Outline and Work Areas for a Technology Development Plan to be proposed to the NSF

For the US SKA Consortium

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Summary

In acknowledgement of the USSKA Consortium's desire to develop a Large-N/Small-D concept for the SKA with support from the NSF, the NSF has suggested that our funding request should be in the form of a 5-year SKA Technology Development Plan. The goal of the TDP is to develop the US LNSD concept into a design for the SKA. This document contains a draft summary of the aims of the TDP, a tentative list of work areas, and a scenario for developing the proposal. The Consortium as a whole needs to decide on how to implement the TDP: who is willing to do what? Table 1 gives the process and schedule for developing the proposal. The due date for the proposal is 1 December 2003.

The funding level was not specified by the NSF, other than to imply that we should ask for what we need to advance the Large-N/Small-D concept into a design. For reference, the dollar amount mentioned in the Decadal Survey was $22M. We should keep this figure in mind while also recognizing the current funding environment.

Action Items for Consortium Members

- Please comment on this document, especially the work areas and how they will be addressed, and how the proposal should be constructed. Comments are needed by 15 September in order to prepare for our first telecon on 18 September.
- Please assess what work areas you would like to participate in. Keep in mind that (a) the work effort needs to contribute to the overarching coherent goal of producing a detailed design for the SKA under the LNSD concept; (b) we must avoid duplication of effort while also ensuring that we cover all areas to the needed completeness. These should be communicated to us at Cornell well before the telecon on 18 September.
- Be ready to critically discuss the TDP and the proposal plan during the 18 September telecon (1:30 pm EDT).

1. Goals of the Technology Development Plan (TDP)

In June 2003, the NSF communicated with us[1] via a video/telecon its view that a detailed TDP for the SKA and a plan for its implementation was needed from the US SKA Consortium. The NSF emphasized the general goal of supporting the development work for the SKA (as summarized in the last decadal survey report) and the specific goal of developing a design that would be chosen at the international level for the construction phase of the SKA. A more centralized and focused management of the project was strongly recommended. The NSF also advised us that a much clearer and focused science case was needed for the SKA. The Consortium has discussed the NSF's recommendations in a telecon and in a short meeting at Geraldton in 2003 July. At Cornell, we have discussed how we would like to implement the NSF's recommendations, including how the TDP would be managed. We have concluded that the National Astronomy and Ionosphere Center is the appropriate organization for centralizing the management of the development effort.

In somewhat more detail, the goals of the TDP and its implemention should be:

1. to develop technology needed for advancing the Large-N/Small-D (LNSD) concept for the SKA with special attention to elements on the critical path and to costs.
2. to provide deliverables in technology relevant to the SKA (and perhaps to other radio astronomical facilities).
3. to develop necessary prototypes to advance the LNSD concept.
4. to satisfy international milestones for providing documents and plans for the LNSD project and thus lead to the choice of the LNSD concept as an integral part of the SKA project.

2. The Proposal Committee

As discussed at our 2 July telecon and subsequently, the Proposal Committee is currently:

Bob Brown (NAIC)
Jim Cordes (Chair, Cornell)
Lincoln Greenhill (SAO)
Paul Goldsmith (Cornell)
Bob Preston (JPL)
Jill Tarter (SETI Institute)
Sandy Weinreb (Caltech/JPL)

In addition, Ken Kellerman (NRAO) has volunteered to read the proposal critically as it unfolds.

[1]NSF participants were Richard Barvainis, Andrew Clegg, Robert Dickman, Eileen Friel, and Vern Pankonin; Consortium participants were Jim Cordes, Ken Kellerman and Yervant Terzian; Richard Schillizzi, International SKA Project Director, also participated.

3. Timeline for the Proposal

The proposal needs to be submitted in early December in order for it to be reviewed in time for us to receive funding in FY 2004. For the proposal, we need to define the work areas or tasks that we are requesting funding for, designate who will do the tasks, identify prototyping that needs to be done, determine how the funded work will be combined into a coherent proposal to the International SKA Steering Committee (ISSC) in 2007, and forsee document preparation and oral presentations to relevant committees, etc. for the next decadal survey in the US. As part of the proposal, we also need a well thought out management plan for the development work. An appropriate timeline for discussing these tasks and writing the proposal is given in Table 1.

