Major National Research Facilities Program

Annual Report by the Australia Telescope National Facility to the Department of Industry, Science and Tourism

Report Number 2, 1 July 1997 - 30 June 1998

Earthworks in progress at the site of the Australia Telescope Compact Array, near Narrabri. The main east-west rail track has been cut to allow construction of new antenna stations and a north spur line, the combined effects of which will allow greatly improved imaging when using the high-frequency receivers now being constructed for the Telescope. ATCA operations have continued throughout most of the civil works, and several antennas are visible at the western end of the track.

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P J Hall, 24 August 1998

Foreword

The first full year of the MNRF Program has been an exciting one for the ATNF and its associate, the University of Tasmania. With major civil works under way at the Compact Array site at Narrabri, our commitment to the extensive high-frequency upgrade is now very visible. Less obvious perhaps, but just as essential to the success of the Program, are the other science and engineering projects which have, in the past year, established the design and implementation paths to be followed in capitalizing on the Compact Array's niche in world astronomy.

The MNRF upgrade of the ATCA has made it possible to secure two further significant development grants. To exploit the full potential of the MNRF upgrade to millimetre wavelengths, we have been particularly fortunate in obtaining CSIRO Capital Investment funds to build a north-south base-line in addition to the new stations on the east-west base-line already included in the MNRF program. The high-frequency upgrade, which is based on current receiver technology, also provides a superb test-bed for the next generation of millimetre-wave receivers; the availability of this test-bed was a key component of our successful bid for CSIRO's Special Executive Funds. In this project we will develop monolithic millimetre-wave integrated circuits using indium phosphide technology in collaboration with the CSIRO Division of Telecommunications and Industrial Physics. These upgrades will make the Compact Array a truly forefront facility and a stepping stone, both scientifically and technologically, to the very large southern millimetre-wave arrays which are being constructed in the first decade of the next century.

The MNRF Program extends beyond the Compact Array. This first year has already seen the delivery of many improvements to the Australian Very Long Baseline Interferometry (VLBI) network, the highlight being the commissioning of the Ceduna Radio Astronomy Observatory. In conjunction with the University of Tasmania and the astronomy community, the ATNF now faces the challenge of operating these new telescopes as National Facilities in a manner which capitalises on their huge scientific promise.

Our high-frequency and VLBI upgrades are important, but the MNRF Program has also supported some extraordinarily valuable "seed" projects through the MNRF International Astronomy Collaboration program. These projects are directed at increasing Australia's participation in major international astronomy facilities. The program funds a range of international collaborations which are not well covered by existing DIST or ARC programs. The proposal filter, which was developed from the MNRF concepts, requires international participation in facilities which satisfy the MNRF research facilities guidelines. Examples include the Gemini 8 m optical telescopes, instrumental developments for ESO, the Auger high-energy observatory, new Antarctic astronomy facilities and the one square-kilometre radio telescope.

While our millimetre-wave and VLBI upgrades will deservedly be showcases of innovation, the strategic and collaborative benefits of the MNRF Program undoubtedly contribute to the longer-term future of Australian astronomy.

I am pleased to present this second Annual Report of the ATNF – University of Tasmania MNRF Program.

Prof Ron Ekers
Program Director

Executive Summary

The CSIRO Australia Telescope National Facility (ATNF) and the University of Tasmania (U. Tas.) are undertaking, under the auspices of the Major National Research Facilities (MNRF) Program, a number of scientifically significant upgrades to Australian radio astronomy facilities. The upgrade costs, together with those of an MNRF-sponsored program fostering international collaboration by Australian astronomers, total $A11M. Contracts were signed between the Commonwealth, CSIRO and U. Tas. in February 1997, and the last of the upgrades will be complete in early 2002.

The largest MNRF upgrade involves extension by the ATNF of its Compact Array radio telescope to operate at frequencies beyond 100 GHz; the present upper operating frequency is near 10 GHz. The extended instrument will allow astronomers to produce much more detailed images of the sky, and to observe a rich selection of radio emission from cosmically abundant molecules. These new Southern-Hemisphere capabilities are essential if radio astronomy is to complement adequately the optical astronomy being undertaken with new-generation ground- and space-based telescopes.

The Compact Array upgrade uses leading-edge engineering science, technology and fabrication. Examples include 100 GHz integrated-circuit amplifiers, precision antenna reflecting surfaces, highly stable fibre-optic signal distributors, and a remote-sensing system to correct the distortion of radio signals by atmospheric water-vapour. The ATNF is active in encouraging participation by Australian industry and researchers in these and related areas; similar technology transfer was a notable success of the original Compact Array construction project in the 1980s.

The Compact Array extension is proceeding well, and MNRF funding has been augmented by CSIRO funds, enabling the provision of a north spur rail track and improved high-frequency low-noise amplifiers. The past year has seen considerable progress with achievements such as:

- commencement of civil works for the new rail track and antenna stations;
- manufacture of prototype high-precision panels (to be evaluated soon on one Array antenna);
- overall design of a multiband, high-frequency, receiver.

First engineering test observations will start in mid-1999 and the completion estimate for the Compact Array upgrade as a whole remains January, 2002.

The second MNRF upgrade, being undertaken by both the ATNF and U. Tas., expands the existing Australian Very Long Baseline Interferometry (VLBI) network. In VLBI, information is collected from widely separated antennas and combined to form images. These images have similar detail to those which would be produced by a single telescope having a diameter equal to, for example, the width of the Australian continent. Much of the MNRF VLBI upgrade has already been completed, with the last year seeing:

- commissioning of the ex-Telstra 30 m communications antenna at Ceduna as a radio telescope;
- completion of a 22 GHz VLBI receiver for the ATNF's 22 m Mopra telescope;
- delivery of three hydrogen-maser frequency standards, allowing high-frequency VLBI observations to be made;
- participation by the Australian network in VLBI experiments with an orbiting Japanese radio astronomy satellite.

Installation of a 22 GHz receiver at Ceduna - the last of the VLBI upgrade projects - is scheduled for March, 2000. While this target is expected to be met, studies of the Ceduna antenna optics have revealed complications in providing a receiver at 1.6 GHz - the other VLBI frequency extreme. Further investigations are underway, and a final decision on the feasibility of implementing bands below 2 GHz will be made in the next year.

The third major area covered by the MNRF Program involves support for Australian astronomers collaborating with international groups which are operating, or planning, large facilities. Eleven projects have been identified by the Australian Academy of Science's National Committee for Astronomy (NCA) as worthy of support and, while essentially all of the MNRF funding has now been allocated, the obvious success of the international astronomy collaborations has led the NCA to consider seeking additional support for the scheme from other sources. Collaborations currently being supported include projects aimed at ensuring Australian participation in new-generation radio, optical, infrared and gamma-ray observatories.

The table below summarizes the financial situation for the MNRF Program as at 30 June, 1998. The category "associated projects" includes funds for ATNF strategic research, project management, manpower and test equipment.

ATNF - U. Tas. MNRF Program - Summary Financial Information as at 30 June 1998

Project	Provision	Expenditure + Liabilities	Balance
AT Compact Array High-Frequency Upgrade	5 550 000	1 279 199	4 270 801
VLBI Upgrade (ATNF + U. Tas.)	2 040 000	1 142 657	897 343
International Astronomy Collaboration	1 260 000	595 717	664 283
Associated Projects	2 150 000	1 145 027	1 004 973
TOTAL	**11 000 000**	**4 162 600**	**6 837 400**

(All amounts in Australian dollars).

1. Introduction

This document is the second annual report by the CSIRO Australia Telescope National Facility (ATNF) to the Department of Industry, Science and Tourism (acting for the Commonwealth of Australia) covering activities supported under the Major National Research Facilities (MNRF) Program. The report covers the period 1 July 1997 to 30 June 1998. It incorporates material supplied by the University of Tasmania, a co-signatory to the MNRF agreement, as well as summaries lodged by recipients of funds paid under an MNRF-supported international astronomy collaboration scheme. For completeness, background and management summaries in this second report draw substantially on material submitted in the first annual report, an abbreviated document covering the first months of the MNRF Program operation.

2. Background

The ATNF, together with co-proponents the University of Tasmania and the (then) CSIRO Division of Radiophysics, lodged an initial funding submission under the Major National Research Facilities Program scheme in November 1994. A final proposal by the ATNF and the University of Tasmania was submitted in January 1995. Following notification of the success of the application in January 1996, a contract was signed between the Commonwealth, CSIRO and the University of Tasmania on 19 February 1997. The contract covers three major areas:

- an ATNF upgrade of its Compact Array radio telescope to operate at high frequencies (corresponding to millimetre wavelengths), and an extension of its very long baseline interferometry (VLBI) capabilities;

- a University of Tasmania expansion of its VLBI capabilities at radio observatories in Hobart and Ceduna, and the operation of those observatories as national facilities;

- a program to fund international astronomical collaboration, administered by the ATNF acting on recommendations from the Australian Academy of Science's National Committee for Astronomy.

In addition to the major ATNF upgrades, the contract provides for the funding of two small ATNF strategic research projects, purchase of test equipment by both the ATNF and the University of Tasmania, program definition and project management, and project manpower. The contract also specifies a number of milestones, the principal dates being March 2000 and January 2002 for completion of the VLBI and high-frequency upgrades.

The upgraded ATNF and University of Tasmania telescopes will provide Australian astronomers with important new observational tools with which to view the Universe. The ATCA millimetre-wave capability will permit astronomers, for the first time in the Southern Hemisphere, to image, at resolutions comparable with space-based optical telescopes, the signature emission from many cosmically abundant molecules in the near and distant universe. Similarly, the VLBI upgrades will allow data from radio telescopes, separated by thousands of kilometres, to be combined to produce images with a resolution far superior to those from the largest optical telescopes, whether ground- or space-based.

Figure 1 is a diagram illustrating the placement of various specific projects and sub-projects in the MNRF Program. In the next Section, overall Program management details are outlined, and subsequent Sections contain reports on the individual projects grouped according to the three major contractual areas outlined above. A financial and asset statement is also included (Section 7). Appendix 1 contains details of the ATNF Steering Committee, and additional information required under the terms of the contract is contained in Appendix 2 (senior personnel) and Appendix 3 (publications). Appendix 4 lists the panel of international experts in the field of millimetre-wave astronomy constituted by the ATNF as an Advisory Committee for its high-frequency upgrade. Appendix 5 is the first report of the Committee, which held its initial meeting in September 1997.

