SEVENTH FRAMEWORK PROGRAMME

Capacities Specific Programme
Research Infrastructures

Grant agreement for Combination of Collaborative Project and Coordination and Support Actions

Annex I - "Description of Work"

Project acronym: ***PrepSKA***

Project full title: A Preparatory Phase proposal for the Square Kilometre Array

Grant agreement no.: ***212243***

Date of preparation of Annex I (latest version): 20 February (tidy up)
Date of approval of Annex I by Commission: *(to be completed by Commission)*

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PART A: Budget breakdown and project summary

A1: Overall budget breakdown for the project

Table 1: Budget breakdown form (copy of A3.2 form of the GPFs).

Project Number	212243	Project Acronym	PrepSKA

Participant number in this project	Participant short name	Estimated eligible costs (whole duration of the project)						Total receipts	Requested EC contribution
		RTD (A)	Coordi-nation (B)	Support (C)	Management (D)	Other (E)	TOTAL A+B+C+D+E		
1	STFC			274653.26	99931.54		374584.80		374584.80
2	NWO			293167.16	86400.00		379567.16		379567.16
3	CNRS								
4	INAF			260258.87	291400.00		551658.87		551658.87
5	IT								
6	DIISR								
7	NRF								
8	NRC-HIA								
9	UMAN	4101811.57		404460.00	712865.41		5219136.98		4193684.09

10	ASTRON								
11	MPG								
12	Cornell								
13	UCAM								
14	UOXF.DL								
15	CSIRO								
16	JIVE								
17	OBSPARIS								
18	UORL								
19	UCAL								
20	RUG								
Total		4101811.57		1232539.29	1190596.95		6524947.81		5499494.92

A2: Project summary form

Project Number	212243	Project Acronym	PrepSKA

ONE FORM PER PROJECT

GENERAL INFORMATION				
Project Title	*A Preparatory Phase Study for the Square Kilometre Array*			
Starting date	*1 April 2008*			
Duration in months	*36*	*Call (part) identifier*	*FP7-INFRASTRUCTURES-2007-1*	
Activity code(s) most relevant to your topic	INFRA-2007-2.2-01			
Free keywords	Radio astronomy, SKA, global			

Abstract (max. 2000 char.)

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 project is to address all of these points. PrepSKA will 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, all of the options for the policy-related questions will be investigated. 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.

A3: List of Beneficiaries

Table 2: List of Beneficiaries

Beneficiary Number *	Beneficiary name	Beneficiary short name	Country	Date enter project**	Date exit project**
1(coordinator)	Science and Technology Facilities Council	STFC	UK	1	36
2	Netherlands Organisation for Scientific Research	NWO	NL	1	36
3	Centre National de la Recherche Scientifique	CNRS	FR	1	36
4	Istituto Nazionale di Astrofisica	INAF	IT	1	36
5	Instituto de Telecomunicações	IT	PT	1	36
6	Department of Innovation, Industry, Science & Research	DIISR	AU	1	36
7	National Research Foundation	NRF	ZA	1	36
8	National Research Council	NRC-HIA	CA	1	36
9	The University of Manchester	UMAN	UK	1	36
10	Netherlands Foundation for Research in Astronomy	ASTRON	NL	1	36
11	Max-Planck Institut fur Radioastronomie	MPIfR	DE	1	36
12	Cornell University	Cornell	USA	1	36
13	University of Cambridge	UCAM	UK	1	36
14	University of Oxford	UOXF.DL	UK	1	36
15	Commonwealth Scientific and Industrial Research Organisation	CSIRO	AU	1	36
16	Joint Institute for VLBI in Europe	JIVE	EU(NL)	1	36
17	Observatoire de Paris	OBSPAR	FR	1	36
18	Universite d'Orleans	UORL	FR	1	36
19	University of Calgary	UCAL	CA	1	36
20	University of Groningen	RUG	NL	1	36

Table 2a

Other organisations participating in PrepSKA

Organisation name	Organisation short name	Country
National Science Foundation	NSF	USA
Associated Universities Inc	AUI	USA
Fundacion General de la Universidad de Alcala Instituto Geografico Nacional	FG-IGN	ES
SKA Programme Development Office	SPDO	Global
Vetenskapsradet	VR	SE

The Central Design Integration Team (CDIT) will be formed at the University of Manchester, under the direction of the SPDO to undertake much of the coordination work described in WPs 2 and 3 below. Therefore, UMAN delegates this part of the work to the SPDO and CDIT, however UMAN remains formally responsible for the purposes of the project.

PART B

B1. Concept and objectives, progress beyond state-of-the-art, S/T methodology and work plan

B 1.1 Concept and project objective(s)

Concept
The Square Kilometre Array will have a collecting area of up to one million square metres spread over at least 3000 km, providing a sensitivity of up to 50 times higher than the Expanded VLA (which will soon be the world's currently 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, and 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.

The baseline design for the SKA is an interferometer array capable of imaging the radio sky at frequencies from ~70 MHz to ~25 GHz, and providing an all-sky monitoring capability at frequencies below 1 GHz. The telescope is to be built in three phases, and will be able to carry out significant scientific observations as it is being built. 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, with the first three years being under the aegis of PrepSKA.

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.

Objectives
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 demonstrate the impact of the SKA on society, the economy and knowledge.
- to integrate all of the activities, reports and outputs of the various working groups to form an SKA implementation plan.

B 1.2 Progress beyond the state of the art

State of the art and beyond

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 ASKAP project in Australia (with Canadian involvement), APERTIF in the Netherlands and the US TDP (Technology Development Program). In total, an estimated €150M will have been invested by 2010 in R&D which is directly relevant to the technologies that will be required for the SKA.

The SKA is planned to progress from the Pathfinder telescopes to the first 15-20% of the SKA (designated Phase 1) by 2016 with a restricted frequency range at a cost of about €300M, to Phase 2 of the SKA in 2020 (cumulative total ~1.5 B€), and Phase 3 in the decade thereafter. The Phase 1 stage will initially focus on the mid-band frequencies from several hundred MHz to a few GHz; Phase 2 will extend the array to its full sensitivity and configuration in the mid and low bands; while Phase 3 will further extend the array to frequencies above the mid-band limit.

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 (International SKA Steering Committee) 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 exploring a framework in which the project can further develop once a coherent proposal is submitted by the scientific community. In particular, a 'Forum' is being created that will facilitate detailed discussion between the SKA project and associated funding agencies and organisations on all issues of concern.

This PrepSKA programme, 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. More than 50 institutes in 17 countries are actively contributing to the R&D effort. PrepSKA 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.

Performance indicators

Each of the Work Packages has clearly defined tasks or sub-Work Packages with clear objectives, milestones and deliverables in order to provide outcomes in a measurable and verifiable form. Most PrepSKA deliverables are reports, and their delivery on time will be a clear indicator that the project is progressing as expected. A smaller number of deliverables involves prototype hardware (amplifiers, feeds, data links, etc); again on-time delivery will be a measure of project progress.

B 1.3 S/T Methodology and associated work plan

B 1.3.1 Overall strategy and general description

PrepSKA is a complex project involving a mixture of technical work-packages, aimed at pulling together the international design efforts, and policy work-packages, needed to develop the governance and legal framework required for construction. Table 3 below provides a summary of the 7 work-packages supported by this project. Other work-packages exist, all of which are funded or about to be funded by national programmes, which demonstrate the level of 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.

Figure 1 is a Gantt chart showing the overall timing of the PrepSKA-supported work-packages and their principal components. As can be seen, it is envisaged that the project will last for 3 years, although the principal technical work-package (WP2) requires a fourth year to achieve its final goals.

Risks

The completion of the final deliverable for PrepSKA - an initial implementation plan for SKA funding and construction - is dependent on the component Work Packages being completed on time. There is little risk associated with the Work Packages investigating the governance and funding of the project and procurement issues (WP4-6). There is the normal level of risk associated with the exact finishing date of the Radio Frequency Interference measurements in WP3.

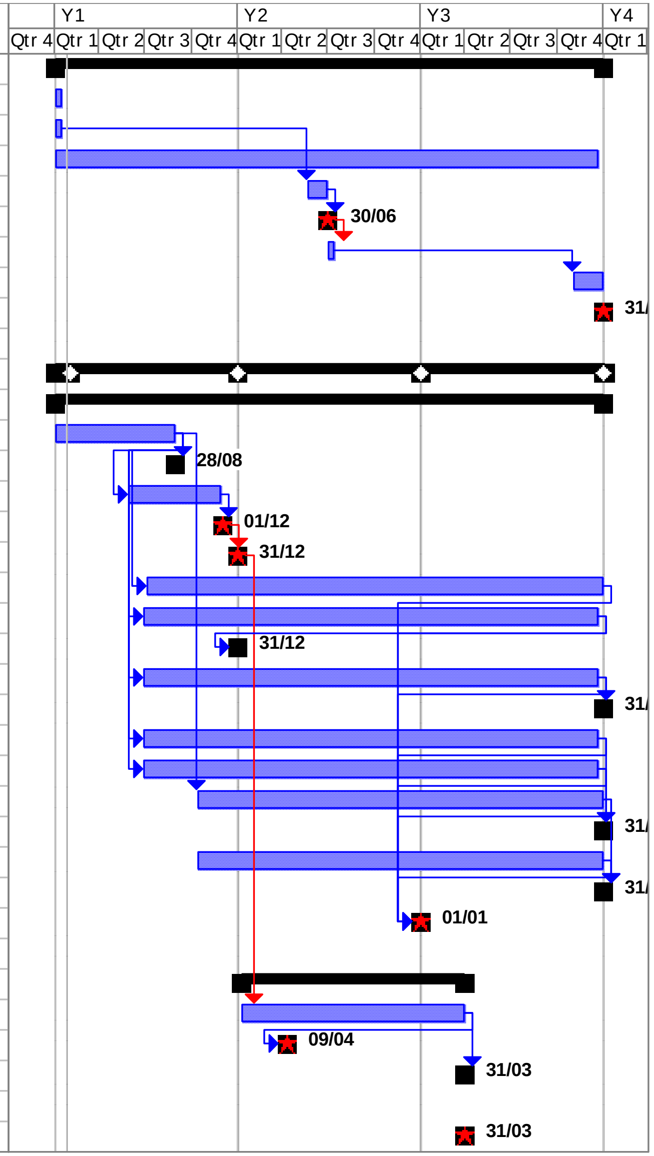
The highest risk lies in WP2 on the costed system design. WP2 is a technical Work Package of four years duration, of which PrepSKA is funding the first three years. There is therefore a risk that the additional funding necessary for the fourth year is not forthcoming, in which case generation of the full implementation plan for the SKA will be delayed. 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 ASKAP, 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 multi-strand path to the telescope design being followed by PrepSKA allows the risk to be distributed.

