NATIONAL RESEARCH FOUNDATION

Review of the South African Astro-geosciences Facilities

REPORT

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Review of the South African Astro-geosciences Facilities

25 November to 3 December 2004

REPORT

Review panel

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Executive Summary

The purpose of the review was to provide an assessment of the performance of the NRF Astro-Geosciences National Facilities over the previous five years and an assessment of means to stimulate their optimal use in the next five-year period, in particular in respect of the coming on stream of the Southern African Large Telescope (SALT), the national bid to host the Square Kilometre Array (SKA), the extent to which HMO has positioned itself as a national research facility and the possible rationalisation and consolidation of existing and new initiatives in geosciences within HartRAO and HMO.

The panel reviewed the National Facilities in relation to the core missions of the NRF and found that each was performing satisfactorily and attaining, in varying degrees, the goals set in respect of human resource development, generation of high-quality knowledge, the utilisation of such knowledge and the provision of a research infrastructure essential to the development of human resources and knowledge. We believe that the National Facilities are contributing significantly to the National System of Innovation, actively addressing transformation and attempting to redress past employment inequities, adhering to quality, internationalising research, focussing on Africa where possible and generally assisting in the transformation of the NRF organisationally.

Strong National Facilities require that to further research at national and international level they demonstrate at all times an ongoing commitment to the undertaking and publication of top-quality science, both on the part of individuals in the Facilities and with national and international collaborators. In this respect SAAO has performed outstandingly (3 ISI publications per staff in 2003-4) given their considerable ongoing involvement in the planning and commissioning of SALT before and during the period of review. HMO has performed very well (2 ISI papers per person) as they have transformed from a revenue-earning CSIR operation to a National Facility. The more recent productivity at HartRAO (0.75 ISI papers per person) is more problematic. NRF should insist on a better performance in future.

In respect of the future, comments are made below by National Facility.

SAAO

SAAO has performed extraordinarily well in all respects in commissioning SALT and in planning for the transition to the SALT era. That SALT is going to be a telescope so much better than the HET on which it was based is testimony in large part to the design and engineering skills of the South Africans involved. Technologically South Africa has benefited much from SALT and should continue to do so in the future. All those involved in the SALT endeavour deserve the highest praise.

In order to capitalise on the achievements to date of SAAO and SALT a number of recommendations are made:

RECOMMENDATIONS:

1. That further investment in people to match the investment in facilities is required. In particular it will be necessary to:

    a. enhance software support in the SALT era, including that involved with the data reduction software process (pipeline reduction), innovation and general observatory support,

    b. re-examine the operations budget with a view to increased staffing to continue the innovation of the past into the future when, justifiably, international and local user expectations will be high,

c. consider ways to begin thinking immediately about second-generation instrumentation for SALT, and

d. increase support for and expand the successful Collateral Benefits Programme, but not at the expense of research support (outreach may require partnering with other governmental entities).

2. That increased and continuing support for the over-subscribed NASSP (in which there are more students wanting admission than places available) be sought as soon as possible.

3. That every effort be made by government, funders and users to build upon the scientific advantages that SAAO has worked so hard to create for South Africa with the building of SALT and to recognise and meet the challenges presented by increased levels of competition at the cutting edge of international science.

4. That the 1.9m and 1m SAAO research telescopes continue to be used and be integrated into the SALT programme to provide a competitive edge for Southern African astronomers.

5. That consideration be given to enhancing South African theoretical astronomical programmes to fully exploit the SALT observational programmes in order to maximise scientific intellectual property within the country.

6. That the looming tensions between the town of Sutherland and SAAO/SALT over night-time tourist use of telescopes and light pollution need to be resolved soon, and certainly before the SALT opening, in order to defuse later problems of unrealistically high expectations regarding the benefit of SALT to the town of Sutherland. In so doing the present excellent community-SAAO relationship should be preserved as far as possible.

HartRAO

In all respects except publication of research, HartRao has performed well over the period of review and is in a position to be a major player in the South African bid to host the SKA. The success of SALT shows that South African skills are commensurate with the challenges of SKA and its pathfinder. Care must be exercised not to lose these skills as SALT development winds down. HartRAO must play a central role in SKA. To this end a number of recommendations are made about HartRAO and its involvement in SKA.

These are:

1. That involvement in SKA activities be continued and strengthened.
2. Additional funding for research, including additional scientific staff, earmarked bursaries and funds for local and international visiting scientists, is needed to add capacity in South African radio astronomy.
3. That in order to ensure a strong research underpinning and scientific leadership of HartRAO, every effort must be made to increase scientific output as a matter of urgency. The target of 2 publications per year per researcher (including collaborative papers) must be re-established and adhered to.
4. That consideration be given by DST, NRF and HartRAO to a central location of a SKA/HartRAO office.
5. A means needs to be found to relieve current acute time pressures on the Director of HartRAO.
6. Pulsar work must be rejuvenated and ways to bring in staff, possibly on secondment to HartRAO should be investigated as a matter of urgency, including appropriate ways to fund this.
7. The question of possible ways to separate space geodesy and radio astronomy at HartRAO needs to be given consideration.

HMO

The transition from the CSIR to a NRF National Facility has been managed well by the HMO and the Facility is now operating most satisfactorily as such. Recommendations to further improve this functioning are given below.

1. That thought be given to a change in name for the institution that will be more in keeping with its broader modern function.
2. That consideration be given to developing a flagship project that will give the Facility a clear international identity and possible funding advantages.
3. That current and appropriate future contract work be continued.
4. That HMO should seek opportunities to become more involved in SKA planning.
5. That additional funding be granted to enable an expansion of HMO activities in NASSP.

Cross-cutting issues

Three major cross-cutting issues have emerged from the review. All concern funding issues common to all three facilities. Creating science awareness is proceeding well and raising a good deal of interest. Outreach into schools is likewise proving most valuable. Visitor centres need expanding or creation afresh. The Facilities simply do not have the funds to expand these programmes without imperilling their generally small science budgets. Capacity building in higher-education institutions to produce the high-level scientific personnel that will be required to complete the transformation process and redress of equity needed at higher professional levels is urgently needed and far beyond the budgets of National Facilities and University departments. New money is going to be needed for this development.

Finally, the provision of data and access to federated data bases will open the way for many more to perform research in the astro-geosciences via the web. This in turn will open up opportunities far beyond the privileged few who will be successful in their bids to use SALT and the SKA pathfinder. For this purpose the creation of virtual observatories offers exciting possibilities. Again funds will have to be found for this in ways that will protect existing budgets.

Recommendations to give effect to these ideas are:

1. That the NRF is urged to co-ordinate an approach to various government departments (DST, Education, Local Government, etc) to raise funds for outreach for all the National Facilities as additional funds to be used in a separate and protected component of their budget.

2. That the NRF find ways of enhancing capacity-building in the higher-education institutions of South Africa to take full advantage of SALT and the SKA pathfinder, without this resulting in a diminution of funding to research generally in the country.

3. That the NRF find ways of stimulating and funding developments in virtual observatories in South Africa.

The three Astro-Geosciences National Facilities are national assets. Nurturing them will bring great gains not only to the university and research communities of South Africa, but also to the country as a whole.

