs	3.6	Report	CO	T+36 months
3.10	Report on progress and prospects for Radio Quiet Zones for the short-listed SKA sites (WP3.2).	3.2	Report	CO	T+36 months
3.11	WP3 Final Report		Report	CO	T+36 months
4.3	White paper on governance model and legal framework for construction and operation of SKA	4	Report	CO	T+36 months
5.7	White paper on procurement model incorporated into the PrepSKA final report		Report	PP	T+36 months
1.4	Annual Report, AR3	1	Report	PU	T+37 months
2.3.1	IVS specification – final form	2.3.1	Report	PU	T+38 months
2.9.3	IVS demonstration hardware	2.9.2	Prototype	-	T+39 months
2.9.4	IVS demonstration software	2.9.3	Prototype	-	T+39 months
2.3.2	IVS hardware complete	2.3.2	Report	PP	T+42 months
2.4.1	Report detailing performance and cost data for high dynamic range MIRA antenna	2.4.1	Report	CO	T+42 months
2.4.2	Report detailing performance and cost data for composite MeerKAT antenna	2.4.2	Report	CO	T+42 months
2.4.3	Final report detailing performance and cost data for carbon fibre antenna	2.4.3	Report	CO	T+42 months
2.4.4	Final report detailing performance and cost data for TDP antenna	2.4.4	Report	CO	T+42 months
2.5.2	Final Prototypes and written evaluations of four single-pixel feeds operating in the range 0.3 – 25 GHz	2.5.1	Prototypes and report	CO	T+42 months
2.5.3	Final Prototype and written evaluation of an AA tile conforming to SKA specifications	2.5.2	Prototypes and report	CO	T+42 months
2.5.4	Final Prototype and written evaluation of a PAF conforming to SKA specifications	2.5.3	Prototypes and report	CO	T+42 months.
2.5.5	Final Prototype and written evaluation of a MFC conforming to SKA specifications	2.5.4	Prototypes and report	CO	T+42 months
2.6.2	Final delivery: At least one functional low-noise amplifier per SKA band, packaged or suitable for direct feed connection according to the SKA Phase 1 sub-system specification, and complying with noise temperature, bandwidth and other key specifications	2.6.1	Prototype	-	T+42 months
2.6.4	Final prototype integrated receivers suitable for operation in all SKA bands, demonstrating both monolithic and packaged solutions, and complying with key specifications	2.6.2	Prototype	-	T+42 months
2.6.5	Final report on the applicability of new-generation cryo-coolers to the SKA and, if applicable, prototype cooling systems for single-pixel, phased array and cluster feeds	2.6.3	Report and Prototype (if applicable)	PP	T+42 months
2.7.2	Final demonstration of complete low-cost	2.7.1,	Prototype	PP	T+42 months

	antenna-to- central processing link, with performance report	2.7.2, 2.7.3	and report		
2.1.5	Composite volume incorporating SKA life cycle study, operations plan and support model documents – final report	2.1.3, 2.1.4, 2.1.5	Report	PU	T+45 months.
2.1.7	Composite volume incorporating SKA cost and performance optimization, manufacturing studies and technical documentation reports – final report	2.1.6, 2.1.7, 2.1.8	Report	PU	T+45 months
2.3.3	IVS integration and test summary	2.3.3	Report	PP	T+45 months
2.4.6	Review of all SKA dish options	2.4	Report	PU	T+45 months
2.5.10	Final Review of all SKA feed options	2.5	Report	PP	T+45 months
2.6.6	Final review of SKA receiver development	2.6.1	Report	PU	T+45 months.
2.7.3	Detailed report on contemporary and emerging options for SKA Phase 1 station to core links	2.7.3	Report	PU	T+45 months
2.7.4	Strategy document, including costing, for LO and Timing distribution	2.7.4	Report	PU	T+45 months
2.7.5	Report on implementation approach for array monitoring and control	2.7.5	Report	PU	T+45 months
2.8.2	Final costed DSP and correlator design options	2.8.1, 2.8.2	Report	PU	T+45 months
2.8.4	Final SKA RFI mitigation strategy, including new algorithm evaluation	2.8.3	Report	PU	T+45 months
2.8.5	Report on implementation and algorithms for non-imaging processing	2.8.4	Report	PU	T+45 months
2.9.5	Composite volume incorporating final SKA computing and software specification, computing strategy, software system architecture and top-level software plan, data product and delivery strategy, calibration strategy, and algorithms and architecture for science post-processing	2.9.1, 2.9.2, 2.9.3, 2.9.4, 2.9.5, 2.9.6	Report.	PU	T+45 months
2.1.9	SKA system design – final report	2.1.9	Report	PP	T+48 months.
1.5	Annual Report, AR4	1	Report	PU	T+49 months
7.1	Costed SKA system design	7	Report	PP	T+48 months
7.2	SKA implementation plan incorporating all of the output from the other work-packages. The plan will include an outline of the content, the process and the schedule necessary for an SKA MoU	7	Report	PP	T+48 months

*Table 3b - List of **milestones***

Milestone number	Milestone name	Work package(s) involved	Expected date [5]	Means of verification[6]
		WP1: Management		
1.1	AR1	WP1, Del 1.1	T+14	Report
1.2	AR2	WP1, Del 1.2	T+26	Report
1.3	MTR	WP1, Del 1.3	T+27	Review

[5] Measured in months from the project start date (month 1).

[6] Show how you will confirm that the milestone has been attained. Refer to indicators if appropriate. For example: a laboratory prototype completed and running flawlessly; software released and validated by a user group; field survey complete and data quality validated.

1.4	AR3	WP1, Del 1.4	T+38	Report
1.5	AR4	WP1, Del 1.5	T+49	Report
1.6	FR	WP1, Del 1.6	T+51	Review
WP2: SKA design				
2.1	IEAC review	WP2	T+11	Review
2.2	SKA specs set	WP2, Del 2.1.2	T+12	Report
2.3	SKA operations goals	WP2, Del 2.1.3	T+12	Report
2.4	SKA Phase 1 prototyping: sub-system hardware spec set	WP2, Del 2.2.1	T+15	Report
2.5	Interim life cycle, operations and support plan	WP2, Del 2.1.4	T+21	Report
2.6	Interim cost, performance, manufacturing and technical docs	WP2, Del 2.1.6	T+24	Report
2.7	SKA system design – interim report	WP2, Del 2.1.8	T+24	Report
2.8	Draft computing reports, with SKA Phase 1 focus	WP2, Dels 2.9.1, 2.9.2	T+24	Reports
2.9	SKA Phase 1 prototype sub-systems evaluation	WP2, Dels 2.4.n through 2.8.n	T+27	Prototypes and reports
2.10	SKA Phase 1 first design review (1DR)	WP2	T+27	Report
2.11	IVS specification – final form	WP2, Del 2.3.1	T+38	Report
2.12	IVS construction completed	WP2, Del 2.3.2	T+42	Prototype
2.13	IVS integration and test summary	WP2, Del 2.3.3	T+45	Report
2.14	SKA prototype sub-systems evaluation	WP2, Dels 2.4.n through 2.8.n	T+45	Prototypes and reports
2.15	Final life cycle, operations, support, cost, performance, manufacturing and technical docs	WP2 Dels 2.1.5,2.1.7	T+45	Reports
2.16	Final computing reports	WP2, Del 2.9.5	T+45	Reports
2.17	SKA Phase 1 second design review (2DR)	WP2	T+45	Report
2.18	SKA system design – final report	WP2 Del 2.1.9	T+48	Report
WP3: Additional studies of the shortlisted sites for the SKA				
3.1	Ionospheric scintillation	WP3, Del 3.1	T+7	Report
3.2	RFI software and hardware delivery	WP3 Del 3.3	T+12	Report and software and hardware
3.3	Array configuration, influence of site	WP3, Dels 3.4 and 3.5	T+18	Reports
3.4	Infrastructure and risk analysis	WP3, Dels 3.6 and 3.7	T+30	Reports
3.5	Sites RFI reports and radio quiet zone	WP3, Dels 3.8, 3.9, 3.10	T+33	Reports
3.6	Final site report	WP3, Del 3.11	T+36	Report
WP 4: Governance and Legal				

4.1	White paper	WP4, Del 4.3	T+33	Report
WP5: Procurement and Industrial Involvement				
5.1	Guidelines for procurement	WP5, Del 5.1	T+12	Report
5.2	Inventory of industries	WP5, Del 5.2	T+24	Report
5.3	Report on final procurement model	WP5, Dels 5.6, 5.7	T+36	Reports
WP6: Developing the Funding model				
6.1	Complete survey of National funding agencies	WP6, Del 6.1	T+9	Report
6.2	Full funding model	WP6, Dels 6.4 and 6.5	T+33	Reports
WP7: Implementation Plan				
7.1	PrepSKA final report and implementation plan	WP7, Del 7.1	T+48	Report, Plan

*Table 3c - Summary of **staff effort***

Participant no. / short name	**WP1**	**WP2**	**WP3**	**WP4**	**WP5**	**WP6**	**WP7**	**Total person months**
STFC	**12**			6	6	**36**+6	3	69
NWO				**36**+9	5	5	2	57
CNRS				6	6	2	5	19
INAF		55		6	**36**+6	6	3	112
FG-IGN		12		1	1	1	1	16
DEST				12	6	6	3	27
NRF				3	6	3	3	15
NRC				3	2	3	0.5	8.5
UMAN	**48**+4	132	36	2			3	225
ASTRON		222	9	2	2		3	238
MPIfR		100					1	101
Cornell				6	6	6	3	21
UCAM		132					1	133
UOXF		132					1	133
CSIRO		123	36	2	1		2	164
JIVE		24					0.5	24.5
OBSPARIS		84					0.5	84.5
UORL		16					0.5	16.5
UCAL		6					0.5	6.5
RUG		48					0.5	48.5
ISPO		**420**+144			3	3	3	573
NSF				1	1	1	1	4
DRAO		72						72
MeerKAT		111	36					147
TDP		222						222
IPSO host (TBD)		90						90
Total	64	2145	117	92	88	79	42	2627

Notes: Values in **bold** signify the personnel to be funded by the EC contribution to PrepSKA. The UK contribution for WP2 is split evenly between UMAN, UCAM and UOXF for purposes of proposal accountability. The Cornell contribution for WP4-7 comprises effort from various US organisations, including AUI.

1.4 Work packages to be supported by the EC:

Work Package 1 on PrepSKA Management
WP1 provides the project management for PrepSKA, it is described in detail in Section 2.1

Table 4.1: Work Package 1 - Management

Work package number	1	**Start date or starting event:**				T+0 months	
Work package title	**Management of the SKA Preparatory Phase Project**						
Activity Type[7]	MGT						
Participant number	1	9					
Person-months per participant:	**12**	**48**+4					

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To manage the PrepSKA project (see Section 2.1)

Description of work (possibly broken down into tasks), and role of participants

- To ensure that the appropriate management structure is in place;
- To ensure that there is excellent communication and interaction between all relevant parties and work-packages, and particularly the various funding agencies;
- To ensure that reporting is done according to an established procedure and schedule;
- To ensure that the appropriate mechanisms for monitoring progress within work-packages are in place and that milestones and deadlines are achieved;
- To distribute the EC and other financing in a timely manner, including the central administration of travel funds associated with all WPs.
- Liaison with ISPO-CDIT

Deliverables

Annual reports, mid-term review report and final report.

[7] Please indicate one activity type per work package (corresponding to the types used in Forms A.3):
RTD = Research and technological development (i.e. technical work); COORD = coordination activities (e.g. general meetings); SUPP = Support Activities (e.g. legal, financial, strategic and organisational work); MGT = Management of the consortium.

Work Package 2 on SKA Design

WP2 is a technical work package of four years duration. It is organized as a programme covering system design and prototyping activities. Prototyping projects have been defined for each of the major SKA sub-systems in an arrangement mirroring that of the established international SKA engineering development structure. Specific objectives of WP2 are to produce:

a) A costed top-level design for the SKA, and a detailed system design for SKA Phase 1;

b) Advanced prototype SKA sub-systems specified in the course of (a), the sub-systems being based on technology development in current regional Pathfinders and Design Studies;

c) Base technologies for SKA Phase 1 and critical wide field-of-view design technology extensions; and

d) An Initial Verification System (IVS) which rolls together the most advanced SKA Phase 1 technology components and demonstrates the functionality, cost effectiveness and manufacturability of the adopted SKA Phase 1 design.

In developing a costed top-level design, this work package will build on technology developments being undertaken within a >€200M suite of international SKA Pathfinder telescopes and Design Studies, as well as other radio astronomical and industrial developments. The Design Studies are SKADS (FP6, Europe) and TDP (USA, to be funded); the Pathfinders are the Allen Telescope Array (USA), e-MERLIN (UK), EVLA (USA), LOFAR (Netherlands, Germany), APERTIF (Netherlands), MeerKAT (South Africa), and MIRA (Australia, Canada). Tasks within each WP2 project are led by an institute which is expert in the relevant field; lead institutes coordinate the input of their own and other expert contributors. WP2 projects themselves are coordinated and led by relevant domain specialists (see Table 1.4.1) in the Central Design Integration Team (CDIT) to be formed within the International SKA Project Office, ISPO. The ISPO and CDIT are described in section 2.1 on Management Structure. There is a high degree of interdependency between the tasks, the ISPO, through the CDIT, will have the responsibility of coordinating activities across all of WP2.

The key areas of synergy between the Pathfinder activities and Design Studies and the PrepSKA WP2 are:

- Receptor technologies, antennas, feeds
- Wide Field of View technologies
- Signal transport and processing
- Software and computing Image analysis

Risk mitigation is a strong feature of SKA engineering development. with the most conventional receptor technology option for SKA Phase 1 – dishes and single-pixel feeds with 10:1 bandwidth – being the initial starting point for the PrepSKA design. At the same time, strong links between WP2 and regional programs will allow the latest developments in wide field-of-view technologies – aperture array tiles (eg SKADS) and phased array feeds (eg MIRA, APERTIF) – to be incorporated into SKA and Phase 1 designs when they become available. In fact, the Pathfinders and Design Studies, with their diverse but coherent technology developments, afford effective risk mitigation for all WP2 design and prototyping tasks. The envisaged design integration of the global R&D effort to be carried out by the ISPO-CDIT is shown schematically in the Figure below.

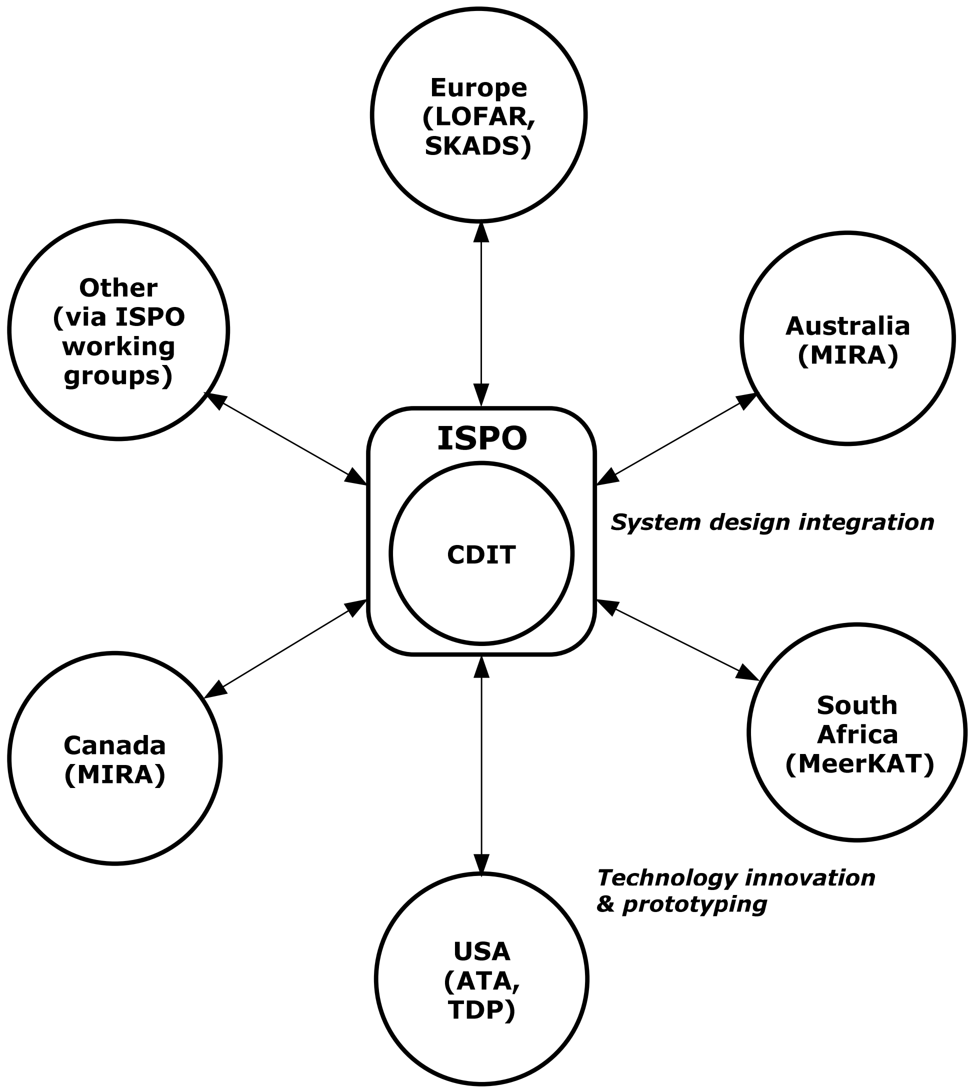


Figure 1.4.1: Schematic diagram showing the central role to be played by the ISPO-CDIT in taking the technology innovation and prototyping carried out by the Design Studies like SKADS in Europe and TDP in the USA and the Pathfinder telescopes (ATA, EVLA, e-MERLIN, LOFAR, APERTIF, MeerKAT, and MIRA) to an integrated end design for the SKA.

To ensure coherence, the entire WP2 design and prototyping effort is mapped into a single project and task matrix. The table below (1.4.1) summarizes the project designations and lists the project leaders.

Table 1.4.1

Project designation	Project name	Project leader (ISPO-CDIT domain specialist)
WP2.1	SKA Design	WP2 Programme leader and System engineer
WP2.2	Sub-system specification and integration	System engineer
WP2.3	Initial Verification System (IVS)	System engineer
WP2.4	Dish design and optimization	Receptor specialist
WP2.5	Feed development and prototyping	Receptor specialist
WP2.6	Receiver development and prototyping	Receptor specialist
WP2.7	Signal transport specification and prototyping	Signal transport specialist
WP2.8	Signal processing development and prototyping	Signal processing specialist
WP2.9	Software and computing specification and prototyping	Software/Computing specialis
WP2.10	WP2 management	Programme manager

As shown in the Gantt chart in section 1.2, WP2 commences with design and specification tasks, which continue to produce insights into SKA design for the duration of the programme. Approximately one year after programme commencement, these tasks deliver the starting points for a series of SKA Phase 1 prototyping projects undertaken principally by contributing regional institutes. A year further on, these tasks feed into the specification and construction of the Phase 1 Initial Verification System, delivered jointly by the ISPO-CDIT and regional partners. At its conclusion WP2 will have provided a top-level costed SKA design and a detailed, verified, system design for Phase 1. Major reviews within the programme occur at T+27 and T+45 months, with design finalization and programme completion being at T+48 months.

The tables following outline WP2 projects in detail, and show the ISPO-CDIT and matching resources allocated to each. By design, many projects require substantial additional engineering input; this is summarized in Table 3c (Section 1.3)

Note for interpreting resource levels: In the tables below there are columns denoting the number of person-months each participant will be contributing to the task. The values in **bold** signify that they will be funded by EC funds; those in normal type are in-kind contributed resources. We do not yet know which institute will host the ISPO-CDIT, this will be known at the time of proposal evaluation, so the tables just show ISPO; the personnel funded in this manner will be employed by the ISPO host institute. Resources contributed by the TDP will come from various institutes in the USA. Resources contributed by the UK will come from either Manchester, Oxford or Cambridge. In WP2.3 you will note that 90 person-months will be contributed by the ISPO host institute, primarily for testing of the Initial Verification System (IVS); again, we do not yet know which institute will be hosting the ISPO-CDIT, however, all potential hosts have indicated their willingness to provide the resources.