Table 1: TDP Proposal Preparation Timeline (Fall 2003)

Event	Date	What?
Distribute Outline & Work Areas	05 Sept	This document
Responses from Consortium	15 Sept	Comments on work plan to Cornell, Propose your contributions to WBS*
Telecon†	18 Sept **1:30 pm EDT**	**Subjects:** Work areas and proposal outline, Assignments for writing and graphics, Discussion of TDP timeline for Gantt Chart, Discussion of WBS
NSF Visit	22 Sept	Brown, Cordes, Terzian
Telecon	25 Sept **1:30 pm EDT**	**Subjects:** Report on NSF Visit, Proposal section status, Discussion of TDP Gantt Chart Discussion of WBS.
Drafts of sections	01 Oct	Send to JMC, Assemble & Distribute to Consortium
USSKA Consortium Meeting	03 Oct	Pasadena
Proposal Draft	07 Oct	Distribute Cornell → Consortium
Telecon	09 Oct	**Subjects:** Proposal draft, Gantt, WBS TDP vis a vis ISSC time line
Comments from Consortium	16 Oct	Written comments on proposal draft
Proposal draft	21 Oct	Distribute Cornell → Consortium
Telecon	22 Oct	**Subjects:** Proposal draft, TDP vis a vis US Decadal Survey
Telecon	30 Oct	**Subjects:** Proposal draft
Telecon	06 Nov	**Subjects:** Proposal draft
SKA Science Retreat (Leiden)	10-14 Nov	Prepare science case
Comments from Consortium	14 Nov	Written comments on proposal draft
Proposal draft	18 Nov	Distribute Cornell → Consortium
Telecon	20 Nov	**Subject:** Proposal final draft
Final comments from Consortium	21 Nov	Written comments on final draft
Submit Proposal to the NSF	1 Dec 2003	
Reverse Site Visit at NSF	February 2004	Presentation to Review Panel
Funding Commences	1 July 2004	

∗ WBS = Work Breakdown Structure

† Telecons will be 1 hour in length and will be coordinated through an 800 number and passcode.

4. Work Areas for the TDP

The design for the LNSD concept needs to be driven by science. Key science goals and capabilities need to be defined before we can design the SKA. Simulations are an integral part of the process of linking science to design. To optimize and completely define the LNSD concept and evolve it into an actual design for the SKA, we need to develop key components, prototype subsystems, design the SKA as a working system, and estimate costs. Some central aspects of the concept rely on synergies with other telescope facilities. The ATA in particular will serve as an important testbed for key aspects of the LNSD concept. Outreach is an appropriate part of our development work. Indeed, the SKA and its science goals are a superb focus for outreach.

The work areas summarized below follow from the discussion in our Roadmap, submitted to NSF in April 2001, and in our original, comprehensive 3-year proposal to the NSF/ATI program, which was funded at a substantially lower level than our request.

How is our proposed new TDP different from the original Roadmap and ATI proposal? The overall goals are not different and the work areas are nearly identical. The international timeline set by the ISSC has been modified (such that siting and concept selection each have been pushed forward by two years). The new plan differs in that (a) it is more comprehensive owing to it being a 5-year project that spans from next year through the concept downselection process and to the time of the next US decadal survey; (b) antenna prototypes (and other subsystems) are an integral part of the new plan; and (c) Finally, the management structure is more explicit and centralized.

The following enumerated list is a first pass at identifying an 'end-to-end' description of the elements of an SKA based on the LNSD concept. The list also serves to itemize work areas for which we should request funding from the NSF in our grant proposal. Under each main item we list "Issues" that need to be resolved or determined under the work plan and "Deliverables", which are specific outcomes (in the form of documents, hardware and software) that result from the work done under the grant.

In terms of work areas for the TDP and its implementation, the items in this list do not have equal weight! Perhaps only a few will be worked on actively during the TDP. But we need to consider them all when we propose an actual SKA design, first to the ISSC, and later to funding agencies.

1. **Science Case**
   Issues:

   - What science goals is the LNSD concept optimized for?
   - What is the survey yield?
   - What other science areas should be enabled?

