Proposal full Title	Square Kilometre Array Design Studies
Proposal Acronym	SKADS

List of contents **Page Number**

Table 1 – List of Participants of the Design Study

Participants Number (Co-ordinator as Participant No.1)	Organisation (name, city,country	Short Name (as specified on From A2)	Short description (i.e. fields of excellence) and specific roles in the consortium
1	ASTRON, NL	ASTRON	*Expertise:* Netherlands Foundation for Radio Astronomy operates the Westerbork Synthesis Radio Telescope and has major research and development laboratories for astronomy instrumentation and technology covering a wide wavelength range: optical/mm/sub-mm/radio. ASTRON first developed phased arrays for decimetric radio astronomy (culminating in the THEA project) and has developed low-frequency multi-beaming technology (the LOFAR project); it is also involved in large software system development. *Roles:* Overall coordination of SKADS (DS1); coordinator for DS3 (The Network and its output data) and DS5 (Aperture Array Demonstrator EMBRACE); major participant in DS4 (technical foundations and enabling technologies) and DS8 (Overall System Design and Preliminary Project Plan)
2	The University of Manchester, UK	UMAN	*Expertise:* A combination of the Jodrell Bank Observatory (JBO; Dept. of Physics and Astronomy) and the Department of Electrical Engineering (formerly UMIST). JBO operates the UK MERLIN/VLBI National Facility and develops rf technology; long-distance optical-fibre systems for e-MERLIN and ALMA; real-time software systems; data-processing and archiving systems via the GRID and Virtual Observatories. JBO astronomers are world-leaders in pulsar observations. Electrical Engineering undertakes fundamental research and develops a wide range of rf and communication technologies including MMIC devices. The expertise and equipment to perform advanced semiconductor device R&D followed by material and device assessment using state-of-the art MBE machines and X-ray and C-V profiling. *Roles:* Coordinator for DS4 (Technical Foundations and Enabling Technologies); and DS8 (Overall System Design and Preliminary Project Plan); major participant in DS3 (The Network and its output data); participant in DS2 (Science and Astronomical Data Simulations
3	The Joint Institute for VLBI in Europe, NL	JIVE	*Expertise:* Radio astronomy & Very Long Baseline Interferometry (VLBI). Developed and now operates the 16-telescope European VLBI Network (EVN) correlator. Supports visiting astronomers, and monitors the detailed performance of the EVN telescopes. Currently leads the major distributed astronomical software development in Europe (ALBUS), is involved in data pipelining and is a key player in the transmission of data from remote telescopes, across fibre optic networks. *Role:* Coordinator for DS2-T2 and involved in various other work packages DS2-T1. DS3 T3 and DS5-T4

4	Observatoire de Paris, FR	OPAR	*Expertise:* The Observatoire de Paris has a long tradition in astronomical and astrophysical research. Involved in SKADS are three of its scientific Departments (GEPI, LERMA andLESIA) and its Nançay radio astronomy Station (USN), all of which are Joint Research Units of the Observatoire de Paris and the Centre National de la Recherche Scientifique (CNRS). These Departments, along with their partner Institutes (e.g., IAP, CEA and L2S), have major research activities in multi-wavelength (including radio) astronomy. Technical developments at the Nançay Station, which operates several radio telescopes including the $7000m^2$ collecting area Decimetric Radio Telescope, involve ASIC receiver front-ends, numerical receivers and radio interference mitigation methods. *Role:* Coordinator of DS7 (Assessment of Preparatory work and Studies); major participant in DS1 (Management) and DS4 (Technical foundations and enabling technologies); participant in DS2 (Science and Astronomical Data Simulations), DS3 (The Network and its output data) and DS5 (Aperture array demonstrator, EMBRACE)
5	Instituto di Radioastronomia, IT	IRA	*Expertise:* The Instituto de Radioastronomia (IRA) operates national radio astronomy facilities in Medicina and Noto including two 32-m telescopes and the Northern Cross. IRA develops antenna technology; RF and digital technology, imaging analysis software; numerical and graphic sim ulations. *Role:* Coordinator of DS6 (Cylinder array demonstrator, BEST); major participant in DS4 (Technical foundations and enabling technologies); participant DS3 (the Network and its output data) Potential Sub-contractors: IEIITT Torino: electromagnetic antenna simulation. DEIS Bologna (Bologna University): Hybrid MIC and and MMIC design and simulation DET (Firenze University)*:* Reliability; risk analysis and quality computation/estimation Osservatorio Astronomico di Cagliari: pulsar observations, computer science, simulations with PC clusters
6	Fundacion General de la Univ. De Alcala, ES	FG-IGN	*Expertise:* FG-IGN operates national facilities at Yebes including a 14-m radio telescope and a soon-to-be-complete 40-telescope. FG-IGN is particularly involved in rf technology development including quasi-optics. *Role:* Major participant in DS4 (Technical foundations and enabling technologies); participant in DS2 (Science and Astronomical Data Simulations) and in DS3(The Network and its output data) and DS8(Overall System Design and Preliminary Project Plan)
7	Max Plank Institute fur Radioastronomie, DE	MPIfR	*Expertise:* MPIfR operates the 100m Effelsberg telescope; MPIfR has a large electronic division which has developed and assembled a wide range of electronic equipment for the 100 m Effelsberg telescope and other telescopes around the world. *Role*: Participant in DS2 (Science and Astronomical Data Simulations), DS4 (Technical foundations and enabling technologies) and DS5 (Aperture Array Demonstrator "EMBRACE")

8	University Of Oxford, UK	OXF-DB	*Expertise:* U. Oxford has a major research programme in observational and theoretical cosmology. An Oxford astronomer is vice chair of the SKA International Science Advisory Committee (ISAC). A team of PhD students is already starting work on science simulations on the SKA. *Role:* Major participant in DS2 (Science and Astronomical Data Simulations - coordinating the science simulations.); participant in DS3 (The Network and its output data)
9	CSIRO, AU	CSIRO	*Expertise:* The CSIRO, through the Australia Telescope National Facility (ATNF), operates the major southern hemisphere radio observatories at Parkes (64m), Narrabri (the Australia Telescope Compact Array), Mopra and the Australian Long Baseline Array (LBA). CSIRO-ATNF maintains continuous development of its facilities and has played a leading role in SKA R&D via national funding for the past five years. Together with the antenna engineering group within the CSIRO Information and Communications Technology Centre (ICTC), CSIRO has world-leading expertise in antenna and systems design, signal processing, astronomical systems software development and SKA feasibility studies. Role: Major participants in DS3 (The Network and its output data) and in DS4 (Technical foundations and enabling technologies); participants in DS2 (Science and Astronomical Data Simulations), DS5 (Aperture Array Demonstrator EMBRACE) and DS6(Cylinder Array Demonstrator)
10	Puschino RAO, RU	PRAO LPI	*Expertise:* PRAO have constructed and operate the meter-wavelength Large Phased Array (of 16384 dipoles) with two independent multi-beam patterns and have gained much experience in pulsar investigations as well as in study of interstellar and interplanetary scintillations. *Role:* Participants in DS2 (Science and Astronomical Data Simulations) and DS4 (Technical foundations and enabling technologies).
11	National Research Council, CA	NRC	*Expertise:* The Dominion Radio Astrophysical Observatory is part of the Herzberg Institute of Astrophysics, which is an institute within the National Research Council of Canada. It is the primary laboratory in Canada for the development and deployment of instrument and software for radio astronomy; technical expertise encompasses antenna design, digital signal processing, observing and control software, and imaging software. Canada has had a long interest in the SKA and has contributed to its international development. *Role:* Participants in DS4 (Technical foundations and enabling technologies).
12	National Research Foundation, SA	NRF	*Expertise:* The NRF coordinates the participation in this Design Study of a diverse group of South African research institutions through a Research and Technology Collaboration Centre (RTCC). The RTCC partner institutions have expertise in the following relevant technology areas: computational electromagnetics, phased array antenna design, digital signal processing, signal transport, high-performance computing, radio-frequency devices and radio frequency interference measurement and mitigation. *Role:* participants in DS3 (The Network and its output data) and DS4 (Technical

			foundations and enabling technologies) and DS5 (Aperture Array Demonstrator, EMBRACE)
13	Torun Centre for Astronomy, PL	TcfA	*Expertise:* TCfA operates the 32-m radio telescope as a National Facility ; and as a member of the European VLBI Network. TCfA develops cm -wave receiver technology and astronomical data reduction software. *Role:* participation in DS2 (Science and Astronomical Data Simulations); DS3 (The Network and its output data)
14	Chalmers University, SE	Chalmers	*Expertise:* The Onsala Observatory operates 25-m cm-wave and 13-m mm-wave telescopes as national facilities and develops rf and mm-wave technology. It also has extensive experience in the design of interferometer arrays and is contracted to produce the final layout of telescope stations for ALMA; the design is now under construction. *Role:* Major participant in DS2 (Science and Astronomical Data Simulations)
15	University of Cambridge, UK	UCAM DPHYS	*Expertise:* Cavendish Astrophysics (Cav-Ap) at Cambridge University has long experience in the construction and operation of radio telescopes, this includes the building of one of the world's first phased arrays for radio astronomy which made the Nobel prize winning discovery of Pulsars. Cav-Ap has a very active Galaxy Evolution group specializing in the evolution of star-forming galaxies and AGN and associated feedback processes; several members of the group are already investigating the problems involved with handling massive data-sets which will be crucial to the success of the SKA project. *Role:* Major participant in DS2 (Science and Astronomical Data Simulations) and DS3 (The Network and its output data); participants in DS4(Technical foundations and enabling technologies); DS5 (Aperture Array demonstrator EMBRACE).
16	Kapteyn Astronomical Institute, NL	Kapteyn Institute	*Expertise:* The Kapteyn Institute is part of Groningen University and has a fundamental research programme concerned with the formation of structures in the universe, the formation and evolution of galaxies and the structure and dynamics of galaxies. There is ample expertise in radio astronomy at the Institute, in particular in the area of spectral line studies of galaxies using synthesis arrays. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
17	University Leiden, NL	Leiden Observatory	*Expertise:* Leiden Observatory (Sterrewacht Leiden) is the Astronomy Department of Leiden University, and was the progenitor of the Stichting ASTRON. Leiden was where the LOFAR project was proposed in the Netherlands. Leiden staff members are involved in the management and planning of many major international astronomical facilities. A particular interest of the Leiden instrumentation programme is attaining very high spatial resolutions at all wavelengths. Astrophysical research at Leiden Observatory presently focuses on i) the formation and evolution of galaxies: from high redshift to the present; ii) the birth and death of stars: the life cycle of gas and dust. A major observational interest is in carrying out deep surveys of the sky. Leiden Observatory is a partner in the Lorentz Center, an international research centre for Astronomy, Computer Science,

			Role: participant in DS2 (Science and Astronomical Data Simulations)
18	Cardiff University, UK	CU	*Expertise:* Cardiff University is the main European centre for the HIPASS and HIJASS all-sky HI surveys. The Cardiff group will use this expertise to work on the simulations of the HI sky, one of the five key science areas for the SKA. The other role of the Cardiff group within the consortium will be to work on the data analysis issues. This will build on Cardiff's experience as the data-analysis centre for the GEO 600 gravitational wave telescope, for which the data-handling problems are very similar to those which will be faced by the SKA. *Role:* participant in DS2 (Science and Astronomical Data Simulations); participant in DS3 (The Network and its output data)
19	University of Glasgow, UK	U.Glasgow	*Expertise:* The University of Glasgow supports solar, stellar and plasma-based astrophysics research as well as radio astronomy and cosmology, all within the Physics and Astronomy Department. The department also houses the Institute for Gravitational Research - one of the foremost research centres f or the detection of gravitational waves. Relevant fields of expertise include low-frequency radio astronomy, radio propagation and radio astronomy from the Moon. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
20	Swinburne University of Technology, AU	Swinburne	*Expertise:* The Swinburne University of Technology has developed a high level of expertise in astronomical data processing and other applications of super-computers. It will contribute in the areas of SKA data, technical and science simulations (with the leader of the International SKA Simulations Working Group coordinating). Swinburne will implement a model description for the SKA concepts on its supercomputer which will be used by all the Consortium members. Swinburne is host to Australia's only theoretical cosmology and galaxy formation group, with 10 members engaged in High-Performance Computing simulations related directly and indirectly to the formation of structure throughout the Universe, including gas phase physics (neutral hydrogen at high-redshift) and continuum emission in the field and in clusters at all redshifts." *Role:* major participant in DS2 (Science and Astronomical Data Simulations);
21	Univ. of Adelaide, AU	U. Adelaide	*Expertise:* U. Adelaide has a world-ranking cosmic ray group and is interested in science simulations focussing on tests to find the origin of the ultra-high energy cosmic rays using the SKA to observe radio Cherenkov emission from neutrino-induced cascades in the lunar regolith. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
22	University of Melbourne, AU	Umel	*Expertise:* U. Melbourne has an active research programme in physical cosmology. It is interested in SKA science simulations focussing on the evolution of HI in the Universe and large-scale structure. Predicting the properties of the earliest galaxies and quasars in the Universe, and analyses of how to detect them. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
23	University of Sydney, AU	U. Sydney	*Expertise:* U. Sydney has a long history of world-ranking radio astronomy development and operates the Molonglo Observatory Synthesis Telescope (MOST).

			It has a very active interest in SKA concept demonstrators. In partnership with the Italian consortium (or IRA/CNR), Sydney will develop and test the cylindrical array concept for the SKA. The main contribution will be to develop the array line feed, correlator and filter bank designs. *Role:* major participant in DS6 (cylindrical concept demonstrator)
24	The University of New South Wales, AU	UNSW	*Expertise:* UNSW has an active research programme in physical cosmology. and is interested simulations of HI surveys of galaxies to determine the detailed observational tests required to find the dark energy equation of state of the Universe. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
25	University d'Orleans, FR	UORL	*Expertise:* At the University of Orléans the LESI has expertise in signal and image processing and real-time electronics. The LPCE, whose expertise in instrument design is recognized by the French "Centre National d'Etudes Spatiales" (CNES), is a Joint Research Unit of the University of Orléans and of the Centre National de la Recherche Scientifique (CNRS) *Role:* major participant in DS4 (Technical foundations and enabling technologies)
26	Centre National de la Recherche Scientifique, FR	CNRS	*Expertise:* IRCOM is a Joint Research Unit supported by the French Centre National de la Recherche Scientifique (CNRS) and the University of Limoges. IRCOM has a world-wide acknowledged excellence in electromagnetism, microwaves and photonics. *Role:* participant in DS4 (Technical foundations and enabling technologies)
27	University of KwaZulu-Natal, SA	Natal University	*Expertise:* U. KZNa has an active programme in physical cosmology and a computational physics program *Role:* coordinate South African participation IN SKADS; participant in DS3 (The network and its output data)
28	University of Leeds, UK	UNIVLEEDS	*Expertise:* Leeds has substantial expertise in high resolution observations of star forming regions covering a variety of wavelengths and techniques, including extensive use of radio interferometery. The star formation group will perform simulations of the radio recombination and H I line emission from a variety of protoplanetary discs, winds and jet models. Leeds is also a world-leading centre for cosmic ray research with Prof Watson as the spokesperson for the international Pierre Auger Observatory. Members of this group will perform simulations of the radio emission from ultra-high energy cosmic rays. *Role:* participant in DS2 (Science and Astronomical Data Simulations)
29	Universidad de Valencia, IT	Univ. Valencia	*Expertise:* The University of Valencia possesses a last-generation parallel supercomputer (SGI Altix 3700 Server - 28+72 processors). A large amount of this computer power could be dedicated to both science and array performance simulations of the SKA. *Role:* Participant in DS2 (Science and Astronomical Data Simulations)
30	OMMIC, FR	OMMIC	*Expertise:* OMMIC is a leading supplier of advanced III-V semiconductor

			technologies in Europe. As part of the SKADS project OMMIC will manufacture MMICs based on in-house and SKADS consortium designs during the development and production phases. OMMIC will also make available its advanced short-gate-length high-Indium content process to allow the SKADS consortium to research and produce ultimate low-noise circuits. *Role:* participant in DS4 (Technical foundations and enabling technologies)
31	BAe Systems: Advanced Technology Centre, UK	BAE	*Expertise:* The BAE SYSTEMS Advanced Technology Centre (ATC) provides innovation, expertise and services for the creation and development of future technology capability covering a broad spectrum. From hardware to software development, composite materials to stealth techniques, sensing systems to synthetic environments, the ATC provides innovative solutions to Customer requirements. In addition to supporting BAE SYSTEMS the ATC works with external organisations including UK Ministry of Defence, US Department of Defense, European Space Agency, Universities and third part research and product organisations. ATC employs over 300 professionally qualified scientists and engineers at four locations in the UK. The Sensor Systems Department of ATC has wide experience in a range of technologies relevant to SKA. These include broadband antenna design, multiple beam antennas, thinned antenna arrays, receivers & digitisation, reconfigurable receivers, beamforming (analogue, optical, digital, adaptive beamforming), local oscillator & high quality reference generation, signal distribution (analogue, digital, optical), calibration techniques, data reduction and signal processing. *Role:* Participant in DS4 (Technical Foundation and Enabling Technology)
32	Qinetiq Ltd, UK	Qinetiq	*Expertise*: QinetiQ is Europe's largest science and technology organisation. Formerly an agency of the UK Ministry of Defence, the company has a distinguished heritage as a leading provider of a broad range of technology solutions and a supplier of impartial and trusted advice. In particular, the microwave design and prototyping group, based at QinetiQ Malvern, is one of the world's leading centres for the design, development, prototyping and manufacture of advanced high frequency solutions. *Role:* Working in collaboration with UMIST/ASTRON to investigate circuit techniques for realising low cost receiver front-ends in DS4-T1.

Table1-bis: Other entities contributing to the Design Study not listed as participants

Entity	Involvement
UK SKA Industry	A large, invited, proposal for UK national matching funds will be submitted to PPARC in late March 2004. This will not only be to support the UK university involvement in SKADS but also, importantly, industrial R&D. On February 18 2004 a PPARC-sponsored meeting on the SKA was attended by fifteen representatives from 10 companies or UK government or (government-related) organizations potentially interested in SKA technology development (and/or construction for SKADS via sub-contracts). Two of the largest, BAE Systems and Qinetiq, are participants in SKADS and several others have already expressed a strong interest in becoming involved. The intention is that all the UK industrial effort for SKA will be supported by national funding and hence contributing companies will not sign the EC FP6 Design Study Contract. The process of focussing this UK industrial interest in SKA R&D and, the manner in which these entities can contribute, will take place during Q1 and Q2 2004.
Italian Technical Consortium:	Sub-contractors: IEIITT Torino: electromagnetic antenna simulation. DEIS Bologna (Bologna University): Hybrid MIC and and MMIC design and simulation DET (Firenze University): Reliability; risk analysis and quality computation/estimation Osservatorio Astronomico di Cagliari: pulsar observations, computer science, simulations with PC clusters
IBM (Netherlands)	IBM (Netherlands) has expressed a strong interest in studying the computational requirements of the SKA project; this follows on their direct involvement in the LOFAR project. A letter expressing this interest in included in Annexe 3.
South Africa Research and Technology Collaboration Centre	The South African government has earmarked a grant for about 2M€ from the Innovation Fund to support participation by South African research institutions, universities and industry in the development of SKA. About two thirds of the funds probably be used to support participation in SKADS.

Table 2 - List of Tasks of the Design Study (DS)

Task No	Descriptive Title	Leading Participant	Short description and specific objective of the task
DS1	Management of the Design Study SKADS	ASTRON (Netherlands Foundation for Research in Astronomy)	To provide the overall management of this complex and highly inter-related project.
DS2	Science and Astronomical Data Simulations	Joint Institute for Very Long Baseline Interferometry Europe (JIVE)	To establish the scientific requirements in a quantitative manner; to establish the capabilities of the observing system necessary to deliver them and thus to derive a quantitative set of design specifications.
DS3	The Network and its Output Data	ASTRON (Netherlands Foundation for Research in Astronomy)	To study the intra- and inter-station signal connection networks, the (central) data handling and the physical infrastructure of the SKA.
DS4	Technical Foundations and Enabling Technologies	University of Manchester	To establish the level of maturity of key technologies for a multi-fielding SKA; a make a set of technology selections; to identify the gaps where future work may be needed.
DS5	Aperture Array Demonstrator EMBRACE	ASTRON (Netherlands Foundation for Research in Astronomy)	To design, develop and critically assess the performance of a multi-field aperture array demonstrator system for high sensitivity, high resolution, radio astronomy observations.
DS6	Cylindrical Concept Demonstrator	Instituto di Radio Astronomia (IRA)	To design, develop and critically assess the performance of a multi-field cylindrical concept demonstrator for high sensitivity radio astronomy observations.
DS7	Assessment of Preparatory Work and Studies	Observatoire d'Paris (OPAR)	To continually assess the whole programme of work and to organise the mid-term and final design reviews.
DS8	Overall System Design and Preliminary SKA Plan	University of Manchester	To produce the overall system design and a preliminary project plan.