Table 4.2: Work Package 2 – SKA Design

Work package number	WP2.1	**Start date or starting event:**			T+0 months		
Work package title	SKA design						
Activity Type	RTD						
Participant number	ISPO	10	15	4	11	5	17
Person-months per participant:	**99+**99	48	8	9	9	6	12
Participant number	MeerKat	TDP	UK				
Person-months per participant:	57	39	36				

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

WP2 is the main SKA design activity, it will produce a costed top-level design for the SKA and a detailed system design, incorporating costing, for Phase 1 of the SKA.

Description of work (possibly broken down into tasks), and role of participants

This project is the over-arching international activity for the engineering design of the SKA and addresses both short and long-term challenges. The projected 2020 completion date of the SKA, and technology advances still to arrive in the coming decade, mean that a comprehensive concept design (including projected costing) is the feasible SKA deliverable on FP7 timescales. For SKA Phase 1 (the first ten-percent SKA) the technology base is much firmer and the present project will produce a detailed, verified, design to allow Phase 1 construction in the period 2012 – 2015.

Project objectives will be achieved by a process which continues definition and delineation of the SKA concept within astronomy and engineering communities, sets and reviews the specifications for SKA and Phase 1, undertakes cost and performance optimization studies, examines trade-offs, and formulates conceptual SKA and detailed Phase 1 system designs. The adopted designs will reflect inputs from manufacturing, operations, instrument support (including maintenance) and life cycle studies performed as part of the project, as well as from regional Pathfinders and Design Studies. In addition to the participants listed in the various task outlines, this project will be linked to the wider SKA community via the SKA Forum and the ISPO's already functional science, engineering and operations working groups.

WP2.1 is divided into the nine tasks set out below, the relatively large number reflecting the complexity of the undertaking. The project will be coordinated by the CDIT, with the Programme Leader (who will also be the SKA International Project Engineer) and System Engineer jointly leading WP2.1.

WP2.1.1 is the **SKA concept delineation** task. Building on the existing SKA Reference Design, and on prioritized science goals and technical updates to be available in early 2008, this task will outline an SKA concept which meets the majority of science requirements using technologies likely to be affordable over the next decade. The concept will outline stages in the capability development of the SKA and will include in-depth discussion of the SKA Phase 1 vision.
Participants: This task will be led by the CDIT, drawing on the inputs of both WP2 and external participants, the latter via ISPO working groups. A major role of the working groups is to review continuously progress and results from SKA Pathfinders and Design Studies.

WP2.1.2 is the SKA **specification** task. This task will use plans developed in WP2.1.1 to frame performance goals for each stage of the SKA. It will develop top-level specifications for SKA Phase 1 and outline a technology path to its implementation. This path may involve a number of receptor technologies and will include decision points in the technology proving process. At the end of the task the International Engineering Advisory Committee (IEAC), a panel of independent experts, will review the proposed SKA concept and staged specifications paying particular attention to (i) the compatibility of SKA Phase 1 with longer-term SKA requirements and (ii) the likely ability of SKA Phase 1 to meet its agreed specifications.
Participants: This task will be led by the CDIT, drawing on the inputs of both WP2 and external participants, the latter via ISPO working groups.

WP2.1.3 is the SKA **life cycle study** task. It will outline an end-to-end life cycle description of the SKA, and develop a first-order cost model applicable to major stages of the instrument's life. WP2.1.3 will be closely linked with the SKA system design (WP2.1.9), especially in terms of setting out design precepts in key areas

such as telescope expandability and flexibility, design standardization, and documentation requirements. The task has two main parts. First, major aspects of the life cycle of the SKA will be described in terms of stages such as development, construction (including production), commissioning, operation, maintenance, upgrading and de-commissioning. Second, a life cycle support model, with an allied costing model, will be developed. This involves consideration of issues such as reliability, instrument availability, maintainability, and requirements at each SKA facility. As well as building on the experience of the current SKA Pathfinders and Design Studies the task will examine closely the plans and experience of major instruments such as the VLA, MERLIN, WSRT, PdBI, ATCA and ALMA.
Participants: This task will be led by the CDIT. Other contributors include MeerKAT (which is developing a life cycle formalism for the South African Pathfinder), MIRA:*CSIRO* (with large array operational experience), ASTRON (with LOFAR experience and background in relevant SKADS studies) and UK (with experience in SKADS and in the operation of large radio observatories).

WP2.1.4 is the SKA **operations plan** task. This task will develop a high-level operational model for the SKA and a detailed operational plan for the operational of SKA Phase 1. The aim is to ensure that the SKA can be operated in an effective and efficient way, both in terms of operational modes and performance, and in terms of total lifecycle costs (including aspects such as power consumption, maintenance and upgrades). WP2.1.4 provides key inputs to the WP2.1.9 system design task. It will seek ways of breaking the present operational cost paradigm for radio telescopes (~10% of capital cost p.a.) while retaining the broad user access and instrumentation versatility needed for transformational science. The task will incorporate experience gained from existing instruments while analyzing the operational impact of new SKA operating modes (e.g. multi-user access in at least some frequency bands). Inputs from SKA Pathfinders will be incorporated as these telescopes become operational.
Participants: This task will be led by ASTRON, which has recent experience in developing operational models for the new-generation LOFAR telescope. Other key contributors are the CDIT (via the Programme Leader and System Engineer), TDP, MIRA:*CSIRO* , UK:*Manchester* (each of which brings substantial operational experience from instruments in the USA, Australia and UK), and MeerKAT (which has developed an operational formalism for the South African Pathfinder). Wider consultation is also planned via the ISPO working groups.

WP2.1.5 is the SKA **support model** task. This task will produce a top-level support model for the SKA, including a maintenance plan for SKA Phase 1. It is linked closely with the life-cycle and operational tasks (WP2.1.3, WP2.1.4) and is a primary input to the system design task (WP2.1.9). SKA maintenance aspects are crucial in realizing the operational goals while simultaneously containing costs. This task will look at issues such as usage (mission) profile, availability and reliability requirements and targets, and required lines of support. Modelling will take into account items such as maintenance and repair schedules and resources, renewal of software and hardware components built using low-cost consumer technologies, equipment operating environment and power consumption, performance-reliability trade-offs, and maintenance and re-investment costs. A comprehensive audit of maintenance experiences at existing telescopes and SKA pathfinders will be made, at the same time studying the SKA as a “complex” system with new possibilities in areas such as expert system based diagnosis, and design for graceful degradation.
Participants: WP2.1.5 will be coordinated by the CDIT with key contributions from ASTRON, TDP, and MIRA:*CSIRO*, each of which has operational experience with large arrays. MeerKAT will also contribute, principally in helping to define the formal links between WP2.1.5 and the system design task, WP2.1.9.

WP2.1.6 is the SKA **cost and performance optimization** task. This task will continue development of cost and performance (C&P) estimation tools for the SKA, and will illuminate key trade-offs in the design of the instrument. It will collect and distil high integrity C&P data from Pathfinders, Design Studies and other sources. Initially, the task will facilitate refinement of SKA first-round engineering specifications, thereby providing input to the WP2.1.1 and WP2.1.2 delineation and specification tasks. Detailed SKA Phase 1 optimizations and initial SKA investigations will be completed during PrepSKA, and the tools developed will be used for the life of the SKA project. These tools will allow optimization of implementation techniques taking into account, for example, likely maturity dates of pivotal technologies. Examples of this include comparison of different realizations of digital signal processors and the impact of commercial super-computer C&P limitations on SKA evolution.
Participants: This task will be led by the CDIT. The CDIT will focus on development of a C&P software tool, while ASTRON and UK will build on the efforts of the SKADS programme to contribute detailed costing information on Aperture Arrays and related systems. TDP will undertake a similar role for dishes and single-pixel feeds. MIRA:*CSIRO* will contribute information for phased array feeds and software. MPIfR and FG-IGN will contribute component-level C&P data for key data transport and RF systems.

WP2.1.7 is the SKA **manufacturing studies** task. This task will ensure that, from the outset, the SKA and SKA Phase 1 designs incorporate optimizations for cost and reliability at the required production volumes. It will consider both electronic and mechanical systems and will be linked closely to the WP2.1.9 system design and to WP5 Procurement and Industrial participation activities. The task will access and extend industry expertise available via regional Pathfinders and Design Studies. It will outline consistent (and optimum) manufacturing practices for the SKA, investigating issues such as up-front versus downstream costs (including non-recoverable engineering resources), long lead-time items, and implementation of quality control practices throughout the SKA design and its manufacturing processes.
Participants: This task will be led by UK:*Manchester*, which has extensive links to industry partners with relevant expertise in both electronic and mechanical systems. Other contributors have, or shortly will have, substantive industry engagement programs in areas such as antennas (ASTRON, TDP), signal transport (MPIfR, INAF), and RF systems (OBSPARIS). MIRA:*CSIRO* will contribute through its experience with the Australian SKA Industry Cluster.

WP2.1.8 is the SKA **technical documentation** task. This task will design and implement a technical documentation system appropriate to the complex, geographically diverse SKA project. The documentation system will be scaleable and will be used initially for WP2 design activities, including the WP2.1.9 system design task. The methodology will accommodate various SKA stages, from design to SKA Phase 1 to later implementation stages. It will define formal standards for the content of technical documentation for various SKA support purposes (WP2.1.5), for Interactive Electronic Technical Publications (IETPs), and for change-management and archiving practices. The adopted documentation solution will be hierarchical in complexity, facilitating its use in activities ranging from innovation capture through to design, production and maintenance.
Participants: This task will be led by the CDIT, with contributions from MeerKAT (which has been trialing elements of an on-line documentation formalism for the South African Pathfinder), ASTRON and TDP, the latter two contributors having experience in operating a range of synthesis radio telescopes.

WP2.1.9 is the SKA **system design** task. This task produces the major WP2 deliverables: a costed top-level design for the SKA and a much more detailed system design, including costings, for Phase 1. It draws on many other WP2 activities but is especially tightly coupled with other WP2.1 tasks. Primary design goals include expandability of SKA capability from Phase 1 to the full SKA, and low total cost of ownership.

The system design task will focus on three facets.

(a) Physical design. This will use WP2.1.2, WP2.1.6 and other results (e.g. from Pathfinders and Design Studies) which set out the proposed sub-system implementation technologies. A hierarchical physical architecture will be developed, one aspect of which is a physical description of the array and its constituents. The architecture will describe major electrical interfaces between physical building blocks for data, control and power distribution. Where applicable, mechanical assemblies and mechanical interfaces will also be described. A mapping of sub-systems to physical components, at module level, will be made.

(b) Behavioural design. This will use information from WP2.1.4 to define the input and output data, and the associated "black box" behaviour of the SKA system. A hierarchy of system functions will be developed to describe the functional design of the system, including aspects such as user interfacing, system control, system monitoring, signal conditioning, signal processing, and data product packaging. Major software components will be identified in association with WP2.9.1. The behavioural design will include the flow of signal data and control data through the system, and function will be linked to physical design in key areas such as data flow and electrical interfaces

(c) Performance design. This uses links to WP2.1.2 and WP2.1.6 to formulate system-level performance requirements. These requirements will be broken down into sub-system requirements via development of system architecture performance models. Performance design will be linked to other design facets by mapping performance to physical components, functions and data interfaces. Cost modelling, including cost allocation to sub-systems in a form suitable for use in WP2.1.6, will also be included.

At the end of the system design task the SKA system architecture will have been described in terms of a list of hardware and software sub-systems; the top-level physical composition of sub-systems defined; interfaces between sub-systems specified; and functions and performance mapped to sub-systems. While WP2.1.9 will contain formal risk tracking and management sub-tasks, links to technology prototyping tasks (WP2.3 –

WP2.9) and thence to the diverse suite of large-scale SKA Pathfinder and Design Studies, provide a strong practical risk mitigation strategy.
Participants: This central task will be led by the CDIT in association with all WP2 participants, including those listed in linked tasks. Recognizing the wide interest in this activity, further links with the wider SKA community will be in place via the ISPO working groups.

Deliverables (brief description and month of delivery)

1. SKA concept delineation (WP2.1.1). Type: Report. Delivery: T+8 months.
2. SKA Phase 1 specifications and SKA performance goals (WP2.1.2). Type: Report. Delivery: T+11 months.
3. SKA operations goals. Type: Report. Delivery: T+12 months.
4. Composite volume incorporating SKA life cycle study, operations plan and support model documents (WP2.1.3, WP2.1.4, WP2.1.5). Type: Report. Delivery: Interim – T+21 months; Final – T+45 months.
5. Composite volume incorporating SKA cost and performance optimization, manufacturing studies and technical documentation reports (WP2.1.6, WP2.1.7, WP2.1.8). Type: Report. Delivery: Interim – T+24 months; Final – T+45 months.
6. SKA system design (WP2.1.9). Type: Report. Delivery: Delivery: Interim – T+24 months; Final – T+48 months.

Work package number	WP2.2	**Start date or starting event:**			T+12 months		
Work package title	SKA Phase 1 sub-system specification and evaluation						
Activity Type	RTD						
Participant number	ISPO						
Person-months per participant:	**54**						

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To expand the sub-system requirements formulated within the WP2.1.9 system design into a form enabling the design and test of hardware prototypes for SKA Phase 1.

Description of work (possibly broken down into tasks), and role of participants

This is an interface project, sitting between the WP2.1 system design and the WP2.4 – 2.8 hardware prototyping projects. It enables the production of optimized SKA Phase 1 sub-systems by regional Pathfinder and Design Study groups, and the evaluation of this hardware preparatory to the definition and construction of the Initial Verification System (WP2.3).

WP2.2 will be coordinated by the CDIT, with the System Engineer being the WP2.2 Project Leader.

WP2.2.1 is the **SKA Phase 1 sub-system specification and evaluation** task. This task will translate module-level specifications produced by the system design activity (WP2.1.9) into hardware specifications of sufficient detail to allow regional SKA groups to design and construct prototype hardware. This hardware will be broadly similar to that produced within Pathfinder and Design Studies but will reflect another level of optimization for the SKA Phase 1 application. WP2.2.1 will evaluate prototypes produced by WP2.4 – WP2.8, this evaluation being part of the SKA Phase 1 1DR (design review) and the basis of the Initial Verification System (WP2.3) specification.
Participants: The task will be led by the CDIT and have extensive interaction with regional SKA groups participating in hardware prototyping tasks WP2.4 – 2.8.

Deliverables (brief description and month of delivery)

1. Sub-system hardware specifications (WP2.2.1). Type: Report. Delivery: T+15 months.
2. Sub-system evaluation summary (WP2.2.1). Type: Report. Delivery: T+27 months.

Work package number	WP2.3	Start date or starting event:			T+24 months	
Work package title	Initial Verification System (IVS)					
Activity Type	RTD					
Participant number	ISPO	10	4	TDP	UK	ISPO host	
Person-months per participant:	**72**	4	3	9	6	90	

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To produce an Initial Verification System (IVS), a field prototype which rolls together the most advanced SKA Phase 1 technology components and demonstrates the functionality, cost effectiveness and manufacturability of the adopted SKA Phase 1 design.

Description of work (possibly broken down into tasks), and role of participants

The IVS will integrate the best versions of SKA sub-system prototypes, as developed in WP2 projects, regional Pathfinders and Design Studies. It will demonstrate the functionality of the SKA Phase 1 system design while placing particular emphasis on large-scale manufacturing, assembly, integration and test (MAIT) aspects, a relatively new demand in radio astronomy. These “design for manufacture” aspects include unit cost effectiveness, production quality control, rapid deployment capability and field maintainability.

At a minimum the IVS will comprise two complete signal chains, from collector systems (such as dishes or aperture arrays) to post-processing platforms. The collector systems will not be constructed as part of WP2 but will be provided by one or more Pathfinder or Design Study projects. The IVS will be deployed at the site of an SKA Pathfinder – preferably on the selected SKA site, if the site decision were to be available on the timescale of the FP7 program. Basic two-element interferometry with the IVS will test most of the engineering functionality of the system design, while the combination of the IVS and Pathfinder will ensure that an essentially complete astronomical characterization is available by the end of WP2.

The IVS can be thought of as a pilot installation, showing the way to a manufacturable SKA Phase 1. A final Production Verification System (PVS), incorporating pre-production collector systems, will require specialized and potentially expensive tooling and is therefore deferred until the beginning of the SKA Phase 1 construction project. Although the IVS will rely on Pathfinder and Design Study antennas – which may in fact be close to SKA Phase 1 requirements – the IVS will demonstrate effectively the bulk of the WP2 system design, with the MAIT emphasis outlined above. Significantly though, overlapping IVS and Pathfinder timescales, and close collaboration between the CDIT and regional engineering groups, make it likely that the IVS will also lead to standardization of at least some major sub-systems across the suite of SKA Pathfinders.

WP2.3 is divided into three tasks, set out below. All tasks are coordinated by the CDIT, with the System Engineer being the WP2.3 project leader.

WP2.3.1 is the **IVS specification** task, in which the detailed requirements for the field prototype will be set out. These requirements will be drawn from the SKA system design task (WP2.1.9) and based on the experience gained in the hardware and software prototyping tasks (WP2.4 through WP2.9). Results from regional Pathfinders and Design Studies will also be essential inputs to WP2.3.1.
Participants: This will be led by the CDIT. TDP will collate and supply prototyping results relevant to dish antennas. UK will provide additional domain knowledge in data transport solutions, while ASTRON will contribute specialist services in the linking of hardware and software specifications.

WP2.3.2 is the **IVS construction** task. The IVS will be constructed in modular form, with the various modules being assigned to institutes having production expertise and strong industry ties. It is expected that the IVS will have a strong Pathfinder and Design Study heritage, with its sub-systems being based on optimizations produced in the course of WP2.4 – WP2.9.
Participants: This task will be led by the ISPO host institute, which will have extensive in-house production facilities and strong industry links to potential manufacturers of most IVS sub-systems. TDP will manage the interface of dish antennas with the remainder of the IVS, while INAF will provide short-haul optical transport links.

WP2.3.3 is the **IVS integration and test** task. This task will verify and characterize the IVS and, by extension, the system design adopted for SKA Phase 1. IVS evaluation will be a major part of the SKA Phase 1 2DR (design review). Review results, and other results from WP2.3.3 will be fed back to the system design task (WP2.1.9), allowing design finalization prior to the end of the PrepSKA program.
Participants: This task will be led by the CDIT with inputs from the ISPO host institute, ASTRON, UK, TDP and INAF, each of which will assign commissioning and test personnel to validate IVS design and construction contributions.

Deliverables (brief description and month of delivery)

1. IVS specification (WP2.3.1). Type: Report. Delivery: T+38 months.
2. IVS hardware (WP2.3.2). Type: Prototype. Delivery: T+42 months.
3. IVS integration and test summary (WP2.3.3). Type: Report. Delivery: T+45 months.

Work package number	WP2.4	Start date or starting event:			T+13 months	
Work package title	Dish design and optimization					
Activity Type	RTD					
Participant number	ISPO	15	DRAO	MeerKat	TDP		
Person-months per participant:	**12**	12	12	12	12		

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To evaluate cost-efficient dish antenna prototypes funded and produced by SKA Pathfinders and Design Studies, each antenna being constructed using manufacturing technologies having potential application to the SKA. In the context of the SKA system design, to provide a detailed analysis of these antennas in terms of performance metrics, cost-performance trade-offs and flexibility attributes.

Description of work (possibly broken down into tasks), and role of participants

Dish antennas are likely to be the basis of SKA Phase 1 and will be major components of SKA. Current Pathfinders have made, and are still making, substantial progress in producing and testing designs in the critical 6-20-m diameter range. However, with SKA Phase 1 specifications being set during the course of PrepSKA, it is essential to optimize dish specifications and manufacturing technology in the context of the overall SKA design. This project will inform system design decisions and, via links with continuing Pathfinder and Design Studies work, will generate comprehensive design, cost, and performance data for SKA dish options. These inputs will be fed to the system design carried out in WP2.1.9.