The Report

Introduction

The South African astro-geosciences National Facilities comprise the South African Astronomical Observatory (SAAO), Hartebeesthoek Radio Astronomy Observatory (HartRAO) and the Hermanus Magnetic Observatory (HMO). Further acronyms are defined in Appendix 1. The review addresses, first, a retrospective assessment of the period 1999 to 2004 against the objectives stated in the Facilities' strategic and business plans and using the performance indicators used by the NRF. Secondly, and most importantly, the review considers a prospective assessment covering the next five years.

In the case of SAAO, how the Facility had positioned itself in view of SALT coming on stream was a prime objective. In the case of HartRAO, an important priority was to consider the functioning of the Facility in relation to the preparatory work for the South African bid to host the SKA and the pathfinder development. In the case of HMO, the review focused on the transformation and the repositioning of HMO from being a commercially driven service provider to a National Facility.

The review was conducted from 25 November to 3 December 2004 and was based on extensive documentation, interviews with staff of the facilities, written reports from users and stakeholders and interviews with substantial numbers of stakeholders representing the research community, resource management, representatives of private industry and government, and public outreach sectors and local communities. A comprehensive spectrum of opinions regarding the standing and performance of the facilities was sought and obtained.

The Review Panel

Professor P D Tyson, University of the Witwatersrand (Convenor), Professor G Basri, University of California, Dr A J Kemball, University of Illinois, Dr D J Kerridge, British Geological Survey, Dr V Munsami, Department of Trade and Industry, South Africa and Professor P D Sackett, Australian National University.

Terms of reference

The purpose of the review was to provide an assessment of the performance of the National Facilities under review over the previous five years and an assessment of means to stimulate their optimal use in the next five-year period, in particular in respect of the coming on stream of the Southern African Large Telescope (SALT), the national bid for the Square Kilometre Array (SKA), the extent to which HMO has positioned itself as a national research facility and the possible rationalisation and consolidation of existing and new initiatives in geosciences within HartRAO and HMO.

The review was to cover:

- strategic directions of the facilities,
- performance,
- utilisation by external users,
- management,
- transformation, and
- impact and stakeholder satisfaction.

In so doing, adhering to quality, internationalising research and focussing on Africa were to be considered carefully.

An overriding priority

In undertaking the review, no attempt has been made to place the terms of reference in any order of priority, except that it was recognised that to further research at national and international level at the three National Facilities requires an ongoing commitment to the undertaking and publication of top-quality science, both on the part of individuals in the facilities and with national and international collaborators.

Documentation before the panel and consultations

Extensive documentation was before the Panel and a large number of consultations with staff of the facilities, users and stakeholders were held (see Appendices).

THE RETROSPECTIVE ASSESSMENT

The panel reviewed the cluster of NRF Astro-Geoscience National Facilities in relation to the core missions of the NRF and found that each was performing satisfactorily and attaining, in varying degrees, the goals set in respect of human resource development, generation of high-quality knowledge, the utilisation of such knowledge and the provision of a research infrastructure essential to the development of human resources and knowledge. We believe that the National Facilities are contributing significantly to the National System of Innovation, are actively attempting to redress past employment inequities, are adhering to quality, internationalising research, focussing on Africa where possible and assisting in the transformation of the NRF organisationally. In respect of each of the National Facilities under review individual assessments follow.

The South African Astronomical Observatory

Historical background

SAAO's history begins with the founding of the Royal Observatory at the Cape of Good Hope in 1820. This was the first scientific institute in sub-Saharan Africa. In 1972 the much younger Republic Observatory in Johannesburg and the Radcliffe Observatory in Pretoria were merged with the Royal Observatory to form the South African Astronomical Observatory as it is today. This was administered jointly by the CSIR in South Africa and the Science Research Council/Science and Engineering Research Council in the UK up to 1985 when the UK suspended the agreement and the CSIR took over as sole administrator. In 1991 SAAO became part of the former Foundation for Research Development and since 1999 it has been one of the National Facilities of the NRF.

The Headquarters are located in Observatory, Cape Town, on the grounds of the old Royal Observatory and the main building (completed in 1828) houses offices, the national library for astronomy, and computer facilities. Historic telescopes can be found in a number of domes on the grounds, and a small museum displays historic scientific instruments. The major observing facilities, consisting of modern instrumentation and large telescopes, are situated near Sutherland in the Northern Cape.

Between 2000 and 2004, South Africa and its German, Polish, American, New Zealand and UK partners have built the largest single telescope in the southern hemisphere, one having an 11m hexagonal mirror array. The Southern African Large Telescope (SALT) will be able to record images of distant stars, galaxies and quasars a billion times too faint to be seen with the unaided eye.

Strategic directions

SAAO continues to meet the requirement that it have a unique position in production of knowledge in South Africa. The driving strategic decision during the last five-year review period was the audacious move into the different order of magnitude of instrumentation that SALT represents. SAAO correctly perceived that the world

was moving into the era of 8-10m telescopes, and in order to insure that their technologies and research areas continue to meet international standards, SAAO facilities would have to be significantly improved.

Under the leadership of Bob Stobie and with the support of DST and the NRF, SAAO can take credit for having conceived the idea behind the current SALT, and being visionary and confident enough to expand the vision of 1996 (which was for a 4m telescope) into the 10m class. Although cost-effective, SALT required a major increase in funds, and NRF/SAAO agreed to raise a substantial fraction of these from international partners. That it could succeed in this was due to the ongoing history of networking and international collaborations, and the international scientific respect that SAAO personnel had earned. The project got underway, and as described below, appears to be have been remarkably successful to date in meeting deadlines and budgetary goals. Because of the size of the undertaking and qualitative improvement inherent in the project, it of necessity and correctly dominates the strategic direction of SAAO.

Performance and adherence to quality

The performance of SAAO over the review period has been remarkable, not only for its continued excellence in knowledge generation and internationally peer-reviewed publications, but also for the speed, dedication and professionalism with which it has achieved a quantum jump in the quality of its facilities.

SAAO decided to commit their future to a relatively inexpensive class of 10-m telescope (which can accomplish more than half the science of a general purpose telescope of that size at one-tenth the cost). This was in line with the generally excellent past performance of SAAO as a cost-effective research unit. Although SALT intended to take advantage of the technology pioneered by the HET (Hobby-Eberly Telescope) in Texas, the performance of the HET had yet to be demonstrated at the inception of SALT. In fact, the HET did not perform as hoped. Not only did SAAO learn from the mistakes of its predecessor, but created many totally new approaches to HET problems. One example of this is the redesigned spherical aberration corrector (SAC), which tests now show performs at least 15 times better than the HET equivalent. The SAAO-produced tracker unit (with extremely demanding mechanical requirements) is another good example of the manner in which South African technology has improved significantly upon the original HET design.

Along with rigorous management procedures, these improvements have led to what appears at the time of this review to be an amazingly successful execution of a huge, very complicated, high-technology project. The project is on budget and on schedule, and SAAO has demonstrated that it has produced a substantially better telescope than the HET. This was accomplished with a remarkably small number of staff, in a remarkably short time, and with excellent use of national skills whenever possible. As a collateral result, the staff became more technically versatile and competent in many areas. Project management skills were transferred from the SALT construction team to SAAO, new expertise and equipment for precision machining was developed, and skill levels were increased in the areas of optics and detector electronics.

