South African radar knowledge used in support of the acquisition of Swedish Gripen jets for the SAAF

On 30 April 2008 the South African Air Force (SAAF) received the first of its 26 new Gripen fighters, a two-seat aircraft. The Gripen is at the heart of the SAAF's modernisation plan with the acquisition of 17 single-seat and nine two-seat jets from the Swedish company, Saab.

The 4th-generation Gripen fighter is the first truly modern, front-line fighter aircraft owned by South Africa since the acquisition of the Mirage F1s in the mid 1970s. Throughout the Gripen acquisition programme, CSIR radar engineers Francois Anderson and Andre le Roux were involved in supporting the acquisition of the radar system, mounted in the nose of the Gripen.

Anderson explains that the radar is an essential part of the ears and eyes of the Gripen and greatly enhances the pilot's situation awareness. It is also used to launch and guide air-to-air or air-to-ground weapons and for aerial reconnaissance.

Anderson and Le Roux initially provided 'radar expert' support to the development of the SAAF User Requirement for their new fighter's multifunction radar. After the contract was placed on Saab, they supported the SAAF and Armscor during each of the phases of the radar part of the acquisition project. This involved many visits to the Gripen Joint Project Team and the facilities of the aircraft and radar industries in Sweden.

"This was a long phase that included attending design reviews; acceptance of verification evidence of radar functions and performance; development of the electronic counter-countermeasures definition and acceptance of its verification evidence. It also included the definition of SAAF radar data acquisition requirements; development of acceptance procedures for this capability and supporting decisions about changes in aircraft radome paint types, as well as aircraft radar cross section verification methods," explains Anderson.

In 2009, the Gripen radar acquisition support phase was finally concluded after 13 years. "In addition to the successful completion of the various stages of the acquisition programme, this work resulted in the SAAF now having access to detailed local knowledge at the CSIR regarding the multifunction radar in their new front line fighter," notes Anderson.

He says that both the SAAF and the CSIR have since received support on follow-up projects based on this knowledge. One example of this is the radar model of the tactics development tool developed by the CSIR for the Senior Staff Officer Air Capability Planning.

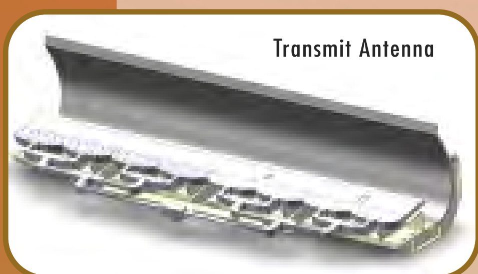
CSIR future plans include continued support to the SAAF as users of this advanced technology radar. "The aim is to support the development and evaluation of tactics, doctrine and standard operating procedures designed to provide SAAF pilots with the winning edge in their missions in Africa," says Anderson. He reports that all nine dual-seat Gripen aircraft had been delivered and 17 single-seat aircraft would be delivered in batches until the third quarter of 2011.

One of the key subsystems of a modern fighter jet is its multifunction radar. It provides vitally important situation awareness to the pilot, measured target state vectors for accurate air-to-air and air-to-ground weapon delivery and radar imagery for all weather, day and night reconnaissance. Being such an important contributor to mission success, it is critically important for the acquisition team to ensure that it will provide the specified functions and performance under all conditions expected during missions in the probable African operational scenarios and to continue to do so even when faced with an enemy's electronic countermeasures. Such a radar is one of the more complex subsystems of a modern fighter and can contribute as much as 25% of its total cost.

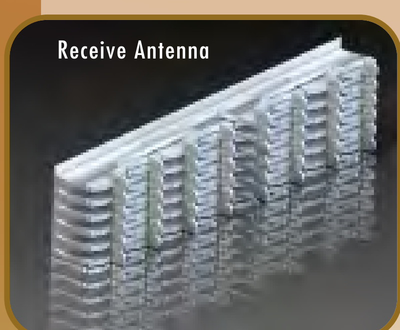
A Gripen photographed over Cape Town. Copyright: Gripen International Photographer: Frans Dely

Collaborative radar technology development programme reaches important milestone

In what was probably the largest collaborative radar technology development project ever undertaken in South Africa, the DBR-XL Radar Technology Development Programme reached an important milestone during February 2010.



18 Channel Receiver



DBR-XL CONCEPT DEMONSTRATOR (as on 24 February 2010)

Images courtesy Reutech Radar Systems

DBR-XL is an abbreviation for a radar system that operates simultaneously in two electromagnetic frequency bands (hence Dual-Band Radar), in this case, the so-called X and L bands.

THIS WAS A DEPARTMENT of Defence-funded technology development programme conducted over five years. The aim was to develop multi-target 3D surveillance and target designation radar technology based on the SA Army GBADS phase 2 requirements for a combined battery and missile fire Control Post.

The project included the CSIR, Armscor, the universities of Cape Town and Stellenbosch, industry stakeholders such as RRS, Denel Dynamics and Denel Integrated Systems Solutions (DISS), and the SA Army GBADS Programme Office.

In February 2010 the second phase of this project was concluded with a final joint project progress meeting and then a major demonstration of the hardware developed at RRS. The CSIR presented its independent assessment as radar technical specialists with many years of experience of the use of radars in air defence systems.

Representatives from DISS commented that the integrated systems modelling showed that the DBR-XL concept was superior to all overseas offerings modelled and Denel Dynamics indicated that the radar would be suitable as a missile fire control radar for the current model of the Umkhonto missile as well as all future models.

The CSIR's role in this project included providing independent evaluation of the technical concepts based on previous radar and GBADS experience and detailed radar and algorithm level modelling and simulation; developing optimised signal processing algorithms; participating in missile fire control system level performance analysis workshops; and providing specialist input based on its MARS and LYNX radar signal processor design and development experience.

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Andre le Roux and Francois Anderson

Ensuring optimal handling of the Gripen aircraft

During the much anticipated 2010 FIFA World Cup, soccer fans will have their eyes firmly fixed on events unfolding on the fields. However, it is not only events on the ground that will be closely monitored. The Gripen combat aircraft is a key component of the South African National Defence Force's (SANDF's) security plan for the World Cup, and will be responsible for identifying and intercepting any unknown aircraft entering the airspaces surrounding stadiums.

Technology applications have come a long way, from this 1970's technology Mirage F1CZ aircraft which is now retired in front of the CSIR's aeronautical research building, to today's sophisticated Gripen aircraft. The CSIR's Dr Bennie Broughton has been instrumental in helping to develop a local capability in understanding and evaluating the complex digital flight control system used in the Gripen, pictured right. Both images copyright Gripen International. Photographer Gripen image: Frans Dely.

THE GRIPEN is by far the most sophisticated and technologically superior combat aircraft operated by the South African Air Force (SAAF) to date. In comparison with previous fighters it boasts better performance, new sensors, weapon systems, communication systems, electronic warfare equipment and many other fully integrated subsystems. The Gripen is a true swing-role fighter designed for air-to-air, air-to-ground and reconnaissance missions, and is capable of switching roles with the mere flick of a switch. However, the human pilot remains responsible for interpreting the information that he/she receives.

Pilot workload

Dr Bennie Broughton, principal aeronautical engineer at the CSIR explains, "Although the Gripen probably has one of the most sophisticated human machine interfaces in operational fighters today, dealing with the sheer number and sophistication of subsystems can be incredibly demanding for the pilot, especially during combat operations. The pilot must be able to interpret information and make tactical decisions to complete the mission in the most effective way, with the least amount of risk to himself/herself and other friendly forces."

It is thus crucial that the aircraft is easy to fly, allowing pilots to focus their attention on the tactical situation. To achieve this, the aircraft was equipped with a fly-by-wire (FBW) control system to enable what is known as 'carefree handling'.

Flying qualities

Flying qualities are the characteristics of an aircraft that govern the ease, precision, and safety with which a pilot is able to perform a mission. The Gripen differs from conventional aircraft in several important ways. Conventional aircraft are aerodynamically stable, which means that they have a natural tendency to return to the trimmed condition after a disturbance and pilots only need to make occasional corrections. These aircraft have direct mechanical links between the control stick and control surfaces, and control surfaces move in direct proportion to the control stick.

In contrast, the Gripen was designed to be aerodynamically unstable to improve aircraft performance, and cockpit controls are not mechanically linked to control surfaces. Instead, the control stick position is sent to a computer which then uses sophisticated feedback sensors to apply the correct control surface deflections. The FBW control system is responsible for stabilising the aeroplane by continually making small corrections and for interpreting pilot inputs. In this way, the FBW computer essentially 'flies' the aircraft.

This has several advantages for design engineers and pilots. For design engineers, it provides more freedom to optimise other aspects such as performance during the initial design stage, as flying qualities can to some extent be ignored. As this system is software driven, the manufacturer can make small improvements throughout the life of the aircraft, although these must be evaluated to ensure that improvements in one area do not interfere with other areas. For pilots, it means that aircraft flying qualities can be optimised for the task at hand. However, if the control system computer fails, the aircraft becomes unflyable and the pilot has to eject.

The role of the CSIR

Because fighter FBW systems were new to South Africa, the CSIR was called upon to establish the knowledge base required to understand and support this new technology.

The project aimed to:

- Assist the SAAF in becoming knowledgeable users to interact properly with the original equipment manufacturer
- Determine areas that require special attention on FBW equipped aircraft and identify shortcomings
- Develop test and analysis techniques for evaluating Gripen flying qualities
- Develop a process for dealing with aircraft in which flying qualities are changed by software.

Since 2004, engineers at the CSIR and the SAAF have collaborated to address these challenges, and have made considerable progress. A custom flying qualities reference specification for the Gripen in SAAF service has been developed, taking engineers through a systematic process of evaluating each flying qualities aspect. New test and analysis techniques have been developed with the unique control system in mind. This required original work because information is often not shared on an international level due to security and intellectual property concerns. Currently, the team is in the process of baselining the aircraft as delivered to establish a dataset for comparison to future software upgrades or other changes.

Impact

The project had a great impact on the acquisition and operational development process of the Gripen within the SAAF. The team successfully identified certain shortcomings which were either rectified by the manufacturer, or communicated to pilots to promote safe and effective flying.

The CSIR will continue to provide new insight into flying qualities and related disciplines, while spin-off technologies such as the systems identification work (a new analysis method developed for the Gripen) will be used in other areas such as unmanned aerial vehicle programmes.

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Gripen fighter aircraft to benefit from desktop tactical simulation tool

With the acquisition by the South African Air Force (SAAF) of a number of fourth-generation JAS-39 Gripen fighter aircraft, the tactics employed to date by the SAAF to safeguard the nation need revision.

WHILE THE GRIPEN BRINGS WITH IT a number of advanced capabilities, including higher levels of situation awareness and the ability to share information over a data link, it also calls for new tactics and standard operation procedures to be devised. This can be an extremely costly exercise, but one cost-effective way of doing this is to develop these tactics in a simulated environment. Such a synthetic environment is currently under development at the CSIR in the form of a desktop tactical simulation tool.

Gus Brown, research group leader of computational aerodynamics at the CSIR, states, "In the past, we were able to provide support with the acquisition of new aircraft and systems allowing the nation to become a 'smart buyer' of technology. Now, we must provide insight for operational support so that we can also become 'smart users'."

Unlocking fourth-generation aircraft capabilities

The SAAF aims to unlock the fourth-generation capabilities of Gripen fighter aircraft in a phased approach. The CSIR was asked to assist in the first phase, which involved the creation of a desktop tactical simulation tool. This tool was intended to create an environment in which different concepts on aircraft posturing could be tested and evaluated without access to expensive equipment becoming necessary.

Once a number of promising concepts are selected, the next phase will involve setting up suitable missions to evaluate the newly-created postures in the Mission Support System (MSS). The MSS, which was provided by the Gripen manufacturers, is a tool for mission planning, simulation and analysis. Pilots plan their missions on the MSS, and the information is then transferred to the aircraft so that the pilot can view the information in the cockpit. After the mission, the MSS can play flights back in real time to evaluate success of tactics.

Thereafter follows test-flying these missions in the Squadron Level Mission Trainer (SqLMT). The SqLMT comprises two flight simulators that the Gripen manufacturers provided along with the aircraft. These simulators replicate the interior of the Gripen, with a full dome and representation of the cockpit. Missions can be flown on the simulator to practise various tactical manoeuvres and situations. Ultimately, missions will be flown in the real aircraft, at which stage costs increase substantially.