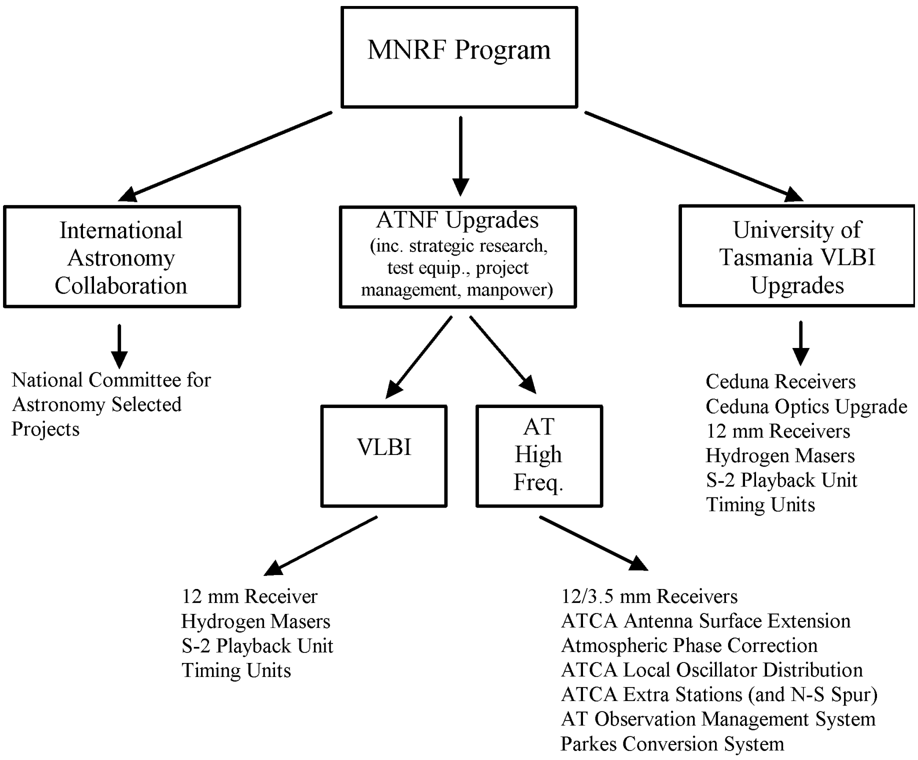


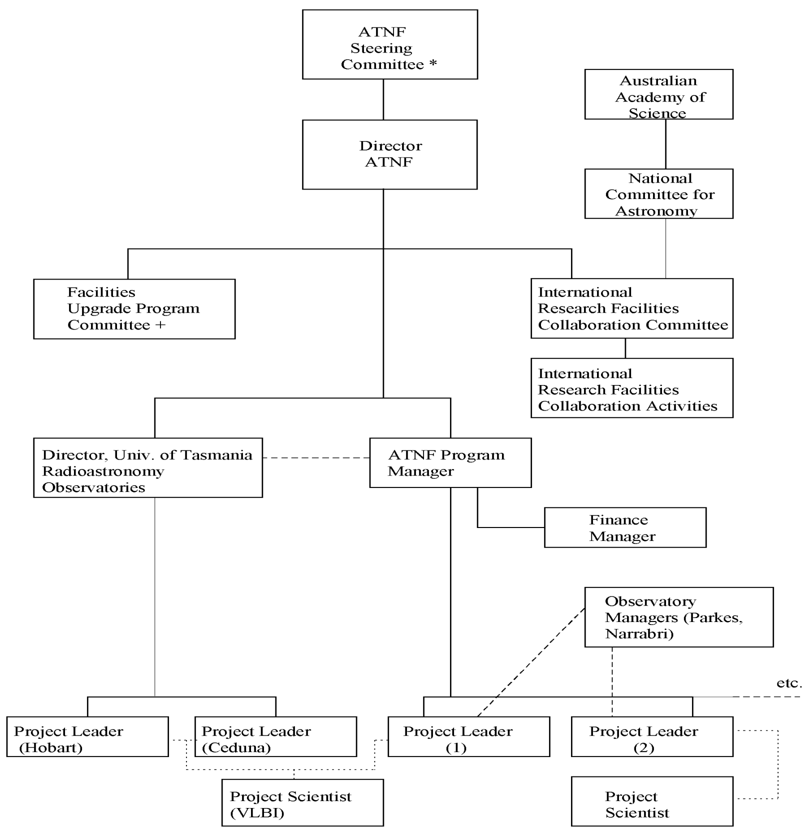
Figure 1 - MNRF Program Structure

3. MNRF Program Management

Figure 2, extracted from the MNRF upgrade contract, shows the overall structure of the MNRF Program. The ATNF Steering Committee (Appendix 1) is the principal policy body advising the ATNF Director. It is an independent body appointed by the Minister responsible for CSIRO. Annex 3.1 to the MNRF-upgrade contract details the operation of the Committee in terms of its role in overseeing ATNF operation and reporting to the CSIRO Executive and Minister for Science. In the MNRF context, the Steering Committee has no direct management function but is responsible for Program guidance and annual report submission. To expedite the reporting process, the Steering Committee has established a sub-committee (Appendix 1) charged with reviewing the MNRF Program progress and expenditure as presented in the draft annual reports.

At its meeting of April 1-2, 1998, the Steering Committee endorsed the MNRF Program Annual Report Number 1; affirmed the constitution and function of the Committee's existing MNRF sub-committee but requested that Prof J Storey be added to this review panel; and received submissions from the Program Director and Program Manager. In particular, the Director noted the contribution of the Advisory Committee (Appendix 4) in producing an excellent report (included in this document as Appendix 5). The Director further noted the ATNF's efforts at addressing substantial issues raised by the Advisory Committee, especially the Facility's response to items 5, 7 and 15 of the Committee's report. Section 5 of this document outlines ATNF initiatives in these areas.

Schedule 5 of the MNRF-upgrade contract details the operation of two working committees: the Facilities Upgrade Program Committee and the International Research and Collaborations Committee. In addition, the Schedule specifies the responsibilities of the Program Manager and executive staff. Committee members and senior Program personnel are listed in Appendix 2.



* During the Upgrade period, the University of Tasmania has a representative on the Steering Committee.

\+ The Director, University of Tasmania Radioastronomy Observatories, is a member of this Committee.

Figure 2 - MNRF Program Management and Overall Structure

Figure 3 shows the MNRF-upgrade management in more detail; note that the ATNF Director is also the MNRF Program Director. For a complete list of senior personnel, refer to Appendix 2.

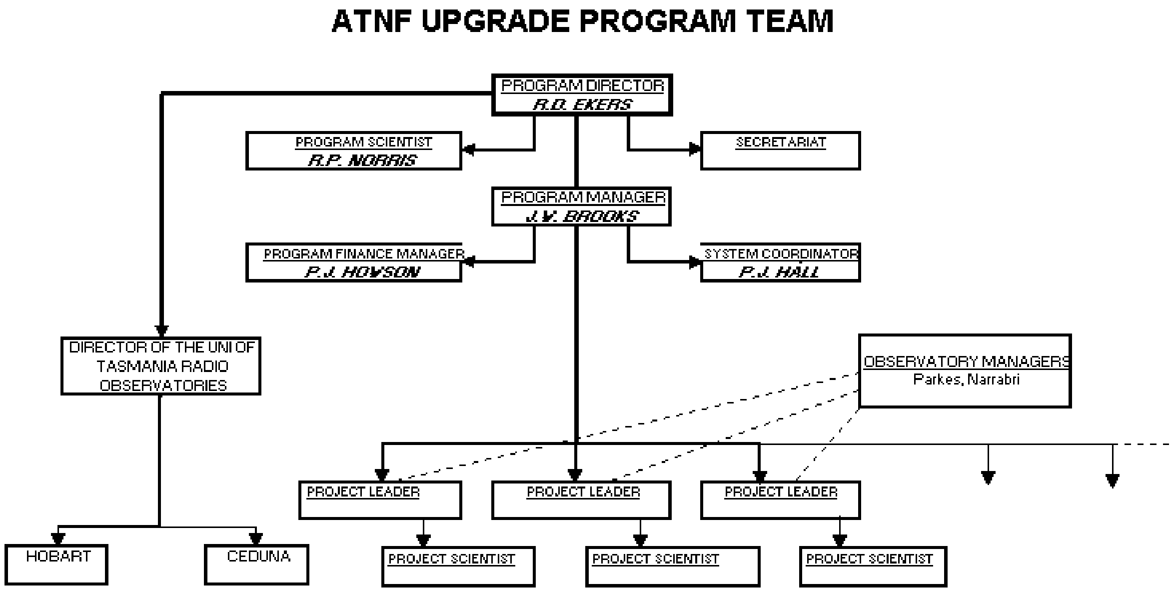


Figure 3 - MNRF Executive and Program Structure

4. International Astronomy Collaboration

The MNRF Program funding included an allocation of $1.26M to enhance international collaboration by Australian astronomers. A call for proposals was made in November 1996 and, at a preliminary review meeting of the National Committee for Astronomy (NCA) held in December 1996, 16 proposals were reviewed. Further deliberations by an NCA-appointed sub-commitee consisting of Prof R Ekers (CSIRO), Prof J Mould (ANU) and Dr E Sadler (U Syd) resulted in the nine projects listed in Table 4-1 being initially funded, or having funds set aside for future disbursement. As well as funding for individual projects, an amount of $70k was reserved for international travel grants; details of the bulk of this travel are contained in MNRF Annual Report Number 1, while disbursement of the remaining funds is summarized in Section 7 of this report.

In August 1997 two additional project proposals were received and funded at essentially the levels requested. These projects are outlined in Table 4-2. An overall financial statement for the International Astronomy Collaboration is shown in Table 7-2, while Table 7-3 records travel funding for the financial year 1996-97. All MNRF international collaboration funds have now been committed and, while further detailed deliberations are unlikely, the NCA may re-balance individual allocations based on project progress and needs; any such adjustments will be noted in future annual reports.

Table 4-1 International Collaboration Projects Funded Prior To July 1997

Proposer	Affiliation	Proposal
R Morganti, E Sadler	ATNF, U. Sydney	A Joint ESO/Australia Workshop: "Looking Deep in the Southern Sky"
B McA Thomas	ATNF	The One Kilometre Square Telescope (1 kT)
R Clay	U. Adelaide	Studies of the Highest Energy Particles in Nature
L Allen, J Storey/M Dopita, J Mould	UNSW/ANU (MSSSO)	SPIRIT: "The South Pole Imaging Telescope" (NOAO-CARA Collaboration)
J Patterson	U. Adelaide	γ-ray Observatory - CANGAROO Project
J Whiteoak	ATNF	Phase 2 Activities of European Large Southern Array (LSA) Project
K Taylor, M Colless	AAO, ANU (MSSSO)	Australis Phase A Study
K Nugent, R Webster	U. Melbourne	LOBSTER X-ray Satellite
M Bessell	ANU (MSSSO)	Australia-Japan Collaborative Workshops

Table 4-2 International Collaboration Projects Approved Since July 1997

Proposer	Affiliation	Proposal
M Brennan	Australian Research Council	Gemini Partnership - Contribution to the Capital Cost of Australia's Participation in the Gemini Project
J Davis	U. Sydney	Collaboration with ESO on Instrumentation for the VLTI

The following projects have submitted reports to the ATNF. The material submitted has been edited for inclusion in this Program report.

(a) A Joint ESO/Australia Workshop "Looking Deep in the Southern Sky"
Proposers: R Morganti and E Sadler

This meeting was held 10-12 December 1997 at the State Library of NSW. There were about 110 participants, with approximately 50 international visitors attending. The conference focussed on current and planned surveys of the southern sky in wavelength ranges covering most of the electromagnetic spectrum. In particular, the meeting assesed the impact of these surveys on the science to be conducted with the new-generation eight metre class telescopes being constructed by ESO and other observatories. These telescopes will be able to view the very early universe, including the first epoch of galaxy formation.

The meeting was judged succesful in bringing together a diverse range of observers to discuss areas of collaboration. Of particular note was an impromptu discussion aimed at co-ordinating observations of the southern Hubble deep field. A number of distinguished international visitors attended the meeting, and funding received from the MNRF Program was used to support travel to Australia by these key participants. The proceedings of the workshop will be published by Springer-Verlag and will be edited by Drs R Morganti and W Crouch; MNRF funding will be acknowledged in all publications arising from the workshop.

(b) The One-Kilometre-Square Telescope (1kT)
Proposer: B MacA Thomas

The 1 kT is the next-generation centimetre-wave radio telescope, having a collecting area of 1 km^2 (or 10^6 m^2) - the equivalent of more than one hundred dishes of 100 m diameter. In contrast, the largest and most sensitive existing array has a physical area of 1.3×10^4 m^2. The new telescope project involves collaborative strategic research with partners from The Netherlands, Canada, China, India and the USA; overall co-ordination is provided by working groups within the International Astronomical Union (IAU), the International Union of Radio Science (URSI), and the OECD Megascience Forum. The detailed specifications of the instrument are currently being established and, on present estimates, the 1 kT could be completed in the decade 2010-2020.

The Australian contributory project is being supported by both the ATNF and the MNRF International Astronomy Collaboration. The International Astronomy Collaboration funding is providing the salary (but not all overheads) for a Post-Doctoral Research Fellow. The main thrust of the associated research is in the area of 1 kT system studies, particularly the definition of an optimum antenna array configuration and the study of dynamic range issues given strong man-made and cosmic interference.

In work so far, predictions have been made of how the radio sky might appear at flux density limits 100 times as faint as those of known surveys. In addition, studies are under way of the response functions of large, many-element, interferometers operating in a variety of configurations. By the end of 1998 these two research areas will be combined. Simulated observations of the predicted radio sky will be made for various model telescope array configurations. These studies will be important in determining an optimum telescope design.

A scientific workshop entitled “The Sub-MicroJansky Sky” was held in June 1998 at the ATNF headquarters in Sydney. The scientific goals of the 1 kT were discussed and a summary of how these goals might affect the telescope design process will be presented in July at two major forums: the annual scientific meeting of the Astronomical Society of Australia (Adelaide) and the International Scientific 1 kT Meeting (Calgary, Canada).

(c) Studies of the Highest Energy Particles in Nature
Proposer: R Clay

MNRF funds have been used to enable attendance by University of Adelaide researchers at Project AUGER Collaboration Board Meetings, allowing Australians to play a major part in the development of the Auger high-energy cosmic-ray observatory. Two Collaboration Board Meetings have been attended. The first, in May 1997, was held in Utah, USA and was mentioned in the last annual report. The second, in August the same year, was held in Durban, South Africa and was attended by Dr B R Dawson on behalf of the proposer.

These visits are enabling Clay and colleagues to maintain a high profile involvement in the AUGER project, which now involves 18 countries. While Australia has provided relatively little in the way of funding for the project, the Adelaide group's regular involvement in the project has, so far, allowed them to have significant influence on its direction. This has been through their leadership in the design of the fluorescence detection system and, now, in proposals for atmospheric monitoring.

The Auger project is progressing well, with a design essentially completed and final details under discussion. A Finance Board will have its inaugural meeting at UNESCO in Paris in October 1998. Until then, the total funding of the project will not be completely firm but an initial $100 million appears to be in place to construct the first of the two observatories (in Argentina). Clay and colleagues are attempting to ensure that Australia is represented on the Finance Board, which will control the flow of funds.

The Australian group is the sub-task leader for atmospheric monitoring, which means that they will be responsible for funds related to that task through the Finance Board. Many monitoring issues are common to other observatories, and the group expects to make useful contributions to solving problems faced in other areas of astronomy.

