USSKA Consortium Technology Development Project: Outline for Proposal to the NSF

For the US SKA Consortium

30 September 2003

Description:

This document is to be discussed at the Pasadena meeting this Friday, 03 October, in our afternoon session on the TDP proposal. It attempts to include points of view and ideas from our telecons and from emails. The last table contains a preliminary (note: **preliminary**) list of groups who will be responsible for writing proposal sections. I've not gotten prior approval from any of you about this but the groups are consistent with our discussions, etc.

Tables Included:

1. TDP Proposal Preparation Timeline
2. NSF Proposal Outline (Sections required for Fastlane submission)
3. Timeline for Implementing the 5-yr TDP
4. TDP Activity List (initial prioritization)
5. Proposal Section Groups (for writing proposal sections: first pass)

1. 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.

2. Goals of the Technology Development Project (TDP)

The goals of the TDP and its implemention are to:

1. 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. provide deliverables in technology relevant to the LNSD concept, its scientific capabilities, and its costing.
3. develop necessary prototypes to advance the LNSD concept.
4. lead to the choice of the LNSD concept as an integral part of the SKA project. This entails satisfaction of international milestones for providing documents and plans for the LNSD project as it develops.

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.

4. Primary Issues for the TDP (The Big Questions)

Here is a first crack at identifying the main issues for the TDP. Under each numbered item is a short list of things to consider.

1. **How do we address science goals in terms of technical specifications of the LNSD concept?**
   - International Level 0 and Level 1 science goals
   - LNSD specifications
   - integrated LNSD-science plan
   - integrated SKA "hybrid" plan
   - input to simulator for an SKA system
2. **How do we achieve A_e/T_{sys} at lowest cost?**
   - at the single-antenna level, including manufacturing/transport costs
   - vs. frequency
   - vs. baseline configuration
3. **How do we maximize signal bandwidth and data processing throughput?**
   - define modes of operation (imaging, non-imaging)
   - data transport
   - channelization, correlation and beam forming
   - post processing
4. **Can we mitigate RFI to achieve sensitivity goals and science specifications?**
   - Algorithm development
   - ATA testbed for large-N context
   - other testbeds
5. **How do we sell the SKA project and use it to promote science?** (EPO)
   - Outreach at all levels (peer scientists, K-12, etc)
   - Educational tool development (antennas at selected venues, etc.)
6. **How does the LNSD concept fit into a hybrid design for the SKA?**
   - selection process at the international level
   - anticipate possible hybrids
   - consider overall optimization (science, costs) in hybrid

5. Elements of the LNSD Concept for the SKA

An SKA based on the LNSD concept would be proposed with the following enumerated areas described in detail. That is, a comprehensive description of the SKA would necessarily include everything from the science case to outreach and a technical description of the physical elements, siting, operations, maintenance, etc.

For the TDP, we expect to concentrate on only a subset of these areas while, at the same time, keeping the complete project in mind.

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 (ATA +)
- Assessed outputs from simulators and interpretation for the SKA design

2. **Antennas, Feeds, Optics and Mount** (broken into 2a, 2b in Tables)
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
- Transport 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

6a. **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

6b. **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

7. **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

8. **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

9. **Data Management**
Issues:

- How do users use the SKA?
- Data processing (imaging, non-imaging)
- 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

10. **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

11. **Upgrade Plan**
Issues:

- How to keep the SKA current?

Deliverables:

- An upgrade assessment

12. **Costing**
Issues:

- Cost equation(s) for elements (subsystems) that drive capital costs
- Identification of cost/performance trades to meet price target
- Land acquisition costs
- Operations and maintenance costs
- Upgrade costs

Deliverables:

- Cost Budget

13. **Education and Public 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:

- The SKA as a teaching platform
- Venues: science and visitor centers

Additional items:

Management:

ATA Testbed Use:

US Siting Proposal

International Participation Costs

6. Proposal Issues and Outline

Table 2 presents an outline for the proposal sections.

The proposal will be submitted through Fastlane. Page limits and inclusion of appendices need to be preapproved with the NSF before submission.

A boundary condition (from hard experience) is that the proposal should be self-contained, with minimal reference to other US SKA documents.

The review panel is likely to include non-radio astronomers and managers of large projects. Radio astronomer panel members are unlikely because of conflict-of-interest requirements. Therefore, the proposal should be aimed at a non-specialist audience, justifying the TDP in a comprehensive, top-down manner.

The NSF suggests providing hard copies of the proposal and CDROMs of the proposal (and additional material).

7. Timeline for Technical Development

Table 3 sketches the time line for the TDP and its implementation. It needs to be fleshed out with significant milestones.

8. TDP Activity List

Table 4 lists the activities that should be funded under the TDP and has a very preliminary prioritization expressed in the 'Costing' column. The 'Who?' column is a first pass at identifying institutions involved in the the various areas.

9. Proposal Section Groups

Table 5 lists the main work areas of the TDP and identifies individuals or institutions who can and hopefully will contribute to the writing of the appropriate sections. Note that the introductory sections are not included in this list. They will be written by the proposal committee and any 'volunteers' that are identified.