Equally remarkable is that the scientific output of SAAO has been essentially maintained during this time of greatly increased staff duties. An impressive number of papers in top refereed journals have been produced, with a good mix of internal authorship and international collaborative papers. The SAAO performance report indicates 3 scientific ISI-refereed publications per researcher in 2003-4. There are 16 PhD level research scientists at SAAO and another 35 engineers and technologists. The previous review noted that the scientific output is among the most cost-effective in the world; this is even truer today in light of the rapid appearance of a world-class telescope at Sutherland.

Internationalising research

The facility has produced over 331 ISI scientific papers in the review period, of which ~20% are SAAO publications, another ~40% of which have an SAAO author with international collaborators, and ~10% with local

South African collaborators. Furthermore, during the review period, physical facilities owned by international partners, to which South Africans have some access, have appeared on the Sutherland site. In every way internationalising South African astronomical research has been a resounding success.

Focussing on Africa

Successful visits from African users (the potential pool of which is rather small) are reported. SAAO provides the current coordinator of the Working Group on Space Sciences in Africa, which has members from 25 African countries. It is worth noting that SALT is an acronym for *Southern* African Large Telescope, not *South* African Large Telescope, an indication that the facility is seen as regional. SAAO is working on agreements with other African institutions for access to SALT.

The National Astrophysics and Space Science Programme (NASSP), discussed more fully below, accepts students from other African countries, appropriate for a discipline as international as astronomy.

Utilisation by external users

SAAO continues its tradition of offering well-supported facilities to external users, who have unanimously reported, as evidenced by the results of written surveys and interviews, that they are pleased with their scientific access and collaboration at SAAO. Approximately one-third of SAAO telescope time is awarded, on the basis of merit, to overseas users. Visiting researchers alone are responsible for 30% of publications using SAAO facilities, in addition to the publications generated by international facilities on the Sutherland site.

Management

The review panel was struck by the leadership, dedication and fiscal responsibility of the SAAO management at all levels. The transition towards strict system project planning, oversight and reporting appears to have been well managed, even though this necessitated a cultural sea-change for staff in daily work practices. Clear indication of increased levels of multi-skilling, to increase flexibility and opportunities for individual staff members, was also in evidence. At the midpoint of the review period, the death of SAAO Director Bob Stobie left the institution without a formal Director for over two years. Despite this, SAAO continued the unfaltering progress toward SALT without misstep. This is a testament to all concerned and deserves the highest praise.

The Panel considered the plan to maintain the vitality of the scientific staff at SAAO during the coming SALT era. One issue is to bring new scientists of top quality to replace the several retirements that will occur during the next review period. The other issue is to have sufficient expertise and resources to make full use of the substantial amount of 10m-telescope time that the SAAO has earned for itself. The Director indicates that there will be several so-called SALT Astronomer positions opening soon, which will carry Observatory duties but allow for up to 40% research time. This, in tandem with the opportunity to possibly convert to a permanent position down the line, should prove attractive to top young candidates of the desired calibre. There are also Stobie Fellows being trained at partner institutions who should be returning during this period and who may also be excellent candidates. The continued presence of the opportunity to do research on SALT will itself serve as an excellent inducement for retaining good people, subject to the availability of sufficient research grants to allow them to conduct their science.

Transformation

SAAO has made considerable progress in transforming the cross-section of the South African population that it engages at junior levels, and in its technical and administrative staff. For example, in appointments during 2003-04, only 2 of 14 were white males, and all appointments were from South Africa. At senior levels, owing to the

small pool available from which to draw, the solutions have proven more difficult and slower to implement. The appointment of a Collateral Benefits Manager is a significant step.

Scientifically, SAAO is taking the grow-your-own approach by becoming active in the training of young people through several programmes. In this regard, the panel was particularly impressed with the NASSP programme. Since its inception three years ago, the total number of Honours and MSc astronomy students has risen from 1 to 27. Of these 27, seven are black South Africans, and several others are other black Africans and women (the increase in black South Africans in the Honours programme has grown from 0 to 7 over that time). This rapid progress is commendable and vital to the creation of a broad and ethnically varied scientific community for South Africa.

Impact and stakeholder satisfaction

Local government officials at Sutherland reported high satisfaction and gratitude for the level of interaction between the town and SAAO, in particular noting the flow-on benefits in the arenas of education and tourism from the SALT Collateral Benefits Programme. Astronomical researchers throughout the country are looking forward to collaborative access to SALT. University stakeholders interviewed and polled by the panel indicated a high level of satisfaction in their collaborative work with SAAO and their enthusiasm for NASSP, stressing that the programme appeared to be producing high quality students and had resulted in improved University-SAAO relationships.

A potential conflict is threatening to appear between the expectations of the stakeholders in the Sutherland region and SAAO. One aspect of this is the collision between the obvious desirability of night-time observations through a telescope by visitors, and the need to maintain darkness and security for research astronomers and their equipment. Another is the planning for development of a large (and very attractive) visitor centre by the Municipality (with private funding) and the danger of placing this facility either too close or too far away from the Observatory. There is also an issue of timing here: the opening of SALT is only a year away, and will generate a great deal of publicity and visitor demand. The feasibility of getting something really good in place in time is not fully resolved. The possibility of moving one or both of the smallest telescopes off the working plateau to a visitor site should be explored. It would be extremely damaging to the goals of NRF and SAAO if this great opportunity were squandered, or worse, generated negative publicity over unfulfilled expectations. SAAO has done some thinking on this issue, but needs to move rapidly to design and execute a successful plan (with the aid of the NRF).

Outreach and developing scientific awareness

The appointment of a Collateral Benefits Manager has greatly enhanced the overall outreach and community relations between SALT, SAAO, its Sutherland and Cape Town communities, as well as on a national scale. The interim visitor centres at Cape Town and Sutherland received nearly 20,000 visitors during the review period. SAAO was mentioned nearly 1500 times in the media. The institution has begun teacher training and networking programmes, as well as providing a preparatory summer programme for NASSP students. In addition, Technikon students are receiving training at SAAO engineering facilities.

Many other plans are under development, but fiscal and human resources are limited. We note that only ~3.5 staff are devoted to the Collateral Benefits Programme. In addition they are sometimes able to receive support from astronomers. In general, it is believed that more use should be made of the resources of National Facilities in relation to NRF outreach activities, providing this does not begin to subsume a significant portion of the research budget.

The Hartebeesthoek Radio Astronomy Observatory

Historical background

The only major radio observatory in Africa is HartRAO located at Hartebeesthoek near Krugersdorp. It was originally built in 1961 by NASA as a tracking station for its probes that were being sent to explore space beyond Earth orbit. The facility was operated as a Deep Space Station by the CSIR on behalf of NASA until its closure in 1974. It then became a radio astronomy observatory administered by the CSIR until 1991 when it became a FRD national facility. After 1999 it continued as a NRF national facility.

The primary research instrument at HartRAO is a 26m-diameter centimetre-wavelength radio telescope. The facility also supports an active programme of space geodesy, including operation of a MOBLAS 6 Satellite Laser Ranger (SLR), a GPS network and is an important geodetic fiducial reference station.