Development of a desktop simulation tool

While the MSS and SqLMT are effective tools for developing and practising new tactics, they have some practical limitations with regard to accessibility and cost. Both the SqLMT and MSS are located at the Air Force Base Makhado, Limpopo province, and can be accessed only if pilots are physically at the airbase. They are also more expensive to operate than a desktop tool. Another consideration was that the MSS contains sensitive information and thus cannot be distributed widely. The SAAF wanted another system that it could access easily and use freely.

Brown states, "Because the costs associated with each subsequent phase grow exponentially, it is important that every effort be expended to gain as much knowledge and understanding as possible before proceeding to the next stage. Thus, the development of an effective mission simulator to be used in the first phase could greatly improve efficiency and reduce the cost of the whole process."

The desktop tactical simulation tool is the perfect solution, as pilots can install it on a portable but secure laptop, develop concepts there and refine them before moving on to the MSS, SqLMT and finally, the aircraft. This allows the SAAF to gain a good understanding of the new technology in an environment that encourages creative thinking.

The development of the desktop simulation tool required the cooperation of various individuals and organisations in the defence arena and the integration of a number of multidisciplinary skills. Brown explains, "Because the simulation tool had to simulate missile performance, radar and flight, we needed to gather information from aircraft, missile and radar suppliers. This was really a group effort combining skills and knowledge from within the CSIR and from external sources."

He concludes, "This exercise serves as a good example of how the CSIR continues to play an important role in bringing together different role players for the benefit of the nation's safety."

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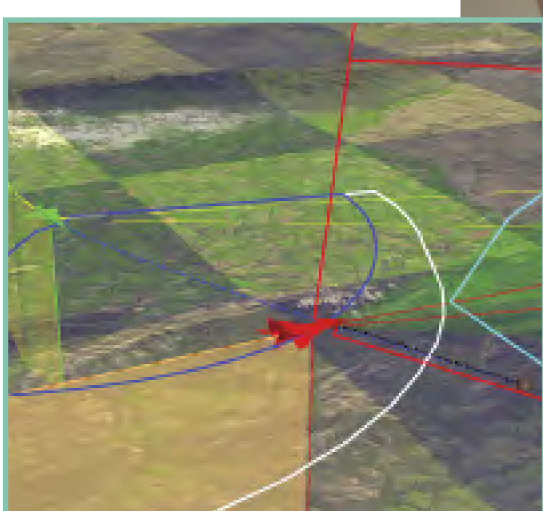

The two images left depict a fighter aircraft approaching a pair of Gripens on patrol. While the enemy aircraft appears to have the upper hand, a third Gripen uses its 4th-generation capabilites to sneak up for a successful intercept. These simulations were undertaken in a simulated environment developed by CSIR researchers. Pilots and tacticians are able to use the desktop environment to evaluate various tactical postures. Pictured above is Gus Brown, research group leader for computational aeronautics at the CSIR who heads up the team that is helping South Africa's air force to be smart users of cutting edge technology.

Making the most of the fifth-generation missiles of SA's newly acquired Gripens

TAKING HELMET-MOUNTED DISPLAYS A STEP FURTHER BY MASTERING 'OVER THE SHOULDER' SHOTS

OVER THE PAST FEW DECADES, there have been significant advances in short-range infrared air-to-air missiles. When they were first introduced in the late 1950s, they could only be fired from directly behind the target aircraft after the seeker had locked onto the target. While second and third generation missiles saw improved seeker performance, they still lead to classic dog-fight scenes as depicted in movies such as *Top Gun*. In fourth generation missiles there were dramatic improvements in agility and seeker sensitivity, and helmet-mounted displays (HMDs) allowed the pilot to merely look at the target and fire the missile. Fifth-generation missiles are characterised by even greater seeker sensitivity and resistance to countermeasures such as flares. A lock-on-after-launch capability further improves their versatility.

The new Gripen aircraft recently acquired by the South African Air Force (SAAF) are armed with fifth-generation missiles, and pilots are equipped with an HMD targeting system. The JAS 39 Gripen fighter utilises the Cobra HMD, which was developed by BAE Systems, Denel Optronics of South Africa and Saab.

Helmet-mounted displays and firing 'over the shoulder'

The HMD projects key aircraft information such as airspeed, altitude, target range, threat and engagement data directly onto the pilot's visor. This means that the pilot does not have to continually look down at the instruments in the cockpit, which greatly reduces pilot workload and increases ease of flying. The HMD also uses the pilot's head angle as a weapons targeting system, so that he can fire at anything he can look at. This provides tactical advantages because it reduces the amount of necessary aircraft manoeuvring, provides greater situation awareness and increases chances of pilot survival.

Gus Brown, research group leader of computational aerodynamics at the CSIR, explains, "The important thing about our new fighter aircraft is that the pilot never has to take his hands off the two control sticks because he can see all necessary information in the HMD. In whichever direction he turns his head, he can still see the information on the visor. However, one important problem remains: the missile can only see what is in front of it, while the pilot can turn and look over his shoulder to see what is behind him. In a dog-fight situation, the first to fire is likely to be the one who survives. The obvious question is thus: can the HMD be used for 'over the shoulder' targets when aircraft are outside of the missile seeker view limits?"

In this case, the aircraft would use inputs from the HMD to guess where the target is and communicate this information to the missile prior to launch. The missile would then have to turn towards the estimated location of the target and lock-on-after-launch.

New guidelines for the SAAF

While the combination of fifth-generation missiles with HMDs provides significant tactical advantages, new technology always calls for updated guidelines to maximise effectiveness of use. Major General Des Barker, CSIR aeronautics manager and former SAAF fixed-wing test pilot, explains, "Engineers have provided fighter pilots with such 'smart technology' that a completely new set of tactics and standard operating procedures had to be developed to maximise the lethality of fifth-generation missiles without placing the wingman in danger. "

The SAAF thus called upon the CSIR to explore 'over the shoulder' scenarios and provide it with guidelines on using the HMD to designate off bore-sight targets. Brown states, "We needed to establish some rules of thumb to help pilots understand when they can fire a missile in this scenario, and when they shouldn't. We needed to establish which parameters were important for the success of shots, what type of missiles could be used and how pilots could avoid being hit by 'over the shoulder' shots."

The CSIR used its modelling and simulation expertise to build a computer simulation to

The Cobra helmet, as used in the SAAF's Gripens, can display critical data directly onto the visor and tracks where the pilot is looking. Displaying information on the pilot's visor means that the pilot does not have to continually glance down at the cockpit instrumentation while the head tracking allows aircraft sensors to be automatically directed towards targets of interest.
Images copyright Gripen International
Photographer: Katsuhiko Tokunago

study this scenario. This allowed the evaluation of a large number of different conditions and parameters, which were used to build up a good understanding of the important factors involved. Different guidelines were drawn up for specific manoeuvres and situations, taking into account distances between aircraft, flight speed and range, which all affect how much time the pilot has to launch a missile. This also has implications for missile design, as the better the manoeuvrability of a missile, the higher the chance of success.

The study covered a number of different manoeuvres including the 'blow-through', the 'scissors' and the 'chase', and a set of guidelines for the SAAF was successfully compiled. Brown states, "Various rules of thumb were derived for the use of fifth-generation missiles in 'over the shoulder' firing, giving the SAAF confidence about the performance of its new missiles."

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CSIR-designed flutter-flight test equipment to be used as SA jets prepare to carry new stores

BY LOUW VAN ZYL

The CSIR's Louw van Zyl, pictured at the CSIR's high-speed wind tunnel. Picture top right is the CSIR-developed flutter exciter. The CSIR has been supporting the South African Air Force in flutter testing since 1978

The South African Air Force (SAAF) is in the process of upgrading its training and fighter jets. However, these aircraft will be required to carry new weapons and sensors as new threats and countermeasures evolve. The CSIR has set out to assist in meeting potential new challenges relating to flutter.

THE INTRODUCTION of new external stores on an aircraft always involves the risk of flutter, a self-sustaining structural vibration that can destroy the aircraft in a second.

The introduction of a new store therefore involves a flutter clearance process: first the structural dynamic properties of the aircraft with the new stores attached are determined, then an analysis is performed to determine whether there is a risk of flutter within the intended operating range of the aircraft with the particular stores and finally the analysis is confirmed in a flutter-flight test.

Flutter-flight testing involves 'shaking' the aircraft while it is flying at a constant speed. The structural response is measured using a number of accelerometers distributed over the airframe. The response of the structure is analysed to determine whether a sufficient safety margin exists between the test speed and the flutter speed. If the safety margin is sufficient, the speed is increased and the process repeated.

Shaking an aircraft in flight is quite a challenge. In the past, the SAAF had a flight test Mirage F1 with an aileron excitation system installed for this purpose. On the Cheetahs, an external rotating cylinder excitation system, mounted under the wing, was used.

Over the past decade the CSIR has been involved in a number of flutter-flight tests of civilian aircraft and developed a very simple and effective system that utilises a rotating annular wing.

Compared to inertial excitation systems, an aerodynamic exciter is more effective at low frequencies. Control surface excitation, on the other hand, becomes less effective at high frequencies due to the inertia of the control surface. Since the rotating annular wing rotates rather than oscillates, it does not lose its effectiveness at high frequencies.

The rotating annular wing exciter is built into the flutter-flight test dummy of the store that needs to be tested. This does not require any structural modification to the aircraft. Some wiring needs to be installed, but once it is installed to a particular store station, it can be used for any store to be carried at that station.

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Developing knowledge for weapons integration on aircraft

Weapons integration (WI) on aircraft is crucial for the defence of any country. But as CSIR researcher Sean Tuling explains, the engineering process to achieve this requires electrical, mechanical, structural and aerodynamic knowledge.

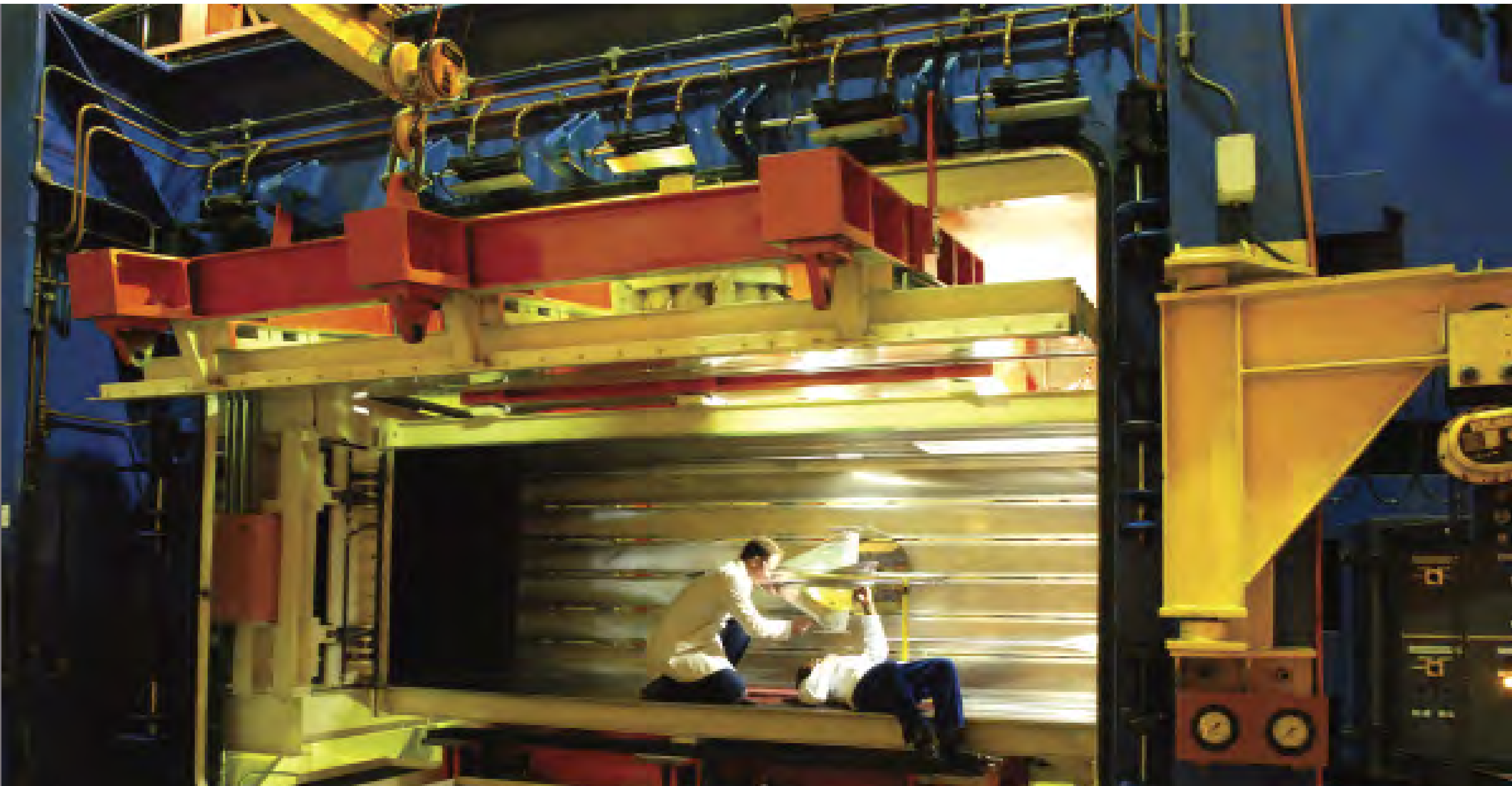
THE SOUTH AFRICAN AIRFORCE (SAAF) can effectively control risk areas, such as South Africa's borders, through weapons integration. Many weapons are engineered to be integrated into aircraft, where they can be carried and released safely and utilised to perform optimally. Furthermore, the ability to deliver a weapon by an aircraft has been recognised as a force multiplier for any armed force as it makes it possible to maintain and improve security with fewer aircraft.

