Request for Proposals for Siting the SKA

International SKA Project Office

1 September 2004

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I. INTRODUCTION

A. General remarks

New developments in all fields of astronomy have brought the current generation of astronomers to the brink of probing the origin and evolution of the Universe as a whole. To attack these questions directly, a new generation of astronomical facilities is needed with a revolutionary new instrument at radio wavelengths playing a critical role.

The international radio astronomical community is proposing that such a radio telescope, with a million square meters of collecting area, be built at centimeter and meter wavelengths. The project is called the Square Kilometre Array (SKA).

An International SKA Steering Committee (ISSC), established via an MoU among SKA Consortia and other Institutes in countries and regions around the world, is coordinating the development of the SKA. The ISSC is aided by an International SKA Project Office (ISPO), funded by the MoU parties, and a number of technical and scientific working groups. A full description of the project can be found at http://www.skatelescope.org/.

A sensitive radio telescope needs an environment that is as free from man-made radio interference as possible. Six countries/regions reacted to an earlier preliminary request (Appendix I) for statements of interest, and submitted Initial Site Analyses, supported by historical and newly measured data about the physical and radio environments, to site the SKA.

Five of the six responses were of sufficient merit to continue to consider the countries/regions as viable SKA sites. The current Request for Proposals to site the SKA is directed towards the remaining originators of the Initial Site Analyses only.

Proposals to site the SKA should be submitted by 24:00 UTC on 31 December 2005 to:

International SKA Project Director
c/o ASTRON,
P.O. Box 2,
7990AA Dwingeloo
The Netherlands.
(director@skatelescope.org)

Parties that intend to submit a proposal should indicate their intention in writing to the Project Director by 15 October 2004.

Any request for clarification about the content of the Proposal and its supporting documentation can be made in writing to the Project Director at the above address, who will distribute the question and its answer to all proposing parties.

Proposals should not exceed 150 pages in length and should include an Executive Summary of no more than 10 pages. Technical information can be included in Appendices as necessary. Eleven copies (ten paper and one electronic) are required by the due date.

Parties that intend to provide data or other information in addition to that requested in this document should announce their intention to do so to the International SKA Project Director by 15 October 2004. The ISPO will decide whether the proposed extra information is desirable and will inform all Parties submitting proposals. The additional data should be provided in separate Appendices to the original proposal.

B. Overall layout and configurations of the SKA

The detailed design of the receptors for the SKA is not yet determined. As can be seen from the SKA web pages (http://www.skatelescope.org/) a number of competing designs are being investigated and combined solutions are under consideration as well.

General criteria for defining the configuration *for siting purposes* have been defined. Note, however, that the ultimate SKA configuration, following the choice of technology, may differ in some respects from that defined below. These criteria are based on the SKA science requirements, as given in Appendix II, and adopted by the ISSC.

1. The SKA will have a physical distributed receiving area of about one million square meters distributed in a large number (many thousands) of small size receptors (called large N-small D configurations), or a small number (50-60) of large size receptors (called small N-large D configurations). For the purposes of this Request for Proposals, 60 large size receptors may be assumed.
2. 20% of the receptors will be within a 1km diameter ‘core’ area, randomly placed but with the distances between receptors and core center following a Gaussian distribution.
3. The remaining 80% of the area of the SKA will be distributed as “stations”, either large diameter receptors, or concentrations of smaller receptors. Each station will need a footprint of at least 200 m diameter (up to 400m for the large size receptors). For the purposes of this Request for Proposals, the number of stations can be taken to be 50 for the small N-large D configurations, and 100 for the large N-small D configurations.
4. An indicative layout would typically consist of stations located on a number of logarithmic spiral arms, with the distance of each station relative to the origin increasing logarithmically.
5. Of the 80% of the collecting area outside the core, 30% will be within an annulus whose inner diameter is 1 km and outer diameter 5 km. This is called the ‘central area’. We expect that 20 large size receptors or 40 concentrations (stations) of small size receptors will be located in the central area on logarithmic spiral arms emerging from the core area.
6. The remaining 50% of the area will be distributed over logarithmic spiral arms in stations, with a distance between the core and the farthest station being at least 3000km, and a scale size such that half of these will be within 150km from the core, and the remaining 25% between 150km and at least 3000km. This collecting area will be concentrated into either 60 stations composed of small receptors with a footprint of at least 200m diameter each, or in 30 large diameter reflectors with a footprint of at least 400m each.
7. Visible sky. For UV-plane purposes and sky visibility definitions, it will be assumed that stations are limited to observations at elevations greater than 30deg above the horizon. Visible sky is defined as being above the 30deg limit for all stations for a period of at least 4h per 24h.

8. Array configurations under consideration by Proposers should first be tested for suitability by the SKA Simulations Working Group (SimWG), prior to the Proposer adopting a final configuration for detailed consideration for submission in the Proposal. All "as-built" station positions between 1 and 150 km of the array center should be within 10 percent of the nominal distance of the station from the center of the core as deduced from the definition of the logarithmic spirals given above. Adherence to the logarithmic spiral configuration is desirable for stations at distances greater than 150 km from the array center, but deviations of greater than 10% on these distances are allowable if the configuration has been checked and approved by the SimWG and the most distant station is at least 3000 km from the core.
9. Data from each station should be transported in real-time to a central processor area (with a minimum of 100Gb/s). Further information is contained in Part III B (Bench-mark data).

C. Selection process

Details of the selection process are presented in Part II. Part III gives the evaluation criteria that will be used and issues that need to be addressed in the proposals. Note that the information relating to site requirements are often required separately for the central 5 km diameter area containing 50% of the collecting area of the array, and the "remote" stations containing the remaining 50% of the area.

