Safety & Security Applications from a Magnetically Clean Environment

SANSA Policy Brief

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Executive Summary

This policy brief is aimed at creating awareness of the value that an established and well maintained magnetically clean environment, operated by the relevant experts, can have for safety and security applications within a country such as South Africa. The main recommendation from this policy brief is that the South African government include the protection and preservation of the magnetically clean environment located within the town of Hermanus into the legislative framework. An additional six recommendations are made for the utilisation and maintenance of this unique infrastructure and capability.

The Earth's magnetic field is a key factor for accurate navigation and long-range weapons delivery, and is a dynamic, changing phenomenon. The impact of this natural phenomenon is that annual updates of the changing magnetic field as well as geomagnetic field models are required in order to ensure the accuracy of maps, and positioning information. The Earth's magnetic field is also an important influencing factor on aircraft landing compasses, and the navigation systems of dynamic platforms, such as unmanned aerial vehicles. Navy vessels at sea have specific magnetic signatures that provide a unique identification tag for each vessel, and knowledge of magnetism assists in protecting these vessels from harm.

Although this policy brief is mostly focussed on the benefits of a magnetically clean environment to the safety and security sector, it is also important to note that there are several other areas in which this unique environment plays an important role. These areas include applications for aerospace and maritime sectors (such as calibration of specialised coil systems, and corrosion identification), magnetic data availability for space weather applications, space industry applications and the prediction of hazards such as earthquakes.

Building on over 80 years of monitoring the Earth's magnetic field the South African National Space Agency (SANSA) has developed unique capabilities and a wide range of state-of-the-art equipment to provide specialised magnetic technology related services. SANSA's facilities in

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Hermanus are located within a well preserved magnetically clean environment, making the facility well suited for characterising and calibrating magnetic sensors, as well as identifying the magnetic signature of dynamic platforms prior to sensor integration. The magnetic observatory foundation ensures an accurate long term baseline of magnetic measurements, and access to established research on the space environment and the effects of the magnetic field on technological systems.

Knowledge of the magnetic signature of a specified mass, such as a marine vessel, is important to role players in the military and naval sectors.

Currently, the magnetically clean environment in South Africa is not protected by legislation, and is not well known. It is, therefore, important to put forward this environment as a national asset operated by SANSA and demonstrate the value of this asset to the country, as well as the importance of protecting and preserving the environment for optimum utilisation in the future.

Figure 1: SANSA operates the only large tri-axial Helmholtz Coil system in Africa. The system can create or cancel any geomagnetic field and is used to evaluate and calibrate various magnetic sensors and magnetic systems prior to being integrated onto dynamic platforms such as satellites and UAVs.

Introduction

Earth is surrounded by an invisible force field known as the geomagnetic field which protects humans and other life forms from the harmful effects of space weather. Without this field life on Earth would not exist. The geomagnetic field also plays a role in navigation and mapping applications as well as having an effect on technological systems. Monitoring and compensating for this field requires specialised facilities that are classified as "magnetically clean", meaning that no external magnetic disturbances are present. External magnetic disturbances could come from the presence of an electric railway line, pipelines, industrial applications of DC currents, vehicles, and building materials used or ferromagnetic anomalies within the geological structure.

The Earth's magnetic field is a key factor for accurate navigation and long-range weapons delivery, and is a dynamic, changing phenomenon. This means that there is a requirement for annual updates of magnetic inclination and declination to enable charts and maps to be updated. Magnetism is also relevant in other respects, the most obvious being the integration and calibration of magnetic compasses and other equipment with dynamic platforms such as aircraft, unmanned aerial vehicles (UAVs), ships or combat vehicles[1]. The magnetic signature of a dynamic platform is a critical factor, for instance in the case of a warship transiting potentially dangerous waters, and can also be used to deal with landmines or improvised explosive devices that use a magnetic sensor as a trigger or selective trigger[2] that is linked to the unique magnetic signature.

The defence sector require quality controlled services that support their magnetic navigation and protection needs. SANSA has developed unique capabilities and a wide range of state-of-the-art equipment to provide specialised magnetic technology related services[3]. SANSA's facilities in

Hermanus are located within a well preserved magnetically clean environment, making the facility well suited for characterising and calibrating magnetic sensors, as well as identifying the magnetic signature of dynamic platforms prior to sensor integration. There is no other such facility on the African continent. The applications made possible through this facility are due to the unique location and the development and preservation of this magnetically clean area. Therefore, it is necessary to create an understanding and awareness of the importance of the magnetically clean area to the nation, particularly with respect to safety and security. SANSA's space related expertise and facilities are also valuable to many non-space applications. This policy brief aims to put forward recommendations to assist decision-makers in understanding the importance of these unique facilities to many sectors in South Africa, and in particular with regards to safety and security.

