ATNF ATUC Memorandum

To: ATUC
From: Colin Jacka
Date: 1 December 2004
Subject **NTD Summary for ATUC Meeting 9 December 2004**

Project Description

The New Technology Demonstrator (NTD) will be a technology demonstrator for wide field-of-view SKA solutions operating in a remote, radio quiet site. It will comprise a “mini-station” of a next-generation radio telescope, and its principal sub-systems and core technologies will be:

- Wide FoV antenna systems
- Optical signal transport
- DSP techniques such as achromatic beamforming, wide-field imaging, and RFI mitigation.

The NTD project will consist of the development of these sub-systems and the systems engineering to integrate them into an operating instrument which would benefit the development path towards the SKA.

Where possible, the NTD will make use of project deliverables (and sharing of development resources) from a number of other projects being funded from the same MNRF grant. Specifically, these would be the CABB, MMIC, SKAMP and SKA Siting projects.

The revised project, from July 1 2004 will concentrate on the development of focal plane array technology in association with parabolic reflectors for the antenna systems. This decision was taken after it was found not practical to further pursue the development of Luneburg lenses for the SKA, and after various other options such as the use of cylindrical antennas were also considered.

The NTD will play a major role in attracting the SKA to Australia, which in turn will increase opportunities for Australian industry participation (manufacturing, ICT). Some of the important SKA decisions eg siting and technology selection, are scheduled to occur during the development phase of the NTD.

The Project Team has been put in place with the Project leader being Colin Jacka, Project Manager Tony Sweetnam, Project Scientist Simon Johnston, Project Engineer John Kot. A number of experienced staff has also been allocated responsibilities for management of various sub-sections. These include; Antennas: Mike Kesteven, Feed Systems: John Kot, LNA: Paul Roberts, Digital Systems: John Bunton, Focal Plane Array Integration: John O’Sullivan, Calibration, Control, Monitoring: David McConnell, Data Transport: Ron Beresford, Post-correlation Astronomy Software: Tim Cornwell, Site and Infrastructure: Tony Sweetnam.

The strategic directions of the project are monitored by various groups. The Australian Astronomy Board of Management (AABoM) has to approve changes to the project. However, within the ATNF significant changes are reviewed and approved by the ATNF Project Review Board. ASKACC is also kept aware of our intentions for the xNTD as a core part of their strategy as laid out in the SKA Roadmap.

A number of other projects affect the NTD, eg SKA Siting, CABB, MMIC, SKAMP. Also, external projects such as the Low Frequency Demonstrator (LFD) from MIT has influence on various options available to the NTD project. Later projects which might be impacted by this project are SKA Pathfinder (and SKA)

Several external agreements will be required during the course of the work. These will include aspects concerned with selection, development and operation on the site, arrangements where collaboration and shared funding is being used for various sub-systems, external contractors during development, and possible use of shared data transmission facilities.

A letter of understanding has already been received from the Director of the ICT Centre confirming collaborative arrangements between the ATNF and the ICT Centre.

A letter of support has also been sent to MIT that outlines the degree of collaboration between ATNF and MIT for the MWA, consistent with the NTD's objectives.

Technology Objectives

This revised NTD Project Plan has had careful consideration made of the original project objectives, but since that time there have been significant developments in Australia's plan for the pathway to SKA, and the NTD is now seen to provide an opportunity for important new science to be achieved from such a new instrument, with a number of national and international organisations keen to collaborate in its development. Hence the new plan caters for various situations where other funding may be made available, with full use being made of leveraging opportunities, but also allowing various fallback options which prevent external factors from adversely affecting the basic NTD goals.

(a) The technology objectives of the NTD, using existing (MNRF) funding:

1. 10x10 FPA operating over the frequency range 800-1700 MHz, with 1 to 3 parabolic reflector antennas (cost dependent, but probably two reflectors, each 12m to 15m diameter).
2. RFI and spectral line ripple cancellation using FPA (commercial applications are possible)
3. RF and IF beam-forming to give extremely wide fields of view.
4. Polarization purity
5. Correlation of large number (at least 20) of independent beams
6. Wide band operation with low RFI levels
7. Proof of infrastructure in remote desert environment (power supply, on-site data transport)

(b) Enhanced Technology Objectives with additional funding (xNTD):

1. Modular upgrade path. Twenty parabolic reflectors equipped with 10x10 FPAs.
2. Correlation of a large number of (typically 20) antenna stations, and 20 independent beams being formed
3. Real-time VLBI using high speed fibre-optic data links with other antennas forming long baselines on the continent of Australia
4. Multiplexed VLBI exploiting wide FoV and multiple beams
5. Special purpose signal processors (eg for pulsar searches) using phased array beams
6. Operational and processing software development.