The establishment of radio astronomy in South Africa would not have occurred without the long service of the past Director of HartRAO, Dr George Nicolson, who retired in this review period, and his substantial contributions are acknowledged here.

Against the background provided, the retrospective performance of HartRAO may be assessed.

Strategic directions

The Panel believes that HartRAO continues clearly to meet the criteria for designation as a National Facility. The geographic location of the telescope is a significant natural advantage and HartRAO makes vital contributions to several large-scale international projects. The telescope has recently completed an important technical upgrade, which was required to maintain its scientific competitiveness. There have also been significant expansions in the space geodesy and science awareness programmes in the period covered by this review.

The strategic direction followed by HartRAO over the period of review was clearly appropriate, but will have to change in future with the advent of the SKA era.

Performance and adherence to quality

We believe that HartRAO operates cost-effectively in meeting its performance goals. The staff is dedicated and hard-working and operate the facility within tight budget constraints. Financial resources are limited relative to the scope of operations. Observing and data quality metrics are excellent.

The panel was concerned however with the low refereed scientific publication rate per scientific researcher per year and noted HartRAO's acknowledgement of this unsatisfactory state of affairs in their self evaluation. Only 0.75 ISI papers per staff were produced in 2003-4. At a National Facility, an appropriate level of in-house research is vital to guide long-term technical development decisions and to maintain strong student and community scientific relationships. While recognizing the difficulty of publishing in an environment with substantial service obligations and other constraints we recommend that incentives be developed to encourage science output. This might include the implementation of short-term visiting science fellowships to foster science output from staff collaborations, the indexing of internal science travel or research funds to science output or other forms of internal prioritisation.

In the 1996 review a target of 2 refereed publications per researcher per year was set. In 2004 the Panel believes this remains a reasonable goal that should be adhered to. In mitigation of the low publication rate, it was argued that a more pressing objective was to train higher degree students. It must be pointed out that efforts to increase higher-degree student participation in the work of the Facility does not exclude increasing research output. On the contrary, the two activities are inextricably bound together and the first must be used to produce the second.

Internationalising research

HartRAO has a long history of involvement in international programmes due to its geographical location and active engagement with partners abroad. The Observatory is an Associate Member of the European VLBI network and an important participant in the International VLBI Service for Geodesy and Astrometry and the International GPS Service. Since 2001, HartRAO has also continued to provide high-quality Satellite Laser Ranging data to the International Laser Ranging Service (ILRS).

The SA SKA project has marked an exponential increase in international contacts for South African radio astronomy, and new collaborations have been built with European, US and Australian partners as part of the pathfinder construction effort. We commend these efforts fully.

Focusing on Africa

HartRAO has developed a science collaboration with the University of Nigeria which has allowed two students to complete PhD degrees using Observatory pulsar data in the past. We note also the GPS deployment to the SADC countries by the space geodesy group to assist these countries to move their maps to a modern datum. We encourage the continuation of these efforts.

Utilisation by external users

During this review period HartRAO has fostered new ties in local higher education institutions to support new student research and education projects. We found direct evidence that involvement in University Honours courses at HartRAO has led to increased numbers of graduate students in astrophysics at South African universities. We encourage HartRAO to schedule additional student and researcher workshops focused on data reduction and instrument use in order to share knowledge and facilitate even greater access by the local higher education community.

There is an urgent need to increase research activity in relation to pulsar work and the enhanced Wits-RAU participation that is sought by these users should be encouraged. Other users should should also be encouraged to participate.

Management

The panel was concerned that the Director’s time is severely over-committed in multiple simultaneous appointments. This leaves little time on-site, despite heroic efforts by him to fulfil multiple obligations of significant importance. We are deeply concerned that the current arrangement is not sustainable. We urge NRF to explore alternatives to relieve these resource pressures.

The HartRAO staff is to be commended for their exceptional efficiency and dedication to maintaining a high standard of Observatory infrastructure and equipment for community use. Given the very tight budget pressures we encourage HartRAO to expand their use of project planning tools at the appropriate level for future technical developments so that scarce resources can be assigned carefully and monitored in more detail and balanced against other core missions.

Transformation

The commitment of HartRAO management to gender and race equity in staff and student support and development is real and unqualified, and important advances have been made in these areas as part of a continuing process. We are concerned that the Observatory needs to expand its total scientific staff numbers however, and there are no free

positions at present or any retirements on the immediate horizon. We encourage NRF to add additional scientific researcher positions at HartRAO as part of the resource capacity development required by SKA.

We believe that the NASSP programme, in which HartRAO participates, is an outstanding transformation initiative, and we urge the Observatory to continue their full engagement in this programme.

Impact and stakeholder satisfaction

External users polled by the committee using a response questionnaire were uniformly satisfied with the level and quality of support provided by HartRAO. We would summarize their view of Observatory support as excellent.

Outreach and developing scientific awareness

HartRAO has had a strong commitment to its science awareness programme since 1990 and has added two staff positions to this effort since 1998 from the budget for researcher positions. The programme is firmly established at the Observatory as a high priority for all staff and fulfils a key NRF core mission. This programme has grown and the increase in numbers to their visitor centre is a tangible indicator of success. We encourage NRF to consider additional sources of funding which could be used to augment this successful programme.

The Hermanus Magnetic Observatory

Historical background

The Hermanus Magnetic Observatory (HMO) officially commenced operation in 1941, having grown out of an earlier activity established at UCT in 1932 in connection with activities associated with the International Commission for the Polar Year in the same year. In 1969 the HMO was incorporated into the CSIR and in 1987, when the CSIR commercialised its activities, the HMO was obliged to become commercially oriented. In 2001 the HMO was transferred from the CSIR to the NRF and it became a National Facility. Strategic planning to position it as such took place in early 2002. It must be borne in mind that this review comes early after that event. Despite staff losses in 2003, tangible evidence of rapid progress under difficult circumstances has been provided. The panel was struck by the spirit of optimism and dedication that pervades the HMO and which is indicative of good leadership.

It is against this background that the retrospective performance of HMO is assessed.

Strategic directions

The observational programme in geomagnetism, running Hermanus Observatory and conducting repeat station measurements in South Africa and neighbouring countries continued across the transition from the CSIR to the NRF. This was also the case with the activities in geomagnetic field modelling to provide magnetic declination information for the South African region. The technology group, which, under the CSIR, had become strong through contract work, largely in support of the civil and military defence sectors has also continued as before. In terms of *scientific research* a new space physics group was created which has built on past experience in pulsation studies and expanded to include research into plasma physics and, particularly into new areas using GPS and HF radar techniques for ionospheric mapping. *Science outreach* started from a zero base and in a short time has shown an impressive record of engagement with education department officials, teachers and school learners. This has culminated in the building of the Interactive Science Centre, providing visitors with the opportunity for hands-on experience of science. At tertiary level positive developments include winter school activities, involvement with NASSP and developments to enhance computing skills for students from historically black universities.