Table 3 – Summary table of expected budget and of the requested Community contribution

	Participant number																	
Task Number	1		2		3		4		5		6		7		8		**Total Expected Budget (Ke)**	**Max Community contribution Requested (Ke)**
Amount (Ke)	**Exp Budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**		
DS1	597	597	0	0	0	0	364.8	364.8	0	0	0	0	0	0	0	0	961.8	961.8
DS2	196.4	98.4	233.3	233.3	233.3	233.3	349.9	349.9	680.4	272.2	16.2	6.5	116.6	116.6	330.5	330.5	2156.6	1640.4
DS3	923.4	461.7	194.4	194.4	116.6	116.6	64.8	64.8	777.6	311.0	388.8	155.5	0	0	155.5	155.5	2621.1	1459.5
DS4	1540.8	770.4	1288.6	1288.6	0	0	1105	1105	1209.2	483.7	777.6	311	77.8	77.8	0	0	5999	4036.5
DS5	6904.8	3452.4	754.7	754.7	97.2	97.2	666.2	666.2	0	0	0	0	38.9	38.9	0	0	8461.8	5009.4
DS6	32.4	16.2	0	0	58.3	58.3	0	0	2466.1	986.4	0	0	0	0	0	0	2556.8	1060.9
DS7	0	0	0	0	0	0	419.2	419.2	0	0	0	0	0	0	0	0	419.2	419.2
DS8	210.6	105.3	181.4	181.4	0	0	0	0	0	0	24.3	9.7	0	0	0	0	416.3	296.4
Total Expected Budget (Ke)	**10405.**		2652		505		2970		5133		1207		233		486		23591	
Max Community contribution Requested (Ke)		5501		2652		505		2970		2053		483		233		486		14883

Expected bdget- frm last page	Max Comm Contrbn-frm last page	Participant number
23591 (Ke)	14883 (Ke)	

Task Number	9		10		11		12		13		14		15		16		Total Expected Budget (Ke)	Max Community contribution Requested (Ke)
Amount (Ke)	Exp Budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib		
DS1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	178.2	5.3	11.5	11.5	0	0	0	0	38.9	38.9	239.8	239.8	233.3	233.3	155.5	155.5	857.2	684.3
DS3	1053	31.2	0	0	0	0	194.4	5.8	0		0	0	233.3	233.3	0	0	1480.7	270.3
DS4	713.3	19.9	11.5	11.5	388.8	11.5	388.8	11.5	0	0	0	0	156.1	156.1	0	0	1658.5	210.5
DS5	103.2	2.9	0	0	0	0	388.8	11.5	0	0	0	0	**527.7**	527.7	0	0	1019.7	542.1
DS6	120.4	3.4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120.4	3.4
DS7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Expected Budget (Ke)	2168		23		389		972		39		240		1150		156		28728	
Max Community contribution Requested (Ke)		63		23		12		29		39		240		1150		156		16595

Expected bdget- frm last page	Max Comm Contrbn-frm last page	Participant number																
28728 (Ke)	16595 (Ke)																	
Task Number	17		18		19		20		21		22		23		24		**Total Expected Budget (Ke)**	**Max Community contribution Requested (Ke)**
Amount (Ke)	**Exp Budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**	**Exp budget**	**Req contrib**		
DS1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	155.5	155.5	77.8	77.8	38.9	38.9	20.2	20.2	2.9	2.9	2.9	2.9	0	0	2.9	2.9	301.1	301.1
DS3	0	0	116.6	116.6	0	0	0	0	0	0	0	0	0	0	0	0	116.6	116.6
DS4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS6	0	0	0	0	0	0	0	0	0	0	0	0	8.6	8.6	0	0	8.6	8.6
DS7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Expected Budget (Ke)	156		194		39		20.2		2.9		2.9		8.6		2.9		29154	
Max Community contribution Requested (Ke)		156		194		39		20		2.9		2.9		8.6		2.9		17021

Expected bdget- frm last page	Max Comm Contrbn-frm last page	Participant number																
29154 (Ke)	17021(Ke)																	
Task Number	25		26		27		28		29		30		31		32		Total Expected Budget (Ke)	Max Community contribution Requested (Ke)
Amount (Ke)	Exp Budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib	Exp budget	Req contrib		
DS1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS2	0	0	0	0	0	0	38.9	38.9	77.8	77.8	0	0	0	0	0	0	116.7	116.7
DS3	0	0	0	0	2.9	2.9	0	0	0	0	0	0	0	0	0	0	2.9	2.9
DS4	867.6	347.0	234.9	94.0	0	0	0	0	0	0	420.8	168.3	388.8	0	388.8	0	2300.9	609.3
DS5	0	0	0	0	0	0	0	0	0	0	518	207	0	0	0	0	518	207
DS6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DS8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Expected Budget (Ke)	868		235		2.9		39		78		939		389		389		2940	
Max Community contribution Requested (Ke)		347		94		2.9		39		78		376		0		0	**32094**	**17958**

1. EUROPEAN ADDED VALUE OF THE NEW INFRASTRUCTURE

Special interest and need at the European level: The Square Kilometre Array (SKA) represents the future of *world* radio astronomy. When completed in the second half of the next decade it will be able to scan and map the sky with a sensitivity ~100 times greater than is currently possible. It will be a distributed array and its collecting elements will be connected as an interferometer to deliver resolutions from arcminutes to milli-arcseconds. The SKA's frequency coverage will extend from ~0.1 to ~20 GHz, realised probably in two frequency bands involving different collector technologies: low, ~0.1 GHz to ~1.4 GHz (the main concern of this *Design Study*) ; and high, ~1.4 GHz to ~20 GHz. In the low band, the field-of-view will be sufficient to allow a range of `all-sky' surveys. In the high band, the resolution will complement that of the James Webb Space Telescope (JWST) and the Atacama Large Millimetre Array (ALMA). The SKA is also a real-time VLBI instrument with baselines extending across several thousand km, hence it will deliver angular resolutions up to two orders-of-magnitude greater than in any other band. The sensitivity of the SKA means that, for the first time, there is a high probability that an object discovered in any other waveband can also be studied in the radio band.

The SKA is internationally-agreed vision and much formal planning for its development has been taking place on a fully-global basis since an international Memorandum of Understanding was signed in, Manchester,UK at the General Assembly of the International Astronomical Union in 2000 (see http://www.skatelescope.org). Timescales have been agreed and an International SKA Director has been in post since 2003. The site will be agreed in January 2006, after an on-going process of site evaluation. An affordable SKA can now be envisaged with technical convergence of the design scheduled for 2008. By this time "engineering demonstrators" must have been delivered and a wide range of scientific and technical simulations must have been undertaken and their results assimilated. A second development phase will occur from 2008 to 2012 with final construction planned to start in 2012, and with the full SKA scheduled to come on-stream before 2020. The cost of the globally-funded project is likely to be of order €1 billion with a contribution from Europe of perhaps 40% with a comparable amount from the USA and the remainder from the rest of the world.

European radio astronomers were the first to outline the basic rationale for such a telescope over ten years ago. As a result of nationally-funded work European radio astronomers and engineers are now in a position to develop a fundamentally new design concept for the SKA during the course of this *Design Study* (SKADS). *The concept will involve a dramatic paradigm shift in the collector and beam-forming philosophy for radio telescopes; during SKADS we aim to develop the "breakthrough technologies" required for the design of a cost-effective all-electronic telescope of unprecedented capability, flexibility of operation and upgrade potential.* The scientific potential of such a telescope is astonishing and will certainly enable European astronomers of the 21st century to add to the long list of fundamental discoveries made by their predecessors in the previous century.

Many physical phenomena are only - or most clearly - observed at radio wavelengths. Over the last 50 years, this has allowed radio astronomy to play a leading discovery role in astrophysics and cosmology – well-known examples are the after-glow of the Big Bang, neutron stars, gravitational radiation (via the binary pulsar), dark matter, black holes in galaxies, and gravitational lenses. Three of these discoveries have been awarded Nobel Prizes for Physics. Central to these discoveries have been innovations in technology pushing the observational frontiers.

Since the 1960s, when it can be said that modern radio astronomy came-of-age, radio astronomers have enhanced the capability of their instruments many fold in terms of sensitivity, spatial, spectral and temporal resolution. In 1970 the Westerbork Synthesis Array (WSRT, The Netherlands) became the world's most sensitive imaging instrument. A decade later the Very Large Array (VLA) in New Mexico, the MERLIN array (UK) were completed and global VLBI became mature. These arrays enormously increased the imaging capability and all have recently been, or are in the process of being, upgraded. However, further substantial increases in sensitivity are no longer possible: receiver noise temperatures and usable bandwidths are approaching practical limits and the collecting areas available have not changed. The Arecibo telescope in Puerto Rico completed in 1965 has remained the world's largest radio telescope over four decades.

The global community of radio astronomers has concluded that the SKA should be the next step. Its combination of raw sensitivity coupled with its range of resolutions and thus its range of surface brightness sensitivities will be unique. Despite its limitations in sky coverage, in frequency coverage and in resolution the outstanding scientific output of the Arecibo telescope amply demonstrates the advantage of raw sensitivity – while the success of the WSRT, VLA and MERLIN demonstrates the power and flexibility of high-resolution aperture synthesis arrays. Is there a threshold which makes particular choices of collecting area and resolution "natural" for the next step in radio arrays? The following simple argument remains as valid now as when it was first proposed by a SKADS team member over ten years ago[1]. A fundamental constituent of the universe, atomic hydrogen (HI), emits at a specific wavelength of 21cm but its transition rate, and hence its volume emissivity and thence its surface brightness is low—as a result the VLA, for example, can only image HI with a resolution of ~5 arcsec. Imaging HI with the same resolution as ground–based optical telescopes, ~0.5 arcsec, requires a telescope with ~100 times the collecting area of existing instruments to produce the same surface brightness sensitivity; this leads to the concept of a synthesis array with a collecting of ~1 km^2 with most of the collecting area available on baselines of order 100 km or less. Such an instrument would also allow the detection of HI at cosmological distances. At the time this suggestion was made, Dutch astronomers were also seriously considering large synthesis arrays for imaging HI while Russian colleagues (non-EU participants in this proposal) had also suggested the next generation collector of ~1 km^2. In the 1990s the SKA concept took shape in Europe, Australia, Canada and the USA. Many of the proponents have now come together for this Design Study. A separate and complementary study is being proposed in the USA.

The SKA is not affordable if one simply scales up present array designs. Over the past 5 years this fact has driven an exhaustive consideration of new ideas for collector elements and for the exploitation of industrial R&D for signal processing and data transport. Within Europe we have developed a radically different concept for the SKA, in which the entire collector is a composed of large areas of low-cost, low-noise phased-arrays[2] with the beam formation carried out electronically – in this vision the SKA will essentially be a giant IT facility completely unlike any other astronomical instrument. This concept offers major advantages in terms of the efficiency of data-collection, in particular it offers the potential of very large fields-of-view and access to multiple simultaneous users. In SKADS a large European consortium will cooperate to carry out a detailed investigation of the cost-effectiveness of this new concept—its exciting potential has also attracted European industry and research institutes from non-EU countries to join in. We also wish to explore a second, more conventional, concept in which phased-arrays would also play a major role. Here, however, the basic collection of the radiation is carried out by curved metal surfaces—principally in the form of cylindrical paraboloids. Cylindrical antennas are long established in radio astronomy but the new options of digital beam forming and the use of phased arrays along their line-foci offers the promise of a major improvement in their capabilities. While not as flexible in operation as aperture arrays, cylinder arrays are potentially cheaper.

European significance and interest of proposed infrastructure to potential users: The vision is of a telescope which will both test fundamental physical laws and transform our picture of the Universe. Because of the size and complexity of the project *only one SKA is presently being considered in the world, although it could involve two types of collector technology sharing the same infrastructure. Inevitably, therefore, SKA also represents a significant part of the future of European astronomy and fundamental physics.* A particular advantage of the concepts being addressed in this *Design Study* is the option for producing multiple independent, or semi-independent, fields-of-view, which can be controlled by different groups of observers. This will enable several such groups to gain access to the full power of the array simultaneously, in manner analogous to the mode of operation of particle accelerators and synchrotron light sources. Although the *core* of the SKA will not be sited within Europe (because the radio spectrum usage is not conducive to high sensitivity observations in a large fraction of the spectrum), long-baseline stations could be sited in Europe and it is certain that, with advances in communications technology over the next ten years, the overall SKA will in part be controlled, and observations collected and analysed from within Europe. A detailed study of this process ("SKA for the User") forms one of the important *Design Study* Tasks within SKADS.

New areas of scientific research: The SKA science impact will be extraordinary. Recently the SKA's International Science Advisory Committee (ISAC) has agreed upon five principal science drivers against whose requirements any technical design must be tested[3]. These are, in brief:

Strong Field Tests of Gravity Using Pulsars and Black Holes: Pulsar surveys with the SKA can discover tens of thousands of pulsars, amongst which we expect to find a pulsar in orbit around a stellar-mass black hole and pulsars in close orbit around the super-massive black hole at the Galactic Centre. Thousands of millisecond pulsars will form an immense pulsar timing array to detect primordial gravitational waves. These can be used to provide unique tests of gravity and General Relativity in the strong-field regime.

---

[1] Wilkinson, P.N., 1991, "The Hydrogen Array" in *Radio Interferometry: Theory, Techniques and Applications ,* IAU Colloquium 131, ASP Conference Series, Vol. 19, T.J. Cornwell and R.A. Perley (eds.) , pages 428-432.

[2] A 2003 European SKA "White Paper" on the aperture array concept is at http://www.skatelescope.org/documents/dcwp.shtml (no. 14).

[3] See SKA Documents (number 44) at http://www.skatelescope.org

Probing the Dark Ages: The epoch at which the first luminous objects formed in the Universe, and the subsequent re-ionization of the neutral inter-galactic-medium, can best be studied at radio wavelengths. In the red-shifted HI line the SKA can map out the complicated processes occurring during the Epoch of Re-ionization; through red-shifted CO, the SKA can detect star-forming galaxies at these redshifts; with deep continuum observations, the SKA can detect the first AGNs. The ensemble of these data can provide unique information on how the first galaxies and black holes assembled themselves, and how they influenced their environment.

The Origin and Evolution of Cosmic Magnetism Radio astronomy is uniquely placed in its capability to study magnetic fields at great distances. Large-scale polarimetric studies will allow us: i) to completely characterize the evolution of magnetic fields in galaxies, clusters and the inter-galactic medium; ii) to investigate the connection between the formation of magnetic fields and the formation of structure in the early Universe, and iii) to provide solid constraints on when and how the first magnetic fields in the Universe were generated.

The Cradle of Life: There is increasing interest in the community in astrobiology and in the search for Earth-like planets. The SKA has enormous potential for finding evidence of extra-solar terrestrial planets and of other life like us. At 20 GHz, the SKA will provide thermal imaging at 0.15-AU resolution out to a distance of 150 pc, encompassing many of the best-studied Galactic star forming regions. Such observations will allow the process of terrestrial planet formation, evolving on timescales of months, to be studied. For the first time with the SKA, we will have the capability of detecting leakage radiation from ETI transmitters out to a few hundred parsecs, involving of order a million solar type stars. Finally, the SKA will have the resolution and sensitivity to study the J=1-0 transitions of amino acids and other complex carbon bio-molecules, and to follow their progress from molecular clouds to proto-planets.

The Evolution of Galaxies and Large Scale Structure: The original motivation for building the SKA was to detect HI in normal galaxies at high redshift. Such an experiment promises a particularly exciting result, in that the vast volume of space probed by an SKA HI galaxy survey will provide an exquisite matter power spectrum, with which we can compute the Universe's Equation of State, and map out the strength of Dark Energy as a function of cosmic epoch. At the same time, the SKA's unique capability to observe the neutral atomic component of gas in galaxies will allow us to chart the kinematics, merger history and environment of ordinary galaxies as they evolve from redshifts z~5 to the present.

Exploration of the unknown: History tells us that the enormous increase in sensitivity and survey speed provided by the SKA will lead to the discovery of new phenomena in the cosmos. The SKA offers astronomers in the 21st century an unparalleled opportunity to add to the many discoveries made by radio astronomy in the 20th century. All astronomers, from cosmologists to planetary scientists, will wish to make use of the SKA, and all physicists will be eager to learn about the results of the unique tests of gravity and the constraints on the properties of the early universe which it will make possible.

New areas of technology research and collaborations: At the heart of this study is the enabling technology of low-cost phased arrays. This technology, in which Europe already has a lead in terms radio astronomy applications, is vital to achieve our aims of large, independently steerable fields-of-view. Phased arrays can be deployed either as “aperture plane” arrays – large physical area systems in which the incoming electric field is collected directly, or at the focus of either parabolic or cylindrical antennas in which the passive reflector provides the physical collecting area. *A principal goal of the study and its proposed demonstrator programme is, for the first time, establish the viability of “aperture plane” array technology for radio astronomy.* The SKA requires a major involvement of European engineers and technologists in developing the new technologies and it will catalyse the development of completely new links between academic and industrial engineers (more details given in section 3.1).

Organisations interested in the proposed infrastructure: In the international SKA community 34 institutes in 15 countries currently participate in technology development (see http://www.skatelescope.org). These numbers will inevitably grow as a result of the SKADS collaboration. In SKADS alone, there are 32 participating organisations from 13 different countries. There is no involvement from institutes in the USA since funding is being sought for a separate US study focusing on a different collector concept. T*he Framework 6 Design Study instrument has therefore acted as a catalyst for the assembly of a large “critical-mass” of research activity and hence for a completely new level European and international involvement in radio astronomy and radio engineering research. Only a minority of the funding is being sought directly from the Commission.*

2. SCIENTIFIC AND TECHNOLOGICAL EXCELLENCE

2.1 Quality of the new infrastructure

Comparison with current international state-of-the-art:

As outlined in section 1 the SKA will be an enormous leap in continuum sensitivity over current radio telescopes. Fig. 1 shows a logarithmic plot of sensitivity against time from the start of radio astronomy before WWII to the present day and beyond. The sensitivity has increased exponentially, to produce a factor of ~10^5 improvement over 60 years. The results of completed upgrades to the Arecibo telescope (Arecibo-II) and the upgrades underway to the sensitive high resolution arrays WSRT, VLA and MERLIN arrays and the European VLBI Network (WSRT2; eMERLIN; EVLA and eEVN) are shown. The latest advances in performance principally arise from an increase in the usable bandwidth. When observing spectral line-emission, however, the increased bandwidths have no effect on the sensitivity and hence the original arguments for the SKA based on detecting and imaging the 21-cm line radiation of atomic hydrogen remain. The exponential increase in sensitivity shown by Fig. 1 cannot be sustained if the technology remains the same as that now employed—basically dependent on large (25m plus) diameter reflectors, since the construction costs of larger facilities will simply rise in parallel. To make the step in sensitivity demanded by the SKA science drivers requires a new approach. *The fundamental driving force behind all SKA planning is, therefore, to identify and pursue new "breakthrough" technologies which will allow us to reduce the cost-per-unit-area by up to an order-of-magnitude.*

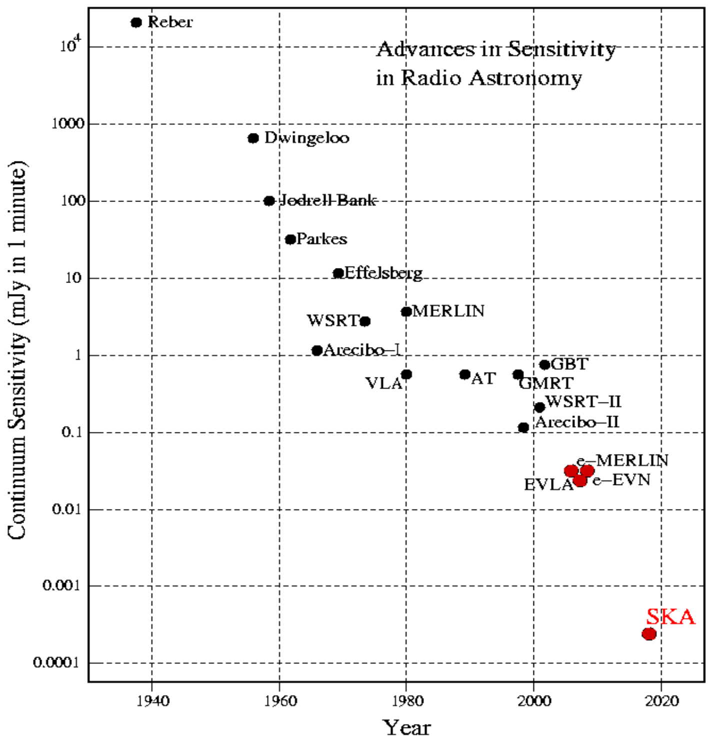


Fig. 1 The continuum sensitivity of radio telescopes as a function of time. The exponential rate of improvement has produced a factor ~10^5 since 1940. In order to make the major step demanded by the SKA science drivers requires a change of technology to reduce the cost-per-unit-area.

A new initiative in radio astronomy, LOFAR[4] (Low Frequency Array) is directed towards exploring the decametric region of the radio spectrum at wavelengths longer than those currently proposed for the SKA. LOFAR uses existing antenna and data distribution technologies to realise a large highly-flexible multi-station, multi-user sensor network. While the technology development for LOFAR has bearing on the SKA programme

[4] see http://www.lofar.org

(in particular the feasibility studies in DS3), the scale and complexity of the SKA system will be orders-of-magnitude greater than that of LOFAR. The lessons learned from LOFAR will be readily incorporated in the SKADS programme, via the joint link with ASTRON.

World-class qualities of the new infrastructure:

The SKA will be a quantum leap forwards as compared with current telescopes. The low-frequency "electronic SKA" of the type we are proposing to develop in SKADS, would be very different to any current telescopes in any waveband and would be continuously upgradeable as computing power and memory becomes cheaper.

A picture of what the SKA might look like, in the broad sense, is presented in Figs 2 and 3. These show a distributed array of at least one hundred "stations", each of collecting area 10^4 m^2, connected by a broad-band optical fibre network. Note that the distribution of stations in Fig 2 is merely illustrative, and as yet no work has been done to optimise the configuration with respect to the science goals (a task for DS2). The essence of much of the technology R&D around the world, and also within SKADS, concerns the cost-effective realization of the stations. Much of the data transport, physical infrastructure and computational requirements will be common to all concepts—although the SKADS multiple-field-of-view concepts will place a significantly greater requirement on computation than the others. The current phase, including SKADS, is the precursor phase where the cost-effectiveness of the various possible approaches to delivering the SKA science programme is being developed. After the technology concept selection in 2008, the whole world will come together to design and construct the SKA, and the very best technologies available will be sought for its construction. Further discussion of the technology within SKADS, and the critical role of industry in the development of the SKA, is given in section 3.1.

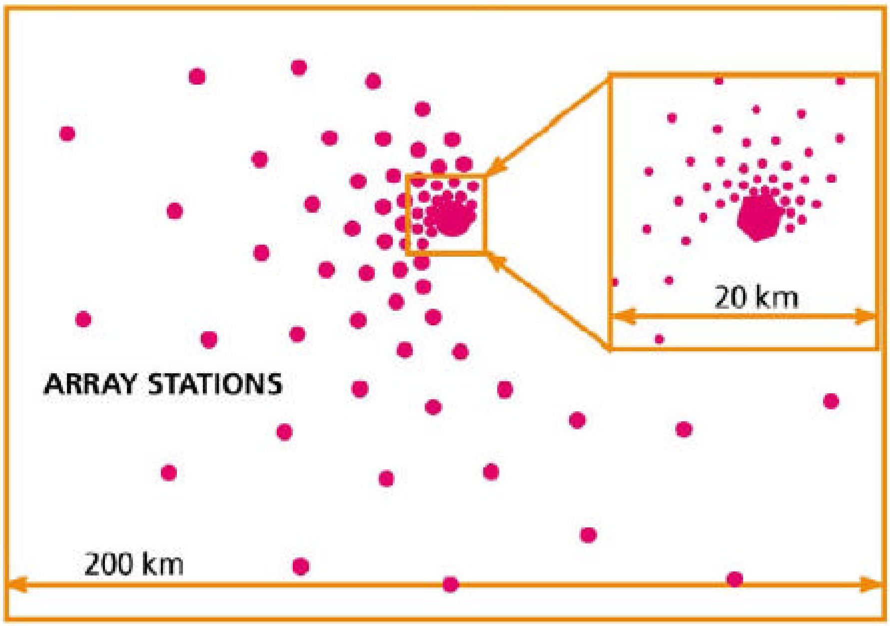


Fig 2: A schematic of one possible SKA configuration. The collecting elements are concentrated into stations each with a collecting area ~10^4 m^2. About 50% of the stations will lie within the central 5 km region (the "Inner Array") with the majority of the remainder lying within ~200km. A small fraction ~10% will be sited at distances out to 3000km. Stations are linked via optical fibres to a central processing centre. The optimization of the overall configuration with respect to the science goals is part of DS2-T2.

The concepts being proposed for the SKA are very demanding of technology and, vitally, of unit cost. As such they provide a challenging focus for engineers and technologists to push at the frontiers of what is currently possible. Technologies that must be developed for the SKA include: i) improved RF receivers and their direct integration into antennas for phased arrays; ii) low-cost manufacturing of large area phased arrays; iii) low-cost signal digitization and conditioning; iv) radio frequency interference mitigation techniques; v) low-cost computing for real-time beam-forming and data processing; vi) wide-band data transmission via optical fibres; vii) high speed real-time data processing of massive data sets and viii) application of the GRID to the huge data sets that will be generated. Above all the goal of mass production of high technology for low cost makes SKA-related R&D likely to result in spin-offs in the broad arena of telecommunications. A feature of the SKA as a pure-science-driven project is its requirement to involve industry at a very early stage of its development.

As part of the drive both to increase the flexibility while reducing the cost of the SKA it will make use of the emerging technology of “software radio”. In contrast to the previous and current generation of receiver and signal processing equipment, which uses special-purpose hardware, the next generation will inevitably exploit the convergence of radio and digital computing technologies—replacing hardware with firmware or software and allowing unprecedented versatility via the use of programmable processing engines. It will also use commercial off-the-shelf components or systems where possible.