Overall, there is therefore a high level of confidence that the PrepSKA goals are achievable.

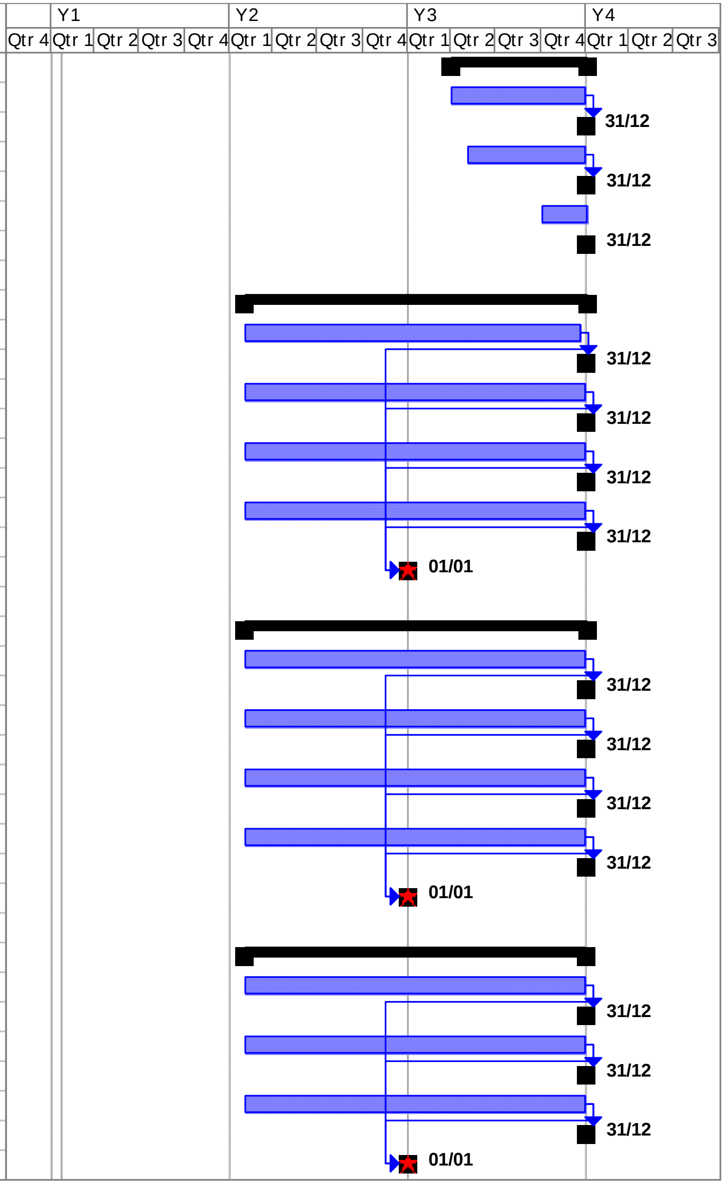
B 1.3.2 Timing of work packages and their components

See the Gantt chart below

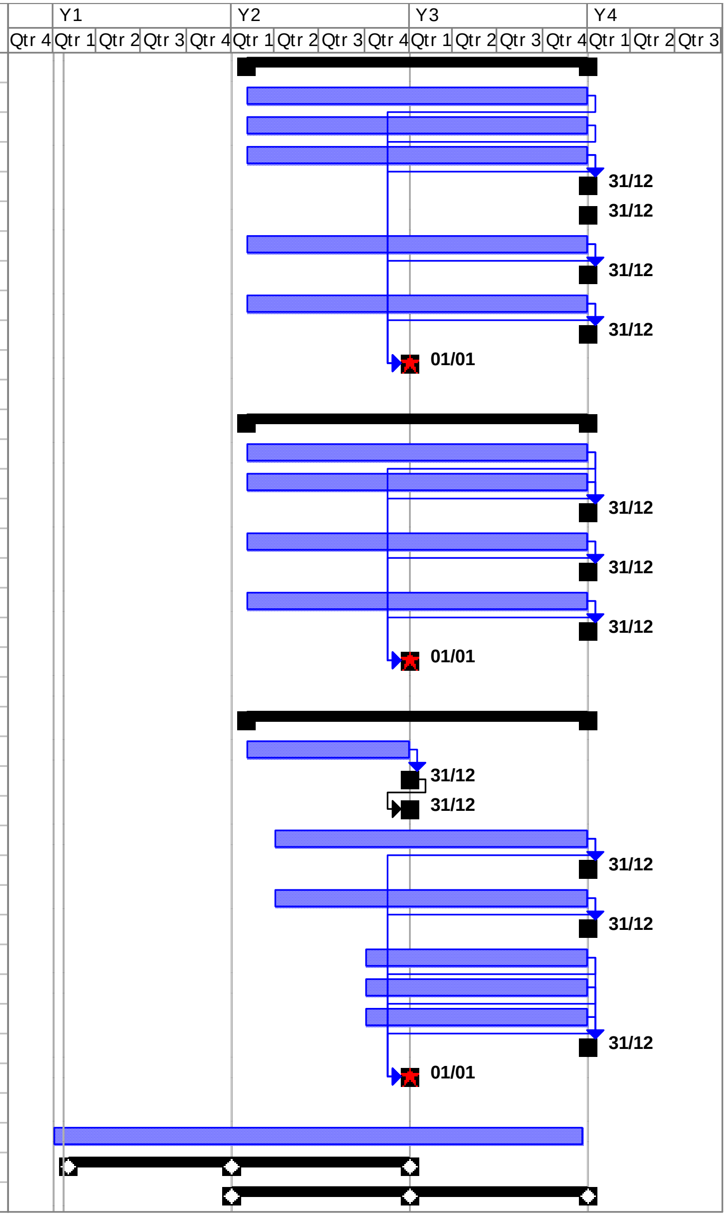
ID	Task Name
1	**WP1 - Management**
2	Set up management structure
3	Initial dist of EC financing
4	Project communication and interaction
5	Preparation for AR1/Mid Term review
6	Deliver AR1 (Del 1.1), Mid term Review
7	Dist of EC financing 2
8	Preparation for AR2/Summary Report
9	Deliver AR2/Summary report (Del 1.2)
10	
11	**WP2 SKA Engineering Design**
12	**WP 2.1 SKA design**
13	WP2.1.1 SKA concept delineation
14	Deliver Concept delineation report (Del 2.1.1)
15	WP 2.1.2 SKA specification
16	IEAC Review
17	SKA spec set: deliver SKA phase 1 spec and SKA performance goals (Del 2.1.2)
18	WP 2.1.3 SKA Life cycle study
19	WP 2.1.4 SKA Operations Plan
20	Deliver SKA Operations goals report (Del 2.1.3)
21	WP 2.1.5 SKA support model
22	Deliver Y3 Report on Life Cycle, operations plan and support model (Del 2.1.4)
23	WP 2.1.6 Cost and performance optimisation
24	WP 2.1.7 SKA manufacturing studies
25	WP 2.1.8 SKA technical Documentation
26	Deliver Y3 Report on cost and perf. optimization, manufacturing and technical doc. (Del 2.1.5)
27	WP 2.1.9 SKA system design
28	Deliver Y3 Report on SKA system design (Del 2.1.6)
29	Mid-term review of life cycle, operations, support, cost, performance, manufacturing & technical status
30	
31	**WP 2.2 SKA Phase 1 sub-system specification and evaluation**
32	WP 2.2.1 SKA Phase 1 sub-system specification and evaluation
33	Sub-system hardware specification set & report delivered (Del 2.2.1)
34	Deliver Report on sub-system integration and evaluation (Del 2.2.2)
35	
36	**SKA-Phase 1 First Design Review (1DR)**



ID	Task Name
38	**WP 2.3 Initial Verification System (IVS)**
39	WP 2.3.1 IVS specification
40	Deliver Y3 Report on preliminary IVS specification (Del 2.3.1)
41	WP 2.3.2 IVS construction
42	Deliver Y3 prototype IVS hardware (Del 2.3.2)
43	WP 2.3.3 IVS integration and test
44	Deliver Y3 Report on IVS integration and test (Del 2.3.3)
45	
46	**WP 2.4 Dish Design and Optimization**
47	WP 2.4.1 Dish Design 1 MIRA
48	Deliver Y3 Report on performance and cost for MIRA antenna (Del 2.4.1)
49	WP 2.4.2 Dish design 2 KAT
50	Deliver Y3 Report on performance and cost for KAT antenna (Del 2.4.2)
51	WP 2.4.3 Dish Design 3 DRAO carbon fibre antenna
52	Deliver Y3 Report on performance and cost for DRAO antenna (Del 2.4.3)
53	WP 2.4.4 Dish design 4 TDP
54	Deliver Y3 Report on performance and cost of TDP antenna (Del 2.4.4)
55	Mid-term review of all SKA dish options
56	
57	**WP 2.5 Feed Development and prototyping**
58	WP 2.5.1 Wideband single pixel feed
59	Delivery Y3 prototypes and report evaluating four single pixel 0.3-25GHz feeds (Del 2.5.1)
60	WP 2.5.2 WFoV aperture array tiles
61	Deliver Y3 prototype and report evaluating an AA tile to SKA spec (Del 2.5.2)
62	WP 2.5.3 WFoV phased array feed
63	Deliver Y3 prototype and report evaluating a PAF to SKA spec (Del 2.5.3)
64	WP 2.5.4 WFoV multiple-feed cluster
65	Deliver Y3 prototype and report evaluating a MFC to SKA spec (Del 2.5.4)
66	Mid-term review of all SKA feed options
67	
68	**WP 2.6 Receiver Development and prototyping**
69	WP2.6.1 Low noise amplifiers
70	Deliver initial 1 or more LNA prototype per band to SKA spec (Del 2.6.1)
71	WP 2.6.2 Integrated receivers
72	Deliver initial prototype integrated receivers for all SKA bands to SKA spec (Del 2.6.2)
73	WP2.6.3 New-generation cryogenics
74	Deliver Y3 report on cryo-coolers and protptype if applicable (Del 2.6.3)
75	Mid-term review of LNA, receiver and cryogenic options