Figure 2: SANSA developed and designed a Magnetic Test Bench which is used for verification of standby (emergency) compasses prior to installation aboard aircraft. The system won several local and international design awards and is used extensively by the SA Air Force.

Safety and Security Applications relevant to South Africa

From aircraft to ships at sea and satellites magnetic technology is utilised to characterise, calibrate and navigate dynamic platforms that use the Earth's magnetic field as a guiding compass. There are several key applications within the safety and security sector that require magnetic technology expertise delivered from within a magnetically clean environment.

Aviation is an important aspect of safety and security with factors such as safety of life operations, border control, and transport of critical supplies and personnel to strategic locations. The aviation sector is also a highly regulated industry with detailed requirements for relevant applications in the military, civil and private operations environment. A key application is that of the calibration of landing compass equipment for aircraft[4]. International safety regulations require that there be mechanical compasses on board all aircraft and marine vessels, for emergency loss of power conditions, in addition to the more modern Global Positioning System (GPS) systems with electronic compasses. The compass calibration procedure is a highly specialised procedure requiring scarce expertise and a magnetically clean environment to manually adjust the compass and compensate for the host platform's magnetism and alignment to the Earth's magnetic field. Furthermore, the calibration of these Landing or reference compasses can only be done in close physical proximity of magnetic observatory instruments (e.g. D/I inclinometer) and these instruments can only operate in a magnetically clean environment. The South African Civil Aviation Authority (SACAA) requires every aircraft landing compass to be calibrated once per annum. Linked to this is the procedure for aircraft compass swings; a procedure where the magnetism of the aircraft is measured and calculated and the aircraft's compass is adjusted accordingly. This procedure is usually only performed within a magnetically surveyed area.

Space know-how and infrastructure provides unique solutions to the non-space sector.

South Africa has the patent for a magnetic test bench that is currently deployed in many air force bases across the country, acting as magnetic navigation ground support test equipment for the verification of a mechanical compass prior to their installation in aircraft. Furthermore, this safety and security solution has optimised the calibration requirements for the air force, as well as being a cost saving device that saves money and time as well as allowing the air force some independence in adhering to regulations and safety of life requirements.

Similar procedures are required for the maritime sector although performing a compass calibration for a ship is a far greater challenge than that for an aircraft due to the large

vertical field of the super-structure on a surface vessel or the conning tower of a submarine[2]. Reducing the magnetism of a marine vessel is vital as it can trigger active sea-mines that can still be found in certain places at sea. Thus, it is in the interest of the South African Navy to measure and manage the magnetic signature of their vessels. Marine vessels are treated magnetically at a degaussing measurement facility, where deperming of the vessels and other systems is achieved by wrapping the vessel in copper coils and using high currents in a specialised procedure to reduce the magnetism of the vessel. Often additional components added to a vessel will alter the magnetic signature and a solution will need to be found where the component can be accommodated while maintaining the ship's magnetic identity and navigation capabilities. For example, a highly magnetised component could be placed on a ship for the purpose of protecting the vessel against small arms fire. Due to the high level of magnetism of the component the ship compasses would not be correctly calibrated, which would affect navigation at sea. The solution here would be to apply an external magnetic field to deperm the material of the component. The deperming process of vessels and other platforms is usually conducted on an annual basis however sometimes a platform can get magnetised so quickly that more regular deperming is needed. Factors such as heat, vibration, corrosion and lightning strikes can accelerate the rate at which a deperming is needed. Overall, SANSA's deperming services play a significant role in the country's safety and security.

Dynamic platforms, such as unmanned aerial vehicles (UAVs), contain various sources of magnetism, which need to be compensated for when integrating a magnetic sensor onboard. These magnetic sensors are required for navigation purposes, and the magnetic signature of the platform needs to be characterised prior to integrating the sensor. In addition, the sensor used should be applicable to the purpose and life time of the platform. This kind of integration can only be achieved within a magnetically clean environment and by appropriate expertise.

Due to the fact that the Earth's magnetic field is constantly changing there is a requirement to continuously update charts and maps utilised for navigation and positioning[1,2]. These updates require magnetic inclination and declination information that can only be derived from measurements taken within a magnetically clean environment. A division of the South African defence sector is dedicated to ensuring accurate mapping at all times. The magnetic information provided by SANSA contributes to the output of this division thereby contributing to safety and security across Africa.

An essential component to the applications required for the safety and security sector is the training of personnel within that sector. This training is required at all levels from the basics of magnetic awareness (why is the magnetic field so important for the daily job of protecting the country) to specialised training (how does the sector look at itself and its equipment within a magnetised environment). One area that is crucially important is meeting the requirements of the South African Navy for more qualified marine compass adjustors in South Africa. The aging experienced workforce in this area will soon retire, and these skills are critical for protecting South Africa's marine assets. Other important skills required are compass base surveying and compass calibration skills, particularly for those in the aviation sector including aviation technicians and pilots. SANSA provides this specialised training to the defence sector on an annual basis from its magnetically clean facilities.