The SKA dish diameter will remain unspecified during WP2.4 (the specification being part of the WP2.1.9 system design process) but it is expected that antenna designs chosen in current SKA Pathfinders and Design Studies will all yield critical information. While four specific antenna options are addressed in WP2.4, a fifth option involving 6-m dishes is being well-characterized in the context of the operational Allen Telescope Array; results will be reported as part of WP2.4.4. This diversity in dish design and realization is a practical risk mitigation strategy for the SKA design process.

WP2.4 is divided into four tasks, set out below. All tasks are coordinated by the CDIT, with the Receptor Specialist being the WP2.4 project leader. In all cases performance, cost, manufacturability and other attributes will be reported against standard metrics developed by the CDIT. While including comprehensive commentaries on specific antennas, all tasks will report on the design flexibility attributes of the base technologies and manufacturing techniques employed.

WP2.4.1 is the **dish design 1** task. It will focus on producing a costed design for a “reference” metal antenna optimized for operation in the 0.3 – 3 GHz range. In particular, dish mounting arrangements yielding high dynamic range synthesis images will be studied. These arrangements, of which there are several variations, give an antenna reception pattern which is fixed on the sky. The 12-m antennas deployed for the Australian MIRA pathfinder will yield much information about this type of antenna and it is intended to make extensive use of MIRA results in preparing design and evaluation material.
Participants: This task will be led by the MIRA:*CSIRO*, with other contributions coming via the ISPO Engineering Working Group.

WP2.4.2 is the **dish design 2** task. It will examine options for SKA antennas having reflectors (and possibly some structures) based on very low-cost composite materials. The antenna to be studied in detail is a 15-m design produced for the MeerKAT pathfinder.
Participants: This task will be led by MeerKAT, with other contributions coming via the ISPO Engineering Working Group.

WP2.4.3 is the **dish design 3** task. It will focus on design and characterization of an antenna fabricated using a stiff carbon fibre material, allowing construction of a much lighter reflector with correspondingly less massive mountings. While dish material costs are higher than in some other approaches, the lightness and stiffness advantages may lead to a more attractive overall optimization for SKA Phase 1, especially if extension to higher operating frequencies is contemplated as part of SKA evolution. The antenna to be evaluated will be produced by the Canadian SKA program, which will draw on progressive results in WP2.1 and other WP2.4 tasks in order to specify the dish diameter and other key attributes.

Participants: This task will be led by DRAO, with other contributions coming via the ISPO Engineering Working Group.

WP2.4.4 is the **dish design 4** task. It will involve design and characterization of an antenna which is optimized with respect to sensitivity (G/T) but which also accounts for an evolving capability in SKA Phase 1 and, eventually, the SKA itself. The capabilities of the prototype may therefore be a superset of what is required for SKA Phase 1 but the antenna design (including the diameter) will remain influenced strongly by progress in the WP2.1 design project. As well as characterizing the new prototype dish, comprehensive information on the existing 6-m Allen Telescope Array antennas will also be reported. The antenna to be evaluated will be produced as part of the TDP. WP2.4.4 will also deliver reviews of all SKA dish antenna developments.
Participants: This task will be led by TDP, with other contributions coming via the ISPO Engineering Working Group and, in the case of the final review, other WP2.4 participants.

Deliverables (brief description and month of delivery)

1. Report detailing performance and cost data for high dynamic range MIRA antenna (WP2.4.1). Type: Report. Delivery: T+42 months.
2. Report detailing performance and cost data for composite MeerKAT antenna (WP2.4.2). Type: Report. Delivery: T+42 months.
3. Report detailing performance and cost data for carbon fibre antenna (WP2.4.3). Type: Report. Delivery: T+42 months.
4. Final report detailing performance and cost data for TDP antenna (WP2.4.4). Type: Report. Delivery: T+42 months.
5. Final review of all SKA dish development (WP2.4.4). Type: Report. Delivery: Initial – T+24 months; Final - T+45 months.

Work package number	WP2.5	**Start date or starting event:**			T+13 months		
Work package title	Feed optimization and prototyping						
Activity Type	RTD						
Participant number	ISPO	10	15	DRAO	4	MeerKat	5
Person-months per participant:	**12**	24	40	6	3	12	6
Participant number	TDP	UK					
Person-months per participant:	51	48					

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To produce and evaluate prototype single-pixel, phased array and cluster feeds suitable for use with SKA dishes and to continue development of aperture phased arrays in order to optimize performance in accordance with WP2.1 SKA specifications.

Description of work (possibly broken down into tasks), and role of participants

The SKA project has been pursuing technologies for realizing low-cost receptors with the sensitivity required to meet ambitious single-field and survey sensitivity goals. There are different optimum receptor technologies for different frequency bands, with frequencies < 0.3 GHz being the domain of sparse aperture arrays (e.g. LOFAR). Above 3 GHz parabolic dishes with wideband, single-pixel feeds are likely to be the only feasible technologies. Over the decade 0.3 – 3 GHz the single-pixel solution is again likely to be viable but three wide field-of-view (WFoV) options promise additional scientific benefits, at comparable costs. However, for SKA Phase 1 it is possible that WFoV technology will not be sufficiently mature (in terms of simultaneous astronomical and manufacturability demonstrations) for large-scale implementation. As a risk mitigation strategy, the Phase 1 system design will therefore adopt single-pixel receptors as a base technology, folding in WFoV results as they become available.

Two WFoV solutions retain the first-stage optical beam-forming action of a parabolic dish but expand the available FoV using a focal plane array, either in the form of a dense phased array feed (PAF) or a more conventional multiple-feed cluster (MFC). The third solution, addressed by the SKADS program, discards the dish and uses dense phased arrays in an aperture array (AA). Technology development for all of these “feed” options is being done within current SKA Pathfinder and Design Studies. By virtue of interaction between the CDIT and regional engineering teams, WP2.5 will ensure that prototype feeds conforming to the SKA specifications generated by the WP2.1 design tasks are constructed and characterized. As with risk mitigation in the dish design area (WP2.4), the pursuit of multiple options increases the likelihood that at least one WFoV feed technology will prove viable on SKA development timescales.

WP2.5 is divided into four tasks, set out below. The project is coordinated by the CDIT, with the Receptor Specialist being the WP2.5 project leader.

WP2.5.1 is the **wideband single-pixel feed** task. It will design, prototype and evaluate at least four wideband feeds: the ATA feed, the Chalmers/Kildal feed, a quad-ridge feed from Caltech, and a quasi-self-complementary feed from Cornell. Work within the task will include electromagnetic design and evaluation of the feed designs for the expected range of SKA reflector diameters and optics. Prototypes will be tested on appropriate antenna test ranges. The outcome will be one or more viable feed solutions for the SKA in the frequency range 0.3 to 25 GHz. WP2.5.1 will also coordinate production of reviews of all SKA feed development work.
Participants: This task will be led by TDP which will conduct the main single-pixel design study. MeerKAT will provide test beds for experimental feeds, one platform being a 15 m composite dish (WP2.4.2). The final review will produced in conjunction with other WP2.5 participants and the ISPO Engineering Working Group.

WP2.5.2 is the **WFoV aperture array tiles** task. This task will build on the results of the FP6 SKA Design Study (SKADS) to verify further, through simulation and demonstration, the suitability of aperture array (AA) technology for the SKA. WP2.5.2 will focus on performance, cost, power requirements, very high volume manufacturability and ease of installation, taking into account SKADS studies that have already studied basic manufacturability and performance trade-offs. At the end of the task, and building on the SKADS conclusions, it will be clear how the integration of AA technology can contribute most effectively to SKA performance and what effect this has on SKA Phase 1 design and roll-out.

Participants: This task will be jointly led by UK:*Manchester* and ASTRON, following a SKADS task management model. UK will lead system-level integration aspects while ASTRON will focus on array manufacturability and distillation of tile performance results. Additional contributions from FG-IGN will focus on array testing.

WP2.5.3 is the **WFoV phased array feed** task. It will show, through simulation and demonstration, the suitability of phased array feed (PAF) technology for the SKA. As in WP2.5.2 performance, cost and power will be major issues but, with the relative immaturity of this technology, the present task will also address methodologies for large-scale manufacture of PAFs. It will leverage on work in the MIRA Pathfinder, the first interferometer to use PAFs.
Participants: The task will be led by MIRA:*CSIRO* and will include contributions from ASTRON (where the related APERTIF upgrade of the WSRT is proceeding), UK and DRAO. MIRA:*CSIRO* and ASTRON will be concerned primarily with PAF astronomical demonstration, while UK and DRAO will emphasize radiator element technologies and antenna-range measurement tasks, respectively.

WP2.5.4 is the **WFoV multiple-feed cluster** task. This task will show, through simulation and demonstration, the suitability of multiple-feed cluster (MFC) technology to the SKA. This WFoV approach is similar in principle to "multi-beam" receivers now used on some cm and mm-wave single-dish telescopes. The present task will examine performance, cost, power and manufacturability issues while investigating the potential for increasing fractional bandwidth in relatively close-packed feed designs. It will make extensive use of the MeerKAT Pathfinder, in which MFCs may be used.
Participants: This task will be led by MeerKAT, with contributions from TDP. Allied to WP2.5.1 efforts, MeerKAT will focus on the optimization of wideband feeds in a cluster environment, the base feed design flowing primarily from TDP.

Deliverables (brief description and month of delivery)

1. Prototypes and written evaluations of four single-pixel feeds operating in the range 0.3 – 25 GHz (WP2.5.1). Type: Prototypes and report. Delivery:Initial – T+24 months; final - T+42 months.
2. Prototype and written evaluation of an AA tile conforming to SKA specifications (WP2.5.2). Type: Prototype and report. Delivery: Initial – T+24 months; final - T+42 months.
3. Prototype and written evaluation of a PAF conforming to SKA specifications (WP2.5.3). Type: Prototype and report. Delivery: Initial – T+24 months; final - T+42 months.
4. Prototype and written evaluation of a MFC conforming to SKA specifications (WP2.5.4). Type: Prototype and report. Delivery: Initial – T+24 months; final - T+42 months.
5. Review of all SKA feed options (WP2.5.1). Type: Report. Delivery: Initial – T+24 months; Final – T+45 months.

Work package number	WP2.6	**Start date or starting event:**			T+13 months	
Work package title	Receiver optimization and prototyping					
Activity Type	RTD					
Participant number	ISPO	10	15	DRAO	4	MeerKat	11
Person-months per participant:	**9**	36	15	12	3	3	6
Participant number	17	TDP	UK				
Person-months per participant:	42	72	45				

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To produce a suite of advanced receiver prototypes covering the frequency range 0.1 – 25 GHz, based on technologies being developed in SKA Pathfinders and Design Studies.

Description of work (possibly broken down into tasks), and role of participants

This project will deliver at least one prototype receiver in each of the low (0.1 - 0.3 GHz), medium (0.3 – 3 GHz) and high (0.3 – 25 GHz) SKA bands. Emphasis will be placed on highly-integrated (chip) solutions for SKA Phase 1 and, while ambient temperature operation of most SKA receiving components is foreseen, the applicability of new-generation cryogenic coolers to the SKA mid and high bands will be explored. The project will verify, through simulation and prototyping, the overall SKA receiver chain and, via industry links, emphasize manufacturability and power consumption considerations.

WP2.6 is divided into three tasks, set out below. All tasks are coordinated by the CDIT, with the Receptor domain specialist being the WP2.6 project leader.

WP2.6.1 is the **low-noise amplifiers** task in which a variety of integrated circuit processes will be employed to produce low-cost cm-wave amplifiers with noise equivalent temperatures rivalling those hitherto found only in more expensive, and often one-off, radio astronomy solutions. SKADS will have produced detailed reports on the relative performance of ambient temperature LNA designs and technologies for phased arrays; WP2.6.1 will optimize and refine these designs for the very high volume requirements of phased arrays. Studies of LNA cooling and/or temperature stabilization requirements will also be undertaken, and a final review of all SKA receiver developments produced.
<u>Participants:</u> This task will be led by ASTRON, which will focus on low and mid-band LNA designs based on InP, CMOS and SiGe processes. Contributors include UK (mid and high-band LNAs, GaAs and InP materials, processes and manufacturability), TDP (mid and high-band LNAs, InP processes), DRAO (mid-band LNAs, CMOS and SiGe processes), and OBSPARIS (mid-band LNAs, CMOS and SiGe processes). MPIfR and MeerKAT will contribute additional circuit design expertise, including new topologies made possible by high gain-bandwidth product semiconductor processes.

WP2.6.2 is the **integrated receivers** task in which two approaches to very highly integrated (chip) receivers will be demonstrated. These approaches are monolithic (single chip) fabrication of complete receivers (from post-LNA amplifiers to digitizers), and advanced packaging and connection of RF sub-systems based on multiple-chip technologies.
<u>Participants:</u> This task will be led by MIRA:*CSIRO*, which will concentrate on low-cost, monolithic CMOS receivers. UK and OBSPARIS will focus on high performance, custom-fabricated sub-systems, while ASTRON, OBSPARIS and TDP will contribute specialist knowledge of advanced connection and packaging solutions.

WP2.6.3 is the **new-generation cryogenics** task. This work will identify cost-effective cryogenic solutions for potential use with single-pixel feeds, cluster feeds and phased-array feeds. It will interact with vendors and independent experts; assess commercial coolers in terms of lifetime, failure modes, reliability, maintenance requirements, power consumption and efficiency; recommend whether off-the-shelf or custom cooling solutions are applicable to the SKA; and (if applicable) procure prototype coolers for prototype feed and receiver systems.
<u>Participants:</u> This task will be led by TDP (bringing the direct experience gained during construction of the Allen Telescope Array to the study), while inputs from UK, MPIfR, MIRA:*CSIRO* and MeerKAT will provide specifications, customization studies and, if applicable, test platforms for practical cooling systems associated with various SKA feed types.

Deliverables (brief description and month of delivery)

1. At least one functional low-noise amplifier per SKA band, packaged or suitable for direct feed connection according to the SKA Phase 1 sub-system specification, and complying with noise temperature, bandwidth and other key specifications (WP2.6.1). Type: Prototype. Delivery: Initial – T+24 months; Final – T+42 months.
2. Prototype integrated receivers suitable for operation in all SKA bands, demonstrating both monolithic and packaged solutions, and complying with key specifications (WP2.6.2). Type: Prototype. Initial – T+24 months; Final – T+42 months .
3. Report on the applicability of new-generation cryo-coolers to the SKA and, if applicable, prototype cooling systems for single-pixel, phased array and cluster feeds (WP2.6.3). Type: Report and Prototype (if applicable). Delivery: T+42 months.
4. Final review of SKA Phase 1 receiver development (WP2.6.1). Type: Report. Delivery: T+45 months.

Work package number	WP2.7	**Start date or starting event:**			T+13 months	
Work package title	Signal transport specification and prototyping					
Activity Type	RTD					

Participant number	ISPO	10	15	4	16	MeerKAT	11
Person-months per participant:	**15**	6	6	9	6	6	6
Participant number	TDP	UK					
Person-months per participant:	18	87					

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To produce advanced prototypes demonstrating SKA data transport on distance scales ranging from less than 20 m to more than 200 km, to report on solutions for transport over still longer distances, and to demonstrate techniques for generation and distribution of local oscillator and timing information within the SKA. A design for the Array monitoring and control systems, in detailed form for Phase 1, will also be produced.

Description of work (possibly broken down into tasks), and role of participants

With terabit per second data rates and petaflop per second computation requirements, the SKA can be justifiably viewed as an enormous ICT machine. Cost-effective data transport over a range of distances is an enabling technology for the instrument. SKA Phase 1 will be less than 200 km in extent, PrepSKA will deliver prototype transport systems which demonstrate that the Phase 1 data transfer challenges can be met, most likely via a combination of off-the-shelf and custom solutions. The project will also review data transport solutions applicable to the full SKA. It will address by demonstration the critical issue of a low-cost, phase stable local-oscillator distribution system for the Array and the related challenge of timing, or synchronization, throughout the instrument. Finally, a conceptual design for SKA control and monitoring will be produced. Design and operational experience from Pathfinders and Design Studies, and other contemporary radio telescopes, will be essential inputs to this project.

WP2.7 is divided into four tasks as set out below. All tasks are coordinated by the CDIT, with the Signal Transport domain specialist being the WP2.7 project leader.

WP2.7.1 is the **intra-antenna data link** task. This task addresses the local connection (distances <30 m) of signals from the collector systems (wideband feed, focal plane array or aperture array) to the receiving systems. Many of these links will likely be analogue owing to RFI constraints. The links will be in copper or optical fibre media, dependant upon cost, frequency or distance requirements. Prototype links will be produced to support various receptor systems.
Participants: MIRA:*CSIRO* will lead the task, primarily in a coordination role, but also by addressing single-pixel and phased array feed requirements. Other contributors will be UK, INAF, MPIfR and MeerKAT, collectively covering aperture array and multiple-feed cluster needs.

WP2.7.2 is the **intra-station data link** task. This task will produce prototypes of the low power, high speed links needed to transfer data between individual SKA antennas (or aperture phased array patches) and station data processors. The typical length of these links is 200 m. The task will examine the relative merits of analogue and digital links meeting the overall system specifications, paying particular attention to cost and power attributes, and to characterization of link variation with, for example, temperature and time.
Participants: The task will be led by the UK:*Manchester*, which has extensive experience in fibre-optic links in e-MERLIN and as part of the European SKADS program. Other contributors are INAF with experience in producing analogue fibre links for BEST, TDP (with Allen Telescope Array and the Extended very Large Array experience), and MPIfR (with SKADS/EMBRACE experience).

WP2.7.3 is the **station to core data link** task. It will produce prototypes and design reports applicable to SKA data links operating over distances ranging from hundreds of metres to several thousand kilometres. Links to a few hundred kilometres are likely to fall within the data network owned by the SKA and data transmission units suitable for this regime will be prototyped in this task. Longer links are likely to involve commercial carriers and a deliverable from this task will be a network design and cost report outlining preferred SKA solutions to the very long-distance data transport challenge. The task will involve extensive interaction with manufacturers of commodity communications products, and with network carriers, to ensure

the lowest transmission costs over three or four sub-regimes likely to be identifiable within the distance range considered. Where appropriate, interactions with regional carriers and academic research networks will be via the ISPO acting in collaboration with regional SKA groups.
Participants: WP2.7.3 will be led by the UK:*Manchester*, with contributions from INAF (see WP2.7.2), ASTRON (building on the LOFAR experience with commercial-off-the-shelf-equipment) and MeerKAT.

WP2.7.4 is the **LO and timing distribution** task. Accurate time and phase transfer is essential for the SKA, and this task will develop and refine cost-effective techniques to ensure picosecond accuracy across the Array. By building on the work already conducted in SKADS and the US, demonstration systems will be built and a clear implementation strategy, probably involving several technical solutions, expounded.
Participants: WP2.7.4 will be led by UK:*Manchester* with direct experience from SKADS and e-MERLIN. Substantial additional contributions will come from from TDP and ASTRON, both of which bring experience from other large-scale synthesis arrays.

WP2.7.5 is the **SKA control and monitor** task. Working with Pathfinder and related projects, this task will produce a conceptual design for cost-effective, highly robust, signalling sub-systems for transporting SKA control and monitor (C&M) data. It will also report on possible software designs for C&M after considering appropriate commercial packages wherever possible. The goal is to provide the large, complex, SKA with effective human interfaces and diagnostic tools for a range of users. The control system must accommodate a highly distributed architecture with a mix of receptor technologies, and must support the widest range of observing/operational modes. A key challenge will be to ensure that C&M timing integrity is maintained throughout the array. The monitor system must log and analyse all the sub-systems of the SKA: effective operation of the telescope will require real-time response of the system to detected faults and anomalies. WP2.7.5 is not an implementation task, but a detailed report in readiness for Phase 1 implementation will be prepared.
Participants: This work will be led by UK:*Cambridge* who have extensive experience of telescope control system implementation. Other contributors are TDP (folding in the experience of operational US arrays) and MeerKAT.

