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Dear Ms. Rädel,

Re: Management response on Space Geodesy Review (June 2016)

We confirm that we have received the final review report and have considered it carefully in regard to operations at HartRAO. We thank you for this opportunity to respond to its recommendations.

It is clear that the review committee went to great lengths to obtain sufficient and relevant information regarding the Space Geodesy Programme through written submissions, personal interviews and by tele-conference.

The reviewers followed a very open process where dialogue and communication featured continuously as part of the process. We are particularly satisfied in that staff members were interviewed, which was not the case with previous reviews. Not only was the programme reviewed in terms of its local impact, also our international commitments and global impacts were considered.

We are therefore confident that the review panel provided appropriate guidance to the NRF and HartRAO through this review and look forward to implement the panel's recommendations. We would like to thank all participants in this review process and are grateful for their valued input. Your efforts towards organising the review are appreciated.

Sincerely

Prof. Ludwig Combrinck
Acting Managing Director: HartRAO

Herewith our detailed response to the 2016 Space Geodesy Review Panel report:

1. Findings

1.1. Importance of the programme

1.1.1. Evidence gathered strongly underlines the national, regional and international strategic importance of HartRAO as one of the two geodetic core stations in the Southern Hemisphere and the only one on the African continent. Because of this station the accuracy and long term stability of positioning is improved by at least a factor of two, enabling many national societal and scientific applications.

We agree with this finding. As more highly accurate positioning capacity will be required in the future on a global scale due to both scientific and societal requirements, we expect that HartRAO will continue to play an important role in the global networks, and will specifically contribute to the establishment of the Global Geodetic Reference Frame if adequately resourced.

1.1.2. HartRAO makes a major contribution to human capacity development in geodesy and is the primary institution that provides post-graduate research and training in space geodesy. Degradation of this capacity will further erode the vulnerable SA knowledge base (CREST report).

Human capacity development is a major objective of the programme. Our inability to retain trained researchers due to budget limitations has severely constrained the major benefits HartRAO and the NRF could have had by retaining a core group of trained young scientists; this also adversely affected our transformation goals.

1.1.3. HartRAO has been remarkably successful in leveraging infrastructure and support from international sources, which reflects the quality of the programme and international confidence in the competencies of staff. This levered infrastructure has been highly beneficial for SA.

We have had to ensure that we remain competitive, relevant and able to make appropriate contributions at an international level regardless of our funding levels. This comment is appreciated.

1.2. Infrastructure

1.2.1. The co-location of instrumentation for the four main space geodetic techniques makes HartRAO unique and the state and maintenance of the infrastructure is sufficient to make a crucial contribution to the global geodetic networks and the Global Geodetic Observing System (GGOS).

We have developed close links to GGOS and serve on the GGOS Coordinating Board and we are a member of the GGOS Interagency Committee (GIAC). HartRAO therefore intends to contribute to GGOS at high level and will make all efforts to ensure that the sparsely equipped Southern Hemisphere and Africa will participate and benefit from the GGOS project.

1.2.2. Although the 26m dish is more than 50 years old it is still sufficient, after recent upgrades, to play an important role in VLBI and in single-dish observations, which are complimentary to the research of MEERKAT and SKA. It also provides an excellent training facility for radio-astronomy, which is a SA flagship research programme.

We appreciate this finding, HartRAO staff have worked very hard over many years to upgrade and maintain the 26-m antenna. We will continue to keep the 26-m efficient and functional, but on the longer term, we need to work towards a larger and modern (~64-m class) antenna which will allow a major expansion in the type of work that will be possible.

1.2.3. The NASA provided SLR equipment (MOBLAS 6) is old, and recent technical problems have led to a low yield. Investments by NASA are expected to bring the equipment back to the forefront.

We agree with this comment, we have close links with NASA GSFC, and have been assured that we will receive a New Generation SLR (NGSLR) in the mid-term; the NGSLR systems are now being constructed, so we expect to have a replacement to MOB-6 in the future.

1.2.4. As in the past the station is actively engaging with international partners to upgrade the infrastructure. A new Russian SLR system is currently under construction and a Lunar Laser Ranging (LLR) system is being developed by HartRAO in collaboration with the Observatoire de la Cote d'Azur (France) and NASA (GSFC). After completion, HartRAO will be the only station in the world with two SLR and one LLR equipment.

Part of our vision is to remain relevant, competitive and fulfil an international role at an appropriate level, and in the Southern Hemisphere, be the leading space geodesy observatory.

1.2.5. A soon to be installed geodetic surveying instrument (total station) will ensure that local ties between the co-located techniques will be monitored on a daily basis with the required accuracy and help to resolve current discrepancies between the techniques.

This initiative is very important to ensure our contributions are of the highest accuracy possible.