Performance and adherence to quality

The primary objective of magnetic observatory operations the world over is to make uninterrupted accurate measurements of the Earth's magnetic field over decades at a stable location. This is required to track the slow variation of the field generated in the Earth's fluid outer core. The *de facto* professional body defining modern magnetic observatory standards for measurement and mode of operation is INTERMAGNET, an international programme sanctioned by the International Association of Geomagnetism and Aeronomy. Hermanus and Hartebeesthoek now operate as INTERMAGNET observatories and an application has been made for the Tsumeb Observatory (operated in collaboration with the Geological Survey of Namibia) to be so recognised. The success in achieving INTERMAGNET status is an independent and objective indicator of the high quality of operations at South Africa's magnetic observatories.

Scientific output since becoming a National Facility has been acceptable and the staff clearly recognise the need to publish. In 2003-4 they published 2 ISI papers per researcher. Once the new appointees (now registered for PhD degrees) begin publishing, output should increase further.

Internationalising research

International collaboration is clearly evident. HMO data and data products incorporating HMO data (e.g. the Dst index) are sought internationally and the staff is publishing with international co-authors. The potential collaboration with Germany through Inkaba ye Afrika is an important new development. Funding to bring scientists from overseas to work on joint projects with staff and students in Hermanus would greatly facilitate and accelerate international collaborative research and broaden the scope of HMO's work.

Focussing on Africa

Involvements in Africa are occurring. Collaboration with the Geological Survey of Namibia in operating the Tsumeb observatory is a successful long-term arrangement. For the IAGA Workshop on magnetic observatory practice hosted by HMO in April 2002 particular efforts were made to attract participants from other countries in Africa.

Future ionospheric research will require data from a wider network of ground-based GPS receivers, and this will naturally encourage wider collaboration in Africa. It also opens up the possibility of collaborative work with the geodetic programme of HartRAO.

Utilisation by external users

Since geomagnetic observatories the world over are continuous monitoring sites and data generators, it is unusual for users to ever require to work on site. Nonetheless, there is some use of the observatory for instrument testing and calibration. We do not see the lack of on-site user involvement as a problem in the operation of HMO as a National Facility. The observatory must continue to generate raw data, contribute measurements for value-added data products such as the Dst index and the IGRF and regional field models for southern Africa, from which a variety of national and international users benefit. Contract work is an important component of HMO work and involves a number of users both on and off site.

Management

The management of the Facility is excellent. The experience of working in a commercial environment in the past has encouraged good project management with tight financial control. The excellent progress towards implementing change over the last year is a clear demonstration of effective leadership by the senior management at HMO.

Transformation

Overall, the balance of staff at HMO is distributed equally between black and white, with about one-third female staff, but this is not reflected at the higher levels. On the face of it, the resignations in 2003 created an opportunity to progress in this respect, but we accept the argument presented to us that it is currently very difficult to find suitably qualified candidates in the black population. We urge a mentoring and succession-planning exercise to ensure continuity and equity in future staffing of the Facility. We are satisfied that there is a positive willingness to act affirmatively and, in due course, the work begun with universities will help remedy the situation by providing a pool of suitably qualified candidates.

Impact and stakeholder satisfaction.

A survey of users, and interviews with many, reveals unanimous satisfaction with the outstanding quality of HMO data and the helpfulness of HMO staff. Users routinely comment on the excellence of the work being undertaken and on the unique knowledge and skills that have been developed. The South African observatories are strategically positioned geographically within the world to monitor many important geomagnetic changes, such as the rapid development of a reverse magnetic flux patch at the surface of the earth's core beneath southern Africa. HMO has particular significance because of its contribution to the Dst index and is a key site in the world and hence of great significance to South Africa.

Outreach and developing scientific awareness

The panel is satisfied that significant progress has been made in developing scientific awareness in local communities and nationally. Outreach has been impressive in the time available and will do much to promote a pool of talent to serve national needs and from which to draw for staff recruiting in future.

HMO involvement in NASSP has been successful, both for the HMO in terms of human capital development in their associated disciplines and for NASSP in drawing a balance between astronomy and space physics, which was previously skewed toward astronomy. A convergence of interest toward NASSP, by all National Facilities under this review, has added immense value to NASSP and this involvement has translated to an over- subscription of student interest to the programme. For 2005, there were 30 applications for the BSc (Hons) programme and 28 for the MSc programme. Not all of these applications could be accommodated given the current constraint on the number of bursaries that are available.

THE WAY FORWARD

SAAO

The SAAO has developed a plan, which the panel supports, to redirect and rationalize the use of its smaller telescopes in support of SALT and its collateral benefits programme. In particular, SAAO's two smallest telescopes would be used for teaching and public viewing (which Sutherland stakeholders have indicated they would be pleased to see increase), while the 1m and 1.9m telescopes would be used to find and follow-up targets for SALT, allowing SALT to spend its time doing what it only can do. Some of this will require new instrumentation that the SAAO can provide. The 1m and 1.9m telescopes will also fill tracking gaps in important time-domain astronomy, and provide a competitive advantage to South Africans in optimum use of SALT. Several international users also indicated support for the continued use of the research-grade 1m and 1.9m telescopes in the SALT era. Even some of the internationally funded telescopes at Sutherland may, through international collaboration, be used in support of SALT.

Expertise of the scientific staff has focused on time-domain astronomy: variable and pulsating stars, the distance scale of the cosmos, evolved massive stars, and accretion disks, studies of some aspects of which were possible with the prior modest facilities available at SAAO. In most of these fields, they are world experts. The challenge is for them is to move into new, high visibility science that utilizes SALT's unique capabilities.

Time-domain capability is being built into SALT instrumentation from the beginning, and SALT will be the only large telescope in world with fast read-out and frame transfer capabilities to enable new frontiers in time-domain astrophysics. Other advantages of SALT which may be exploited include high UV sensitivity, spectro-polarimetry, Fabry-Perot imaging spectroscopy and the flexibility of queue scheduling.

It has been the plan from the outset that astronomers everywhere in southern Africa should be active users of SALT. It is perceived by some that SAAO may have certain advantages as the operating facility for SALT in this respect. To ensure that outsiders have fair access in a manner consistent with top-quality science, extra effort must be made to disseminate knowledge about the SALT usage process and interact with regional astronomers to ensure that their proposals for observing time will fulfil the potential inherent in them. Allocation of time by the Telescope Allocation Committee must always be balanced and transparent to avoid the perception that SAAO-linked scientists have preferential access to the telescope. Possibly including an independent outside member on the TAC will be wise.

Presently, theoretical support is planned through international collaboration. Interpretation of the SALT results will depend on the important interface between theory and observations.

The review panel was pleased to note that the international reputation and prior experience of the new Director of SAAO will significantly assist in continuing the institution's preparation for the SALT era and bringing SALT to the attention of the world community of astronomers.

An operational plan for SALT has been agreed upon by SAAO and the SALT Board in order to establish SAAO as the operating facility for the telescope over the next ten years. The SALT Project Scientist will become Director of SALT Astronomy Operations and interim SALT Board liaison, in a move toward a seamless transition. Most of the project team associated with the construction of SALT will depart sometime during 2005. The first full semester of normal science operations is expected to be from November 2005 to April 2006. It is now apparent that the operational budget originally envisaged over the first ten years is insufficient to cover that period of time. This needs to be addressed.