The magnetically clean facilities combined with the unique geomagnetic expertise and knowledge is a formidable combination that can be utilised to solve a number of challenges within the safety and security domain in South Africa and the rest of Africa.

Figure 4: SANSA provides specialised training courses in magnetic awareness and compass swing procedure to the defence, maritime and aviation sector.

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Additional Applications relevant to South Africa

Although this policy brief is mostly focussed on the benefits of a magnetically clean environment to the safety and security sector, it is also important to note that there are several other areas in which this unique environment plays an important role. These areas include applications for aerospace and maritime sectors, magnetic data availability for space weather applications, space industry applications and the prediction of hazards. In addition, the benefits of a magnetically clean environment are seen in the research that is undertaken which lead to successful solutions and applications.

Hazard prediction is becoming more important and also more achievable internationally. The focus is moving towards the combination of different kinds of sensors, in order to provide a prediction of a certain hazard. One sensor that is currently being deployed is a Superconducting Quantum Interference Device (SQUID) magnetometer, which is utilised as a geosensor for research purposes[5]. This highly sensitive magnetometer can measure very faint magnetic signals, including possibly those created by seismic precursors to help predict earth quakes. A SQUID magnetometer must be operated in a magnetically clean environment where the level of external magnetic interference is zero in order to measure such faint magnetic signals.

Another spin-off is the development, construction and evaluation of coil systems for industry. Often clients in the aerospace and maritime environment require specialized coil systems that are positioned within their workplace – however, the calibration of these coil systems can only be done in a magnetically clean environment.

The space industry also benefits from a magnetically clean environment. Tests in a non-magnetic temperature chamber provide spacecraft manufacturers with knowledge about the temperature behaviour of magnetometers and torquer rods. This enables them to improve navigation and orientation functionality, such as positioning a satellite in its final geo-synchronous orbit around the Earth.

There are many applications within the field of space weather, which refers to the impact that the Sun, and by association the space environment, has on the Earth[6]. This impact is measured through the monitoring of the solar drivers, various parameters within the space environment, and the Earth's magnetic field. The measurements of the Earth's magnetic field can only be obtained from instruments that are operated within a magnetically clean environment. Therefore, the provision of space weather information to various sectors including but not limited to defence, aviation, maritime, and energy, can only be undertaken with access to a local magnetic data source.

Figure 3: SANSA is the only facility in Africa which is able to calibrate magnetic sensors prior to integration onboard dynamic platforms such as UAV's and satellites.

Magnetically Clean Environment in South Africa

The South African National Space Agency (SANSA)[7] operates a magnetically clean environment within its facility located within the town of Hermanus in the Western Cape of South Africa. The facility was previously known as the Hermanus Magnetic Observatory (HMO) and has operated as a magnetic observatory since 1940.

SANSA's facilities in Hermanus are well suited for characterising and calibrating magnetic sensors, as well as identifying the magnetic signature of dynamic platforms such as satellites and UAVs prior to sensor integration. With over 80 years of proven track record in delivering quality magnetic information for research, applications, and products and services, the facility is internationally recognised as a world class facility for magnetic technology and applications.

A magnetically clean environment can only be achieved in locations which are far away from the typical magnetic disturbances found in cities, away from DC electrical railway lines and situated in an area where no large magnetic gradients occur due to magnetized rock formations below the surface. The construction of buildings within a magnetic observatory must be non-magnetic in nature and the scope of activities conducted within the observatory requires an understanding of the impact on the environment1.

SANSA operates the following state-of-the-art equipment and infrastructure at the Hermanus facility, situated on a 16 Ha area that acts as a buffer against DC and low frequency magnetic disturbances:

- Large 2.4 m tri-axial Helmholtz Coil system used to evaluate and calibrate various magnetic sensors and systems.
- Zero-field (≤ 10 nT) magnetic shielding chamber for magnetic evaluation of sensors.
- Non-magnetic temperature chamber (-60°C to + 60°C) for functional temperature evaluation of magnetic sensors and other equipment.
- High temperature Superconducting Quantum Interference Device (SQUID) for the recording of very faint geomagnetic signals.
- A magnetically clean compass swing area for trials, and training.
- Various high sensitive scalar and vector research-grade magnetometers for measurement and evaluation of magnetic environments.

In addition, the facility maintains geomagnetic expertise that allow for accurate baseline measurements to be derived. These measurements are absolutely crucial for providing a magnetic baseline on which most applications can be built. The facility also develops bi-annual geomagnetic field maps that contribute towards the navigation and positioning applications within Africa.