The CSIR has developed and continues to develop a specialised WI capability, providing the SAAF with aero-mechanical knowledge and expertise used primarily to help define the aircraft carriage and release armed envelopes.

"Armed forces and operators interested in carrying and delivering a weapon need to know whether the aircraft is physically able to carry the store and whether the aircraft is structurally strong enough to do so," notes Tuling.

In addition, armed forces assess how the performance and handling of aircraft are affected by the weapons that have been integrated and whether the flexibility of the aircraft and the aerodynamics have been affected adversely. "If need be, the limits of the flight envelope (i.e. the capabilities of the design regarding speed, load or altitude) need to be determined."

When the weapon is being released, operators want to know whether it will do so safely, without striking the aircraft and whether it will



The release of a store off a South African Air Force Hawk is simulated in the image top left. Above: Two CSIR engineers prepare for the testing of a model aircraft in the CSIR medium-speed wind tunnel. Pictured in the inserted photograph is a store release validation, undertaken in the medium-speed wind tunnel at the CSIR, using generic parent and store models. Sean Tuling (right) of the CSIR says an aircraft's aerodynamics influences the trajectory of a weapon when it is released

be delivered accurately, as the aircraft aerodynamics may adversely affect its trajectory. “We take into account four primary areas: carriage, flutter, performance and handling, and release or separation,” adds Tuling.

The CSIR has a well-established record of performing aero-mechanical analysis and flutter-flight testing for WI programmes. “We have developed a variety of validated tools, processes and analysis expertise to support these programmes,” he says.

What typically occurs in a WI programme? “A standard integration programme would initially use an efficient, although less accurate aerodynamic tool, to determine the initial carriage and release envelopes and to identify problematic areas,” explains Tuling.

Then, more expensive methods are used to gain insight into the processes to refine the initial predictions made by engineers. Experimental techniques, such as the use of wind tunnels, are used to validate and fully characterise initial predictions. These forecasts are used as a basis for the flight tests, which further refine the aerodynamic predictions and finally define the carriage and release envelopes.

Ultimately, the CSIR is moving towards a more fully-integrated, model-based approach, where data from all sources, including the flight test, are used to develop a carriage and release model for the final carriage and release envelopes. This approach will allow the weapons integration process to be performed in a more efficient manner, ultimately reducing costs for the SAAF,” says Tuling.

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KNOWLEDGE BASE ON GAS TURBINE TECHNOLOGY

a prerequisite for cost saving and safety of air force aircraft

BY GLEN SNEDDEN

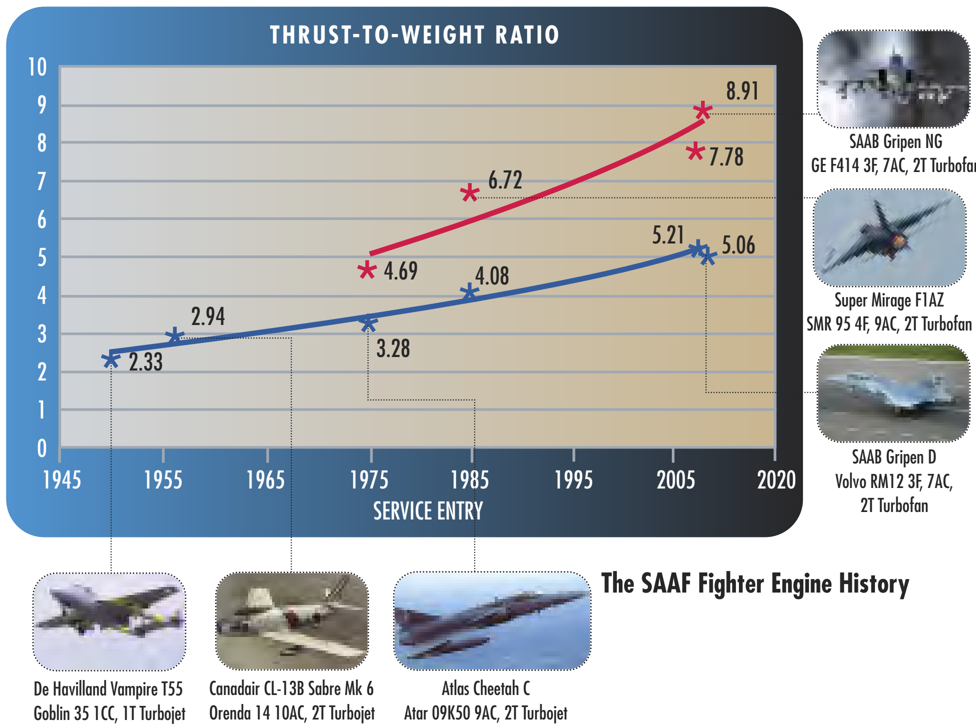
Detailed engineering analyses of the cooling systems of the gas turbine engines of the South African Air Force have contributed to the mitigation of cost and potential risk. It has also helped in making the best decision in terms of maintaining existing systems and procuring new technology.

THAT GAS TURBINE ENGINES are a main driver in the operating cost of an air force, is undeniable. In 2003, fuel cost alone made up roughly 72% of the operating and ownership cost of the Cheetah fleet of the South African Air Force (SAAF). Much has changed since 2003: the fuel price has risen sharply and new equipment is being introduced into the SAAF service, offering dramatic performance improvements – as is evident in the steady evolution in the thrust and thrust-to-weight ratio since South Africa's introduction into the jet age in the early 1950s.

The Goblin 35 engine introduced to the SAAF with the Vampire was a natural development of Sir Frank Whittle's first engine and although he may have conceived the gas turbine as a simple engine mechanically, it is enormously complex in many other ways. It operates at temperatures above the melting point of the best super alloys and at pressure ratios almost eight times higher than the Goblin 35, the Gripen's Volvo RM12 and Hawk's RR Adour 951. It represents a huge leap forward in technology and performance/capability for the SAAF, as well as in terms of the safety and maintainability offered through the engine design philosophy and the addition of health and usage monitoring systems (HUMS) and full-authority digital engine control (FADEC) systems.

The price of this leap in performance comes in subtle ways: on condition maintenance; and access to detailed HUMS data means that many more hours are spent performing detailed inspections and examining data. In short, the engine operator is forced to interact both with the machine and with its manufacturer at a far higher level of engineering than before, making access to knowledgeable people to mitigate both the costs and potential risks as they arise, imperative.

This requirement has led to the CSIR, in partnership with Armscor, maintaining the knowledge base in gas turbines, particularly focusing on the components most affected by South Africa's unique hot and high-operating conditions. The investment, equivalent to just 2% of the projected annual fuel bill for the Cheetah fleet in 2003, not only saw direct benefits to the SAAF in terms of acquisition support activities, but also through cost and risk mitigation as a result of detailed engineering analyses of the C130's T56 engine secondary cooling system in conjunction with Rolls Royce, Atar Plus, developments with Snecma, and the Klimov SMR-95 programme.



The SAAF Fighter Engine History

In addition, more than a third of this money goes into one of the largest targeted schemes supporting postgraduate research in South Africa, funding up to nine PhD and MSc/MEng students each year at various universities since the mid 1990s. While the impact of this human capital development programme is hard to quantify, it has trained a large number of engineers not only for the local aviation industry, but for industry in general. As testimony to the quality of this programme, some of its graduates can be found as far afield as the US Navy Postgraduate School and Rolls-Royce, to name but a few.

One of the keys to the success of this investment has been the ability of the CSIR to leverage the investment made by the SAAF to gain entry to other markets – and in so doing – being able to offer a much-enhanced capability to the SAAF without inflating costs. The CSIR's successful entry into two European Union Framework Programmes bears testimony to this.

As to the future, the CSIR and its partners are ready to render support to the SAAF as it continues to implement new equipment. At the same time, the technology is being made available to the local industry in support of the micro gas turbine industry. The aim is to develop this embryonic industry into a competitive force on the international market. Further spin-offs include an effort to maximise the renewable energy potential inherent in South Africa's solar resources.

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WORLD-CLASS RESEARCH INFRASTRUCTURE CONTRIBUTES TO SAFE AND SECURE SOUTH AFRICA

BY MAURO MORELLI

EXPERIMENTAL AERODYNAMIC researchers at the CSIR have built a solid track record in the early design processes of air-to-air defence systems and unmanned aerial systems (UAS). These are designed to provide tactical superiority during threat situations to our national security. More recently, research input was given during the design phase of the modular UAS as part of a broader research theme into integrated environments used to develop security systems for the 2010 World Cup, and, in a separate project, during the design phase of missile airframes by the local defence industry. World-class research infrastructure in the form of wind tunnels is indispensible in these endeavours.

The CSIR operates a suite of remarkable wind tunnels. Built over a period of 30–35 years and culminating in 1989 with commissioning of its flagship wind tunnel, the transonic medium-speed wind tunnel (MSWT), this suite of tunnels has provided an experimental foundation for the aerodynamic design efforts of the South African aeronautical industry in general.

The purpose of a wind tunnel is to simulate the flow environment encountered by an aircraft during flight. The wind tunnel generates 'wind' or airflow over a static airframe supported in a controlled test environment (test section). Instrumentation in or on the supported test item provides the data with which the aerodynamic behaviour of the airframe at various flow speeds and attitudes are measured.

Airframes ranging from lower subsonic speeds such as gyrocopters, helicopters, UAS and military trainers, to transonic type airframes such as lower speed missiles and combat aircraft and supersonic airframes of high speed missiles – including projectiles flying at more than four times the speed of sound – have been tested in these facilities.

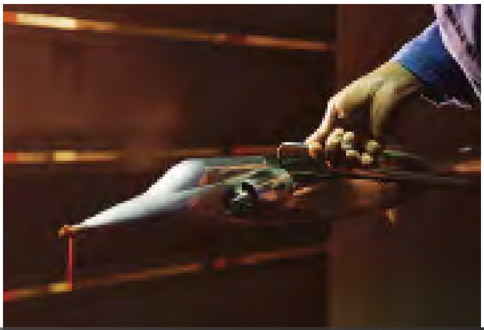
Interest from further afield

Furthermore, growing recognition has led to the CSIR wind tunnels receiving interest from international organisations. One such important collaboration is with the King Abdullah City of Science and Technology in Saudi Arabia (KACST). Work between the CSIR and KACST in the arena of aeronautical sciences will require wind tunnel data as an input to an airframe design process. This data will be used to populate a modelling and simulation environment for broader mission simulation predictions.