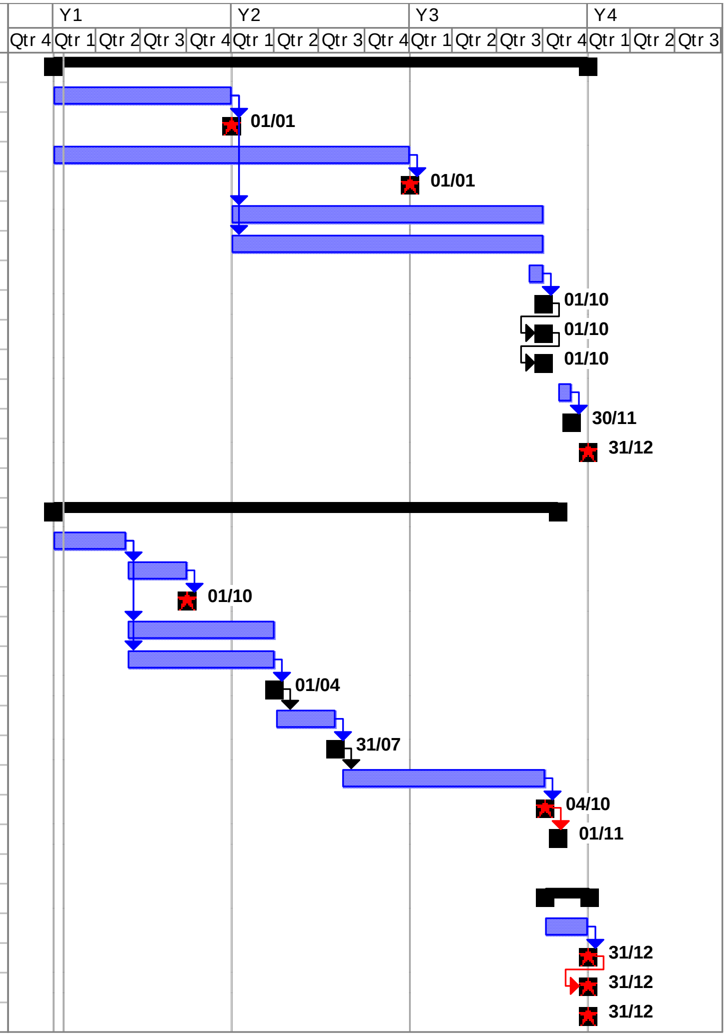


ID	Task Name
77	**WP 2.7 Signal transport specification and prototyping**
78	WP 2.7.1 Intra-antenna data link
79	WP 2.7.2 Intra-station data link
80	WP 2.7.3 Station to core data link
81	Deliver initial prototype and Y3 performance report on antenna to central processing link (Del 2.7.1)
82	Deliver Y3 report on options for SKA Phase 1 station to core links (Del 2.7.2)
83	WP 2.7.4 LO and timing distribution
84	Deliver Y3 report on strategy for LO and Timing distribution (Del 2.7.3)
85	WP 2.7.5 SKA control and monitoring
86	Deliver Y3 report on implementation approach for array monitoring and control (Del 2.7.4)
87	Mid-term review of data links, LO and timing distribution and array monitoring and control
88	
89	**WP 2.8 Signal processing development and prototyping**
90	WP 2.8.1 Station signal digital processing
91	WP 2.8.2 Correlator
92	Deliver Y3 report on costed DSP and correlator design options (Del 2.8.1)
93	WP 2.8.3 Radio Frequency Interference mitigation
94	Deliver Y3 report on SKA RFI mitigation strategy (Del 2.8.2)
95	WP 2.8.4 Non-imaging processors
96	Deliver Y3 report on implementation and algorithms for non-imaging processing (Del 2.8.3)
97	Mid-term review of digital signal processing and RFI mitigation
98	
99	**WP 2.9 Software/computing specification and prototyping**
100	WP 2.9.1 Computing and software specification
101	Deliver draft report on SKA computing and s/ware spec, h/ware and cal strategy (Del 2.9.1)
102	Deliver draft report on s/ware syst. architecture, data products & sci. post-proc. strategy (Del 2.9.2)
103	WP 2.9.2 Computing hardware
104	Deliver Prototype of IVS computing hardware (Del 2.9.3)
105	WP 2.9.3 Software engineering
106	Deliver Prototype of IVS software (Del 2.9.4)
107	WP 2.9.4 Data products and virtual observatory
108	WP 2.9.5 Calibration
109	WP 2.9.6 Science post-processing
110	Deliver Y3 report on SKA computing and software specs and strategies (Del 2.9.5)
111	Mid-term review of software/computing status
112	
113	WP 2.10 WP2 design study management
114	**WP2 project plans (Del 2.10.2)**
118	**WP2 Progress reports (Del 2.10.1)**



ID	Task Name	
123	**WP3 Additional studies of the short-listed sites for the SKA**	
124	WP 3.3 Study Ionospheric fluctuations	
125	Deliver report on ionospheric scintillation and TIDs (Del 3.1)	27/06
126	WP 3.4 Effect of tropospheric turbulence on high frequency measurements	
127	Deliver report on phase referencing and self-calibration for SKA (Del 3.3)	23/12
128	WP 3.5 Optimize array configuration	
129	Deliver report on optimum configuration for SKA (Del 3.4)	26/06
130	WP 3.6 Influence of site physical characteristics on telescope	
131	Deliver report on influence of site characteristics (Del 3.5)	31/12
132	WP 3.7 Infrastructure	
133	Deliver report on infrastructure deployment details (Del 3.6)	30/06
134	WP 3.8 Sustainability against RFI	
135	Deliver report on risk analysis of science environment (Del 3.7)	28/06
136	WP3.1 Investigate RFI -deep integrations on sites	
137	Deliver RFI hardware and software (Del 3.2)	01/01
138	Deliver report on RFI measurements in Australia (Del 3.8)	30/09
139	Deliver report on RFI measurements in South Africa (Del 3.9)	30/09
140	WP 3.2 Prepare Radio Quiet Zone for centre of array	
141	Deliver report on Radio Quiet zones for SKA sites (Del 3.10)	31/12
142	Deliver final site report (Del 3.11)	31/12
143		
144	**WP 4 Governance and legal**	
145	**WP 4.6 Semi-annual reporting**	
151	WP 4.1 Comparative study on best practice Governance and legal frameworks	
152	Deliver study on best practice governance and legal frameworks (Del 4.1)	30/09
153	WP 4.2 Incorporate results from other preparatory study WPs	
154	WP 4.3 Obtain international legal and strategic business advice	
155	WP 4.4 Develop options paper for International SKA forum	
156	Deliver paper on options for Governance and legal framework (Del 4.2)	31/03
157	WP 4.5 Develop proposal for Governance and legal framework based on SKA forum and national agencies input	
158	Deliver white paper on selected governance and legal framework (Del 4.3)	30/09

ID	Task Name
160	**WP 5 SKA procurement and industrial involvment**
161	WP 5.1 Develop working guidelines for procurement for WP2
162	Deliver guidelines for procurement for WP2 (Del 5.1)
163	WP 5.2 Investigate whether industry can contribute to SKA
164	Deliver report on inventory of relevant industries (Del 5.2)
165	WP 5.3 Analyse models for procurement
166	WP 5.4 Risk analyses of procurement models
167	WP 5.5 Develop options paper on procurement for SKA Forum
168	Deliver report on procurement models (Del 5.3)
169	Deliver draft options paper on procurement (Del 5.4)
170	Deliver inventory of policies and goals for Del 5.4 (Del 5.5)
171	WP 5.6 Develop options for procurement for SKA funding agencies
172	Deliver White Paper on final procurement options (Del 5.6)
173	Incorporate white paper on final procurement model in PrepSKA report (Del 5.7)
174	
175	**WP 6 Develop funding model for SKA**
176	WP 6.1 Develop comprehensive cost outline for SKA
177	WP 6.2 Survey of national funding agencies
178	Deliver report on national funding (Del 6.1)
179	WP 6.3 , WP 6.4 Investigate possibility of European Investment Bank loan
180	WP 6.5 Investigate private or corporate funding
181	Deliver report on investigation of funding alternatives (Del 6.2)
182	WP 6.6 Develop detailed options paper on SKA funding model
183	Deliver options paper on SKA funding model (Del 6.3)
184	WP 6.7 Develop options for full funding model
185	Deliver White paper on full funding model for SKA (Del 6.4)
186	Incorporate White paper on financial model for SKA in PrepSKA final report (Del 6.5)
187	
188	**WP 7 Implementation Plan leading to SKA construction**
189	Develop PrepSKA Y3 report and preliminary Implementation plan
190	Deliver preliminary costed SKA system design (Del 7.1)(containing Y3 reports on all WP2 development)
191	Deliver paper on impact of SKA
192	Deliver preliminary SKA implementation Plan (Del 7.2)



B 1.3.3 Work package list / overview

Table 3

Work package No[1]	Work package title	Type of activity[2]	Lead beneficiary No[3]	Person-months funded through the project	Person-months provided by contractors	Start month[4]	End month[5]
WP1	Management of the SKA Preparatory Phase Project	MGT	1 / 9	45	(3)	T+0	T+36
WP2	SKA design	RTD	9	281	144 (1075)	T+0	T+36
WP3	SKA sites	SUPP	9	0	36 (102)	T+0	T+36
WP4	SKA Governance and Legal Framework	SUPP	2	36	(57.5)	T+0	T+36
WP5	SKA procurement and industrial involvement	SUPP	4	36	(51)	T+0	T+36
WP6	Developing the funding model for the SKA	SUPP	1	36	(42.5)	T+0	T+36
WP7	SKA implementation plan	COORD	9	0	(44)	T+33	T+36
	TOTAL			434			

The person-months in parentheses represent the additional effort provided outside the framework of this project (and therefore not auditable), required to achieve the goals of the project. These will be provided by the contractors through their own or other national funding programmes.

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1 Workpackage number: WP 1 – WP n.

2 Insert one of the following 'types of activities' per WP (only if applicable for the chosen funding scheme – must correspond to the GPF Forms):
RTD = Research and technological development including scientific coordination applicable for collaborative projects and NoEs
DEM = Demonstration - applicable for collaborative projects
OTHER = Other activities (including management) applicable for collaborative projects, NoEs, and CSA
MGT = Management of the consortium - applicable for all funding schemes
COORD = Coordination activities – applicable only for CAs
SUPP = Support activities – applicable only for SAs

3 Number of the beneficiary leading the work in this work package.

4 Relative start date for the work in the specific work packages, month 1 marking the start date of the project, and all other start dates being relative to this start date.