(d) SPIRIT: The South Pole Infrared Imaging Telescope
Proposers: L Allen, J Storey, M Dopita, J Mould

The MNRF funding allocation in this area is shared equally between UNSW and MSSSO. The UNSW has devoted its share of the funds to upgrading the existing 60 cm SPIREX infrared telescope (operated by CARA - the US Center for Astrophysical Research in Antarctica) located at the South Pole. MSSSO efforts have centred on producing a Phase A engineering study for a new 2.5 m class telescope to be located at the remote Dome C site on the high (5000 m) Antarctic plateau.

The SPIREX upgrade consisted of the addition of a 1024 x 1024 InSb-based infrared camera, together with a number of smaller projects aimed at improving the quality of images from the telescope. The infrared camera, known as Abu, was developed by NOAO. This project has launched a joint Australian-US partnership, the end result of which will give Australian astronomers access to a unique infrared telescope boasting the largest thermal detector array in existence. After appointment of a Project Manager and weekly UNSW and UNSW-US design meetings throughout 1997, Abu was commissioned successfully on schedule at the South Pole in December 1997.

As well as the Abu installation, four additional significant upgrades have been made to SPIREX by the UNSW group. First, an improved electronic temperature stabilization system (allowing operation at ambient temperatures as low as -80° C) was installed in December 1997 and all specifications were verified as met. Second, various image-quality problems were tackled by the addition of new optical components and modifications to the optical path. The telescope is now diffraction limited at 3 μm and all aberrations and telescope-related imaging problems eliminated (except for slight astigmatism in the visible guider). Third, an autoguider, based on an integrating cooled CCD, was added to remove telescope tracking errors. Finally, a fast guiding system, designed to compensate for shake of the mounting tower and to make first-order corrections for atmospheric seeing, was added. This modification involved the addition of a light-weight, honeycomb-structured, secondary mirror mounted on three piezo-electric transducers. The system was installed in February 1998 and tests show that it successfully locks onto stars, providing fast tip-tilt correction. The control loop can be closed at frequencies up to 70 Hz. First astronomical results are promising, but additional software development will allow the full potential of the fast guiding system to be realised.

On the new telescope design front, MSSSO have completed a detailed report entitled "SPIRIT: The South Pole Infrared Imaging Telescope - The Phase A Engineering Study" . The report outlines optical, mechanical and project management considerations for a 2.5 m telescope cabable of yielding almost diffraction-limited images at 2.4 μm. The telescope is a wide-field design, operating primarily in the 2-4 μm and 10-12 μm observing wavelength ranges. A tip-tilt mirror (oscillating secondary) arrangement and large-format electronic detector arrays are central to the design. Significantly, the telescope is designed for largely unattended, open-air, operation in temperatures as low as -85° C. Bearing in mind the remote Antarctic location envisaged for the instrument, the design is optimized for very low power operation.

The scientific projects undertaken by the SPIRIT telescope will most likely emphasize deep surveys and the instrument design is optimized for the investigation of the epoch of the initial formation of galaxies (redshift 2 to 5), and the star formation which occurred within the galaxies at this time. Comparing the projected performance of the SPIRIT telescope with a number of existing and future infrared telescopes, it is apparent that SPIRIT is competitive in many applications, even when large instruments such as the 10 m Keck telescope are considered.

Allowing for uncertainties in the deployment and operating costs of the SPIRIT instrument on the high Antarctic plateau, MSSSO estimate that the project cost would be of order $A15M, of which $A9.4M represents the actual construction cost of the telescope. If construction were to begin in 2002, and assuming facilities at the high plateau site are developed on schedule by collaborating Italian and French agencies, MSSSO estimate that SPIRIT could be deployed by the end of 2005, with data-taking starting the following year.

(e) γ-ray Observatory - CANGAROO Project
Proposer: J Patterson

The Australian - Japanese CANGAROO project, located at Woomera, studies the most energetic objects in the universe by observing the Cerenkov radiation produced by γ-rays entering Earth's atmosphere. A primary aim is to contribute to the understanding of the origin and acceleration mechanisms of cosmic rays. Two telescopes are presently used, and the University of Adelaide collaborates with 11 Japanese universities. The Japanese Government is also funding a new $3M telescope for the Woomera facility, and the MNRF allocation will be used as a local contribution to the project planning and initial construction phases. Weekly meetings with local engineering consultants are being held and soil testing is under way preparatory to construction of the telescope foundation and pedestal. Work on the concrete foundation is expected to begin around the end of August 1998. Despite some development delays, it is expected that installation of the telescope assembly will begin by the end of the year.

(f) Phase 2 Activities of European Large Southern Array Project
Proposer: J Whiteoak

The Large Southern Array (LSA) is a European project involving the construction of a new-generation, Southern Hemisphere, millimetre-wave synthesis telescope. Present specifications call for a collecting area of 10,000 m^2 and an angular resolution of 0.1 arcsec at 100 GHz. Both specifications are an order of magnitude improvement over those of existing mm-wave instruments and, with at least 50 antennas in the array, the large number of interferometer baselines will yield vastly better image quality. Developments since the LSA concept was first proposed make it likely that the European project will be merged with the US Millimeter Array (MMA) project, leading to a single millimetre and sub-millimetre array located in northern Chile. The MNRF contribution to the Phase 2 LSA Activities is to allow Australian scientists and engineers to contribute to LSA/MMA planning and design groups dealing with matters such as scientific goals, software, system design and calibration. These activities will ultimately facilitate Australian access to the new instrument, as well as lead to techniques contributing to more effective operation of the upgraded Australia Telescope Compact Array.

(g) AUSTRALIS Phase A Study
Proposers: K Taylor and M Colless

The AUSTRALIS project involves the design and procurement of an optical/near-infrared, multi-fibre, spectrograph for the European Southern Observatory (ESO). In particular, the original proposal was for a spectrograph destined for the ESO Very Large Telescope (VLT), a multi-telescope array, based on four 8 m units, currently under construction at Cerro Paranal in northern Chile. The underlying philosophy is to provide, through the use of multiple optical fibre light guides, a spectrograph able to observe many objects simultaneously with a wavelength resolution sufficient to resolve the internal kinematics of very distant galaxies. The main objectives of the Phase A study, as initially proposed, were to develop the original concept design (as detailed in the AUSTRALIS Concept Study) into a full optical, mechanical, electronic and software specification.

However, very early in the Phase A project, ESO requested the AUSTRALIS consortium to provide a costed proposal for the procurement of the fibre positioner for AUSTRALIS. This represented a significant subset of the Phase A study and an opportunity to incorporate the AUSTRALIS spectrograph into ESO's future VLT instrumentation plans; as a result, a re-scheduling of the study was required. Subsequent to the MNRF submission, the AUSTRALIS positioner (now known as OzPoz) is being procured under a separate contract to ESO while, in recognition of the fact that the original Phase A study included substantial work on the positioner, half of its funds were donated to the positioner procurement contract and the study de-scoped and extended to concentrate on the critical engineering design issues surrounding the spectrograph itself.

To date, progress on the Phase A study includes the successful completion of the positioner design study, a continuing investigation into the difficult area of microlensed integral fibre unit (IFU) design, and a detailed evaluation of spectrograph design. The procurement of efficient, state-of-the-art, microlenses requires an iterative design process to arrive at the best performance/cost compromise. This analysis is complete and the proposers are in the procurement phase prior to prototyping, with manufacture and test scheduled for quarter 3, 1998.

(h) LOBSTER X-ray Satellite

Proposer: K Nugent and R Webster

This project is allowing Australian participation in the planning of a proposed X-ray all-sky monitor, known as LOBSTER. The LOBSTER collaboration consists of NASA’s Goddard Space Flight Center, the Los Alamos National Laboratory, and the Universities of Melbourne, Leicester and Wisconsin. The satellite is in the conceptual phase of its development and will be competing for NASA funding of over $A100M, under the “Small Explorer” scheme. In evaluations to date, the project has received excellent assessments of its scientific goals but it has been advised that its technical readiness needs to be improved if funding is to be approved. The MNRF financial allocation has been used to employ a Post-Doctoral Research Fellow (Dr S Brumby) to find solutions to physics problems confronting the application of novel optics developed by the University of Melbourne for the LOBSTER mission.

The project has enjoyed considerable success in the last year; a new approach to analysing defects in the X-ray optics has been proposed and Melbourne’s formal collaborative roles planned. These roles include development of an end-to-end model for the final scientific payload, and participation in development of data-analysis tools for LOBSTER. The operational satellite will use automated ground stations, one of which will be located in Melbourne. Connections with collaboration partners have been strengthened, with the Research Fellow having spent more than a month in late-1997 with the overseas groups. Dr Brumby will continue with the LOBSTER mission beyond the MNRF-sponsored project, having accepted a post-doctoral position with Los Alamos National Laboratory (to begin later in 1998). A new PhD student has been recruited to ensure Melbourne’s continuing participation in the mission. The proposers note that there is considerable uncertainty in obtaining continuing funding of the Australian contribution to LOBSTER, citing difficulties with the Australian Research Council grant submission guidelines relating to instrumental research.

(i) Australia - Japan Collaborative Workshops
Proposer: M Bessell

This project aims to promote contact and collaboration between Australian and Japanese astronomers. In the past year there have been a number of joint discussions held on the best ways of fostering collaboration, together with some visits by Japanese observers to Australian optical astronomy facilities. Dr M Bessell attended the opening of the Japanese SUBARU astronomy facility in Hilo, Hawaii and, in the course of the opening, had discussions with Japanese counterparts. Professors Ando and Kajino, together with students from their respective institutions in Japan, travelled to Australia to use the Anglo-Australian Telescope and the 74 inch MSSSO telescope. Further visits by senior Japanese astronomers are planned in the next year, and Australian participation in a week-long scientific conference at the SUBARU facility is envisaged.

(j) Gemini Partnership - Contribution to the Capital Cost of Australia's Participation in the Gemini Project
Proposer: M Brennan

The International Gemini Project (IGP) is building two 8 m optical/infrared telescopes, one in Chile and one in Hawaii. The telescopes and their instruments represent state-of-the-art technology, and will be important components of the optical astronomy programs of IGP members (US, UK, Canada, Chile, Argentina, Brazil and Australia) well into the next century. The Hawaiian and Chilean telescopes will see first light in late-1998 and 2000 respectively. In February 1998 the Australian Government announced that Australia would contribute 5% of the $US193M project via the Australian Research Council (ARC). The MNRF allocation represents a contribution to the ARC funding package for the initial grant requests involving capital support of the IGP.

(k) Collaboration with ESO on Instrumentation for the VLTI
Proposer: J Davis

The Very Large Telescope Interferometer (VLTI) is an imaging optical interferometer array based on the four 8 m VLT telescopes and three 1.8 m auxilliary telescopes, all located at the Chilean VLT site. The first of the VLT 8 m telescopes will be useable in a stand-alone mode in 1999 but, before an interferometric capability becomes available, extensive tests on many optical components (passive and active) will be required. The University of Sydney Chatterton Astronomy Department, through its own work on the Sydney University Stellar Interferometer (SUSI), has extensive experience in the evaluation of important VLTI sub-systems. The MNRF allocation represents a 50% contribution to the salary of a research fellow for a maximum of two years. The research fellow will work in the area of optical interference fringe visibility measurement, an area of interest for both the VLTI and SUSI.

5. ATNF Upgrades and Extensions

In the first full year of operation of the MNRF upgrade program, significant progress has been made in all areas. As well, the Program has benefited greatly by CSIRO's approving two ATNF initiatives which, while funded outside the MNRF scheme, were in fact made possible by the upgrade. First, as mentioned in the 1997 annual report, CSIRO has provided an additional $1.3M for construction of a north rail spur connected to the existing AT Compact Array track. This will improve enormously the high-frequency imaging performance of the upgraded telescope. Second, the ATNF, in partnership with CSIRO Telecommunications and Industrial Physics (CTIP), has been awarded $2.2M from the CSIRO Executive's Special Fund; this funding is to enable research into the design, fabrication and application of indium phosphide (InP) monolithic microwave integrated circuits (MMICs) - a highly topical area of technological research of direct relevance to the MNRF upgrade. As well as providing advanced electronic devices for the MNRF work, the MMIC program will augment greatly the range of high-frequency test equipment available to ATNF engineers involved in the MNRF upgrades.

While the planning of the high-frequency upgrade has been re-cast slightly to reflect the benefits of the CSIRO MMIC program, the expected completion date remains at January 2002. A change to the initial MNRF direction relates to the involvement of industry in the production of the high-frequency receivers. With changes to the commercial alignment and manufacturing capabilities of potential Australian contractors, supply of advanced millimetre-wave electronic sub-systems from outside the ATNF now appears impractical. In partial compensation, the ATNF has begun using Australian industrial contractors to provide high-precision fabrication services for many of the vital waveguide and associated components in the high-frequency receivers.

In the VLBI upgrade area, all specified milestones have been met, with the exception of the supply of the S2 playback unit; the slippage in commissioning this unit (purchased from Canadian suppliers) has not materially affected the Program. No difficulties are expected in meeting remaining VLBI, or ATNF strategic research, targets.