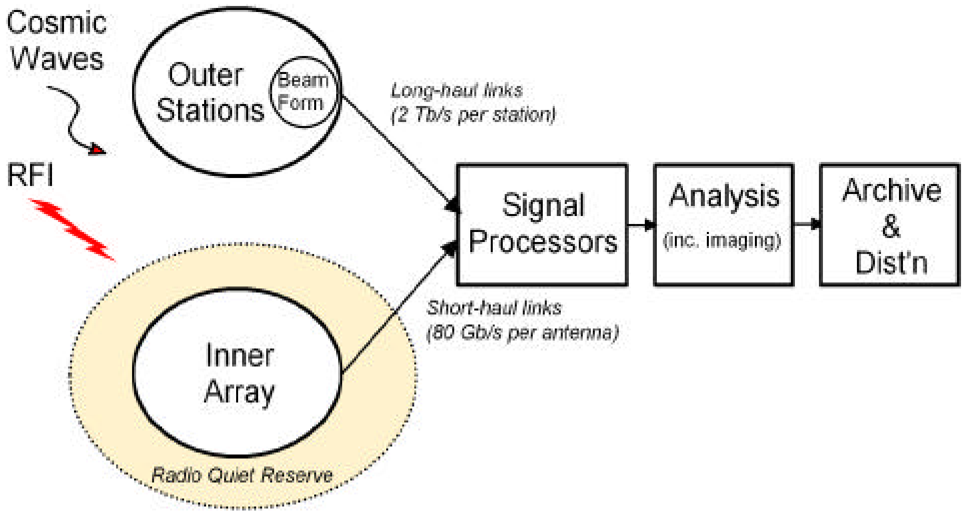


Fig 3: A second visualisation of the network proposed for the SKA. The Inner Array and outer stations receive the cosmic radio waves but are also subject to man-made RFI which must be dealt with via a range of strategies in both hardware and software. It is envisaged, however, that the central few 100km of the SKA will be located within a nationally and internationally agreed radio quiet reserve. The central processing activity is schematically broken down into sub-units.

What new opportunities will these technological advances provide for the user?

1) Greatly increased surveying speed: Why is surveying speed so important? We give three examples relevant to the concepts being developed within SKADS. Consider first the observational requirements of modern-day precision cosmology. A battery of methods have been proposed to study the dark energy content of the universe, which currently rates as perhaps the most important unresolved question in the whole of physics. The precision to which the dark energy parameter *w* can be measured scales, for almost all methods, as the square root of the fraction of the sky covered. The huge field-of-view, and hence surveying speed, achievable with aperture or cylinder arrays will allow radio astronomers the realistic prospect of surveying a large fraction of the whole sky within a few years, locating the ~10^9 HI-emitting galaxies in 3-D (for direct measurement of the galaxy power spectrum) and orders-of-magnitude more galaxies in 2-D projection (for measurement of the dark-matter power spectrum). Radio astronomers will therefore be the first to make the precision measurements on *w* which will determine whether the dark energy is equivalent to Einstein’s Cosmological Constant, or whether it is a signature of new physics and/or extra dimensions.

Through its sensitivity, sky and frequency coverage, the SKA offers the possibility of probing the strong-field realm of gravitational physics by finding and timing pulsars. The SKA will discover over 20,000 new pulsars, including over 1,000 millisecond pulsars. A requirement for achieving the science goals is the regular high precision timing of the new pulsars. Multiple fields-of-view with many independent beams are essential to enable weekly or bi-weekly monitoring of all potentially interesting pulsars. With a single beam instrument such rapid monitoring programmes are impractical, *even if all the telescope time were to be devoted to pulsar work.*

A third example concerns the possibilty of finding the first stars (Population III) to form in the universe. There are now a few observational and theoretical clues as to how these stars formed, but such objects have not yet been directly detected. It seems likely that they were extremely massive, perhaps 100- or 1000-times more massive than our Sun. They will have had a short, action-packed lives, probably ending in explosive events (hypernovae). The sensitivity of the SKA should be sufficient to detect the 'afterglows' of these dramatic radio hypernova events in a wide area "blind" survey.

Since many of the SKA science drivers involve large-scale surveys, a fundamental design driver is the instantaneous field-of-view. The international SKA community has specified this as at least 1 deg^2 at a wavelength 21cm (the hydrogen line). Fig 4 shows that this field-of-view is already large, compared with that available from several current or upcoming world-leading instruments in other wavebands. The design aim for the SKADS team is, at wavelengths longer than 21cm, to produce several fields-of-view each of which is at least an order-of-magnitude larger than the current SKA specification. The surveying speed of a telescope system is proportional to the product of its instantaneous field-of-view and the square of its sensitivity. At the same angular resolution the SKA, as specified, will therefore have a surveying speed at least 10,000 times greater than is possible with the current instruments. If the advantages of the wide-field-of-view concepts being investigated in SKADS can be realised, then a factor > 10^5 can be achieved. We believe that such a step in surveying speed at longer wavelengths is necessary to achieve the full scientific potential of the SKA. Testing these requirements, fully quantitatively, is one of the main targets of the science simulations.

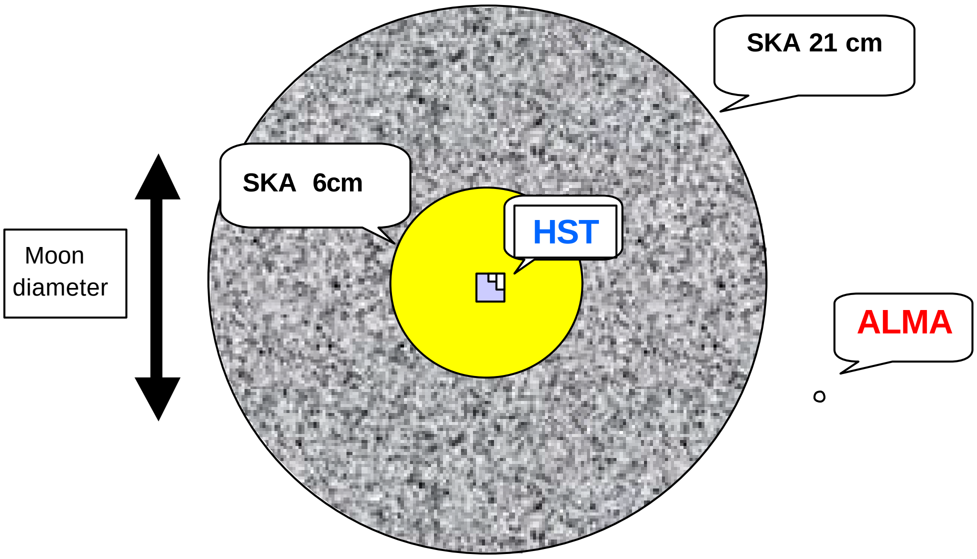


Fig. 4 The specified field-of-view of the SKA, 1 deg^2 at a wavelength of 21cm, compared with the that of the Hubble Space Telescope (HST) and the Atacama Large Millimetre Array (ALMA). Note that the field-of-view of the HST has recently been doubled with the advent of the Advanced Camera for Surveys. The field-of-view of the HST-successor, the JWST, will be a few arcminutes on a side. At 21cm and longer wavelengths the design aim for the collector concepts being investigated in SKADS is to produce several fields-of-views each at least an order-of-magnitude larger area than the baseline specification.

2) Synergy with other new telescope systems: Towards the end of the next decade, the SKA will be a leading member of a complementary group of next-generation instruments including: ground–based optical telescopes in the 30-50m class; the JWST (near- and mid-IR); ALMA (mm- and sub-mm wave); next-generation X-ray observatories. All of these will provide imaging information on the scale ~0.1 arcsec or better and all will provide unique views of the universe. Radio astronomy's particular contribution will come from the provision of:

- information on matter in different phases via synchrotron radiation, maser emission and thermal emission—noting that radio waves penetrate dust and gas, which absorb and scatter radiation in most other wavebands;
- information on cosmic magnetic fields;
- access to millisecond pulsars – the most accurate clocks in the universe;
- access to 21cm line of the fundamental element, hydrogen;

- imaging with a resolution tens to hundreds of times higher than in any other waveband—noting that diffraction-limited imaging in the face of variations in atmospheric propagation, is a long-solved problem in radio astronomy.

The SKA will therefore produce completely new information and it is no surprise that the key science goals identified by the ISAC involve all of the above advantages. Recent dramatic advances in cosmology and astro-particle physics have illustrated the key role that surveys made by astrophysicists now play in fundamental physics. Precision measurements of known particles (like neutrinos), unknown particles (such as those probably constituting cold dark matter) and the mysterious, and now energetically dominant, dark energy, now often rely on huge surveys of galaxies. These surveys have in the past been made only by optical astronomers, but multi-object optical spectroscopy remains limited by the ~1^o field-of-view achievable with large optical telescopes. There is no such physical limitation for the SKA and, as noted earlier in this section, it will therefore be able to make a unique impact on surveys of galaxies in the emission from the fundamental element out to high redshifts.

Completely new information will also flow from a comparison of the enormous data sets which will be produced from synoptic surveys in many wavebands. From a combination of these surveys, statistically significant patterns and subtle correlations between parameters will become apparent, pointing to new phenomena and rare or previously unknown objects will stand out. *The sensitivity of the SKA means that for the first time in the history of astronomy, an object detected in any waveband in the electromagnetic spectrum is also likely to be detected in the radio.*

3) A flexible responsive tool: An SKA with independently-steerable fields-of-view and independently-steerable beams, provides users with a highly flexible and responsive instrument (see Fig. 5). This approach generically incorporates:

- a science survey advantage: required for a range of key science programmes requiring large amounts of telescope time and which would be impossible with conventional systems;
- a “community” advantage: many groups can access the whole aperture simultaneously, allowing the operation of the SKA to resemble that of particle accelerators or synchrotron light sources; students and schools could also obtain observing time;
- a multiplex advantage: simply by increasing the volume of data which can be collected;
- an adaptive beam-forming advantage: “reception nulls” are steered to cancel out sources of radio frequency interference.

The different fields-of-view could, for example, be used for:

- imaging a deep field: integrating for long periods for the ultimate in sensitivity;
- studies of time variable phenomena: seeking transient radio sources and responding instantly to transient discovered in other wavebands;
- pulsar timing: finding and then picking out the unusual ones from 20,000+ pulsars for special attention;
- experimentation: not scheduled by standard peer-review.

The history of radio astronomy, stretching back over 70 years, tells us both that the largest radio telescopes of their day (of a wide range of types) have dominated the list of discoveries, and that what a telescope is “known for” is almost never what its proponents and designers built it for. The corollary is that while the *SKA will address many current outstanding problems in astronomy and astrophysics, in the period 2025 to 2050 (when the SKA will be in its most productive years), the excitement will come from the new questions that will be raised by the new types of observations it alone will permit.* For this reason, the SKADS proposal envisions a design that is highly-flexible, easy-to-use and has an operating philosophy which positively encourages the astronomers of tomorrow to look at the sky, and to examine the data in new and creative ways. Time-buffering and archiving as much as possible of the raw data is part of this vision and will allow new ways of post-processing as computing power increases.

The SKA we are planning is so radically different from current instruments that the conventional way in which the user interacts with the instrument and its data requires a complete re-evaluation. “SKA for the User” (DS3-T5) is a specific study to address this issue within SKADS. Traditional use of telescopes has mostly followed the “peer-reviewed application for time”, “scheduling of individual observations” and finally “analysis and exploitation by observers of specific projects”. This is coupled with access to archive data. An alternative model is “undertake a systematic scientific programme” then “make data products available to all via a Virtual Observatory. Traditional methods of end-user data reduction are not appropriate for the SKA—instead we need to mirror the distributed hierarchical nature of the telescopes with calibration/imaging similarly distributed.

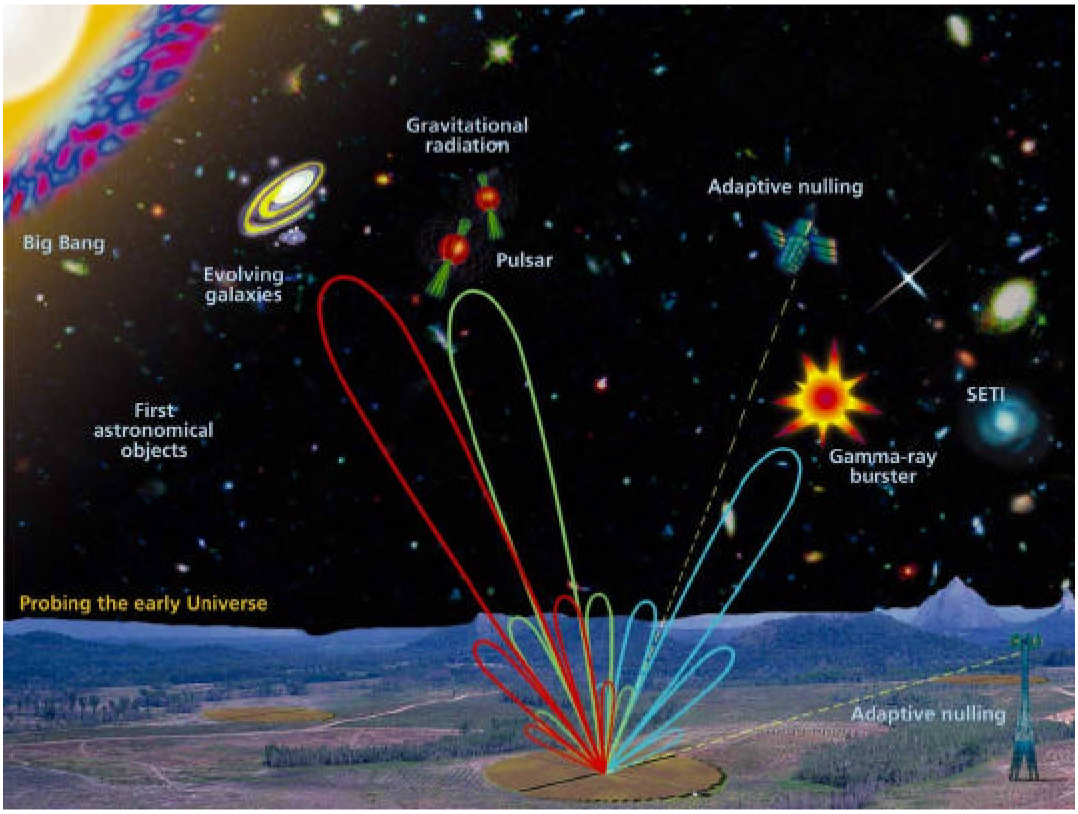


Fig 5: A visualisation of the advantages of a multi-field-of-view aperture array system for radio astronomy. A single SKA station is shown with many fields pointing in different directions. As explained in the text in section 2.1 such a flexible system offers the prospect of supporting many users to carry out separate astronomical programmes coupled with the ability to null out interfering signals. At the sites being investigated for the SKA there will be no TV transmitters (bottom right) but the unwanted emissions from satellites will need to be dealt with.

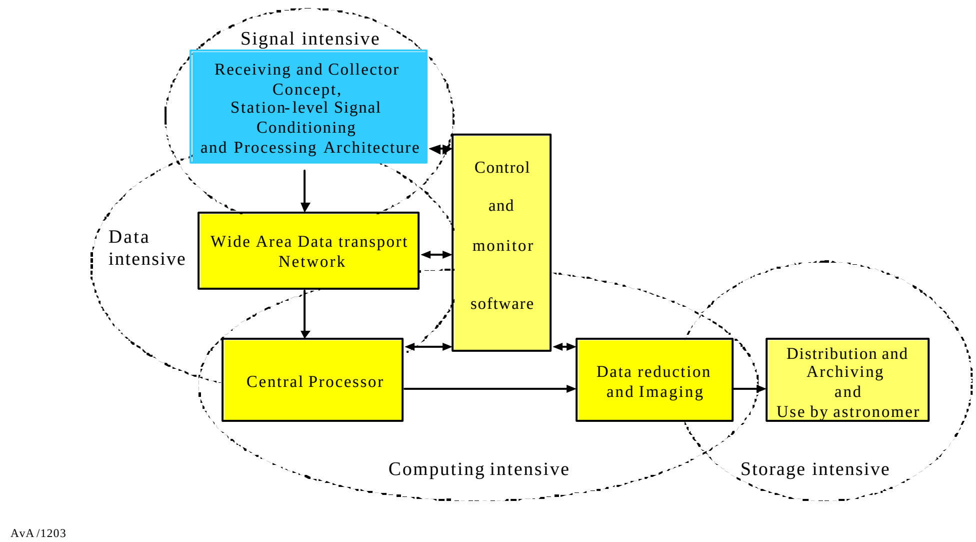


Figure 6 The overall strategy adopted for “SKADS“. The technical preparatory work (dark box) concerns the R&D appropriate to the technology at the $\sim 10^4$ m^2 “station” level and will include basic R&D as well as the construction of demonstration arrays. The feasibility studies (pale boxes) concern the overall design of the array and its infrastructure and do not involve hardware construction.

2.2 Quality of the proposed Design Study

2.2.1 Objectives of the Design Study

Several key science goals of the SKA (at least half of the total) demand a combination of extremely high sensitivity and high-angular resolution observations in multiple, large fields-of-view in the low frequency range 0.1-1.4 GHz. *The basic aim of SKADS is to establish cost-effective technologies appropriate for these key low-frequency science goals.* Solutions for the high-frequency range are being explored elsewhere, in particular the USA. It has been agreed internationally that an SKA covering the frequency range ~0.1 to ~20 GHz is likely to involve two technological approaches for the collector systems with, however, a large amount common infrastructure for the data transfer, signal processing and data analysis systems.

The SKA Design Study has been structured as a series of strategic *Design Studies* (DS) including both feasibility studies and technical preparatory work (see Figs 6 and 7). The feasibility studies (DS2; DS3; DS7; DS8) are "paper" exercises relevant to the design and costing of the SKA network and infrastructure, an overall assessment and a project plan. The technical preparatory work (DS4; DS5; DS6) mainly involves hardware R&D associated with establishing the cost-effectiveness of our specific solutions for an SKA "station". Each of these *Design Studies* has been sub-divided into coherent *Design Study Tasks* with clear aims, milestones and deliverables. At all stages we have been particularly cognisant of the need to provide outcomes in measurable and verifiable form. Further details of the individual Design Study Tasks are given in Table 4 and in the Annexe 1.

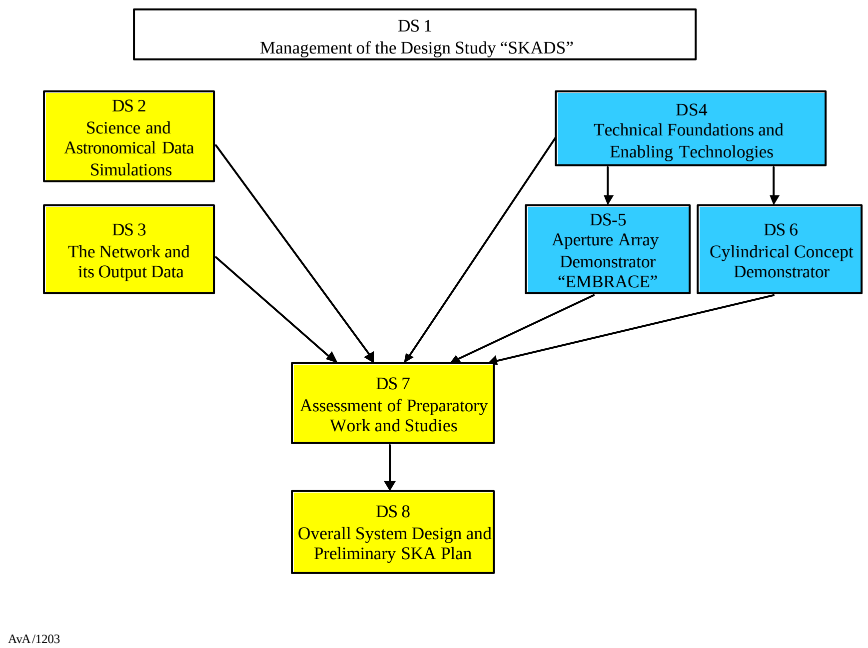


Fig. 7: The main linkages of the Design Studies within SKADS. The feasibility and assessment studies DS2,DS3,DS8,DS8 are shown in pale boxes. The technical preparatory work (DS 4, DS5,DS6) are shown in dark boxes.

The Design Study will address the following aspects of the SKA:

- the development of instrument specifications based on a quantification of key science drivers and a study of the technical requirements associated with the delivery of the science (DS2);
- an end-to-end study of the network, data handling and physical infrastructure from collection to the delivery of data to the astronomical users and its efficient use by them (DS3);
- the design of a cost-effective antenna system comprising an SKA "station" enabling beam forming within fields-of-view in many directions simultaneously, this will involve a range of R&D to develop the technical foundations and enabling technologies (DS4);
- the construction of engineering demonstrator arrays for our vision of an SKA "station" and exploration of the practical issues involved in multi-beam collection and signal-processing concepts (DS5, DS6);
- the operation of links (in SKADS using the "public" fibre network GEANT) to join a number of SKADS muti-beaming demonstrators separated by distances up to many hundreds of kilometres, to demonstrate the high angular resolution imaging capabilities required by the SKA community (DS5);
- a continuous process of critical assessment (DS7);
- an overall system design (involving technology foresight) and a preliminary, multi-component plan of how to realize the SKA (DS8).

There are several possible technological solutions to the stringent observational demands on the station technology—but all of them involve the enabling technology of low-noise, low-cost phased arrays in one form or another. In a phased array the electrical length of the connections between the elementary antenna elements (or groups of them) is varied electronically, enabling "beams" to be formed in many directions at once. Such arrays can be deployed either as "aperture plane" arrays – large physical area systems in which the incoming electric field is collected directly, or at the focus of either parabolic or cylindrical antennas. In the latter case, the passive reflector provides the physical collecting area and the array maximises our ability to use the radio energy collected.

Europe already has a lead in radio astronomy applications of phased "aperture plane" array technology and in this study we wish to build on this in the context of the SKA. A principal goal of the study and its proposed demonstrator programme is, for the first time, establish the viability of "aperture plane" array technology for radio astronomy. We therefore intend to build a >500 m^2 phased array EMBRACE (Electronic Multi-Beam Radio Astronomy ConcEpt) with a total area of about 800m^2 intended to demonstrate multiple, independent beam-forming capabilities of a quality appropriate for radio astronomy, and to demonstrate the ability to produce higher resolution beams using aperture arrays separated by long baselines (DS5) *This is breakthrough technology not being pursued elsewhere in the radio astronomy community.* The EMBRACE array will consist of a larger array (500m^2) close to the WSRT, and smaller arrays (100 m^2) in Nançay, Cambridge and Manchester.

The SKADS collaboration intends to study a second, more conventional, solution involving shaped reflectors for intercepting and focussing the incoming radiation (DS6). Cylindrical antennas are long established in radio astronomy *but the new options of digital beam forming and the use of phased arrays along their line-foci, offers the promise of a major improvement in their capabilities.* Although not as flexible in principle as the aperture array concept, cylindrical reflectors with phased-array feeds, potentially offer the most cost-effective way to obtaining the large sky coverage for the low-frequency survey science we are aiming at. A basic aim of the Design Study is, therefore, to compare and contrast possible technology solutions for our astronomical aims. The demonstrator for this concept, BEST, will be situated in Medicina, Italy.