SAAO has indicated strong interest and enthusiasm for ensuring that SALT data be archived in the International Virtual Observatory, which will particularly benefit researchers at needy institutions in Africa and abroad. The panel applauds this vision, but notes that substantial software resources will be required for success, and that co-operation from all SALT partners is desirable. It should be realised that an automated data reduction software process (pipeline) for SALT observations will require considerable software resources.

The grow-your-own approach adopted by SAAO is planned for all levels, starting with younger learners, partnering with educational activities in other scientific and engineering disciplines. A plan exists to establish a Maths, Science, and Technology Academy in the Northern Cape for school grade 8-12 students. At the upper undergraduate level, NASSP offers honours possibilities, which can be extended to MSc study. At the postgraduate level, Stobie-SALT scholarships allow South African students to study abroad at SALT partner institutions. Currently two such scholars are in the UK, and another two in the USA.

In a broader outreach effort, SAAO has plans for expanded Visitor Centres at both Sutherland and Cape Town. With the opening of SALT, it can be anticipated that very large numbers of visitors will come to Sutherland. Already, the SAAO Sutherland site has experienced an increase in visitor numbers from

500 to 5000 annually. It has to be realised, however, that an influx of night visitors is inimical to the taking of observations and that the expectations of the Sutherland community to increase tourism in this manner are unrealistic. Their future disappointment in this regard may damage the present good relations between SALT, SAAO and themselves. Steps should be taken as soon as possible to lower expectations.

RECOMMENDATIONS:

1. That further investment in people to match the investment in facilities is required. In particular it will be necessary to:

    a. enhance software support in the SALT era, including that involved with the data reduction software process (pipeline reduction), innovation and general observatory support,

    b. re-examine the operations budget with a view to increased staffing to continue the innovation of the past into the future when, justifiably, international and local user expectations will be high,

    c. consider ways to begin thinking immediately about second-generation instrumentation for SALT, and

    d. increase support for and expand the successful Collateral Benefits Programme, but not at the expense of research support (outreach may require partnering with other governmental entities).

2. That increased and continuing support for the over-subscribed NASSP programme be sought as soon as possible.

3. That every effort be made by government, funders and users to build upon the scientific advantages that SAAO has worked so hard to create with the building of SALT and to recognise and meet the challenges presented by increased levels of competition at the cutting edge of international science.

4. That the 1.9m and 1m SAAO research telescopes continue to be used and be integrated into the SALT programme to provide a competitive edge for Southern African astronomers.

5. That consideration be given to enhancing South African theoretical astronomical programmes to fully exploit the SALT observational programmes in order to maximise scientific intellectual property within the country.

6. That the looming tensions between the town of Sutherland and SAAO/SALT over night-time tourist use of telescopes and light pollution need to be resolved soon, and certainly before the SALT opening, in order to defuse later problems of unrealistically high expectations regarding the benefit of SALT to the town of Sutherland. In so doing the present excellent community-SAAO relationship should be preserved as far as possible.

HartRAO

The advent of the SKA as a flagship development for South African science and technology has fundamentally re-shaped radio astronomy in the country and we commend the vision of the DST and NRF in supporting this project. We believe that the SA SKA pathfinder project will fulfil its goal as a mission-driven innovation project within the goals of the NSI and will strengthen South Africa’s bid for the full SKA. We further support the bid to NASA to host the next-generation deep space array network given the clear synergies with the SKA pathfinder development.

The current SA SKA pathfinder development aims to build an instrument that can do new science and which also tests key technologies needed by the full SKA. We support the current hybrid focal-plane design and strong overall project management approach. We encourage a cautious risk mitigation strategy regarding the range of technical areas explored by the prototype given the complexity of some of the underlying research problems. We recommend that sufficient resources be set aside for commissioning and software costs. We strongly encourage a commensurate and simultaneous capacity-building initiative in interferometric techniques so that this expertise is available before first light observations with the pathfinder instrument. We believe that this investment will strengthen the SKA bid, as would an increase in the publication of scientific material in ISI journals. We note that the current SA SKA project leadership are highly respected abroad in the international SKA project.

The major strategic challenge faced by HartRAO at present is that of re-positioning to meet the needs of the SA SKA pathfinder development efforts and the broader South African bid to host the full SKA. Given South Africa's investments in the SKA project, we believe that it is an opportune time to consider the larger strategic and organizational implications of this key project on national radio astronomy efforts. We believe that it is important that HartRAO staff and resources be integrated fully into the SKA activities as early as possible so that the facility can contribute to the maximum extent to the SA SKA project, and that radio astronomy capabilities provided in the NRF national facility framework remain coordinated, integrated and working toward the common goals and national priorities defined by the DST and NRF.

We recommend that NRF consider and investigate some organizational re-alignments that we believe may aid in the transition to the SKA era. The panel found a *de facto* organizational and administrative separation of space geodesy and radio astronomy at the Observatory, and we recommend that NRF explore the re-assignment of space geodesy to a separate programme outside of HartRAO. While such a programme would require careful positioning within broader national geophysical research priorities and needs, and would need to be tightly focused on an identified user community, we believe such a re-alignment may have mutual organizational benefits in the SKA era. We note the likely migration of future geodetic instruments to the Sutherland site over the period 2005-2010 and urge a careful transition programme to ensure continuity in the quality of the fiducial reference point established against VLBI. The possibility of combining the present HartRAO space geodesy activities with activities at HMO does not appear to be encouraging.

We also believe it is timeous for NRF and DST to evaluate and consider the co-location of the SKA RTCC, SKA project office and the non-operational scientific, technical and administrative components of HartRAO at a common, central location in closer proximity to higher-education institutions and industrial partners. The current telescope site would then require staffing levels only to support telescope operations and other site-specific activities, including science awareness programmes, under a local site-manager, but such a model is well-established internationally and should not detract from current HartRAO performance as a national facility.

We believe that capacity building in the local HEI astrophysics community is vital to strengthen the South African bid for the SKA and for the effective utilization of the SA SKA pathfinder after commissioning. We urge NRF to consider earmarked bursaries and other funding mechanisms to support critical mass research groups in the local HEI community who are working on science problems vital to the SA SKA pathfinder. We also strongly encourage that these groups play an active role in compiling the science case for the pathfinder. In focussing on Africa the active engagement of the Observatory in an African Virtual Observatory effort in collaboration with other partners is to be encouraged.

RECOMMENDATIONS:

1. That involvement in SKA activities be continued and strengthened.
2. Additional funding for research, including additional scientific staff, earmarked bursaries and funds for local and international visiting scientists, is needed to add capacity in South African radio astronomy.

3. That in order to ensure a strong research underpinning and scientific leadership of HartRAO, every effort must be made to increase scientific output as a matter of urgency. The target of 2 publications per year per researcher (including collaborative papers) must be re-established and adhered to.
4. That consideration be given by DST, NRF and HartRAO to a central location of a SKA/HartRAO office.
5. A means needs to be found to relieve current acute time pressures on the Director of HartRAO.
6. Pulsar work must be rejuvenated and ways to bring in staff, possibly on secondment to HartRAO should be investigated as a matter of urgency, including appropriate ways to fund this.
7. The question of possible ways to separate space geodesy and radio astronomy at HartRAO needs to be given consideration.