(a) High-Frequency Upgrade

This upgrade will extend the capability of the AT Compact Array to allow observations in the 12 mm (16 - 25 GHz) and 3.5 mm (85 - 95 GHz) bands, making the Australian instrument the first operational millimetre-wave array in the Southern Hemisphere. At present, the highest frequency of ATCA operation is 9 GHz, corresponding to a wavelength of about 3 cm. The high-frequency extension will increase the detail visible in astronomical images by up to a factor of 10, allowing the array to complement new-generation optical telescopes. As well as the increased resolution, the ATCA upgrade will allow astronomers to image, for the first time in the Southern Hemisphere, the radiation from many abundant cosmic molecules, providing insight into the chemical processes and dynamics of objects in both the near and distant universe.

While the precise upper frequency limit of the upgrade is still somewhat uncertain (being dependent on the performance attainable with leading-edge technology), indications are that coverage to 115 GHz may be possible although, in line with MNRF Technical Advisory Committee recommendations (Appendix 5), the ATCA performance below 100 GHz will not be compromised unduly in order to gain this band extension. In planning the 12 mm and 3.5 mm systems, care has been taken to allow provision of a 7 mm (40 - 50 GHz) band option in the future. However, the unique capabilities of the ATCA have already led to international requests for coverage near this band. To satisfy the scientific needs of important investigations of the cosmic microwave background, the ATNF is negotiating with the University of Chicago for the supply of components for two 30 GHz receivers. These receivers would integrate directly with the MNRF-sponsored receivers, temporarily occupying the space designated for the 7 mm systems (see Section 5(a)*(i)*, below).

As well as the ATCA extensions, the MNRF upgrade will provide a new frequency-conversion system for the ATNF’s 64 m radio telescope at Parkes, enhancing its high-frequency observing performance and versatility.

Progress reports on individual high-frequency upgrade sub-projects are given below.

(i) 12/3.5 mm Receivers

The direction of this project became clear in the past year as the requirements of science groups and related MNRF projects were finalised. Particularly significant are decisions not to provide any fast position translation between 12 mm and 3.5 mm feeds, and to use the astronomy 12 mm receiver as part of the atmospheric phase correction system (see Section 5(a)*(iii)*, below).

The overall design of the prototype ATNF high-frequency receiving package is shown in Figure 5-1. Both the 12 mm and 3.5 mm receivers are contained in a common cryogenic dewar, with the separate feed horns being moved to the secondary focus of the ATCA antennas using the existing rotator positioning system. Provision has been made in the dewar for a future 7 mm receiver. Note that the 3.5 mm feed horn is cooled to 20 K (-253° C) to minimize losses, and that the 12 mm receiver is used about 100 mm off-axis during phase correction of 3.5 mm observations, thereby sampling tropospheric water-vapour emission along a line-of-sight displaced only 6 arcmin from the astronomy beam; this small displacement is insignificant in the phase correction process. All receivers in the dewar are dual-polarization (two-channel) types, with polarization splitting achieved using waveguide, rather than the originally proposed wire grid components.

Of particular interest are the low-noise amplifiers (LNAs) in the new package. The 12 mm system uses LNAs constructed using discrete high electron mobility transistors (HEMTs) and covering the whole band 16 - 25 GHz. Prototype amplifiers show equivalent noise temperatures of 40 K, and system temperatures of <80 K at 22 GHz are expected on the ATCA under typical conditions. Amplifiers for the 3.5 mm band represent leading-edge technology, with the ATCA being the first radio astronomy array to be equipped with these new devices. It is likely that ATCA receivers will, in fact, use two generations of LNA, both of which will be developed in conjunction with CTIP. For prototype receivers, and to meet the MNRF target of a working millimetre-wave ATCA by 2002, gallium-arsenide (GaAs) MMIC amplifiers will be used. These devices are expected to cover the range 85 - 115 GHz, with system temperatures of order 250 K being expected on the ATCA at 100 GHz. As superior indium-phosphide (InP) MMICs become available (see above) the receivers will be retro-fitted, reducing typical system temperatures to 180 K.

Present work centres around production of prototype multi-band receivers, with the intention of beginning 22 GHz ATCA test observations in early 1999. As well as providing test receivers which will be invaluable in evaluating system and antenna upgrades, the prototyping process is essential in refining workshop and associated techniques necessary in the production of the new receivers.

(ii) ATCA Antenna Surface Extension

The six 22 m ATCA antennas currently have solid reflector panels to a diameter of 15 m, the outer 7 m section of the dishes being clad in perforated panels which function well to observing frequencies of 50 GHz. To obtain good antenna efficiency at higher frequencies, the perforated panels will be replaced by new solid panels on the five antennas to be used for millimetre-wave observations.

Following the preliminary investigations outlined in the 1997 MNRF annual report, the ATNF itself managed a specification, tendering and tender evaluation process. Two bids were received for the panel manufacture and installation; Evans Deakin Engineering (EDE) P/L was the successful tenderer. EDE will manufacture the panels using a vacuum forming and epoxying technique, a method developed by CSIRO for the initial ATCA construction and since transferred to Australian industry.

Under the terms of the extension contract, EDE will deliver one set of panels for a six-month evaluation by the ATNF. At present progress rates, the initial panel set is expected to be installed in late-August 1998. If the test antenna performance is satisfactory, the remaining ATCA antennas will be outfitted in the first half of 1999.

Present indications are that panel surface errors will be in the range 50 - 100 μm, making the ATNF goal of a 125 μm root-mean-square antenna surface error (corresponding to > 40% aperture efficiency at 100 GHz) appear reasonable. After panel installation by EDE, the ATNF will adjust the panels precisely. Final surface setting will be done using radio holography techniques at 30 GHz.

Modelling of the static and dynamic wind loading effects on the extended ATCA antennas indicates that satisfactory pointing performance can be obtained at high frequencies in winds < 15 km hr^{-1}, the usual situation at Narrabri during weather conditions likely to be suitable for millimetre-wave observing. Importantly, the re-panelling is predicted not to degrade significantly the pointing of the antennas in higher winds during low-frequency observing.

As noted in the MNRF Technical Advisory Committee report (Appendix 5), the performance of the extended antennas is critical to the success of the ATCA upgrade and has implications

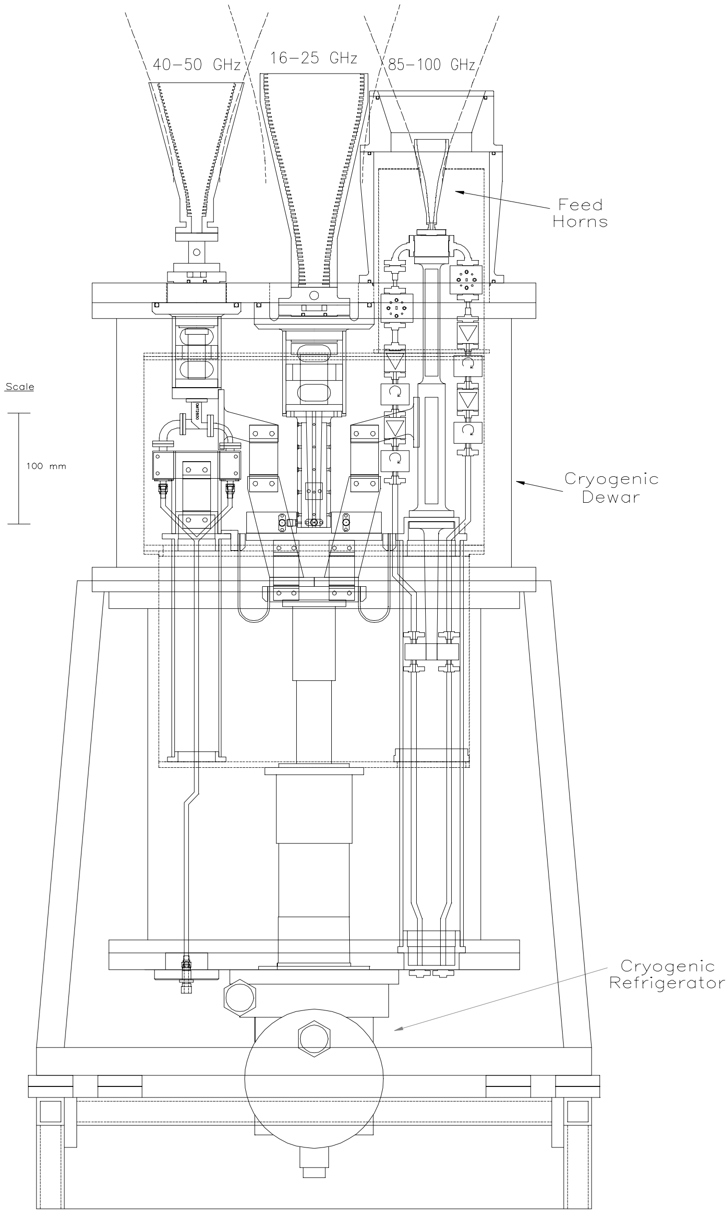


Figure 5-1 *Line drawing showing the general arrangement of the ATCA multi-band, high-frequency, receivers. The feed horns are placed at the secondary focus of the antenna using the ATCA rotating turret arrangement, although the 12 mm receiver will also be used off-axis as a phase correction radiometer. Note that the small 3 mm feed horn is cooled to 20 K, minimizing equivalent noise temperatures in this band. The phase correction system uses the dewar-mounted, first-stage, 12 mm low-noise amplifiers; the remaining phase correction electronics is contained in an external temperature-controlled enclosure (not shown).*

for the science strategy associated with the upgrade program. As well as commissioning the the wind loading studies, the ATNF will take the cautious approach of evaluating a re-surfaced ATCA antenna, rather than using the Mopra telescope for initial tests.

(iii) Atmospheric Phase Correction

This project will provide equipment and techniques to correct the rapid electrical path-length variations or, equivalently, phase fluctuations, which occur when tropospheric winds transport “blobs” of water-vapour through the line-of-sight of individual antennas in a synthesis array. Left uncorrected, these fluctuations limit the image quality available or, in severe cases, make imaging with the array impossible. The effect is most severe at high-frequencies, where the water-vapour induced fluctuation may amount to many turns of phase.

Atmospheric phase correction is a topical area of radio science, promising to allow imaging by the putative next-generation Chilean millimetre-wave arrays at frequencies approaching 1 THz (1000 GHz). The ATNF project maintains active links with various international groups, including one charged with the development of calibration strategies for these new arrays.

Initial ATNF research centred on the development of a prototype high-stability 225 GHz water vapour radiometer (WVR) designed to sense the clear-sky water vapour “seen” by a co-located astronomical antenna. The prototype met or exceeded specifications but present thinking is that phase correction is best performed using a channelized 22 GHz sensing arrangement which makes use of the astronomical feed and receiver first stages. The expectation is that this system will allow correction under both clear-sky and light-cloud conditions, significantly enhancing the amount of high-frequency observing time available on the ATCA.

During the past year the 225 GHz WVR has been installed at the ATCA site, providing valuable atmospheric opacity and stability data needed for effective scheduling of high-frequency ATCA observations. Project personnel have also led science discussions aimed at converging on optimum calibration strategies for the upgraded ATCA, worked with international colleagues in refining phase correction techniques and algorithms, collaborated with CSIRO Telecommunications and Industrial Physics in a study of the near-field response of the new ATCA 22 GHz feed (both on and off-axis), and begun the detailed design of the ATCA water line monitor (WLM) - the channelized sensing system. A prototype WLM is scheduled for delivery by mid-1999. Although the MNRF Program provides only for phase correction systems at the ATCA, the ATNF is, on the advice of the MNRF Technical Advisory Committee (Appendix 5), investigating the feasibility of correction systems for the Australian VLBI network.

(iv) ATCA Local Oscillator Distribution Upgrade

The local oscillator (LO) upgrade will provide a reliable, low-noise, system for distributing master-reference signals to the ATCA antennas. At present, these signals are sent via a co-axial cable series (or “daisychain”) arrangement, the reliability of which is marginal. The new distributor uses a “star” topology and is based on single-mode optical fibre. Used in conjunction with upgraded reference generation equipment to be constructed in the course of the project, this arrangement will meet the demanding phase-noise requirements of a synthesis array operating at 100 GHz. The ATCA will be one of the first millimetre-wave arrays to use a fibre distributor, and the LO electronics will invoke a number of new design concepts, including the use of dielectric resonators in high-frequency reference oscillators.

In the past year an experimental 2 km fibre link has been set up at the ATNF Marsfield headquarters, allowing representative frequency generation, distribution and link equipment to be characterized. The test setup has also been invaluable in formulating a viable electrical line length measurement system, needed to account for minute changes in the fibre length caused by, for example, temperature fluctuations. At present, the total phase noise of the experimental link amounts to about 20° rms at 100 GHz. However, with the use of a wideband laser diode and associated refinements, it is expected that the upgrade specification of 5° rms will be attainable.