It is important to realise that the different international SKA concepts currently being developed share many common features, particularly in terms of overall array configuration; data transport and signal processing methods. Hence, *even if the specific "station" concepts being explored in SKADS are not selected in 2008 as the basis for the next stage in SKA development, a large fraction of the work will certainly contribute to the final end-to-end SKA design.*

DS1 Management: To provide the overall coordination of this complex and highly inter-related project

DS2 Science and Astronomical Data Simulations*:* Before the final SKA design can begin a system definition document will be required. The DS2 team will therefore produce a science requirements and technical specification, based on *quantitative* in-depth studies of both the key science drivers and the requirements of the observing system (both hardware and software) which has to deliver them. As the final part of the science and technical specification the DS2 team will produce a Design Reference Science Plan (DRSP) of the key projects, in particular those involving deep surveys at low frequencies, that could be carried out in ~3-4 years of full SKA operations. DS2 requires a wide range of astronomical and technical knowledge and hence a large team in different institutes has come together to carry out this fundamental programme. Many of the staff will be enthusiastic young scientists (many funded via national contributions) who will work in collaboration with senior astronomers (all funded as in-kind matching contributions). The Study is split into two inter-related Tasks: DS2-T1 "Science" and DS2-T2 "Astronomical Data" simulations.

In DS2-T1 *fully quantitative* implications of the internationally agreed science drivers (see section 1) will be established. Since the principal technology driver for SKADS is the development of the concepts for the low frequency band, the science-quantification group will initially concentrate on the key science drivers best delivered in this band (i.e. tests of gravity; probing the dark ages; evolution of galaxies and large-scale structure; probing the unknown). They will, however, study the full range of ISAC science drivers since is vital that the European astronomical community understands the science potential of the SKA as a whole when the time comes to seek full funding (around the end of the present decade). The output of the "science quantification" programme will provide input to DS2-T2. In DS2-T2 the strategic issues associated with the fulfilment of the scientific potential of the SKA will be studied and quantified, in part via figures-of-merit for alternative realizations of different collector concepts. Since the SKA will be a factor >100 times more sensitive than existing radio arrays, it will routinely be required to generate images of the radio sky with a dynamic range (strongest to weakest features reliably detected in the image) >10^6 and, for long integrations,

>10^7. The requirements regarding image fidelity (i.e. on-source errors) are similarly stringent. These requirements, together with multiple, large, fields-of-view, imply data rates that are at least four orders-of-magnitude larger than current radio telescopes. SKADS work in this area will be strongly linked to the International SKA Simulations Working Group (SSWG) – coordinated from Swinburne University of Technology (Melbourne) which is also a participant in SKADS. During DS2 European simulation team members will spend a significant amount of time using the supercomputer facilities at Swinburne.

DS3: The Network and its Output Data: the overall aim is to study the *practical* issues associated with producing the most *cost-effective* overall architectural design for the SKA "network", interpreted in the broadest sense, to satisfy the specifications established in DS2. This will include: i) all aspects of the site physical infrastructure and the effects of a specific site on engineering/operational concepts and decisions; ii) the real-time control and monitoring software for the array; iii) the transport and handling of unparalled amounts of data on scales from <1km to 1000s km; iv) the economic delivery of electrical power to the network; v) the optimal signal-handling and data processing methodologies (in the new situation processing power can be distributed throughout the system); vi) the clock and local oscillator distribution systems and the potential role of opto-electronics; vii) the ways in which the output data can be most effectively handled and put to scientific use by the astronomer and the astronomical community using the GRID.

DS4: Technical Foundations and Enabling Technologies: the overall aim is to undertake fundamental R&D on a range of foundation and enabling technologies at "sub-system level" . *These activities are vital to push our present capabilities to a " third-generation" of technical sophistication and cost-reduction beyond the "second generation" involved in the EMBRACE programme (DS5).* The work in DS4 falls into two broad categories:

- Basic technologies applicable to all SKA concepts (DS4-T1; DS4-T2; DS4-T3)
- Basic technologies of low-cost phased arrays (DS4-T4; DS4-T5)

In the first category the teams will develop: i) front-end technologies involving the fabrication of semi-conductor devices optimized for radio astronomy rather than commercial and military requirements—the goals will be to combine manufacturability and low-cost with low-noise, high linearity and low power dissipation (DS4-T1); ii) strategies and technologies for the most cost-effective signal conditioning and processing systems—the goals will be to optimize the initial balance between analogue and digital processing approaches, the design of A/D converters and the optimum number of bits required at each stage in the data stream and to reduce the power requirements and cost of the electronics (DS4-T2); iii) methods for ensuring the RFI robustness and high data quality from the SKA from station level to full-array level, taking into account the different RFI environments at potential sites (DS4-T3). In the second category teams will develop: i) the basic technology of a wide-band antenna element suitable for close-packed phased arrays and the most cost-effective solutions for integrating the rf receiver components with these elements (DS4-T4); ii) cost-effective electronics for forming multiple independent fields-of-view from an individual coherent "patch of antenna elements (likely to be of order 100 elements) (DS4-T5); iii) cost-effective digital processing solutions for forming multiple "station-beams" within the separate fields-of-view. At all times we will be seeking to explore the potential of commercial-off-the shelf hardware (DS4-T5).

DS5 Aperture Array Demonstrator "EMBRACE" (see Figs. 8 and 9): the overall aim is to prove the viability and assess the scalability of the aperture array concept and to understand how to calibrate such a system to the required accuracies determined from the science and astronomical data simulations. To achieve these aims we propose: to construct EMBRACE, a network of aperture plane arrays including a ~500 m^2 "core" (equivalent in area to a medium-size parabolic radio telescope) and three smaller ~100 m^2 aperture arrays of identical design at different sites within Europe. This design will enable us to:
1) Develop basic SKA station-level architecture for this concept and to demonstrate the practicality of producing multiple, steerable, fields-of-view each containing many station beams (see Fig 8). EMBRACE will use "second generation" phased array technology for radioastronomy based on an evolution of the first generation THEA array developed by ASTRON (for further discussion section 3.1). *The EMBRACE "core" will be a ~10% prototype of an individual SKA "station" and will be the first of its kind for radio astronomy.* It will be sited close to the existing WSRT, which consists of fourteen 25-m diameter paraboloids. This location will facilitate testing the stand-alone *total power beams* of EMBRACE in comparison to a "standard" 25m parabola and also to test the *complex voltage beams* when EMBRACE is incorporated in a well-calibrated short-baseline (~3km) interferometer.
2) Test out the long baseline (100-1000 km) requirements of a multiple-field-of-view SKA and the requirements of real-time links combined with multiple-fields-of-view (see Fig 9, *right*). A total of four "remote" stations are required in order to test the data quality via the closure phase and closure amplitude quantities. Each stage of the assessment programme (total power; short and long baseline interferometry), provides a

more stringent test of data quality and handling ability than the previous one. Sufficient signal-to-noise ratio is available on the strongest sources to test out the data quality required for synthesising high-resolution "imaging" beams. It is also important to note that this is the only opportunity to test wide-area networking in the entire international SKA programme.

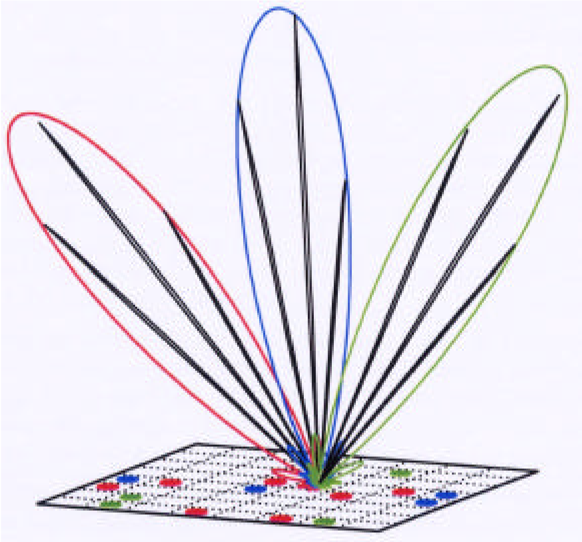
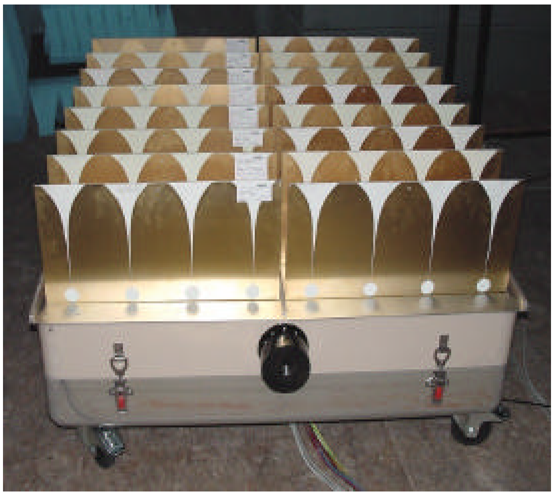


Fig. 8 A simplified representation of the hierarchy of an SKA "station" made up of an "aperture array". Demonstrating the practicality of such an array and developing the superior sub-systems required for the SKA are the main thrusts of SKADS (DS5 and DS4 respectively). The station is built up from a matrix of "patches", which are the basic coherently-connected structures built up from individual antenna elements. The area of the patches is likely to be a few m^2 with the area of the station being ~10,000 m^2. The size of the patch sets the angular area of a field-of-view; this is envisaged to be some tens of deg^2 at 1 GHz. As an example three "fields-of-view" are shown, each of which will be produced by the same number of beam-forming systems within a patch. Within each field-of-view other reception ("station") beams are formed – only a small fraction of which are shown for clarity. The station beams are formed by the coherently-phased addition of signals from all the patches by a much larger station-level beam-forming system. The pointing of both the fields-of-view and the station beams on the sky will be separately controllable by changing the phase relationships within the beam-forming systems. When the signals from all the SKA stations are combined centrally, much higher resolution "imaging" beams will then be formed within each station beam.



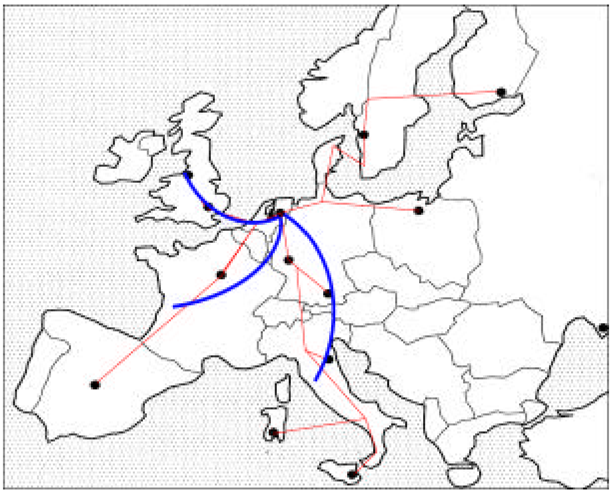


Fig 9 *Left)* A picture of a part (area 1 m^2) of the THEA array built at ASTRON to demonstrate fundamental aspects of the aperture array concept. The individual Vivaldi-antenna elements can be seen; the beam-forming system which produces two independent fields-of-view is within the cabinet beneath. The EMBRACE demonstrator system (in DS5) will be on a scale several hundred times larger than THEA, but its sub-systems will be an evolution of the THEA designs. *Right)* A visualisation of the wide-area SKA demonstration proposed for DS5-T3. Three systems are shown on this diagram: 1) the locations of the European radio astronomy observatories (dots); 2) the wide-band public optical fibre network which will be used to transport data to the Joint Institute for VLBI in Europe (thin lines); 3) a schematic of a set of representative SKA "arms" (as in Figure 3; thick lines). The proposed EMBRACE demonstrators in Westerbork, NL, Cambridge, UK and Manchester, UK can readily be connected to the fibre network; the linking of the EMBRACE demonstrator in Nancay, France (150 km south of Paris) to the network is via national (regional) matching funds.

DS6: Cylindrical Concept Demonstrator: the overall aim is to prove the viability and scalability of the cylindrical concentrator array concept. To achieve these aims we propose, in the BEST programme (Basic Element for SKA Training) to re-engineer a fraction (~25%) of the "Northern Cross"; a T-shaped cylindrical concentrator telescope in Medicina, Italy (Fig 10). An initial small-scale, nationally-funded programme has started at Medicina, and the step within SKADS is to re-engineer a larger part of the Northern Cross to obtain 8,000 m^2 of collecting area—an area comparable with that of a proposed SKA station (10,000 m^2). As well as testing the viability of the cylindrical reflectors, an important generic aspect of DS6 is the study of the *imaging* problems to be overcome when using multiple digitally-formed beams from a large collecting area. Particular issues are the accuracy of the calibration achievable in the face of RFI and RFI mitigation strategies. BEST is an order-of-magnitude larger in area than EMBRACE and hence is susceptible to a different range of calibration problems. In addition, *the results of the BEST programme will be available significantly earlier than EMBRACE*, probably in time for the Mid-term Review (DS7-T2).

SKAMP is another SKA-related initiative in Australia that involves the Molonglo Cross telescope of the University of Sydney. Since both BEST and SKAMP are projects relating to cylinder-array concepts, DS6 incorporates a collaboration and direct interactions between the Italian (CNR) group and the Australian group, who will work together to explore all aspects of the cylindrical reflector concept and related technologies. The skills and activities of the two groups are complementary.

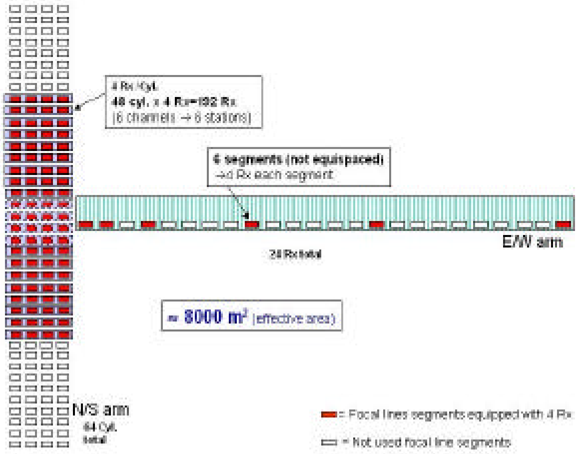


Fig 10. *Left)* The Northern Cross at Medicina, Italy. The North-South (N-S) arm made up of separate cylindrical collectors is seen, with the dark focal lines in each reflector standing out clearly. In the background the larger East-West (E-W) arm consisting of a single cylindrical reflector can be seen. *Right)* Parts of the N-S and E-W arms of the Northern Cross will be re-engineered in a three phase process; the first two of which are entirely nationally funded and the third is part of SKADS. In phase 1 data will flow from 4 focal-line receivers, on 1 N-S cylindrical concentrators (176 m^2 geometrical area) to the data processing room. In phase 2, data will flow from 32 focal-line receivers on 8 N-S cylindrical concentrators, (1400 m^2 geometrical area) to the data processing room. In phase 3 data will flow from a *wide-band* system involving 192 focal-line receivers on 48 cylindrical N-S concentrators and 24 focal-line receivers on 6 E-W single concentrators (~8000 m^2 effective area). In this last phase the E-W receivers (not equally spaced to lower the grating lobes) are introduced in order to produce satisfactory instantaneous coverage of the interferometer visibility-plane and hence imaging capability. Phases 1 and 2 will be completed in 2005, phase 3 in 2006.

DS7: Assessment of Preparatory Work and Studies: the aim is to provide a semi-continuous monitoring activity within the overall project, to provide a link between those supplying deliverables from the various *Design Study* Tasks and those assessing them, and to provide independent advice on the success, or otherwise, of the *Design Study* as a whole. DS7 must produce an objective, quantitative, comparative assessment of all the preparatory work—in line with the EC requirements that DS results should be assessed in "measurable and verifiable form". To this end we intend: i) to appoint a Design Study Scientist and a Design Study Engineer who will also play a significant role in the management of SKADS and act as natural communication channels to the International SKA efforts; ii) to involve several external, independent, consultants in the two main Design Reviews. *At the end of DS7 a preferred design to satisfy the multi-field-of-view requirement will be selected and we will then proceed to a single system design (DS8).*

DS8: Overall System Design and Preliminary SKA Plan : the aim is to produce i) an “end-to-end” architectural and functional design for the preferred concept and a costing, paying attention to the civil works required for the array; ii) a study of funding sources and iii) a preliminary project plan. These are the fundamental products of the SKADS *Design Study* and require us to pull together the results from the entire work programme and to incorporate technology foresight. The deliverable will take the form of a Square Kilometre Array “White Paper” that will contain a preliminary project plan to be submitted to the International SKA Steering Committee in 2008.

2.2.2 Multi-Annual Implementation Plan

As indicated before, SKADS is structured as eight different DS, which together form a coherent approach to achieving its aims. The Gantt chart in Fig 11 below indicates, in broad terms, the relation between the different DS and the Review and others dependencies marking other milestones. Table 4 lists the DS and their component DS-Tasks and gives milestones and deliverables. More details of the task descriptions are given in Annexe1 and in Gantt charts for the two demonstrator projects (DS5 and DS6) are given in Annexe 2. Apart from the Management task (DS1), most Design Study Tasks comprise up to 5 important sub-tasks, each having their own milestones. Most of the DS run for the four years planned for SKADS. An important overall milestone is the Interim Review two years into the study. At this point progress will be critically assessed by a Review Panel drawn from senior SKADS members and independent external scientists and industry consultants. The programme of work will be assessed, and strategic changes may be made based on the results of the review. The results of SKADS as a whole will be similarly assessed at the Final Review. More details on the management of SKADS are given in Section 4.1

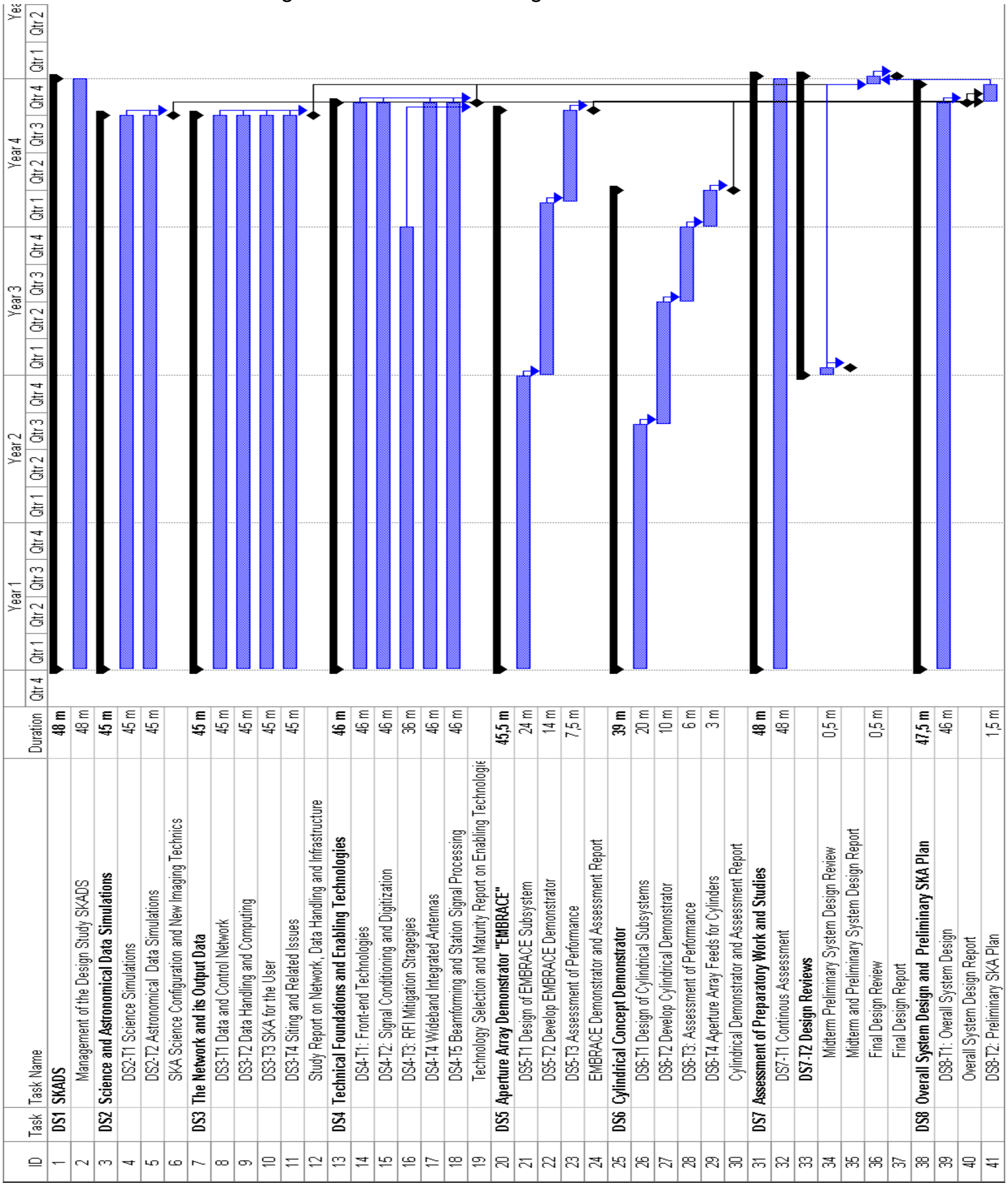


Fig 11: The overall timelines for the individual DS within SKADS

Table 4: The Design Study Tasks, relevant milestones and expected deliverables (for DS2-T1 in detail only for the first 18 month).

Design Tasks	Milestones @ (Sub)Task levels	Deliverables
DS1 Management of Design Study "SKADS"	**T0 to T0+48**	**Progress reports and Yearplans**
DS2 Science and Astronomical Data Simulations	**T0+45**	**SKA Science Configurations and New Imaging Techniques**
DS2-T1 Science Simulations	T0+6	First European SKA Science Simulations Workshop
	T0+12	First H1 Widefield Sky-Model
	T0+ 18	First Continuum Widefield Sky-Model
	T0+18	Second European SKA Science Simulations Workshop
DS2-T2 Astronomical Data Simulations	T0+2	First SKA-ADS Workshop
	T0+10	First Preliminary Report on SKA Configurations
	T0+22	Critical Review of Simulation Software
	T0+28	International SKA workshop on Large Datasets
	T0+37	Report on Optimal SKA Configurations
	T0+45	Report on New Imaging Techniques
	T0+45	SKA science and technical specification document
DS3 The Network and its Output Data	**T0+45**	**Study Report on Network, Data Handling and Infrastucture**
DS3-T1 Data and Control Network	T0+36	Study Report on Definition of Data & Control Transport System
	T0+ 45	Power Requirement and Implementation Scenarios Report
DS3-T2 Data Handling and Computing	T0+44	Study Report Concept Design and Demonstration of Central Processing Machine (HW&SW)
DS3-T3 SKA for the User	T0+44	Study Report on Distributed Grid-enabled Pipeline Data Reduction
	T0+44	Study Report on Data products-, Archiving- and Scientific Exploration Techniques
	T0+44	Study Report on Observing Modes and User Environment
DS3-T4 Siting and Related Issues	T0+30	Study Report on Siting and Related Issues
DS4 Technical Foundations and Enabling Technologies	**T0+46**	**Technology Selection and Maturity Report on Enabling Technologies**
DS4-T1 Frontend Technologies	T0+24 and T0+46	Interim- and Final Technical Report on Frontend Technologies
DS4-T2 Signal Conditioning and Digitisation	T0+24 and T0+46	Interim- and Final Technical Report on Signal Conditioning and Digitisation
DS4-T3 RFI Mitigation Strategies	T0+24 and T0+36	Interim- and Final Report on Implementation of RFI Strategies

DS4-T4 Wideband Integrated Antennas	T0+24 and T0+46	Interim- and Final Technical Report on Wideband Integrated Antennas for Aperture Arrays
DS4-T5 Beamforming and Station Signal Processing	T0+24 and T0+46	Interim- and Final Technical Report on Beamfoming and Station Signal Processing
DS5 Aperture Array Demonstrator "EMBRACE"	**T0+45.5**	**EMBRACE Demonstrator and Assessment Report**
DS5-T1 Design of EMBRACE Subsystems	T0+24	Design of EMBRACE Subsystems and Interim Report
DS5-T2 Develop EMBRACE Demonstrator	T0+38	EMBRACE Demonstrator
DS5-T3 EMBRACE Assessment of Performance	T0+45.5	Technical and Astronomical Assessment and Performance Report
DS6 Cylindrical Concept Demonstrator	**T0+39**	**Cylindrical Demonstrator and Assessment Report**
DS6-T1 Design of Cylindrical Subsystems	T0+20	Design, Develop and Demonstrate Subsystems and Interim Report
DS6-T2 Develop Cylindrical Demonstrator	T0+30	Cylindrical Concept Demonstrator
DS6-T3 Assessment of Performance	T0+36	Technical and Astronomical Assessment and Performance Report
DS6-T4 Aperture Array Feeds for Cylinders	T0+36 to T0+39	Study Report on Aperture Array Feeds for Cylinders
DS7 Assessment of Preparatory Work and Studies	**T0+24, T0+48**	**Reviews and Final Reporting**
DS7-T1 Continuous Assessment	T0 to T0+48	Quarterly Reports
DS7-T2 Design Reviews	T0+24 T0+48	Midterm & Preliminary System Design Review Report Final Design Review Report
DS8 Overall System Design and Preliminary SKA Plan	**T0+ 47.5**	**Overall System Design and Preliminary SKA Plan**
DS8-T1 Overall System Design	T0+46	Overall System Design Report
DS8-T2 Preliminary SKA Plan	T0+47.5	Preliminary SKA Plan

3. RELEVANCE TO THE OBJECTIVES OF THE SCHEME

3.1 Justification of the proposed Design Study

The overall scientific and technological need for SKADS: The international radio astronomy community has come together and agreed that the next major step in radio telescopes should be the Square Kilometre Array. The SKA's power will lead to a transformation of our knowledge of the overall structure of the universe, of many of its fundamental constituents and of its evolution; it will explore fundamental conditions for the emergence of life and may detect signals from other intelligent civilizations. The SKA may find the key to unlock the secret of Dark Energy, test one of the bed-rock theories of physics, General Relativity, to destruction and is likely to produce many fundamentally new and unexpected discoveries.