The CSIR's facilities are regularly used by academic institutions for their undergraduate research programmes as well as postgraduate studies. These collaborations form the basis for a new strategic outlook where this infrastructure will be made available, in a structured manner, to tertiary education institutions with aeronautical interests. It will also include ways of reducing utilisation costs to the South African aeronautical industry and allow the systematic use of this research infrastructure early in the development phase of aeronautical products.

Cost benefits to industry

The wind tunnel provides an optimal tool to study and determine performance predictions early in the design phase where airframe aerodynamic behaviour can be predicted rapidly and at relatively low cost, and later in the development cycle to provide extensive performance characterisation. Another important use of wind tunnels is the validation of computational and empirical methods before application of these methods in productive development processes. The complementary use of computational and experimental methods in aerodynamic research enhances the understanding of flow phenomena and spills over into the development of new simulation techniques reducing the risks in the predictive phases of airframe design.



Pictured left are CSIR engineer Tim King and wind tunnel assistant Robert Mokwebo, installing a 1:12 scale Cheetah model in the CSIR's medium-speed wind tunnel test section. Pictured clockwise from top left are a view of the medium-speed wind tunnel and the high speed diffuser, the CSIR's Mauro Morelli, the 7m wind tunnel wind generation fan matrix and a 1:15 scale Mirage F1 model installation in the test section

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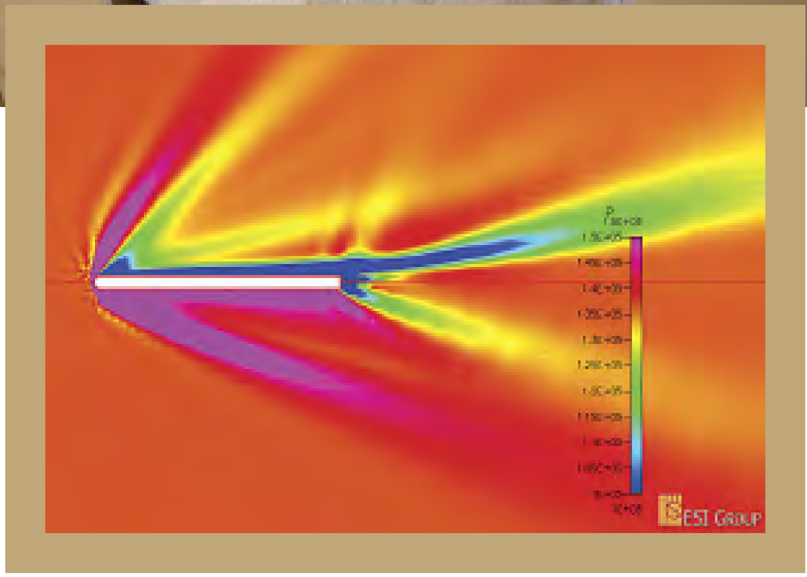
Pulling g's – the science of acceleration

Fighter aircraft are noted for agility and for being able to out-manoeuvre an opponent. Missiles are even more nimble, and a constant battle is waged between more responsive countermeasures and swifter missile tactics. Generation IV and V missiles turn at up to 100 g (g being the acceleration of gravity). The CSIR and its partners, set out to discover whether the aerodynamics of fast manoeuvre could be predicted.

FOR MOST PURPOSES, constant velocity or constant rotation is a good enough assumption for most aerodynamics. Dynamic derivatives are a tool routinely used in flight dynamics. But as missiles get smaller, and unmanned aerial vehicles execute more demanding missions, we move into regimes where the effects are significant and can no longer be ignored. We want to predict accurate aerodynamic loads in arbitrary manoeuvres with severe acceleration.

The CSIR, the Swedish Defence Research Agency and the University of the Witwatersrand have been working together to develop a rigorous prediction method. "The numerics pose some difficulties," says CSIR physicist, Dr Igle Gledhill, "but we have found a simple way of capturing the effects of aerodynamics of fast manoeuvres."

In a paper in *Aeronautical Science and Technology*, the collaborators showed the validity of the scheme and applied it to a missile with strakes (i.e. thin projecting plates) in a sharp turn. "This is a challenging case, because vortices spin off sharp strake edges as well as moving across smooth curved surfaces. The disruption of control surfaces by vortices is well-known, but their movement under acceleration provides new challenges. Control and guidance systems will deal with most interference, and understanding the flow fields provides valuable insight," Gledhill adds.



Pressure waves (legend in Pascals) surround a simple missile moving at Mach 2 in a 300 g turn

Gledhill says these investigations become important in the case of missiles – in the range of 100 g and upwards – a regime which designs are approaching.

She says aerospace engineers have known for many decades that drag forces increase dramatically near the speed of sound. The recent study has shown that if the motor thrust takes the missile through Mach 1 at high acceleration, this sonic drag can be reduced.

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Flying unpiloted in the conflict zone and into civilian territory

A DISRUPTIVE TECHNOLOGY is something that will forever change the way we do things. It is what cellphones, email and the internet did to the way we communicate. It is how unmanned aircraft systems have forever changed the face of warfare and peacekeeping.

Internationally, unmanned aircraft systems (UAS) are beginning to change the priorities in acquisition programmes. This is based on the success of unmanned systems in current operations. A war target on the battlefield is now often taken out with clinical precision – and minimal collateral damage – by someone in an air-conditioned office in a city far away from the conflict zone.

UAS have made this possible. They are, essentially, complex aeroplanes flying autonomously, under remote control. And before you let your mind wander to the model airplane your dad bought you when you were 10 – these are far more sophisticated. The larger UAS fly above commercial airliners, nonstop for more than 24 hours. Other micro UAS are as small as your hand and able to carry intricate cameras for surveillance within office complexes.

South Africa is already manufacturing and exporting smaller UAS – through Denel UAS and ATE. In fact, South Africa was one of the first countries to adopt this technology in the 1980s.

The CSIR's Beeuwen Gerryts says that the safety of South Africa's population and natural resources could be drastically improved with the use of UAS in the not too distant future. "Long-range border surveillance, persistent monitoring of maritime traffic, airborne fire detection, traffic and security patrols, and communication relay functions will be performed by UAS," he says.

Not all about war

UAS have huge potential applications in civil society. Think of the farmer needing to spray his crops with an insecticide, or a power utility that needs to inspect millions of kilometres of high-voltage power lines. Yet, some technological boundaries still exist – especially around the aspect of unmanned aerial system flight in the national airspace.

The CSIR has been tasked by the Department of Science and Technology (DST) with leading the country's UAS research and development for civilian applications.

"The CSIR's aeronautics systems group has been involved in the development of UAS for the past 30 or so years," explains Gerryts. "At first much of the development was focused on military applications. We concentrated mostly on airframe development." (See table on page 31.)

These included the Seeker prototype of the early 1980s, the Delta Wing demonstrator and in the late 1980s, and 1994's Vulture prototype. Research platforms (Indiza, Sekwa and the Modular UAS) were developed in order to evolve new technologies and to serve as flying testbeds for related UAS technology development.

The first local civilian use of UAS was Denel's Seeker in 1994 during the election and subsequent anti-crime operations. The first conscious application at the CSIR of UAS for commercial applications is the development of a concept demonstrator for power-line monitoring and inspection by the Council's mechatronics and micro-manufacturing research group. It has a unique multispectral camera mounted on a rotary wing unmanned aerial system that acts as the primary sensor for picking up electrical faults on power lines.

In order to aid UAS development, the CSIR facilities and capabilities were recently expanded with DST funds, to include a UAS laboratory.

Expanding R&D infrastructure

One of the components of the UAS laboratory is the UA Systems Integration Laboratory (SIL), which consists of a high-fidelity UAS flight simulation capability. This makes it possible to operate virtual, unmanned aircraft systems in a simulated environment. Actual aircraft sub-systems, such as the autopilot and control surface servo actuators, form integral parts of the simulation. Where some of these systems have not been developed, they are simulated. (See next article.) – *Petro Lowies*

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The modular research UAS prototype

Developing a CSIR unmanned aircraft systems research infrastructure

BY JOHN MONK

John Monk

THE SAFETY of the country's population could be in the realm of unmanned aircraft systems (UAS) in the not too distant future. Long-range border surveillance, persistent monitoring of maritime traffic, airborne fire detection, traffic and security patrols will be carried out by UAS. No longer a topic of science fiction, these are real systems currently being developed.

The CSIR's aeronautics systems capacity has been involved in the development of UAS since its earliest developments. The facilities and capabilities provided in support of these developments were recently expanded to include an unmanned aircraft Systems Integration Laboratory in support of a number of UAS research initiatives.

Umanned aircraft systems integration laboratory

The UA Systems Integration Laboratory consists of a high fidelity UAS flight simulation capability that enables virtual UAS to be test flown in a simulated environment. Actual aircraft sub-systems such as the autopilot and control surface servo actuators form integral parts of the simulation. Where some of these items have not been developed, they are simulated. This approach to UAS development is known as modelling and simulation-based systems engineering and is a cost effective

and efficient way of developing the future UAS concepts that could be used to safeguard us.

The laboratory has the capability to be linked to any of the CSIR's UAS airframes and autopilots for development purposes. The visual environment is typically provided by a number of open-source graphics engines.

The laboratory is currently being linked to an 'Iron Bird' version of the modular research UAS (pictured above and on page 29), a complete airframe that contains all the operational systems but is not designed to fly. This airframe incorporates control surface position feedback systems and avionics developed in collaboration with the CSIR by Stellenbosch University.

The first phase of the development of the laboratory with a high fidelity flight model of the modular UAS is approaching completion. Demonstrations of the prototype capabilities have been made to industry and universities from across South Africa to encourage more research.

In addition to the modular UAS, the CSIR currently has two characterised mini UAS that are capable airframes in their own right. Indiza is a 2-m span hand-launch mini research unmanned aerial system, aerodynamically characterised in the CSIR wind tunnels and is being made available for national research use. (See smaller image on page 29.)

Sekwa, a 1,7 m- span variable-stability UAS is currently used for relaxed stability and systems identification research.

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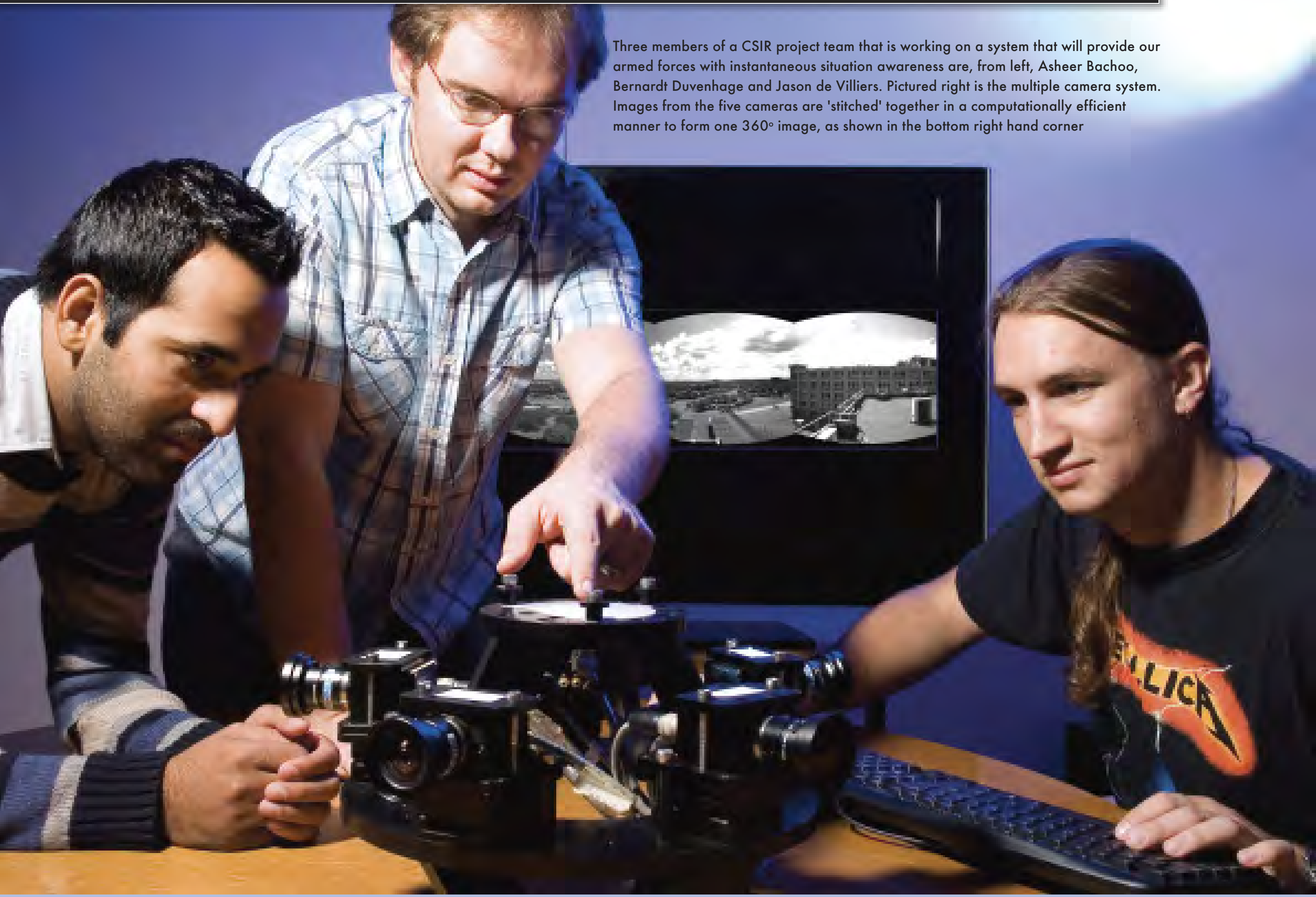
DATE	CSIR DEVELOPED AIRFRAME
Early 1980s	Seeker prototype
1988	Delta Wing UAS demonstrator
1992	Skyfly Target Drone Prototype
1989	OVID/ACE technology demonstrator
1993	Keen-eye RPV
1992	Hummingbird 2-seater observation aircraft prototype
1994	UAOS/Vulture prototype
2005	Indiza – Mini UAS
2007	Sekwa – unstable, tailless UAS
2008	Modular UAS