Scientific Objectives

(a) The science objectives of the NTD, using existing (MNRF) funding:

1. VLBI: (possibly up to) 3000 km baseline: Double the available resolution at 1.6 GHz (2.4 GHz if possible)
2. IDV monitoring to 50 mJy
3. Time-critical experiments requiring flexible scheduling

(b) Enhanced Science Objectives with additional funding:

1. HI emission survey to z ~ 0.1
2. HI absorption to z = 1
3. Transient source searches and continuum survey 1.2 – 1.4 GHz
4. Galactic HI emission
5. Pulsar survey (with new backend)
6. Probe galactic and extragalactic magnetic fields
7. Multiplexed VLBI on faint sources in deep imaging over wide field-of-view
8. OH megamasers to z ~1

Project Purpose:

The Primary purpose of the NTD is a Technology Demonstrator for wide-field-of-view SKA solutions.
Its distinct advantage is its FoV. The actual achievable FoV will depend on a number of factors that will be determined during the initial design phase. There will be a trade-off in the FoV with the number of feed elements in the FPA, and also with the upper frequency limit for which the array is to be used. Presently, it is anticipated that by using a 10x10 element FPA, and an upper frequency limit of 1.7 GHz, we will be aiming for a FoV of 50 deg^2, applicable for frequencies above 800 MHz.

The Secondary purpose of the NTD is to establish a significant presence at a remote low RFI (“Radio Frequency Interference”) site, highly suitable for the SKA and other Pathfinder instruments leading to SKA. This presence may also include the MIT Haystack installation that may share backend digital hardware and infrastructure with the NTD.

Other factors:

- Develop FoV technology using FPAs on parabolic dishes
- Further develop filterbank, beamformer and correlator technology already being developed by the ATNF for the ATCA (Compact Array), so that this technology can be used for FPAs and large numbers of antennas
- Establish an instrument that is likely in terms of siting, technology and capabilities, to be directly on a pathway to the SKA
- Foster support for the preferred site (now selected as Mileura, WA) and enhance its chances of being selected by the international committee as the SKA site.

Presently, the revised NTD concept using FPAs with parabolic dishes, situated at the WA site has already attracted favourable attention and requests to collaborate from the astronomy community, eg MIT Haystack Observatory, University of Melbourne, RSAA Mount Stromlo, Swinburne University, Curtin University and the University of Western Australia. This collaboration greatly increased the attention of the Governments of WA and NSW to provide substantial support for the NTD if it were to be sited in their state. Now that the site has been selected in WA, it is our intention to further develop the interest of the WA Government to include support for the inclusion of high-speed fibre-optic data links.

Project Deliverable:

The major deliverables are:

1. at least two (20 for xNTD) 15m diameter parabolic antennas, with at least one antenna having one 10x10 Focal Plane Array (FPA)
2. Operation in the frequency range 0.8 to 1.7 GHz (possibly 2.4 GHz)
3. High frequency limit dictated by the requirement to retain VLBI option, and optimum pulsar and polarization surveys
4. Fully sampled FPA system
5. Backend correlators and digital beam formers
6. Software for control and processing
7. Infrastructure at remote site
8. Demonstrate ability of SKA candidate site to support such a facility.

Performance Measure:

Whilst there are science objectives, the primary objectives of this project are technical as it is a "technology demonstrator". If the extra funding can be obtained to provide for an increase in surface area, then the science objectives will increase in importance. These science objectives have been outlined above, and provided in more detail later in this document.

The project will be assessed on its being operational by the planned MNRF project end date (July 2007), and by whether it achieves the objectives listed above. The NTD project will be delivering credibility to the international community as to whether Australian technology and siting is the obvious choice for international investment in an SKA Pathfinder project in Australia. This decision would obviously be a measure of the NTD success.

Scientific Merits

This is being presented as a separate document by the Project Scientist.

Project Plan Outline

The NTD Project has been divided into four phases. The accompanying Gantt Chart provides an additional summary view.