HMO

The flagship project proposed by HMO in their strategic plan was a satellite survey mission, ZaSat, to contribute to the International Decade for Geopotential Research. This was an appropriate proposal, but it has been overtaken by events in 2004 with the decision by the European Space Agency to launch a three-satellite mission (Swarm) in 2009. The HMO management have decided, consequently, to abandon the ZaSat proposal. We believe this decision is correct, and note that the decision on Swarm could not have been anticipated.

We believe it is important to identify another major scientifically inspiring project to provide focus. One such could be based on the emergence of the reverse flux path at the core surface below Africa and its consequences in the development of the South Atlantic anomaly, creating a hazard to near-Earth space operations. This could be a natural focus because of the geographical location of the phenomenon, and also because it pulls together the different parts of research interest in HMO. A project could be set up as part of Inkaba ye Afrika if the involvement of Germany is confirmed, but this need not be a necessary condition. What is important in this connection is that a decision on a flagship project is a matter for the staff of HMO themselves and their research collaborators.

The panel notes that the 2007-2008 IPY is a major, high-profile ICSU international initiative to which HMO has submitted a proposal for ionospheric research. Other international initiatives are also planned to mark the 50^{th} anniversary of the IGY. A number of these initiatives have a strong solar-terrestrial physics component and the HMO staff have skills relevant to research in this respect. The ability to understand and predict space weather is likely to be of interest to HMO stakeholders because of interest in, for example, geomagnetically induced currents, radio propagation conditions and GPS accuracy. This is also a focus for the different areas of space physics currently growing within HMO. Participation in endeavours related to the IGY+50 initiatives is to be encouraged as a means for the staff to pursue their science through international collaboration.

We also note that there is considerable scientific potential for research in ionosphere tomography using the combination of South African Low-Earth-Orbit (LEO) satellites combined with ground-based GPS and ionosonde observations. Collaboration with the HartRAO geodetic section may prove beneficial in this respect. It was further noted that the Chief Directorate of Surveys and Mapping would be a significant beneficiary through the services it provides to GPS users in South Africa.

There has been interaction with the SKA in the bidding process. We note that ionosheric predictions are important during pathfinder operations. The HMO team is encouraged to actively take steps to collaborate with the SKA team in this regard.

The widening of the scope of HMO activities through the responsibilities taken on for running the three South African ionosondes and the HF radar component of SHARE offer considerable future research possibilities for staff and students, particularly because of the potential for collaboration with other countries making investments in instrumentation in Antarctica.

Given the small scientific staff complement progress in all the research areas is critically dependent on individual members of staff. Progress in attracting MSc and PhD students will help to alleviate this problem, as will the creation of further dual appointments with universities. The dual appointment approach is to be encouraged.

We note that considerable investment has been made in science outreach in the last year, with considerable success. It is difficult to see how this level of activity can be sustained without compromising progress in developing scientific research given the current budget. There is a good case for increasing the overall funding to ensure that the momentum gained in outreach is maintained without detriment to the research output of the Facility.

Contract work is generating about 40% of HMO's income. We are satisfied that this brings positive benefit to the operations of HMO as a National Facility. The risk of a sudden decline in income appears to be low unless the major customer, the SANDF, decides to withdraw. This appears unlikely, but year-to-year fluctuations in funding from the private sector may occur. The contract work benefits the HMO and should continue. It imposes project discipline and projects are subject to audits of experimental methodologies by external customers in some instances. The contract work is not entirely routine and there are innovative aspects that could be used in HMO science projects.
Several stakeholders cited their work with HMO as excellent examples of effective interaction between academic research and industry.

Thought was given to the possibility of merging the geodetic component of HartRAO work with that of HMO or placing it under HMO management. Both these options appear unlikely to work and the panel suggests that they are not pursued.

RECOMMENDATIONS:

1. That thought be given to a change in name for the institution that will be more in keeping with its broader modern function.
2. That consideration be given to developing a flagship project that will give the Facility a clear international identity and possible funding advantages.
3. That current and appropriate future contract work be continued.
4. That HMO should seek opportunities to become more involved in SKA planning.
5. That additional funding be granted to enable an expansion of HMO activities in NASSP.

Cross-cutting issues

Three major cross-cutting issues are of importance to all three National Facilities.

Public outreach, science awareness and visitor centres

All three National Facilities operate public outreach and science awareness programmes that are an important part of their core mission and are funded out of their main budgets accordingly. The panel believes that these efforts are very important for capacity building in the South African community, for attracting students to the sciences and for advanced training of teachers and educators. We heard strong feedback from stakeholders in support of this view. All science awareness and outreach programmes are under-funded and there is room for growth if external funds can be raised from other government departments, provincial governments or private partners. Regarding visitor centres, there is a pressing need for improving of visitor centres at Sutherland and SAAO, Cape Town that will deliver a satisfactory experience to the increasing numbers of visitors expected in future. Given that all facilities are engaged in similar fund-raising efforts and given the complexity of these fund-raising proposals across many government agencies, the panel urges NRF to extend their central

coordinating role at a corporate level in strategic fund- raising efforts for all the National Facilities as a whole to ensure efficient and effective fund-raising for these important programmes from government.

Capacity-building in the higher-education institutions

With SALT and the SA SKA pathfinder, South Africa will possess two front-line astronomical research facilities. In order to exploit these facilities locally it is vital to build human resource capacity in astronomy research at the local higher-education institutions in South Africa. The NASSP programme is extremely important as a mechanism to generate the future astronomers and space physicists in the country. To invigorate and build the local higher education community, so that SALT and SKA investments can be fully utilised locally, we urge NRF and DST to consider a targeted research funding programme to support critical mass research groups and individuals in the universities who put forward proposals to work on science problems directly relevant to the capabilities of SALT and the SKA pathfinder. We urge that consideration be given to support within such a programme for activities of the form of:

a) Long-term support for the NASSP programme, so that it is not critically dependent on foreign foundation funding.
b) Research grants to build capacity and critical mass in local research groups working on SALT and SKA science, including ear-marked bursaries for students in these groups.
c) Start-up, fixed-term funding for joint university-National Facility appointments to simulate the science potential of both institutions.
d) Funding for sabbaticals for university staff at the National Facilities to build collaborative research programmes using SALT and the SA SKA pathfinder.

Many of these suggestions are equally relevant for HMO and should be so considered.

Each of the three National Facilities are in science areas where theory and observation contribute to progress. Interactions with university mathematics and applied mathematics departments, as well as with the newly formed African Institute for Mathematical Sciences, should be sought as a way of attracting future postgraduate students.

Virtual observatories

The panel noted an absence of active efforts for a South African contribution to current international efforts to build virtual observatories. These programmes aim at federating astronomy databases from different institutions and telescopes so that they can be more accessed readily by the full scientific research community over the web. They also play an important role in public outreach and science awareness efforts. Their primary benefit for science is that they enable greater productivity by making astronomical data available for analysis and interpretation by the full community and enable new forms of integrated scientific research across observing wavelengths.

We found a strong commitment to these efforts at the National Facilities in principle, but no staff assigned at present due to limited resources. We feel that these efforts would help the National Facilities and we urge their involvement in virtual observatory efforts through a regional African Virtual Observatory in collaboration with local researchers in computer science.