In order to achieve these spectacular goals we cannot just build a system similar to those already in use. Present-day radio arrays are typically priced at €5,000 and €10,000 per m^2 when all the costs are added up. *Thus, while an array with a collecting area of 10^6 m^2 could be built now, it would cost an unaffordable €5B-€10B and, importantly, it could not meet all the key science goals identified by the international community for the SKA.* The challenges being faced by radio astronomers and engineers are therefore: first, to reduce overall construction cost to ~€1000/m^2; second, to maximize the observational capabilities and flexibility of operation; third, to design-out obsolescence by designing-in opportunities for upgrade paths as technological capabilities improve; fourth, to minimize the maintenance and running costs. Even if the cost per unit area is slashed, at an overall price of ~€1B there may well be only a single SKA built and we must strive to create a design which extracts the ultimate from this large investment in pure science.

How is all this to be achieved? Some basic strategies are clear. First any realizations of the SKA must take full advantage of industrial R&D in fibre optics and electronics for the transport and processing of massive volumes of digital data. *The science output of SKA will depend directly on the amount of computational power which can be brought to bear.* We must aim to exploit the convergence of radio and digital computing technologies—replacing hardware with firmware, or software and allowing unprecedented versatility via the use of programmable processing engines. Then we must seek to exploit emerging technologies from the consumer and telecommunications field and seek to use commercial off-the-shelf components or systems where possible. We must plan, right from the start, for the evolution of SKA capability since the ultimate signal processing capacity will not exist in ~2015. Last, but certainly not least, we need to develop innovative, cost-effective, new concepts for collector systems. The choices for the latter being explored in SKADS are based on low-cost phased arrays—we explain our strategy on phased arrays in more detail below. Alternative technologies for the SKA antennas are being investigated by the regional SKA consortia and institutes around the world. These other concepts are mostly based on driving down the cost of paraboloids of a wide range of sizes and configurations. For example the US SKA consortium is developing a concept based on small (6-12m diameter) paraboloids, produced by the satellite TV industry.

Timeliness of SKADS: The international selection of the technical design i.e. the optimum architecture (or architectures), is scheduled for 2008. A strong driver of the international community is the desire to present a unified and well worked-out concept for the SKA in time for the next US National Science Foundation's "Decadal Review" of astronomy, for which consultation starts in 2009. In order for any concept to be considered in the 2008 selection process, the proponents must have constructed and tested "engineering/proof-of-concept demonstrators" (DS5; DS6), and must have undertaken and assimilated a wide range of complementary R&D, scientific and technical feasibility and assessement studies (DS2; DS3; DS4; DS7; DS8). As well as testing the concept's ability to deliver the science goals, a principal target is to establish cost equations of the systems and sub-systems, and to estimate the derivatives with time (i.e. technology foresight) and area (i.e. economies of scale). The range of scientific and engineering skills and knowledge required are beyond the scope of any individual European country and hence progress requires funding on a trans-national basis. *The EC Framework 6 Design Study instrument is, therefore both ideally-suited and ideally-timed for meeting this purpose.* It is noteworthy, that many international partners have joined in with the SKADS proposal, bringing in a range of unique capabilities. SKADS is therefore acting as an international, not just a European cohering mechanism for SKA development. It is also noteworthy that, following the recommendation for SKA development funds in the 2000 US Decadal Review, the US SKA Consortium is submitting a proposal to the National Science Foundation for $30M in March 2004. If funded, the comparably-sized European and US R&D programmes will be by far the major components in the international effort to develop the SKA.

Phased arrays and radio astronomy: Phased arrays are well known to antenna engineers and have been much-used in the aerospace and military arenas. Pulsars, whose study provides one of the SKA's key science drivers, were discovered in Cambridge, UK with a low-frequency (~80 MHz) phased array employing several beams and won their discoverer a Nobel Prize. In general, however, phased arrays have been little used in radio astronomy and certainly not in the sophisticated form which we envisage for SKA. With the march of technology we believe that the time has come for a paradigm-shift in radio telescope design and our principal goal in SKADS is to establish the credibility of large-area phased arrays (aperture arrays) for the SKA. *Aperture arrays offer the possibility of a quantum jump in terms of the size and number of independent fields-of-view and other operational flexibilities, and also of forging a fundamental link with IT technologies whose unit costs are continuously reducing with time.*

Why cannot we just scale-up existing phased-array designs? The answer is two-fold. First their cost per-unit-area is too high and second their capabilities are not optimized for radio astronomy use (receive only) but invariably for radar applications (transmit and receive). In the latter minimising the system noise level and maximizing the main beam efficiency, are not such critical design drivers as they are for radio astronomy. Astronomical applications also place different demands on our knowledge of the beam-shape and sidelobes compared with radar applications. The SKA will be a multi-fielding *imaging* instrument with extra-ordinary instantaneous sensitivity coupled with the requirement to integrate on selected areas of sky for hundreds of hours; as a result, each field-of-view will be full of cosmic radio sources. In order to deliver the required dynamic range (>10^7: 1) and image fidelity, the overall reception pattern must be extremely well-understood at all times. We cannot simply change the complex antenna weights to suppress sidelobes at the expense of main beam efficiency—in contrast to the radar situation there is no way to increase the signal level from a distant radio source! Achieving this control of the reception pattern requires a highly-accurate beam-forming system, coupled with a sophisticated understanding of the behaviour of close-packed antenna elements as a function of angle from the zenith. Achieving the required level of understanding is one of the aims of SKADS. Another problem to be understood and overcome, is the effect of RFI mitigation techniques; for example creating and steering reception nulls, inevitably affects the entire reception pattern.

The best way to establish the credibility of aperture arrays is to construct a network of stations in order to mimic the basic functions of the future SKA network—this is the rationale behind the EMBRACE demonstrator programme (DS5). *A critical step is to show that an aperture array of a size comparable to that of a conventional medium-sized paraboloid, can perform well as a "calibratable" multi-field radiometer with wide-angle scanning capabilities and at least two independently controlled fields-of-view.* Since it is critical to deliver and test EMBRACE well before the end of this *Design Study,* we cannot expect to optimise all aspects of the design which will therefore be a (second-generation) evolution of the existing (first-generation) THEA design developed by ASTRON[5] (see Fig 9). The first 18 to 24 months of the EMBRACE programme (DS5-T1) is set aside for this phase. The noise performance target for EMBRACE is 100K (cf. the final target of <50K for SKA via DS4-T1), and EMBRACE will only be sensitive to a single polarisation. In DS4, however, all the sub-systems of a dual-polarised phased array will be developed continuously over the full period of SKADS into third-generation technology. At the end of the study, we will therefore be confident of predicting the performance of a large-area aperture array. And with the several EMBRACE stations separated by distance of 100s of km, it will also be possible to test out the means by which high-resolution images will be formed from an SKA constructed from aperture arrays. In summary the EMBRACE system is a complete test-bed for the most ambitious of the European concepts for the SKA. It is important to note that the SKA's International Engineering Management Team (IEMT) strongly endorsed the EMBRACE concept in its recent review[6] of all the SKA concepts for the International SKA Steering Committee. A letter of support from the chairman of the IEMT is attached in Annexe 3.

Since the science drivers associated with low-frequencies and large, multiple, fields-of-view are so compelling, we are also developing a concept involving multi-beaming with a cylindrical reflector array (DS6). Cylinder arrays have potential to be viable large-area survey instruments, and although they offer much less operational flexibility compared with aperture arrays they may have a real advantage in terms of cost. The BEST programme itself can be completed more cheaply and more quickly than the EMBRACE programme and, with an area comparable to that of an SKA "station", will provide unique information on the performance of sensitive digitally-formed adaptive beams in the face of RFI. The BEST programme is also tied-in with the SKAMP project of our Australian participants. The shared activity between groups in Italy and Australia will broaden the science and technology base for the exploration of the cylinder array concept.

Forging of new links: *The challenging multi-disciplinary requirements of SKA-related R&D, will forge close research linkages between European radio astronomy observatories, technology manufacturers and research institutions – both in academia and in industry. The links between these institutions will establish critical*

---

[5] More details of the THEA project can be found at http://www.astron.nl/tl/thea.htm

[6] See SKA Memorandum Series: Number 41 at http://www.skatelescope.org/documents/index.shtml

masses of people and knowledge involving both basic technology and potential novel uses of the technology. Because its combination of challenging requirements, radio astronomy provides an ideal focus for such R&D which relies on sharing of knowledge and expertise. The scale and style of the SKA project as whole, makes the development of a close working relationship with industry mandatory—an unusual feature for a pure-science-driven project. And although the timescale for completing the SKA is long, there are many opportunities for collaborative and/or sub-contracted pre-competitive R&D and construction in the project definition and proof-of-concept stages i.e. SKADS. Other types of involvement (project management; construction; commissioning; operation and maintenance) will come after the full SKA project is funded. The results of the SKA-related R&D will inevitably be mutually advantageous for European industry and pure science and the partners in this proposal are forming these relationships with industry as part of the SKADS programme and its components of national matching funding.

Deliverables and exploitation: The deliverables are listed in Table 4; for the feasibility studies they are in the form of reports. The main hardware deliverables from SKADS are the EMBRACE aperture array demonstrators and the BEST cylinder array demonstrator. These will allow the European and international radio astronomy community to assess the capabilities of new styles of data gathering techniques. The deliverables from DS4 are third-generation radio-astronomy sub-systems. The generic technology developed in DS4-T1; DS4-T2 and DS4-T3 can be exploited by radio astronomers on much shorter timescales than that of the SKA. In particular, the development of low-cost, improved performance, semi-conductor technologies for uncooled SKA applications (DS4-T1) will certainly have potential spin-off in the commercial arena. The developments of low-cost phased arrays with digital beam-forming (DS4-T4; DS4-T5) will have a long term benefit to radio astronomy as “smart antennas” for focal-plane applications in existing large radio telescopes and also has obvious spin-off potential. The SKADS work programme also provides a long-term educational platform for trainees at all levels (vocational to post-graduate). SKA is a ready-made international exchange vehicle; benign in purpose, non-threatening commercially, and is generating great goodwill.

Expected users of the results: all radio astronomy institutes and industrial partners. The innovative work programme being undertaken within SKADS is undoubtedly required for the next generation radio astronomy systems, and all at a cost which makes their study likely to result in industrial spin-offs in the arena of telecommunications as well as for SKA.

The partnership policy in respect of IPR: the proposed policy is that new results will be in the public domain and made available to all interested parties. However, in view of the developing relationship with industry and the need to protect existing IPR, the Consortium Agreement will have to be carefully drawn. The partners have experience in drawing up three previous such agreements associated with EC-funded programmes; most recently the FP6 Integrated Infrastructures Initiative, “RadioNet”.

Exploitation and dissemination: The work being undertaken in SKADS will put the partners in a strong position to contribute to the overall design of the next generation radio telescope. If, as we confidently expect, phased arrays will form a vital element of the design adopted for the SKA, the specific technical expertise developed in SKADS will put the European radio astronomy community, and European industry, in a leading position to bid (but not necessarily with preferred status) for final SKA contracts. There is also an obvious commercial spin-off potential of low-cost, high-performance phased arrays. It is traditional in the radio astronomy field that new technical results are published in the open literature: they will also be presented at appropriate conferences.

Enhancement of existing infrastructures: A regionally-funded high-bandwidth optical fibre link between the Medicina station and GEANT will be implemented in the first half of 2004. A similar regionally-funded high-bandwidth optical fibre link is planned, as part of the SKADS matching funding,to join the Nancay Observatory to GEANT and hence JIVE. In both cases the forging of the link to JIVE, will enable the existing large radio telescope at Medicina and Nancay to take part in highly-sensitive real-time European VLBI observations. In terms of increased access and more efficient use we point to the exploration and development of GRID-based data processing methodologies within SKADS. The SKA is likely to generate more data than any other scientific instrument of its day, and hence critically depend on, and hence force, the development of the GRID. Alongside this the radio astronomy community will continue to be a major user of pan-European public data transport networks such as GEANT, and hence will also push forwardtheir development.

Risk Analysis: The multi-faceted structure of SKADS is such as to spread the risk among tasks of very different natures. The basic feasibility studies (DS2; DS3), are inherently low-risk activities. There are risks involved in the technology development programmes (DS4) but these are also spread and are again relatively low, since they are based on developments of current work and involve leading experts in their fields. The EMBRACE programme (DS5) is based on an evolution of the existing THEA technology while the BEST programme (DS6) is also based on developing an existing programme. We are therefore highly confident that all our goals are achievable but there is the normal level of risk associated with the exact finishing date. We will be constantly monitoring progress via the DS7 Tasks.

3.2 Exploring the feasibility of the infrastructure

The SKA, with an estimated capital cost of €1 billion, is a massive project for astronomy and is clearly of such scope that its construction and operation will require the collaboration and cooperation of more than one country. This fact has been recognised and welcomed from the start, and is reflected in the structure of the International SKA Steering Committee (ISSC). The membership of the ISSC was set up in such a way as to mirror the expected contribution of different regions and countries: ~1/3 from Europe; ~1/3 from the USA and the remainder from other participating countries (currently Australia, Canada, China and India).

Obtaining the requisite funding from countries/areas which have a diverse range of funding opportunities, timescales and constraints will be a challenge. However, other international scientific projects have been successful, and with the appropriate political endorsement, we are confident that the SKA will also succeed.

On the European scene, several things need to happen:

- A legal entity, capable of receiving funds, must either exist or must be created;
- Political endorsement of the project at the national and broader level must be obtained;
- The timescale for the appropriation of funds must be coordinated and a mechanism established to ensure a smooth and appropriate cash-flow.

Legal Entity

Currently, European SKA efforts are coordinated through the European SKA Consortium (ESKAC), a loose organisation of radio astronomy facilities from 8 countries. It is envisaged that the ESKAC will be succeeded in a more formal sense by the SKADS Board. As described below in Section 4.2, the SKADS Board will work with the Board of the RadioNet I3 to explore the format and structure of an appropriate organisation that might provide coordination and coherence to all of radio astronomy within Europe. The SKA will be the largest activity that this new organisation might oversee. It is clear from the experience gained in previous international scientific endeavours (e.g. ALMA), that Europe needs to speak with one voice within large-scale global projects.

The establishment of a new organisation as a legal entity, would then provide the appropriate mechanism for the receipt and disbursement of funding to enable a strong and major European role within the broader SKA project.

On the global-scale the ISSC will investigate the necessity for, and the nature of, any legal entity required to construct and operate the SKA. At the current time an interim solution is being explored in which the OECD might act as banker for the SKA project; a move designed to enable the easy transfer of the modest funding required in these early days of the project.

Political Endorsement

Since it is likely that the majority of the funding for the SKA will come from national governments, it is self-evident that for the SKA to be constructed the project must be identified as a scientific priority by the participating nations. The SKA is already established as a priority in several countries and is expected to become so in others as their review processes proceed. As a future scientific facility, it will also be vital that the SKA is taken-up by supra-national bodies as the European Strategic Forum for Research Infrastructures (ESFRI) and the OECD's Global Science Forum (GSF).

Funding

As part of the SKADS project the Board will investigate possible funding mechanisms for the construction of the full SKA. Discussions on the possible facilitating role that the EIB could play have already taken place under the auspices of the Directorate-General for Research, which sponsored two meetings between representatives of the astronomy community and the European Investment Bank (EIB). These meetings occurred in 2002/2003 in Brussels. EIB officers laid down the ground-rules whereby low-interest loans might be available for the construction of the SKA. It is clear that such a loan would only be possible if supported by guarantees from the national governments supporting the project. It was also clear that the loan would be an excellent instrument for enabling a cash-flow designed to support a construction project. The SKADS Board will pursue these discussions as an integral part of the project.

Regional and trans-regional dimensions of the SKA and its environmental impact.

The site for the SKA will be selected by the ISSC, in 2006. Technical advice on the site selection will be provided by an ISSC-appointed committee, the Site Evaluation and Selection Committee (SESC). The SESC has a broad international membership and has the following remit:

- To evaluate submissions from the candidate countries on the suitability of their sites for the SKA
- To define and implement the necessary radio frequency interference (RFI) tests.

At the time of writing, four countries have responded with detailed expressions of interest and have produced the necessary white papers: Australia, China, S.Africa and the USA. The European SKA Consortium has concluded that the best site for the core of the SKA cannot be in Europe—the main reason being the need to maximize the use of the radio spectrum. The SKA will *a fortiori* wish to observe in frequency bands outside those in which measures for the protection of astronomical observations (from unwanted radio emissions by other spectrum users) have been defined by the international and national regulatory bodies. There are no sites within Europe, which can compare with sites in other parts of the world in terms of very low population density—a crucial consideration regarding the radio interference environment of the SKA. Scientists and engineers from Australia and South Africa are participating in SKADS.

We understand that locating the SKA outside of Europe is not a barrier to obtaining Europe's full share of the construction and operating costs of the SKA; the ALMA project acts as a precedent in astronomy.

The process of site selection is on-going. The detailed studies of the potential sites are currently underway are being funded by both the nations involved and the ISSC. The outcome of the current work will be a detailed report on all aspects of the potential sites: scientific, political and environmental. The report will be the major document that is used in the selection of the site. The international site selection will occur part-way through SKADS. In DS3-T4 we will study more detailed aspects of the chosen site and its impact on low frequency multi-beaming concept.

If SKADS is successfully funded, the SKADS board will offer assistance to the ISSC in its efforts to establish an International Radio Quiet Zone (IRQZ) around the site that is eventually selected; this will involve negotiations within the ITU structure. The IRQZ will be a unique resource that will have enormous benefit to the SKA.

Environmental impact: this study will form part of DS3-T4

4. QUALITY OF MANAGEMENT

4.1 Management and Competence of the participants

The network collaborating in the SKA Design Study is a large superset of those institutes involved in the successfully-funded FP6 Integrated Infrastructure Initiative called RadioNet. Many of the participating institutes have a long history of working together, primarily resulting from the long-standing success of the European VLBI Network (EVN). Therefore, a management plan has been constructed that is derived from that adopted for RadioNet and builds upon the close links that already exist within that team.

SKADS will be run by a management board, whose members comprise the Directors or representatives of all institutes involved in the activity. Members of the Board will have authority to make decisions on behalf of their institutes. A Consortium Agreement, modelled on that drawn up for RadioNet, will be implemented.

The day-to-day management of SKADS will be led by the SKADS Coordinator, supported by a SKADS Management Team (SMT). The Coordinator will be a member of the Board, but not its Chairman. The Coordinator will be the contact person with the European Commission, will be the person through whom the EC contribution is paid and will be responsible for administering the distribution of the financial contribution according to decisions taken by the SKADS Board regarding its allocation to participants and activities. The position will not be funded by SKADS but by the Coordinator's institute; it will require ~25% of the Coordinator's time. Ir. Arnold van Ardenne of ASTRON, NL will be the SKADS Coordinator.

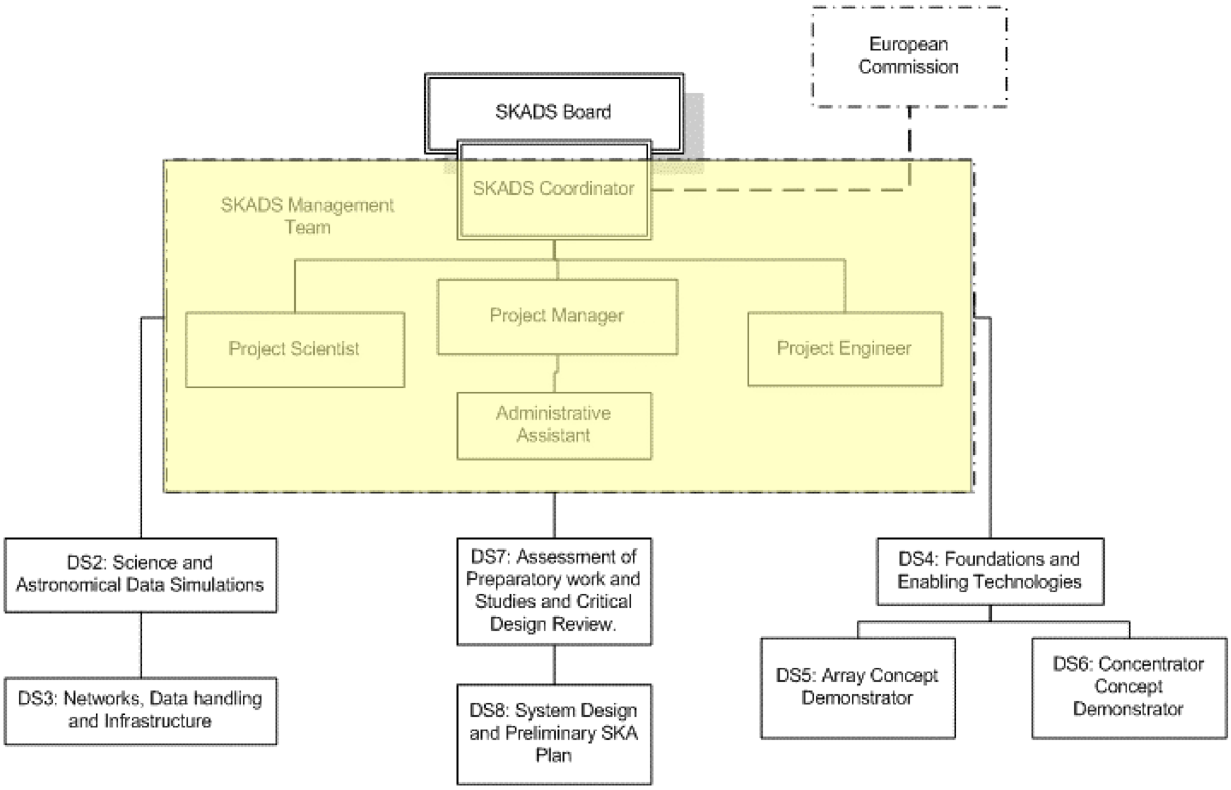


Fig 12: The SKADS management structure

The Board will elect a Chairman who will serve for a period of two years. 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. New applicants to SKADS will be accepted only by a unanimous decision of the Board.