1. Requirements Analysis and System Design
2. Detailed Design and Development
3. Manufacture and Installation
4. Commissioning

The **Requirements Analysis and System Design** phase is scheduled to run from 1 July 2004 until the Preliminary Design Review (PDR) on the 15 March 2005.

Following the decision not to proceed with the Luneburg lens antenna, the NTD project has effectively started anew from 1 July 2004, re-examining the technical and scientific objectives of the project, and developing this revised Project Plan.

The requirements have now largely been determined with revised objectives and a new science case with key architectural decisions having been made. System design is well in progress.

Timing for the later phases of the project has been set by the need to have an operational NTD installed on the preferred radio-quiet site by 30 June 2007, as per the original NTD project plan funded from the 2001 MNRF grant.

The extended NTD project (xNTD), will probably need at least a further whole year for manufacture and installation, and six months to commission the telescope, simply because of its scale and the number of antennas (around 20) that will be built.

The **Detailed Design and Development** phase is scheduled to run from April 2005 until December 2005, ending in a Critical Design Review (CDR). During this phase, each subsystem will be designed in detail and key subsystems will be prototyped.

The **Manufacture and Installation** phase for the NTD is scheduled from January 2006 until December 2006. Hardware components will be manufactured and installed, whilst firmware and software components will be coded, tested and expanded to fully-featured operational versions. Installation of the required site infrastructure and antennas will be staggered across this phase.

Finally, the **Commissioning** phase from January 2007 until June 2007 will ensure that the system operates as a whole and provides useful astronomical data.

If it is decided to extend the project to include the xNTD, then further installation and commissioning time will probably be required. The timelines for developing the digital processing and software systems have yet to be determined.

For the first two phases, work has been broken down into the following task groups:

1. Antenna
2. Feed System
3. Data Transport
4. Local Oscillator and Control Signalling
5. LNA
6. Receiver
7. FPA Integration
8. Calibration, Control and Monitoring
9. Digital Signal Processing
10. Offline Astronomy Software
11. Wide Area Network
12. Site and Infrastructure

A number of activities are under way in this work. Some of these are indicated below:

Antennas:
We have considerable interest in an antenna design concept provided by the Indians. We recently sent three engineers to India investigating possibilities for the use of this design, and consider manufacturing possibilities. We also have attracted considerable interest from the South Africans, who wish to visit us later this month. We also have been investigating local design and manufacturing in Australia. Additionally, we are considering making use of two 13.8 m dishes from Fleurs.

Feed System:
The ICT Centre has been commissioned to work with us in the development of Focal Plane Array (FPA) technology. There are a number of actions being taken with this. We have also been contacted by other overseas groups wishing to collaborate with us in this area.

Receiver:
We are working closely with the MIMIC project team to ensure we take full advantage of the latest developments in RF CMOS technology and that these two projects are appropriately aligned. We are also well aware of the importance of obtaining the best LNA performance possible, and are investigating ways of incorporating the best possible technology, eg SiGe for this. As a backup, we have had an alternative design done within the ICT Centre using discrete components.

Digital Processing:
We have had extensive discussions with the people from MIT Haystack Observatory who have applied for NSF funding for their LFD array, also to be on the Milleura site with the NTD. There is considerable overlap in the digital requirements for these two systems, and we have considerable work being undertaken to ensure we get the best collaboration between NTD, xNTD, MIT, CABB, SKAMP requirements in these areas.

Post-Correlation Software:
This used to be referred to as “off-line software”, but it is evident that the extreme data rates and quantities of data emanating from these multi-beam telescopes requires a rethinking on post-correlator processing. Much of this will need to be done on-line with powerful FPGA-based processing. A considerable amount of money has been budgeted for this work for the xNTD in particular. We have also been successful in attracting Tim Cornwell to the project. This will be of great benefit.

Project Risk Management Strategy.

What we have and need for this project is a “risk management” strategy, since we know by its very nature it consists of many elements of "New Technology" each with a high technical risk and so a simple calculation would suggest that the overall project risk is extremely high, viz. Probability of unsatisfactory system outcome = (1- Product of (1- probability of unsatisfactory outcome for each system element)).

There is the risk of not achieving the xNTD objectives, and the risk of not meeting the NTD objectives that we have set ourselves, and then there is a the risk of not meeting the NTD objectives as required by the MNRF deed. These are all different. We have indeed set ourselves an extremely ambitious target for the NTD with the aim of being able to extend the NTD to the xNTD and produce a state-of-the-art radio telescope for a relatively cheap price.