We strongly support wider efforts in South Africa that are synergistic with virtual observatories. These include efforts to improve the speed and reach of computer networks, and an effort to create a digital library and online subscriptions to research journals (SARIS) along the Belgium model.

RECOMMENDATIONS

1. The NRF is urged to co-ordinate an approach to various government departments (DST, Education, Local Government, etc) to raise funds for outreach for all the National Facilities as additional funds to be used in a separate and protected component of their budget.

2. That the NRF find ways of enhancing capacity-building in the higher-education institutions of South Africa to take full advantage of SALT and the SKA pathfinder, without this resulting in a diminution of funding to research generally in the country.

3. That the NRF find ways of stimulating and funding developments in virtual observatories in South Africa.

Conclusions

All three National Facilities reviewed performed well over the period of review; all are national assets worth nurturing in order that their work individually and, more importantly, that in collaboration with universities may be used to contribute significantly to South Africa's total research productivity and international standing. One aspect of performance over the last five years needs to be highlighted specifically. The SAAO preparation for SALT has been astounding and serves as a model for how, building on a secure science base and a good international reputation for its science, the Facility and the SALT team have exceeded technological expectations in the planning, construction and commissioning phases of SALT. Congratulations must be extended to all concerned.

The panel was also required to comment on the plans, preparedness and standing of the Facilities for the work to be done in the next five-year period; SAAO in relation to SALT science, HartRAO in connection with the SKA bid and HMO as it continues to adapt to its role as a National facility.

The success of the SALT venture and the vision of DST and the NRF in supporting the development this bodes well for the SKA bid. The role South African technology has played in SALT has been outstanding and exceeded all expectations. Care must be taken not to lose the expertise of the SALT team as the next phase of SALT work commences and as planning for the SKA bid proceeds.

HMO has moved vigorously to reposition itself as a National Facility and its plans for the next five years give confidence that its scientific work will make a significant contribution to the national research effort in future.

All three National Facilities are visibly committed to transformation, capacity building and outreach and are proceeding as fast as circumstances allow within the constraints of their budgets in all three respects. They are National Facilities of which the NRF may be proud.

Acknowledgements

The Panel wishes to thank the staff of the three National Facilities for the hard work they put into preparation for the review at a time when all were heavily committed in other ways. They are also thanked for their patience with the review process. The welcome and hospitality shown to the panel by the three directors and their staffs were much appreciated by the Panel.

Likewise the Panel appreciates the time given by users and stakeholders for consultation, especially when many of them wondered why they needed to be consulted in person at all!

Appendix 1: List of Acronyms

CDSM	Chief Directorate: Surveys and Mapping
CHAMP	Challenging Mini-Satellite Payload
CSIR	Council for Scientific and Industrial Research
DCI	Declared Cultural Institution
DST	Department of Science and Technology
Dst	Disturbance Storm Time Index
DTI	Department of Trade and Industry
FRD	Foundation for Research and Development
GAAP	Generally Accepted Accounting Practice
GIS	Geographic Information System
GPS	Global Positioning System
HartRAO	Hartebeesthoek Radio Astronomy Observatory
HBUs	Historically lack Universities
HEI	Higher Education Institutions
HET	Hobby Eberly Telescope
HDI	Historically Disadvantaged Institution
HMO	Hermanus Magnetic Observatory
ILRS	International Laser Ranging Services
IAGA	International Association of Geomagnetism and Aeronomy
ICSU	International Council for Science
IGRF	International Geomagnetic Reference Field
INTERMAGNET	International Magnetic Observatory Network
iThemba LABS	iThemba Laboratory for Accelerator Based Sciences
KPI	Key Performance Indicator
LEO	Low Earth Orbit
MoU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NASSP	National Astronomy and Space Science Programme
NEPAD	New Partnership for African Development
NRF	National Research Facility
NSI	National System of Innovation
RAU	Rand Afrikaans University
RU	Rhodes University
SAAO	South African Astronomical Observatory
SAASTA	South African Agency for Science and Technology Advancement
SAC	Spherical Abberation Correction
SADC	Southern African Development Community
SALT	Southern African Large Telescope
SARIS	South African Research Information System
SET	Science, Engineering and Technology
SETI	Science, Engineering and Technology Institute
SKA	Square Kilometer Array
SHARE	Southern Hemisphere Auroral Radar Experiment
SLR	Satellite Laser Ranging
TAC	Time Allocation Committee
ToR	Terms of Reference
UCT	University of Cape Town
US	University of Stellenbosch
UW	University of the Witwatersrand

UWC	University of the Western Cape
VLBI	Very Large Baseline Interferometer
Wits	University of Witwatersrand

Appendix 2: Background documents used by the Panel

1. Self-evaluation reports by the South African Astronomical Observatory (SAAO), Hermanus Magnetic Observatory (HMO) and Hartebeesthoek Radio Astronomy Observatory (HartRAO) respectively
2. NRF Act
3. White Paper on Science and Technology
4. SETIs (Science, Engineering and Technology Institutions) Report on the System Wide Review
5. SETIs (Science, Engineering and Technology Institutions) Report on National Facilities (completed in 1998)
6. SETIs (Science, Engineering and Technology Institutions) Report on the National Research Foundation and the Agency Function (completed in 1998)
7. South Africa's National Research and Development Strategy
8. Reports on previous reviews of the South African Astronomical Observatory (SAAO), Hermanus Magnetic Observatory (HMO) and Hartebeesthoek Radio Observatory (HartRAO), where applicable
9. NRF Strategic Plans
10. Strategic and Business plans of SAAO, HMO and HartRAO respectively
11. Latest annual reports of HartRAO, HMO and SAAO

Appendix 3: Organisations and individuals interviewed by the Panel.

Extensive discussions were held with staff at all three Facilities. In addition over 75 users and stakeholders were interviewed. The institutions they represent are listed below.

1. HartRAO

South African SKA Steering Committee
Council for Scientific and Industrial Research
Wise Innovation Management
University of Cape Town
Johannesburg Planetarium
University of the Witwatersrand
Rand Afrikaans University

2. HMO

Centre for Interactive Graphical Computing of Earth Systems, UCT
University of Stellenbosch
Rhodes University
Surveys and Mapping, Department of Land Affairs
Denel Aerospace Missiles
South African Air Force
University of North-West
State Information Technology Agency
Defence Intelligence Division
Denel Aerospace Systems
University of KwaZulu-Natal

3. SAAO

Karoo Hoogland Municipality
Previous Mayor of Sutherland
University of Cape Town
University of the Western Cape
National and Space Science Programme (NASSP), University of Cape Town
Masakheke Combined School, Robertson
Peninsula Technikon
MTN Science Centre
Iziko Museum Planetarium
Astronomical Society of Southern Africa
University of KwaZulu-Natal
University of South Africa
South African Association of Science and Technology
University of Free State
University of North-West
Rand Afrikaans University
Students from the University of Cape Town
National and Space Science Programme (NASSP) students at University of Cape Town

4. GENERAL

Department of Science and Technology
Vice-President of the NRF
Manager, Evaluation Centre
President of the South African Institute of Physics
SAIP Convenor of the review “Shaping the future of Physics in South Africa”
Council for Geosciences