Proposers should bear in mind the different requirements demanded by correlation interferometers compared to single dish instruments. In the core area all interference is correlated between stations, so that only very low levels of Radio Frequency Interference (RFI) are acceptable. At the remote sites, interference is uncorrelated and thus less stringent RFI limits are needed.

The proposal must be for only one overall layout of the array consisting of the central 5 km diameter area and remote stations on spiral arms. Two specific configurations must be proposed within the overall layout to allow for the large N-small D and the small N-large D concepts as detailed in Part IB.

II. THE SKA SITE SELECTION PROCESS

A. Selection Procedures by the ISSC

The ISSC is following an open and transparent procedure in making the selection of the site for the SKA. The steps that have been taken, and will be taken in the future, to ensure this open process are the following:

2002:	Invitation to all regions of the world to submit Initial Expressions of Interest to site the SKA. All national URSI Commission J representatives were invited by the ISSC to submit expressions of interest by 31 May 2002.
Jul 2002:	Initial Expressions of Interest were received and evaluated by the ISSC.
Nov 2002:	Invitation to submit Initial Site Analyses. A total of six countries/regions were invited by the ISSC to submit Initial Site Analyses by 31 May 2003.
Jun-Jul 2003:	Evaluation of the Initial Site Analyses by the SKA Site Evaluation and Selection Committee (SESC). The Initial Site Analyses from four of the six potential countries were received by the deadline and evaluated by the SESC. The results of that evaluation were considered by the ISSC in July 2003. The ISSC decided that all four responses were of sufficient merit to continue to be considered for the SKA site. Recommendations by the SESC for additional questions to be put to the site proponents were also adopted by the ISSC. The additional two site proponents were given until 31 March 2004 to submit their Initial Site Analyses.
Dec 2003:	Evaluation of the responses to the additional questions. The responses submitted by the four site proponents to the additional questions raised by the ISSC by 1 December 2003 were evaluated by the SESC in time for consideration by the ISSC in January 2004. The responses of all four site proponents were judged to be satisfactory by the ISSC.
Apr 2004:	Additional Candidate Sites Initial Site Analyses were received by the ISSC from two additional candidate countries and evaluated by the SESC.
Jul 2004:	One of the two additional candidate countries was approved by the ISSC for inclusion in the list to receive this Request for Proposals.

1 Sep 2004: Request for Proposals to site the SKA (the present document). The RFP has been issued by the ISSC.

15 Oct 2004: Deadline for initial reply by Proposers.

Proposers indicate their intention to reply to the RFP, and communicate their intention to supply additional information to the ISPO.

Sep 2004-Dec 2005: Radio Frequency Interference Monitoring.

Each potential site is required to carry out a program of RFI monitoring to provide quantitative information on RFI throughout a 12 month period following the RFI Measurement Protocol as defined in SKA Memo 37. The ISSC, through the International SKA Project Office (ISPO), will carry out an RFI monitoring program of its own in the period October 2004 to December 2005 at the nominated candidate central sites, to provide benchmark calibrations for the local measurements and ensure the uniformity for the presentation of the results. This will involve month-long visits to each proposed central site by an ASTRON team under contract to the ISPO.

31 Dec 2005: Deadline for submitting proposals to the International SKA Project Director

Jan-Apr 2006: Proposal Evaluation

Analysis of the data provided by the Proposers will be made by the Site Evaluation Working Group (SEWG) and the Simulations Working Group (SimWG) as input for the International Site Selection Advisory Committee (ISSAC).

Apr-May 2006: Review of the proposals by the independent, external ISSAC. The ISSAC will report their findings to the ISSC.

Jun-Sep 2006: The ISSC will carry out further discussions with highly-ranked Proposers in order to come to a final decision on a single site.

Sep 2006: Decision by the ISSC, and communication of result to Proposers.

B. Role of the Evaluation and Selection Committees

Several Committees and Working Groups are involved in the SKA Site Selection Process.

The International SKA Project Office (ISPO) will be the contact point for all Proposers.

The Site Evaluation Working Group (SEWG) will work within the International SKA Project Office. Its role will be to focus on the detailed site evaluation, and in particular, on coordinating the environmental testing of the candidate sites and evaluating the results of the tests.

The Simulation Working Group (SimWG) will work within the ISPO to evaluate proposed configurations, and provide assistance to site Proposers in their preparation of array configurations.

In 2005 the ISSC will establish an independent ad-hoc advisory body, the International Site Selection Advisory Committee (ISSAC). This committee will comprise an international group of independent experts who will review proposals for candidate sites. The ISSAC will report their recommendations to the ISSC.

The ISSC is the final authority in all aspects of the decision process.

C. Principles of Evaluation

The evaluation of the proposed telescope sites will be based on the following global criteria:

1. the ability of the SKA to maximize the science return of the instrument if located at the proposed site;

2. the construction cost to project at the proposed SKA Site (as defined in Part IIIA);

3. the operational cost to project for the proposed SKA Facility (as defined in Part IIIA);

4. physical and political issues

The final selection of the SKA Site will be based on weighing all factors that influence the above criteria.