5 Relative end date, month 1 marking the start date of the project, and all end dates being relative to this start date.

B 1.3.4 Deliverables list

Table 4: List of Deliverables – to be submitted for review to EC

Del. no.	Deliverable Name	WP no.	Lead beneficiary number	Estimated indicative person-months	Nature	Dissemi-nation level	Delivery date (project month)
1.1	AR1	WP1	1/9	18	R	PU	19
1.2	AR2/Summary	WP1	1/9	30	R	PU	36
2.1.1	SKA concept delineation	WP2	9	9	R	CO	9
2.1.2	SKA Phase 1 specifications and SKA performance goals	WP2	9	12	R	PU	12
2.1.3	SKA operations concept	WP2	9	6	R	PP	12
2.1.4	Composite volume, SKA life cycle study, operations plan and support model – Y3 report	WP2	10	89	R	PP	36
2.1.5	Composite volume, SKA cost and performance optimization, manufacturing studies and technical documentation – Y3 report	WP2	9	133	R	PP	36
2.1.6	SKA system design – interim report	WP2	9	47	R	PP	36
2.2.1	Sub-system hardware specifications	WP2	9	12	R	PU	15
2.2.2	Report on sub-system integration and evaluation	WP2	9	24	R	PP	27
2.3.1	Y3 Report on IVS specification	WP2	9	33	R	PP	36
2.3.2	Y3 prototype IVS hardware	WP2	9	48	P	PP	36
2.3.3	Y3 Report on IVS integration and test	WP2	9	42	R	PP	36
2.4.1	Y3 report detailing performance and cost data for high dynamic range ASKAP antenna	WP2	15	10	R	CO	36
2.4.2	Y3 report detailing performance and cost data for composite MeerKat antenna	WP2	7	10	R	CO	36

2.4.3	Y3 report detailing performance and cost data for carbon fibre antenna	WP2	8	10	R	CO	36
2.4.4	Y3 report detailing performance and cost data for TDP antenna	WP2	12	10	R	CO	36
2.5.1	Delivery of Y3 prototypes and report evaluating four single pixel 0.3-25GHz feeds	WP2	12	34	R,P	PP	36
2.5.2	Delivery of Y3 prototypes and report evaluating an AA tile to SKA spec	WP2	9/10	52	R,P	PP	36
2.5.3	Delivery of Y3 prototypes and report evaluating a PAF to SKA spec	WP2	15	37	R,P	PP	24
2.5.4	Delivery of Y3 prototypes and report evaluating an MFC to SKA spec	WP2	7	8	R,P	PP	24
2.6.1	Initial delivery: at least one functional low-noise amplifier per SKA band	WP2	10	108	P	-	24
2.6.2	Initial delivery prototype integrated receivers suitable for operation in all SKA bands	WP2	15	45	P	-	24
2.6.3	Y3 Status report on the applicability of new-generation cryo-coolers to the SKA and, if applicable, prototype cooling systems	WP2	12	27	R,P	PP	36
2.7.1	Initial demonstration of complete low-cost antenna-to-central processing link, with Y3 performance report	WP2	4/15	36	P,R	PP	24
2.7.2	Y3 report on options for SKA phase 1 station to core links	WP2	9	20	R	PP	36
2.7.3	Y3 report on strategy for LO and timing distribution	WP2	9	20	R	PP	36
2.7.4	Y3 report on approach to array monitoring and control	WP2	13	26	R	PP	36
2.8.1	Deliver Y3 report on costed DSP and correlator design proposals	WP2	14/8	166	R	PP	36

2.8.2	Deliver Y3 report on SKA RFI mitigation strategy	WP2	17/10	75	R	PP	36
2.8.3	Deliver Y3 report on implementation and algoritms for non-imaging processing	WP2	9	60	R	PP	36
2.9.1	Composite volume, (draft) SKA computing and software specification, computing hardware strategy, calibration strategy	WP2	9	85	R	PU	24
2.9.2	Composite volume, (draft) software systems architecture, SKA data products strategy and science post-processing strategy	WP2	10/13/15	85	R	PU	24
2.9.3	Prototype IVS demonstration hardware	WP2	9	41	P	PP	36
2.9.4	Prototype IVS demonstration software	WP2	9	41	P	PP	36
2.9.5	Y3 report on computing and software specs and strategies for science post-processing	WP2	15	5	R	PP	36
2.10.1	Periodic WP2 progress reports	WP2	9	16	R	PP	12, 24, 36
2.10.2	Annual WP2 project plans	WP2	9	16	R	PP	1, 12, 24
3.1	Report on Ionospheric scintillation and TIDs	WP3	9	12	R	CO	6
3.2	Deliver RFI hardware and software	WP3	9	12	O	-	12
3.3	Report on phase referencing and self-calibration	WP3	9	12	R	PU	12
3.4	Report on optimum configuration for the SKA	WP3	9	12	R	CO	18
3.6	Report on infrastructure deployment	WP3	9	12	R	CO	30
3.7	Report on risk analysis	WP3	9	12	R	CO	30
3.8	Report on RFI measurements in Australia	WP3	9	12	O	CO	33
3.9	Report on RFI measurements in South	WP3	9	12	O	CO	33

	Africa						
3.5	Report on site physical characteristics	WP3	9	12	R	CO	36
3.10	Report on progress and prospects for short-listed SKA sites	WP3	9	12	R	CO	36
3.11	Summary Report of WP3	WP3	9	14	R	CO	36
4.1	Deliver study on best practice governance and legal frameworks	WP4	2	28	R	PP	9
4.2	Options paper for governance and legal framework	WP4	2	28	R	CO	27
4.3	White paper on governance model and legal framework	WP4	2	37	R	CO	35
5.1	Working guidelines for procurement (WP2 design project)	WP5	4	12	R	PP	12
5.2	An inventory of countries able to contribute to SKA and statements to share costs and risks	WP5	4	12	R	RE	24
5.3	Analysis of procurement models	WP5	4	12	R	RE	33
5.4	Draft options paper on procurement to meet goals	WP5	4	12	R	RE	33
5.5	An inventory of national standpoints, policies and goals to accompany options in (5.4)	WP5	4	12	R	RE	33
5.6	White paper on options for SKA procurement for Plenary Funding Agencies Group	WP5	4	12	R	CO	35
5.7	White paper on procurement model incorporated into PrepSKA AR3/Summary	WP5	4	14	R	PP	36
6.1	Summary of the survey of national funding opportunities, processes and timescales	WP6	1	16	R	PP	9
6.2	Summary of initial investigations on options for alternative funding	WP6	1	16	R	PP	15

6.3	Draft options paper on SKA funding model	WP6	1	16	R	PP	19
6.4	Final version of options paper, with full funding model	WP6	1	16	R	CO	33
6.5	Proposed financial model	WP6	1	16	R	PP	35
7.1	PrepSKA Year 3 system design and technical reports	WP7	9	19	R	PP	36
7.2	Paper on the impact of the SKA, to be delivered in month 36	WP7	9	3	R	PP	36
7.3	Preliminary implementation plan	WP7	1	22	R	PP	36
			TOTAL	1989			

B 1.3.5 Work package descriptions

In all Work Package description tables the available effort is recorded as follows:

- person-months in **bold** are those funded through EC funds
- person-months in normal type are provided as in-kind, auditable contributions
- person-months in parentheses are provided as additional, contributions to the overall SKA design effort, of which PrepSKA is an integral part. These are therefore outside the framework of the present project.
- Wherever associated participants listed in Table 2a contribute explicitly to any WPs, they are listed in brackets together with their (non auditable) contribution.

Work Package 1 on PrepSKA 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[6]	MGT						
Participant id	1	9					
Person-months per beneficiary:	**9**	**36** (+ 3)					

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

Objectives

To manage the PrepSKA project

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 SPDO-CDIT

Deliverables

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

[6] 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

Work package number	WP2.1	**Start date or starting event:**			T+0 months		
Work package title	SKA design						
Activity Type	RTD						
Participant id	4	7	9	10	11	12	13
Person-months per beneficiary:	6	(38)	**66** (+8)	8 (+24)	(6)	(26)	(8)
Participant id	14	15	17	SPDO			
Person-months per beneficiary:	(8)	(24)	(8)	(66)			

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 SPDO'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 UMAN (SPDO-CDIT), with the Programme Leader (who will also be the SKA International Project Engineer) and System Engineer jointly leading WP2.1.

WP2.1.1: **SKA concept delineation**. 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.
<u>Participants:</u> This task will be led by UMAN (SPDO-CDIT), drawing on the inputs of both WP2 and external participants, the latter via SPDO 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: **SKA specification**. 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.
<u>Participants:</u> This task will be led by UMAN (SPDO-CDIT), drawing on the inputs of both WP2 and external participants, the latter via SPDO working groups.

WP2.1.3: **SKA life cycle study**. 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.
<u>Participants:</u> This task will be led by UMAN (SPDO-CDIT). Other contributors include NRF (which is developing a life cycle formalism for the South African Pathfinder), CSIRO (with large array operational experience), ASTRON (with LOFAR experience and background in relevant SKADS studies) and UCAM, UOXF.DL (with experience in SKADS and in the operation of large radio observatories).

WP2.1.4: **SKA operations plan**. 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.
<u>Participants:</u> This task will be led by ASTRON, which has recent experience in developing operational models for the new-generation LOFAR telescope. Other key contributors are UMAN (CDIT) (via the Programme Leader and System Engineer), Cornell (TDP), CSIRO (ASKAP) (each of which brings substantial operational experience from instruments in the USA, Australia and UK), and NRF (MeerKAT) (which has developed an operational formalism for the South African Pathfinder). Wider consultation is also planned via the SPDO working groups.

WP2.1.5: **SKA support model**. 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.
<u>Participants:</u> WP2.1.5 will be coordinated by UMAN (SPDO-CDIT) with key contributions from ASTRON, Cornell (TDP), and CSIRO (ASKAP), each of which has operational experience with large arrays. NRF (MeerKAT) will also contribute, principally in helping to define the formal links between WP2.1.5 and the system design task, WP2.1.9.

WP2.1.6: **SKA cost and performance optimization**. 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.
<u>Participants:</u> This task will be led by UMAN (SPDO-CDIT). UMAN (SPDO-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. Cornell (TDP) will undertake a similar role for dishes and single-pixel feeds. CSIRO (ASKAP) 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. ASKAP: Curtin University of Technology will contribute expertise in SKA system design and C&P software development areas

WP2.1.7: **SKA manufacturing studies**. 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 UMAN, 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, Cornell (TDP)), signal transport (MPIfR, INAF), and RF systems (OBSPARIS). CSIRO (ASKAP) will contribute through its experience with the Australian SKA Industry Cluster.

WP2.1.8: **SKA technical documentation**. 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 UMAN (SPDO-CDIT), with contributions from NRF (MeerKAT) (which has been trialing elements of an on-line documentation formalism for the South African Pathfinder), ASTRON and Cornell (TDP), the latter two contributors having experience in operating a range of synthesis radio telescopes.

WP2.1.9: **SKA system design**. 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 UMAN (SPDO-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 SPDO 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; year 3 – T+36 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; Year 3 – T+36 months.
6. SKA system design (WP2.1.9). Type: Report. Delivery: Interim – T+24 months; Year 3 – T+36 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 id	9						
Person-months per beneficiary:	**36**						

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 UMAN (SPDO-CDIT), with the System Engineer being the WP2.2 Project Leader.