Pictured from left are John Monk, Nasi Rwigema and John Morgan with the CSIR's modular UAS



Three members of a CSIR project team that is working on a system that will provide our armed forces with instantaneous situation awareness are, from left, Asheer Bachoo, Bernardt Duvenhage and Jason de Villiers. Pictured right is the multiple camera system. Images from the five cameras are 'stitched' together in a computationally efficient manner to form one 360° image, as shown in the bottom right hand corner

New camera system redefines 'being on the lookout'

Unparalleled situation awareness as new 360° surveillance prototype reaches field trial stage

CSIR RESEARCHERS have developed a prototype surveillance system that provides a 360° view of a surrounding environment. In one example of its use, the commander of a navy vessel could dock in a harbour and be completely aware of what is happening around his vessel at all times by watching a technologically 'stitched together' video view in real time. With items of interest tracked and highlighted and the ability to zoom in on suspicious persons and vehicles, informed decisions can be made.

The issue: the changed nature of threats and defending South Africa's armed forces

CSIR senior engineer, Jason de Villiers, outlines the need for this technology. "The South African Navy has to protect the sovereignty of the country. Its members have to perform peacekeeping missions in Africa and undertake search and rescue operations when necessary. To do this, they are equipped with sophisticated, high-technology equipment. A frigate, for example, is an asset worth several billion rand – the mere cost of it is sufficient reason to invest in the most innovative and effective ways of protecting it, with surveillance being the first component of protection."

"When a ship is at sea, radar technology is typically used as its surveillance mechanism, primarily because visibility is not a requirement – approaching vessels and aircraft can be spotted in the dark, during rain or foggy conditions and their range, altitude or speed can be determined."

"But," says De Villiers, "because the nature of threats has changed, new surveillance systems are needed to augment radar technology. The threat is no longer necessarily in the form of a warship in organised warfare, but could be in the form of a small fishing boat, or hostile forces posing as civilians who then carry out a terror attack from a crowded harbour environment. In such an instance the ability to zoom in and visually assess the potential threat, is key. To boot, the decision needs to be taken almost instantly, because of the closeness of the threat.

"In short, we believe this innovation can play an enormous role in strengthening our armed forces in terms of safety and decision-making," he says. The technology is equally suited to terrestrial environments.

Francois le Roux, principal researcher, says the system also aims to reduce the pressure on the crew and thereby enhance the safety of the ship and its personnel.

Technical challenges galore: distortion, motion, reflection, data volume

In progressing to this prototype, the researchers have overcome numerous technical challenges and managed to outperform the technical milestones published in literature. De Villiers explains, "A human has just under a 180° field of view, but can only see detail in the centre few degrees. We have managed to 'stitch together' the view from five overlapping cameras, each with an 80° view to form a 360° field of view. This is no slight feat. Because we use wide-angled lenses, the images are distorted – they literally curve at the edges. We have had to correct this distortion and stitch these images together more accurately and quicker than reported in the available literature."

"Because one of the deployments of the system could require mounting on a navy vessel, we also had to stabilise the image content, regardless of the motion of the camera." Fellow scientist Bernardt Duvenhage got this working in real-time on the large stitched image. Just imagine the movement involved on a ship at sea: the background is not static – the ocean and the clouds are continuously moving and changing. Targets become temporarily obscured, for example the ship upon which the camera system is mounted, will be moving up and down with the swell and may cause the horizon to move in and out the field of view.

"One of the biggest challenges relates to processing the volume of incoming data. The bits stream in from five high-resolution cameras – at a rate that would fill one CD in less than five seconds. This required that a custom image processing framework to optimally transport and store the image data had to be developed by CSIR senior engineer JP Delport. We can only process this now thanks to the advances in graphic processing cards – driven primarily by our gaming generation's demand to outplay one another," De Villiers quips.

Le Roux adds that the optical environment presents enormous challenges. "You have different illumination at different stages of the day. The water causes extreme reflection and glint and can saturate the cameras."

"Presenting a human being with 360° visibility implies providing a lot of information. The surveillance system therefore has to be able to pick up movement and then isolate those parts of the imagery. In the final system, the operator should be able to maintain full operational awareness, while being able to zoom in on areas with changes and movement."

The human capital behind the project

Le Roux says countries around the world are working to improve their maritime surveillance. He says the value of a system that is developed under local conditions for local conditions, is significant. The team working on the system has skills in mathematics, optics, electronics and computer engineering. De Villiers says the project also forms part of the Armscor LEDGER programme, called PRISM, which funds postgraduate studies under CSIR supervision and which aims to expose students to challenges that the CSIR is trying to solve.

A Master's-level student, Zygmunt Spzark, of the University of KwaZulu-Natal, used various algorithms to help develop real-time tracking, which is currently under further development. De Villiers and his colleague Asheer Bachoo are both pursuing PhDs based on the project. De Villiers is interested in determining range information from an image, while Bachoo is keen to understand what constitutes a specific image. "The human mind understands what parts of an image constitutes, for example, a ship, but Asheer wants to understand what it would take for a computer to say a group of pixels constitutes a ship."

Future developments

A next round of field testing will take place later this year during which the crew on some of the ships will be able to comment on the usefulness of the technology. Ultimately it is envisaged that an industry partner will take the prototype to implementation. The project is funded by the Department of Defence.

– Alida Britz

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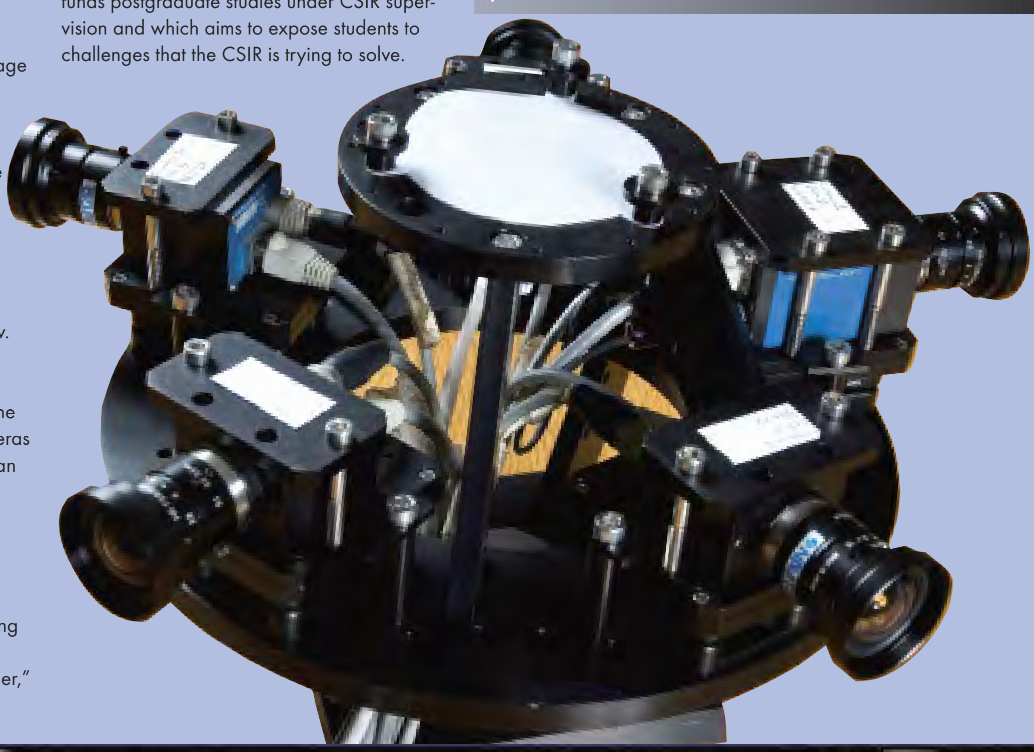

Securing stable images in rough seas

MECHANICAL STABILISATION ACHIEVED USING ONLY PHOTOGRAMMETRIC DATA

Pictured alongside the CSIR's three-axis motion simulator that was programmed to simulate the motion of a frigate in heavy seas (as pictured on page 35), is Fernando Camisani-Calzolari. Scenes from a camera placed on a frigate are affected due to frigate motion. These effects are counteracted by placing the camera on a pan-and-tilt unit and stabilising the scenes using image feedback

Surveillance is a fundamental ability for any defence force mandated to ensure the safety of its citizens. At the CSIR, a large and diverse skills and knowledge set – rooted in optics, electronics and mechanics – is drawn upon to ensure that the observation abilities of our armed forces are optimal.

CSIR RESEARCHERS are investigating new methods, techniques and equipment to be able to 'see' further (long-range surveillance), 'see' under all conditions (thermal imaging, infra-red) and 'see' better (for example by improving the interpretation of satellite imagery, enhancing images and stabilising images).

Wanted: stable images

The need for stabilised imagery is evident from the previous article, in which researchers comment on their development of a prototype camera system that provides a 360° view of a surrounding environment. In a maritime context this is naturally a significant challenge. Ideally, a ship with a mounted camera should be able to provide stabilised images, even in very rough conditions with swells of 8 m and 100 m apart – a so-called 'sea state 7'.

Simulating rough-sea frigate motion in a lab

Central in the challenge to mechanically stabilise cameras, is CSIR senior control systems engineer, Fernando Camisani-Calzolari. Camisani-Calzolari and senior engineer Jason de Villiers recently published results of an experiment in which a simulated lighthouse had to be kept upright and centered vertically in the camera's field of view in simulated rough sea conditions. Ship motion was simulated using a three-axis rate table and the camera position was controlled using a pan-and-tilt unit mounted on the rate table to counteract the effect of the sea motion on the images.

Stabilisation using only data from the image

"There are existing ways of achieving a degree of stabilisation, based on software techniques or mechanical stabilisation using inertial measurement units, in other words, using a fixed reference point. Our experiment, however, focused on mechanical stabilisation, working only with data obtained from the image itself – literally working with the 'absolute error' in the image. This 'deviation' was fed back to the pan-and-tilt unit," Camisani-Calzolari explains. He says the team was encouraged by the results of the experiment. De Villiers undertook the photogrammetric measurements, while Camisani-Calzolari developed the control system.

"This means that it could in future become possible to stabilise images in the presence of sea surges without costly inertial measurement equipment," he concludes.

The results were made public at the International Symposium on Optomechatronic Technologies, a technical symposium focusing on optomechatronics, in Turkey. The full paper can be downloaded from the CSIR website at www.csir.co.za, by selecting 'Access research'.