A smaller Executive Committee consisting of the Chairman and vice-Chairman of the Board, the SMT and the leaders of the Design Study tasks will be appointed. This committee will be chaired by the Coordinator and will oversee the day-to-day implementation of the SKADS programme. Due to the necessary complexity of this Design Study the Executive Committee will be the essential tool that enables good communication between the participants and will monitor the progress of the programme elements. The structure of the SKADS management is shown in Figure 12. The responsibilities of the Board, the Executive Committee and the SMT are listed in Table 5.

Table 5: SKADS Committees

Body	#	Principal activities	Meetings
SKADS Board	20-25	- Oversee the operation of SKADS - Develop annually an 18-month plan for the strategic direction of the SKADS project and the distribution of resources therein. - Receive and approve progress reports from the Executive Committee and the SMT. - Confirm the appointments of Project officers and the leaders of the Design Study tasks.	Meeting – 2 times per year
Executive Cmte	~11	- Monitor progress of the SKADS activities against the milestones agreed by the Board. - Receive progress and financial reports of all activities via the SMT. - Receive periodic reports from the Design Study Task leaders. - Act on strategic decisions and recommendations made by the SKADS Board. - Report to the Board on a regular basis on the progress of SKADS and on any strategic issues requiring attention.	Telecon – 6 weeks
SKADS Mgmt Team (SMT)	5	- Commission and receive progress and financial reports from all SKADS activities. - Commission and receive plans for next stage of SKADS programme from all activities. Pass to the Executive Committee and Board for review. - Assemble reports, pass to the Executive Committee for approval by the Board. - Submit approved reports to SKADS coordinator for submission to the EU. - Manage the SKADS budget, including reconciliation of annually audited accounts. - Maintain all financial, administrative and statistical records for review by the Board. - Distribute funds to all SKADS facilities/activities. - Provide Secretariat support for the SKADS Board and Executive Committee.	Telecon – 2 weeks

The SMT will be funded or part-funded by SKADS. Staff involved will be the project manager (PM: 1.0 FTE); the project scientist (PS: 0.4 FTE); the project engineer (PE: 0.4FTE) and administrative support (0.5 FTE). Brief job descriptions for these posts are given in Table 6. Table 7 lists the projected costs of the management of SKADS. Note that the PE and PS functions are fulltime functions for SKADS but besides their role on the SMT described here, 0.6 of these functions are part of the DS7 task acting in an assessment, overall system design and coordinating role.

Table 6: Responsibilities of SKADS Officers

Position	Responsibilities
Project Manager	Will be responsible for the day-to-day operation of SKADS and the SMT; Will be responsible for the detailed management of all financial aspects of SKADS; Will receive financial and progress reports for all SKADS activities; Will be responsible for coordinating the generation of reports, both technical and financial; Will be the primary contact person for technical details regarding contractual issues; Will be the contact person for all the DS-task leaders. Will be responsible for industrial and educational relations and for in- and external communication (e.g. public outreach);
Project Scientist	Will be the scientific eyes and ears of the coordinator; Will be responsible for the scientific oversight of the SKADS activities Will attend meetings of the various activities and to report back to the coordinator and the Board on scientific aspects.

	Will be responsible for running the SKADS web-site; Will play a facilitation role in education and public outreach; Will be responsible for the minuting of the Board meetings. Will support person for DS2 and DS3. Will be involved in the continual assessment and reviews of the SKADS project (DS7). Will be the contact point to the International SKA Project Scientist
Project Engineer	Will provide the technical oversight of the SKADS activities Will attend meetings of the various activities and to report back to the coordinator and the Board on engineering aspects. Will coordinate the involvement of industry; Will be the contact person for DS4, DS5 and DS6. Will be heavily involved in the continual assessment, overall system design and reviews of the SKADS project (DS7). Will be the contact point to the International SKA Project Engineer.
Admin Asst	Will provide all administrative support to the SMT

It is not necessary that the whole management team reside in the same institute as the coordinator. However, the Project Manager and Administrative Assistant should be located with the Coordinator. If split between institutes, the management team will require bi-weekly tele- or video-conferences.

Table 7: Management Costs of SKADS

Activity	Costs p.a. incl 20%	EC contribution	Total request (4 years)
Personnel	€196,000	100%	€784,000
Travel budget	€39,200	100%	€156,800
Admin. Costs	€4,000	100%	€16,000
Annual Total	€239,200	100%	€956,800
	Year 1 only		
Computers	€5,000	100%	
Total request Assume, PM, PS and PE at 80 Keuro/year; administrative staff at 40 Keuro/year. A one-off purchase of computing equipment for the SMT will be required in year 1. Annual travel costs calculated as €22,000 for SMT staff and €20,000 for SKADS Board travel per year.			€961,800

Management of SKADS Funds

Funds for the SKADS project will be received by the Coordinator, and will be distributed to the participating institutes as agreed by the SKADS Board, and in accordance with the plan agreed with the EC. Financial dealings will be in accordance with an institute's financial policies and procedures. Each institute will be required to conduct an annual audit of costs following their usual policies.

Each Design Study leader will be allocated a budget for the activity. The funds will be transferred to the institutes participating in an activity. The DS leader will, in cooperation with a designated contact person at each institute, ensure that the funds are spent in a manner required to achieve the goals of the activity.

Link with RADIONET

The RadioNet I3 is a collaboration of existing radio astronomy facilities and technology groups focused on improving the current suite of European facilities for the benefit of European astronomers. RadioNet is a 5-year programme and is expected to have a long-term structuring effect on radio astronomy in Europe; one of its networking activities will be studying, and possibly beginning the implementation of, models for the future structure of radio astronomy in the era of the SKA. It is vital that there be strong, formal and visible links between SKADS and RadioNet, over and above those that exist within the institutes participating in both programmes. To that end, the following principles have been adopted:

1. The coordinator of RadioNet will be an at-large member of the SKADS Board; the SKADS coordinator will have the same role on the RadioNet Board
2. The SKADS web-site will be hosted on the RadioNet web-site (http://www.radionet-eu.org).
3. Members of the Boards of both projects will collaborate on the RadioNet networking activity mentioned above.

Management and communication within the Design Studies:

Senior staff members at the leading participants in SKADS are experienced in the management of EC-funded projects. ASTRON has led a Framework 4 RTD project; UMAN leads a current Framework 5 RTD project ("FARADAY"); UMAN leads the new FP6 I3 Project "RadioNet". The project manager for SKADS (Dr. P.D. Patel, ASTRON) has managed a Framework 5 industrial RTD project "CAST" (Configurable-radio with Advanced Software Technology). Many other SKADS participants have participated in these projects, sometimes as sub-project coordinators (e.g. ASTRON, IRA; TCfA) . The main Australian participant (CSIRO) is also well-versed in EC requirements, as a self-financing partner in the Framework 5 FARADAY project mentioned above. *There is therefore a good understanding of the communication and reporting requirements throughout the SKADS collaboration.* The already close relationships between many of the participants, alluded to above, will aid this. Our experience has shown that:

- bi-annual meetings of two days duration, with a full set of meeting notes as the outcome, are both necessary and sufficient to keep teams up-to-date;
- well-structured Annual reports, following one of these meetings, are vital both for accountability and also help to cement the relationships within the team;
- at an appropriate time one of the bi-annual meetings becomes a mid-term review meeting.

Interspersed between these meetings and reports should be:

- monthly teleconferences and video conferences, also properly minuted;

All the meeting reports, and teleconference minutes should be placed on the web.

These generic management and communication tools will be common to all the DS within SKADS; however some specific comments on the individual DS are appropriate:

DS2: Will be coordinated by JIVE in close collaboration with the University of Oxford. The science and technical simulations programme involves a large fraction of the participants in the SKADS programme and hence management of this DS therefore requires particular care. The role of Design Study Project Scientist is certainly vital for continuous coordination. The most critical components of the programme will be concentrated in a few centres with the necessary expertise (e.g. Oxford for cosmology, OPAR for numerical simulations, OSO for array configurations). The main centres have already established cross-links which will be supported by employing EC-funded researchers who will split their time between these centres e.g. Oxford and JIVE plan a joint appointment to work at the interface between the science and technical simulations who can expect to also spend a substantial period of time working with the supercomputer facilities at Swinburne University of Technology.

DS3: Will be coordinated by ASTRON. The experience of the LOFAR team will be invaluable for this study.

DS4: Will be coordinated by the University of Manchester. As well as the listed participants, it is intended that a significant fraction of this R&D programme will be carried out by UK industry (in addition to the participants BAE and Qinetiq), financed entirely from national funds. Thus there is both a UK national and a European coordination activity to be carried out. It is intended that the University of Manchester will host a SKA Research and Technology Coordination Centre (SKA RTCC) as a "virtual centre of excellence for SKA technology" directed by a senior staff members of the University. The Design Study Engineer will also play an additional, vital, coordinating role.

DS5: Will be coordinated by ASTRON, as a significant level of experience resides within ASTRON through its involvement in the design and construction of the THEA system. This task is at the heart of the SKADS proposal and interleaves with DS4. The particular importance of team building and communications is recognized, and ASTRON has experience in dealing with both industry and research institutes. ASTRON also recognizes the importance of setting up design teams for the RF tiles and the digital signal processing as soon as possible in 2004.

DS6: Will be coordinated by IRA: DS6 is largely a collaboration between IRA and U. Sydney with some participation from elsewhere. This means that the management is relatively straightforward and close links are already developing between the main participants.

DS7: Will be coordinated by OPAR: the main tasks is to organize the interim and final assessment reviews which will include independent consultants.

DS8: Will be coordinated by the University of Manchester: This DS will not be required until very close to the end of the study, and its format and structure will be decided closer to time.

Benefits to the community of non-EU participants:

Australia (CSIRO; U. Sydney and other universities): potential site for SKA and hence detailed knowledge of the environment; development of the SKAMP cylinder array concept in concert with BEST in DS6; long-experience in SKA concepts in general and involvement in SKA international planning ; high technology capabilities for radio astronomy instrumentation in general and development of low-cost integrated receiver technology with national funds in particular; large university/academic interest in science potential of SKA, in particular in cosmological studies via HI observations.

Canada: long-experience in SKA concepts and involvement in SKA international planning; national development of phased array technology for radio astronomy and SKA (hence contribution with DS4 and DS5); design of high throughput correlator systems for radio astronomy (potential link with DS3).

South Africa: potential site and hence detailed knowledge of the environment; high technology capabilities for radio astronomy instrumentation. Substantial national funding in place to support SKA R&D, particularly in collaboration with Framework 6.

Russia: design and experience in the operation of a unique low-frequency dual-beam phased array at Puschino Observatory. The link with Puschino therefore offers an exceptional opportunity to gain immediate experience of calibration methods in a radio astronomy context.

Table 8: Participants, their planned tasks of involvement, role and estimated size of the research effort in professional person-months

Parti-cipation No.	Participant	Tasks	Role	Size of research effort (personmo.)
1	ASTRON	DS1	Task Leader SKADS Coordination and Management	72
		DS2-T2	Participant in Astronomical Data Simulations	24
		DS3 DS3-T1 DS3-T2 DS3-T3 DS3-T4	Task Leader The Network and its Output Data Participant in Data & Control Transport Systems Coordinator of Array Data Handling Participant in SKA for the User Participant in Siting and Related Issues	12 24 48 12 18
		DS4-T1 DS4-T2 DS4-T3 DS4-T4 DS4-T5	Participant in Frontend Technologies Participant in Signal Condit. and Digit. Participant in RFI Mitigation Strategies Coordinator of Task Wideband Integrated Antennas Participant in Beamforming and Station Signal Processing	36 24 24 48 36
		DS5 DS5-T1 DS5-T2 DS5-T3	Task Leader EMBRACE Demonstrator Coordinator of Design EMBRACE Coordinator of Develop EMBRACE Participant in EMBRACE Assessment of Performance	48 240 84 36
		DS6-T4	Coordinator Aperture Arrays for Cylindrical reflectors	4

		DS8-T1 DS8-T2	Participant in Overall System Design Coordinator of T2: Preliminary SKA Plan	24 2
2	University of Manchester	DS2-T1	Participant in Science Simulations	72
		DS3-T1 DS3-T3	Coordinator of Data Handling & Control Transport Systems Participant in SKA for the User	36 24
		DS4 DS4-T1 DS4-T2 DS4-T4 DS4-T5	Task Leader Founding and Enabling Technologies Coordinator of Frontend Technologies Participant in Signal Conditioning and Digitization Participant in Wideband Integrated Antennas Coordinator of Beamforming and Station Signal Processing	36 108 12 72 108
		DS5-T1 DS5-T2 DS5-T3	Participant in Design EMBRACE Participant in Develop EMBRACE Participant in EMBRACE Assessment of Performance	48 48 32
		DS8 DS8-T1	Task Leader Overall System Design and Preliminary SKA Plan Coordinator of Overall System Design	8 48
3	Joint Institute for VLBI in Europe (JIVE)	DS2 DS2-T1 DS2-T2	Task Leader Simulations Participant of Science simulations Coordinator of Astronomical Data Simulations	12 12 48
		DS3-T3	Participant in 'SKA FOR THE user'	36
		DS5-T3	Participant in EMBRACE Assessment of performance	30
		DS6-T3	Participant in Cylindrical Concept Assessment of performance	18
4	L´Observatoire de Paris (OPAR)	DS1	Participant in SKADS Coordination and Management	38
		DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations	84 24
		DS3-T3 DS3-T4	Participants in SKA for the user Participant in Siting and related issues	10 10
		DS4-T1 DS4-T2 DS4-T3 DS4-T4 DS4-T5	Participants in Frontend Technologies Coordinator of Signal conditioning and digitization Participant in RFI Mitigation strategies Participant in Wideband integrated antennas Particpant in Beamforming and station signal processing	66 64 96 60 18
		DS5-T2 DS5-T3	Participant in Develop EMBRACE Participant in EMBRACE Assessment of Performance	48 28
		DS7 DS7-T1/T2	Task Leader and SKADS Management Coordinator - Assessment of Work (excluding external consultants)	12 60
5	Instituto di Radioastrono-mia (IRA)	DS2-T2	Participant in Astronomical Data Simulations	84
		DS3-T1 DS3-T2	Participant in Data & Control Transport Systems Participant in Array Data Handling	48 48

		DS4-T1 DS4-T2 DS4-T3 DS4-T4 DS4-T5	Participant in Frontend Technologies Coordinator of Signal Conditioning and Digitization Participant in RFI Mitigation Strategies Participant in Wideband Integrated Antennas Participant in Beamforming and Station Signal Processing	36 48 12 18 18
		DS6 DS6-T1 DS6-T2 DS6-T3 DS6-T4	Task Leader Cylindrical Concept Demonstrator Coordinator of Design CC Demonstrator Coordinator of Develop CC Demonstrator Participant in Cylindrical Concept Assessment of Performance Participant in Aperture Array Feeds for Cylinders Participant in Aperture array feeds for cylinders	36 96 24 24 1
6	FG-IGN	DS2-T1	Participant in Science Simulations	2
		DS3-T3	Participant in SKA for the User	48
		DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas	48 48
		DS8-T1	Participant in Overall System Plan; Survey of Potential Industrial Involvement	3
7	Max Planck Institute für RadioAstrono-mie (MPIfR)	DS2-T1 DS2-T2	Participant in Science Simulations Participants in Astronomical data simulations	18 18
		DS4-T5	Participant in Beamforming and Station Signal processing	24
		DS5-T3	Participant in EMBRACE Assessment of Performance	12
8	University of Oxford	DS2-T1 DS2-T2	Coordinator of Science Simulations Participant in Astronomical Data Simulations	90 12
		DS3-T3	Participant in SKA for the user	48
9	Commonwealth Scient.and Industr.Res.Org(C SIRO), Aus.	DS2-T2	Participant in Astronomical Data Simulations	22
		DS3-T1 DS3-T3 DS3-T4	Participant in Data & Control Transport Systems Participant in SKA for the User Coordinator of Siting and Related Issues	58 24 48
		DS4-T1 DS4-T2 DS4-T4 DS4-T5	Participant in Frontend Technologies Participant in Signal Conditioning and Digitization Participant in Wideband Integrated Antennas Coordinator of Beamforming and Station Signal Processing	38 3 18 24
		DS5-T1	Participant in Design EMBRACE Demonstrator	12
		DS6-T1 DS6-T2 DS6-T4	Participant in Design Cylindrical Demonstrator Participant in Development of Cylindrical Concept Participant in Aperture Arrays for Cylindrical reflectors	10 2 2
10	Puschino Radio Astronomical Observatory, Russia	DS2-T2	Participant in Astronomical Data Simulations	48
		DS4-T5	Participant in Beamforming and Station Signal Processing	48
11	National Res. Council (NRC), Canada	DS4-T4	Participant in Wideband Integrated Antennas	48
12	National Research Foundation (NRF), S.A.	DS3-T4	Participant of Siting and Related Issues	24
		DS4	Participant in several Tasks in DS4	48

	S.A.	DS5	Participant in several Tasks in DS5	48
13	Torun Centre for Astronomy (TcfA), Poland	DS2-T2	Participant in Astronomical Data Simulations	12
14	Chalmers University, Sweden	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations	2 60
15	University of Cambridge (UCAM DPYS)	DS2-T1	Participant in Science Simulations	72
		DS3-T3	Coordinator of "SKA for the User"	72
		DS4-T3 DS4-T5 DS5-T1 DS5-T2 DS5-T3	Participant in RFI mitigation strategies Participant in Beamforming and Station Signal Processing Participant in Design EMBRACE Participant in Develop EMBRACE Participant in Assessment of performance	18 24 48 48 36
16	Kapteyn Astronomical Institute @ RUG, Neth.	DS2-T2	Participant in Astronomical Data Simulations	48
17	University Leiden, Leiden Observatory	DS2-T1	Participant in Science Simulations	48
18	Cardiff University	DS2-T1	Participant in Science Simulations	24
		DS3-T3	Participant in SKA for the User	36
19	University of Glasgow	DS2-T1	Participant in Science Simulations	12
20	Swinburne Univ. of Techn., Australia	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations	12 72
21	Univ. of Adelaide, Aus.	DS2-T1	Participant in Science Simulations	12
22	Univ. of Melbourne, Aus.	DS2-T1	Participant in Science Simulations	12
23	Sydney Univ., Australia	DS6-T1 DS6-T2	Participant in Design of Cylindrical Concept Demonstrator Participant in Development of CC Demonstrator	24 12
24	Univ. NSW, Australia	DS2-T1	Participant in Science Simulations	12
25	Univ. d´Orleans (UORL)	DS4-T1 DS4-T2 DS4-T3 DS4-T4	Participant in Frontend Technologies Participant in Signal Conditioning and Digitization Participant in RFI Mitigation Strategies Participant in Wideband Integrated Antennas	12 17 60 7
26	Centre Nat. de la Rech. Scient. (CNRS)	DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas	15 14
27	Univ. of KwaZulu-Natal,(Natal Univ.), S.A.	DS3-T4	Participant in Siting and Related Issues	12
28	Univ. of Leeds (UNIVLEEDS)	DS2-T1	Participants in Science Simulations	12
29	Universidad de Valencia, Spain	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations	12 12

30	OMMIC, Fr.	DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas	12 6
		DS5-T1 DS5-T2	Participant in Design of EMBRACE subsystem Participant in Develop EMBRACE demonstrator	18 12
31	British AE, UK	DS4-T4	Wideband Integrated Antennas	48
32	Qinetiq	DS4-T1	Participant in Frontend Technologies	48

Table 9: List of Publications and/or patents for each of the participants. The relevant qualifications, experience and knowledge for each participant is given in Table1

Participants Number (Co-ordinator as Participant No.1)	Short Name (as specified on From A2)	Publications and /or Patents
1	ASTRON	1. A. van Ardenne, "Active Adaptive antennas for radio astronomy; results of the R&D program toward the Square Kilometer Array", Proc. SPIE Conf. 4015 Radio Telescopes, Munchen, Germany, March 2000 2. J. G. Bij de Vaate, G. W. Kant, W. A. van Cappellen, S. van der Tol, "First Celestial Measurement Results of the Thousand Element Array", URSI GA, Maastricht, August 2002 4. A.J. Boonstra, A.J. van der Veen and J. Raza, "Spatial Filtering of Continuous Interference in Radio Astronomy", Proc. IEEE ICASSP, vol. 3, pp. 2933-2936, Orlando (FL), May 2002, IEEE 4. S. Alliot, "Architecture Exploration for Large Scale Array Signal Processing Systems", PhD thesis, Leiden, Dec. 2003 5. B. Smolders, J. G. Bij de Vaate, G. W. Kant, A. van Ardenne, D. Schaubert, T. H. Chio, "Dual-beam Wide-band Beamformer with Integrated Antenna Array", Antenna and Propagation Symposium, Davos, April 2000
2	UMAN	1. Wilkinson, P.N., 1991, in *Radio Interferometry: Theory, Techniques and Applications ,* IAU Colloquium 131, ASP Conference Series, Vol. 19, T.J. Cornwell and R.A. Perley (eds.) , pages 428-432. 2. M. Missous, C. Y Yuca, J. Allam, J.T Cleaver "Manufacturable pHEMT process for time-domain mesurements of ultra-fast transistors" 1998 Workshop on High Performance" Electron Devices for Microwave and Optoelectronic Applications. EDMO (Cat. No.98TH8345). IEEE. 1998, pp.7-12. New York, NY, USA 3.. Aziz AA and Missous M. `"Fabrication and characterisation of AlGaAs/InGaAs/GaAs pseudomorphic HEMT with in-situ epitaxial aluminium grown by MBE", 1997 Workshop on High Performance Electron Devices for Microwave and Optoelectronic Applications. EDMO (Cat. No.97TH8305),IEEE. 1997, pp.297-302. New York, NY, USA 4. Brown,A.K. "The theory and practice of microwave antenna modeling", in IEE Colloquium on High Frequency Simulation in Practice, 1997 p.11/15 5. Brown,A.K. "CEM for antennas in a concurrent engineering environment" Third International Conference on Computation in Electromagnetics ,1996 (Conf. Publ. No.420) p.106-123)
3	JIVE	1. Garrett, M.A. 2003, "The FIR/Radio correlation of high redshift galaxies in the region of the HDF-N", Astronomy and Astrophysics, v.384, p.L19-L22 2. Garrett, M.A., Wrobel, J.M., Morganti, R. 2003, "The deepest and widest VLBI survey yet: VLBA+GBT 1.4 GHz observations in Bootes", New Astronomy Reviews, Volume 47, Issue 4-5, p. 385-389. 3. R. Hughes-Jones, S.M. Parsley, R. Spencer, 2003, "High Data Rate Transmission in High Resolution Radio Astronomy" VLBIgrid, FGCS: iGRID 2002 Conference special issue. 4. S.M. Parsley, A. Mujunen, S. Pogrebenko, J. Ritakari, "PCEVN", in "New Technologies in VLBI", ed. Y.C. Minh, ASP Conference Series, vol. 306. 5. Schilizzi, R.T., Aldrich, W., Anderson, B., et al. "The EVN-MarkIV VLBI Data Processor," Exper. Astron., 12, 49--67, 2001.
4	OPAR	1. Hatton, S., Devriendt, J. E. G., Ninin, S., Bouchet, F. R., Guiderdoni, B., & Vibert, D. "GALICS- I. A hybrid N-body/semi-analytic model of hierarchical galaxy formation", MNRAS, 343, 75; 2004 2. Crovisier, J., Colom, P., Gérard, E., Bockelée-Morvan, D., Bourgois, G., Observations at Nançay of the OH 18-cm lines in comets: The data base. Observations made from 1982 to 1999. Astron. Astrophys. 393, 1053-1064; 2002. 3. Le Bertre T., Gérard E. The circumstellar environments of EP Aqr and Y CVn probed by the HI emission at 21 cm", Astron. Astrophys., in press (http://wwwusr.obspm.fr/~lebertre/Paper3.ps) 4. Rosolen, C., Lecacheux, A., Gerard, E., Clerc, V., Denis, L. "High dynamic range, Interferences Tolerant, Digital Receivers for Radioastronomy: Results and Projects at Paris and Nanay Observatory", in The Universe at Low Radio Frequencies, Proc. of IAU Symp. 199, Ed. A. P. Rao, G. Swarup, & Gopal-Krishna, p.506; 2002