III. DETAILED EVALUATION CRITERIA

A. Definition of Terms

1. **Array Configuration** is the arrangement of Stations across the proposed area of land to be used for siting the SKA Array, and which ideally should be configured to meet the overall science requirements for the facility (see Appendix II). The nominal bench-marks for the overall layout of the array and possible configurations of receptors within that layout are described in Part IB.
2. **Basic Infrastructure** includes all the infrastructure such as roads, power systems (as applicable) and reticulation (aerial and trenched), water, optic-fiber interconnects, security fencing for all Stations, etc. It does not include infrastructure relating to the construction of the array itself and buildings associated with the construction phase.
3. **Central Site** includes the "core" area and the "central" area, as defined in Part IB. The Central Site is nominally 5km in diameter.
4. **Core Site** is synonymous with "core" area, as defined in Part IB, and is nominally 1km in diameter.
5. **Facility Support Center** provides facilities for ongoing maintenance and upgrades to the SKA Facility. It may also provide short-term accommodation for visiting staff.
6. **Footprint** means the area needed to accommodate an SKA station. Note that specific designs may require restrictions outside this area or in the vertical direction (e.g. the Large Adaptive Reflector see www.drao-ofr.hia-iha.nrc-cnrc.gc.ca/science/ska/#background)
7. **Frequency ranges** (nominal): Low: 100MHz – 1.5GHz; High: 1.5 – 25GHz.
8. **ITU** means the International Telecommunication Union.
9. **Lifetime infrastructure costs** means the sum of the costs of building the basic infrastructure for the SKA (by 2012), operating and maintaining the infrastructure during construction (8 years), and full operation (30 years).
10. **Party** is the organization or country that has been requested to submit a Proposal by this Request for Proposals.
11. **Proposer** is the organization or country representative submitting a Proposal to this Request for Proposals (RFP).
12. **Radio-Quiet Zone** (or Reserve) is a protected area established under regulation and/or legislation and which has a major fraction of defined spectrum below the levels defined in Recommendation ITU-R RA.769 for interferometers, and which fraction should be maintained and improved after its establishment.
13. **Remote Sites** are those SKA Sites outside the Central Site (see also Part IB).
14. **SKA Facility** consists of the Core and Stations, the dedicated land (part of which may be a Radio-quiet Zone), all Basic Infrastructure, and related buildings established for the housing of equipment and personnel.
15. **SKA Processing Center** means a location for computing and other resources necessary to manipulate SKA data for astronomical and other purposes.

16. **SKA Site** consists of the land that has been set aside for the construction of the SKA Facility.

17. **Station** consists of a discrete antenna system (which may consist of just one antenna or a number of closely-connected antennas), and which forms one component of the SKA Array.

18. **Visible sky** is defined as being that part of the sky that is above an elevation of 30deg for all stations for a period of at least 4h per 24h.

B. Benchmark Data

The following preliminary data is supplied to enable Proposers to determine technical requirements and to estimate indicative related costs.

1. Power requirements

Total for Stations on Central Site:	8MW (avg)	10MW (peak)
Facility Support Center:	1.2MW (avg)	2MW (peak)
Remote Station (one off)	120kW (avg)	150kW (peak)

2. Data transport – optic-fiber links

Custom network (Central Site and near-in Remote Stations):		1Tb/s
Remote Stations:	initial operation:	100Gb/s (min.)
	final operation:	1Tb/s.
Link from Facility Support Center to national and international SKA Processing Centers:		100Gb/s (min.)

3. Units

All data provided should be given in international SI units.

C. Evaluation Criteria

The selection of the SKA site will be based on the detailed responses to questions under the following headings:

The quality of Science:

a) Short- and long-term radio-frequency interference and protection issues.

b) Array configuration and performance.

c) Ionospheric and tropospheric conditions.

Infrastructure, climatic and costing issues:

a) Climatic issues.

b) Physical site-characteristics for Stations.

c) Impact of land-use and urban centers.
d) Existing infrastructure.
e) Data interconnects.
f) Costs – capital and operating.

National attributes for siting the SKA:

a) General issues.

b) Government and departmental interaction with SKA community.

c) Support for astronomy and the SKA Facility by national and regional governments.

Each of these issues will now be considered by providing summary background material on each topic, and by giving a description of the information that Proposers are requested to provide in their submission.

Proposers should endeavor to be concise in their responses; use of Appendices for detailed information is encouraged.

1. The Quality of Science

a. Short- and long-term radio-frequency interference and protection issues

Preamble

The Central Site needs to be located in an area that is radio-quiet across a significant proportion of the SKA frequency range. This radio-quiet area needs to be as large as possible (at least 150 km in diameter). For the Remote Stations, the separation of the Stations increases with distance from the Central Site, so that the degree of radio-quietness required decreases. Nevertheless, these more distant stations must still be able to be strategically placed to avoid high-level radio-frequency signals that exceed the levels defined for VLBI in ITU Recommendation ITU-R RA.769.

Proposers are required to perform radio-frequency measurements over a 12-month period at the central site according to the protocol outlined in SKA Memo 37: "RFI Measurement Protocol for Candidate SKA Sites" (www.skatelescope.org/pages/p_docsandpres.htm). In addition RF measurements or reports on RFI should be available for typical Remote Sites.

The International SKA Project Office has initiated a site monitoring campaign to enable cross-calibration between the standard and locally provided RFI measuring instrumentation. This will also be conducted according to the protocol outlined in SKA Memo 37. From an analysis of the data obtained, the degree of radio-quietness as determined by the bandwidths and mean peak intensity levels in the signals measured at the Central Site and Remote Sites will then be evaluated and compared by the ISPO.

i. RFI measurement programs and spectrum use

Information required

In addition to the reports required to be submitted following the completion of the measurement program defined above, and the associated analysis of results, Proposers are requested to describe the likely changes in spectrum use and associated power levels across the full frequency band of the SKA, into the foreseeable future. This study should include land-, air-, and space-based man-made interference, including the expected change in use with time. This study should be done for both the Central Site and a few typical (e.g. with respect to distance to population centers) Remote Sites.

ii. Spectrum protection.

Preamble

Typical methods of protection can include:

- Legislation and/or regulation of use of the spectrum, and, if necessary,
- Control of land-use through legislation to prevent the construction or use of incompatible activities.