1.2.6. The installation of a next generation VGOS system, which will significantly enhance the geodetic VLBI capabilities, is in progress, but hampered by the devaluation of the Rand.

We are monitoring our financial situation closely and will utilize future calls for infrastructure grants if required.

1.2.7. HartRAO houses infrastructure, such as gravimeters and seismometers, that are contributing to geodesy and geoscience at the national level. The anticipated acquirement of a high accuracy clock would initiate a new era of linking the geometric and gravimetric references and improving the accuracy of both geodetic and astrometric observations.

Such a clock would open up new avenues of science internationally, and we monitor development in this field continuously. If an appropriate opportunity arises to pursue such a clock, we will make all effort to procure or host such a clock.

1.2.8. The lack of contingency funding has caused long gaps in the time series of data collection after equipment failures.

We try to minimize downtime of equipment as far as possible. Large failures, such as the failure of the 26-m antenna main bearing, require financial support from the DST. Ideally we should have some reserve available for major failures, at least in the form of critical spares of items with long lead times (e.g. motor gearboxes, encoders, etc). This however requires sufficient spare funds.

1.2.9. The engineering and technical support is innovative and of a high quality, which is crucial for an under-resourced facility.

The HartRAO engineering and technical team is a stalwart section at HartRAO and we are very grateful to have such a team on-board. Losing, shrinking, or further loading this capacity will cripple operations.

1.3. **Quality of the programme**

1.3.1. Benchmarked against similar stations, the contribution of the programme to the global networks is of very high quality in terms of

- *Participation in internationally coordinated observation sessions, and*
- *Data delivery for globally coordinated processing, resulting in products supporting many scientific studies and service products.*

Thank you for this comment, to operate all equipment at an adequate level and participate in internationally scheduled sessions is a constant challenge at HartRAO and requires all departments to operate efficiently.

1.3.2. *The quality of the programme is strongly enhanced by the synergy between radio-astronomy and geodesy (VLBI techniques).*

This synergistical approach maximizes efficiency of equipment use, creates a multi-disciplinary approach and leads to active and constructive interaction between staff as well as between HartRAO and our international collaborators.

1.3.3. *The panel emphasizes that the programme is severely under-resourced in terms of human resources for research, which negatively impacts the quantity of scientific outputs.*

Agreed, the debilitating effects of underinvestment in an adequately sized core research group has been plaguing HartRAO for decades. This is particularly true for the space geodesy, but also the astronomy programmes.

1.3.4. *Despite the high operational workload, the quality of the scientific output is internationally acknowledged. It should be noted that credit for the international impact would be considerably higher if data citation would be fully implemented. For example, the publications on the different versions of the ITRF, which are based on data of the geodetic stations, are among the most cited publication in Earth Sciences.*

The IAG and its services (ILRS, IERS, IVS, IGS) are concerned about this issue and are investigating how contributors to the services should be recognized more readily in publications. One option is that DOIs be assigned to IAG service scientific datasets and that we should link into this. In the USA, a consortium called DataCite seems to be working with NASA, NOAA etc. The CDDIS has started assigning DOIs to data sets but have not implemented them yet for all data sets, including SLR. As an example you can see what has been done thus far for GNSS:

http://cddis.gsfc.nasa.gov/Data_and_Derived_Products/GNSS/daily_30second_data.html (click on “View Code Table) at the bottom of the page

http://cddis.gsfc.nasa.gov/Data_and_Derived_Products/GNSS/orbit_products.html

According to CDDIS assigning DOIs for SLR data and products at CDDIS will be done soon. The IVS has taken this route as well. They wrote a paper for J Geodesy (Bachmann et al., 2016), and then the IVS GB decided they needed a separate citation that would allow the stations or their representatives to also be part of the "author list". We have ensured that several of HartRAO’s staff members are on this “author list”.

1.3.5. *Quality of student training in terms of supervision, workshops, interaction and opportunities seems to be outstanding. This is evidenced through the high demand of these students in corporate and governmental organisations.*

Student training and capacity building is part of our vision to change the demographic landscape of South Africa and provide a core of young scientists at HartRAO; we have support from the NRF in the training phase, but not in the employment phase due to budgetary constraints.

1.3.6. *The attraction of the programme is highlighted by the fact that students are drawn from diverse backgrounds.*

Agreed.

1.3.7. The absence of a research strategy results in a lack of coherency and research being driven by opportunism and student projects. There are no well-defined medium to long term research questions and goals focused on space geodesy and utilizing the infrastructure of this core station. These impacts negatively on infrastructure planning and human capacity development.

Agreed. Although there is a research vision, one cannot develop a research strategy as defined here with no research personnel. Until 2016, there was only one full-time PhD staff member in the Space Geodesy Programme; therefore the strategy to channel local development and research through student projects and other opportunities.