As an example, the SQUID magnetometer is located in a magnetically clean hut, and is not shielded from the environment due to its main function as a geosensor. However, the SQUID is a very sensitive instrument and large changes in the magnetic field could cause saturation. Therefore, the SQUID needs to operate in a magnetically clean environment, away from industrial and other sources of magnetic disturbance. Even the smallest interference, for example, the movement of a wheelbarrow in proximity to the hut where the SQUID is housed, will create disturbances that will render the data (and by association any application) useless.

Maintaining a magnetically clean environment requires specialised expertise that can assess the impact that factors introduced into the environment would have. All buildings, tools, doors, and any component required for operating the instrumentation needs to be non-magnetic. For example, the absolute house where the main magnetic field measurements are recorded at SANSA is built around a wooden pillar which is mounted directly onto the bedrock. This is to prevent any movement (expansion or contraction) of the building to ensure the magnetic field measurements are not affected.

SANSA has the infrastructure and know-how to provide unique magnetic technology solutions to the safety and security sector.

A major risk to the environment often comes from external sources, where growth and development of industry within the town can impact the maintenance of the magnetically clean area. Hermanus does not have an electric railway system, which is what makes it an ideal town to host the SANSA facility. However, it is of utmost important that the local government structures understand the importance of this national facility, and assist in preserving its unique service offerings. Various examples can be cited of how local facilities can grow while still conserving the business of a magnetic observatory. One example is that of the private hospital located across the road from the SANSA facility. When the hospital installed a Magnetic Resonance Imaging (MRI) facility a few years back the hospital and the local municipality consulted with SANSA which resulted in additional shielding being added to the MRI construction. This allowed both SANSA and the hospital MRI facility to continue to operate within the same suburb in harmony. Activities such as jack hammer construction typically utilised for road building can also significantly impact the operations of the magnetically clean facility.

The SANSA facility is primarily a magnetic observatory, and the base functions that are essential for a magnetic observatory are also essential for delivering unique

products and services to the space and non-space sectors. The legacy of an 80 year old facility also provides a certain level of recognition and assurance of quality that is required for the safety of life operations that a magnetically clean environment contributes to. There is, therefore, a requirement for South Africa to preserve such an environment and the facility that provides the underlying expertise needed to operate and maintain this infrastructure.

Figure 5: The development of a maritime solution for vessel protection is just one of the examples of how a magnetically clean environment can benefit both the space and non-space sectors.

Recommendations

One of South Africa's national assets is a magnetically clean environment located within the town of Hermanus in the Western Cape, South Africa. The value proposition for this environment is primarily related to the utilisation of the magnetic data and infrastructure to safety and security applications. In addition, applications within the aerospace, maritime, and space sectors depend on this environment for solutions that cannot be obtained elsewhere. The maintenance, and operations of the magnetically clean environment, including geomagnetic expertise, is crucial for the continued delivery of essential products and services for the nation. This also demonstrates the importance of space related infrastructure to non-space applications, and is one of the roles that the space sector plays in ensuring the safety and security of the South African people.

The main recommendation from this policy brief is that the South African government include the protection and preservation of the magnetically clean environment within its legislative framework. One way to do this would be to expand the Astronomy Geographic Advantage Act (Act No 21 of 2007)[8] to include the Hermanus area and magnetic technology applications and research. In addition, the following recommendations are put forward within this policy brief for consideration:

- Research and Development within the field of magnetic technology is required in order to identify future safety and security solutions, and to provide a foundation on which challenges in the sector can be addressed;
- Appropriate regulations need to be strengthened and/or put in place, particularly with respect to aviation, that are aligned to international standards and govern the need for magnetic capabilities;
- The magnetic observatory facility in Hermanus should be declared a national resource, and should be considered for protection under appropriate legislation;
- The existing facilities should be expanded to support the growing local space industry, and to deliver international standards within one location;
- The unique expertise and know-how should be expanded to capture a share of the international market for magnetic technology related products and services;
- Training, education and awareness sessions should be held across the country to educate and create awareness amongst the affected industries of the role that this infrastructure can play in developing solutions to safety and security challenges.

These recommendations are put forward as a means to protect, preserve and grow a unique facility and expertise base that can continue to contribute to national requirements within South Africa and Africa. It is important to recognise the legacy of the Hermanus facility and the contribution that this facility has made to many sectors in South Africa over the past 80 years. This contribution comes

from the foundation of a magnetically clean environment which should be recognised as a national asset which requires continued protection.

Figure 6: SANSA training courses are hosted within the magnetically clean facility in Hermanus which allows participants to actively engage with the facility and expertise available.

Conclusion

This policy brief is aimed at guiding South African policy makers towards being in a position to recognise the contribution that a magnetically clean environment makes to the country, and the need to protect and preserve this environment. SANSA is in a position to work together with all the affected sectors, and government, to make provision for this protection as well as to ensure optimum utilisation of the infrastructure to provide safety and security solutions. The recommendations put forward in this policy brief would be the first point of consideration.

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