Information required

- Following the measurement protocol defined in SKA Memo 37, Proposers will measure the Radio Frequency spectrum from which the current radio-quietness characteristics for the proposed Central Site can be determined..
- Proposers are requested to define appropriate strategies which will not only improve the current radio-quietness characteristics of the Central Site to the interferometric levels defined in ITU Recommendation ITU-R RA.769, but which will also ensure that the radio-quietness characteristics of the Central Site will continue to be maintained over the lifetime of the SKA Facility (a period of 50-80 years is to be assumed). In addition, protection of the Remote Sites needs to be considered, particularly to ensure that man-made electro-magnetic signals do not exceed the levels for VLBI observations defined in ITU Recommendation ITU-R RA.769.
- Current regulatory controls for national spectrum allocation
- Discussions and in-principle agreements that have taken place to date with the appropriate legislative and regulatory authorities concerning the establishment of procedures for protection of the Central Site and Remote Sites, and the establishment of a Radio-Quiet Zone of at least 150km diameter at the Central Site for compatible scientific facilities and experiments.

b. Array configuration and performance

Preamble

The general requirements for the Array Configuration are set out in Part IB of this RFP. Of importance is the distribution of Stations on the proposed Central Site and the Remote Sites. The distribution of such Stations defines the Array Configuration. The performance of a given array configured as a radio telescope can be determined by the use of appropriate computer simulations. Proposers should contact the International SKA Project Office to evaluate the performance characteristics of possible array configurations being considered.

Information required

i. The Proposer is to define two Array Configurations as described in the Introduction, to cater for both stations consisting of concentrations of small receptors and stations consisting of a single large receptor.

ii. The locations of the Remote Sites are to be specified, following the definitions in Part I B.

iii. For the proposed location of the SKA, Proposers are also required to provide the following information relating to visible sky:

- Show the extent of coverage by the SKA of key astronomically interesting objects such as the center of the galaxy.
- Show the extent of common visible sky between the proposed Core Site and other major astronomical instruments which operate or will operate in other parts of the EM spectrum.
- Show the extent of common visible sky with major VLBI instruments and networks and the general ability to link to telescopes on other landmasses.

c. Ionospheric and tropospheric conditions

Preamble

The ability to carry out high quality radio astronomy observations with the SKA depends on the ionospheric conditions, particularly at low-frequencies (around 1.5 GHz and below), and on the tropospheric conditions at the high frequencies.

Information required

Proposers are requested to provide the following information:

i. Total electron content (TEC) variation over the site of the SKA facility including diurnal, annual and variation with solar activity, to be given in the form of histograms and plots;

ii. Ionospheric scintillation (S4 index) at various frequencies and at various times of the year (such as equinoxes and three months after), to be given in the form of plots;

iii. Describe, for your site, large-scale phenomena in the ionosphere such as “gravity waves” (TIDs) (provide occurrence statistics and ‘spread F’) and presence or nearness of the Equatorial Anomaly;

iv. A plot of gradient vs. latitude of energetic particle precipitation rate in regions falling within the South Atlantic Anomaly (SAA).

v. Comments by Proposers on the impact of the Equatorial Electro-jet on the proposed SKA site, in case the site is near the equator.

vi. Local tropospheric transparency and microscopic tropospheric stability;

vii. Diurnal and annual variation of the precipitable water vapor content towards the zenith including statistical insight into its value (such as percentages and quartiles);

2. Infrastructure, Climatic, and Costing Issues

Preamble

Proposers will use the Array Configuration defined in Part I as the basis for the general planning of the SKA Facility, and for specifying the infrastructure requirements and indicative costing.

To obtain an indicative cost for the provision of Basic Infrastructure for the proposed SKA Facility, it is necessary to provide information on the physical characteristics of the terrain in the vicinity of the Central Site and Remote Sites. This should include detailed information about soil conditions for foundations and infrastructure such as roads and buried cable. An important part of the SKA Array is the optic-fiber interconnects between all Stations and the Facility Support Center, and the links to the national and international optic-fiber networks. Finally, it will be necessary to determine the costs of the items defined under Basic Infrastructure.

The information to be provided is set out below. In some cases, information requested in this section has already been provided in response to the earlier call for Initial Site Analyses. This should be repeated in your proposal, and updated if required.

Proposers are to use International SI units and express their costs in USD(2005).

Information required

a. Climatic issues

i. *General:* The following standard statistical data should be provided for the Central Site and Remote Sites: average monthly rainfall, worst-case daily maximum rainfall, average daily maximum and minimum temperatures for each month; mean and peak (as appropriate) monthly values for relative humidity, cloud cover, wind (mean and peak) and direction, thunderstorm days, and occurrence of hail, frost, and snow.

ii. *Lightning statistics:* Lightning statistical data should be provided for all Sites.

iii. *Severe weather:* The incidence of severe weather conditions at all Sites which could impact on the operation of the SKA Facility should be addressed. In particular, this aspect may include the effect of flooding, winds, storms and snow.

b. Physical site characteristics for Stations

Geographic location: The geographic latitude, longitude and altitude of the proposed Central Site and all Remote Sites, including the Facility Support Center, should be given. The relative positions of these Sites in the country or the continent should be described, especially in relation to large cities and important industries which can provide expertise, infrastructure, and provision of technical services, but can also be a source of Radio Frequency Interference. One or more maps on different scales should be used to show this type of information. Include the location of the proposed Central Site and an area of 200 km diameter around the Central Site on a World Aeronautical Chart or Operational Navigation Chart (both 1:1000000 scale and readily available via local or internet sources eg http://www.maptown.com/worldaviation/).

i. *Topography and terrain:* Topography and terrain of the area in the vicinity of representative Stations should be described in some detail. For instance, topographic characteristics, type of sand and rock that might be associated with building costs and resources should be reported. One or more topographic maps marked with colors, contours with legends, and appropriate photographs should be provided.