WP2.2.1: **SKA Phase 1 sub-system specification and evaluation**. 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 UMAN (SPDO-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 id	4	9	10	12	13	14
Person-months per beneficiary:	2	**48** (+62)	(2)	(6)	(2)	(2)

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. 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 UMAN (SPDO-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 UMAN (SPDO-CDIT), with the System Engineer being the WP2.3 project leader.

WP2.3.1: **IVS specification**, 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 UMAN (SPDO-CDIT). Cornell (TDP) will collate and supply prototyping results relevant to dish antennas. UMAN 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: **IVS construction**. 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 UMAN, which will have extensive in-house production facilities and strong industry links to potential manufacturers of most IVS sub-systems. Cornell (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: **IVS integration and test**. 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 UMAN (SPDO-CDIT) with input from ASTRON, UCAM, UXOF, Cornell (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+36 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 id	7	8	9	12	15	
Person-months per beneficiary:	(8)	(8)	**8**	(8)	(8)	

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 UMAN (SPDO-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 UMAN (SPDO-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: **dish design 1**. This task 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 ASKAP pathfinder will yield much information about this type of antenna and it is intended to make extensive use of ASKAP results in preparing design and evaluation material.
<u>Participants:</u> This task will be led by CSIRO (ASKAP), with other contributions coming via the SPDO Engineering Working Group.

WP2.4.2: **dish design 2**. This task 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.
<u>Participants:</u> This task will be led by NRF (MeerKAT), with other contributions coming via the SPDO Engineering Working Group.

WP2.4.3: **dish design 3**. This task 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.
<u>Participants:</u> This task will be led by NRC-HIA, with other contributions coming via the SPDO Engineering Working Group.

WP2.4.4: **dish design 4**. This task 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 Cornell (TDP), with other contributions coming via the SPDO 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 ASKAP antenna (WP2.4.1). Type: Report. Delivery: T+36 months.
2. Report detailing performance and cost data for composite MeerKAT antenna (WP2.4.2). Type: Report. Delivery: T+36 months.
3. Report detailing performance and cost data for carbon fibre antenna (WP2.4.3). Type: Report. Delivery: T+36 months.
4. Report detailing performance and cost data for TDP antenna (WP2.4.4). Type: Report. Delivery: T+36 months.
5. Final review of all SKA dish development (WP2.4.4). Type: Report. Delivery: Initial – T+24 months; Year 3 - T+36 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 id	4	7	8	9	10	12	13
Person-months per beneficiary:	2	(8)	(4)	**8** (+11)	10 (+6)	(34)	(11)
Participant id	14	15					
Person-months per beneficiary:	(11)	(26)					

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 UMAN (SPDO-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 UMAN (SPDO-CDIT), with the Receptor Specialist being the WP2.5 project leader.

WP2.5.1: **wideband single-pixel feed**. This task 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 Cornell (TDP) which will conduct the main single-pixel design study. NRF (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 SPDO Engineering Working Group.

WP2.5.2: **WFoV aperture array tiles**. 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 UMAN and ASTRON, following a SKADS task management model. UMAN, UOXF.DL 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**: WFoV phased array feed**. This task 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 ASKAP Pathfinder, the first interferometer to use PAFs.
Participants: The task will be led by CSIRO (ASKAP) and will include contributions from ASTRON (where the related APERTIF upgrade of the WSRT is proceeding), NRC-HIA. CSIRO (ASKAP), ASTRON and UMAN, will be concerned primarily with PAF astronomical demonstration, while UOXF.DL and NRC-HIA will emphasize radiator element technologies and antenna-range measurement tasks, respectively.

WP2.5.4: **WFoV multiple-feed cluster**. 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 NRF (MeerKAT), with contributions from Cornell (TDP). Allied to WP2.5.1 efforts, NRF (MeerKAT) will focus on the optimization of wideband feeds in a cluster environment, the base feed design flowing primarily from Cornell (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; Year 3 - T+36 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; Year 3 - T+36 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; Year 3 - T+36 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; Year 3 - T+36 months.
5. Review of all SKA feed options (WP2.5.1). Type: Report. Delivery: Initial – T+24 months; Year 3 - T+36 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 id	4	5	8	9	10	11	12
Person-months per beneficiary:	2	(18)	(2)	**6** (+10)	10 (+14)	(4)	(48)
Participant id	13	14	15	17	19		
Person-months per beneficiary:	(10)	(10)	(10)	12 (+16)	(8)		

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 UMAN (SPDO-CDIT), with the Receptor domain specialist being the WP2.6 project leader.

WP2.6.1: **low-noise amplifiers**, 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.
Participants: 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 UMAN, UXOF (mid and high-band LNAs, GaAs and InP materials, processes and manufacturability), Cornell (TDP) (mid and high-band LNAs, InP processes), UCAL (mid-band LNAs, CMOS and SiGe processes), OBSPARIS (mid-band LNAs, CMOS and SiGe processes) and IT. MPIfR and NRF (MeerKAT) will contribute additional circuit design expertise, including new topologies made possible by high gain-bandwidth product semiconductor processes.

WP2.6.2**: integrated receivers,** 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.
Participants: This task will be led by CSIRO (ASKAP), which, with UCAL, will concentrate on low-cost, monolithic CMOS receivers. UMAN and OBSPARIS will focus on high performance, custom-fabricated sub-systems, while ASTRON, OBSPARIS, IT and Cornell (TDP) will contribute specialist knowledge of advanced connection and packaging solutions.

WP2.6.3: **new-generation cryogenics**. 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.
Participants: This task will be led by Cornell (TDP) (bringing the direct experience gained during construction of the Allen Telescope Array to the study), while inputs from UMAN, UXOF, MPIfR, CSIRO (ASKAP) and NRF (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; Year 3 – T+36 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; Year 3 – T+36 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+36 months.
4. Year 3 review of SKA Phase 1 receiver development (WP2.6.1). Type: Report. Delivery: T+36 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 id	4	5	7	9	10	11	12
Person-months per beneficiary:	6	(28)	(4)	**10** (+10)	(4)	(4)	(12)
Participant id	13	14	15				
Person-months per beneficiary:	(10)	(10)	(4)				

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 UMAN (SPDO-CDIT), with the Signal Transport domain specialist being the WP2.7 project leader.

WP2.7.1: **intra-antenna data link**. 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.
<u>Participants:</u> CSIRO (ASKAP) will lead the task, primarily in a coordination role, but also by addressing single-pixel and phased array feed requirements. Other contributors will be UCAM, INAF, MPIfR and NRF (MeerKAT), collectively covering aperture array and multiple-feed cluster needs.

WP2.7.2: **intra-station data link**. 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.
<u>Participants:</u> The task will be led by the INAF, which has experience in producing analogue fibre links for BEST. Other contributors are UMAN (with e-MERLIN experience), Cornell (TDP) (with Allen Telescope Array and the Extended very Large Array experience), MPIfR (with SKADS/EMBRACE experience) and IT (with commercial telecoms experience).

WP2.7.3: **station to core data link.** 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 SPDO acting in collaboration with regional SKA groups.
Participants: WP2.7.3 will be led by the UMAN, with contributions from INAF (see WP2.7.2), ASTRON (building on the LOFAR experience with commercial-off-the-shelf-equipment) and NRF (MeerKAT).

WP2.7.4: **LO and timing distribution**. 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 UMAN with direct experience from SKADS and e-MERLIN. Substantial additional contributions will come from Cornell (TDP), IT and ASTRON.

WP2.7.5: **SKA control and monitor**. 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 UCAM who have extensive experience of telescope control system implementation. Other contributors are Cornell (TDP) (folding in the experience of operational US arrays) and NRF (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; Year 3 – T+36 months.
2. Report on contemporary and emerging options for SKA Phase 1 station to core links (WP2.7.3). Type: Report. Delivery: T+36 months.
3. Strategy document, including costing, for LO and Timing distribution (WP2.7.4). Type: Report. Delivery: T+36 months.
4. Report on implementation approach for array monitoring and control (WP2.7.5). Type: Report. Delivery: T+36 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 id	4	7	8	9	10	11	12
Person-months per beneficiary:	8	(10)	(28)	**8** (+22)	**8** (+18)	36 (+18)	(8)
Participant id	13	14	15	16	17	18	
Person-months per beneficiary:	(22)	(22)	(4)	(8)	12 (+22)	12 (+35)	

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 UMAN (SPDO-CDIT), with the Signal Processing domain specialist being the WP2.8 project leader.

WP2.8.1: **station digital signal processing**. This task 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.

<u>Participants:</u> The WP2.8.1 leader will be UOXF.DL, with station DSP experience in SKADS. Contributors will be MPIfR, ASTRON, NRC-HIA, INAF and NRF (MeerKAT), all of whom have substantial DSP resources.

WP2.8.2: **correlator**. 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.

<u>Participants:</u> NRC-HIA will lead this task, drawing on their wide experience in correlator design, most recently with the EVLA and e-MERLIN correlators. Contributors will be the UCAM, with correlator experience and the DSP design in WP2.8.1, JIVE with extensive operational knowledge and Cornell (TDP) (folding in US experience).

WP2.8.3: **radio frequency interference mitigation**. This task will refine and further develop RFI mitigation techniques, ensuring the SKA system design is robust to current and foreseen interference conditions. Via UMAN (SPDO-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 jointly by OBSPARIS and ASTRON, who will draw heavily on LOFAR and SKADS experience to frame an SKA RFI mitigation strategy in collaboration with UMAN (SPDO-CDIT) engineers. Other participants will be UORL, INAF, MPIfR and Cornell (TDP).

WP2.8.4: **non-imaging processors**. 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 UMAN, which has extensive experience in designing pulsar processing systems. Contributors will be ASTRON, CSIRO (ASKAP), MPIfR, NRF (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; Year 3 – T+36 months.
2. SKA RFI mitigation strategy (WP2.8.3). Type: Report. Delivery: Initial – T+24 months; Year 3 – T+36 months.
3. Report on implementation and algorithms for non-imaging processing (WP2.8.4). Type: Report. Delivery: T+36 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 id	4	7	9	10	12	13	14
Person-months per beneficiary:	10	(4)	**59** (+17)	(42)	(12)	(17)	(17)
Participant id	15	16	19	20	SPDO		
Person-months per beneficiary:	(24)	(4)	(4)	(18)	(30)		

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 UMAN (SPDO-CDIT). The UMAN (SPDO-CDIT) Software/Computing domain specialist is the WP2.9 project leader.

WP2.9.1: **computing and software specification**. 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 UMAN (SPDO-CDIT), with contributions expected from WP2 participants and members of the relevant SPDO working groups.