Deliverables (brief description and month of delivery)

1. Demonstration of complete low-cost antenna-to- central processing link, with performance report (WP2.7.1 – WP2.7.3). Type: Prototype and report. Initial – T+24 months; Final – T+42 months.
2. Detailed report on contemporary and emerging options for SKA Phase 1 station to core links (WP2.7.3). Type: Report. Delivery: T+45 months.
3. Strategy document, including costing, for LO and Timing distribution (WP2.7.4). Type: Report. Delivery: T+45 months.
4. Report on implementation approach for array monitoring and control (WP2.7.5). Type: Report. Delivery: T+45 months.

Work package number	WP2.8	**Start date or starting event:**			T+13 months		
Work package title	Signal processing optimization and prototyping						
Activity Type	RTD						
Participant number	ISPO	10	15	DRAO	4	16	MeerKAT
Person-months per participant:	**12**	40	6	42	12	12	15
Participant number	17	TDP	UK	18	11		
Person-months per participant:	30	12	102	16	79		

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To design and demonstrate the SKA signal processing chain from antenna through to the correlated or time-detected data.

Description of work (possibly broken down into tasks), and role of participants

The SKA is an IT telescope, and much of the instrument's projected performance gains will come from new signal processing techniques and technologies. This project extends work underway in Pathfinders and Design Studies, giving insight into the design of the very powerful, scaleable processing platforms needed to make the SKA a reality.

WP2.8 is divided into four tasks as set out below. All tasks are coordinated by the CDIT, with the Signal Processing domain specialist being the WP2.8 project leader.

WP2.8.1 is the **station digital signal processing** task. It will provide the design for a cost and power-effective DSP solution capable of linking various receptor technologies within an SKA station. The architecture of this system will be vital to providing observational flexibility for the SKA. Initially drawing on the expertise of the participants and reviewing the most appropriate semiconductor technologies, a prototype will be built. It is likely that the production system will use custom devices to optimize performance, cost and power requirements; these will be specified within this task. Algorithms for the station DSP functions will also be developed and tested. A particular requirement is to develop the hardware calibration methodology to provide the high integrity signal path required by the SKA. This task will link closely with the correlator development in WP2.8.2, and indeed it is likely that some of the correlator functions will be performed within the station DSP. The final deliverable will be a costed hardware design, inclusive of a suite of demonstrated algorithm design solutions.

Participants: The WP2.8.1 leader will be UK:*Oxford*, with station DSP experience in SKADS. Contributors will be ASTRON, DRAO, INAF, MPIfR and MeerKAT, all of which have substantial DSP resources.

WP2.8.2 is the **correlator** task. This task will evaluate the feasibility and merits of various correlator architectures, given SKA cost and scalability requirements. The correlator is literally central to the SKA system and will be built progressively with the implementation schedule of the telescope, in order to benefit from improvements of technology over time. WP2.8.2 will evaluate the feasibility of various architectures, select an expandable system and produce an associated cost model. Available technology will be reviewed in close collaboration with WP2.8.1. Key correlator specifications such as scale, processing bandwidths, power requirements, software requirements and control needs will be delivered. A small test correlator demonstrating architecture (but probably not using the SKA or Phase 1 chip technology) will be developed.

Participants: DRAO will lead this task drawing on their wide experience in correlator design, most recently with the EVLA and eMERLIN correlators. Contributors will be the UK, with correlator experience and the DSP design in WP2.8.1, JIVE and MPIfR with extensive operational knowledge, and TDP (folding in US experience).

WP2.8.3 is the **radio frequency interference mitigation** task. This task will refine and further develop RFI mitigation techniques, ensuring the SKA system design is robust to current and foreseen interference conditions. Via the CDIT, it will provide input and guidance to the various SKA Phase 1 sub-system designers, and will develop advanced algorithms and implementations to optimize the performance of the

instrument. WP2.8.3 will build on work in Pathfinders and Design Studies, emphasizing the impact of RFI mitigation on system design in general terms for SKA and more specifically for Phase 1. Interactions with other design tasks (especially WP2.1.9) will ensure sufficient flexibility, processing power, and monitoring and control information are available throughout the system to implement effective mitigation strategies. Full use will be made of Pathfinders and the WP2.3 Initial Verification System in demonstrating reliable approaches to RFI mitigation.
Participants: This task will be led by ASTRON, which will draw heavily on LOFAR and SKADS experience to frame an SKA RFI mitigation strategy in collaboration with CDIT engineers. ASTRON will also contribute to the development of new algorithms, as will OBSPARIS, UORL, INAF and TDP.

WP2.8.4 is the **non-imaging processors** task. This task will design and verify new signal processing techniques required to make observations in observing domains little investigated by previous radio arrays. Some of the most exciting SKA science is expected to come from observations that do not result in images. These include the search for, and timing of, pulsars; searches for radio transient phenomena, a field which is largely unexplored; and the Search for Extra Terrestrial Intelligence, SETI. The SKA (including Phase 1) will have a superb ability to observe and monitor large areas of the sky, and its non-imaging processors must maximize the returns from these capabilities. WP2.8.4 will have strong links to other WP2.8 tasks, and will define specialist signal processing techniques to be implemented using station and correlator systems, as well as additional special-purpose hardware platforms. Links will also be in place to WP2.9.6, ensuring that imaging and non-imaging applications are well-integrated at the SKA post-processing level. WP2.8.4 deliverables will be a design report plus tested algorithms.

Participants: This work will be led by UK:*Manchester*, which has extensive experience in designing pulsar processing systems. Contributors will be ASTRON/LOFAR, MIRA:*CSIRO*, MPIfR, MeerKAT, OBSPARIS and UORL, all of which have backgrounds in time-resolved astronomy.

Deliverables (brief description and month of delivery)

1. Costed DSP and correlator design proposals (WP2.8.1, 2.8.2). Type: Report. Delivery: Initial – T+24 months; Final – T+45 months.
2. SKA RFI mitigation strategy (WP2.8.3). Type: Report. Delivery: Initial – T+24 months; Final – T+45 months.
3. Report on implementation and algorithms for non-imaging processing (WP2.8.4). Type: Report. Delivery: T+45 months.

Work package number	WP2.9	**Start date or starting event:**		T+13 months		
Work package title	Software/computing specification and prototyping					
Activity Type	RTD					
Participant number	ISPO	10	15	4	16	MeerKAT	TDP
Person-months per participant:	**87**+45	64	36	16	6	6	18
Participant number	19	UK	20				
Person-months per participant:	6	78	48				

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To formulate and demonstrate strategies for the implementation of SKA computing hardware and software, data management solutions, calibration techniques and science application software.

Description of work (possibly broken down into tasks), and role of participants

The SKA will be essentially a software defined telescope, requiring that computing and allied topics be primary inputs to the SKA system design process. Software in particular has proved challenging to radio astronomy projects in the past and the structure of WP2.9 has been designed to allow formal, top-down design as well as more pragmatic learning from existing arrays and Pathfinders. There is an emphasis on risk mitigation via the up-front formulation of plans for evolution of system complexity, and via demonstrations of capability (and scalability) using both Pathfinders and the Initial Verification System (WP2.3).

WP2.9 addresses a number of key computing areas and is divided into the six tasks set out below, with all tasks being coordinated by the CDIT. The CDIT Software/Computing domain specialist is the WP2.9 project leader.

WP2.9.1 is the **computing and software specification** task. This task is the primary link from the computing domain to the SKA system design task, WP2.1.9. It will ensure that key computing requirements are properly reflected in the SKA and Phase 1 system designs. Within WP2.9.1 the computing and software upgrade path from Phase 1 to the full SKA will be a prime consideration.
Participants: This task will be led by the CDIT, with contributions expected from WP2 participants and members of the relevant ISPO working groups.

WP2.9.2 is the **computing hardware** task. This task will investigate hardware options for SKA computing at all points in the instrument's data path. It will consider primarily commercial off-the-shelf (COTS) solutions, and will compare the likely demands of SKA and Phase 1 with the evolving capability of COTS computing. Scalability of possible solutions will be examined and elements of one or more possible architectures will be demonstrated via the delivery of a small-scale computing platform for the Initial Verification System (WP2.3).
Participants: This task will be led by the CDIT, with contributions from UK, INAF and TDP, all of which have industry links in relevant areas. Additional input is expected from ISPO working groups.

WP2.9.3 is the **software engineering** task. This task will establish appropriate software engineering methods and tools, and develop a top-level software architecture for the SKA, allowing for flexible development of the overall SKA software base with maximum reuse of existing developments and packages. Specifically, it will (1) develop software engineering "best practices", standards and procedures for the SKA, taking into account the global nature of the project and the working cultures of the organizations involved; (2) set up a common codebase and tooling environment, maximally reusing resources already available in astronomical projects; (3) establish a top-level software architecture for the SKA, covering both the on-line and off-line/distributed components; (4) establish a top-level software development plan for the SKA, including overall costing; and (5) deliver software for the Initial Verification System which demonstrates key architectural elements, including scalability. WP2.9.3 is closely coupled to the WP2.1.9 system design task and will build on insight gained from LOFAR and SKADS.
Participants: This task will be led by ASTRON, which has recent experience in the delivery of the LOFAR software system. Other contributors to (4) above are UK, INAF and TDP, the latter also contributing to (1) via experience from the ATA and other contemporary US instruments.

WP2.9.4 is the **data products and virtual observatory** task. This task will establish the strategies for the delivery of SKA and SKA Phase 1 data products to the astronomer, and for the management of the massive data sets produced. The data products for each of the key science areas of the SKA will be considered, along with more generic products to be delivered into a virtual observatory environment. A key requirement is that the astronomer is presented with data in a form which maximizes the scientific utility of the instrument. The overall design of a data reduction pipeline, and the quality of the products from a fully automated pipeline, will be specified. There will be strong interaction with the science post processing task, WP2.9.6.

Participants: This task will be led by UK:*Cambridge*, which will draw on experience from both radio telescopes and instruments operating in other wave-bands. AstroWise (University of Groningen) will contribute in the area of managing complex astronomical data bases and general information systems; TDP and ASTRON will also contribute, bringing in experience from operational US and European radio arrays.

WP2.9.5 is the **calibration** task. This task will establish the overall calibration strategy for the SKA and develop the architecture and algorithms for the SKA calibration system, in close collaboration with WP2.9.4 and WP2.9.6. It will (1) extend the work in LOFAR and SKADS, and set out the requirements on the calibration (performance, dynamic range, etc.) given models of telescope, environment and sky over the full-frequency range; (2) verify and improve available algorithms (in particular by re-using the LOFAR calibration system), demonstrating them through simulations and observations with Pathfinders and existing facilities; (3) assess processing requirements for on-site and distributed processing, given the phased roll-out of the SKA; and (4) determine the optimum use of real-time monitor data in the calibration strategy, via links with WP2.7.5.

Participants: This task will be led by ASTRON, which is developing a new calibration approach for LOFAR. ASTRON will contribute to all sub-tasks while TDP, UCAL, JIVE and INAF will contribute to (1) and (2), above. MeerKAT and UK will contribute to (3) and (4). MIRA:*CSIRO* will contribute to (2), (3) and (4).

WP2.9.6 is the **science post-processing** task. This task addresses the final processing required for imaging and non-imaging observations. With its large number of antennas, baselines to 3000 km, wide FoVs and very high dynamic range, the SKA requires a formidably large processing system. It is clear that the final processor will be ranked high in the list of the world's fastest computers. New algorithms, and re-casting of existing algorithms, will be required to ensure that super-computer architectures are used effectively. It is likely that an important part of the new work will be the real-time extraction of at least a sub-set of imaging data to drive array-wide calibration schemes. WP2.9.6 will deliver algorithms for, and demonstrations of, the post-processing solution, together with strategies for scaling from Phase 1 to SKA implementations. It has strong links to WP2.8.4 since many non-imaging applications are likely to require special-purpose hardware processors.

Participants: This task will be led by MIRA:*CSIRO*, with contributions from UK, ASTRON, INAF, JIVE, TDP, MeerKAT and UCAL, all of which have (or will shortly have) experience with operational synthesis arrays.

Deliverables (brief description and month of delivery)

1. Composite volume incorporating (draft) SKA computing and software specification, computing hardware strategy, and calibration strategy, all with SKA Phase 1 focus (WP2.9.1, WP2.9.2, WP2.9.5). Type: Report. Deliverable: T+24 months.
2. Composite volume incorporating (draft) software system architecture, SKA data products strategy, and science post-processing strategy, all with SKA Phase 1 focus (WP2.9.3, WP2.9.4, WP2.9.6). Type: Report. Deliverable: T+24 months.
3. IVS demonstration computing hardware (WP2.9.2). Type: Prototype. Delivery: T+39 months.
4. IVS demonstration software (WP2.9.3). Type: Prototype. Delivery: T+39 months.
5. Composite volume incorporating final SKA computing and software specification, computing strategy, software system architecture and top-level software plan, data product and delivery strategy, calibration strategy, and algorithms and architecture for science post-processing (WP2.9.1, WP2.9.2, WP2.9.3, WP2.9.4, WP2.9.5, WP2.9.6). Type: Report. Deliverable: T+45 months.

Work package number	WP2.10	**Start date or starting event:**				T+0 months
Work package title	WP2 design study management					
Activity Type	MGT					
Participant number	ISPO					
Person-months per participant:	**48**					

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

This project will provide support for the WP2 engineering study in terms of project planning, reporting, and financial and related interactions between the CDIT and regional SKA programs.

Description of work (possibly broken down into tasks), and role of participants

WP2 is a diverse programme with aggressive timescales. This project will provide senior CDIT personnel with expert support in strategic and operational programme planning and tracking. It will also coordinate the many financial and logistical links between the CDIT and regional SKA programs, including those related to manufacture and test of prototype SKA sub-systems. This activity will be steered by procurement guidelines developed in the course of PrepSKA WP5. An important additional function of WP2.10 will be to prepare WP2-specific reports needed to satisfy PrepSKA and related reporting requirements.

Participants: WP2.10 will be led by the CDIT supported by additional financial, legal and administrative services from the ISPO host institute via the ISPO hosting agreement.

Deliverables (brief description and month of delivery)

No formal deliverables

Work Package 3 on Site Characterisation

Australia and Southern Africa have been short-listed as acceptable locations for the SKA. In view of the importance of site selection, a number of additional studies need now to be carried out in order to further characterize the sites before the final selection. These studies include areas such as radio frequency interference, ionospheric turbulence, configuration optimization, infrastructure costs and deployment timescales, and will be carried out by the ISPO, other institutes, and the sites proponents. The studies will be supervised by a Working Group under the chairmanship of the ISPO Site Engineer.

Table 4.3: Work-package 3: Additional site studies

Work package number	WP3	**Start date or starting event:**			T+0 months		
Work package title	Additional studies of the short-listed sites for the SKA						
Activity Type[8]	SUPP						
Participant number	9	10	15	7 (MeerKat)			
Person-months per participant:	36	9	36	36			

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To inform the decision making process leading to final selection of the SKA site

- carry out further measurements and studies of the characteristics of the two sites short-listed by the International SKA Steering Committee,
- investigate infrastructure deployment costs and timescales, and
- carry out an analysis of scientific, technical and operational risks associated with locating the SKA at each of the short-listed sites

Description of work (possibly broken down into tasks), and role of participants

A Site Characteristics Working Group will be formed to coordinate the additional studies of the two sites. It will be chaired by the ISPO site engineer and comprise representatives of the sites in Australia (CSIRO) and South Africa (NRF) and other participants from Europe (ASTRON, JIVE, Paris Observatory) and the USA (Cornell University), together with the chairs of the ISPO Site Evaluation Working Group (SEWG), Operations Working Group (OWG), Engineering Working Group (EWG), and Simulations Working Group (SimWG). Eight tasks will be carried out in WP3.

WP3.1: Investigate the RFI environment by carrying out deep integrations at the central site and selected remote sites

Measure the radio frequency spectrum down to as close to the ITU-specified levels as possible according to the High Sensitivity Protocol for Candidate SKA Sites, 1) in continuum and line mode across the spectrum between 100 MHz and 1.42 GHz, and 2) in continuum and line mode in the six RA frequency bands between 1.4 and 22.3 GHz. 3) Following a simplified 2003 SKA protocol, measure the radio frequency environment for 3 years in order to look for any long-term trends in RFI. Results from regional pathfinders MIRA and MeerKAT will also be incorporated into RFI results and conclusions.

Participants: The ISPO will contract with ASTRON for the acquisition and preparation of the RFI measurement equipment, and will coordinate and supervise the RFI measurements in Australia and South Africa, as well as be responsible for the analysis and reporting of the results. The CSIRO and NRF will support and carry out the measurements in Australia and South Africa respectively.

WP3.2: Make preparations for the establishment of a Radio Quiet Zone (RQZ) for the central region of the array

The two sites are pursuing the establishment of RQZs individually. They will keep the ISPO informed of the expected end result and progress in its achievement. The ISPO/SEWG Regulatory Affairs Task Force will provide comments on the individual RQZ processes when requested. The ISPO/SEWG Task Force will participate in international efforts to have the RQZ issue brought to the attention of the International Telecommunications Union with the aim of obtaining an ITU Recommendation on the longer term. Protection for remote array-stations will also be considered and assessed.

Participants: The NRF and CSIRO will be responsible for contacts with their local telecommunications authorities and for informing the ISPO of progress, on a regular basis. OBSPARIS will lead the international effort, including that by the ISPO/SEWG, to obtain ITU recognition of RQZs.

WP3.3: Carry out detailed studies of ionospheric fluctuations pertaining to the two sites
Obtain models of the scintillation index, S4, as a function of elevation, azimuth, time of day, and solar cycle at the central and selected remote sites to better characterise the ionosphere. Acquire detailed statistics on the size, velocity and occurrence of Travelling Ionospheric Disturbances (TIDs) for solar maximum and minimum.
Participants: The ISPO will lead this task and contract external consultants to provide the primary information.

WP3.4: Carry out studies of the effects of tropospheric turbulence on high frequency observations.
Study the high-frequency limits of phase-referencing and self-calibration, and determine the implications for the SKA design.
Participants: The ISPO will lead this task and draw on the knowledge in the radio astronomy community for the report.

WP3.5: Optimize the array configuration
Study the ideal configurations for the SKA for the different Key Science Projects and determine the single configuration that optimises the total return from the Key Science Projects. Match the "ideal" configuration to the geographical realities of the two short-listed sites in order to determine the optimum configuration for each site. This task will draw on the work done in SKADS DS2T2 to provide the primary information on the ideal configuration.
Participants: The ISPO will lead this task and, through the SimWG, will interface with JIVE (representing SKADS), CSIRO and NRF.

WP3.6: Determine the influence of the site physical characteristics on the telescope design, operations, and costs
The characteristics of the sites (e.g. ambient temperature, wind levels, level of RFI) are likely to have an influence on the telescope design. Information from the Pathfinder telescopes and from the European SKADS DS3T1 and US TDP studies will be gathered to address this issue and its potential influence on the costs.
Participants: The ISPO will lead this task, consult with NRF and CSIRO, and integrate the SKADS and TDP results in the design considerations.

WP3.7: Investigate infrastructure deployment costs and timescales, operational models
1) Deployment costs based on uniform designs and standards
Develop uniform designs and standards for estimating the costs of the infrastructure and its decommissioning.
2) Timescales for the deployment of the telescope infrastructure
Refine current estimates of the timescale for infrastructure deployment for each of the sites specifically, in consultation with the sites.
3) Operational models
Develop the "ideal" operational model for the SKA which can then be applied to the two sites individually and adapted to the local realities, liaising with WP2.1.3, WP 2.1.4 and WP2.1.5. Provide draft operations agreements for remote stations in other countries, where appropriate.
Participants: This task will be led by the ISPO who will engage external consultants for the infrastructure cost and timescale studies. The ISPO/OWG and ISPO/EWG will generate the operational model in consultation with NRF and CSIRO. CSIRO and NRF will be responsible for the operations agreements for remote stations.

WP3.8: Sustainability of the science environment in the face of potential RFI threats
Acquire additional demographic studies of the regions surrounding the central array and the remote stations to refine estimates of the future RFI threat. Analyse the potential consequences of any mining or other development interests near the central sites.
Participants: This task will be led by the ISPO who will contract external consultants to supply the demographic and other information required.