   Deliverables:

   - Input skies to simulators
   - Demonstrator observations using existing telescopes (Arecibo, ATA)

- Assessed outputs from simulators and interpretation for the SKA design

2. **Antennas, Feeds and Optics (including mount)**
   Issues:

   - Antenna type and size (symmetric, off-axis, diameter)
   - Optics (Gregorian + prime focus? f/D for each focus?)
   - Feed design (planar and/or traveling-wave types; bandwidth? how many? location?)
   - Antenna parameters (A_e/T_{sys}, polarization performance, radiation patterns)
   - Mechanical design (structural design, mount design including foundation, feed positioning system (if needed) for combined prime focus/Gregorian system)
   - Fabrication (antenna manufacturing, feed manufacturing, LNA-feed integration)
   - Monitoring and control
   - Transportation
   - Cost per A_e/T_{sys} (including LNAs, below)

   Deliverables:

   - Electromagnetic designs
   - Manufacturing plan
   - Prototype(s): fully optimized "final" antenna + feeds + receivers + mount (number of prototypes TBD).

   Marketability:

   - Antennas to other facilities (e.g. EVN, EVLA, university lab courses).
   - Probably depends on size.

3. **Receiver Design**
   LNAs:
   Issues:

   - Noise figure, bandwidth, cost
   - How many needed to cover frequency range?
   - Dynamic range

   Cryogenics:
   Issues:

   - Operating temperature
   - MTBF
   - Cost

   IF Design:
   Issues:

   - At antenna/station vs. centralized
   - LO distribution

   Deliverables:

- LNAs for tests on existing antennas
- LNAs for final LNSD antenna and feed system
- Full receiver design and costing

Marketability:

- Other radio facilities

4. **Configuration definitions:**
Issues:

- Science drivers
- Core array, intermediate array, "VLBI" array
- Scale invariance?
- Achievable imaging dynamic range (see correlator and algorithms)
- Geographic issues (brief consideration of site specific issues)

Deliverables:

- Detailed knowledge from simulator results
- Lessons learned from ATA usage
- Synergy with LOFAR and EVLA
- Specific configurations for relevant sites (before site selection in early 2006; refined for site decision of 2006)

5. **Data Transport**
Issues:

- Deliverable bandwidth
- Cost estimates for US site

Deliverables:

- Results of tests on long paths using commercial networks

6. **Signal Processing: Correlator/Beamformer**
Issues:

- Channelization and Samplers
- Large-N operating modes (imaging, multiple beams, multiple FOV)
- Feasibility for LNSD concept using particular configuration(s)
- Full-FOV sampling
- RFI excision
- Postprocessing plan (real time and off-line processing) (seti, transients, pulsars, imaging)
- Number of directly-connected antennas
- Total bandwidth and number of channels
- Dump times (esp. time-domain science)
- Cost

Deliverables:

- Algorithms for large-N contexts (e.g. high dynamic range imaging)
- Conceptual correlator design for the SKA with costing
- Postprocessing plan
- Definitions of operational modes
- Proof of principle and science return using the ATA

7. **Signal Processing: Backend processing**
   Issues:

   - Imaging
   - Spectroscopy
   - Time domain (pulsars, transients)
   - SETI
   - Storage and data products

   Deliverables:

   - Backend processing requirements document
   - Test observations on existing facilities where feasible
   - Costing

8. **RFI Management**
   Issues:

   - Can we achieve specified sensitivity?
   - Available bandwidth
   - Site assessments

   Deliverables:

   - Algorithms for use on existing facilities and on array prototypes (ATA and LOFAR)
   - An RFI plan for the eventual SKA design

9. **Modes of operation**
   Issues:

   - How to achieve science goals (imaging, non-imaging)
   - Complexity of operations (multiple beams, multiple FOV, subarrays, single antennas vs. stations)

   Deliverables:

   - Requirements on correlator and beam former

10. **Data Management**
    Issues:

    - How do users use the SKA?
    - Archiving of data products (high and low level)

- Interfacing to the NVO and IVO (National and International Virtual Observatories)

Deliverables:

- A data management plan with costing

11. **Maintenance and Operations**
Issues:

- Large N implies need for small MTBF in order to minimize number of 'down' antennas
- However, large N also implies a high level of fault tolerance if dN antennas are down
- Where are maintenance crews and spare parts located?
- Is data transport from distant antennas part of the operations cost?
- Operations costs

Deliverables:

- FTE requirements for operations
- FTE requirements for maintenance
- Costs

12. **Upgrade Plan**
Issues:

- How to keep the SKA current?