In addition to general land profiles surrounding Remote Sites, adequate information of soil conditions and geological structure should be provided for representative sites for foundation and trenching purposes, and for roads.

ii. *Central Site:* Special requirements for the proposed Central Site should be addressed in some detail. Descriptions of large-scale features such as ridges, valleys, rivers and ground slope should be provided. On the small-scale, soil type and condition should be defined together with geological aspects, hydrology, and seismic stability. Detailed maps should be used in support of the description.

c. Impact of land-use and urban centers

i. *Land ownership and cost:* The ownership and current use of the land intended for the Central Site, the Facility Support Center, and the Remote Sites should be listed and illustrated by the use of appropriate maps. An indication of land purchase or lease value should be given in each case, together with any current land control issues.

ii. *General land usage:* Distribution maps are to be provided to show protected areas, natural forests, production forests, agricultural fields, grazing lands, wastelands and uninhabited lands in the general area of the Stations. In addition, those lands currently being utilized or available for mining, and other uses (such as defense facilities, industry, rail lines, power stations etc.) should also be discussed.

iii. *Urban centers:* Urban centers within approximately 200km of the Central Site and within 100km of Remote Sites should be indicated on maps. The population, distance to the Central Site in each case, and to the nearest Remote Site should be given. Information on socio-economic amenities at the urban centers should be included.

iv. *Population density:* The population densities across the central 150 km region and within 100 km of the remote stations should be given, including any expected significant future change.

d. Existing infrastructure

i. *General transport access:* Information, including maps, should be provided showing existing infrastructure which may be used to access the Central Site, Facility Support Center and the Remote Sites for transport of heavy loads from a city, an airport, or sea-port (such as equipment being transported to a Site by containers) and for the movement of personnel. The conditions of such transport infrastructure, the possible need for upgrade, and the additional infrastructure that may be required to access the SKA Sites should be described.

ii. *Air transport:* Describe the local air-line routes including the relative locations of international and inter-connecting domestic airports which would be used to access the Central Site and the Facility Support Center in particular.

iii. *Urban center as support for Facility Support Center*: Describe the urban center which would be suitable to support the Facility Support Center. Give the facilities available, including type of supplies, trades, professional services, casual and long-term accommodation, housing, health care, educational institutions, remoteness and attractiveness to potential SKA staff. Comment on the expected long term expansion or contraction of the center and its facilities.

e. Data interconnects

i. Specify the existing major data trunks that straddle the proposed extent of the SKA Facility.

ii. Indicate how data transport links are foreseen to be developed into the future, and how they will conform to the bandwidth requirements of the SKA. (Indicative data-rate requirements are given in Part IIIB "Bench-mark data"). Projected lifetime unit cost (i.e. cost per Mb/s/km) for the data interconnect. This information should be backed up by letters of intent from service providers and regulatory authorities where appropriate

iii. Using the two Array Configurations being proposed, provide a connectivity plan together with projected estimates for its construction and the recurring (operations and maintenance) costs.

f. Costing – capital and operating

Preamble

The SKA Facility will be built on a tight capital budget and it is likely that the budget for recurring expenses will also have tight constraints. It is therefore important that construction and operational costs are minimized.

Information required

In order to evaluate the impact of costs, the following bench-mark information is needed in USD(2005) with justification:

i. *Person costs (per hour):* construction labor, professional engineers, architects, technical, trades, secretarial, (para) medical and security support.

ii. Bench-mark building costs (per square meter) at the Facility Support Center for residential houses, single-story observatory properties and multi-story observatory properties

iii. Unit costs for building materials, such as concrete, steel and aluminum on the sites. Include the fabrication cost (per 1000 kg) for steel structures in urban and rural areas.

iv. Land costs per hectare (acquisition and/or lease) at the Central Site and at the Remote Sites.

v. Legal costs associated with land acquisition.

vi. Road construction – tarred surface and gravel surface (per km).

vii. Type of security fencing necessary for the local circumstances, and the cost (per km, and per site where appropriate).

viii. Trenching and laying of buried conduits for depths applicable to that required for optic-fiber and power distribution in a remote area (per km).

ix. Lifetime costs for providing power to the SKA facility.

x. *Total costs:* For the Array Configurations being proposed, provide a detailed (itemized) estimate (with error bounds) for the total cost associated with the installation of the Basic Infrastructure. Include the cost of the data networks (see Part IIIC2e above). In addition, estimate the Lifetime Infrastructure Costs (see Part IIIA).

3. National Attributes for Siting the SKA

a. General issues

Preamble

In addition to the items discussed in Parts IIIC1 and IIIC2 above which impact on the quality of science and infrastructure issues affected by location and the general environment, the ISSC is requesting information about national issues and factors which may impact on both the short- or long-term efficiency of SKA Facility operation and its long-term viability.

Information required

Proposers are requested to supply information relating to the following questions:

i. Describe the general political and economic structure of your country/region and also of any other countries which have agreed to place Remote Stations as part of the overall SKA Facility under consideration.

ii. Provide letters of intent by the appropriate geopolitical entities on siting the central and remote sites in the locations specified

iii. Give the economic profile of your country's currency relative to the Trade Weighted Index (TWI) for the last 10 years. Concerning economic stability, comment on the susceptibility to economic shock.

iv. Include information on (i)-(iii) for other countries where Stations may be located.

v. In view of planning and other local, state or national issues, outline the procedures to be followed and provide a typical timescale to completion. Indicate what problems may be encountered in such a process. Provide details of any indigenous land-claims or heritage sites and sites of religious significance which may impact on the proposed location of the SKA Facility.

vi. Comment on the ease of entry to your country for all possible SKA related matters. Examples are entry visas for scientists, engineers and other SKA staff.

b. Government and departmental interaction

Preamble

In addition to the request for information on governmental and/or departmental interactions relating to the protection of the SKA Facility from man-made electro-magnetic interference, there are also other issues relating to government interaction which need to be considered. In particular, this refers to the necessary linkages for the overall planning and in the construction and operational phases of the SKA Facility, not only for the country of the central site, but for those other countries where Remote Stations may be located.