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	**Subjects:** Work areas and proposal outline,
	1:30 pm EDT	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	**Subjects:** Report on NSF Visit,
	1:30 pm EDT	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

Table 2. NSF Proposal for a Technology Development Program for the LNSD Concept

Section	Description	Approx. No. Pages
Project Summary.		1
Table of Contents.		1
Project Description:		
I. **Introduction**		10
	SKA Science Goals (International)	
	The International SKA Project (including timeline)	
	The US SKA Consortium	
II. **The LNSD Concept**		5
	The LNSD Concept: What it is, what science it enables	
	Relation of LNSD to other concepts	
	Costing	
	Purpose of the TDP	
II. **Big Questions and Issues for the TDP**		5 to 10
	How to achieve science goals?	
	How to achieve $A_\mathrm{e}/T_\mathrm{sys}$ at lowest cost?	
	How to maximize signal bandwidth and data processing throughput?	
	How to mitigate RFI to achieve science specifications?	
	How do we sell the SKA project and use it to promote science?	
	How would TDP results be used in a hybrid design for the SKA?	
III. **Work to be done**		~ 30
	Work areas (complete picture) (see text)	
	Prioritization of work areas for the TDP	
	Synergies with other projects (ATA, DSN, etc.)	
	Prototypes	
	Key decisions and results	
	Work Breakdown Structure	
	Gantt time line	
IV. **Management Plan**		
	NAIC/Cornell (incl. Project Office)	5
	Individual Institutions	2
	Decision-making process	2
	Meeting milestones	3
	Interactions with the International project	
References Cited.		as needed
Biographical Sketches.		2 pp/PI, co-PI
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

Table 2—Continued

Section	Description	Approx. No. Pages
Special Info. & Supplementary Documentation		as needed
Appendices		as needed

Table 3. 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

Table 4. TDP Activity List

Activity	Costed* in Proposal?	TDP Priority** (1-5, 1 highest)	Costing (FTEs) (guesses)	Who?
Development Areas:				
1. Science (simulations)	y	3	1+	MIT et al.
2. Antennas & mounts	Y	1	2	CIT/NAIC/UCB
2b. Feeds and optics	Y	1	2	CIT/NAIC/UCB
3. Receivers	Y	1	2	CIT
4. Configuration	y	3	1-	MIT
5. Data transport	y	2	1	SAO/NRAO
6. Signal Processing (hardware)				
a. correlator/beamformer	Y	1	1	MIT/NRAO
b. backend processing	Y	1	1	NAIC/NRAO
7. RFI management	y	2		(primarily via ATA usage) All, UCB, VT
8. Modes of operation	y	2		(ATA usage) UCB,NAIC,NRAO
9. Data management (software, databases)				
a. post processing	y	1	?	?
b. archiving/virtual obs.		5	?	
10. Maintenance/Ops		5		JPL/NAIC/NRAO/UCB
11. Upgrade plan		5		All
12. Costing	Y	1		JPL/NAIC/NRAO/UCB
13. Outreach	Y	2	1	SI, Cornell, VT, UWin

Table 4—Continued

Activity	Costed* in Proposal?	TDP Priority** (1-5, 1 highest)	Costing (FTEs) (guesses)	Who?
Management:	Y	1	1.5-2 FTE	Cornell/NAIC
Project Manager + office				
Document Preparation				
(inc. whitepapers)				
ATA Testbed Use:	Y	1	block grant	UCB + USSKAC
Items 2-13 above				
US Siting Proposal:	Y	1	TBD	SWC/NRAO?
site specs vs. science specs				
costing of dominant siting elements				
whitepaper preparation				
Implicit Costs:				
travel				
computer/lab costs				
International Participation Costs:				
Direct contributions to IPO	Y	1	$\sim$ 200k/yr	
Travel to ISSC meetings	Y	1	$\sim$ 30k/yr	

Table 5. TDP Proposal Section Groups

	Group	Who (* ⇒ leader [**tentative**])
1	Science	Carilli, Cordes, Doeleman, Gaensler, Jones, Lazio, Wilcots
2a	Antenna & Mount	Cortés, Weinreb*, Welch
2b	Feeds & Optics	Cortés*, Weinreb, Welch
3	Receivers	Goldsmith, Weinreb*
4	Configuration	Lonsdale, Walker
5	Data Transport	Owen*, MIT/Haystack, NRAO, SAO, Weinreb
6a	Signal Processing (correlator/beamformer)	D'Addario*, MIT/Haystack, UCB
6b	Signal Processing (backend processing)	Cordes, MIT, NRAO
7	RFI Management	Bower, Ellingson*, Fisher
8	Modes of operation	Cordes, Ellingson, Lazio*, Tarter
9a	Data Management (post processing)	NAIC, NRAO, MIT, UCB
9b	Data Management (archiving, virtual obs)	NAIC, NRAO, MIT, UCB, Churchwell*
10	Maintenance/Ops	Goldsmith*, JPL, NRAO
11	Upgrade plan	Kellerman (?)
12	Costing	Goldsmith*, NRAO (Perley/Clark), UCB, Weinreb
13	Outreach	Goldsmith, Ellingson, Salter, Tarter*, Wilcots
	Management	Brown*, Cordes, Terzian
	ATA Testbed	Bock, Welch*, Kassim
	US Siting Efforts	Duric*, Kellerman, Terzian