		5. Samson V., Champagnat F., & Giovannelli J.-F. "Detection of Point Objects with Random Subpixel Location and Unknown Amplitude", Applied optics, Special Issue on Image processing for EO sensors, in press (http://www.lss.supelec.fr/perso/giovannelli/)
5	IRA	1. I.G. Prandoni et al. 2001, Astronomy and Astrophysics 365, 392 'The ATESP Radio Survey' 2. M. Bondi et al. 2003, Astronomy and Astrophysics 403, 857 'The VLA-VIRMOS Deep Field I. Radio Observations probing the microJy source population' 3 . S. Montebugnoli et al. 'SKA Activity at the Medicina radiotelescope: The Northern Cross as a very promising SKA Test Bed', 2002, European SKA 2002, Groningen, NL 4 G. Tuccari 'Devolopment of a Digital Base Band Converter: Basic Elements and preliminary results', 2002, New Technologies in VLBI, Gyeongju, Korea- 5. M. Poloni, F. Perini, et al SKA: The next generation radiotelescope and related requirements of state of the art of low cost high performance front-end presented at ICEA Conference Torino 2003
6	FG-IGN	1. Quasioptical approach for meniscus lens corrected horn: Application to cassegrain systems". F.Tercero, J.A.López Fernández, E.García, L.de Haro, M.C.Carter, A.Barcia, B.Galocha, J.L.Besada. International Journal in Infrared and Millimetre Waves, May. 2003 2. "Analisys of the defoused gaussian beam telescope on cassegrain feeds". E. Garcia, J.A. Lopez Fernandez, L. de Haro, F. Tercero, B. Galocha, A. Barcia, J.L. Besada. Microwave and Optical Technology Letters, Vol. 32, Issue 10, pp. 420-423. March 2002 3. Title: Mutual Coupling Effects Correction in Microstrip Arrays for Direction of Arrival (DOA) Estimation, D. Segovia, R. Martín, M. Sierra, IEEE Proceedings on Microwave, Antennas and Propagation, Vol: 149, número 2, 113-118, April 2002 4. Low Bias BAR Modes HEAP Transmitting antennas, V. González, J.M. Rodríguez, C. Rueda, D. Segovia, E. Rajo, C. Martin, Microwave and Optical Technology Letters, Vol: 29, no 3, pp. 163-167, May 2001 5. Bandwidth Enhancement in Non-Centered Stacked Patches, E.Rajo, D. Segovia, J.L. Vázquez, V. González and C. Martín, Microwave and Optical Technology Letters, Vol: 31, no 1, 53-56, 5-10-2001
7	MPIfR	1. Beck, R., Shukurov, A., Sokoloff, D., Wielebinski, R.: Systematic bias in interstellar magnetic field estimates. Astron. Astrophys. 411, 99-107 (2003). 2. Berkhuijsen, E. M., Beck, R., Hoernes, P.: The polarized disk in M 31 at $lambda6 cm. Astron. Astrophys. 398, 937-948 (2003). 3. Kharb, P., Gabuzda, D., Alef, W., Preuss, E., Shastri, P.: Magnetic field geometry of the broad line radio galaxy 3C111. New Astronomy Reviews 47, 621-624 (2003). 4. Horneffer, A., Falcke, H., Kampert, K.H.: LOPES - Detecting radio emission from cosmic ray air showers. In: Proceedings of the 6th European VLBI Network Symposium. (Eds.) E. Ros et al. Max-Planck-Institut fr Radioastronomie, Bonn 2002, 23-24. 5. Krichbaum, T.P., Graham, D.A., Alef, W., Polatidis, A.G., Bach, U., Witzel, A., Zensus, J.A., Greve, A., Grewing, M., Doeleman, S.S., Phillips, R.B., Rogers, A.E.E., Titus, M., Fagg, H., Strittmatter, P., Wilson, T.L., Ziurys, L., Freund, R., Knnen, P., Peltonen, J., Urpo, S., Rantakyro, F., Conway, J., Booth, R.S.: VLBI observations at 147 GHz: first detection of transatlantic fringes in bright AGN.Proceedings of the 6th European VLBI Network Symposium. (Eds.) E. Ros et al. Max-Planck-Institut fr Radioastronomie, Bonn 2002, 125-128.
8	OXF-DB	1. Probing dark enery with baryonic oscillations and future radio surveys of neutral Hydrogen. Abdalla F.B. & Rawlings S., MNRAS, submitted. 2. Two 100-Mpc scale structures in the 3D distribution of radio galaxies and their implications, Brand K., Rawlings S., Hill G.J., Lacy M., Mitchell E., Tufts J., 2003, MNRAS, 344(1), 283-306. 3. No evidence for a different accretion mode for 3CR FRI radio galaxies, Cao X. & Rawlings S., MNRAS, in press, astro-ph/0312401. 4. Implications for unified schemes from the quasar fraction and emission-line luminosities in radio-selected samples, Grimes J.A., Rawlings S., Willott C. J., MNRAS, in press, astro-ph/0311366. 5. The radio galaxy 3C 356 and clues to the trigger mechanisms for powerful radio sources Simpson, C., Rawlings, S., 2002, MNRAS, 334, 511
9	CSIRO	1. Bird, Trevor; Design of a Multibeam Feed Array for the Arecib Radiotelescope. 8th Australian Symposium on Antennas, pp. 25, 2003 2. FERRIS, R.H., BUNTON, J.D. & STUBER, B, A 2GHz digital filterbank correlator SKA: Defining the Future, Univ. of California, Berkeley, 9-12 July 2001. 3. CHIPPENDALE, A.P., EKERS, R.D., FERRIS, R.H., HALL, P.J., JACKSON, C., JAMES,G.L. & SADLER, E.M., Eyes on the sky : a refracting concentrator approach to the SKA : concept extension

		& responses to EMT/ISAC", International SKA Conference, Geraldton, 28 July, 2003. 4. (RFI) Interference Mitigation and Radio Astronomy Kesteven, M. J, Sault, R. J. 2001 Asia-Pacific Radio Science Conference AP-RASC '01, Proceedings of a conference held 1-4 August, 2001 at Chuo, University, Tokyo, Japan. Sponsored by Japan National Committee of URSI and the Institute of Electronics, Information and Communication Engineers. Co-sponsored by International Union of Radio Science., p.248 5 Bunton, J.D., Jackson, C.A., Sadler, E.M., $B!F(JCylindrical Reflector SKA$B!G(J, SKA Design Concept White Paper,7, July 2002 http://www.skatelescope.org/documents/SKA_AUS_CONCEPT_Cylindrical_17072002.pdf
10	PRAO LPI	1. Dagkesamanskii, R.D., 2001, "Monitoring of Cherenkov Emission Pulses with Kalyazin Radiotelescope: real sensitivity and prospective program", AIP Conf. Proc.579: Radio Detection of High Energy Particles (RADHEP-2000), pp.189-195. 2. Dagkesamanskii, R.D., Samodourov V.A.& Lapaev K.A., 2000, "Sky Survey at 102.5 MHz: Radio Sources at Declinations 27.5deg - 33.5deg and 67.5deg - 70.5 deg.", Astronomy Reports (Astron. Zhurnal, V.77, pp.1-9). 3. Dagkesamanskii, R.D., Kovalenko, A.V. & Udal'tsov, V.A., 1994, "Nonthermal Radio Sources And Interstellar Gas in the Galactic Center Region", Astronomy Reports (Astron. Zhurnal, V.71, pp.30-36). 4. Dagkesamanskii, R.D. & Zheleznykh, I.M., 1989, "A Radio Astronomy Method of Detecting Neutrinos And Other Superhigh-Energy Elementary Particles", JETP Let. (Pis'ma v Zhurnal Eksp. i Theor. Fiziki, V.50, pp.233-235). 5. Dagkesamanskii, R.D., Kuzmin, A.D., Gubanov, A.G. & Slee, O.B., 1982, "Observations of X-ray Clusters of Galaxies at 102.5 MHz", Monthly Notice of the RAS, V.200, pp.971-991.
11	NRC	1. Bandwidth limits of beamforming networks for focal-plane arrays, Veidt, B.; Dewdney, P.; IEEE Antennas and Propagation Society International Symposium, 2003, Volume: 1 , June 22-27, 2003. Pages:132 - 135. 2. The Large Adaptive Reflector: A Giant Radio Telescope with an Aero Twist, Dewdney P.E., Nahon M., Veidt B. 2002, Can. Aero. Space J., 48, 239. 3. The LAR: A 200-m diameter, wideband, cm-m wave radio telescope, Carlson B., Bauwen L., Belostotski L., Cannon W., Chang Y.-Y., Deng X., Dewdney P.E., Fitzimmons J., Halliday D., Kurshner K., Lachapelle G., Lo D., Mousavi P., Nahon M., Shafai L., Steimer S., Taylor A.R., Veidt B, 2000 Proc. SPIE Int. Symp on Astronomical Telescopes and Intstrumentation, p 4015.
12	NRF	1. Tiplady, A. J., Jonas, J. L., "Development of a Digital Pulsar Timer", ASP Conference Proceedings, Vol. 302, p.323, 2003 2. Giardino, G., Banday, A. J., Górski, K. M.; Bennett, K., Jonas, J. L., Tauber, J., "Towards a model of full-sky Galactic synchrotron intensity and linearpolarisation: A re-analysis of the Parkes data", A&A 387, 82, 2002.
13	TcfA	1. Blaszkiewicz L., Kus A.J., “12.2 GHz survey towards 6.7 GHz methanol masers. A comparison of 12.2 GHz and 6.7 GHz Spectra”, Astronomy & Astrophysics, 413, 233-240 (2003) 2. Dyks, J., Rudak, B., “Two-pole caustic model for high-energy light curves of pulsars.” 2003, AJ, 598, 1201-1206 3. Gozdziewski, K., Konacki, M., Mciejewski, A., “Where is the second planet in the HD 160691 planetary system?” 2003, ApJ, 594, 1019-1032 4. Marecki A., Spencer R.E., Kunert M., “Location of weak CSS sources on the evolutionary path of radio loud AGNs”, PASA, 2003, 20, 46-49. 5. Niedzielski, A., Maciejewski, G., Czart, K, “ First results of the Semi-Automatic Variability Search” , 2003, AA 53, 281
14	Chalmers	1. Conway, J. E., Cornwell, T. J., Wilkinson, P. N., 1990, 'Multi-Frequency Synthesis – a New Technique in Radio Interferometric Imaging', MNRAS 246}, 490. 2. Carill, C. L., Menton, K. M., Stocke J. T., Perlman, E., Vermeullen, R., Briggs, F., De Bruyn, A. G., Conway, J.E., Moore, C. P. 2000, 'Astronomical constraints on the cosmic evolution of the fine structure constant and possible quantum dimensions' Phys. Rev. Lett., 85, 5511. 3. Beasley, A.J. and Conway, J.E., 1995, \`Phase Referencing', Chapter 13 \`VLBA and VLBI Imaging',July 1993, Eds P.Diamond and A.Zensus, Publ ASP.' 4. Conway, J.E., 2001, 'A Preliminary ALMA Zoom Array Design for the Chanjnantor Site', ALMA Memo 348. 5. Horellou, C., Berg'e, 2004, MNRAS, submitted \`Dark energy and the evolution of spherical overdensities".
15	UCAM DPHYS	1. Alexander, ~P. 2002, 'On the interaction of FRII radio soures with the intracluster medium', MNRAS, 335, 610. 2. Clemens, M.S., Alexander, P., Green, D.A., 2000, 'Ram pressure stripping of the ISM in NGC4485', MNRAS, 312, 236.

		3. Grainge, K., 2000, 'The Very Small Array', Astron, Comm, Lett., 37, 299. 4. Maisinger, K., Hobson, M. P., Lasenby, A. N., 2004, MNRAS, 347, 339. 5. P. Duffett-Smith, K. Grainge, 1996 ``Position determining system'', 'International patent application No. PCT/G896/02308'
16	Kapteyn Institute	1. High resolution observations of galaxies with SKA", van der Hulst, J.M., 2000, Perspectives on Radio Astronomy", ed. M. van Haarlem, Published by NFRA, p. 229. 2. High-Resolution HI mapping of NGC 4038/39 (``The Antennae'') and its TidalDwarf Galaxy Candidates" , J.E. Hibbard, J.M. van der Hulst, J.E. Barnes,and R.M. Rich, 2001, A. J. 122, 2969-2992. 3. Interactions, Mergers and Accretion: What Can the HI Tell Us?: van der Hulst, J.M., 2001, ASP Conf. Ser. 230: "Galaxy Disks and Disk Galaxies", 425 4. The Westerbork HI survey of spiral and irregular galaxies. I. HI imaging of late-type dwarf galaxies", Swaters, R.A., van Albada, T.S., van der Hulst, J.M., & Sancisi, R. 2002, A&A, 390, 829 5. Star Formation Thresholds in Low Surface Brightness Galaxies", J. M. van der Hulst, E. D. Skillmann, T. R. Smith, G. D. Bothun, S. S. McGaugh and W. J. G. de Blok, A.J. 106 p. 584, 1993
17	Leiden Observatory	1.Carilli,C.L., Harris, D. E., Pentericci, L., Rottgering, H. J., et al, 2002, The X-Ray-Radio Alignm ent in the z=2.2 Radio Galaxy PKS 1138-262, ApJ **567**, 781 2. De Breuck, C. Tang et al, 2002a, A sample of ultra steep spectrum sources selected from the Westerbork in the Southern Hemisphere (WISH) survey, A&A **394**, 59 3. De Breuck, C. van Breugel et al, 2002b, Optical and Near – Infrared Imaging of Ultra-Steep_Spectrum Radio Sources: The K-z Diagram of Radio-selected and optically selevted Galaxies, AJ **123**, 637
18	CU	1. Davies, J., Minchin, R., Sabatini, S., van Driel, W., Baes, M., Boyce, P., de Blok, W. J. G., Disney, M., Evans, Rh., Kilborn, V., Lang, R., Linder, S., Roberts, S., & Smith, R. 2003, MNRAS, accepted, "An HI Survey of the Virgo Cluster - two isolated HI clouds?" ArXiv ref: astro ph/0312531 2. Dunne, L., Eales, S., Ivison, R., Morgan, M. & Edmunds, M. 2003, Nature, 424, 285, "Type II supernovae as a singnificant source of cosmic dust". 3. Minchin, R. F. et al. 2003, MNRAS, 346, 787, "HIDEEP - An extragalactic blind survey for very low column-density neutral hydrogen" 4. ang, R. H., Boyce, P. J., Kilborn, V. A., Minchin, R. F., Disney, M. J., Jordan, C. A., Grossi, M., Garcia, D. A., Freeman, K. C., & Phillipps, S., 2003, MNRAS, 342, 738, "First Results from the HI Jodrell All Sky Survey: Inclination-Dependent Selection Effects in a 21-cm Blind Survey" 5. Zwaan, M. A. et al. 2003, AJ, 125, 2842, "The 1000 Brightest HIPASS Galaxies: The HI Mass Function and OmegaHI"
19	U.Glasgow	1. Allen, B., Woan, G, et al.Upper limits on the strength of periodic gravitational waves from PSR J1939+2134,Class.Quant.Grav. bf 21, 761, 004 2. Jones, D. L., et al, The ALFA Medium Explorer Mission,Advances in Space Research,bf 26, 743 ,2000 3. Shrauner, J. A., Taylor, J. H., Woan, G. The Second Cambridge Pulsar Survey At 81.5 MHz ,Astrophysical Journal, bf 509, 785 ,1998 4. O'Sullivan, Creidhe, Yassin, G., Woan, G., et al., Asearch for primordial anisotropies in the cosmic microwave background radiation: first observations at 13.5 GHz with the Cosmic Anisotropy Telescope, MNRAS, bf 274, 861, 1995)} 5. Woan, G., Duffett-Smith, P. J., A deep search for pulsed emission from Cassiopeia A MNRAS, bf 260, 693, 1993
20	Swinburne	1. Kawata, D. & Gibson, B.K. "GCD+: A New Chemodynamical Approach to Modelling Supernovae and Chemical Enrichment" (2003). MNRAS, 340, 908 2. Tingay, S.J. "A VLBI study of free-free absorbed compact radio sources in the NGC 253 startburst" (2004). AJ, 127, 10 3. Kawata, D. & Gibson, B.K. "Multiwavelength Cosmological Simulations of Elliptical Galaxies" (2003). MNRAS, 346, 135 4. Brook, C.B., Kawata, D., Gibson, B.K. & Flynn, C. "Stellar Halo Constraints on Simulated Late-type Galaxies" (2004). MNRAS, in press
21	U. Adelaide	1. Protheroe, Raymond J.; Stanev, Todor; Limits on Topological Defects Models of the Ultrahigh Energy Cosmic Rays. Phys. Rev. Lett., v. 77, pp. 3708-11. 1996 2. Protheroe, Raymond J.; High energy neutrino astrophysics. Nucl.Phys.B (Proc.Suppl.), v. 77, pp. 465-473. 1999 3. Stanev, Todor;Engel, Ralph; Muecke, Anita; Protheroe, Raymond J.; Rachen, Joerg P.; Propagation of ultra-high energy protons in the nearby universe.Physical Review D, v. 6209 (9): 3005. 2000 4. Protheroe, Raymond J.; Clay, Roger W.; Ultra High Energy Cosmic Rays. PASA,

		v. 21, pp. 1-22. 2004 5. Protheroe, Raymond J.; Effect of energy losses and interactions during diffusive shock acceleration: applications to SNR, AGN and UHE Cosmic Rays. Astroparticle Physics, in press. 2004
22	Umel	1. Wyithe, J.S.B., Loeb, A., Cosmic Hydrogen Was Significantly Neutral a Billion Years After the Big Bang, Nature, 427, 815-817 2. Wyithe, J.S.B., Loeb, A., Self-Regulated Growth of Supermassive Black Holes in Galaxies as the Origin of the Optical and X-ray Luminosity Functions of Quasars, ApJ, 595, 614-623 3.Wyithe, J.S.B., Loeb, A., Was the Universe Reionized by Massive Metal-free Stars?, 2003, ApJ, 588, L69-L72 4. Wyithe, J.S.B., Loeb, A., Reionization of Hydrogen and Helium by Early Stars and Quasars, 2003, ApJ, 586, 693-708 5. Wyithe, J.S.B., Loeb, A., A Physical Model for the Luminosity Function ofHigh-Redshift Quasars, 2002, ApJ, 581, 886-894
23	U. Sydney	1.Green, A.J., Bunton, J.D., Campbell-Wilson, D., Cram, L.E., Davison, R.G., Hunstead, R.W., Mitchell, D.A., Parfitt, A.J., Sadler, E.M., Warr, G.B. JPrototype SKA Technologies at Molonglo: 1. Overview and Science Goals (J, The SKA: Defining the Future, Berkeley Workshop, July 2001 http://www.skatelescope.org/skaberkeley/ 2 Warr, G.B, Bunton, J.D, Campbell-Wilson, D., Davison, R.G., Hunstead, R.W., Mitchell, D.A., Parfitt, A.J., JPrototype SKA Technologies at Molonglo: 2. Antenna and Front End (J, The SKA: Defining the Future, Berkeley Workshop, July 2001 http://www.skatelescope.org/skaberkeley/ 3 Warr, G.B., Bunton, J.D., Campbell-Wilson, D., Cram, L.E., Davison, Green, A.J., R.G., Hunstead, R.W., Mitchell, D.A., Parfitt, A.J., Sadler, E.M., (JPrototyping SKA Technologies at the Molonglo Radio Telescope=(J, WARS02, Leura, Australia, 20-22 February 2002 http://www.ips.gov.au/IPSHosted/NCRS/wars/wars2002/proceedings/comm-j/screen/warr.pdf 4 Adams, T.J. (JThe SKA Molonglo Prototype Correlator (J International SKA Workshop, Geraldton, Western Australia 27th July - 2nd August 2003 http://www.atnf.csiro.au/projects/ska/events/geraldton/Adams_SKAMP_Continuum_Correlator.pdf
24	UNSW	1. Blake, Chris; Mauch, Tom; Sadler, Elaine M.; Angular clustering in the Sydney University Molonglo Sky Survey. MNRAS, 347, 787. 2004 2. Blake, Chris; Glazebrook, Karl; Probing Dark Energy Using Baryonic Oscillations in the Galaxy Power Spectrum as a Cosmological Ruler. ApJ, 594, 665. 2003 3. Blake, Chris; Wall, Jasper; Quantifying angular clustering in wide-arearadio surveys. MNRAS, 337, 993. 2002 4. Blake, Chris; Wall, Jasper; A velocity dipole in the distribution of radio galaxies. Nature, 416, 150. 2002 5. Blake, Chris; Wall, Jasper; Measurement of the angular correlation function of radio galaxies from the NRAO VLA Sky Survey. MNRAS, 329L, 37. 2002
25	UORL	1. R.Weber, C. Faye, F. Biraud and J. Dansou, Spectral detector for interference time blanking using quantized correlator, Astrophysics & Astronomy Journal Supplement Series, 126, pp.161-167, Novembre 1997. 2. R. Weber, C.Faye, Coarsely Quantized Spectral Estimation of radio Astronomic Sources in Highly Corruptive Environments, Chapter 7 of Signal Analysis and Prediction, Prochazka et al., Birkhauser Boston Ed. , 1998. 3. R. Weber, L. Denis, S. Bretteil, DSP enabled radio astronomy in highly corruptive environment, DSPenabledRadio, Edinburgh, Scotland, sept.2003. 4.V. Clerc, R. Weber, L. Denis, C. Rosolen, High performance receiver for RFI mitigation in radio astronomy : Application at decameter wavelengths, EUSIPCO'02, Toulouse, France, Sept. 2002. 5. R. Weber, C. Faye, Real Time Detector for Cyclostationary RFI in Radio Astronomy, EUSIPCO'98, Grèce, Septembre 1998.
26	CNRS	1. I. Hunter, L. Billonnet, B. Jarry, P. Guillon, " Microwave Filters - Applications and Technology ", Invited paper - Anniversary Issue, IEEE Transactions on Microwave Theory and Techniques, vol. 50, no. 3, March 2002, pp. 794-804. 2. S. Qintanel L. Billonnet B. Jarry B. Marcilhac, J.C. Mage, « Low-Temperature Solutions for UMTS Base-Station Receivers Using Superconducting and Low-Noise Active Filtering Techniques », Microwave and Optical Technology Letters February 5, 2004, p. 242 3. E. Rius, C. Person, G. Tanné, B. Jarry, L. Billonnet, P. Blondy, " Planar microwave filters for new telecommunication systems ", Invited paper - Workshop "New Technologies for Microwave and Millimeter Wave Filters", IMS'2003, IEEE MTT-S International Microwave Symposium, June 2003, Philadelphia, USA. 4. E. Neber, L. Billonnet, B. Jarry, M.H.W. Hoffmann, « Novel Detector Structure for Automatically Tuned Filters at Microwave Frequencies », IMS'2004, IEEE MTT-S