WP2.9.2: **computing hardware**. 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 preparation of the delivery of a small-scale computing platform for the Initial Verification System (WP2.3).
Participants: This task will be led by UMAN (SPDO-CDIT), with contributions from UCAM, INAF and Cornell (TDP), all of which have industry links in relevant areas. Additional input is expected from SPDO working groups.

WP2.9.3: **software engineering**. 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 UCAM, INAF and Cornell (TDP), the latter also contributing to (1) via experience from the ATA and other contemporary US instruments.

WP2.9.4: **data products and virtual observatory**. 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 UCAM, which will draw on experience from both radio telescopes and instruments operating in other wave-bands. RuG (AstroWise) will contribute in the area of managing complex astronomical data bases and general information systems; Cornell (TDP) and ASTRON will also contribute, bringing in experience from operational US and European radio arrays.

WP2.9.5: **calibration**. 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 Cornell (TDP), UCAL, JIVE and INAF will contribute to (1) and (2), above. NRF (MeerKAT), UOXF.DL, UCAM and UMAN will contribute to (3) and (4). CSIRO (ASKAP) will contribute to (2), (3) and (4).

WP2.9.6: **science post-processing**. 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 CSIRO (ASKAP), with contributions from UOXF.DL, UMAN, ASTRON, INAF, JIVE, Cornell (TDP), NRF (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+36 months.
4. IVS demonstration software (WP2.9.3). Type: Prototype. Delivery: T+36 months.
5. Preliminary version of a 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+36 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 id	9						
Person-months per beneficiary:	**32**						

Objectives

This project will provide support for the WP2 engineering study in terms of project planning, reporting, and financial and related interactions between UMAN (SPDO-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 UMAN (SPDO-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 UMAN (SPDO-CDIT) supported by additional financial, legal and administrative services from the SPDO host institute via the SPDO hosting agreement.

Deliverables (brief description and month of delivery)

1. Periodic progress reports on WP2 tasks; (T+12; T+24; T+36)
2. Annual project plans for WP2 tasks (T+1; T+12; T+24)

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[7]	SUPP						
Participant id	6	7	9	10	15		
Person-months per beneficiary:	(3)	(36)	36	(9)	(54)		

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 SPDO site engineer and comprise representatives of the sites in Australia (CSIRO) and South Africa (NRF) and other participants from Europe (ASTRON, JIVE, OBSPAR) and the USA (Cornell (TDP)), together with the chairs of the SPDO 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 ASKAP and MeerKAT will also be incorporated into RFI results and conclusions.

Participants: ASTRON will lead this task, it will receive a contract from the SPDO 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 SPDO informed of the expected end result and progress in its achievement. The SPDO/SEWG Regulatory Affairs Task Force will provide comments on the individual RQZ processes when requested. The SPDO/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 SPDO of progress, on a regular basis. OBSPARIS will lead the international effort 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: UMAN (SPDO-CDIT) will lead this task. UMAN, will 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: UMAN (SPDO-CDIT) 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: UMAN (SPDO-CDIT) will lead this task and, through the SimWG, will interface with JIVE (representing SKADS), CSIRO (including Curtin University of Technology) 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: UMAN (SPDO-CDIT) 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 UMAN (SPDO-CDIT) who will engage external consultants for the infrastructure cost and timescale studies. The SPDO/OWG and SPDO/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 UMAN (SPDO-CDIT) 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 – Governance and Legal Framework

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

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 governance 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

This work-package will focus on a study of 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.

Tasks/Milestones

- Develop comparative study on best-practice Governance and legal frameworks for international mega-science projects (T + 12 months)
- Incorporate outputs from other Preparatory phase WPs (e.g. WP5: industry mapping & procurement) as appropriate (T + 33 months)
- Obtain international legal advice on appropriate legal framework and business models for the SKA. (T + 27 months)
- Develop options paper for an appropriate Governance and legal framework for the SKA project for discussion at the International SKA Forum (T + 27 months)
- 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. (T + 33 months)
- Semi-annual reporting of progress to preparatory phase co-ordinator. (March & September)

<u>Participants' Role</u>
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 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)

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[8] 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.

IDeliverables will be:

4.1 An initial study of best practice governance and legal frameworks as applied to other international science projects. Type: Report. Delivery: T+9 months.

4.2 A paper on the options for a governance and legal framework for the SKA . Type: Report. Delivery: T+27 months.

4.3 A white paper on options for the SKA governance and legal framework. Type: Report. Delivery: T+35 months.

Work Package 5 on 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 id	1	2	3	4	6	7	8
Person-months per beneficiary:	(6)	(5)	(6)	**36 (**+6)	(6)	(6)	(2)
Participant id	10	12	15	NSF	SPDO		
Person-months per beneficiary:	(2)	(6)	(1)	(1)	(3)		

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, DIISR (drawing on expertise from Curtin University of Technology), SPDO (by the SKA Director and Project Engineer), NRF and NSF and other interested parties. Industry representation will be sought via SPDO 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:

- With input from the SKA Program Development Office, develop guidelines for procurement in Work Package 2 on System Design.
- 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.
- 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
- Undertake comparative risk analyses of the procurement models.
- 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.
- Discuss, with the WP6 working group, the potential for decoupling expenditure from project finance.

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.

1. Working guidelines for procurement in the course of the WP2 SKA design project. Type: Report. Delivery: T+12 months.
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.
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.
4. Draft options paper on procurement that will meet technical, policy and geographic distribution goals. Type: Report. Delivery: T+33 months.
5. An inventory of national standpoints, general policies and specific goals to accompany each option in (4). Type: Report. Delivery: T+33 months.
6. A White Paper on options for SKA procurement, for the Plenary Funding Agencies Group. Type: Report. Delivery: T+35 months.
7. Proposed procurement model incorporated into the PrepSKA final report. Type: Report. Delivery: T+36 months

Work Package 6 on Funding of the SKA

Work package number	6	**Start date or starting event:**		T+0		
Work package title	Developing the funding model for the SKA					
Activity Type[9]	SUPP					
Participant id	1	2	3	4	6	7	8
Person-months per beneficiary:	**36 (**+6)	(5)	(2)	(6)	(6)	(3)	(3)
Participant id	12	SPDO	NSF				
Person-months per beneficiary:	(6)	(3)	(1)				

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. Several key activities are required for the work-package:

- The development of a document, with input from the PrepSKA work-packages on System Design (WP2), Governance (WP4), Procurement (WP5) and the SKA Program Development Office (SPDO) and its working groups, outlining the full costs of all phases of the SKA.
- With input from PrepSKA WP5 on procurement, undertake a survey of the national funding agencies in all countries that might potentially invest in the SKA to understand the processes by which they allocate funding to large, international projects.
- To approach 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.
- To approach other organisations which have previously obtained EIB loans in order to develop a view on the advantages and disadvantages of the practice.
- To investigate the possibility of private and/or corporate funding of the SKA project.
- To develop a detailed options paper for a funding model for the SKA project for discussion with stakeholders at the International SKA Forum
- 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 will conduct most of its business by e-mail but will 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 (see

[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.

also page 58).

Deliverables

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

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

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

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

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

Work package number	7	**Start date or starting event:**			T+33 months		
Work package title	An implementation plan leading to construction of the SKA						
Activity Type[10]	SUPP						
Participant id	1	2	3	4	5	6	7
Person-months per beneficiary:	(3)	(3)	(5)	(3)	(1)	(3)	(3)
Participant id	8	9	10	11	12	13	14
Person-months per beneficiary:	(0.5)	(3)	(3)	(1)	(3)	(1)	(1)
Participant id	15	16	17	18	19	20	SPDO
Person-months per beneficiary:	(2)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(3)
Participant id	NSF						
Person-months per beneficiary:	(1)						

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:

- 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 will comprise representatives of the funding agencies together with the co-ordinators of the various PrepSKA work-packages, the Director of the SPDO and any other parties required to contribute 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.

WP7 will also produce a report that describes the socio-economic and knowledge impact of the SKA on the European Research Area. Such a report may also be useful to other countries/regions in producing their own, similar study

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

Deliverables

7.1 Initial SKA system design and technical report. Type: Report. Delivery: T+36 months

7.2 A paper on the socio-economic and knowledge impact of the SKA on the European Research Area. Type: Report; Delivery: T+36 months

7.3 A preliminary implementation plan for the SKA. Type: Report. Delivery: T+36 months.

[10] 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.

B 1.3.6 Efforts for the full duration of the project

Table 5: Project Effort Form 1 - Indicative efforts per beneficiary per WP

Beneficiary short name	WP 1	WP 2	WP 3	WP 4	WP 5	WP 6	WP 7	Total per Beneficiary
STFC (1)	**9**			(6)	(6)	**36** (+6)	(3)	66
N W O (2)				**36** (+6)	(5)	(5)	(3)	55
CNRS (3)				(6)	(6)	(2)	(5)	19
INAF (4)		36		(6)	**36** (+6)	(6)	(3)	93
IT (5)		(46)					(1)	47
DIISR (6)			(3)	(12)	(6)	(6)	(3)	30
NRF (7)		(74)	(36)	(3)	(6)	(3)	(3)	125
NRC-HIA (8)		(40)		(3)	(2)	(3)	(0.5)	48.5
UMAN (9)	**36** (+3)	**281** (+140)	36	(2)			(3)	501
ASTRON (10)		36 (+ 110)	(9)	(2)	(2)		(3)	162
MPIfR (11)		36 (+ 32)					(1)	69
Cornell (12)		(154)		(6)	(6)	(6)	(3)	175
UCAM (13)		(80)					(1)	81
UOXF.DL (14)		(80)					(1)	81
CSIRO (15)		(100)	(54)	(2)	(1)		(2)	(159)
JIVE (16)		(12)					(0.5)	12.5
OBSPAR (17)		24 (+46)					(0.5)	70.5
UORL (18)		12 (+35)					(0.5)	47.5
UCAL (19)		(12)					(0.5)	12.5
RUG (20)		(18)					(0.5)	18.5
NSF				(1)	(1)	(1)	(1)	4
SPDO		(96)			(3)	(3)	(3)	105
AUI				(1)	(0.5)	(0.5)	(1)	3
FG-IGN				(0.5)	(0.5)	(0.5)	(0.5)	2
VR				(1)		(0.5)	(0.5)	2
Total	**45** (+3)	**425** (+1075)	**36** (+102)	**36** (+57.5)	**36** (+51)	**36** (+42.5)	(44)	**614** (+1375)

Table 6: Project Effort Form 2 - indicative efforts per activity type per beneficiary[11]