Deliverables (brief description and month of delivery)

1) Report on ionospheric scintillation and TIDs for Australia and Southern Africa (WP3.3). Type: Report. Delivery: T + 6 months

2) Deliver RFI hardware and software (WP3.1). Type: Other. Delivery: T + 12 months

3) Report on phase referencing and self-calibration for SKA measurements at high frequencies (WP3.4). Type: Report. Deliver: T + 12 months

4) Report on the optimum configuration for the SKA (WP3.5). Type: Report. Delivery: T + 18 months

5) Report on the influence of the physical characteristics of the sites on telescope design, operations, and costs (WP3.6). Type: Report. Delivery: T + 36 months

6) Report on the infrastructure deployment timescales, costs and operational models (WP3.7). Type: Report. Delivery: T + 30 months

7) Report on the risk analysis of the science environment (WP3.8). Type: Report. Delivery: T + 30 months.

8) Report on RFI measurements in Australia (WP3.1). Type: Other. Delivery : T + 33 months

9) Report on RFI measurements in South Africa (WP3.1). Type: Other. Delivery: T + 33 months

10) Report on progress and prospects for Radio Quiet Zones for the short-listed SKA sites (WP3.2). Type: Report. Delivery: T + 36 months

11) Final report. Type: Report. Delivery: T + 36 months

Work Package 4 on Governance

The establishment of the management, governance and legal framework of a global project such as the SKA will be a complex undertaking. In many ways the SKA will be the most complex major scientific project ever undertaken. Currently, scientists and agencies from at least 17 countries are interested in participating, this number will undoubtedly grow. It will be a major challenge to develop a structure which enables all interested parties to participate at an appropriate level, especially when one considers the different potential funding timescales around the world.

The WP4 working group will spend time studying the governance models for existing multi-national collaborations; it will attempt to distil the best-practice that has emerged from these projects, thus ensuring that the SKA can benefit from previous experience. The working group will then develop options for the optimal structure that might be proposed for the SKA during its construction and operational phases. It will also study potential legal frameworks under which the SKA project might ultimately be established, again building on the experience gained in similar complex projects.

Table 4.4: Work-package 4 – Governance and Legal Framework

Work package number	4	**Start date or starting event:**			T+2		
Work package title	Governance and Legal Framework						
Activity Type[9]	SUPP						
Participant number	1	2	3	4	5	6	7
Person-months per participant:	6	**36**+9	6	6	1	12	3
Participant number	8	9	10	12 (US)	15	NSF	
Person-months per participant	3	2	2	6	2	1	

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

- To study options for viable models of governance and a legal framework for the SKA project during its construction and operational phase.
- To obtain professional legal and business advice as appropriate to inform the development of such options.
- To provide input to the proposed International SKA Forum for the discussion and resolution of favoured options.

Description of work (possibly broken down into tasks), and role of participants

4.1 Develop comparative study on best-practice Governance and legal frameworks for international mega-science projects.
4.2 Incorporate outputs from other Preparatory phase WPs (e.g. WP5: industry mapping & procurement) as appropriate.
4.3 Obtain international legal and strategic business advice on appropriate legal framework and business models for the SKA.
4.4 Develop options paper for an appropriate Governance and legal framework for the SKA project for discussion at the International SKA Forum.
4.5 Based on feedback from International SKA Forum and appropriate national agencies, develop a White Paper for an appropriate Governance and legal framework for the SKA for consideration by decision-makers.
4.6 Semi-annual reporting of progress to preparatory phase co-ordinator. (March & September)

Participants' Role

[9] Please indicate one activity type per work package (corresponding to the types used in Forms A.3):
RTD = Research and technological development (i.e. technical work); COORD = coordination activities (e.g. general meetings); SUPP = Support Activities (e.g. legal, financial, strategic and organisational work); MGT = Management of the consortium.

The work-package will be led by an NWO policy officer with expertise in project governance leading a specialist Working Group. A core group will be formed, comprising representatives from the funding agencies together with the International SKA Steering Committee (ISSC) Chair and the Preparatory Phase proposal co-ordinator that will meet by telecon regularly, augmented by a wider membership that will meet face-to-face once each year. The activities and reports of the Working Group will be reported to contract participants via a protected web-site.

The WG will seek legal/business advice as appropriate to carry out its tasks.

Deliverables (brief description and month of delivery)

4.1 Deliver study on best practice governance and legal frameworks (WP4.1). Type: Report. Deliverable: T+9 months

4.2 Deliver paper on options for Governance and legal framework to Intenational SKA forum (WP4.2) Type :Report. Deliverable: T+27 months

4.3 Deliver White Paper for a governance model and legal framework for the construction and the operation of the SKA. Type: Report. Deliverable: T+36 months.

Work Package 5 on SKA Procurement

SKA procurement will likely differ in important respects from the procurement of most other large research facilities.

On the one hand, mass production of custom, advanced signal processing components will be crucial to controlling overall cost. This suggests that the intimate involvement of the commercial ICT sector will be highly desirable. Agreement on formal protocols, including intellectual property management and the potential for shared risk development, should therefore be explored with industrial parties. Attached to this proposal is a letter from IBM indicating their willingness to participate in such discussions.

On the other hand, the SKA project is planned as a global cooperation, and procurement might in principle proceed globally to maximize scientific potential within a fixed budget. Procurement models must consider the geographical requirements to be imposed on the procurement process. National industrial policies differ considerably among countries and how a global project might realize project goals, and ensure added-value to participating nations should be examined in some detail.

It is recognized at the outset that procurement options may need to account for different requirements in different phases of the SKA project and may need to be tuned to the type of procurement involved (e.g. high-risk technology, off-the-shelf components, infrastructure and facilities, operations and maintenance services).

Procurement planning must also take specific account of the role of radio astronomical research institutes in participating countries. These organizations will provide essential astronomical and specific technical expertise to the project. They will be responsible for training the generation of researchers that will be needed to exploit the SKA to its fullest. The protocols for cooperation among institutes, and interfacing these to industry for production engineering and for allied test and validation tasks should be clearly defined and agreed at the outset. These protocols will need to be flexible enough to take account of e.g. IP heritage flowing from regional Pathfinders and Design Studies.

Given the requirements for mass production of components as well as for advanced functional integration at the sub-system level, significant early expenditure might result in important cost savings later in the project. It may, therefore, be financially advantageous to decouple expenditure from financing, but a careful study of the extent of the decoupling required and how it might best be realised should be carried out.

This work package will examine these matters and provide decision makers with clear options based on a standard cost-benefit analysis.

Table 4.5 Work-package 5: SKA Procurement and industrial involvement

Work package number	WP5	**Start date or starting event:**			T+0 months		
Work package title	Decision support for SKA procurement and industrial involvement						
Activity Type	SUPP						
Participant number	1	2	3	4	5	6	7
Person-months per participant:	6	5	6	**36**+6	1	6	6
Participant number	10	12(US)	15	NSF	ISPO		
Person-months per participant:	2	6	1	1	3		

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

To set out options for decision makers on

- How the SKA project should approach procurement, and
- How it should involve industry in global, regional and national contexts.

Description of work (possibly broken down into tasks), and role of participants

This work package will initiate discussions among national funding agencies concerning protocols for procurement, as well as strategies for the involvement of commercial industry and of national research institutes.

A Procurement Working Group (PWG) will be formed to guide these discussions. It will be led by an INAF policy officer with expertise in procurement policy. Contributed effort to the PWG will be provided by STFC, INAF, DEST, ISPO (by the SKA Director and Project Engineer), NRF and NSF and other interested parties. Industry representation will be sought via ISPO working groups. Strategic and operational procurement investigations will be undertaken by expert consultants. A core group will be formed that will meet by telecon regularly, augmented by a wider membership that will meet face-to-face once each year. The activities and reports of the Working Group will be reported to contract participants via a protected web-site.

The key tasks for this work-package are:

5.1 With input from the International SKA Project Office, develop guidelines for procurement in Work Package 2 on System Design.

5.2 With input from external consultants, acquire information on the potential for industry, particularly the ICT segment, to contribute to, and participate in, the development and construction of the SKA.

5.3 With input from external consultants, analyse models for procurement of the SKA Design, including

1) A fully global procurement process based on WTO guidelines,

2) Regionally- or nationally-restricted procurement relying on the availability of regional or national funding

3) Agreed-on deliverables by regional or national entities

5.4 Undertake comparative risk analyses of the procurement models.

5.5 Develop a detailed options paper on procurement policy for discussion with stakeholders at the International SKA Forum. This will include proposals for:

The protocol for formal procurement;
Industrial policy, including national goals for translating SKA involvement into desirable returns;
A protocol for the involvement of national research institutes in the procurement process.

5.6 Discuss, with the WP6 working group, the potential for decoupling expenditure from project finance.

5.7 Based on feedback from the International SKA Forum, develop options for the SKA procurement policy for presentation to the Plenary SKA Funding Agencies group for their consideration

Deliverables (brief description and month of delivery)

The work package will deliver the following.

5.1 Working guidelines for procurement in the course of the WP2 SKA design project. Type: Report. Delivery: T+12 months.

5.2 An inventory of the relevant industries in participating countries able to contribute to SKA, and statements of potential willingness to share development costs and risks. Type: Report. Delivery: T+24 months.

5.3 A report in which procurement models are analyzed, the results to include cost-benefit estimates based on experience at national and international laboratories (e.g. CERN, NASA, ITER), and taking comparative risk into account. Type: Report. Delivery: T+33 months.

5.4 Draft options paper on procurement that will meet technical, policy and geographic distribution goals. Type: Report. Delivery: T+33 months.

5.5 An inventory of national standpoints, general policies and specific goals to accompany each option in (4). Type: Report. Delivery: T+33 months.

5.6 A White Paper on options for SKA procurement, for the Plenary Funding Agencies Group. Type:

Report. Delivery: T+35 months.

5.7 Proposed procurement model incorporated into the PrepSKA final report. Type: Report. Delivery: T+36 months

Work Package 6 on Funding of the SKA

The scale of the future SKA project, and the global extent of the eventual collaboration, demands that substantial effort is employed on understanding the opportunities and constraints that will describe the funding envelope for the construction, operation and eventual decommissioning of the facility. STFC will lead this coordinated activity which addresses key financial issues. WP6 will support the activity of a Working Group, bringing together information and inputs from several other PrepSKA activity areas and the wider SKA community, through the SKA Forum, into a White Paper on the future funding model for the SKA. WP6 will survey all relevant opportunities for funding options for the SKA and develop options and strategies for implementation of the full development phase.

Table 4.6 : Work-package 6 – Funding Model

Work package number	6	**Start date or starting event:**			T+0	
Work package title	Developing the funding model for the SKA						
Activity Type[10]	SUPP						
Participant number	1	2	3	4	5	6	7
Person-months per participant:	**36**+6	5	2	6	1	6	3
Participant number	8	12 (US)	NSF	ISPO			
Person-months per participant:	3	6	1	3			

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

This is a support activity to develop the funding model for the development of the SKA. The specific objectives are as follows:

- To lead the activities of a Working Group investigating all aspects of the financial model required to ensure the construction, operation and, ultimately, the decommissioning of the SKA.
- To determine and inform all partners of the timescales and constraints governing possible national funding opportunities for the construction and operation of the SKA.
- To investigate the possibility of obtaining a loan from the European Investment Bank (EIB) and other similar national and/or regional bodies to provide a smooth funding profile for the construction phase of the project.
- To understand the implications of such a loan(s) on the long-term operational funding of the SKA.

Description of work

This work-package proposes the creation and support of a Working Group to examine all aspects of the financial model for the complete lifetime of the SKA project, extending from construction, through operation into eventual decommissioning. This is a key work-package, bringing together information and inputs from several other PrepSKA activity areas into a White Paper on the future funding model for the SKA.

The work-package will be led by an STFC policy officer with expertise in large project financial planning leading a specialist Working Group. The Working Group will comprise representatives from funding agencies together with representatives of the SKA astronomical community. The EC would participate in Working Group activities in an advisory capacity. Several key activities are required for the work-package:

6.1 The development of a document, with input from the PrepSKA work-packages on System Design (WP2), Governance (WP4), Procurement (WP5) and the International SKA Project Office (ISPO) and its working groups, outlining the full costs of all phases of the SKA.

6.2 With input from PrepSKA WP5 on procurement, undertake a survey of the national funding agencies

[10] Please indicate <u>one</u> activity type per work package (corresponding to the types used in Forms A.3):
RTD = Research and technological development (i.e. technical work); COORD = coordination activities (e.g. general meetings); SUPP = Support Activities (e.g. legal, financial, strategic and organisational work); MGT = Management of the consortium.

in all countries that might potentially invest in the SKA to understand the processes by which they allocate funding to large, international projects.

6.3 To approach, with the EC acting as a facilitator, the European Investment Bank in order to understand the processes, constraints and timescales associated with an EIB loan for the construction phase of the SKA.

6.4 To approach other organisations which have previously obtained EIB loans in order to develop a view on the advantages and disadvantages of the practice.

6.5 To investigate the possibility of private and/or corporate funding of the SKA project.

6.6 To develop a detailed options paper for a funding model for the SKA project for discussion with stakeholders at the International SKA Forum

6.7 Based on feedback from International SKA Forum, to develop a White Paper for an appropriate funding model for the SKA for presentation to decision makers for their consideration.

The Working Group would conduct most of its business by e-mail but would meet at least once a year, with meetings scheduled next to those of the International SKA Forum or International SKA Steering Committee. The activities of the working group will be facilitated and supported by the Work-package secretariat.

Deliverables

6.1 T+9 months – Report summarising the survey of national funding opportunities, processes and t imescales presented to the International SKA Forum.

6.2 T+15 months – Report summarising initial investigations on options for alternative (eg private and/or corporate) funding of the SKA.

6.3 T+19 months – Draft options paper on the SKA funding model provided to the International SKA Forum.

6.4 T+33 months – Final version of options paper, with full funding model for the SKA presented to the interested SKA Funding Agencies.

6.5 T+35 months – White Paper on the financial model for the SKA incorporated into the PrepSKA final Report.

Work Package 7 on an SKA Implementation Plan

The principal deliverable from the Preparatory phase will be an implementation plan for the SKA. This will be a critical document, which will form the basis of the major funding proposals that astronomers around the world will submit in a coordinated fashion. The implementation plan will consist of a detailed and costed SKA design, a well-worked out series of options for the governance, legal framework, procurement and industrial involvement. This plan will be developed through close cooperation between funding agencies and scientists.

Table 4.7: Work-package 7 – implementation plan

Work package number	7	**Start date or starting event:**			T+45 months		
Work package title	An implementation plan leading to construction of the SKA						
Activity Type[11]	SUPP						
Participant number	1	2	3	4	5	6	7
Person-months per participant:	3	2	5	3	1	3	3
Participant number	8	9	10	11	12 (US)	13	14
Person-months per participant:	0.5	3	3	1	3	1	1
Participant number	15	16	17	18	19	20	NSF
Person-months per participant:	2	0.5	0.5	0.5	0.5	0.5	1
Participant number	ISPO						
Person-months per participant:	3						

Person-months in bold are funded by the EC, those not in bold are in-kind resources

Objectives

This is a support activity to bring together all of the activities in the earlier work-packages and to produce the final documentation from PrepSKA. The specific objectives are as follows:

- To ensure adequate communication between the diverse range of SKA activities as the project progresses;
- To integrate all of the activities, reports and outputs of the other work-packages into a summary document, or series of documents that will form an SKA implementation plan;
- To publish a costed SKA system design.

Description of work

The Working Group would comprise representatives of the funding agencies together with the co-ordinators of the various PrepSKA work-packages, the Director of the ISPO and any other parties who might be co-opted by the PrepSKA Board. The PrepSKA co-ordinator will lead the work of the team.

It is anticipated that the other PrepSKA working groups will have provided documents that will inform the work of WP7. The principal role of the WP7 team towards the end of the PrepSKA project will be to integrate the work, harmonise the language and appearance of the final report and begin drafting the SKA Implementation Plan. The work will be accomplished by e-mail and teleconference and will culminate in a one-week meeting to produce the final documents.

The documents will be submitted to the PrepSKA Board for approval and then passed to the decision-makers.

The documentation work will occur over the period T+45 to T+48 months.

[11] Please indicate one activity type per work package (corresponding to the types used in Forms A.3):
RTD = Research and technological development (i.e. technical work); COORD = coordination activities (e.g. general meetings); SUPP = Support Activities (e.g. legal, financial, strategic and organisational work); MGT = Management of the consortium.

Deliverables

The principal deliverables from PrepSKA:WP7 will be:

7.1 Costed SKA system design (WP7). Type: Report. Deliverable: T+48 months.

7.2 SKA implementation plan incorporating all of the output from the other work-packages. The plan will include an outline of the content, the process and the schedule desired for an SKA MoU. Type: Report. Deliverable: T+48 months

1.5 Work packages not directly supported by the EC:

The Work Packages summarized in Table 2b and described below will generate R&D knowledge that is directly relevant for the SKA. In the case of the Pathfinder Telescopes (LOFAR, ATA, MIRA, MeerKAT, EVLA, e-MERLIN) a major additional goal is the creation of science-capable instruments. Note that all projects, with the current exception of the TDP, are funded.

1.5.1 WP8: FP6-SKADS (Europe)

SKADS is carrying out a study of the design of the SKA with emphasis on aperture arrays, its resources are not counted as a matching contribution, but its results will feed into the PrepSKA activities.

Tasks:

- i) study the technical requirements associated with the delivery of the science. Simulate the operation of aperture arrays separated by distances up to many hundreds of kilometres, to demonstrate the high angular resolution imaging capabilities required by the SKA community;
- ii) design and construct an engineering/development demonstrator single polarization aperture array EMBRACE (Electronic Multi-Beam Radio Astronomy ConcEpt) and explore the practical issues involved in multi-beam collection and signal-processing concepts;
- iii) design a cost-effective antenna system at the level of the “Tile” as a key building block for a SKA “station” enabling beam forming within fields-of-view in many directions simultaneously. This will involve key R&D areas to develop the technical foundations and enabling technologies and will result in a dual-polarized tile (“2-PAD”) as Technology Demonstrator for aperture arrays;
- iv) carry out an end-to-end study of the architectural design, the networks (intra-station and to the central node), data handling and physical infrastructure from collection to the delivery of data to the astronomical users and its efficient use by them.

1.5.2 WP9: LOFAR (Netherlands, Germany)

LOFAR, the Low Frequency Array, is a next-generation 10-20% SKA Pathfinder that is being built in Northern Europe and expected to be fully operational by 2009. It will operate at frequencies from 15 to 240MHz.

Tasks:

- i) final design of the high frequency antennas between 115 and 240 MHz which consist of 4x4 arrays of dual-polarization dipoles combined at RF frequencies;
- ii) final design of the Transient Buffer Board with enhanced embedded processing;
- iii) completion of advanced software systems for calibration, RFI removal, monitoring and control; system health management and dependable streaming processing;
- iv) verification of initial stations and performance optimisation; implement operations plan;
- v) LOFAR site characterisation, issues of site acquisition, legal issues related to radio-quiet zones;
- vi) implementing procedures for mass-procurements, resolving legal issues related to industrial collaborations, IPR.

1.5.3 WP10: APERTIF (Netherlands)

APERTIF will enhance the field-of-view, and consequently the survey speed, of the Westerbork Synthesis Radio Telescope by a factor of 25 using phased arrays in the focal planes of each of the 14 dishes.

Tasks:

- i) *system architecture and design*. Define the system architecture and the partitioning of the system in terms of signal transport, location of the digital beam former, beam former concept and correlator. Optimize for survey speed and sensitivity.
- ii) *feed design*. Design wide band antenna array for 0.85 – 1.75 GHz, a sub-set of the 0.3-3GHz defined in WP2 as an application area for the smart feed research.
- iii) *calibration and imaging.* Design and implement a calibration and imaging approach taking into account the added complexity of the (digitally) synthesised Field of Views.
- iv) *receiver and digital beam former design and realization.* Design and realize the receivers including low noise amplifiers, cooling, signal transportation and digital signal processing. Optimise for performance and costs.

1.5.4 WP11: e-MERLIN (UK)

e-MERLIN is a fibre-linked 7-telescope array in the UK, spanning a distance of 250 km, and observing at frequencies from 1 to 24 GHz. It will become operational in 2008.