Information required

i. Proposers are requested to describe existing interactions and linkages between the various layers of government and their departments for the current planning of the possible SKA Facility in your country, and also those of other countries where Remote Stations may be located. In addition, future linkages which will be established for the planning, construction and operation of the SKA Facility should your country be selected for the SKA should also be described.

ii. Proposers are requested to comment on import/export restrictions and taxes on goods, products, materials and people that could influence the construction and operation of the SKA facility

iii. Proposers are requested to comment on the possibilities for foreign companies to compete for local infrastructure contracts.

c. Support for astronomy and the SKA Facility.

Preamble

The current support of astronomy in your country is seen as an important indicator for the future health of astronomy in your country and for underpinning the design, construction and operation of the SKA Facility through the participation of both scientific and technical expertise. In addition, the siting of the SKA Facility is seen as bringing many economic and other benefits (such as the prestige value, participation in major infrastructure and engineering contracts for the construction of the SKA, and resultant spin-offs into other applications).

Information required

i. Describe the commitment of your government to supporting science and technology. Give examples of such commitments, particularly in regards to international projects.

ii. Describe the academic and scientific population in your country with emphasis on the astronomical sciences. Indicate the approximate number of professional astronomers and graduate students, and any proposed expansion should your country be selected for the SKA Facility. Similarly, discuss the availability of engineers and technical personnel with the relevant expertise to guide the planning, construction and operation of the SKA Facility.

IV. CONCLUDING REMARKS

Parties are reminded that their proposals to site the SKA should be submitted by 24:00 UTC on 31 December 2005 to:

International SKA Project Director
c/o ASTRON
P.O. Box 2
7990 AA Dwingeloo
The Netherlands
(director@skatelecope.org)

Parties should inform the Project Director of their intention to submit a proposal by 15 October 2004. Parties should also inform the Director of their desire to include information in addition to that requested in the Request for Proposals, by the same date.

The questions posed in the Request for Proposals should be answered as concisely as possible. Detailed information can be included, as appropriate, in Appendices.

The ISSC plans to make its decision in September 2006 taking into account the responses to this invitation, the results of monitoring of radio frequency interference at the candidate sites, and the advice of the International Site Selection Advisory Committee. Parties will be informed shortly thereafter of the decision.

APPENDIX I: INITIAL LETTER OF REQUEST FOR PROPOSALS

International Square Kilometre Array Secretariat
Physics and Astronomy
University of Calgary
2500 University Dr. N.W.
Calgary, Alberta
Canada, T2N 1N4

17 November 2002

Dear ,

This letter is being forwarded to all entities that have indicated an interest to host a site for the Square Kilometre Array radio telescope. With it, the SKA International SKA Steering Committee (ISSC) is requesting each applicant entity to provide necessary information about their proposed SKA location in the form of an "Initial Site Analysis Document", which we would like to receive by May 31, 2003. Information about the SKA project is available on multiple web sites, all of which are connected to <www.skatelescope.org>.

Please keep in mind that the final SKA design has not been selected yet and hence the exact extent of the instrument is not known. The most general criteria are a site that provides the ability to do the best science, and a site where the construction and operating costs are minimal. However, one can assume that the final design is likely to include a centrally condensed area up to tens of kilometers across, with additional stations out several hundred kilometers, and further additional stations out to distances of several thousand kilometers.

The ISSC would like certain specific data on your site (see points A to H below); more detailed information would be required at a later stage.

Initial Site Analysis Document for Hosting and Siting the SKA

(Dateline May 31, 2003).

A) MAPS THAT SHOW THE FOLLOWING FOR THE REGION:

a) extent of territory to be used for siting (overlaid with geographical coordinates), and the extent of accessible part of the sky
b) population density and land use
c) roads and rail links
d) major air traffic routes
e) licensed broadcast transmitters (with frequencies)
f) radars (with frequencies)
g) fixed microwave links (with frequencies)
h) annual rainfall and wind data
i) topography
j) existing fiber optic trunks
k) the location of major metropolitan centers (possible operations centers)
l) power availability
m) site security

B) ANALYSIS OF RADIO QUIETNESS, INCLUDING:

a) a notice of intent from the local regulator(s) that they are committed to creating and maintaining radio quiet zones in the region. (if possible)
b) results of surveys of the radio environment made in the region (both pre-existing and new results, in the bandwidth from 150 MHz to 25 GHz)
c) prediction of the evolution of the ground based radio environment over the lifetime of the SKA

C) REPORT ON THE NATURE OF THE IONOSPHERE OVER THE REGION (IMPORTANT FOR LOW FREQUENCIES).

D) CRITICAL REVIEW OF POLITICAL AND ECONOMIC STABILITY IN THE REGION (PARTICULARLY IF THE SITE EXTENTS BEYOND ONE COUNTRY).

E) ANALYSIS OF LABOR COSTS.

F) ANALYSIS OF THE COST OF LAND ACQUISITION AND/OR HIRE.

G) CRITICAL REVIEW OF TECHNICAL AND SCIENTIFIC RESOURCES IN THE REGION.

H) A PLAN AND COSTING SCHEDULE OF HOW THE HIGH-BANDWIDTH DATA LINKS WOULD BE IMPLEMENTED (DEPENDING ON DESIGN).

The required “Initial Site Analysis Document” should not exceed 20 pages. However, appendices (such as maps and tables) are accepted. The reports should be addressed to Professor Richard T. Schilizzi, International Project Director, Square Kilometre Array, ASTRON, Post Box 2, 7990 AA Dwingeloo, The Netherlands.