ATCA antennas are re-positioned quite frequently by the standards of comparable arrays, and the implementation of robust, optically stable, intensive-use connectors for single-mode optical fibre is not trivial. Commercial solutions have recently become available but are prohibitively expensive; the ATNF is therefore designing and evaluating sturdy connectors based on standard fibre components.

As well as the work on the LO distributor, project members are responsible for all signal distribution associated with new antenna stations on the E-W and north interferometer tracks, together with patching and related hardware at the the ATCA control building. It is expected that service cabling of the new stations will be completed by mid-1999 and that one antenna will be available for evaluation of the fibre LO distributor at that time. Changeover of the whole array to the new system is expected to take place in mid-2000.

(v) ATCA Extra Stations

The original MNRF specification was for three additional stations on the existing 3 km east-west rail track of the ATCA. As mentioned above, CSIRO is providing additional funds for the construction of a five-station, 230 m-long, north spur track, converting the ATCA to a two-dimensional array. The combined effect of these upgrades will be to enhance significantly the quality of images from the telescope, especially at higher frequencies where, owing to the effects of atmospheric water vapour, it is important to complete the imaging process quickly and with high average antenna elevations.

Given the commonality between the E-W track and north spur works, the ATNF effectively combined the projects for management purposes, engaging Connell-Wagner P/L to specify in detail civil and electrical works, co-ordinate tendering, assist with tender evaluation, and supervise site works. Tenders for civil works closed in February 1998 and a contract with the successful bidder, Barclay Mowlem Construction Limited (Railway Engineering and Construction Group), was signed in April. The ATNF itself has taken responsibility for overall contract administration, together with electrical power and communication work associated with the testing and commissioning of the new stations.

Site works began in late-May 1998 although heavy rain, both in May and June, will delay completion of the civil works until the end of September. To date, all major earthworks, including works associated with the boring of all piers for the new stations and the associated concreting, have been completed. The E-W stations will be completed first, allowing antennas to be moved across the new works during array re-configurations. Acceptance testing of the turntable, at the junction of the E-W and north tracks, is expected to begin in September. Following completion of the civil and electrical power activities, ATNF electronics personnel will progressively outfit the new stations with fibre optic and copper communications cabling. Tests using the new stations will begin mid-1999, with full astronomical use being possible by early 2000.

(vi) AT Observation Management System (ATOMS)

The more stringent antenna control and monitoring requirements of the high-frequency ATCA make it essential to upgrade the telescope antenna control computers (ACCs). The task of implementing the next-generation ACCs has been absorbed into the ATOMS project, with the aim of demonstrating the effectiveness of new software design and management techniques. Among the general ATOMS initiatives are: implementation of a basic software engineering process suitable for development of observatory on-line software; use of software and management metrics to aid planning of future ATNF software projects; regular management and technical reviews; use of object-oriented software development methodologies; and development of an intranet server to make project material available across all ATNF sites.

The MNRF contribution to the ATOMS project is in the form of funding for two positions (each of two-year duration) to help with the implementation of the ACCs. Both these positions were filled in September 1997 by recent graduates. Three peer reviews of the project have been held since July 1997. A number of important tasks have been completed, including the design of an antenna-independent low-level interface and an easily extended antenna control framework using object-oriented techniques. A number of high-integrity software components required for real-time interaction with the antenna hardware have also been designed, and coding of these is progressing using the C++ language in a commercial (pSOS+) real-time environment. Finally, several observatory data management utilities have been completed using the Java programming lanaguage.

It is expected that a prototype ACC will be available by mid-1999 and that production machines will be installed in the ATCA antennas in early 2000. Project timescales have slipped approximately six months from preliminary predictions, principally because of delays in establishing a reliable real-time development environment and in converging upon an ACC design allowing the required level of flexibility.

(vii) Parkes Conversion System

The new four-channel frequency-conversion system for the 64 m Parkes radio telescope will increase the versatility and performance of the instrument for many observations. It will also make Parkes compatible with new-generation equipment and observing techniques developed under the MNRF Program for use at the ATNF's other facilities. The project is progressing well and it is anticipated that the July 1998 target for hardware completion will be met. The new conversion system will be tested at Parkes during the ensuing months and it is anticipated that it will be in routine astronomical use by the end of the year.

(b) ATNF VLBI Upgrade

In addition to supporting the provision of high-frequency capabilities on ATNF instruments, the MNRF Program funding provides for extension and improvement of the Australian VLBI network and, in particular, facilities managed by the ATNF and the University of Tasmania. Although the two institutions are managing separate (but co-ordinated) upgrades, for reasons of economy and standardization the ATNF has placed some orders on behalf of the University.

Significant progress has been made over the past year in the VLBI network upgrade, with Australian telescopes participating in a number of experiments, including several involving the orbiting Japanese VSOP radio astronomy spacecraft. Reports on items identified specifically in the MNRF contract are given below and in Section 6.

(i) 12 mm (22 GHz) Receiver

The ATNF has built and tested a 22 GHz VLBI receiver for the Mopra telescope. The receiver performance is exceptional, with a minimum system temperature of less than 80 K being measured on the 22 m telescope. Astronomical tests indicate a 22 GHz aperture efficiency of around 65%, auguring well for the performance of the very similar ATCA antennas in the 12 mm band. The Mopra receiver forms the basis for two similar receivers to be assembled by the University of Tasmania. It is also regarded by ATNF engineers as a test system for the 22 GHz section of the multi-band ATCA millimetre-wave receiver. With successful installation of the ATNF receiver at Mopra, this section of the MNRF upgrade is complete.

(ii) Hydrogen-Maser Frequency Standards

The ATNF purchased three masers from the Russian firm Vremya-CH, together with a fourth unit which is designated a non-operational spare under an agreement with the Russian suppliers. Two of the masers were purchased on behalf of the University of Tasmania and have been installed at Ceduna and Mopra; the third (ATNF) unit has been installed at the ATCA. The Australian experience of the Vremya-CH masers has been of some interest internationally, since the relatively economical Russian units are attractive to research institutions needing alternatives to more expensive Western masers. Figure 5-2 shows one of the Vremya-CH masers under test at the ATNF.

In general, the Russian frequency standards are all functioning well, meeting or exceeding vital stability specifications. Two-maser intercomparisons show Allan variances of 2 parts in 10^{13} and 1 part in 10^{14} for averaging times of 1 s and 100 s respectively. This order of stability has allowed successful VLBI imaging at frequencies as high as 22 GHz. Minor reliability problems have been experienced with the Ceduna maser, possibly as a result of the poor quality power supply to the site. VLBI data involving Mopra also identified a residual low-frequency modulation problem, prompting the Russian designers to supply upgraded signal distribution hardware. The initial problems are considered minor relative to the

Figure 5-2 *A Vremya-CH maser under test at the ATNF. The maser package includes extensive computer monitoring and control facilities.*

complexity of the technology involved and present indications are that all the masers will continue to perform well. This section of the MNRF upgrade is now complete.

(iii) S-2 Playback Unit

Negotiations are in progress with the Canadian suppliers of this unit and it is expected to be delivered by December 1998, giving the ATNF VLBI correlator the signal processing capacity to match the load generated by the upgraded VLBI network.

(iv) Timing Units

These units provide accurate timing information (obtained from Global Positioning System satellites) at Australian VLBI observatories. All seven systems (five ATNF, two University of Tasmania) have been installed and associated software developed. The timing units are now in use and the project is complete.

(c) Associated ATNF Projects

As well as the major upgrade projects outlined in Sections 5(a) and (b), the ATNF is responsible, under the terms of the MNRF contract, for additional miscellaneous items falling under the headings of project management, manpower, test equipment, and strategic research. An outline of each of these areas is given below.

(i) Project Management

Activities in this area have been concerned largely with establishing a planning and reporting infrastructure able to operate effectively across the geographical diversity of the MNRF Program. In particular, MNRF funding has been used by the ATNF to set up a high-quality teleconferencing system across its four sites. The funding has also contributed to the maintenance of higher quality voice and communication links from ATNF Headquarters to the Observatories. Other notable activities in the management area have been the funding and organization of the Technical Advisory Committee meetings in September 1997, funding of a small number of overseas study trips by ATNF project specialists, and funding of legal work associated with contract negotiation and administration.

(ii) Manpower

Whilst the ATNF has not recruited additional staff for the MNRF upgrade, funding from the Program has allowed retention of four professional engineers and technologists whose employment contracts were drawing to a close. As well as these directly-funded positions, the ATNF is aligning the goals of several of its other employment initiatives with the needs of the MNRF Program. Examples include revised selection criteria for postdoctoral appointments, increased participation in new technology projects by engineering “sandwich” and similar students, and new opportunitities for engineering trainees and apprentices.

(iii) Test Equipment

The MNRF upgrade has required the ATNF to expand substantially its test, measurement and manufacturing capabilities to meet the demands of new engineering research projects, especially those involved with the ATCA high-frequency developments. As well as purchasing instruments such as a high-speed digital oscilloscope, spectrum analyser, frequency synthesizer, and sweep generator, the ATNF has used MNRF funding to increase its PC workstation capabilities in the microwave and millimetre-wave computer aided design (CAD) area. Finally, the purchase of a high-precision lathe and mill has enabled accurate machining of prototype waveguide structures and feed assemblies for the upgrade.

(iv) Strategic Research

ATNF efforts in this area centre on the development of technologies and techniques applicable to the 1 kT, the next-generation radio telescope described in Section 4(b). Projects funded under the direct ATNF MNRF allocation complement, in practice, the telescope and sky modelling work outlined in that Section. In the past year, two broad strategic research projects have been established in the ATNF. The first involves 1 kT systems work, which incorporates antenna array technology, array configuration studies, and support for the 1 kT international project planning. The second project groups all ATNF activities associated with radio frequency interference (RFI) mitigation, including those associated with the 1 kT.

- *1 kT Systems Project*

In the area of array technology, research is proceeding in collaboration with the Royal Melbourne Institute of Technology (RMIT) in the area of wide-band microstrip antenna arraying. Some project payments have been made to RMIT to support the collaboration, and the first six-monthly progress report has been received. Future support may be provided to investigate the “double stacking” of array elements, allowing dual-band operation.

Preliminary research is under way into optimising the configuration of the 1 kT array. Early work was performed with somewhat restrictive software but the recent purchase of the “MATLAB” program suite will allow much more realistic simulations to be performed. It is anticipated that the performance evaluation of up to 100 “concentrators” (perhaps dishes) forming a single array “station” will be feasible.

In the international 1 kT planning area, the major event was a technical workshop held at the ATNF in December 1997. Approximately 100 people attended, with 31 international visitors, as well as a number of representatives from Australian universities and industry, participating. The aim of the meeting was to discuss the current technical research being undertaken and to identify areas requiring further effort. It is anticipated that specifications for the 1 kT will be refined further at the next science meeting to be held in Canada in July 1998.

With considerable assistance from the WA Government, an initial survey has been made of the Upper Gascoyne-Murchison area of WA as a possible site for the 1 kT. Preliminary work has shown that, at this site, there is neglible ground-based radio interference within a 100 km-diameter zone. More detailed evaluations of additional sites in WA and other states will be made in the course of the project.

- *Interference Mitigation*

Man-made radio-frequency interference (RFI) is now so pervasive that many radio astronomical observations are rendered difficult, or even impossible. As well as the hazard from terrestial transmitters, geostationary and earth-orbiting satellites, used nowadays in a plethora of communication and navigation applications, cause significant interference. Many satellites now render the radio astronomer's traditional defence of retreating to isolated locations ineffective, since "constellation" deployment strategies achieve almost total global coverage. New radio astronomical techniques to mitigate RFI are therefore highly desirable in existing telescopes and, given the enormous sensitivity of the next-generation 1 kT instrument, such mitigation must be central to the design if the 1 kT is to achieve its scientific goals.

ATNF researchers and colleagues from several universities have experimented successfully with basic RFI mitigation techniques, including data processing algorithms devised using signals from the Parkes 64 m telescope and the AT Compact Array. In particular, the unique 13-beam receiver at Parkes has been used to demonstrate, in a conceptual sense, the identification and excision of interference by the use of focal plane array feeds and associated cross-correlation techniques.

An important component of the ATNF interference mitigation project has centred on characterizing the nature and extent of RFI at Australian observatory sites, both operating and planned. Good progress has been made in this area, with briefing material now available to observers, engineers, and 1 kT planners via the World Wide Web (see Appendix 3). This work had its origins in a joint ATNF - University of Technology (Sydney) collaboration. Figure 5-3 is an example of the RFI characterization for the ATCA site at Narrabri. The challenge to radio astronomers in using an increasingly congested spectrum is clear. An expanding area of the UTS collaboration involves the simulation and characterization of practical signal quantization (digitization) and digital interference suppression sub-systems, areas of great relevance to 1 kT designers.