1.4 **Operational and management issues**

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1.4.1 As already remarked, the quality of the programme is strongly enhanced by the synergy between radio-astronomy and geodesy (VLBI techniques). However, the national organizational structure creates a problem for the placement of the programme due to the splitting between space science and astronomy. The panel discussed a number of scenarios to resolve this issue, of which three are considered here:

1. Placement of the programme under the SARAO. The current SKA top management endorses geodesy i.t.o. its value to astronomy and society and indicated that the programme will not be under threat in a larger radio-astronomy environment. However, on the longer term a concern exists that the programme may lose its identity in the much larger and better resourced radio-astronomy environment, which may have severe national and international repercussions i.t.o service delivery relying on accurate geodetic data (see Introduction).

2. Placement under SANSA (Space Science). However, feedback indicates differences in the scope and objectives of HartRAO and the Space Science Programme as the latter is more service orientated.

3. Placement within a consolidated national geodetic and geospatial information environment. This would remove any current duplication that exists between HartRAO and other national organisations performing geodetic observations and services, such as the Chief Directorate: National Geospatial Information, which, by legislation, is responsible for the national geodetic system. It would also provide a more coherent response to South Africa's obligation to the UN General Assembly Resolution on the Global Geodetic Reference Frame. It must also be noted that the geodetic reference frame provides the foundation for all geospatial information. While the panel is of the opinion that this option holds many benefits for the country, it does not consider the current situation ready for immediate implementation due to:

3.1 The current fragmentation in the geodetic and geospatial information environment, and

3.2 The vulnerability of the HartRAO space geodesy programme in terms of human capacity.

This is a difficult issue; none of these scenarios provide a solution to the current 'dilemma'. Under 'SARAO', the programme will eventually become minimalistic; it already was a tough and lengthy process to build the programme to its current state within the HartRAO environment. Within the bigger, better resourced and better politically supported SARAO it is bound to experience additional organisational head-

winds, as it will be perceived to be non-core business. Even though there is top-level support at present, past experience has shown that this can change very quickly. This is outside of our control.

Placement within a consolidated national geodetic and geospatial environment would be ideal, but as this does not exist and is not likely to exist within the foreseeable future, this is (as the review panel points out) not a current option.

If the consolidated national geodetic and geospatial environment is to be pursued and established within a framework of 5 years, the current merging process must be re-considered, or else we will be merging and un-merging and merging again within this 5 year period, and considering that the current merging process has been with us since 2010, that will give us a 12 year "merging" period, which is untenable.

We fully appreciate the rationale behind the merger; it would appear that keeping the status quo is the more logical option.

1.4.2 The uncertainty of the future of HartRAO impacts negatively on staff's morale and productivity. For example, the current talks of a merger and having an acting director for two years have enhanced uncertainty, which is unhealthy.

We have tried to allay the fears of staff, and have requested higher level intervention to assist on this issue. The two year acting director status is unfortunate; it should rather have been for a specified period as 'director'.

1.4.3 The geodesy programme is severely under-resourced i.t.o. human resources, with current staff being overstretched by a large demand on time for operations and student supervision. This impacts negatively on research productivity. This is further exacerbated by the supervision of students from non-geodesy fields.

Agreed. This can only be remedied through additional funding, or we have to reduce our output.

1.4.4 The retention of staff and high quality students is problematic due to attractive alternative employment opportunities and the current lack of available posts at HartRAO. This also impacts on succession planning.

Agreed.

1.4.5 Although there is an active outreach programme, a comprehensive communication strategy that promotes the importance of geodesy among the general public and decision makers is lacking. This has impacts on the national recognition of the programme.

Agreed. There is no capacity for such a strategy. We have been active at various levels in the scientific community, locally and internationally, and this seems to be a global problem. The IAG Board had a strategic session during April 2016 to specifically discuss the visibility of geodesy. This type of intervention needs to be large, intensive and continuous, and will fit in well with the envisioned consolidated national geodetic and geospatial information environment.

1.4.6 A scientific advisory body that could guide and monitor medium to long term research strategies and goals is absent.

Agreed. We should establish such an advisory board, but would prefer it to serve the observatory as a whole, otherwise we could have a tug-of-war between astronomy and geodesy, which would adversely affect the facility.

1.4.7 The infrastructure of the facility is open to external users, especially for astronomy, while it is less so for geodesy due to commitments to global networks which control accessibility. However, the lack of capacity in geodesy at SA universities is also a limiting factor for external use.

We have made several links with universities, and have trained more post-graduate students in space geodesy than in the astronomy programme. The nature of the instrumentation and the mode in which they are useful does not lend itself to the same access model as astronomy. However, this does not preclude any university from approaching HartRAO towards submitting a collaborative project which could be submitted to any of the IAG Services, we would definitely support such an initiative if feasible.