Task:

i) Phase and time transfer: Develop and commission a phase and time transfer system over optical fibre for long baselines.

1.5.5 WP12: MIRA (Australia, Canada, USA)

MIRA covers the frequency range from about 80 MHz to 2 GHz, a sub-set of the SKA frequency range.

Tasks:

i) *overall system design and engineering of MIRA.* Ensure the viability of the design and planned implementation, and the quality of the final product in meeting the scientific goals.

ii) *site characterisation and development.* Carry out RFI measurements, pursue RFI protection legislation, infrastructure costing and optimization, and the development of operations/logistics models for remote telescope operation, at one of the potential SKA sites.

iii) *antenna design*. Examine a range of antenna configurations and technologies including economical reflector surfaces to deliver fully costed MIRA antenna designs. Optimise the antenna performance for the cost.

iv) *smart feeds.* Design, develop, manufacture and install Focal Plane Arrays (FPA). Includes electromagnetic design and modelling, the resultant array prototyping and testing, integration with subsequent components, economical and reliable manufacture, cooling, delivery and installation.

v) *Beamformers and Correlators*. Design, develop, manufacture and install the beamformer and correlator for MIRA. 'Innovative feeds' approach relies upon a phased array of feeds (the PAF) producing signals that are immediately digitised for subsequent beamforming and later correlation.

vi) *Receivers.* Investigate a range of alternative receiver and LNA architectures, including a monolithic integrated "receiver on a chip" design that may be an important precursor for the huge volumes of economical receiver systems required for the SKA.

vii) *Computing.* Includes scheduling of observations, monitor and control of the telescope during observations, acquisition of data, pipelining and processing of observations into scientifically useful data products, and archiving of data products.

viii) *Data transport.* Develop the signal distribution and data interconnectivity systems for MIRA and includes the external network connectivity from the Murchison Radio Observatory site to the major WAN backbones.

1.5.6 WP13: MeerKAT (South Africa)

The MeerKAT radio telescope is a 2-4% scale pathfinder for the mid/high frequency element of the SKA. MeerKAT sub-system development programmes are closely aligned with the requirements of the SKA.

Tasks:

- *Reflector:* Design and construct a prototype dish reflector that satisfies the specifications and is suitable for low-cost/high-volume dish manufacture.
- *Feed:* Design and construct a prototype wideband single-pixel feed and low-noise receiver system that satisfies the frequency coverage and system temperature specifications.
- *Signal paths:* Investigate technologies for the analogue and digital signal paths; develop scalable reconfigurable computing platform necessary for the data processing system
- *Software:* Develop the software for a scalable generic distributed control system for radio telescope, and the software backends required to produce data products from raw radio astronomy array data.
- *System engineering/cost equations:* Use formal systems engineering principles to constrain cost and implementation risks. Determine the cost equations for both capital and operating costs of all of the sub-systems, and use these models to determine the optimal configuration of the MeerKAT. Devise robust systems engineering methodologies that are appropriate to the MeerKAT and various implementation phases of SKA.
- *Operations models:* Investigation of logistics and operations models for the remote operation of radio telescopes, including the effects on operations costs and reliability.
- *Simulations:* Simulations using sky models to guide the configuration and specifications of the MeerKAT ; inform the SKA configuration studies..

- *Site characterization:* Conduct site specific studies and work programmes for the Karoo Radio Astronomy Reserve, including RFI measurements, RFI protection legislation, infrastructure costing and optimization, and the development of operations/logistics models for remote telescope operation.

1.5.7 WP14: Canada

The objectives of the Canadian SKA R&D activities are to evaluate the critical design parameters of key SKA technologies.

Tasks:

Dominion Radio Astronomy Observatory:

1. *Composite antenna development:* investigate cost and upper frequency capability of SKA antennas. Composite material technology holds the promise of inexpensive production and high upper-frequency performance.
2. *Phased Array Feed development:* build experimental prototypes that permit individual signals from the feed elements to be recorded to provide data on the interactions between feed elements.
3. *Correlator* for the Expanded Very Large Array (EVLA): This correlator will soon be the largest, most advanced correlator for cm-wave astronomy. Many large-digital-system issues are being explored at a scale relevant to the SKA.
4. *Software Simulation:* A deep understanding of the issues of synthesis imaging using antennas equipped with phased array feeds will be required for the SKA. These problems are being tackled via simulation.
5. *Low Noise Amplifiers for the high frequency band:* HIA is designing a cooled 18-26 GHz LNA. Experimental prototypes will be developed that can be inexpensively packaged for the SKA.

University of Calgary:

6. *Low Noise Amplifiers:* Both aperture arrays and phased array feeds will require thousands of low noise amplifiers. This R&D is directed at inexpensive amplifiers that can achieve competitive noise levels.
7. *Calibration, Imaging and Data-Reduction:* Software for SKA imaging, calibration and data handling will be developed.

1.5.7 WP15: EVLA (USA, Canada, Mexico)

The EVLA Project is taking the current most powerful radio telescope, the VLA, into the modern digital era. It will contribute both the development and day-to-day operation of key modern technologies for the SKA.

Tasks:

i) *Station to core data link*: Install 3-bit, 4 Gigasample/s samplers at each antenna and test full transmission of over 3Tbit/s on an operational basis over tens of km.

ii) *Intra-antenna data link and RFI*: Monitor the frequency range 1-50 GHz for self-generated RFI, and explore possible implications for future designs

iii) *LO & timing distribution:* Determine the adequacy of the round-trip phase correction over fibre connections of 10's of km and explore possible implications for future designs.

iv) *System design and operations plan:* Operation of the EVLA will provide experience with one particular system design and the associated operations plan for running a large digital radio telescope that may (or may not) be appropriately scaleable to the SKA.

v) Data products and Virtual Observatory. Probe issues involved with producing a large volume of interferometric data products in a cost-effective way on a daily basis, and identify the cost and technology difficulties the SKA will face in producing similar products.

1.5.8 WP16: Technology Development Program (USA, Canada)

The TDP is a five-year program that is aimed at designing the SKA at all levels, from technical to operational in an overall program of phased deployment.

Tasks;

i) *Antenna/feed/receiver:* Develop parabolic antenna technology in order to optimize performance, to identify cost-performance tradeoffs. Provide a working prototype antenna, fully outfitted with broadband, low-noise, single-pixel feeds and receivers.

ii) *Systems and array issues:* Identify solutions to systems and array issues, including high-bandwidth signal transport, high-dynamic range and high-fidelity imaging, excision of RFI, and developing survey approaches that address SKA science. Investigate the management and processing of high data volumes because they will dwarf current needs.

iii) *Cost and tradeoffs:* Assess costs of systems and sub-systems and conduct trade-off studies
iv) *SKA design:* Contribute to the design of the SKA at all levels (subsystems, connectivity, operations)

1.5.9 WP17: Allen Telescope Array (USA)

The ATA will consist of 350 x 6.1 m hydro-formed dishes operating in the frequency range 0.5 – 11 GHz. With 42 antennas currently operational, much innovative engineering work has been completed but on-going projects ensure a continuing relevance to SKA.

Tasks:

i) *Highly programmable digital signal processing engines:* Bring design experience, including cost and performance trade-offs, of the BEE2 (Berkeley Emulation Engine 2) system - a highly modular, scaleable FPGA system - to the SKA system design.
ii) *RFI mitigation:* Use the ATA platform to test RFI mitigation techniques needed for the large number of antennas and wide instantaneous bandwidths in the SKA design.
iii) *Calibration and imaging:* Operational use of ATA beamforming and direct correlation solutions will inform further development of the wide-field imaging techniques needed for SKA.
iv) *Operations:* With a 5 deg^2 FoV at 1.4 GHz and parallel backend signal paths the ATA will support multiple observers, making it ideal as a platform for development of operational strategies involving simultaneous experiments.

1.6 Focus on needs of users:

Over the past few years, as astronomers study the structure and evolution of the Universe and explore fundamental physics using distant objects as cosmological probes, it has become clear that even though our level of knowledge has grown enormously, we understand less of the Universe than we had thought. Key questions remain unanswered:

- What is Dark Energy? Does it vary with Cosmic Time?
- When was the Epoch of Reionisation?
- What is the nature of dark matter?
- Can we detect gravitational waves?
- Is Einstein's General Theory of Relativity a correct description of space-time under the most extreme gravitational conditions in the Universe?
- When and how did the first stars and galaxies form?
- What was the origin of cosmic magnetism? How does it affect the structure and evolution of the Universe?
- How do Earth-like planets form?
- Is there life, intelligent or otherwise, elsewhere in the Universe?

These and many other questions are fundamental to our understanding of the Universe around us; to answer them requires that astronomers around the globe collaborate to construct ever more complex machines. The SKA is one of these machines.

The SKA will be 50 times more sensitive than the Expanded VLA, it will have an enormous field-of-view, many times the area of the full moon, thus making it the world's premier survey instrument and above all, it will be the only instrument in the world capable of directly observing neutral Hydrogen, the most abundant element in the Universe. These capabilities, which define the basic specifications of the SKA, will provide a service to users that has never before been achieved. The broad astronomical community, over and above that of the traditional radio astronomy facility users, have recognised the scientific potential of the SKA. This will be most visible in Europe in the soon to be published Astronet Science Vision for Astronomy, which summarises Europe's aspirations in astronomy for the next two decades (http://www.astronet-eu.org). The SKA science case is also a central plank of the Decadal Plan for Australian Astronomy 2006-2015, which was recently published (http://www.aao.gov.au/nca/decadalplan.html); it features strongly in the Long Range Plan for Canadian Astronomy (http://www.casca.ca/lrp/mtr_approved.pdf) and will, it is hoped, also feature in the next US Decadal Plan, planning for which is currently underway.

1.7. Coordinating effect of the Preparatory Phase:

Radio Astronomy in Europe has a long history of natural collaboration, dating back to the pioneering Very Long Baseline Interferometry (VLBI) observations of the 1970s, with a major milestone being the establishment of the Joint Institute for VLBI in Europe in the 1990s. As a result, coordinated efforts in the technical, operational and scientific domains are relatively well advanced. In particular, the distributed, multi-partner FP5 and FP6 RadioNet programmes and the FP6 SKADS and EXPReS e-vlbi projects have played a vital cohering role in joint European activities in general. Many of the technologies now considered as potential concepts for the SKA have arisen from these projects: the Focal Plane and Aperture Array technologies being the chief examples.

At the same time, the radio astronomy community is well aware that the “bar” is set to rise. As a global project, the SKA takes us into an entirely new and much more ambitious phase in its evolutionary path, and challenges will arise that are new to our community and of which we have only limited experience. These will arise not only in the areas of joint science and technology developments but especially in the areas of governance, funding and procurement.

For a project of this scope and magnitude it is essential to fully involve the funding agencies, Most major European funding agencies have agreed to participate in PrepSKA and it is fortunate that three (STFC, NWO and INAF), have agreed to lead the PrepSKA policy work packages (WP4, 5 & 6), with STFC agreeing to lead the proposal as a whole. This is a crucial step forward in fully engaging the funding agencies within the PrepSKA project and ultimately the SKA.

Other challenges include the coordinated involvement of the radio astronomy community with Industrial Partners. Experience with other relatively large European projects (e.g. LOFAR) is beginning to engage major industrial partners (including IBM). Similar industrial contacts are seen in other regions, in particular the potential host sites of South Africa and Australia. The establishment of an International SKA Industrial Forum is an obvious next step and is a likely outcome of the PrepSKA Procurement work package (WP5).

Although SKA is very much a global project, from a European perspective it will be important to ensure that the European community of astronomers and engineers maintains a coherent European response to policy issues that effect common European interests. PrepSKA brings together all the institutes in Europe that have a significant stake in the future development of the SKA project. The PrepSKA proposal (e.g. WP2) will bring focus to the various activities in Europe that are likely to have a major impact on the final SKA design. The programme is set up so that the major European radio astronomy technology programmes are well connected to PrepSKA. This will ensure that the investments associated with European pathfinder projects (LOFAR, e-MERLIN, e-VLBI & APERTIF) will have a strong connection with the PrepSKA work programme. PrepSKA itself (together with FP7 RadioNet) will ensure that there is significant collaboration between the pathfinder projects themselves.

As the SKA moves into a new era, the coordinating activities of the European SKA Consortium (ESKAC) will become even more important. An enlarged or at least strengthened role for ESKAC is likely to emerge from the FP7 RadioNet programme. ESKAC will ensure a coherent policy line is adopted by the European SKA partner institutes, and continue to ensure that the many European scientists and engineers that are working hard towards establishing the SKA are fully aware of the higher-level processes being driven by PrepSKA.

2 Implementation

2.1 Management Structure

The SKA Preparatory Phase Project is different from previous EC-funded astronomy projects in that, for the first time, the scientists and funding agencies will be working together to further a global project. The management of such an enterprise, coupled with the broad range of activities to be undertaken, presents significant challenges and will require strong and active leadership to ensure a smooth and efficient process.

Co-ordination

The EC prefers that a funding agency from a major European country be the lead partner in PrepSKA. STFC (the successor to PPARC) has agreed to act as such, and so will submit the proposal and receive and distribute EC-funding to the other partners as appropriate. STFC has agreed to delegate the day-to-day co-ordination of PrepSKA to Prof. Philip Diamond, Head of Astronomy and Astrophysics and Director of Jodrell Bank Observatory at the University of Manchester. Prof. Michael Garrett, General-Director of ASTRON in the Netherlands, will be the Deputy Co-ordinator. The PrepSKA Co-ordinator will devote ~25% of his time to the project, he will be supported by the PrepSKA Management Team (PMT). The Co-ordinator will be a member of the PrepSKA Board (see below) but not its Chairman.

The principal responsibilities of the Co-ordinator are as follows:

- To monitor all activities and ensure that each is following the plan laid down by the WP leaders and approved by the Board;
- To ensure that the project web-site is kept up to date and that all documents emerging from project activities are available under version control;
- To ensure that WP leaders provide all reports and documentation on a timely basis to the Board and to the EC as appropriate;
- To be responsible for and monitor all financial matters pertaining to the project;
- To report any and all activities to the Board;
- To act as the representative on PrepSKA activities to the funding agencies and national governments.

The Deputy Co-ordinator will support the Co-ordinator in activities when and where appropriate, he will stand in at events and meetings for the Co-ordinator if the latter is absent; he will assist the Co-ordinator in preparing reports and documents if required.

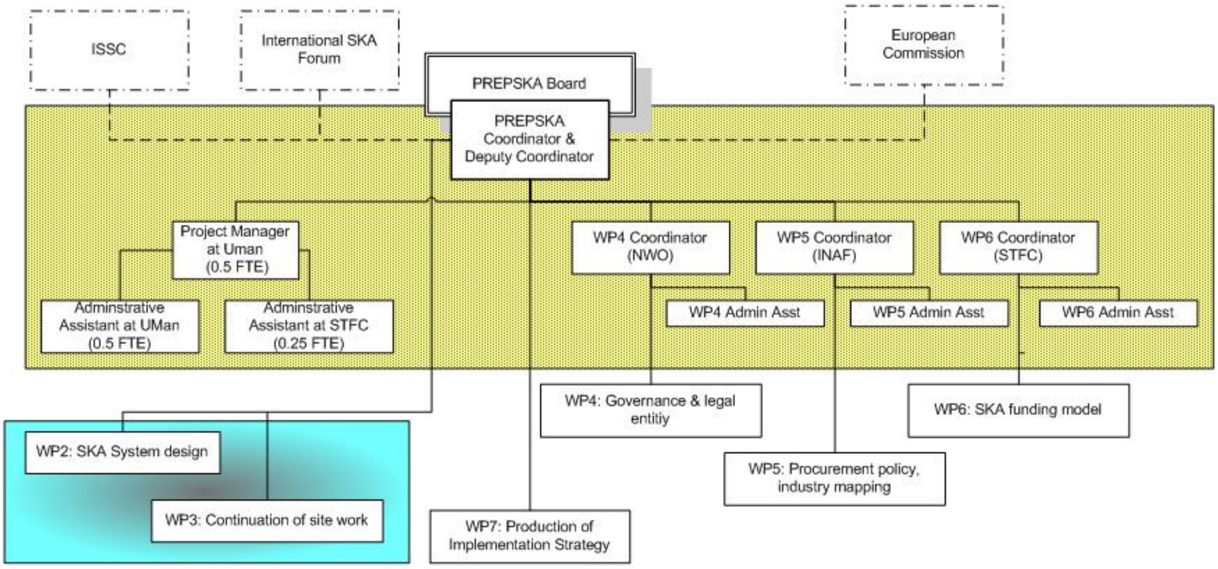


Figure 2.1.1: PREPSKA Org chart. Solid lines show reporting structure; dashed lines show information flow. The large yellow box delineates the PrepSKA management team. The smaller blue box on the bottom left represents the ISPO, which has responsibility for WP2 and WP3

The Co-ordinator will be supported by a Project Management Team (PMT: see yellow area in Figure 2.1.1). The PMT will have two components, one will be the administrative support team centred at the University of Manchester, the other will be the Work Package Secretariat (WPS).

The role of the Project Manager (0.5 FTE at UMan) will be to support all partners in ensuring an effective administrative and reporting structure, to assist the Co-ordinator in tracking expenditure, to assist in providing management reports to the Board and to the EC, and to set up and run the PrepSKA web-site. Two administrative assistants (0.5 FTE at UMan, 0.25 FTE at STFC) will be required to support the Co-ordinator, Project Manager and STFC in all aspects of project management.

Work-package leaders
The leaders of the individual work-packages will be appointed by or approved by the Board. Each WP-leader will have responsibilities as follows:

- To ensure that the agreed work programme is followed and that the dates of milestones and deliverables are adhered to;
- To monitor the WP cash-flow and to provide quarterly financial reports to the co-ordinator;
- To provide quarterly reports on an exception basis; to deliver half-yearly progress reports and a comprehensive annual report, including financial statements, in a timely fashion to the co-ordinator;

The Work-Package Secretariat, which runs the policy WPs, will be distributed, it will have 1 FTE at each of NWO (for WP4) INAF (for WP5) and STFC (for WP6). Each of the FTEs will normally be split, with 0.75 FTE being a senior policy expert at each of the agencies, who will lead the relevant policy WP. 0.25 FTE at each of the three agencies will be allocated to administrative support for the WP activities. The role of the policy WP leaders, in addition to those listed above, will be to coordinate the activities of the WPs. In conjunction with the associated administrative assistant, the leader will

- organise the WP meetings and all associated travel arrangements,
- organise teleconferences.
- develop the meeting agendas and the generation and distribution of appropriate paperwork.
- ensure that minutes of WP meetings are taken and distributed,
- be responsible for producing the various reports and documents which arise from WP activities.

PrepSKA Board
The PrepSKA Board will consist of representatives of the organisations that sign the PrepSKA contract. The signatories will be the funding agencies able to formally participate in the PrepSKA project, and the astronomical research organisations and universities who are playing a key technical, managerial or political role within PrepSKA.

The Board will meet by teleconference quarterly and will hold a plenary face-to-face meeting on an annual basis.

The Board will be chaired by a representative from STFC, who will serve for the four year extent of PrepSKA. The Board will make decisions based on consensus. If consensus cannot be achieved then a decision will be passed by majority vote of a quorum. A quorum will be achieved if 2/3 of the Board members are present.

Organisations which do not sign the PrepSKA contract, but who are participating in PrepSKA activities, will be granted Observer status on the PrepSKA Board; observers may attend Board meetings but will not be entitled to vote.

Work-package leaders will normally be invited to Board meetings, at the discretion of the Chairman of the Board.

The principle responsibilities of the PrepSKA Board are as follows:

- Oversee all activities defined in the work programme;
- Receive regular reports on all PrepSKA activities;
- Ensure compliance with the EC contract and the PrepSKA Consortium Agreement;
- Approve allocation of resources;
- Maintain control of the project contingency and allocate contingency funds in support of PrepSKA activities as and when appropriate.