Our project plan is aimed at the xNTD in terms of schedule and saleability of design, however we have a decision gate built in for the end of 2005 by which time we should have resolved most of the "new technology" technical risks, and if we decide we are unable to meet the xNTD objectives in terms of technological performance, cost or schedule, we will be able to scale back as required right down to proceeding with just a plain NTD only to meet our MNRF deed contractual obligations. In other words if we decide we cannot meet certain objectives then we can de-scope the project, and save most of the money.

We have broken the project down into work packages to develop the key system elements and we have built a team so that for each work package we have the best person available to drive that part of the system. Further, for each new technology system element we are looking at alternative and parallel solutions.

For example we are hoping to get cheap dishes from the Indians but we are also considering what we can do ourselves in conjunction with industry to produce an Australian cheap dish design or a hybrid of Indian and Australian technology. For focal plane arrays we are looking at several alternatives. For focal plane array integration and data transmission we are looking at both digital and analog transmission from the focal plane array. And whilst we are counting on the RFCMOS MMIC chip as a receiver, we are also designing a discrete component alternative receiver design. etc. etc.

There is no doubt that the 20-dish xNTD project, each with a wide field of view focal plane array, installed and producing useful astronomy data at the chosen SKA site by mid 2007, is a high risk project. The minimum NTD completed as required by the MNRF deed is a much lower risk.

Major Milestones

Date	Milestone
1 July 2004	Revised NTD Project start – concept design
16 August 2004	Decision on antenna system
30 September 2004	Revised Project Plan for Review
5 November 2004	FPA specification complete
9 November 2004	Site selection determined
19 November 2004	Commonality of DSP components identified between NTD, MWA, SKAMP, CABB. Strategies in place for cost-effective development of digital systems for NTD
30 November 2004	Confirmation of Indian dish suitability
18 February 2005	Planned dish assembly at Marsfield
25 March 2005	Alternative (backup) Receiver design tested
30 March 2005	Preliminary Design Review (PDR) – System Design Completed
20 May 2005	LNA design completed
15 July 2005	Sufficient LNAs available
1 June 2005	Off-line software definition complete
1 September 2005	Final testing of RFCMOS chips
30 September 2005	Control & Monitor software complete for testing @ Marsfield
4 November 2005	FPA prototype testing & characterisation complete
15 December 2005	Critical Design review (CDR) – ie Detailed Design Complete
15 December 2005	GO/NOGO decision for xNTD development
6 March 2006	Design and Development Stage Complete Manufacturing of antennas on selected site begins
6 March 2006	RFCMOS chips available
1 December 2006	All digital and software systems ready for installation
15 January 2007	Commissioning begins
30 June 2007	NTD Project Completion and Operational Demonstration

Project Resource Estimate:

Materials costs: $1.175m + $455K/antenna

Justification for costs & scale factors applied for materials: best estimates of costs