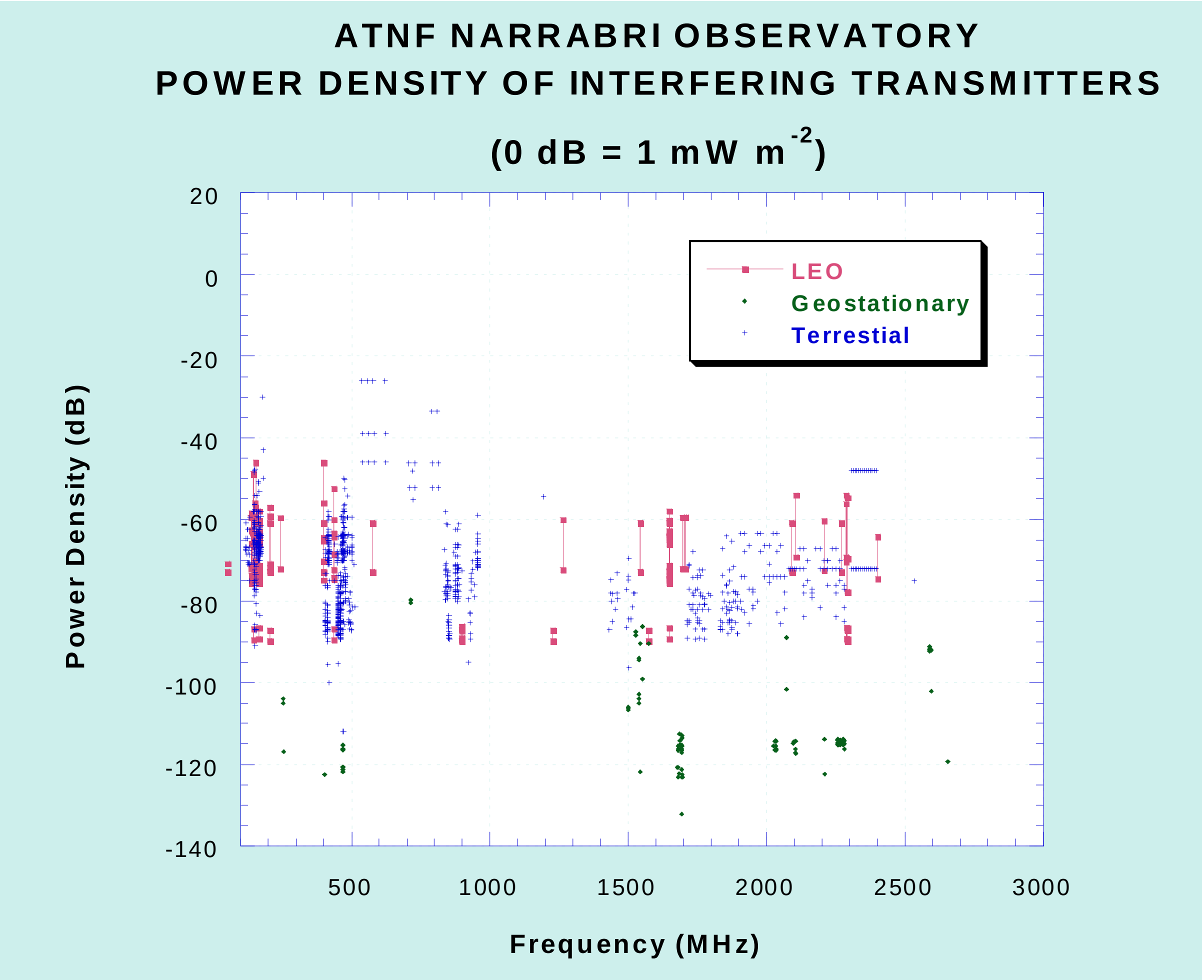


Figure 5-3 *Plot showing the distribution in frequency of licenced radio transmitters visible from the ATCA site, near Narrabri in north-western NSW. Even at this relatively isolated site, interference from land-based and satellite (both low earth orbit and geostationary) services is pervasive, pointing to the need for interference mitigation strategies for both existing and future radio telescopes.*

(d) Program Science Report

Each ATNF upgrade project has both a Project Leader and a Project Scientist; Table A2-2 (Appendix 2) lists these personnel. The main roles identified for the Program Science team (the collective of Project Scientists) are to maintain an overview of the MNRF Program, to identify areas that need astrophysics input, and to help in defining system specifications (for example, the high-frequency receiver band-coverage and polarization requirements, and the locations of new antenna stations). A secondary role is to maintain communications between the Program and the ATNF user community. Next year, as prototype high-frequency receivers are installed on the ATCA, the roles will be expanded to include systematic observing programs designed to test and hone calibration strategies, and to build expertise and data needed to make effective use of the completed instrument. The major issues currently confronting the Science Team are noted below. In each case, more details are available from the MNRF Web site (Appendix 3).

(i) Calibration Strategy

At present, the ATNF expects to use a three-stage calibration process during 3.5 mm observations in which:

- the ATCA is driven to a pointing and baseline calibrator every five minutes, and observes it using the offset 12 mm feed;
- the Telescope is then driven to an atmospheric phase calibrator every minute or so, and observes it using the offset 12 mm feed;
- continuous three-channel water-vapour measurements are made around 22 GHz using the offset 12 mm feed, and this radiometric measurement inverted to correct the 3.5 mm phase between calibrator observations.

(ii) Dynamic Scheduling

It is likely that some form of dynamic (or queue) scheduling will be needed at high frequencies. The way in which the ATNF might implement this is has been discussed, but further work must await better statistics on the distribution of good high-frequency observing time. These statistics are now starting to accumulate from the cloud-cover monitor and 225 GHz water-vapour radiometer (WVR) installed recently at Narrabri. For dynamic scheduling to be effective, an objective measure of high-frequency “seeing” is needed; it is likely that the highly-stable 225 GHz WVR can provide this information, although use of a dedicated interferometer to observe communications satellite beacons remains an option.

(iii) Pointing

Various factors relating to ATCA pointing have been examined. At present, the best estimate is that pointing (using the calibration model described in *(i)*, above) is not likely to be a problem under most circumstances. However, this needs to be re-visited after the antennas have been re-surfaced. In any case, ways of improving pointing during mosaicing observations, which are likely to be common at high frequencies, can usefully be explored.

(iv) Calibrator Sources

A good network of calibrator sources will be essential for successful operation at high frequencies. At present, there is no suitable calibrator catalogue for the Southern Hemisphere. Various options for catalogue compilation have been examined, with the consensus emerging that the ATNF itself should undertake the task. Calibrator observations will therefore begin in mid-1998, when the first prototype high-frequency receivers become available on the ATCA.

(v) Computing

Members of the Science Team have been examining the computing needs of the upgraded ATCA. At present it appears that the new antenna control computers (Section 5(a)*(vi)*) will cope with the needs of new receivers and systems, but trial observations will, no doubt, be especially valuable in testing the new controllers. Present off-line processing systems should be adequate for the data from the upgraded ATCA, although the Science Team is currently examining some areas of concern (for example, how to attach radiometric phase and other calibration information to the astronomical data, and how to subsequently apply the calibration).

6. University of Tasmania VLBI Expansion

In October 1995 the University of Tasmania acquired the former Telstra 30 m antenna at Ceduna, in South Australia. After an extensive refurbishment effort (refer to MNRF Anuual Report No. 1 for details) which included considerable assistance from the ATNF, the Ceduna Radio Astronomy Observatory was opened formally on October 7 1997 by the Hon. Barry Jones, AO. Figure 6-1 shows the Ceduna antenna in its new role as a radio astronomy instrument.

A number of major improvements have been made at Ceduna in the past year. Apart from those noted under the MNRF contract headings (below), two important astronomy systems have now been installed. The final S2 VLBI data acquisition system (DAS) has been delivered, replacing the prototype used in initial VLBI experiments. In addition, a new 8K-channel autocorrelation spectrometer, allowing stand-alone spectral-line observations, is operational. Both of these items were supplied by the ATNF and, in fact, the outfitting of Ceduna represents the completion of the ATNF's commitment to establishing an S2-based VLBI network on the Australian continent.

In December 1997 Ceduna Observatory was used in a 1-week national and international VLBI session, including an experiment involving VSOP, the orbiting Japanese VLBI spacecraft. By November 1998 the Observatory will be fully operational in the VLBI national facility mode at 2.3, 4.8 and 6.7 GHz.

(i) Ceduna Receivers

The receivers now operational at Ceduna have been developed and constructed by the University of Tasmania. These systems use un-cooled, low-noise amplifiers based on high electron mobility transistors (HEMTs). A program to improve the performance of all receivers at Ceduna and Hobart is progressing well, with a number of new low-noise amplifiers currently being evaluated at the 26 m Mt Pleasant (Hobart) antenna.

(ii) 12 mm Receivers

Two receivers will be constructed by the University of Tasmania, for use at Ceduna and Mt Pleasant Observatories. While the receivers will use many of the sub-systems developed for the ATNF receivers destined for Mopra and the ATCA, it is expected that the different optical arrangements at the two University telescopes will make customised packaging and installation necessary.

(iii) Hydrogen Masers

The two Vremya-CH maser units purchased by the University of Tasmania have been installed at Ceduna and Mopra for use as master frequency and time references. Both units are functioning reliably and within specification. See Section 5(b)*(ii)* for further details.

Figure 6-1 *General view of the 30 m antenna at the Ceduna Radio Astronomy Observatory.*

(iv) Timing Units

Both the Ceduna and Hobart units are installed and working well; see Section 5(b)*(iv)* for details.

(v) Ceduna Antenna Optics

The panels of the 30 m antenna have been surveyed and re-set, giving a surface error of less than 0.4 mm rms, a figure allowing operation at frequencies up to at least 22 GHz with an expected aperture efficiency of better than 50%. At the lower frequency extreme, computer modelling has verified that it is not feasible to construct a 1.6 GHz feed to work at the tertiary (Nasmyth) focus. However, a preliminary design has been completed for a prime focus feed. Part of this design involves a revised, and movable, sub-reflector assembly, allowing both unobstructed prime focus operation and axial focus adjustments. In the intermediate VLBI bands, wideband feeds for 2.3, 4.8 and 6.7 GHz have been fabricated and installed by the University of Tasmania according to ATNF specifications. An 8 GHz feed is currently under construction at the University and is due for installation at Ceduna before the end of 1998.

7. MNRF Financial Statements

Table 7-1 summarizes the overall MNRF financial situation as at 30 June 1998. The report is a basic, unaudited, one in the same format used in MNRF Annual Report Number 1. Guidelines for the production of audited MNRF financial and asset reports are currently being drafted by the Department of Industry, Science and Tourism. When these directives become available, ATNF quarterly and annual reports will be produced in accordance with the new directives.

Table 7-2 is a summary of international astronomy collaboration projects funded under the MNRF Program. Table 7-3 shows details of international travel requests supported in the financial year 1996-97; MNRF Annual Report Number 1 contains full details of earlier grants.

Table 7-1 MNRF Financial Summary as at 30 June 1998

Projects	Provision	Exp 1995/96	Exp1996/97	Exp1997/98	Liabilities	Balance
AT High Frequency Upgrade						
12/3.5mm ATCA receivers	2860000		11371	222917	185729	2439983
Atmospheric phase correction	160000		23925	6687	450	128938
ATCA antenna surface extension	910000		350	15109	155874	738667
3.5 new E-W stations for ATCA	440000		10192	124952	124580	180276
ATCA local oscillator upgrade	750000			44023	10940	695037
ATOMS	200000			86228	0	113772
Parkes conversion system	230000		113975	128811	13086	-25872
AT VLBI Upgrade						
12mm receiver for VLBI	200000		35272	6531	0	158197
Other VLBI improvements	336000	4257	16150	166447	0	149146
Strategic Research						
Array technology	150000		9269	36046	0	104685
Interference Excision	50000			8249	0	41751
Project Management						
Infrastructure	300000	35148	44169	103702	667	116314
Test Equipment	400000		73880	307029	0	19091
Manpower	1250000	151267	186495	189106	0	723132
Payments to University of Tasmania	1504000		414000	500000	0	590000
International Collaboration	1260000	0	247696	348021	0	664283
TOTAL	**$11000000**	**$190672**	**$1186744**	**$2293858**	**$491326**	**6837400**

(all amounts in Australian dollars)