Activity Type	1	2	3	4	5	6	7	8	9	10
RTD										
WP2				36	(46)		(74)	(40)	**281** (+140)	36 (+110)
Total RTD				36	46		74	40	421	146
Consortium management										
WP1	**9**								**36** (+3)	
Total mgmt	9								39	
Coordination										
WP7	(3)	(3)	(5)	(3)	(1)	(3)	(3)	(0.5)	(3)	(3)
Total Coord	3	3	5	3	1	3	3	0.5	3	3
Support										
WP3						(3)	(36)		36	(9)
WP4	(6)	**36** (+6)	(6)	(6)		(12)	(3)	(3)	(2)	(2)
WP5	(6)	(5)	(6)	**36** (+6)		(6)	(6)	(2)		(2)
WP6	**36** (+6)	(5)	(2)	(6)		(6)	(3)	(3)		
Total supp.	54	52	14	54		27	48	8	38	13
Total Beneficiaries	66	55	19	93	47	30	125	48.5	501	162

Activity Type	11	12	13	14	15	16	17	18	19	20
RTD										
WP2	36(+32)	(154)	(80)	(80)	(100)	(12)	24 (+36)	12 (+35)	(12)	(18)
Total RTD	68	154	80	80	100	12	70	47	12	18
Consortium management										
WP1										
Total mgmt										
Coordination										
WP7	(1)	(3)	(1)	(1)	(2)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)
Total Coordination	1	3	1	1	2	0.5	0.5	0.5	0.5	0.5
Support										
WP3					(54)					
WP4		(6)			(2)					
WP5		(6)			(1)					
WP6		(6)								
Total support		18			57					
Total Beneficiaries	69	175	81	81	159	12.5	70.5	47.5	12.5	18.5

[11] Please indicate in the table the number of person months over the whole duration for the planned work , for each work package, for each activity type by each beneficiary

B 1.3.7 List of milestones and planning of reviews

Table 7: Milestones List

List and schedule of milestones					
Milestone no.	**Milestone name**	**WPs no's.**	**Lead beneficiary**	**Delivery date from Annex I** [12]	***Comments***
1.1	Annual Report 1	WP1	1/9	14	
1.2	Annual Report 2/Mid-term Review	WP1	1/9	24	
1.3	Annual Report 3 / Summary	WP1	1/9	36	
2.1	IEAC Review	WP2.1	9	11	
2.2	SKA specs set	WP2	9	12	
2.3	SKA Phase 1 prototyping: sub-system hardware spec set	WP2	9	15	
2.4	SKA design MTR	WP 2.1	9	24	
2.5	SKA dish options MTR	WP2.4	9	24	
2.6	SKA Feed options MTR	WP2.5	9	24	
2.7	LNA,receiver and cryogenics MTR	WP2.6	9	24	
2,8	Signal transport MTR	WP2.7	9	24	
2.9	Signal processing MTR	WP2.8	9	24	
2.10	Software/computing MTR	WP2.9	9	24	
2.11	SKA Phase 1 first design review (1DR)	WP2	9	27	
3.1	Ionospheric scintillation	WP3	9	7	
3.2	RFI Software and hardware delivery	WP3	9	12	
3.3	Array configuration, influence of site	WP3	9	18	
3.4	Infrastructure and risk analysis	WP3	9	30	
3.5	Sites RFI reports and radio quiet zone	WP3	9	33	
3.6	Summary site report	WP3	9	36	

[12] Month in which the milestone will be achieved. Month 1 marking the start date of the project, and all delivery dates being relative to this start date.

4.1	White paper	WP4	2	33	
5.1	Working guidelines for Procurement (WP2 design project)	WP5	4	12	
5.2	Inventory of industries	WP5	4	24	
5.3	Report on procurement model	WP5	4	36	
6.1	Complete survey of National funding agencies	WP6	1	33	
6.2	Full funding model	WP6	1	33	
7.1	PrepSKA year 3 summary technical report and preliminary implementation plan	WP7	1/9	36	Includes review of status of all WP2

Table 8: Planned reviews

Tentative schedule of project reviews			
Review number	**Review Type**	**Planned venue of review**	**Timing**
RV1	IEAC Review	Manchester	After 11 months
RV2	End of reporting Period 1	Manchester	Activity Report 1 (AR1) Mid-term review
RV3	SKA Phase 1 First design Review (1DR)	Manchester	After 27 months
RV4	End of reporting Period 2	Manchester	AR2/Summary review

B2. Implementation

B 2.1 Management structure and procedures

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 project, 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 Science and Technology Facilities Council is the lead partner in PrepSKA and will 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 to 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.

The Co-ordinator will be supported by a Project Management Team (PMT: see yellow area in Figure 2). The PMT will have two components, one will be the administrative support team centred at the UMAN, the other will be the Work Package Secretariat.

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.

The WP Secretariat will be distributed; it will have 1 FTE at each of NWO (for WP4), INAF (for WP5) and STFC (for WP6). The role of these policy WP leaders will be to coordinate the activities of the WPs. In conjunction with the associated administrative assistant, a WP leader

- Will organise the WP meetings,
- Will organise teleconferences.
- Will develop the meeting agendas and the generation and distribution of appropriate paperwork.
- Will ensure that minutes of WP meetings are taken and distributed,

- Will be responsible for producing the various reports and documents which arise from WP activities.

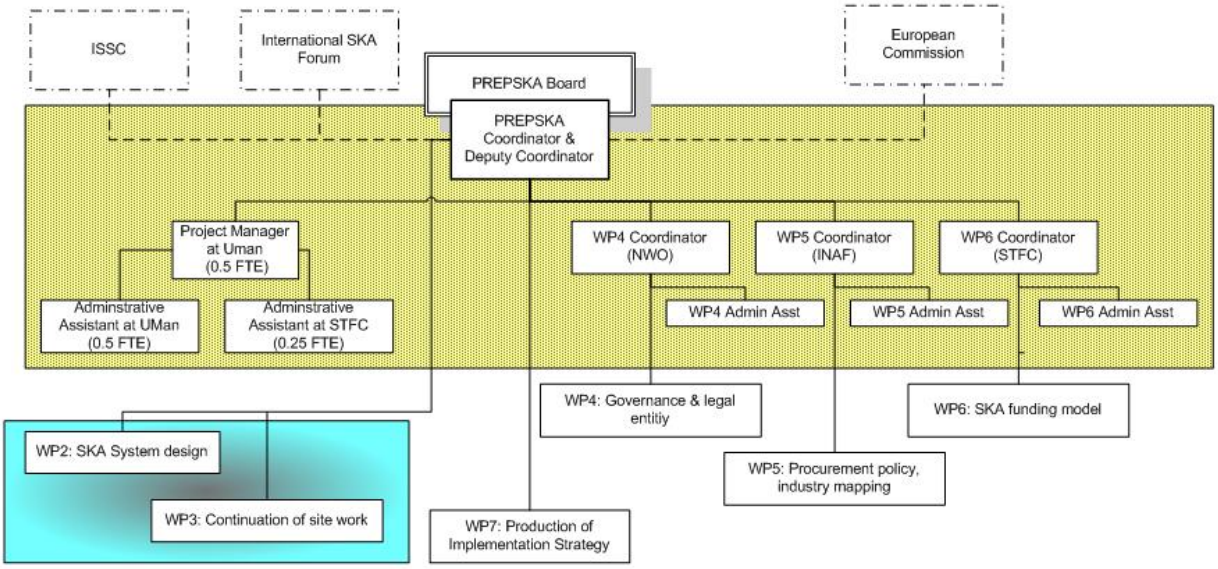

Figure 2: PREPSKA Org chart. Solid lines show reporting structure; dashed lines show information flow. The large yellow box delineates the PrepSKA management team. The smaller blue box on the bottom left represents the SPDO, which has responsibility for WP2 and WP3

Since the policy Work-packages WP4, WP5 and WP6 are interconnected with each other they will be loosely coupled e.g. by regular meetings/telecons of the WP-leaders or other common events as appropriate.

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 three 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 principal 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.

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;

SKA Program Development Office (SPDO)

The SPDO, which is hosted by UMAN, will have a major role to play in PrepSKA in leading WP2 and WP3. Its role in the International SKA Program is, through UMAN (SPDO-CDIT), 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 will report to the Executive Committee of the SKA Science and Engineering Committee. It comprises a Directorate that coordinates the global activities in SKA engineering, science, operations analysis, site characterization, simulations and outreach, and the Central Design Integration Team (CDIT, see below).

SPDO 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 SKA Program Development Office to coordinate the tasks in WP2. WP2 activities are shared between the SPDO-CDIT and existing engineering groups within regional consortia as shown in Figure 3.

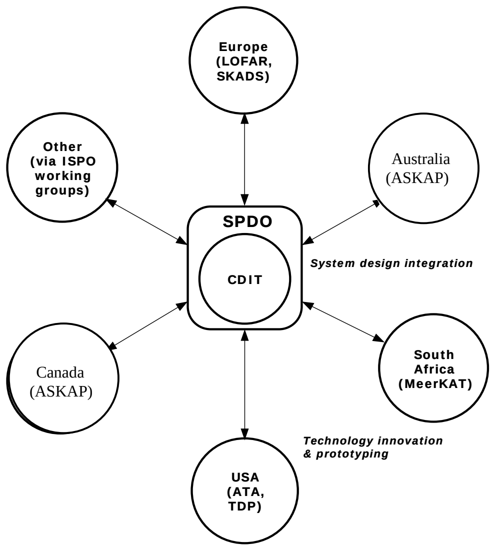

Figure 3: Schematic diagram showing the central role to be played by the SPDO-CDIT in taking the technology innovation and prototyping carried out by the Design Studies like SKADS in Europe and TDP in the USA and the Pathfinder telescopes (ATA, EVLA, e-MERLIN, LOFAR, APERTIF, MeerKAT, and ASKAP) to an integrated end design for the SKA.

The CDIT organisation diagram is shown in Figure 4.

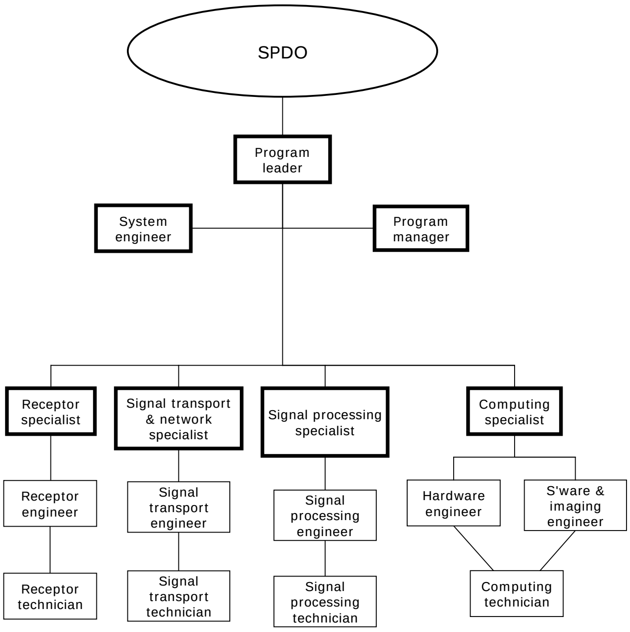

Figure 4: The CDIT Organisational diagram

The SPDO International Project Engineer will function as Program 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 SPDO-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 SPDO-CDIT, particularly to the domain specialists and system engineer. The liaison engineers will provide an active link between the SPDO-CDIT and regional engineering programs and, in particular, provide the SPDO-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 SPDO-CDIT tasks. They will manage prototyping contracts between the SPDO-CDIT and regional groups and ensure that SPDO-CDIT priorities are reflected in regional engineering programs.