International SKA Project Office (ISPO)

The ISPO will have a major role to play in PrepSKA in leading WP2 and WP3. It was established by the International SKA Steering Committee in 2003, primarily to provide the overall leadership and management of the joint development of the SKA design concept, and to coordinate SKA institutions involved in SKA development to achieve a structured and efficient global effort. It comprises a Directorate that coordinates the global activities in SKA engineering, science, operations analysis, site characterization, simulations and outreach, and if PrepSKA is funded, a Central Design Integration Team (CDIT, see below)

ISPO Central Design Integration Team

A major focus of PrepSKA will be in facilitating the integration of the SKA domain knowledge being generated by national and regional teams into a costed SKA design. This will be done by establishing a Central Design Integration Team (CDIT) within the International SKA Project Office to coordinate the tasks in WP2. WP2 activities are shared between the ISPO-CDIT and existing engineering groups within regional consortia as shown in Figure 1.4.1 (section 1.4)

The CDIT organisation diagram is shown in Figure 2.1.2.

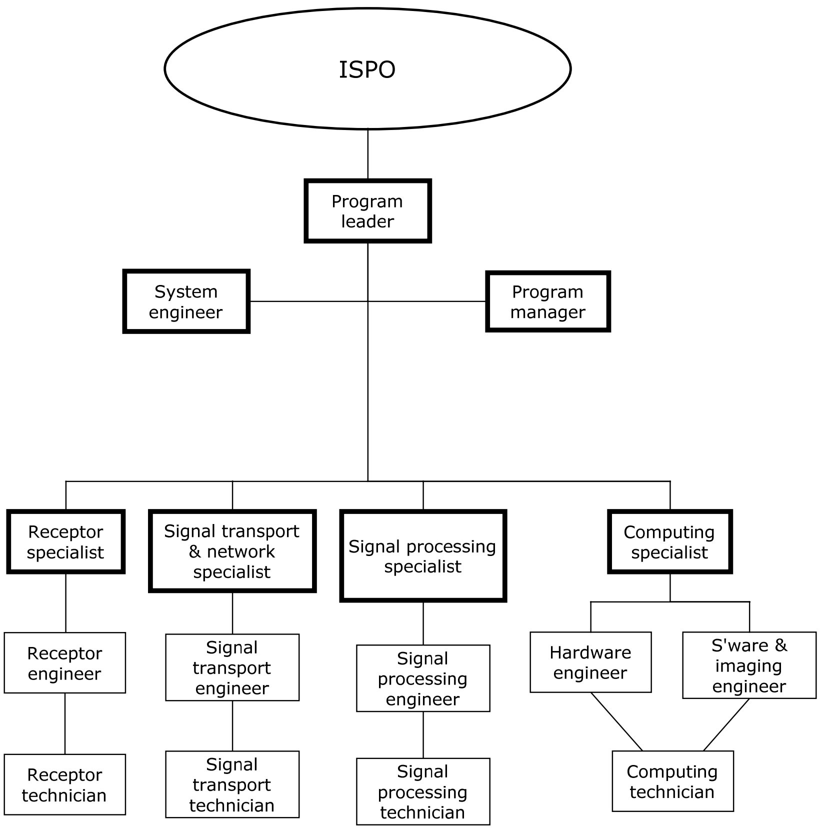


Figure 2.1.2: CDIT Org chart

The ISPO International Project Engineer will function as Programme Leader. The Domain Specialists (Receptor, etc) will use their knowledge of, and extensive experience in, radio astronomy and engineering to provide leadership in domain areas during the SKA system design and associated prototyping and integration activities. As members of the senior integration team, they will also contribute to wider aspects of the SKA design and to the generation of effective interactions with regional SKA groups.

Good communication between the ISPO-CDIT and regional teams is crucial. Regional programme managers, via a delegated senior engineer (acting as a regional liaison engineer), will have responsibility for strategic and operational links to the ISPO-CDIT, particularly to the domain specialists and system engineer. The liaison engineers will provide an active link between the ISPO-CDIT and regional engineering programs and, in particular, provide the ISPO-CDIT with comprehensive updates on regional technology development and demonstration programs. They will establish SKA design consultative groups within regional programs, ensuring that the expertise of engineers working on pathfinders and design studies is reflected in key ISPO-CDIT tasks. They will manage prototyping contracts between the ISPO-CDIT and regional groups and ensure that ISPO-CDIT priorities are reflected in regional engineering programs.

The ISPO will receive funding for the CDIT from the PrepSKA Board via the institute hosting (to be decided by the ISSC in May 2007) the ISPO. On all issues related to FP7 funding and statutory reporting, the ISPO will report to the Board via the Project Coordinator.

Management of funds

EC funds for PrepSKA will be received by the STFC and will be distributed as agreed by the PrepSKA Board in accordance with the plan agreed with the EU. Funds for the work of individual work-packages will be distributed to the organisation that employs the work-package leader. Once distributed, all financial dealings will be in accordance with an organisation's financial policies and procedures. Each organisation will be required to conduct a periodic audit of costs following their usual policies.

10% of all PrepSKA funds will be held in a central, non-interest bearing, contingency account of the STFC. These may be used at the discretion of the Board to support activities whose scope has expanded or to support new activities identified during the project.

Consortium Agreement

A draft Consortium Agreement is being drawn up. This agreement will be refined as appropriate and signed before contract negotiations between the Coordinator and the EU are finalised.

2.2 Relevant Parties.

As shown in Table 1a there are 20 formal participants in the Preparatory phase, 8 of which are funding agencies or other government bodies. The agencies are the principal funders of astronomical research and facilities around the world. Their involvement in the Preparatory phase is crucial to its success; the agencies will co-ordinate the policy activities and will have significant influence in developing the legal, procurement and industrial framework options that will be an essential component of the final implementation plan.

Agencies and other government bodies from outside the EU are playing a major role in PrepSKA. As well as such bodies from the UK, NL, FR, IT and ES, formal project participants will be government organisations from Australia, Canada and South Africa. In addition, the US National Science Foundation, although not a formal participant, will be engaged in the policy work-packages. For a global project such as the SKA, this involvement is regarded as essential. If the implementation plan, and subsequent funding proposal, which will flow from this Preparatory phase is to have any chance of success then the governments will need assurances that all aspects of the project have been thought through with due care and attention. This is best achieved by their active participation in discussion of the many issues involved and hopefully their resolution.

At a scientific and technical level, the preparatory work for SKA is being conducted by more than 50 institutions worldwide, representing a considerable financial and intellectual investment. In particular, substantial investment is being made in demonstration telescopes of SKA prototype technology on the short-listed candidate sites for SKA. Input from these worldwide activities will provide essential information to the PrepSKA workpackages. Europe is benefiting greatly from the close collaboration of the international technical and scientific partners in PrepSKA. The technology risks involved in delivering a project of the scale and vision of the SKA are significant. It is only by engaging a global alliance that these risks can be effectively mitigated. Without input - and funding - from countries outside Europe it will be impossible to deliver the scale of infrastructure required for European research to reach its full potential.

The commitment of resources from each participant is shown explicitly in Table 3c. The Table below (2.2.1) describes briefly the relevant experience and knowledge of the participants.

Table 2.2.1

Participant	Participant organisation name	Country	Relevant experience and knowledge
1	Science and Technology Facilities Council	UK	The Council is one of Europe's largest multidisciplinary research organisations supporting scientists and engineers world-wide. The Council operates world-class, large scale research facilities; it provides funds for the UK SKADS programme as well as all other aspects of UK radio astronomy.
2	Netherlands Organisation for Scientific Research	NL	The NWO is responsible for enhancing the quality and innovative nature of scientific research principally by the allocation of resources and the dissemination of knowledge gained. NWO provides funds for the Dutch radio astronomy programme, as well as astronomy research in the NL.
3	Centre National de la Recherche Scientifique	FR	CNRS is the largest and most prominent public research organization in France. It employs 26,000 permanent staff (researchers, engineers, and administrative staff) and a further 4,000 temporary staff. Its budget for 2006 was 2.738 billion EUR.
4	Istituto Nazionale di Astrofisica	IT	INAF promotes, realizes and coordinates research activities in the fields of Astronomy, Radio astronomy, Astrophysics, Space and cosmic Physics, it collaborates with the University sector and private, national and international organisations.
5	Fundacion General de la Universidad de Alcala Instituto Geografico Nacional	ES	FG-IGN is the organization in Spain responsible for the funding and operation of the major radio astronomy facility, the 40-m radio telescope at Yebes. It provides support for SKA in conjunction with SKADS.
6	Department of Education Science and Training	AU	DEST provides national leadership and works in collaboration with the States and Territories, industry, other agencies and the community in support of the Government's objectives. DEST ensures high quality and value for money in delivering Government funded programmes. Through its National Collaborative Research Infrastructure Strategy it is funding the MIRANdA SKA pathfinder.
7	National Research Foundation	ZA	NRF provides leadership in the promotion and support of research and research capacity development in the natural, social and human sciences, engineering and technology to meet national and global challenges through: a) investing in knowledge, people and infrastructure; b) promoting basic and applied research and innovation; c) developing research

			capacity; d) facilitating strategic partnerships and knowledge networks; and e) upholding research excellence. NRF is providing funding for the Karoo Array Telescope.
8	National Research Council	CA	The NRC is the Government of Canada's premier organization for research and development. NRC employs close to 4,000 people across Canada, providing substantial resources to help Canada become one of the world's top five R&D performers by 2010. It provides funding for Canada's radio astronomy programme.
9	The University of Manchester	UK	UMAN is the largest single-campus university in the UK, with 27,000 undergraduate and 10,000 postgraduate students. It spends ~£300M annually on research. It owns and operates Jodrell Bank Observatory and coordinates the UK SKADS programme.
10	Netherlands Foundation for Research in Astronomy	NL	ASTRON manages the Dutch radio astronomy programme. It provides front-line observing capabilities (e.g. WSRT and LOFAR) for Dutch and international astronomers across a broad range of frequencies and techniques. It has a strong technology development program, encompassing both innovative instrumentation for existing telescopes and the new technologies needed for future facilities. ASTRON coordinates the EC SKADS programme.
11	Max-Planck Institut fur Radioastronomie	DE	The MPIfR in Bonn, with its staff of 183 people, is dedicated to researching astronomical objects through radio and infrared emissions. In the field of radio astronomy it owns and operates the 100-m telescope at Effelsberg. MPIfR has long experience in international astronomical collaborations and participates in the EU SKADS programme.
12	Cornell University	USA	Cornell is one of the USA's premier universities. It has 11,200 staff and over 20,000 students. It operates the world's largest radio telescope, the 300-m dish at Arecibo. Cornell is leading the US SKA Technology Development Program.
13	University of Cambridge	UK	The University of Cambridge, established in 1209, has ~9,000 staff and ~16,000 students. It owns and operates the Mullard Radio Astronomy Observatory and is a major participant in the EC SKADS programme.
14	University of Oxford	UK	The University of Oxford was founded in the 12th Century. It employs ~7,000 staff and has ~18,000 students. Its Physics Department has a strong astrophysics group, prominent in radio astronomy and is a major participant in the EC SKADS programme.
15	Commonwealth Scientific and Industrial Research Organisation	AU	CSIRO, the Commonwealth Scientific and Industrial Research Organisation, is Australia's national science agency and one of the largest and most diverse research agencies in the world. It owns and operates the Australia Telescope National Facility, which runs Australia's SKA programme. CSIRO is funding and building the SKA pathfinder MIRAnDA.
16	Joint Institute for VLBI in Europe	EU(NL)	JIVE is an international organization created by the European Consortium for VLBI and is a member of the European VLBI Network (EVN). Its primary task is to operate the EVN MkIV VLBI Data Processor and provide support to astronomers and the EVN. JIVE participates in the EC SKADS programme.
17	Observatoire de Paris	FR	The Paris Observatory is a Research centre in astronomy and astrophysics. It conducts research in metrology of space and time, Sun and Sun-Earth system, Planetary systems, Interstellar Medium, Stellar Physics, Physics of galaxies, cosmology, Compact Objects and gravitational waves and the History of sciences. OBSPARIS operates the Nancay radio telescope and participates in the EC SKADS Programme.
18	Universite	FR	The University of Orleans (UORL) founded in the 14th Century

	d'Orleans		has over ~15000 students and employs 882 lecturers in 4 Faculties, 1 School of Engineering and Technology and 4 Institutes of Technology. 34 research laboratories are divided into 6 centres of excellence including the "Mathematics, Informatics and Electronics Department". UORL is a participant in the EC SKADS programme.
19	University of Calgary	CA	UCAL has 16 faculties and 36 research institutes and centres. It has more than 28,000 students and ~5000 employees. It brings in over CA$250M of research income annually. It participates in Canadian and international SKA activities.
20	University of Groningen	NL	The University of Groningen, founded in 1614 has 22,500 students, 5,500 staff and an annual turnover of € 499 M. The Kapteyn Astronomical Institute is one of its top institutes, also part of the national research school for astronomy NOVA. The Kapteyn Institute harbours the AstroWise/OmegaCen group which has expertise in developing intelligent information systems for astronomy.

It may well be that new partners will wish to join the Preparatory phase after the entry into contract. The procedure for the adoption of new partners is as follows:

- The potential applicant will contact the Co-ordinator with a statement of why they wish to join PrepSKA, what activities they wish to participate in and what resources they will bring to the Consortium;
- The Co-ordinator will pass the application to the PrepSKA Board who must approve any change in the membership
- If and when approved, the Co-ordinator will initiate a modification to the contract with the EC.

2.3 Resources

Major costs for PrepSKA other than staff costs are listed in the following table.

Table 2.3.1

Work Package	Description	Cost (€)
2	Initial Verification System	500000
2	Sub-system prototyping	500000
3	RFI equipment	100000
3	External consultancy on the ionosphere	10000
3	External consultancy on infrastructure deployment costs, timescales, and operational models	225000
3	External consultancy on potential RFI threats	50000
4	Legal and business advice	100000
5	External consultancy to provide a comparison of procurement models based on the reference design	150000
5	External consultancy on an industrial development model including global procurement	225000
5	External consultancy to generate a world-wide inventory of potential industry partners	40000
6	External consultancy to advise on appropriate ways to approach private and/or corporate donors	50000
	TOTAL	**1950000**

Mobilisation of resources

The global radio astronomy community has a strong track record in mobilising resources for joint projects across international borders. This began with the Very Long Baseline Interferometry networks, and has progressed in scope and complexity to RadioNet, SKADS and e-LOFAR in

Europe, the Mileura Radio Array (Australia, Canada, and the USA), and is in development for MeerKAT in South Africa.

The resources required for a successful conclusion to PrepSKA fall into three categories, 1) those required for studies of the governance and legal structure, procurement issues, and construction and operations funding, 2) those required for the integration of the SKA design, and 3) those required for the additional site characterization.

WP4, WP5, WP6: The manpower resources needed for WPs 4-6 have been agreed with the funding agencies. Their use will be coordinated by the individual WP Working Groups and monitored by the PrepSKA Board.

WP 2: This Work Package will integrate a large external resource of contributing design knowledge into the final SKA design. This includes FP7-concurrent R&D expenditure in the national and regional projects/design studies as well as considerable pre-FP7 expenditure (at least €60 million) on investigating the feasibility of various potential SKA designs, and the final design and verification of the LOFAR, ATA, e-MERLIN and other Pathfinders. Note that FP6-SKADS will contribute its design knowledge to PrepSKA but is not included as matching funds; European matching funds for PrepSKA will be additional.

Mobilisation of the resources provided to PrepSKA by the national and regional Pathfinder telescopes and Design Studies will be coordinated through the International SKA Project Office and monitored by the PrepSKA Board, in addition to any locally operated oversight procedures. External review panels established by the International SKA Steering Committee together with the existing ISPO Working Groups and Task Forces will also play a significant role in international supervision of progress.

WP3: Task Forces have already been established by the International SKA Project Office to take responsibility for developing the necessary protocols for deep RFI measurements, and for the instrumentation required and logistics of the measurement campaigns. The membership of these task forces includes representatives of the two short-listed sites, the International SKA Project Office, and SKADS. The manpower required for preparing for and carrying out of the measurement campaigns will be coordinated by the ISPO, and monitored by the ISSC and the PrepSKA Board.

Financial commitments already available

The matching funds for WPs 4, 5, and 6 have been committed by the Funding Agencies. Matching resources for WP3 site engineer are being sought; other matching is in place. A total of about 5 M€ of matching resources for WP2 has been committed so far in a number of countries including Australia, Canada, France, Italy, Spain, France, Netherlands and South Africa. Additional matching resources for WP2 of up to 9 M€ are being sought in Germany, Netherlands, UK, and USA. In table 2b, a list was given of the other Preparatory Phase work packages not funded by the EC in FP7. These are all funded with the exception of the US Technology Development Programme (TDP) whose funding is expected to be known by mid-2007. Table 2.3.2 below summarises the financial commitments in these other Preparatory Phase WPs.

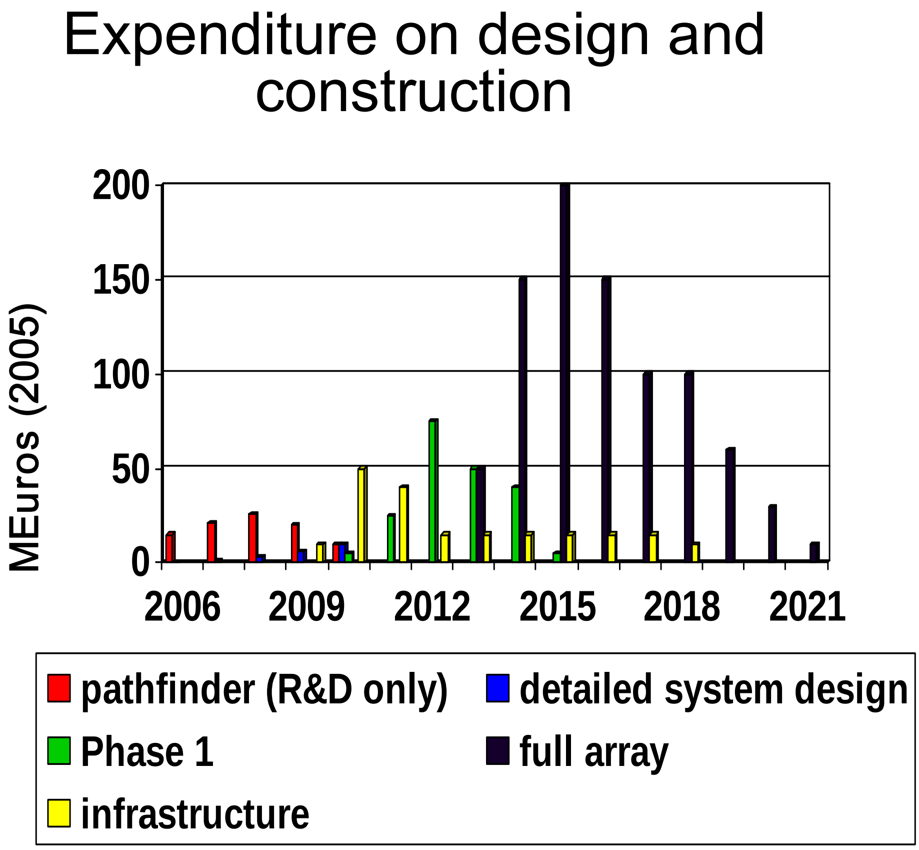
Table 2.3.2

Country/ region	**Programme name**	**Post-2006 design funds committed (€)**
Europe	FP6 design study: SKADS	29 million
Netherlands	LOFAR	15 million
Netherlands	APERTIF	5 million
Australia	MIRA	15 million
South Africa	MeerKAT	22 million
USA	EVLA	5 million

Canada	SKA design; EVLA correlator	7 million
TOTAL		98 million

Preliminary business plan
The EC has a copy of a preliminary business plan for the SKA which includes sections on the scientific and engineering environment, the stakeholders, project description, project management, funding, and risks. Stakeholders include scientists, national and regional research institutes, research councils and government departments, industrial partners, students, and the wider public. The expenditure plan from the design phase to the end of construction is shown in the histogram above. The main risks are identified as the technology, the site selection, and the phasing of participation.