Table 7-2 MNRF International Collaboration Projects - Summary as at 30 June 1998

Proposer	Proposal	Requested	Committed	Reserved	Comments	Payment Details
R Morganti(ATNF) E Sadler (U Syd)	A Joint ESO/Australia Workshop "Looking Deep in the Southern Sky"	$20K	$15K		Held Dec. '97 - 100% travel support for invited workshop speakers.	$15,000 Pd 3/7/96
B MacA Thomas (ATNF)	The One Kilometre Square Telescope (1kT)	$191.8K	$87K	$45K	2-yr post-doc position; possible extension to 3 yrs; salary overheads from MNRF Strategic Research project.	$11,024 Pd 30/6/98
R Clay (U Adel)	Studies of the Highest Energy Particles in Nature	$198K	$6K	$24K	Travel support grant.	$6000 Pd 30/4/97
L Allen/ J Storey (UNSW) M Dopita/J Mould (MSSSO)	SPIRIT 'The South Pole Infrared Imaging Telescope' - NOAO/CARA collaboration	$255K	$225K		Progress payments to UNSW.	$225,000 Pd 26/6/97 & 6/5/98
J Patterson (U Adel)	γ-ray Observatory - Cangaroo Project	$90.5K	$30K		Seed money for Japanese collaboration.	
J Whiteoak (ATNF)	Phase 2 Activities of European Large Southern Array (LSA) Project	$100K		$100K	On hold awaiting further developments.	$782 Pd 22/12/97
K Taylor (AAO)/M Colless (MSSSO)	Australis Phase A Study	$400K	$320K			$205,000 Pd 29/9/97
K Nugent/R Webster (U.Melb)	LOBSTER X-Ray Satellite Project	$141K	$58K		Salary Research Fellow + travel.	$58,000 Pd 26/6/97
M Bessell (MSSSO)	Australia-Japan Collaborative Workshops	$115K	$20K		Seed money for Japanese collaboration.	$20,000 Pd 16/7/97
D Jaucey (ATNF)	VLBI Exploration of Radio Astrometry (VERA)	$255K			Information requested was received after Feb. '97 mtg. No decision.	
M Brennan (ARC)	Gemini partnership	$200K	$200K		Awaiting instructions to transfer funds.	
J Davis (U Syd)	Collaboration with ESO on instrumentationfor the VLTI	$67K	$60K		Research Fellow salary for 2 years	
	Travel related to international collaboration; misc. establishment costs		$70K		Direct reimbursements from ATNF to 30/6/98 *	$54,910
	TOTALS	**$2033.3K**	**$1091K**	**$169K**		**$595,716**

Total Commitment { $1091K
Reserved { $169K
Total Budget $1260K

* Includes unpaid claims - refer Table 7-3

Table 7-3 International Collaboration Funding - Overseas Travel Summary For Financial Year 1997/98

Name	Institution	Travel Dates	Destination	Purpose	Travel funding Committed	Date Paid
Dr K Taylor	Anglo-Australian Observatory	27/4/97 - 14/5/97	Amsterdam & Munich	Gemini Instrumentation Forum; meetings on SUBARU project	$5961.65	15/12/97
Dr G Da Costa	MSSSO, Australian National University	3/9/97 - 9/9/97	Tucson, Arizona	Gemini Instrumentation Forum	$2426.25	21/10/97
Dr G Da Costa	MSSSO, Australian National University	17/2/98 - 23/2/98	Gainesville, Florida	Gemini Science Retreat	$3445.39	21/4/98
Dr G Da Costa	MSSSO, Australian National University	16/3/98 - 19/3/98	Kona, Hawaii	Gemini Instrumentation Forum	$3016.27	13/5/98
Dr K Taylor	Anglo-Australian Observatory	18/3/98 - 21/3/98	Kona, Hawaii	Gemini Instrumentation Forum	$3016.27	Unpaid
Dr K Taylor	Anglo-Australian Observatory	15/4/98 - 18/4/98	Porto Alegre, Brazil	Gemini GCS meeting	$3700.00	Unpaid
Dr D Jauncey Dr E Sadler Mrs B Siegman	ATNF U Sydney ATNF	12/7/98 - 25/7/98 12/7//98-25/7/98 3/5/98-11/5/98	ISAS, Tokyo	VSOP Science Review Committee Mtg; training of ISAS staff in telescope time assignment processes	$5000.00	Part paid
Dr A Hopkins	U Sydney, ATNF	19/7/98 - 9/8/98	Calgary, Canada	1kT Science Workshop	$2560.00	4/6/98
Dr M Bailes	Swinburne University of Technology	20/7/98 - 22/7/98	Calgary, Canada	1kT Science Workshop	$2759.00	Unpaid

Appendix 1 - ATNF Steering Committee Membership, 1998

CHAIRMAN
***Dr R Webster**, University of Melbourne

Deputy Chair
Prof D B Melrose, Director, Research Centre for Theoretical Astrophysics, University of Sydney

MEMBERS
Ex-officio
Prof R D Ekers, Director, CSIRO Australia Telescope National Facility
Dr B Boyle, Director, Anglo-Australian Observatory
Dr D N Cooper, Chief, CSIRO Telecommunications & Industrial Physics
Dr R H Frater, Deputy CEO, CSIRO
Prof P M McCulloch, Director, University of Tasmania Radio Astronomy Observatories

Astronomers
Dr R M Price, Officer-in-Charge, Parkes Observatory, CSIRO ATNF
***Prof J R Mould**, Director, Mt Stromlo and Siding Spring Observatories
***Prof J W V Storey**, University of New South Wales

International Advisors
Dr J Bergeron, European Southern Observatory, Munich, Germany
Prof J Welch, Director, Hat Creek Observatory, University of California, USA (until December, 1997)
Dr P Goldsmith, National Astronomy and Ionosphere Center, Cornell University, USA (appointed January, 1998)
Prof H Hirabayashi, Professor of Deep Space Communication & Research, Institute of Space and Astronautical Science, Japan

Industry
***Dr P Scaife,** Chief Environmental Scientist, BHP
Dr J O'Sullivan, Director of Technology, News Limited

* Denotes membership of the sub-committee responsible for MNRF Program annual reports.

Appendix 2 - Senior MNRF Program Personnel

Facilities Upgrade Program Committee

Prof R D Ekers, ATNF Director
Mr J W Brooks, ATNF Program Manager
Prof P M McCulloch, Director, Univ. of Tasmania Radio Astronomy Observatories
Dr R P Norris, Program Scientist
Mr P J Howson, ATNF Divisional Secretary and Finance Manager

International Research Facilities Collaboration Committee

Prof R D Ekers, ATNF Director
Mr P J Howson, ATNF Divisional Secretary
Prof J Mould, Chairman, National Committee for Astronomy
Dr E Sadler, Astronomy Community Representative (NCA appointee)

Table A2-1 MNRF Program (Executive)

Executive Position	Officer
Program Director	Prof R D Ekers (Director, ATNF)
Program Manager	Mr J W Brooks (Assistant Director and Engineering Manager, ATNF)
Program Scientist	Dr R P Norris (ATNF Group Leader, Astrophysics and Computing)
System Co-ordinator	Dr P J Hall (ATNF Principal Research Scientist)
Program Finance Manager	Mr P J Howson (ATNF Divisional Secretary)

Table A2-2 ATNF Projects (Senior Personnel)

Project	Project Leader	Project Scientist(s)
12/3.5 mm ATCA Receivers	Mr M Sinclair	Dr R Manchester (12 mm) Dr B Koribalski [1] (3.5 mm)
ATCA Antenna Surface Extension	Dr M Kesteven	Dr B Thomas
Atmospheric Phase Correction	Dr P Hall	Dr R Sault Dr M Wieringa Mr G Carrad [2]
ATCA Local Oscillator Distribution Upgrade	Dr W Wilson	Dr J Higdon
ATCA Extra Stations	Mr J Brooks	Dr J Caswell
AT Observation Management System	Mr D Loone	Dr W Brouw
Parkes Conversion System	Mr G Moorey	Dr J Caswell
VLBI 12 mm Receiver	Mr M Sinclair	Dr D Jauncey
VLBI, Other Projects	Dr W Wilson	Dr J Reynolds

Table A2-2 Notes

1. The 3.5 mm Receiver project has special status and has a science team consisting of Drs T Bourke, M Burton (UNSW), P Hall, B Koribalski (chair), R Norris, and J Whiteoak.
2. Mr G Carrad is the Project Engineer.

University of Tasmania Projects (Senior Personnel)

The management of all University of Tasmania projects is undertaken by Prof P M McCulloch, Director, University of Tasmania Radio Astronomy Observatories.

Appendix 3 - Publications and Related Material

The following publications and communications have been produced by ATNF staff and associates since the beginning of the MNRF upgrade program.

Web Site

The ATNF has established a World Wide Web site describing the MNRF Program and its progress. The site URL is <http://www.atnf.csiro.au/mnrf/mnrf.html>.

Publications in Refereed Journals or Conference Proceedings

1. Abbott, D. A. and Hall, P. J., A Stable Millimetre-Wave Water Vapour Radiometer, submitted to JEEEA.
2. Hall, P. J. and Brooks, J. W., The Australia Telescope Millimetre-Wave Upgrade, in “Millimeter and Submillimeter Astronomy at 10 Milli-Arcseconds Resolution”, Proc. Japan - US joint workshop (Tokyo), NRO Report No. 430, 1997.
3. Hall, P. J., Brooks, J. W., Sinclair, M. W., Wilson, W. E. and Kesteven, M. J., The Australia Telescope Millimetre-Wave Upgrade, Proc. Workshop on Applications of Radio Science (Aust.), Barossa Valley, pp. 65 - 70, 1997.
4. Hopkins, A., Summary of the Sub-MicroJansky Radio Sky Workshop, submitted to Proc. Astron. Soc. Aust.
5. Norris, R. P., The MNRF Upgrade to the Australia Telescope, accepted Proc. ESO Workshop “Looking Deep in the Southern Sky”, Sydney, Dec. 1997.
6. Thomas, B. M., Hall, P. J. and Brooks, J. W., The Australia Telescope Large-Array Research Project, Proc. Workshop on Applications of Radio Science (Aust.), Barossa Valley, pp. 136 - 138, 1997.

Presentations

1. Ekers, R. D., The ATNF Upgrade, Joint Discussion 9, International Astronomical Union General Assembly, Kyoto, Japan, August 22, 1997.
2. Ekers, R. D., Director’s Presentation to CSIRO Board, April 28, 1998.
3. Hall, P. J., The ATNF MNRF Upgrade - A Progress Report, Anglo-Australian Telescope and ATNF Joint Symposium, Canberra, March 19,1998.
4. Koribalski, B., The Millimetre-Wave Upgrade of the Australia Telescope Compact Array, Workshop on Applications of Radio Science (Aust.), Barossa Valley, September 21 - 23, 1997.
5. Norris, R. P., The MNRF Upgrade to the Australia Telescope, Astronomical Society of Aust., July 7, 1997.
6. Norris, R. P., Radio Astronomy into the Next Millenium, Conference “Astronomy and Space Science”, Mafraq, Jordan, May 5, 1998.

7. Thomas, B. MacA., Possible Siting of the 1 kT in Australia, Western Australian Department of Commerce and Trade; Department of Conservation and Land Management; and Gascoyne and Mid-West Development Commissions, May 12 - 15, 1998.
8. Thomas, B. MacA. and Ekers, R. D., The 1 kT Project, Department of Industry Science and Tourism, May 26, 1998.

Internal Reports or Un-refereed Conference Papers

1. Ekers, R. D., Interference Excision in Radio Astronomy Measurements, Proc. 1 kT International Technical Workshop, Sydney, Dec. 15 - 18, 1997.
2. Ghorbani, K. and Waterhouse, R., Investigation of RF Phase Shifting Using Optical Technology and Broadband Printed Antennas for the 1 kT Project, RMIT Department of Communications and Electronics Engineering, Internal Report, March 1998.
3. Hall, P.J., Mohan, A.S. and Soretz, R. S., Interference Characteristics of Australian Astronomy Sites, Proc. 1 kT International Technical Workshop, Sydney, Dec. 15 - 18, 1997.
4. Kesteven, M. J., ATCA Upgrade - Pointing Considerations, AT/39.3/081.
5. Kesteven, M. J. and Parsons, B. F., Mechanical Stability of the AT Subreflectors, AT/39.3/070.
6. Kesteven, M. J. and Parsons, B. F., Antenna on the Rail Observations, AT/39.3/072.
7. Kewley, L., Interference Excision Using the Parkes Multibeam Receiver, Proc. 1 kT International Technical Workshop, Sydney, Dec. 15 - 18, 1997.
8. Norris, R. P., Scheduling the ATCA at Millimetre Wavelengths, ATNF Report. Sept. 1997.
9. Norris, R. P., Notes from ATCA Calibration Meeting, ATNF Report, Oct. 1997.
10. Sault, R., Cross-Correlation Approaches to Interference Elimination, Proc. 1 kT International Technical Workshop, Sydney, Dec. 15 - 18, 1997.
11. Thomas, B. MacA., The 1 kT - Application of Phased Array Technology, AT/39.3/064.
12. Thomas, B. MacA., The 1 kT Project: Optimum Phased-Array Element Configuration for Forming a Large Co-sited Collecting Area (Station), AT/39.3/078.
13. Thomas, B. MacA., Interference Mitigation - An R & D Strategy for the 1 kT Array, ATNF Workshop on Electromagnetic Compatibility, Sydney, April 27, 1998.

Workshops and Symposia

1. “Looking Deep In the Southern Sky”, Joint ESO-Australia Workshop, Sydney, Dec. 10 - 12, 1997.
2. “The URSI Large Telescope Working Group Meeting and the 1 kT International Technical Workshop”, Sydney, Dec. 15 - 18, 1997.
3. “The Sub-MicroJansky Radio Sky”, Sydney, June 17, 1998.