Sincerely,

Jill Tarter

Chair, ISSC

APPENDIX II: SKA SPECIFICATIONS: SCIENCE REQUIREMENTS

SKA Science Requirements: version 2 SKA Memo 45

D. L. Jones

26 February 2004

The system-level performance requirements[1] for the SKA have been slowly evolving for several years, largely in response to additional science drivers. Ron Ekers published a summary of technical specifications as SKA Memo 4 in 2002 (regarded as version 1 of the requirements). However, it was recognized that the specifications were not complete or sufficiently detailed in some areas. For example, one of the primary SKA specifications for many years has been an A/T of 20000 m 2 /K. This value is well justified by the requirements of deep HI surveys. But this one number cannot plausibly apply to all possible observing frequencies and elevations. To guide concept design work, we need an expanded set of requirements that take into account variations in parameter values and that provide as much internal consistency as possible.

Following the 2003 international SKA workshop in Geraldton, a small working group was formed by the ISSC and charged with developing a revised and expanded set of requirements for the SKA. The members of this group were Richard Schilizzi, Ron Ekers, Chris Carilli, Steve Reynolds, Bryan Gaensler, Russ Taylor, Ken Kellermann, Jill Tarter, and Dayton Jones. After several iterations by this group, a revised set of requirements was distributed to the ISSC, ISAC, IEMT, and others for comments. After some additional revisions the expanded

[1] The term "requirement" indicates something that the SKA must do to achieve a key science goal. Other documents have sometimes used "specification" in the same way. The term "goal" is used to indicate an area of expanded capability that would significantly enhance the SKA's scientific productivity, but which may not be feasible for technical or financial reasons. The terms "level 0 science" and "key science" are synonymous.

requirements were presented and discussed at the Leiden meeting in Nov 2003.

In parallel with the requirement revision effort, a working group of the ISAC led by Bryan Gaensler has developed a set of “level 0”, or highest priority, science goals for the SKA. The definition of level 0 science, now called Key Science Projects, and the process used to determine what science topics should be included are described in SKA Memo 35, published by B. Gaensler in 2003. Five key science topics were presented and discussed at the Leiden meeting (see Memo 44 by Gaensler and the ISAC):

- Gravity – probing strong field gravity via timing of pulsars in very compact binaries
- Probing the Dark Ages – epochs of reionization, star formation, black hole formation
- Cosmic Magnetism – origin and evolution of magnetic fields in galaxies and clusters
- The Cradle of Life – terrestrial planet formation, SETI, astrochemistry
- Evolution of Galaxies and Large Scale Structure – observations of HI in galaxies at high redshifts leading to the strength of dark energy as a function of cosmic epoch

The SKA requirements are intended, above all, to allow the Key Science Project goals to be achieved. They should also allow a wide range of “level 1” science areas to be addressed, and as much flexibility as practical.

The most recent version of the science-based SKA requirements, incorporating results from Leiden, are listed in Table 1. The values in this table have not yet been approved by the full ISSC, and further revisions are likely. Following the table are a discussion of the science drivers for each item and a summary of how these requirements differ from previous versions.

Table 1 – Expanded SKA Science Requirements

1. Frequency range	100 MHz - 25 GHz Goal: 60 MHz - 35 GHz
2. Simultaneous independent observing bands[2]	2 pairs (2 polarizations at each of two independent frequencies, with same FoV centers)
3. Max. freq. separation of observing bands	Factor of 3 between observing band center frequencies (same FoV centers)
4. Instantaneous bandwidth of each observing band	Full width = 25% of observing band center frequency, up to a maximum of 4 GHz BW for all frequencies above 16 GHz
5. Sensitivity at 45 degrees elevation (A/T)	Goal: 2500 at 60 MHz 5000 at 200 MHz, 20000 between 0.5 and 5 GHz, 15000 at 15 GHz, and 10000 at 25 GHz Goal: 5000 at 35 GHz
6. Configuration	Minimum baselines 20 meters, 20% of total collecting area within 1 km diameter, 50% of total collecting area within 5 km diameter, 75% of total collecting area within 150 km diameter, maximum baselines at least 3000 km from array core (angular resolution < 0.02 / f_{GHz} arcsec)
7. Image quality	Dynamic range > 10^6 and image fidelity > 10^4 between 0.5 and 25 GHz, over a range of 90 degrees in declination and 100 in angular resolution

[2] An "observing band" is a contiguous set of frequencies that pass through all processing steps simultaneously.

8. Contiguous imaging field of view (FoV)	1 square degree within half power points at 1.4 GHz, scaling as λ^2, 200 sq. deg. within half power points at 0.7 GHz, scaling as λ^2 between 0.5-1.0 GHz
9. Number of separated fields of view	1 with full sensitivity Goal: 4 with full sensitivity 10 simultaneous sub-arrays
10. Correlator and post-correlation processing	Input bandwidth 25% of center frequency for frequencies below 16 GHz and 4 GHz for frequencies above 16 GHz (per observing band) Imaging of 1 square degree at 1.4 GHz with 0.1 arcsec angular resolution Imaging of 200 sq. degrees at 0.7 GHz with 0.2 arcsec angular resolution Imaging of 10^4 separate regions within the FoV, each covering at least 10^5 beam areas at full (maximum baseline) angular resolution Spectral resolution of 10^4 channels per observing band per baseline Minimum sampling interval 0.1 ms for wide-field pulsar searches
11. Beamformer capability	50 simultaneous summed (phased array) beams within FoV, inner 5 km diameter of array. No time averaging, 8 bits/sample.
12. Survey speed	FoV x $(A/T)^2$ x BW = 3 x 10^{17} $deg^2\, m^4\, K^{-2}\, Hz^{-1}$ at 1.5 GHz FoV x $(A/T)^2$ x BW = 1.5 x 10^{19} $deg^2\, m^4\, K^{-2}\, Hz^{-1}$ at 0.7 GHz
13. Antenna pointing and slewing	Blind pointing < 0.1 HPBW, move between adjacent sky positions separated by 0.5 HPBW in 3 sec, move between sky positions sep. by 90 deg. in < 60 s
14. Instrumental polarization	Polarization error / total intensity –40 dB at FoV center, -30 dB out to FoV edge (after routine calibration)
15. Spectral dynamic range	10^4 (flatness of bandpass response after calibration)
16. Total power calibration	Total power (zero-spacing) flux density measured with 5% error in 1 hr.