Long term sustainability of the infrastructure
The SKA is not yet funded for construction and operation. Indeed the final deliverable of PrepSKA is an implementation plan for the SKA including an outline of the content, process and schedule necessary for an SKA MoU on construction and operation. Assuming SKA is funded, it will be the world's premier radio telescope for many decades.



3 Impact

3.1 Critical Questions

There are five critical questions that need to be addressed in order to reach a multi-lateral, global agreement on the joint implementation of the SKA, these are:

1. What is the optimum design of the SKA that will meet the demands of the science case, and that can be built on the required timescales within the target budget?
2. Where will the SKA be located?
3. What is the legal framework and governance structure under which the globally-funded SKA project will operate?
4. What is the most cost-effective mechanism for the procurement of the various components of the SKA? This must take into account the global nature of the SKA and the essential involvement of industry.
5. How will the SKA be funded? This question is especially important as different countries around the world have different natural cycles to their major funding decisions and may wish to join the project at different times.

PrepSKA will provide the information to enable all of these questions to be answered. WP2 is aimed directly at the first question. The WP3 report will provide critical information to the funding agencies and other decision-makers on the results of further investigations of the characteristics of the short-listed sites. It will enable the funding agencies to take the vital decision on the location of the SKA, and thereby answer question 2. WP4 will investigate the options for an appropriate internationally acceptable governance structure, building upon the extensive experience that has been gained in other large-scale science projects. It will therefore address question 3.

A cost-effective procurement policy that also satisfies the requirements of those nations that will fund the SKA is a key component of the legal framework to be adopted. WP5 will involve all interested parties and representatives of critical industries in developing the options that will form a central plank of the project's policy on procurement , thereby answering question 4.

Last, but clearly not least, is question 5. This will be addressed by WP6, which will develop a full understanding of the funding timescales and constraints that each relevant funding agency around the world operates under. WP6 will also explore the possibility of private and industrial contributions to SKA funding, as well as mechanisms for the smoothing of funding profiles.

3.2 Attractiveness of ERA

Europe will be a major partner in the SKA. It is, and will continue to be, heavily involved in the technology development required to enable the construction of the SKA at an affordable cost. The technology under development via SKADS and other national programmes will establish a firm basis for the construction of the SKA, will be of huge benefit to other radio astronomy initiatives and facilities, and will continue to attract the interest and engagement of industry. This will reinforce the research-based clusters of excellence that have developed around the radio astronomy institutes in Europe (and the world) and will significantly enhance the scientific excellence of Europe as a whole by ensuring that European scientists and engineers remain at the forefront of both technology and the science that it enables.

3.3 Catalytic effect of the EC contribution

EC funding of the Preparatory Phase proposal is the ***only*** way in which the international SKA community has been able to identify resources which will provide the central integration and coordination of technical and policy-related work which is required to develop the implementation plan leading to SKA construction. If the proposal is funded, the EC will have facilitated a major step forward in this complex international project. The writing of the PrepSKA proposal alone has triggered the provision of, or proposals for, significant national funding to support the generation of the fully costed design of Phase 1 of the SKA, and the overall SKA deployment plan. As such, the proposed EC contribution has had a leveraging effect far beyond the funding requested in PrepSKA.

Although significant national funding is, or will be, forthcoming for SKA activities, it is difficult to direct this towards the central coordination of the global SKA project because the formal governance structures and legal framework have not yet been established. One of the principal aims of PrepSKA is to discuss options for such structures to enable decision-makers to establish the SKA programme on a formal basis. It is hoped that this will occur following the preparation of a proposal to construct Phase 1 of the SKA, which will emerge from the implementation plan (one of the principal deliverables of PrepSKA). The proposal will be prepared by the international community and submitted to funding agencies around the world in a coordinated fashion.

Work-package 6, led by STFC, will focus on understanding the options for funding of SKA construction and operations. One of the avenues that it will explore is the use of funding opportunities offered by the EC, such as a loan from the European Investment Bank. WP6 will seek to understand the mechanics of obtaining a loan and the obligations and benefits that arise from such an approach.

4. Ethical Issues (if appropriate)

There are no known ethical issues arising from this proposal. It is entirely focused on the scientific, technical and policy activities required in the next stage of planning for the SKA.

ETHICAL ISSUES TABLE

	YES	PAGE
Informed Consent		
• Does the proposal involve children?		
• Does the proposal involve patients or persons not able to give consent?		
• Does the proposal involve adult healthy volunteers?		
• Does the proposal involve Human Genetic Material?		
• Does the proposal involve Human biological samples?		
• Does the proposal involve Human data collection?		
Research on Human embryo/foetus		
• Does the proposal involve Human Embryos?		
• Does the proposal involve Human Foetal Tissue / Cells?		
• Does the proposal involve Human Embryonic Stem Cells?		
Privacy		
• Does the proposal involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)		
• Does the proposal involve tracking the location or observation of people?		
Research on Animals		
• Does the proposal involve research on animals?		
• Are those animals transgenic small laboratory animals?		
• Are those animals transgenic farm animals?		
• Are those animals cloning farm animals?		
• Are those animals non-human primates?		
Research Involving Developing Countries		

• Use of local resources (genetic, animal, plant etc)		
• Benefit to local community (capacity building ie access to healthcare, education etc)		
Dual Use		
• Research having potential military / terrorist application		
I CONFIRM THAT NONE OF THE ABOVE ISSUES APPLY TO MY PROPOSAL	P.Diamond	

5. Consideration of gender aspects

It is self-evident that astronomy as a whole tends to be dominated by males. In general, women represent about 50% of the total student population in European universities but later attain only 10% of the senior positions. Women are particularly under-represented in the sciences (especially in the physical sciences such as astronomy) and engineering. As a result, they are often poorly represented in decision-making bodies concerned with institute or project management, and strategic scientific policy. The SKA community is well aware of these problems and it is essential that projects like PrepSKA undertake all appropriate actions that maximise the full potential of existing human capital.

All institutes involved in PrepSKA have a policy of promoting and developing their staff equally, regardless of gender or race. The PrepSKA board will adopt a policy of equality in the treatment of members of its personnel, regardless of sex, ethnic origin, physical handicap, sexual orientation or religion. The board and participating institutes will endeavour to provide a working environment that is free of discrimination or harassment, that addresses the day-to-day needs of all genders, religions and race, and that enables all personnel to work in an atmosphere of safety, dignity and mutual respect. Where appropriate, flexible working hours (including possible part-time appointments) and the ability to work at home, will be encouraged.

The process of recruitment and promotion within PrepSKA will be fair and transparent – all appointments will be made on the basis of merit alone and the selection panel will (whenever possible) include a female staff member that will not only participate in the interview process, but will also be involved in drawing-up the associated selection criteria. All staff involved in any PrepSKA recruitment process, will be made aware of their obligation to enforce equal opportunity regulations.

What is noticeable over recent years is that there are an increasing number of young female astronomers and engineers entering the profession. It is therefore our aim to develop a more equitable distribution of the genders in the future. In order to sustain and support this development, the PrepSKA partners are resolved to encourage all staff (both men and women) to engage and participate in local actions that tackle gender (and other related) issues.

Actions currently underway at many PrepSKA institutes include:

(i) setting-up mentoring programmes that support women in all aspects of their career development, including encouragement to apply for promotion;
(ii) encouraging the inclusion of women as leading members of Scientific & Technical Organising Committees;
(iii) the emergence of institute diversity committees charged with addressing local gender and minority issues with a direct reporting line to senior management;
(iv) the organisation of "girls days" – in which local school girls are invited to visit and tour PrepSKA Research Facilities.

With these policies and actions in place, we believe that the PrepSKA project can positively promote gender equality issues, and at the same time, raise public awareness of the opportunities that are now available to women (and other minorities) within the domain of research infrastructures and the realm of the physical sciences more generally.

Glossary

AA	Aperture Array
ALMA	Atacama Large Millimeter Array
APERTIF	Aperture Tile in Focus
AR	Annual Report
ASTRON	Netherlands Foundation for Research in Astronomy
ATA	Allen Telescope Array
ATCA	Australia Telescope Compact Array
ATNF	Australia Telescope National Facility
AU	Australia
AUI	Associated Universities Inc
CA	Canada
CDIT	Central Design Integration Team
CERN	European Organization for Nuclear Research
CNRS	Centre National de la Recherche Scientifique
CO	Confidential, only for members of the consortium (including the Commission Services).
COORD	Coordination activities
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DE	Germany
DEST	Department of Education Science and Training
DR	Design review
DRAO	Dominion Radio Astronomy Observatory
DSP	Digital Signal Processing
EC	European Commission
e-EVN	e-European VLBI Network
EMBRACE	Electronic Multi-Beam Radio Astronomy Concept
e-MERLIN	e-Multi Element Radio Linked Interferometer Network
ERA	European Research Area
ES	Spain
ESFRI	European Strategy Forum for Research Infrastructures
EU	European Union
EVLA	Expanded Very Large Array
EVN	European VLBI Network
FG-IGN	Fundacion General de la Universidad de Alcala Instituto Geografico Nacional
FOV	Field of view
FP6	Framework Programme 6
FP7	Framework Programme 7
FPA	Focal Plane Arrays
FR	France
FTE	Full time equivalent
GBT	Green Bank Telescope
GMRT	Giant Metrewave Radio Telescope
HIA	Herzberg Institute of Astrophysics
IBM	International Business Machines
ICT	Information & Communications Technology
IEAC	International Engineering Advisory Committee
IN	India
INAF	Istituto Nazionale di Astrofisica
ISPO	International SKA Project Office

ISSC	International SKA Steering Committee
IT	Italy
ITER	International Thermonuclear Experimental Reactor
IVS	Initial Verification System
JIVE	Joint Institute for VLBI in Europe
LNA	Low noise amplifier
LOFAR	Low Frequency Array
MAIT	Manufacturing, assembly, integration and test
MeerKAT	Karoo Array Telescope
MERLIN	Multi Element Radio Linked Interferometer Network
MFC	Multiple-feed cluster
MGT	Management of the Consortium
MIRA	Mileura International Radio Array
MoU	Memorandum of Understanding
MPIfR	Max-Planck Institut fur Radioastronomie
MTR	Mid-Term Review
MWA	Mileura Widefield Array
NASA	National Aeronautics and Space Administration
NL	Netherlands
NRAO	National Radio Astronomy Observatory
NRC	National Research Council
NRF	National Research Foundation
NSF	National Science Foundation
NWO	Netherlands Organisation for Scientific Research
OBSPAR	Observatoire de Paris
PAF	Phased array of feeds
PdBI	Plateau de Bure Interferometer
PMT	PREPSKA Management Team
PP	Restricted to other programme participants (including the Commission Services).
PrepSKA	A Preparatory phase for the Square Kilometre Array
PU	Public
PVS	Production Verification System
PWG	Procurement Working Group
R&D	Research and development
RE	Restricted to a group specified by the consortium (including the Commission Services)
RFI	Radio Frequency Interference
RQZ	Radio Quiet Zone
RTD	Research and technological development
RUG	University of Groningen
SKA	Square Kilometre Array
SKADS	Square Kilometre Array Design Study
STFC	Science and Technology Facilities Council
SUPP	Support activities
TDP	Technology Development Program
TID	Travelling Ionospheric Disturbance
UCAL	University of Calgary
UCAM	University of Cambridge
UK	United Kingdom
UMAN	The University of Manchester
UORL	Universite d’Orleans

UOXF	University of Oxford
USA	United States of America
VLA	Very Large Array
VLBA	Very Long Baseline Array
WA-DOIR	The Western Australian Department of Industry and Resources
WAN	Wide Area Network
WFoV	Wide Field of View
WG	Working group
WP	Work package
WPS	Work Package Secretariat
ZA	South Africa

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DE EDUCACION
Y CIENCIA

SECRETARIA GENERAL
DE POLITICA CIENTIFICA
Y TECNOLÓGICA

DIRECCION GENERAL DE
POLÍTICA TECNOLÓGICA.

University of Manchester
Jodrell Bank Observatory
Att. Prof. Phillip J. Diamond
Macclesfield
Cheshire SK11 9DL
UK

Madrid, April 12th 2007

Dear Prof. Phillip J. Diamond,

Concerning the interest of the Spanish institution Observatorio Astronomico Nacional (OAN), to eventually become an active part in the preparatory phase of the ESFRI project entitled

> **Square Kilometer Array (SKA)**, under the 7th Framework Programme, Capacities Workprogramme, Part 1 - Infrastructures, Call Identifier FP7-INFRASTRUCTURES-2007-1,

for which you are the Current Director / Coordinator, I am pleased to transmit, on behalf of the Spanish Ministry of Education and Science (MEC), my support to the participation of OAN in the SKA team, and express my conviction that their competence in the field will contribute to the success of this challenging European initiative.

The OAN, as a qualified Spanish agent in this scientific field, receives hereby the support of MEC for participating in the preparatory phase of the **SKA project**, in the understanding that this support does not mean in any aspect a decision on the financial contribution from the MEC to the construction phase of this project.

Sincerely yours,

Mª Carmen Andrade
Director-General for Technology Policy

CORREO ELECTRÓNICO:
mailto:DGPT@mec.es

Pº Castellana, 160
28071 MADRID
TELF :91 349 42
FAX : 91 349 43

8501 IBM Drive
Charlotte, NC 28262-8563

27 April, 2007

To the Coordinator of the EU FP7 SKA Preparatory Study Proposal Team
Professor Philip Diamond
Head of Astronomy & Astrophysics and
Director, Jodrell Bank Observatory
University of Manchester
Macclesfield
Cheshire SK11 9DL, U.K.

Dear Professor Diamond,

The Square Kilometre Array (SKA) will be the largest radio telescope ever built worldwide and quite possibly the largest digital processing system of its time, considering the entire digital path from the Analog to Digital Converter (ADC) near the antenna feeds to the Fast Fourier Transform (FFT) and beam-forming steps, to the correlators and post-processing. It will require data transport rates and digital processing rates, both in the field and at central stations, that stretch the envelop of all projections for Moore's law and other previous trends for chips, processor technology, storage, and Input/Output (I/O) scaling. This comes at a time when Moore's exponential growth, i.e. the doubling of performance every 18 months, is seriously being questioned for individual processors and hardware systems.

Continued growth requires increasing the speed of integrated, whole Information Technology (IT) solutions. These solutions may be comprised of many thousands, perhaps millions of processors with high bandwidth and flexibility for interconnections and external connections. They will require streamlined operating systems, specialized optimization tools for user software, enormous storage capacity, and heightened reliability to ensure full-time operation.

IBM views the SKA Programme as one of the foremost challenges for digital technology in the next decade. Nearly every requirement for the SKA is also a requirement for the IT industry in general. Depending on conditions and acceptability of those IBM would be interested to be invited for discussions to evaluate how IBM could participate in the project, and work alongside the astronomers and engineers planning the SKA in order to stay at the forefront of scientific developments in information technology, including Radio Frequency (RF) design, digital architectures, and data streaming.

In that way IBM Global Engineering Solutions would be interested to contribute intellectually to these research collaborations, and eventually provide information related to the required solutions for the SKA and its prototypes, including hardware and software. Similarly an IBM executive team would also like to contribute by providing business counsel, a realistic sense of technology direction, and proven solutions to growth management and cost control.

The European Union (EU) funded SKA preparatory detailed design study, could be the next step in IBM's long path of cooperation and intellectual growth with the International SKA programme. With this step we would like to ensure that all of the pieces that eventually go into the SKA, fit and work together as a single, highly-efficient telescope system. IBM's inter-continental reach will help ensure the global cooperation that is needed to succeed in a project as grand as this.

Yours sincerely,

Raj S. Desai
IBM Vice President
Global Engineering Solutions, Industry Solutions

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RÉPUBLIQUE FRANÇAISE

ministère éducation nationale enseignement supérieur recherche

Paris, le 25 avril 2007

Direction générale de la recherche et de l'innovation

Direction de la Stratégie

Responsable de la Cellule des Très Grandes Infrastructures

DGRI - DS
DV- FM - N°29-2007

Affaire suivie par
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75231 Paris Cedex 05

<u>OBJET</u> : Lettre de support pour le projet SKA

Monsieur le Professeur Philippe Diamond,

Au nom de la cellule des très grandes infrastructures du Ministère délégué à l'enseignement supérieur et à la recherche (DGRI/DS) en France, je confirme l'intérêt et le support pour le projet :

"SKA"

et pour la proposition préparée en réponse à la publication de la Commission européenne: *[Call – Topic: INFRA-2007-2.2.1.31 : Preparatory phase for research infrastructure in the 2006 ESFRI Roadmap, Call-Identifier: FP7-INFRASTRUCTURES-2007-1]*.

Par ailleurs, je vous confirme que Monsieur Win Van Driel est le représentant de l'ensemble des partenaires français pour la préparation de cette proposition.

Sincèrement vôtre,

Dany VANDROMME
Responsable de la Cellule
des Très Grandes Infrastructures

Professeur Philippe Diamond
Jodrell Bank Observatory
Macclesfield
SK11 9DL
Cheshire
UK

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Mr P Diamond
The University of Manchester
Jodrell Bank Observatory
Macclesfield
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SK11 9DL

1 May 2007

Dear Phil

FP7 Infrastructures Proposal: Preparatory Study for the Square Kilometre Array (PrepSKA) – Delegation of Coordinator role

Thanks largely to your own efforts, a proposal will shortly be submitted for FP7 funding for a Preparatory Study for the Square Kilometre Array project (PrepSKA).

At a meeting of Funding Agencies with interests in the SKA held in December 2006, PPARC (now the Science and Technology Facilities Council, STFC) agreed to act as the lead partner in the collaboration, and so will submit the proposal and receive and distribute EC funding to the other partners.

The purpose of this letter is to confirm that STFC has agreed to delegate the day-to-day co-ordination of PrepSKA and its assorted activities to you. I understand that Professor Mike Garrett, General-Director of ASTRON, will act as Deputy Co-ordinator. In addition, I understand that as part of the proposal, you as Co-ordinator will be supported by a Project Management Team, with administrative effort centred at the University of Manchester.

The principle responsibilities of you as Co-ordinator as laid down in the PREPSKA proposal are as follows:

- To monitor all project activities and ensuring that each is following the plan as laid down by the Work-Package(WP) leaders and approved by the PrepSKA Board;
- To ensure that the project web-site is kept up to date and that all documents emerging from project activities are available under version control.
- To ensure that WP leaders provide all reports and documentation on a timely basis to the PrepSKA Board and to the EC as appropriate;
- To be responsible for and monitor all financial matters pertaining to the project.
- To report any and all activities to the P Board.

- To act as the representative on PrepSKA activities to the funding agencies and national governments

In return, in addition to providing policy and project management support to the PrepSKA programme (specifically in Workpackages 1 and 6), STFC will be responsible for monitoring and reporting its own financial activity to the EC and providing required audit approval. As overall budget holder, STFC will also be responsible, based on advice from the Co-ordinator and his team, for the distribution of EC funds to each participant.

A detailed statement of our respective responsibilities within the PrepSKA project will be agreed at the contract negotiation stage, but in the meantime, I propose that an exchange of letters will provide the required authorisation to all interested parties that we have agreed delegation of day-to-day coordination to you. If this is acceptable, I would ask you to respond accordingly.

Yours sincerely

Dr C Vincent
STFC Head of Astronomy Division

The University of Manchester
Jodrell Bank Observatory

MANCHESTER 1824

Prof. Philip Diamond
Jodrell Bank Observatory
The University of Manchester
Macclesfield
Cheshire SK11 9DL

01477 571321
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1 May 2007

Dr Colin Vincent
Head of Astronomy Division
Science and Technology Facilities Council
Polaris House, North Star Avenue
Swindon, Wiltshire
SN2 1SZ

Dear Colin,

FP7 Preparatory Phase proposal for the SKA

Thank-you for your letter today. I am pleased that you have the confidence in me to confirm that I will act as the Co-ordinator of the FP7 PrepSKA project on behalf of the STFC.

I confirm that the division of duties that you outlined in your letter is planned and appropriate. As you state, we should define this in more detail at the contract negotiation stage, which the EC informs me should take place around September – if all goes well with the proposal

With my best regards,

Prof Philip.Diamond
Head of Astronomy and Astrophysics, Director of Jodrell Bank Centre for Astrophysics