Appendix 4 - MNRF Advisory Committee

To ensure that the ATCA millimetre-wave upgrade proceeds according to best international science and engineering practice, the ATNF has established an Advisory Committee comprising four radio scientists and astronomers recognized internationally for their expertise in the field of millimetre-wave astronomy. It is expected that, following its first meeting in September 1997, the Committee will meet at about 18-month intervals. The Committee members are:

Dr Stephane Guilloteau, Deputy Director, Institut de Radioastronomie Millimetrique (France), an expert in millimetre-wave aperture synthesis, system and software design, array operations, and astronomy.

Dr Peter Napier, National Radio Astronomy Observatory (USA), Project Manager for the US Millimeter Array, expert in antenna engineering and optics;

Dr Rachel Padman, Assistant Director of Research, Department of Physics, University of Cambridge, expert in millimetre-wave receiver design, observing techniques and astronomy;

Dr Alan Young, Portfolio Manager, Mobile Systems and Networks, CSIRO Telecommunications and Industrial Physics, expert in electronics and signal distribution;

Dr Nick Whyborn, Space Research Office of The Netherlands, expert in millimetre-wave receiver design and antenna optics.

Dr Whyborn was unavailable for the first meeting, being replaced by Dr Guilloteau. Dr Guilloteau has now agreed to contribute indefinitely. It is likely that the Committee will meet again in late 1999.

Appendix 5 - Report No. 1 of the External Advisory Committee for the Australia Telescope MNRF Upgrade Project

S. Guilloteau, IRAM, France.
P. Napier, NRAO, USA.
R. Padman, Cambridge University, UK.
A. Young, CSIRO TIP, Australia.

8 October, 1997

1. Introduction

The committee met during the period 1-5 September, 1997. During a visit to the Paul Wild Observatory we inspected the Australia Telescope Compact Array. Included in the tour were the areas of the railway track where the new pads and N-S spur will be added, the transporter section of the antenna which will be modified to allow transition to the N-S spur and the antenna receiver turret where the new high frequency receiver will be located. Oral presentations were given by AT staff on all aspects of the Upgrade Project and detailed discussions were held on a number of key technical topics including feed array technology, interference excision, radiometric phase calibration and receivers.

We wish to congratulate the ATNF on successfully proposing and receiving funding for the Upgrade Project. The project represents a wise investment to increase the scientific return from a major national instrument. The Australia Telescope is already very productive, and the upgrade will greatly extend the range of scientific problems that can be addressed with this instrument from its valuable southern hemisphere location.
Much preparatory work has already been done, and on the basis of what we were shown we believe that the project is very well-founded and has every chance of achieving its technical and scientific goals. While we have noted some minor reservations and queries in the remainder of this report, we stress that for the most part these have been drawn to our attention by the project members themselves. None of them appear to be "show-stoppers", and we are certain that the relevant expertise is available to the project to overcome any problems.

2. Management

The project has a good management plan with clear statements defining the scope of the project and the responsibilities of key personnel. The only concerns that we have are to do with the amount of manpower available to accomplish the project. It is particularly unfortunate that the beginning of the project coincided with the need for a reduction-in-force for the

ATNF as a whole. This means that the ATNF will have to carry out the upgrade project and continue its normal operations and maintenance functions with little increase in total observatory manpower. We think that it would be wise to try to identify areas where operations or maintenance support could be temporarily reduced during the year or two of peak upgrade activity. One example of such an area could be, for example, the frequency with which the compact array configuration is changed. An area where we are particularly concerned about having key people available to concentrate on the upgrade is the effort to resurface and thoroughly test the Mopra antenna. This activity is particularly important to the upgrade project because it must be finished before it is known with complete certainty that the solid surface will be installed on all antennas.

3. Budget

The project has a clearly defined budget but we did not discuss it in enough detail to be able to comment on the adequacy of the funds allocated for the various parts of the project. We are concerned that there is no specific allocation for contingency in the budget. At this early stage in the project it would be wise to have some contingency funds and urge that the various parts of the project be prioritized so that some parts with lower priority can be left to later in the project. In this way, if more funds for high priority items are needed, they can be found with the minimal possible impact on science capabilities. For example, something that would have minimal impact on science capabilities would be the outfitting of only two, rather than all five, antennas in the compact array with the transporter modifications needed for operation on the N-S spur.

4. Extra Stations and the North - South Spur

Improving the UV coverage is essential for high frequency observations, but also for wide field imaging at lower frequencies. The N-S spur is mandatory to provide good UV coverage at high frequency where observations at low elevations are not possible. However, it is also justified by projects requiring very compact configurations, such as studies of the Sunyaev-Zeldovich effect at 22 or 43 GHz. The location chosen for the N-S spur appears suitable and has the advantage that space exists for a longer spur in the future.

We consider that observations with the antenna on the rails rather than on station pads would be problematic in terms of pointing and baseline length stability, and may also cause serious safety issues. Accordingly, we recommend instead the addition of 4 stations on the E-W track, and to proceed with the construction of the N-S spur as civil work scheduling allows.

5. Solid Surface Upgrade

Whilst we do not think it very likely that the replacement of the perforated panels with solid panels will cause undesirable wind performance degradation in the antennas, the absence of any careful aerodynamic, structural or servosystem analysis of the change is a concern. Apparently the perforated panels were thought to be necessary when the antennas were originally designed and it was not made clear to us why this has changed. Of concern would be the survival wind performance and the antenna pointing and phase stability performance in moderate winds. Note that if there is any significant increase in wind loading as a result of removing the perforations, it is at the edge of the dish where the area and resulting increase in turning moment is largest. Of most concern is probably the pointing performance of the antenna in moderate winds. Although 3 mm observations will only be made in calm conditions, good pointing is also essential for 21 cm mosaic observations which are often done in windier conditions. We recommend that, as soon as possible, an effort be made to do the necessary calculations to give high confidence that there will be no wind performance problems. An additional need for the calculations is to confirm that it is valid to test the modification on the Mopra antenna, which has a different design to the compact array antennas. The modifications at Mopra should be made as soon as possible and should be accompanied by careful before-and-after tests. Additionally, although some measurements have already been made to confirm that gravitationally driven changes in subreflector position and surface shape are acceptable, these measurements should be repeated at 3 mm wavelength with the solid surface in place.

6. Local Oscillator and Backend Upgrade

The only aspect of this area where we have any reservations is the conversion of the LO reference distribution system to work over optical fibre. This is the first application of fibres for reference distribution in a mm radio telescope where there is the need to disconnect frequently. Whilst we support this work, we wish to advise against underestimating the effort in proving such a system. We suggest that the ATNF try to benefit as far as possible from the experience already gained by JPL, BIMA, OVRO and SMA. The upcoming URSI meeting in the US could also be quite useful.

7. Receiver Systems

The MMIC approach to the construction of the 3 mm frontend seemed reasonable to us, and potentially very exciting - if successful the technology would be of value to the entire radio astronomy community, with major implications for the next generation millimetre-wave arrays for example. This may warrant greater investment than is available just through the Upgrade Project, perhaps in collaboration with CTIP. There is an obvious risk of high costs with this approach but in the event that MMICs are not available on the required timescale it is likely that a backup plan would exist in the form of discrete InP HEMT amplifier designs developed at other observatories.

The design of the receiver should NOT be compromised to provide coverage of the upper end of the 3 mm band (100 - 115 GHz). In particular we do not feel it is worthwhile to provide a second (high frequency) channel for this band. This will provide considerable simplifications and cost savings over the initial design discussed during our meeting. It is reasonable to expect that usable performance in the 100 - 115 GHz band will be obtainable in the future by broadbanding the 85 - 100 GHz band.

The outline optical design for the high-frequency receiver package appeared to show possible blockage of one or more feeds, and we would encourage the receiver group to check the blockage with a gaussian-optics calculation before proceeding much further.

It is currently proposed to implement rapid frequency changes (between the 12 mm water radiometer channel and the 3 mm/7 mm channel) by translating the entire feed package. We were somewhat nervous about this, and ask the receiver group to look again at whether this switching can be achieved in the receiver fore-optics or by rotating the receiver package (or by any other means). Again, this problem will be simplified by abandoning the second 3 mm receiver.

Finally, we note that use of the 12 mm receiver for continuous water-vapour monitoring implies that the sounding beam will be off-axis from the observing beam. We endorse the ATNF's plan for a near-field analysis of this off-axis beam to confirm that it will be useful for water-vapour monitoring.

8. Atmospheric Phase Correction

On-going experience with other mm arrays has shown the value of atmospheric phase correction systems. Given the low altitude site and the expected water vapor content, we recommend that the AT concentrate on the development of a 22 GHz water line monitoring system. The cooled astronomy receiver should be used for this purpose if possible, which implies good stability and more detailed investigations of the spillover properties, but also offers the possibility of using narrower filters.

Similar systems would be valuable for VLBI experiments, although these have not been costed in the current development plans.

The atmospheric correction will require dedicated software to be used in real time, either in the correlator or LO system. The ATNF should also explore the possibility of using the IRAM scheme, in which corrected and uncorrected data are both produced and saved for off-line processing.

9. VLBI Upgrade

The committee is happy with all aspects of the VLBI upgrade at this time. We do however wish to commend the ATNF for two very important decisions. The ATNF appears to have made a good choice for the purchase of very cost effective hydrogen maser clocks and it is pleasing to finally see an observatory implement digital filtering technology. As an additional comment we believe that it would be desirable to look for ways that may allow 22 GHz atmospheric phase correction to be implemented at all VLBI antennas.

10. Software/ACC

We were concerned by the parlous state of spares for the current Antenna Control Computers (ACC). Replacement of this system with modern maintainable hardware and software must have very high priority. We emphasize the importance of using standard hardware and programming languages (as far as possible) to minimize the effort required when this next generation system needs replacing in its turn. We note that a project group of 2-3 people has been formed with the defined goal of producing replacement ACCs by late 1998. We stress the importance of this project and recommend that the ACC aspect of the project be, in general, given priority over other developments and operational responsibilities with which the group is charged

In general the plans for software upgrades seem to be reasonable, although we were left with the feeling that there was rather little manpower available for the work that needs doing (and to some extent that manpower is already committed to other aspects of the upgrades project, or to day-to-day operations and maintenance). It is important to prioritize the various projects to cover the possibility that not all of them can be carried out.

11. Array Technology

Although it is clearly too early to apply any of the new ideas in array technology to the MNRF upgrade at this time, we encourage continued research within the ATNF. Both focal plane and aperture plane technologies are likely to be very important for the future and the ATNF is well placed to work in these areas, especially if it could benefit from the connection to CTIP.

12. Interference Excision

Interference excision is likely to be very important for the future of radio astronomy as the number of LEO satellites increase. The Parkes multibeam system provides the ATNF with a unique capability to develop this new technology and we recommend that research be continued in this area. We also encourage continuing involvement in frequency management issues and a greater AT involvement in the IRIDIUM interference tests.

13. 43 GHz Receiver

The 43 GHz receiver is being designed into the new short-wavelength dewar, but there are not adequate funds to include its implementation in the upgrade project. There is a lot of excellent science to be done in this band and we encourage the ATNF to vigorously seek funding for this additional enhancement. This would be an excellent project for funding by a potential foreign partner.

14. Observing and Scheduling

Flexible (dynamic) scheduling will be necessary for high-frequency observations, and should be implemented with the array upgrade. This is an important issue, which represents a significant change from current practice. We recommend the study of the possible operating modes with the ATNF Users committee.

The upgrade itself will have impact on observations, during the civil work for the additional stations and N-S spur, during the antenna resurfacing, and during the local oscillator system modifications. The influence of these items on the observing schedule should be investigated.

15. Science Strategy

Several aspects of the upgrade seem to be predicated on successfully resurfacing the full 22 m apertures of the ATCA elements for operation at 3 mm. At this point it is not absolutely obvious to us that the resurfacing will achieve high enough surface accuracy and/or pointing performance for the telescope to be viable at the highest frequencies. The proof of this capability must await the resurfacing and testing of the Mopra Antenna. If only the present solid surface (15 m diameter) of each dish can be made to operate at 3 mm the range of science that can be done will be somewhat restricted. It is not clear to us at this point whether the science that can be done with an array of 15 m dishes with a minimum 30 m baseline is sufficient to warrant the effort of equipping the telescope with 3 mm receivers.

In the event of NOT being able to utilize the full dish diameter at 3 mm, it may well be better to concentrate on the 7 mm system, where there would still be 5 (or even 6) dishes operating at the full aperture and sensitivity (and a good deal of very useful science to be done). There are thus two possibilities: if there is sufficient 3 mm science to warrant operation with the 15 m useable apertures, then the project can proceed as currently planned; if there is NOT sufficient science, then construction of the 3 mm receivers should wait until the full dish performance at 3 mm can be verified. At present there are different opinions within the ATNF staff and the ATNF user community with respect to the value of this "reduced" 3 mm science: further consideration is clearly required. Clearly, the upgrading and testing of the Mopra antenna should be brought forward as much as is practical since so much of the further work depends on the results of these tests.