Deliverables:

- An upgrade assessment

13. **Costing**
Issues:

- Cost equation(s) for elements (subsystems) that drive capital costs
- Land acquisition costs
- Operations and maintenance costs
- Upgrade costs

Deliverables:

- Cost Budget

14. **Outreach**
To astronomers:

- Promote SKA development to students to attract them to the project
- Promote the SKA to our colleagues (Quarks to Cosmos type documents, the new science case, results of simulations)

To the general Public:

- Venues: science and visitor centers

5. Timeline for Technical Development

Table 2 sketches the time line for the TDP and its implementation. It needs to be fleshed out with significant milestones.

Table 2: Timeline for Implementing the 5-yr Technology Development Plan

Event	Date	Comment
Funding begins	1 July 2004	Subcontracts from Cornell
Work begins on:		Various timelines
Science Simulations		Science simulator (Haystack/Swinburne)
Antennas, Feeds & Optics		
LNAs		
Configuration definition		
Data transport		
Signal Processing:		
Correlators/Beamformers		
RFI excision		
Systems Definition		
• Modes of operation		
• Data Management		
• Maintenance & operations		
• Upgrade plan		
• Costing of subsystems, siting, operations, maintenance		
Outreach		
New LNSD Whitepaper	Mid 2004	
Updated Site Hosting Proposal	Mid 2004	
New LNSD Whitepaper	Mid 2005	Concept downselect by ISSC
Identification of antennas	Mid 2005	Contingent on optimization results
Final Site Hosting Proposal to prototype	Mid 2005	
Site Selection	Jan 2006	by ISSC
Updated LNSD Whitepaper	Mid 2006	
Antenna prototypes	Mid 2006	begin testing/operating
Final LNSD Proposal to ISSC	Mid 2007	
Concept Selection	2007	by ISSC
Decadal Survey begins	2008	
Construction proposal	$\gtrsim$ 2010	
Funding ends	30 June 2009	
Post-TDP Work:	$>$ 2009.5	Refine SKA Design Prepare Funding Proposals

6. Funded activities

1. Work areas in §4 with subcontracts from Cornell to relevant insitutions in the Consortium.
2. Funding use of the ATA as an SKA testbed.
3. Contributions to the international project: office costs, site testing (including hardware), project engineer, project scientist
4. Travel for US participation in ISSC meetings
5. Technical travel associated with work areas of the proposal
6. Management costs (Cornell/NAIC):
    - Project Manager (1 FTE)
    - Administrative assistant for Project Manager and budgets ($\sim$ 1 FTE)

Outline of Proposal

Currently, there is no page limit on the proposal and we expect to deliver the proposal in paper form, not electronically through NSF's Fastlane. (This needs to be confirmed). Paper format allows us to more easily include color graphics, which we should use to our advantage. Table 3 gives the sections of the proposal that are needed, following standard format for NSF proposals. Page numbers are not filled in yet, as they will be determined through our discussions and telecons this Fall.

Table 3: Sections Needed in Proposal

Section		Description	Approx. No. Pages
Project Summary.			
Table of Contents.			
Project Description:			
I.	Introduction	Summarize SKA & US SKA effort, Science Requirements (Use Leiden Science Retreat Results)	
II.	Work to be done	Work areas Work Breakdown Structure Key decisions and results	
III.	Management Plan	Cornell/NAIC Individual Institutions Gantt time line Decision-making process	
References Cited.			as needed
Biographical Sketches.			2 pp./co-I
Proposed Budget:			
		Total Budget	as needed
		Individual Institutions' Budgets	as needed
		Budget Justifications	$\leq$ 2 pages/institution
Current & Pending Support.			as needed
Facilities, Equipment & Other Resources			as needed
Special Info. & Supplementary Documentation			as needed
Appendices			as needed