The project was funded by the Department of Defence through Armscor. Building on the knowledge generated, the team continues its work on other surveillance projects that involve the stabilisation of camera systems.

– Alida Britz

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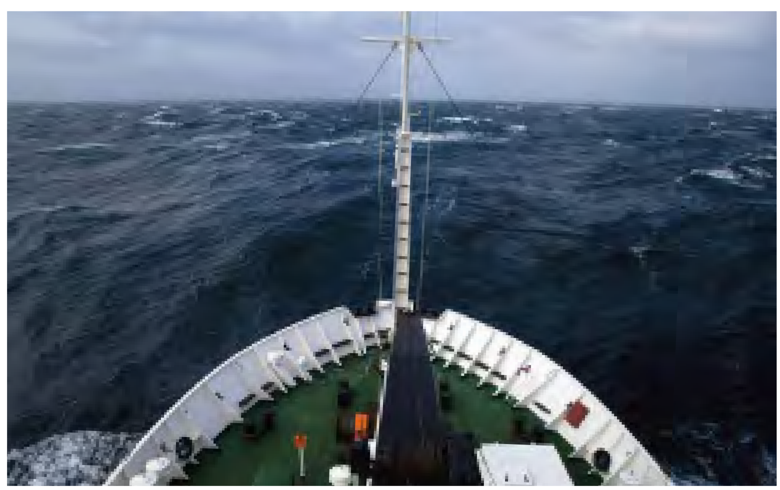

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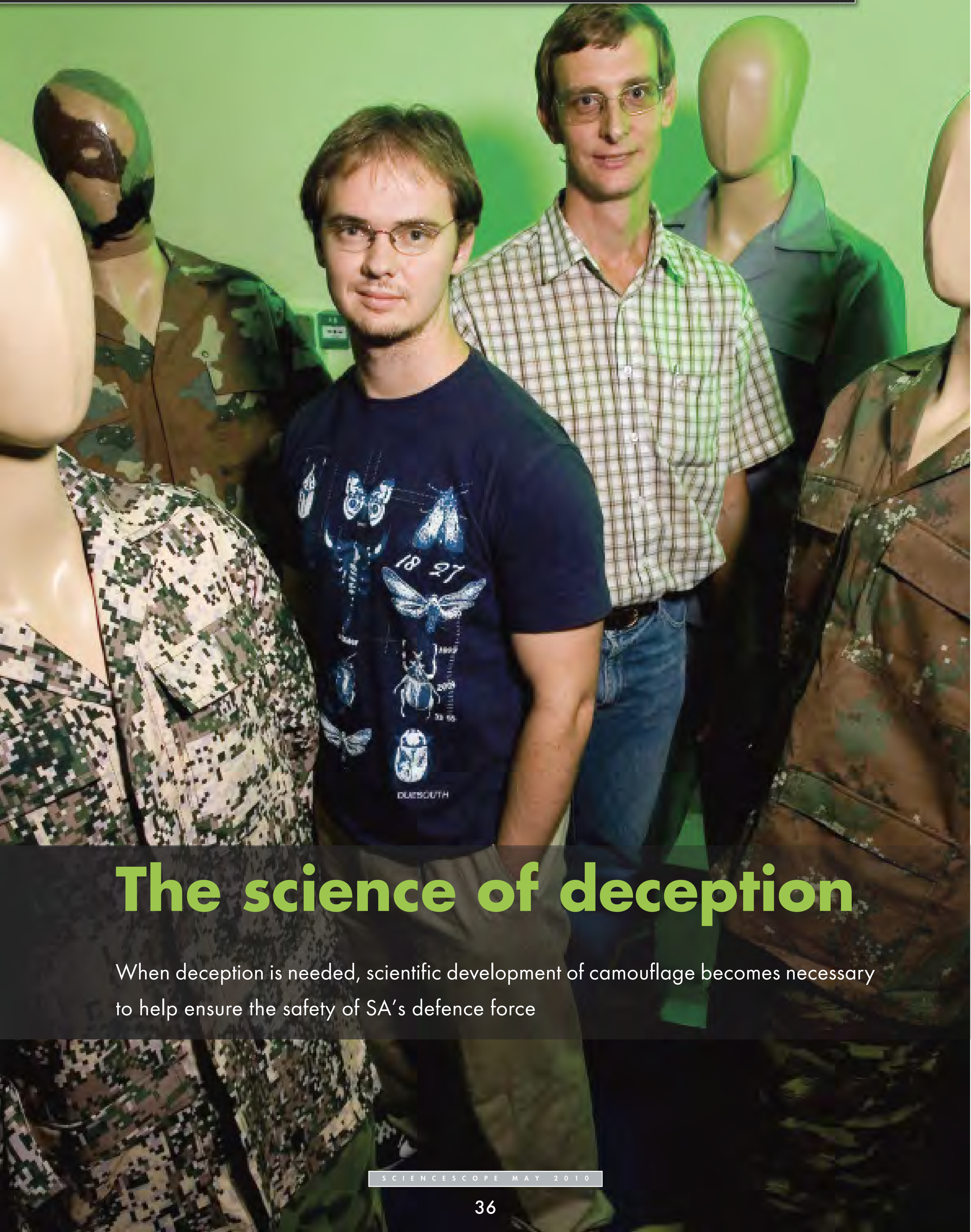


The science of deception

When deception is needed, scientific development of camouflage becomes necessary to help ensure the safety of SA's defence force

WHEN THE ART OF OBSCURING THINGS is your business, you eventually end up viewing the world differently. Ask Johannes Baumbach, CSIR senior researcher in optronics, who has worked with camouflage for the past eight years. As colleagues file into the building where Baumbach works, his eyes are involuntarily drawn to the caterpillars that ravish the Kiepersol tree at the building's entrance.

"It has been bugging me that these caterpillars make no effort at camouflaging themselves. There they are: sporting reddish spots and white spikes running the length of their spongy, black bodies while they feed away on the contrasting grey leaves of the Kiepersol. Needless to say, I just had to look it up, only to learn that the African Emperor Caterpillar has opted for taking on the fearsome looks of a poisonous species rather than camouflaging itself. It is in fact edible and is part of the Mopani-worm family. I guess it is inevitable that my mind ends up interpreting the world in terms of camouflage," he says.

Baumbach, a mechanical engineer by training, is putting his extensive experience in camouflage research to good use by regularly assisting the South African National Defence Force (SANDF) with camouflage-related queries on anything from paints to uniforms. He works with the optronics team at the CSIR: "We are one team: my colleagues focus on detecting things as quickly as possible in all circumstances, while I try to hide things at all costs."

He points out that as technology advanced over the years, it has become harder to 'hide', which in turn led to more and more sophisticated 'hiding' technology. "To counter radar technology, which can detect a moving object kilometres away, stealth technology was developed. Militaries would, for example, develop a vehicle with many flat panes and unusual angles where the panes meet. The radar is then deflected, making it very difficult to detect the vehicle. Similarly, engineers have redesigned equipment to limit the heat emitted by big military aircraft, vehicles or ships to avoid being detected through the use of thermal imagers."

While Baumbach's current focus is on visual camouflage, he has extensive experience in thermal suppression and his design of a thermal cooling system for aircraft exhausts was incorporated in the Rooivalk helicopter design.

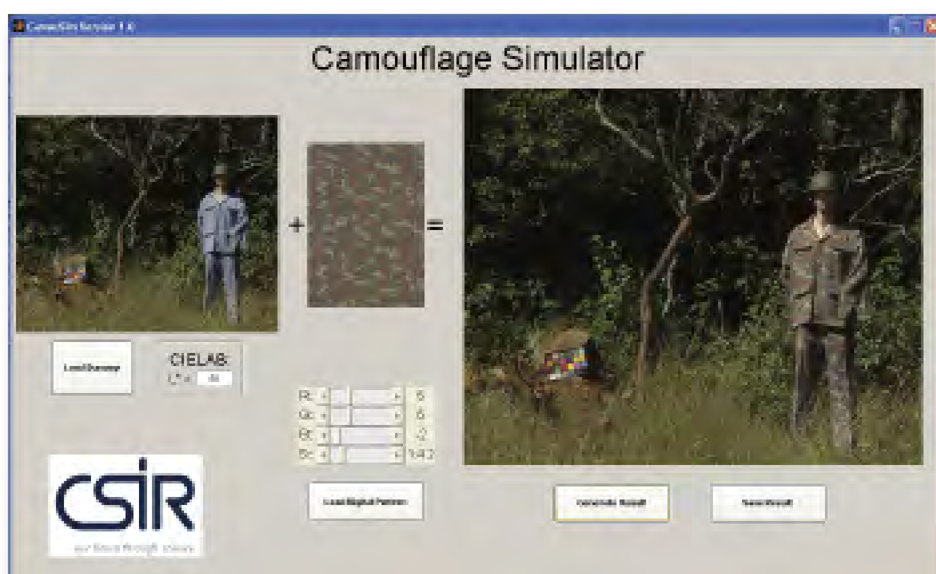
Camouflage as a contributor to the safety of our armed forces

"Camouflage is the first line of defence: it can mean the difference between life and death. A defence force has to protect its soldiers, vehicles, aircraft, buildings and its equipment," says Baumbach.

He adds that to secure the safety of one's armed forces in the future, one has to dedicate research and development now. Scenario planners in the defence force are in tune with instabilities in countries and can, for example, quantify the likelihood of future peacekeeping missions in certain regions. With a scientific understanding of the human cognitive system, it is possible to develop mission-specific camouflage. Failing to do so can have disastrous consequences. In an incident dating back to the eighties, normal paint was used to repair the lightening-damaged tail of an aircraft, instead of the prescribed paint with its near infra-red properties. The aircraft ended up being hit by a ground-to-air missile that locked onto the sun reflection caused by the 'wrong' paint on the tail.

What is the science behind camouflage?

Conventional camouflage relies on three basic elements, namely colour, pattern and texture. For an object to go unnoticed, it needs to closely match the environment's colours, shapes and textures. Human vision is acutely affected by how the brain functions and Baumbach continues to research this aspect, called the psychophysical aspects of vision. The human cognitive system takes what it observes and what clues it has been given and then proceeds to interpret it. Proximity comes into play: elements near one another appear to be grouped together. Likewise, elements that look similar, appear to be grouped together. In addition, the human brain completes views where information is missing – this is called closure.



Pictured left are the CSIR's Bernardt Duvenhage and Johannes Baumbach, who have developed a computerised scene simulator (above), which allows for on-screen evaluation of camouflage patterns

DID YOU KNOW?

The current SANDF camouflage pattern was designed by CSIR researcher, Arnold Jones (now retired).

In 2004, South Africa adopted the Swedish-developed Natural Colour System as the national colour standard.

Left: The CSIR's Johannes Baumbach plays a key role in advising the South African National Defence Force on all issues relating to camouflage

"When patterns with small elements are observed at increased distances, the high-frequency elements start to disappear. In such a case, the brain starts to fill in the missing information, assuming that the missing parts are the same colour as that of the low-frequency (larger) patterns."

Baumbach says colour perception is the most complex of all the psychophysical aspects of human vision. Colours with low chromaticity (more neutral or grey colours) are very prone to contextual perception distortion.

Current research: building a virtual camouflage-testing environment

The current SANDF camouflage pattern has been in use for 14 years and Baumbach believes it to be a very effective pattern for the South African scenario. But having studied the psychophysics of human vision – how humans see their environment – for the past couple of years, Baumbach believes that it is possible to develop a more effective pattern.

To aid the overall aim of designing camouflage for a specific terrain in a short period and at low costs, Baumbach and his colleague, Bernhardt Duvenhage, are developing a computerised scene simulator with funding by the Department of Defence. He explains: "Designing camouflage is a very tedious process. It is also a costly process to print the fabrics and evaluate them in the field. What we are now doing, is to go out in the field and take photographs of a soldier in different scenarios, wearing a grey uniform. This is fed into the simulator and the camouflage designs with their different patterns and colours replace the default grey uniform. This helps to whittle down 40 or 50 designs to a few of the most promising ones. Only the top-performing designs are manufactured and undergo field evaluation. Calibration forms an important part of this process, to cater for the differences in on-screen colours and true environmental colours."