		International Microwave Symposium Digest, June 2004, USA. 5. B. Albert, L. Billonnet, and B. Jarry, « Novel Design Approach for Transversal Notch Filter using Recursive Principles », IMS'2004, IEEE MTT-S International Microwave Symposium Digest, June 2004, USA.
27	Natal University	1. Ress, Catherine M., Kamionkowski, Marc, "Interpreting the clustering of radio sources", MNRAS, 297, 486, 1998
28	UNIVLEEDS	1. Hoare, M. G., Drew J. E., Muxlow T. B., Davis R. J., 1994. ApJ, 421, L51-54, `Mapping the radio emission from massive young stellar objects'. 2. Hoare M. G., Garrington S. T., 1995. ApJ, 449, 874-879,`Further mapping of the radio emission from massive young stellar objects'. 3. Lumsden S. L., Hoare M. G., 1999, MNRAS, 305, 701-706, `Molecular and ionized gas motions in the cometary compact H~II region G29.96-0.02'. 4. Gibb A. G., Hoare M. G., Little L. T., Wright M. C. H., 2003, MNRAS, 339, 1011-1024, `A detailed study of G35.2-0.7N: collimated outflows in a cluster of high-mass young stellar objects'. 5. Hoare M. G., 2002, in P. A. Crowther ed., Hot Star Workshop III: The Earliest Stages of Massive Star Birth, ASP Conf. Ser. 267, p137-144,`High resolution radio observations of massive young stellar objects.'
29	Univ. Valencia	1. Marcaide, J.M., Alberdi, A., Ros, E., Diamond, P., Shapiro,I.I., Guirado, J.C., Jones, D.L., Krichbaum, T.P., Mantovani, F., Preston, R.A., Rius, A., Schilizzi, R.T., Trigilio, C., Whitney, A.R., Witzel, A. , "Expansion of Supernova 1993J", Science, 270, 1475, 1995 2. Marcaide, J.M., Alberdi, A., Ros, E., Diamond, P., Schmidt, B., Shapiro,I.I., Baath, L., Davis, R.J., de Bruyn, A.G., Elosegui, P., Guirado, J.C., Jones, D.L., Krichbaum, T.P., Mantovani, F., Preston, R.A., Ratner, M.I., Rius, A., Rogers, A.E.E., Schilizzi, R.T., Trigilio, C., Whitney, A.R., Witzel, A., Zensus, A. "Discovery of Shell-Like Radio-Structure in Supernova 1993J"Nature, 373, 44, 1995 3. Guirado, J.C., Reynolds, J.E., Lestrade, J.-F., Preston, R.A., Jauncey, D.L., Jones, D.L., Tzioumis, A.K., Ferris, R.H., King, E.A., Lovell, J.E.J., McCulloch, P.M., Johnston, K.J., Kingham, K.A., Martin, J.O., White, G.L., Jones, P.A., Arenou, F., Froeschle, M., Kovalevsky, J., Martin , C., Lindegren, L., Soderhjelm, S. "Astrometric detection of a low-mass companion orbiting the star AB Doradus", ApJ, 490,835, 1995 4. Ros, E., Guirado, J.C., Marcaide, J.M., Perez-Torres, M.A., Falco, E.E., Muñoz, J.A., Alberdi, A., Lara,L., "VLBI imaging of the gravitational lens MG J0414+0534",A&A, 362, 845, 2000 5. Ros, E., Marcaide, J.M., Guirado, J.C., Perez-Torres, M.A., "Absolute kinematics of radio source components in the complete S5 polar cap sample. I. First and second epoch maps at 8.4 GHz". A&A, 376, 1090, 2001
30	OMMIC	Not available at the time of submission.
31	BAE	1. R.F.E.Guy, R.A.Lewis, P.J.Tittensor, 'Conformal Phased Arrays', VDE/EUREL/IEEE, 1st European Workshop on Conformal Antennas, Karlsruhe, October 29, 1999,p4-7. 2. R.F.E.Guy, C.B.Wyllie, J.R.Brain, 'Synthesis of the Inmarsat 4 Multibeam Mobile Antenna', IEE Twelfth International Conference on Antennas & Propagation, ICAP 2003, 31st March-3rd April, Exeter UK,p90-93. 3. R.F.E.Guy, 'General Radiation Pattern Synthesis Technique for Array Antennas of Arbitrary Configuration and Element Type', Proc. IEE, vol 135, part H, No. 4, 1988, p241-245. 4 J.A.Lord, S.P.Benham, R. Mittra, 'Multi-level fast multipole algorithm for antenna modelling', IEE Twelfth International Conference on Antennas & Propagation, ICAP 2003, 31st March-3rd April, Exeter UK,p308-311. 5. J.A.Lord, R.I.Henderson and B.P.Pirollo, 'FDTD analysis of modes in arbitrarily shaped waveguides', IEE Conference on Antennas and Propagation', York UK 31st March-1st April 1999, p221-224.
32	Qinetiq	1. A R Barnes et al., "A 44GHz low noise block downconverter MMIC suitable for EHF satellite communications", IEEE RFIC Symposium, 1998, pp 223-226 2. A R Barnes et al., "A compact 6 to 18GHz solid state power amplifier module with 10W output power", 1999 IEEE International Microwave Symposium Digest", pp959-962 3. A R Barnes et al. "A comparison of W-band resistive mixer architectures", IEEE MTT-S Digest 2002, pp1867-1870 4. A R Barnes et al. "AlGaN/GaN HFETs for LNA and Power applications", invited speaker at 2004 IEEE International Microwave Symposium workshop, June 2004 (to be published)

4.2 Justification of Financing Requested

The fundamental policy which has been adopted in SKADS is to request funding for 40% of the total programme from the EC; the remaining 60% to be contributed from national sources.
These national contributions are a combination of staff and non-staff costs. The financial tables (Tables 3 and 10 in part B and Form A3) must, of course, reflect the different cost models of the participants of which 11 are full-cost (FC and FC-F) and 21 are additional cost (AC). Although for the latter 100% of the additional cost is contributed by the EC, we recognise that this should be matched. The obligation, which this policy implies for each participating country is listed explicitly in Table 11.

The cost of each study in percentage of the EC contribution is given below:

DS1: 5.4%
DS2: 15.3%
DS3: 10.3%
DS4: 27.0%
DS5: 32.1%
DS6: 6.0%
DS7: 2.3%
DS8: 1.6%

Table 10: Participants, their planned tasks of involvement, role and expected Project Budget and Contribution from the Community

(For FC-partners: 1fte = 75k€+20%, For all partners: Travel budget for all partners is 8% of this manpower cost, Generic computer cost is 1k€/myr).

Parti-cipati on No.	Participant	Tasks	Role	Expected Project Budget (TOTAL) (k€)	Expected Contributi-on of the EU/TASK (k€)
		DS1	Task Leader SKADS Coordination and Management	480	
			-Travel	96	
			-Non-manpower (Hard and SW)	21	597
		DS2-T2	Participant in Astronomical Data Simulations	180	
			-Travel	14.4	
			-Non-manpower (Hard and SW)	0	98.2
		DS3	Task Leader The Network and its Output Data	90	
		DS3-T1	Participant in Data & Control Transport Systems	180	
		DS3-T2	Coordinator of Array Data Handling	360	
		DS3-T3	Participant in SKA for the User	90	
		DS3-T4	Participant in Siting and Related Issues	135	
			-Travel	68.4	
			-Non-manpower (Hard and SW)	0	461.7
		DS4-T1	Participant in Frontend Technologies	270	
		DS4-T2	Participant in Signal Condit. and Digit.	180	
		DS4-T3	Participant in RFI Mitigation Strategies	180	
		DS4-T4	Coordinator of Task Wideband Integrated Antennas	360	
		DS4-T5	Participant in Beamforming and Station Signal Processin	270	
			-Travel	180	
			-Non-manpower (Hard and SW)	100.8	770.4

		DS5 DS5-T1 DS5-T2 DS5-T3	Task Leader EMBRACE Demonstrator Coordinator of Design EMBRACE Coordinator of Develop EMBRACE Participant in EMBRACE Assessment of Performance -Travel -Non-manpower (Hard and SW)	360 1800 630 270 244.8 3600	3452.4
		DS6-T4	Coordinator Aperture Arrays for Cylindrical reflectors -Travel -Non-manpower (Hard and SW)	30 2.4 0	16.2
		DS8-T1 DS8-T2	Participant in Overall System Design Coordinator of T2: Preliminary SKA Plan -Travel -Non-manpower (Hard and SW)	180 15 15.6 0	105.3
2	University of Manchester	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	190.1 43.2 0	233.3
		DS3-T1 DS3-T3	Coordinator of Data Handling & Control Transport Systems Participant in SKA for the User -Travel -Non-manpower (Hard and SW)	95.0 63.4 36 0	194.4
		DS4 DS4-T1 DS4-T2 DS4-T4 DS4-T5	Task Leader Founding and Enabling Technologies Coordinator of Frontend Technologies Participant in Signal Conditioning and Digitization Participant in Wideband Integrated Antennas Coordinator of Beamforming and Station Signal Processing -Travel -Non-manpower (Hard and SW)	116.5 349.4 38.8 233.0 349.4 201.6 0	1288.6
		DS5-T1 DS5-T2 DS5-T3	Participant in Design EMBRACE Participant in Develop EMBRACE Participant in EMBRACE Assessment of Performance -Travel -Non-manpower (Hard and SW)	160,5 160,5 107 76.8 250	754.7
		DS8 DS8-T1	Task Leader Overall System Design and Preliminary SKA Plan Coordinator of Overall System Design -Travel -Non-manpower (Hard and SW)	21.1 126.8 33.6 0	181.4
3	Joint Institute for VLBI in Europe (JIVE)	DS2 DS2-T1 DS2-T2	Task Leader Simulations Participant of Science simulations Coordinator of Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	31.7 31.7 126.8 43.2 0	233.3

		DS3-T3	Participant in 'SKA for the user' -Travel -Non-manpower (Hard and SW)	95.0 21.6 0	116.6
		DS5-T3	Participant in EMBRACE Assessment of performance -Travel -Non-manpower (Hard and SW)	79.2 18 0	97.2
		DS6-T3	Participant in Cylindrical Concept Assessment of performance -Travel -Non-manpower (Hard and SW)	47.5 10.8 0	58.3
4	L´Observatoire de Paris (OPAR)	DS1	Participant in SKADS Coordination and Management -Travel -Non-manpower (Hard and SW)	304 60.8 0	364.8
		DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	221.8 63.4 64.8 0	349.9
		DS3-T3 DS3-T4	Participants in SKA for the user Participant in Siting and related issues -Travel -Non-manpower (Hard and SW)	26.4 26.4 12 0	64.8
		DS4-T1 DS4-T2 DS4-T3 DS4-T4 DS4-T5	Participants in Frontend Technologies Coordinator of Signal conditioning and digitization Participant in RFI Mitigation strategies Participant in Wideband integrated antennas Participant in Beamforming and station signal processing -Travel -Non-manpower (Hard and SW)	189.7 183.9 275.9 172.4 51.7 181.4 50	1105
		DS5-T2 DS5-T3	Participant in Develop EMBRACE Participant in EMBRACE Assessment of Performance -Travel -Non-manpower (Hard and SW)	234 136.6 45.6 250	666.2
		DS7 DS7-T1/T2	Task Leader and SKADS Management Coordinator - Assessment of Work (excluding external consultants) -Travel -Non-manpower (Hard and SW)	36 180 43.2 160	419.2
5	Instituto di Radioastronomia (IRA)	DS2-T2	Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	630 50.4 0	272.2
		DS3-T1 DS3-T2	Participant in Data & Control Transport Systems Participant in Array Data Handling -Travel -Non-manpower (Hard and SW)	360 360 57.6 0	311.0

		DS4-T1 DS4-T2 DS4-T3 DS4-T4 DS4-T5	Participant in Frontend Technologies Coordinator of Signal Conditioning and Digitization Participant in RFI Mitigation Strategies Participant in Wideband Integrated Antennas Participant in Beamforming and Station Signal Processing -Travel -Non-manpower (Hard and SW)	270 360 90 135 135 79.2 140	483.7
		DS6 DS6-T1 DS6-T2 DS6-T3 DS6-T4	Task Leader Cylindrical Concept Demonstrator Coordinator of Design CC Demonstrator Coordinator of Develop CC Demonstrator Participant in Cylindrical Concept Assessment of Performance Participant in Aperture Array Feeds for Cylinders Participant in Aperture array feeds for cylinders -Travel -Non-manpower (Hard and SW)	270 720 180 180 7.5 108.6 1000	986.4
6	FG-IGN	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	15 1.2 0	6.5
		DS3-T3	Participant in SKA for the User -Travel -Non-manpower (Hard and SW)	360 28.8 0	155.5
		DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	360 360 57.6 0	311.0
		DS8-T1	Participant in Overall System Plan; Survey of Potential Industrial Involvement -Travel -Non-manpower (Hard and SW)	22.5 1.8 0	9.7
7	Max Planck Institute für RadioAstron o-mie (MPIfR)	DS2-T1 DS2-T2	Participant in Science Simulations Participants in Astronomical data simulations -Travel -Non-manpower (Hard and SW)	47.5 47.5 21.6 0	116.6
		DS4-T5	Participant in Beamforming and Station Signal processing -Travel -Non-manpower (Hard and SW)	63.4 14.4 0	77.8
		DS5-T3	Participant in EMBRACE Assessment of Performance -Travel -Non-manpower (Hard and SW)	31.7 7.2 0	38.9

8	University of Oxford	DS2-T1 DS2-T2	Coordinator of Science Simulations Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	237.7 31.6 61.2 0	330.5
		DS3-T3	Participant in SKA for the user -Travel -Non-manpower (Hard and SW)	126.7 28.8 0	155.5
9	Commonwealth Scient.and Industr.Res. Org(CSIRO), Aus.	DS2-T2	Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	165 13.2 0	5.3
		DS3-T1 DS3-T3 DS3-T4	Participant in Data & Control Transport Systems Participant in SKA for the User Coordinator of Siting and Related Issues -Travel -Non-manpower (Hard and SW)	435 180 360 78 0	31.2
		DS4-T1 DS4-T2 DS4-T4 DS4-T5	Participant in Frontend Technologies Participant in Signal Conditioning and Digitization Participant in Wideband Integrated Antennas Coordinator of Beamforming and Station Signal Processing -Travel -Non-manpower (Hard and SW)	285 22.5 135 180 49.8 41	19.9
		DS5-T1	Participant in Design EMBRACE Demonstrator -Travel -Non-manpower (Hard and SW)	90 7.2 6	2.9
		DS6-T1 DS6-T2 DS6-T4	Participant in Design Cylindrical Demonstrator Participant in Development of Cylindrical Concept Participant in Aperture Arrays for Cylindrical reflectors -Travel -Non-manpower (Hard and SW)	75 15 15 8.4 7	3.4
10	Puschino Radio Astronomical Observatory, Russia	DS2-T2	Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	0 11.5 0	11.5
		DS4-T5	Participant in Beamforming and Station Signal Processing -Travel -Non-manpower (Hard and SW)	0 11.5 0	11.5
11	National Res. Council (NRC), Canada	DS4-T4	Participant in Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	0 11.5 0	11.5
12	National Research Foundation (NRF), S.A.	DS3-T4	Participant of Siting and Related Issues -Travel -Non-manpower (Hard and SW)	180 14.4 0	5.8

		DS4	Participant in several Tasks in DS4 -Travel -Non-manpower (Hard and SW)	360 28.8 0	11.5
		DS5	Participant in several Tasks in DS5 -Travel -Non-manpower (Hard and SW)	360 28.8 0	11.5
13	Torun Centre for Astronomy (TcfA), Poland	DS2-T2	Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	31.7 7.2 0	38.9
14	Chalmers University, Sweden	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	5.3 190.1 44.4 0	239.8
15	University of Cambridge (UCAM DPYS)	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	190.1 43.2 0	233.3
		DS3-T3	Coordinator of "SKA for the User" -Travel -Non-manpower (Hard and SW)	190.1 43.2 0	233.3
		DS4-T3 DS4-T5	Participant in RFI mitigation strategies Participant in Beamforming and Station Signal Processing -Travel -Non-manpower(Hard and SW)	56 74.8 25.3 0	156.1
		DS5-T1 DS5-T2 DS5-T3	Participant in Design EMBRACE Participant in Develop EMBRACE Participant in Assessment of performance -Travel -Non-manpower (Hard and SW)	163 163 122 79.2 0	527.7
16	Kapteyn Astronomical Institute @ RUG, Neth.	DS2-T2	Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	126.8 28.8 0	155.5
17	University Leiden, Leiden Observatory	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	126.8 28.8 0	155.5
18	Cardiff University	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	63.4 14.4 0	77.8
		DS3-T3	Participant in SKA for the User -Travel -Non-manpower (Hard and SW)	95.1 21.6 0	116.6

19	University of Glasgow	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	31.7 7.2 0	38.9
20	Swinburne Univ. of Techn., Australia	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	0 0 20.2 0	20.2
21	Univ. of Adelaide, Aus.	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	0 2.9 0	2.9
22	Univ. of Melbourne, Aus.	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	0 2.9 0	2.9
23	Sydney Univ., Australia	DS6-T1 DS6-T2	Participant in Design of Cylindrical Concept Demonstrator Participant in Development of CC Demonstrator -Travel -Non-manpower (Hard and SW)	0 0 8.6 0	8.6
24	Univ. NSW, Australia	DS2-T1	Participant in Science Simulations -Travel -Non-manpower (Hard and SW)	0 2.9 0	2.9
25	Univ. d´Orleans (UORL)	DS4-T1 DS4-T2 DS4-T3 DS4-T4	Participant in Frontend Technologies Participant in Signal Conditioning and Digitization Participant in RFI Mitigation Strategies Participant in Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	90 127.5 450 52.5 57.6 0	347.0
26	Centre Nat. de la Rech. Scient. (CNRS)	DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	112.5 105 17.4 0	94.0
27	Univ. of KwaZulu-Natal,(Natal Univ.), S.A.	DS3-T4	Participant in Siting and Related Issues -Travel -Non-manpower (Hard and SW)	0 2.9 0	2.9
28	Univ. of Leeds (UNIVLEEDS)	DS2-T1	Participants in Science Simulations -Travel -Non-manpower (Hard and SW)	31.7 7.2 0	38.9
29	Universidad de Valencia, Spain	DS2-T1 DS2-T2	Participant in Science Simulations Participant in Astronomical Data Simulations -Travel -Non-manpower (Hard and SW)	31.7 31.7 14.4 0	77.8

30	OMMIC, Fr.	DS4-T1 DS4-T4	Participant in Frontend Technologies Participant in Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	90 45 10.8 275	168.3
		DS5-T1 DS5-T2	Participant in Design of EMBRACE subsystem Participant in Develop EMBRACE demonstrator -Travel -Non-manpower (Hard and SW)	135 90 18 275	207.2
31	British AE, UK	DS4-T4	Wideband Integrated Antennas -Travel -Non-manpower (Hard and SW)	360 28.8 0	0
32	Qinetiq	DS4-T1	Participant in Frontend Technologies -Travel -Non-manpower (Hard and SW)	360 28.8 0	0

Table 11: National matching-funding from the Participants

Country	National Consortium or Institutes, including industries	Method of obtaining Matching fund and when	Amount of new funds in Euros	In-kind contribution (Total FTE over 4years)
NL	ASTRON	Available staff Grant from Economic Affairs Need NWO grant	 0.8M€ 1.9M€	20FTE
	Kapteyn Astronomical Institute	Availabe staff		2.6FTE
	Leiden University	Available staff		2.6FTE
UK	UK Consortium	Available staff Submit an invited a proposal to PPARC, in April 2004.	 1.4M€	20 FTE 50 FTE
Netherlands	JIVE	Available staff	-	8.4 FTE
France	Observatoire de Paris (OPAR)	Available staff Letter of commitment by Région Centre and Département du Cher to be obtained during contract negotiations I NSU funding attributed year by year between 2004 and 2007	 0.8 M€ 0.25 M€	35.5 FTE
France	Centre National de la Recherche Scientifique (CNRS)	Available (present staff)		1.4 FTE
France	Université d'Orléans (UORL)	Available (present staff)		8 FTE
France	OMMIC	Internally	563K€	-
Italy	Italian Consortium	Available staff Regional funding	 795 K€	25.4FTE
Spain	Fundación General de la Universidad de Alcalá - Instituto Geográfico Nacional (FG-IGN)	Available (present staff		8 FTE
Spain	Universidad de Valencia	Available staff		1.3FTE
Germany	MPIfR	Available staff		3.9 FTE
Sweden	Chalmers	Available staff		4 FTE
Poland	Torun Centrefor Astronomy	-Has automatic matching mechanism for EC grants	-	-
Russia	Puschino Radio Astronomical Observatory	Available staff		8 FTE

South Africa	National Research Foundation and Kwa-zulu University	Available estimate of existing/new staff Innovation Fund grant awarded (spread over 2 years) from Department of Science & Technology. Must be spent in South Africa or on support of South African's abroad.	2.0 M€	10 FTE
Canada	National Research Council of Canada (NRC)	Available staff University of Alberta Research Grants Industrial Contract(s) funded by NRC	Approx. 50 k€ / yr Approx. 100 k€ / yr	8 FTE 0.2 FTE
Australia	CSIRO	National funds	2.2M€	
	Swinburne University of Technology	Available staff		7.0 FTE
	University of Adelaide	Available staff		1 FTE
	University of Melbourne	Available staff		1 FTE
	University of Sidney	Available staff		3 FTE
	University of NSW	Available staff		1 FTE

UK matching funds and industry involvement: A large, invited, proposal for UK matching funds will be submitted to PPARC in late March 2004. This will not only be to support the UK university involvement in SKADS but also, importantly, industrial R&D. On February 18 2004 a PPARC-sponsored meeting on the SKA was attended by 15 representatives from 10 companies or organizations potentially interested in SKA technology development (and/or construction for SKADS via sub-contracts). Two of the largest, BAE Systems and Qinetic, are nationally-funded participants in SKADS and several others have already expressed a strong interest in becoming involved. *The intention is that all the UK industrial effort for SKA will be supported by national funding.* The process of focussing this UK interest in SKA R&D and, the means by which these entities can contribute, will take place during Q1 and Q2 2004.

Other industrial involvement and interest: The semiconductor foundry OMMIC is a participant which will play a significant role in the design and development of the second-generation devices required to build the EMBRACE aperture array demonstrator.

IBM (Europe) has expressed a strong interest in studying the computational requirements of the SKA project; this follows on their direct involvement in the LOFAR project. A letter expressing this interest in included in Annexe 3.

Sub-contracts: Since we wish to construct two significant engineering demonstrators as part of the SKADS programme there will need to be procurement of production hardware, in particular for the aperture array demonstrator EMBRACE. This will be done by normal procurement procedures.

Design and construction of sub-systems for the BEST cylinder demonstrator will be aided by sub-contracts to the entities listed in Table 1 under participant 5 (IRA).

5. OTHER ISSUES

Ethical Issues: We have read Annex 3 – “Ethical rules for FP6 projects” carefully. There are no specific ethical issues associated with radio astronomy research. As regards national legislation all participants will fully conform to current legislation and regulations in their own countries. As regards EU legislation participants in EU member states automatically conform to the listed items. As regards international conventions and declarations all participants will respect the listed items. The other items in Annex 3 refer explicitly to various aspects of bio-technology research and hence do not concern SKADS

Gender Issues: We have read Annex 4 – “Integrating the gender dimension in FP6 projects” carefully. There are no specific ways in which sex and gender are relevant to the objectives and methodology of SKADS Astronomy research is one area of the physical sciences where the female:male ratio is somewhat more equal than in other areas; in radio engineering, however, the ratio is traditionally low. All participants operate strict equal opportunity policies.