Key Science Drivers for Each Requirement

For brevity, the strong-field gravity key science project will be referred to below as “pulsars”, and probing the dark ages will be referred to as either “EoR” for observations of HI at very high redshifts and as “galaxy origins” for continuum and CO line observations. Also, the “cradle of life” key science project will be defined by high resolution imaging of proto-planetary disks and SETI observations. Finally, the evolution of galaxies and large-scale structure key science project will be referred to as “dark energy”.

1. The low frequency limit of 100 MHz is a compromise between what is needed to study the epoch of reionization (EoR) over its full redshift range and what is needed for all other key science projects (200-300 MHz). 100 MHz corresponds to a redshift of 13 for HI. The low frequency goal of 60 MHz corresponds to a redshift of 23 for HI. The final low frequency requirement may be changed when results from LOFAR are available. The high frequency limit is required by the galaxy origins and cradle of life key science projects. The limit is increased from 20 to 25 GHz to cover the H20 and NH3 lines. The goal of 35 GHz allows observation of CO over a wider redshift range, higher resolution imaging and astrometry of AGN/jets and both higher resolution and higher SNR imaging of protoplanetary disks, stars, solar system objects and other thermal sources. Spacecraft tracking in the 32-GHz band would also be possible.

2. No explicit key science requirement, but needed for plasma delay calibration and desired for general observational flexibility.

3. Not explicitly required, but desired for both pulsars and dark energy (to cover 0.5-1.0 GHz frequency range simultaneously, for example), for spectra of fast transients, and for absolute astrometry.

4. Wide bandwidths are required by the pulsars, galaxy origins, cradle of life, and dark energy key science projects. It is desired in general to take full advantage of the SKA collecting area for continuum observations.

5. The sensitivity at low frequencies is required by EoR and (above 200 MHz) the galaxy origins key science projects. Between 0.5 and 5 GHz the requirement is set by the pulsars, galaxy origins, magnetic universe, and dark energy projects. At 10 GHz the requirement is set by the galaxy origins, magnetic universe, and cradle of life projects. At 25 GHz the requirement is set by galaxy origins and cradle of life projects, and also H2O and NH3 observations, AGN/jet imaging, astrometry, and thermal imaging. At the highest frequencies the specification is set by the cradle of life project, and also spacecraft tracking, AGN/jet imaging, astrometry, and thermal imaging.

6. The minimum baseline requirement is set at allow wide-field imaging. The 20% collecting area within 1 km diameter specification is needed for high surface brightness sensitivity in general. The 50% collecting area within 5 km diameter is needed for pulsars, EoR, and cradle of life (SETI). It is also desired for transients and spacecraft tracking. The 75% collecting area within 150 km diameter specification is needed for pulsars, EoR, galaxy origins, magnetic universe, and dark energy. The.maximum baseline length is required by the galaxy origins and cradle of life projects. It is also desired for astrometry, AGN/jets, pulsars, and spacecraft tracking. The detailed breakdown of collecting area vs.

diameter is taken from the recommendations of the configuration working group at the Groningen SKA workshop. An approximately scale-free configuration giving a smooth decrease in surface brightness sensitivity from minimum to maximum angular resolution is desired for maximum imaging flexibility.

7. High dynamic range and high fidelity imaging are required by all key science projects.

8. The 1 square degree FoV is required by all key science projects. In addition, the 200 square degree FoV for 0.5-1.0 GHz is required by the dark energy key science project.

9. One FoV is required for all projects (obviously). None require more than a single FoV, but most would benefit from this (especially the large surveys) and it would dramatically increase the general observational flexibility of the SKA. Sub-arraying is needed for pulsars and desired for astrometry.

10. The correlator and post-correlation processing bandwidth requirement is identical to the observing bandwidths in item 4. The full field (but not full resolution) imaging requirements are needed for pulsars, galaxy origins, magnetic universe, and dark energy. The high angular resolution requirement is needed for pulsars, galaxy origins, and cradle of life. It is also desired for AGN/jets, astrometry, and imaging of stars, solar system objects, and maser sources. The requirement for 10 4 spectral channels is needed for adequate velocity resolution over wide bandwidths for the dark energy project. (Note that the full-field imaging requirement for the dark energy project implies higher spectral resolution to avoid bandwidth decorrelation.) The 0.1 ms sampling interval is needed for the wide-field search phase of the pulsars project.

11. A large number of beamformers is required by pulsars and the cradle of life, and also desired for transients and spacecraft tracking. The exact number is somewhat flexible. Detection equipment for the beamformer signals is expected to be experiment specific and is not considered here.

12. The survey speed specification is required by all key science projects except the cradle of life. The 0.7 GHz requirement is needed by the dark energy project.

13. Accurate blind antenna pointing is required by all projects. The small and wide angle slew requirements are not explicitly needed by key science projects, but the small-angle slew requirement is desired for mosaicing and the large-angle slew requirement is desired for transient source observations and absolute astrometry.

14. The polarization requirement is needed for the pulsars and magnetic universe projects.

15. High spectral dynamic range is required for the galaxy origins, cradle of life, and dark energy projects.

16. Total power calibration is required for the galaxy origins, cradle of life, and dark energy projects. It is desired for all imaging observations.