Two trial patterns that have performed very well in the scene simulating tests have been printed and photographs have been taken in the field for comparison to the simulated results. One of the preliminary camouflage designs is already proving to be more effective in certain environments and judged to be a good overall pattern. The research continues.

Challenges in implementation to be heeded during the research process

The manufacturing process is a limiting factor in designing consistent camouflage wear and is an aspect that the researcher cannot ignore, says Baumbach. Most of South Africa's textile printing does not take place in climatically-controlled environments. The differences in humidity and temperature affect the outcome of colours on garments. Moreover, different textile types reflect colours differently, so: "What one specifies is not always what one ends up with." This requires intense interaction with industry.

Developing different camouflage uniforms for different circumstances is an ideal scenario, but cannot be done without heeding the logistics of a large-scale roll-out, warns Baumbach. He says some of the big nations are cutting back on the number of different camouflage designs in use because of logistical and associated cost implications.

The future and camouflage

The 'ultimate' in camouflage, says Baumbach, is to have wide-band, adaptive camouflage. Wide-band camouflage needs to be effective in the visible (day-time), near-infrared (night vision), thermal and radar bands, as well as the new terrahertz imaging technology. Adaptive camouflage is the term for camouflage 'on demand': through changing the conductivity or reflectivity of the camouflage system (usually through changing the voltage/current), the camouflage system can be adapted to blend with the environment to suit the mission, environment and threat. "Unfortunately, these things generally work against one another. If it's very good in visible radar bands, it's not necessarily good in thermal bands," he says. However, the advent of nanotechnology has made it possible to change the properties of materials and is likely to have a significant influence on camouflage technology in the future. – *Alida Britz*

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David Reinecke

Piet Ramaloko

Thanyani Pandelani

Development of young scientists ensures continued landmine protection validation and certification

Young scientists are scarce in South Africa, creating concern that once the older scientists and researchers retire, there will be few people left to continue their crucial work. This concern has inspired CSIR principal scientist David Reinecke to implement a stringent training and mentoring programme in landwards sciences, specifically in the research unit focusing on vehicle landmine protection validation and certification testing.

YOUNG RESEARCHERS Piet Ramaloko and Thanyani Pandelani are hard at work acquiring the specific skills needed in vehicle landmine protection validation and certification testing. To protect vehicles from blast attacks and to ensure crew survivability, it is important that the researchers have rigorous training in modelling, simulation, testing, measurement and evaluation.

"Vehicle landmine protection validation and certification are a complex process, starting with acquiring the correct equipment for our needs. Then we need to test everything and evaluate its efficacy, which I am responsible for," says Ramaloko.

He explains that he has formal as well as informal training sessions, while also being encouraged to finish his Master's degree. "Our progress is reviewed and a framework is created to assist us in meeting our goals. We also interact with mentors such as Reinecke," he explains.

Pandelani is responsible for research on human response in the context of being in a blasted vehicle. "Our foremost goal is to keep the soldiers protected from serious injury," he adds. Data are gathered from dummies to determine the impact of a blast. These crash test dummies are subjected to vertical blast loading and head-on collisions.

Researchers are able to validate their equipment in the CSIR Detonics Ballistics and Explosives Laboratory in Paardefontein. The kind of resources available to researchers include ultrahigh-speed videography – capable of capturing two-million frames a second – and a digital flash x-ray machine. These can be positioned within five metres of an explosive device.

Reinecke explains that the 'wheel and halt test' would position dummies as close as possible to the blast, with the measuring equipment as far away as possible. Small bombs would be detonated first, followed by a bigger blast. After it is confirmed that everything has been detonated, the data are collected and analysed using special software. This software converts the data into values.

"As we follow strict procedure, the CSIR requires independent verification." Currently, all validation and testing are in accordance with the RSA-MIL-STD-37. This standard is developed alongside the latest NATO group standard, AEP 55 volume three. "The work of Ramaloko and Pandelani is of significant value, as the CSIR, together with Armscor, is the national authority for validating vehicles for landmine protection. Indeed, our validation methodology is internationally recognised," says Reinecke.

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Danie de Villiers looking through the mortar sight

The bearing dial is a new concept

Prismatic mirror and improved mortar set-up technique

CSIR principal engineer Danie de Villiers explains that a newly developed method of mortar set-up could play a crucial role in modern conflict situations. "The mortar as an indirect weapon still has an important place in modern warfare. But it is necessary to investigate technologies that can make mortar systems lighter, more responsive and more lethal. The prismatic mirror addresses these challenges," he says.

Previous studies on the setting up of mortars showed that the method of using aiming posts needed to be improved. The South African National Defence Force artillery took the lead by replacing the aiming post with a prismatic mirror similar to that used on the Ratel attack vehicle. "The CSIR then devised a concept of improving the way the mirror is used by adding a bearing dial to the prismatic mirror," adds De Villiers.

Mortars are traditionally aimed by using a compass, two aiming posts and a mechanical sight. De Villiers, however, improved the current mortar system by using a prismatic mirror and a new set-up procedure. "The uniqueness of the set-up method means that the mirror bearing is tracked, providing a bigger arc of fire with no parallel problems. In the old system, the mirror is fixed and is only used as a reference while it is positioned in the arc of fire," he says.

There are many benefits in using the prismatic mirror instead of aiming posts: it is only an add-on and requires no change to current mortar sights; it is faster than previous set-up procedures of two aiming posts; it improves the reaction speed of engaging opportunity targets and it can be used at night as it does not have a thermal image that the enemy could detect. "It is also cost-effective if the mirror set-up is accurate, as the first hit probability is improved," adds De Villiers. Moreover, the concept can be fully digitised with a GPS compass, tilt sensor for the mortar pipe and shaft encoder to track the bearing. Soldiers can also pack up the system quickly and move to a new position. "Measurement of the effectiveness of the mortar system shows that the concept has many advantages," he says.

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A mortar is a muzzle-loading indirect fire weapon that fires shells at low velocities, short range and with high-arcing ballistic trajectories. A modern mortar consists of a tube into which gunners drop a shell. A firing pin at the base of a tube detonates the propellant and fires the shell. Most modern mortar systems consist of three main components: a barrel, a base plate and a bipod.

Soldiers find way in harsh terrain with new digital technology

A spectrum of digital technology has been researched and tested by the CSIR, enabling a soldier to have full situation awareness at all time.

THE LATEST HAPTIC (SENSE OF TOUCH) technology – involving vibrating sensors placed on a soldier's body – has been a project focus for Stefan Kersop.

"Essentially, if there is vibration on the right hand side of a soldier's body, then he/she knows to head in that direction. It enables navigation to be easier and more efficient where the soldier finds his/her way easily," says Kersop.

Furthermore, other technology has been developed to assist military personnel with situation awareness. "Apart from haptic technology guiding the soldier's movements, a communication device keeps the soldier in contact with his/her team and commander."

This small device, known as a Soldier Data Terminal, connects to a radio, where information can be transmitted over the network. The soldier informs others of his positioning and has the ability to send a short message service, similar to what is possible through cellular networks.

To ensure that the device operates where the customer need it to, it was tested in the laboratory as well as in the field, assessing its heat, water and corrosion resistance. "We had to determine how well it worked in rural areas or near tall buildings," notes Kersop.

Most importantly, soldiers have to evaluate the device, providing feedback to CSIR engineers. "We analyse these results and provide further recommendations for procurement to ultimately improve the device."

Stefan Kersop

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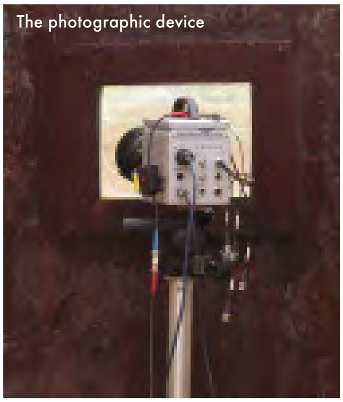
Dummy to test human impact during explosions



The photographic device

Scientific evaluation of equipment

Scientific evaluation in the laboratory and in the field is a tool to ensure that the correct equipment is made and that it works. The CSIR's Marius Olivier explains how scientific evaluation of military equipment ensures that the right tools are procured.

"The test, measurement and evaluation group works in an electronic laboratory as well as a detonics, ballistics and explosives laboratory (DBEL). These have unique abilities, such as the casting of explosives to a customer's specifications and the execution of explosive tests in a safe and efficient manner," says Olivier.

The group deploys portable infrastructure in harsh conditions that would gather rapid data for analysis. In these and other instances, the group will apply advanced technology, scarce measuring and photographic equipment to assist with data collection. "We have electronic design and prototype build capability to solve our clients' unexpected problems."

He explains that the facilities in the electronic laboratory include blast measurement, temperature, velocity of detonation, slug speed measurement, shock arrival times, and video capture. "Video capture can either be at medium, high, or ultra high speed, with the ability to attain up to two million frames a second," adds Olivier.

The DBEL test range include a detonics shelter that houses a flash X-ray system; an ultra high speed camera; blast impulse measurement; a blast research chamber; a T1 test range for explosives research on mine protected vehicles; cubicles with a blast impulse pendulum; magazines; a casting facility with an X-ray facility; an explosives press and lathe for explosives machining; and a demolition capability.

"Our technology to evaluate equipment meets global standards owing to its stringent and comprehensive development," says Olivier.

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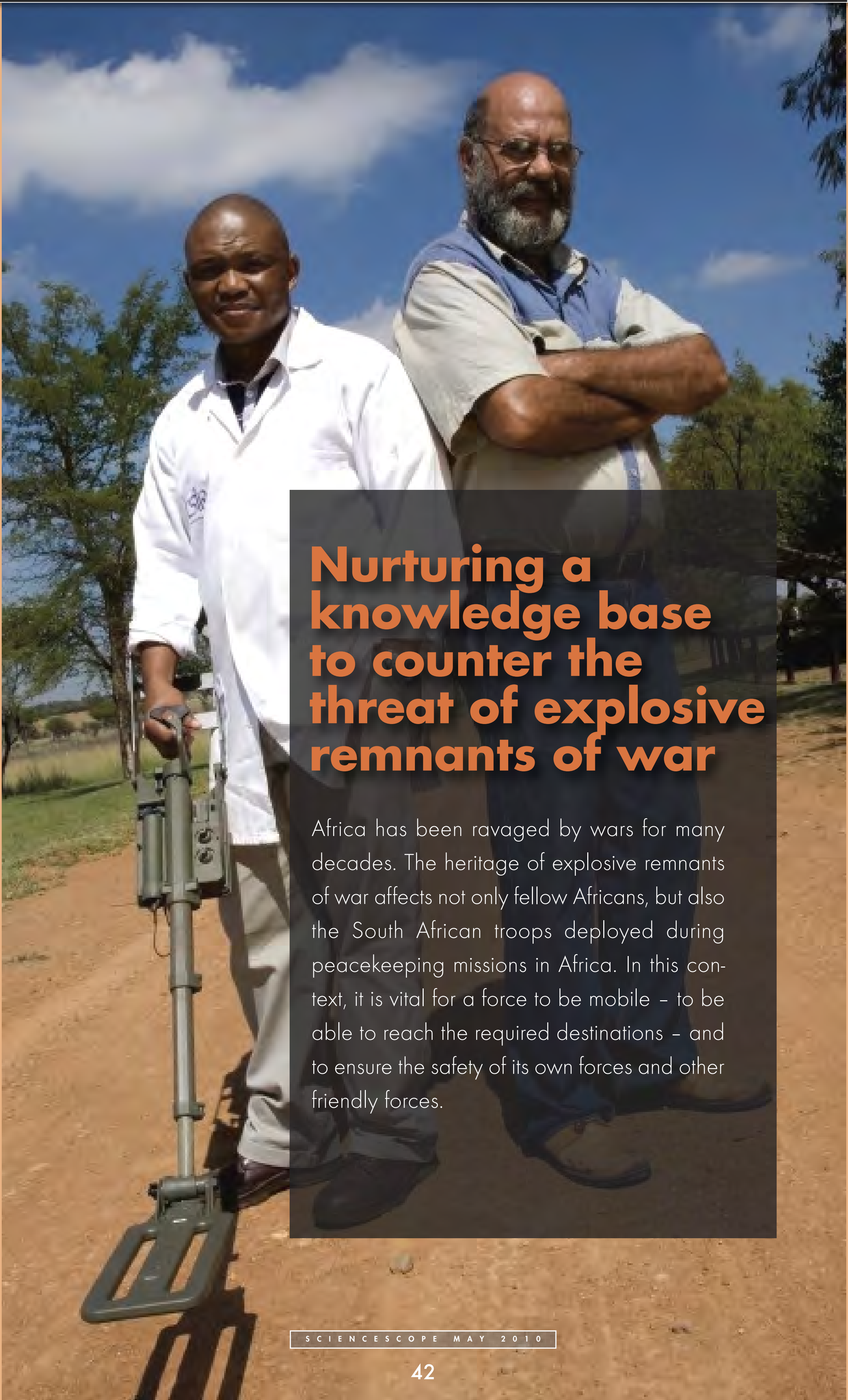

Nurturing a knowledge base to counter the threat of explosive remnants of war

Africa has been ravaged by wars for many decades. The heritage of explosive remnants of war affects not only fellow Africans, but also the South African troops deployed during peacekeeping missions in Africa. In this context, it is vital for a force to be mobile – to be able to reach the required destinations – and to ensure the safety of its own forces and other friendly forces.