UMAN will receive funding for the CDIT from the PrepSKA Board . On all issues related to FP7 funding and statutory reporting, UMAN (SPDO-CDIT) 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
The Consortium Agreement is available as a separate document.

B 2.2 Beneficiaries

Table 9

Participant	Participant organisation name	Country	Relevant experience and knowledge	Key personnel
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.	Dr Colin Vincent
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.	Ms Patricia Vogel
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.	Dr Jean-Marie Hameury
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.	Dr Paolo Vettolani
5	Instituto de Telecomunicações	PT	IT's mission is to create and disseminate scientific knowledge in the field of telecommunications. IT is actively involved in fundamental and applied research in telecommunications both at national and international level.	Dr Domingos Barbosa

			Simultaneously IT is committed to foster higher education and training, by hosting and tutoring graduate and postgraduate students	
6	Department of Innovation, Industry, Science & Research	AU	DIISR 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. DIISR ensures high quality and value for money in delivering Government funded programmes. DIISR administers the Australian Government's National Collaborative Research Infrastructure Strategy, which contributes to funding the Australina SKA Pathfinder (ASKAP).	Ms. Jessie Borthwick
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 (MeerKAT).	Ms Anita Loots
8	National Research Council	CA	The NRC-HIA is the Government of Canada's premier organization for research and development. NRC-HIA 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.	Dr Peter Dewdney
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	Prof. Philip Diamond

			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.	Prof. Michael Garrett
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.	Prof. Anton Zensus
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.	Prof. James Cordes
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.	Dr Paul Alexander
14	University of Oxford	UK	The University of Oxford was founded in the 12^{th} 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.	Prof Steve Rawlings
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	Prof Brian Boyle

			Telescope National Facility, which runs Australia's SKA programme. CSIRO is funding and building the SKA pathfinder ASKAP	
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.	Dr Huib Jan van Langevelde
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. OBSPAR operates the Nancay radio telescope and participates in the EC SKADS Programme.	Dr Wim van Driel
18	Universite d'Orleans	FR	The University of Orleans (UORL) founded in the 14th Century 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.	Dr Rodolphe Weber
19	University of Calgary	CA	UCAL has 16 faculties and 36 research institutes and centres, including the Centre for Radio Astronomy. 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.	Prof Russ Taylor
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	Prof Thijs van der Hulst

			national research school for astronomy NOVA. The Kapteyn Institute harbours the AstroWise/OmegaCen group which has expertise in developing intelligent information systems for astronomy.	

B 2.3 Consortium as a whole

As shown in Table 9, there are 20 formal participants in the Preparatory phase, 7 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 contribute to 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 be successful 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, very 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. 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.

Industrial involvement

Work Package 5 will address the issues involved in SKA procurement and industrial involvement. 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, will therefore be explored with industrial parties.

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 will 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 will 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 is required of the extent of the decoupling required and how it might best be realised.

B 2.3.1 Sub-contractors

Sub-contractors are required in Work Packages 3, 4, 5, and 6**.**

<u>Work Package 3 on further site characterisation</u>

3.1 External consultancy on the properties of the ionosphere as it affects low frequency radio astronomy. Estimated costs: €15000.

Results from detailed modelling of the ionospheric scintillation index are required as a function of elevation, azimuth, time of day, and solar cycle at the central and selected remote sites in Australia and South Africa to better characterise the ionosphere above the two candidate locations for the SKA. Detailed statistics are also required on the size, velocity and occurrence of Travelling Ionospheric Disturbances (TIDs) for solar maximum and minimum.

The contractor will be selected from among the few institutes in the world that carry out this research following a request for tender.

3.2 External consultancy on infrastructure deployment costs, timescales, and operational models. Estimated cost €225000.

Independent estimations are required of the costs and timescales of deploying the SKA infrastructure in Australia and Southern Africa and its eventual decommissioning, based on uniform infrastructure designs and standard methods of calculating costs.

The contractor will be selected from among specialised engineering companies with appropriate experience in large infrastructure projects, following a request for tender.

3.3 External consultancies on potential Radio Frequency Interference threats. Estimated cost: €50000

In order to assess the sustainability of the science environment in the face of potential RFI threats, additional demographic studies are required of the regions surrounding the central array and the remote stations to refine estimates of the future RFI threat due to the population. The potential consequences of any mining or other development interests near the central sites will also be characterised.

One contractor will be selected from among companies specialised in demographic studies, and the other from among companies with appropriate experience in large development projects and their potential for generating electrical interference, in both cases following requests for tender.

Work Package 4 on Governance

4.1 External consultancy on the legal framework and governance model to be adopted for the SKA. Estimated cost: €80000

Legal and strategic business advice will be obtained on the appropriate legal framework and governance models for the SKA in its construction and operational phases.

The contractor will be selected from responses to a request for tender, if appropriate, from legal companies or other organisations with experience in the governance of large scientific projects in their construction and operational phase..

Work Package 5 on Procurement and Industrial involvement

5.1 External consultancy to provide a comparison of procurement models based on the Baseline Design. Estimated cost: €100000.

Different procurement models will be analysed including cost-benefit estimates based on experience at national and international laboratories and taking comparative risk into account.

5.2 External consultancy on an industrial development model including global procurement. Estimated cost: €160000.

Options will be developed for development and procurement that include a fully global procurement model based on WTO guidelines, regionally- or nationally-restricted procurement relying on the availability of regional or national funding, and agreed-on deliverables by regional or national entities.

5.3 External consultancy to generate a world-wide inventory of potential industry partners. Estimated cost: €25000

An inventory will be made of the relevant industries, particularly the ICT segment, in participating countries able to contribute to the SKA and obtain statements of potential willingness to share development costs and risks.

In each case, the contractor will be selected following an open Request for Tenders to organisations and companies with experience of procurement for large scientific infrastructures and knowledge of industry and industrial trends world-wide.

Work Package 6 on Funding of the SKA

6.1 External consultancy to advise on appropriate ways to approach private and/or corporate donors. Estimated cost: €40000

An investigation will be made of the options available for private and/or corporate funding of the SKA project.

The contractor will be selected following an open Request for Tenders to appropriate financial organisations.

Third parties (other than subcontractors):
No third-party participation other than sub-contractors is foreseen.

Funding for beneficiaries from "third" countries*:*
All beneficiaries in PrepSKA from third countries are in the list of 'International Cooperation Partner Countries'.

Additional beneficiaries / Competitive calls:
The Consortium Agreement allows for potential new beneficiaries to join PrepSKA. If any organisation wishes to participate they will first contact the co-ordinator to discuss their potential role in the project and the level of resources that they will provide, at their own cost, to support the activities in which they are interested. A brief case will then be written and submitted to the PrepSKA Board for approval. If approved then an amendment to the contract will be initiated. There will be no competitive calls for new beneficiaries.

B 2.4 Resources to be committed

Table B2.4: Management level description of resources

Beneficiary	Personnel costs	Consulting	Equipment	Direct Costs	Indirect Costs	Total	EC Contribution
WP1							
STFC	33457.22	0	0	4000.00	22474.33	59931.54	59931.54
UMan	206790.88	0	0	55500.00	157374.53	419665.41	419665.41
WP2							
UMAN (SPDO-CDIT)	2032632.23	0	500000.00	253000.00	1554779.34	4340411.57	3314958.68
WP3							
UMAN (SPDO-CDIT)	0	290000.00	100000.00	8000.00	7560.00	405560.00	405560.00
WP4							
NWO	248988.00	80000.00	0	29000.00	21579.16	379567.16	379567.16
WP5							
INAF	218232.59	285000.00	0	29000.00	19426.28	551658.87	551658.87
WP6							
STFC	231685.29	40000.00	0	25000.00	17967.97	314653.26	314653.26
WP7							
UMAN	0	0	0	50000.00	3500.00	53500.00	53500.00
Totals	***2971786.21***	***695000.00***	***600000.00***	***453500.00***	***1804661.61***	***6524947.81***	***5499494.92***

Integration of resources

The global radio astronomy community has a strong track record in integrating 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 (WPs 4, 5, and 6), 2) those required for the integration of the SKA design (WP2), and 3) those required for the additional site characterization (WP3).

<u>WP4, WP5, WP6:</u> 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.

<u>WP 2:</u> 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 SKA Program Development Office and monitored by the PrepSKA Board, in addition to any locally operated oversight procedures. External review panels established by the SKA Science and Engineering Committee together with the existing SPDO Working Groups and Task Forces will also play a significant role in international supervision of progress.

<u>WP3:</u> Task Forces have already been established by the SKA Program Development 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 SKA Program Development Office, and SKADS. The manpower required for preparing for and carrying out of the measurement campaigns will be coordinated by the SPDO, and monitored by the SKA Science and Engineering Committee and the PrepSKA Board.

B3. Impact

B 3.1 Strategic impact

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 design for the SKA that can be built on the required timescales and within the target cost?

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.

Finally, 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.

B 3.2 Plan for the use and dissemination of foreground

Foreground is described in Annex II of the Grant Agreement as 'results…generated under the project'.

As Table 4 shows a significant fraction of the deliverables from PrepSKA are confidential or are limited in their distribution to the participants; this is necessary considering the sensitive nature of the site and funding decision processes that will follow from PrepSKA. However, all publicly available documents, minutes of meetings and journal publications that arise from work conducted under the auspices of PrepSKA will be made available on the PrepSKA web-pages, which will be found through the SKA website (http://www.skatelescope.org).

The Grant Agreement and Consortium Agreement lay down the management process of knowledge and intellectual property. Succinctly, the participants agree to follow the SKA Statement of Common Intent on IPR, which was signed in 2003 and which can be found on the SKA website.

It will be a requirement that PrepSKA and the EU-funding be acknowledged in all relevant publications. A significant level of public outreach will be maintained through public lectures, the web-site, and interaction with amateur astronomical associations.

B4. Ethical issues

Not applicable.

B5. 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 the project's 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 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.