1.4.8 The research staff profile in terms of race and gender is skewed relative to national demographics, but not out of line with other environments in the mathematical and physical sciences.

Agreed. We have lost very good students on completion of their PhD's due to lack of resources, if adequately funded, the situation would be quite different.

1.4.9 The student profile is quite good in terms of race and gender, which supports the transformation agenda.

Agreed.

1.4.10 The core grant of HartRAO is insufficient to achieve the objectives as set out in the mandate of a National Facility. The budget allocation is skewed in favour of astronomy.

Agreed.

1.5 **Commendations**

1.5.1 HartRAO is commended for the long history of international collaboration that brought important infrastructure to South Africa and enabled an important contribution to the global geodetic foundation.

Thank you for this comment.

1.5.2 The panel commends the Acting Director for making an exceptional effort to promote geodesy in South Africa and his ability to leverage international contributions.

Thank you for this comment.

1.5.3 The engineering and technical support is to be commended for the innovative and high quality work in an under-resourced facility.

We have an excellent engineering and technical support team, they often exceed our expectations.

1.5.4 HartRAO must also be commended for the outstanding effort in human capacity development in space geodesy, in particular considering the under-resourced environment.

Thank you for this comment. We see capacity building as part of our core mission.

1.6 **Key Recommendations**

1.6.1 South Africa continues to maintain a core geodetic station on the African continent as a major contribution to a globally mandatory infrastructure and service, which is compliant with the United Nations' resolution on global geodetic reference frames (Resolution 69/266). This is supportive of South Africa's efforts to implement the Sustainable Development Goals (Agenda 2030) and South Africa's leadership in organizations such as the Group of Earth Observations.

Agreed. We see this as one of HartRAO's core functions.

1.6.2 In the short term the space geodesy programme should be located as a division within the proposed SARAO with appropriate representation at the executive level.

Accepted with reservations as detailed previously.

1.6.3 The Department of Science and Technology and Department of Rural Development and Land Reform be requested to develop a national plan for the consolidation of the geodetic and geospatial information environment within a five-year time frame. In particular, this plan should address the future mandate and placement of the geodetic core station within an appropriate institutional arrangement.

Agreed. This will require adequate ring-fencing of all HartRAO's current core functions, budget, and international commitments as well as current and future developments, to ensure that the geodetic core station remains a fundamental station.

1.6.4 Recognizing the need for a strong and focused research programme at the geodetic core station, an immediate effort should be initiated to develop a research strategy in consultation with an international scientific advisory body. This research strategy should address both geodetic research exploiting the co-location of several geodetic techniques at the station and earth science research making use of the geodetic observations for societally relevant research.

Agreed. We would assume that adequate funding will be provided to ensure additional capacity for research so that research is not centred on student projects, which by definition, are based on short term, focussed topics of a certain complexity.

1.6.5 In the short term the space geodesy programme must be strengthened i.t.o. human resources through a redeployment of resources within HartRAO and the larger SARAO environments to prepare it for placement in a consolidated geodetic and geospatial information environment.

Agreed. It is however not practical to redeploy resources within HartRAO as this would adversely affect our efforts to build the radio astronomy programme. The radio astronomy programme should not be adversely affected. We would welcome resources from within the larger SARAO environment, but this would only be possible if excess capacity is available and feasible to transfer.

1.6.6 The NRF must immediately communicate the future of HartRAO to the staff to remove the current uncertainties amongst staff.

Agreed.

1.7 **Other Recommendations**

1.7.1 The immediate establishment of an international scientific advisory committee for the space geodesy programme to assist in developing a long term research strategy. Considering the strategic value of geodesy, this body should be retained after the placement of HartRAO within the SARAO structure.

Agreed. We would also like to assemble this committee to serve HartRAO as a combined astronomy/space geodesy observatory, so that we do not end up with a synthetic tug-of-war situation.

1.7.2 A comprehensive communication strategy that raises awareness of the societal benefits of geodesy among the general public and decision makers must be developed.

Agreed. This should be part of the national plan for the consolidation of the geodetic and geospatial information environment and should not be an isolated effort.

1.7.3 The demographic profile of the HartRAO space geodesy staff must be transformed through interventions such as:

- *Developing a culture of mentorship,*
- *Internships,*
- *Targeted bursaries,*
- *Support for young researchers in geodesy,*
- *Creating greater awareness of geodesy as a career, and*
- *Additional resources should be used to drive the transformational agenda.*

Agreed. All of these activities will require intervention from the NRF.

1.7.4 Create a user platform and mechanisms to engage and communicate with external users, for example the co-location of users' own instruments.

Agreed. This is done to large extent already, and we welcome any form of collaboration.