Labour costs: Number of FTE Years or Months: 20.7 FTEy + 1FTEy/antenna

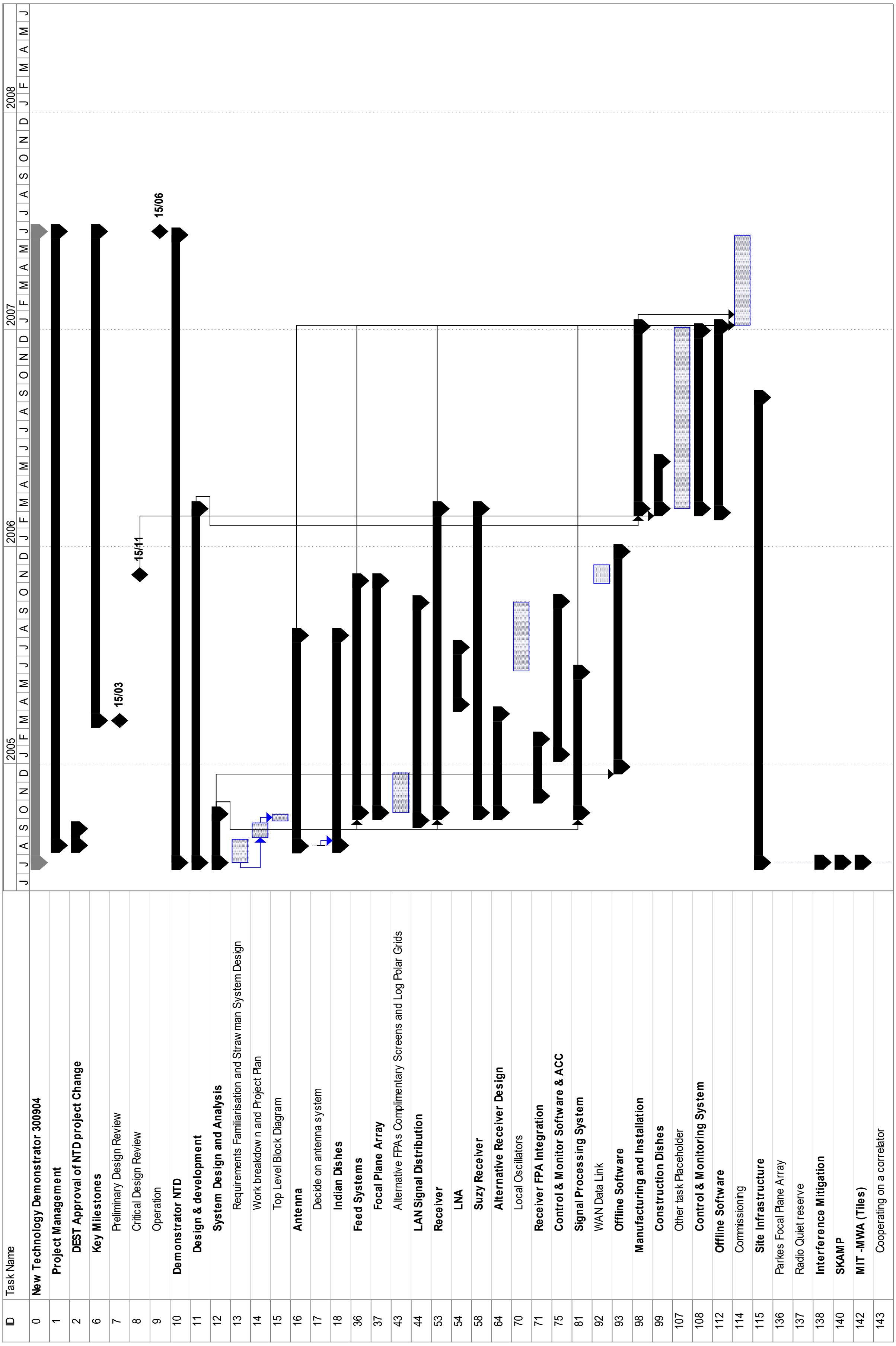
Justification of costs & scale factors applied for labour: $200K/FTE

Total Project Cost: ($6.625m (2 antennas) + $1.9m for infrastructure

Or for xNTD: $18.415m (20 antennas)) + $3.9m for Infrastructure

Project Funding:
At 1 July 2004 (in $M):

Funding Source	Allocated per original MNRF budget	Spent by 30 June 2004	Remaining as at 1 July 2004
DEST	2.535	0.885	1.650
ATNF cash	1.600	0.650	0.950
ATNF in-kind	1.450	0.493	0.957
ICTC in-kind	0.800	0.320	0.480
CEA in-kind	0.100	0	0.100
APT in-kind	0.100	0	0.100
TOTAL	**6.585**	**2.348**	**4.237**
Contributions by shared development with MIT & SKAMP			0.300
Contribution from ATNF Emerging Science Project			0.600
MMIC Project shared development			1.000
Extra ATNF contributions			0.488
Requested Funds from State Gov for NTD infrastructure			1.900
TOTAL Funds for NTD			**8.525**
Extra Requested Funds from State Gov for xNTD Infrastructure			2.000
Extra Required Funds for xNTD			12.278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0 New Technology Demonstrator 300904
1 Project Management
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81 Signal Processing System
92 WAN Data Link
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98 Manufacturing and Installation
99 Construction Dishes
107 Other task Placeholder
108 Control & Monitoring System
112 Offline Software
114 Commissioning
115 Site Infrastructure
136 Parkes Focal Plane Array
137 Radio Quiet reserve
138 Interference Mitigation
140 SKAMP
142 MIT -MWA (Tiles)
143 Cooperating on a correlator