THEO VAN DYK, SENIOR RESEARCHER at the CSIR, has studied explosives for over 30 years. During this time, he has seen and experienced significant technological progress in the detection and disposal of unexploded mines and other ordnance.

Detecting and protecting

"An armed force has to be able to detect in order to protect. Conversely, if you can't detect, you have to be able to protect. A mine made out of a plastic substance is harder to detect than a mine made of metal. In such a case, the need for protection – aimed at mitigation – speaks for itself. But first prize is to be able to detect and eliminate. This is at the core of a Department of Defence-funded project, called Project LILAC: acquiring in-depth knowledge of detecting technologies and testing these technologies in the context of international standards. The CSIR's Paardefontein site houses these testing facilities," Van Dyk says.

Advising on suitability of high-technology products

"Purchasing a high-technology product is not without peril. The CSIR therefore advises the South African Army on state-of-the-art mine detectors that are capable of detecting mines with minimum metallic content. We test these products; develop realistic user specifications; and undertake joint field tests with the defence force," says Van Dyk. This project is set to increase the technological prowess of the South African armed forces.

"A significant component of our work over many years has focused on these aspects. We have established a knowledge base that has helped us understand what happens during the detonation of the various types of mines and what the effect on protected and unprotected vehicle types are, as well as how it all relates to human injuries. This in turn empowered us to contribute to the development of protective vehicles that minimise injuries in the event of an explosion. We have also, for example, developed a technology that is still used in the defusing and dismantling of unexploded and abandoned ordnance."

Pictured left is CSIR senior researcher Theo van Dyk and explosives technician, Tshepo Setlai. Van Dyk has 30 years' experience in explosives, while Setlai's extensive experience and qualifications include six years at the South African Army Ammunition Corps, and a diploma in explosives technology. He is currently doing a BTech in explosives technology. Pictured above is a commercial device which can detect minute quantities of explosive materials, making possible the testing of areas that have been in contact with even trace quantities of explosives. The CSIR verifies the claims of these commercial kits and makes recommendations to the defence force

A changing threat: improvised explosive devices

However, Van Dyk says increased incidences of the use of explosives combined with low-technology, everyday switches and triggering devices used in terror attacks, are being observed. In many of the international incidences, these devices, called improvised explosive devices, are made from the explosive materials of abandoned ammunition stockpiles. And, as has been seen in recent international missions, if an armed force has not strategically planned for this scenario, it can have devastating consequences. "It is all too easy to strip a mine or munition piece and to make an improvised explosive device," he says.

"Besides the use of improvised explosive devices for terror attacks, the South African armed forces also increasingly have to heed the forces of criminal minds that source explosives from abandoned munition for use in poaching, abduction, armed robbery and smuggling."

Van Dyk says the problem is compounded by the fact that the African continent is endowed with rich mineral deposits, resulting in the availability of vast amounts of commercial explosives used during mining.

"This changed threat of explosives being used, for example, by suicide bombers, means that it has become important not only to detect a mine, but to be able to detect miniscule quantities of explosive materials in support of intelligence appreciation and forensic investigations," Van Dyk says.

The objective of the CSIR in this regard is to investigate, test and verify the claims of detection kits available, maintain a database of results, and act as an impartial technology advisor to the defence force. – *Alida Britz*

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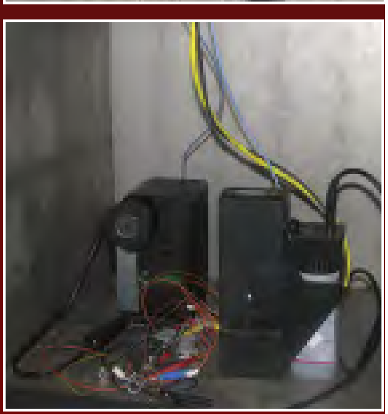
EXPLOSIVE REMNANTS OF WAR

UXO: Unexploded ordnance. This means that explosive ordnance has been prepared for use. It may have been fired, dropped, launched or projected, but it remains unexploded because it may have malfunctioned, for example. It could consist of grenades, mortars or artillery.

AXO: Abandoned explosive ordnance. In some war scenarios, ammunition is simply abandoned and thus becomes a threat many years after the war.



Pictured from the top are a user evaluation session of CSIR-developed technology, a salt water battery and power manager; solar-powered battery system and a fuel cell during environmental tests.

Finding ways to lighten a soldier's load

Think of walking in the desert with in excess of 80 kg on your back. Most would not be able to stand up with that amount of weight tied to them, let alone stay alert in a potentially hostile environment. Yet, soldiers are required to carry that amount while operating at full throttle.

"A soldier needs to carry water, ammunition and equipment such as a radio and a GPS," says Trevor Kirsten, manager of the CSIR's technology for special operations group.

He explains that batteries contribute about 20% to the overall weight of the soldier's backpack because most equipment is powered by batteries. "If the soldier is deployed for a lengthy period, he/she needs to be equipped, hence the need for different kinds of batteries," adds Kirsten.

He says that CSIR researchers are developing ways to address power generation and management. Two researchers, Achmed Giesler and Inus Grobler, are currently involved in a number of projects, and have researched, for the purposes of power management, the possibility of using salt water batteries, fuel cells and solar panels.

"In terms of fuel cell technology, the most suitable for our purposes is the direct methanol fuel cell (DMFC). This means the fuel uses methanol at a low temperature which is converted to electric power," says Grobler.

Adds Giesler, "The CSIR was part of a European consortium that supported the company Smart Fuel Cell (SFC) with the development of a fuel cell for the dismounted soldier. One of SFC's products won the $1-million Defence Advanced Research Programme Agency (Darpa) challenge for fuel cells for the dismounted soldier in 2009."

The CSIR has also been testing and developing new generation rechargeable battery packs to replace older battery packs used by the South African National Defence Force (SANDF). In collaboration with industry, the CSIR developed a new battery pack system for the SANDF VHF radio (A43) and successfully tested and evaluated it in 2009.

"These battery packs are considered 'intelligent' battery packs with built-in protection as well as specialised Coulomb counting. This informs the user of the status and the amount of power left in the battery pack. The end result is a lighter pack with a higher capacity, better reliability, and built-in protection while at the same time informing the user of its charge status," explains Grobler.

The challenge is that the soldier needs to power a vast range of equipment, such as radios, satellite phones, laptops, lights and night vision equipment. "We have therefore developed a power manager that enables the soldier to connect all his/her items into one unit."

Stringent tests have been performed on the power manager and the unit is consistently being developed along customer specifications. "Ultimately we need to ensure that the soldier is performing optimally, and the CSIR's research is aligned with this objective," says Kirsten.

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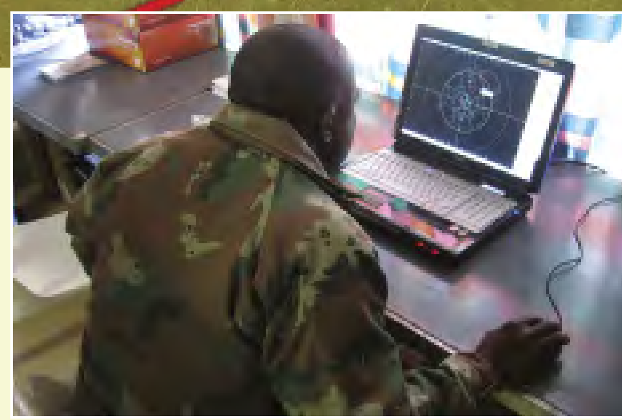
Herman Le Roux says interoperability is key to safety during the World Cup

A safe FIFA World Cup through interoperability



THE MUCH-ANTICIPATED FIFA World Cup is soon to take place in South Africa. It is considered one of the most significant events a country could host, with millions of fans flocking to watch their teams playing the 'magnificent' game. However, amid the carnival and fun, armed forces have to prepare for any potential security threat.

According to Herman le Roux of the CSIR's command, control and information warfare group, techniques have been developed to promote interoperability to support the South African Police Services (SAPS) during the World Cup. Essentially, while the SAPS is primarily responsible for security during the World Cup, the South African National Defence Force (SANDF) will be available should the SAPS require its help. "We have developed tools for interoperability and cooperation between military and civilian policing," says Le Roux.

However, while there are cooperation and tools in place for joint operations, the SANDF will not be visible in areas such as stadiums and fan parks. "We have focused specifically on supporting the South African Air Force (SAAF) in securing the sky," says Le Roux.

He explains that the SAAF has new aircraft and equipment, which were tested during the Confederations Cup in October 2009. The CSIR developed concepts for the SAAF that were also evaluated during this time. "We conceptualised tools and decision aids to enhance situation awareness in the air. It is crucial that a pilot uses these aids to predict a security threat and to understand its implications. For instance, if there is a veld fire close to a stadium, the capability to assess the situation is crucial."

The CSIR has therefore augmented situation awareness, adding to data transmitted from military radars and from the Civil Aviation Authority. "With additional situation awareness tools, the ability to manage the airspace during large events is achievable," he says.

On a broader scale and beyond the immediate need for interoperability at the World Cup, the SANDF's core focus is joint operations. "Interoperability between the different arms of service is important. This means that medical, land, naval and air units will co-operate to enhance and assist security forces," says Le Roux. To achieve this, the CSIR has developed common standards and data systems to integrate into pre-existing situation awareness models.

"Scientists had to determine whether the situation awareness models were compatible with the existing systems and processes, and whether personnel felt comfortable operating them," he adds. All arms of service – land, naval and air – must be able to communicate with each other and understand the same system, involving technical specifications and symbology.

"The CSIR is assisting with the implementation of interoperability and cooperative systems. The technology developed for these purposes is truly a force multiplier," notes Le Roux.

Ultimately, the SANDF's primary objective is to provide effective security, and technology can multiply this effectiveness. "Technology increases productivity, as is seen in any industry with the advent of computers and email," adds Le Roux. Of course, the CSIR is only adding technology to what is in place already. "We are applying the technology we have developed around interoperability, situation awareness and systems integration in a novel way. These assist the SANDF in reaching international benchmarks."

Where else will interoperability and systems integration be leveraged? "We believe that the capabilities tested during the World Cup will extend to other major events and that the SANDF will have effective systems in place for these," says Le Roux.

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South African Army operators experience reality in simulation

Military personnel face numerous scenarios. The Army may need to protect vulnerable assets from aerial threats; peacekeeping forces have to secure their base; and the navy must protect docking ships. How does the military prepare to operate in these scenarios?

"The CSIR, with close cooperation from Armscor, local defence industry and the South African National Defence Force (SANDF), developed a simulation environment for decision support over the past 10 years," says CSIR principal researcher Herman le Roux. This virtual environment enabled the CSIR to support the SANDF in various activities, ranging from computer-aided exercises and doctrine development for new equipment to the evaluation of new concepts and acquisition decisions. Complex scenarios could be evaluated in a virtual setting before committing expensive equipment or scores of people.

In supporting the SANDF, other related research questions are also addressed by the research team. These includes distributed, real-time simulation architectures, data modelling approaches, data and information fusion, situation awareness technologies and automated decision support approaches. All efforts are coordinated to ensure information, engagement and decision superiority for SANDF commanders.

The processes and methodologies used in the research team are on a par with that of international players – as is evident from the numerous international publications.

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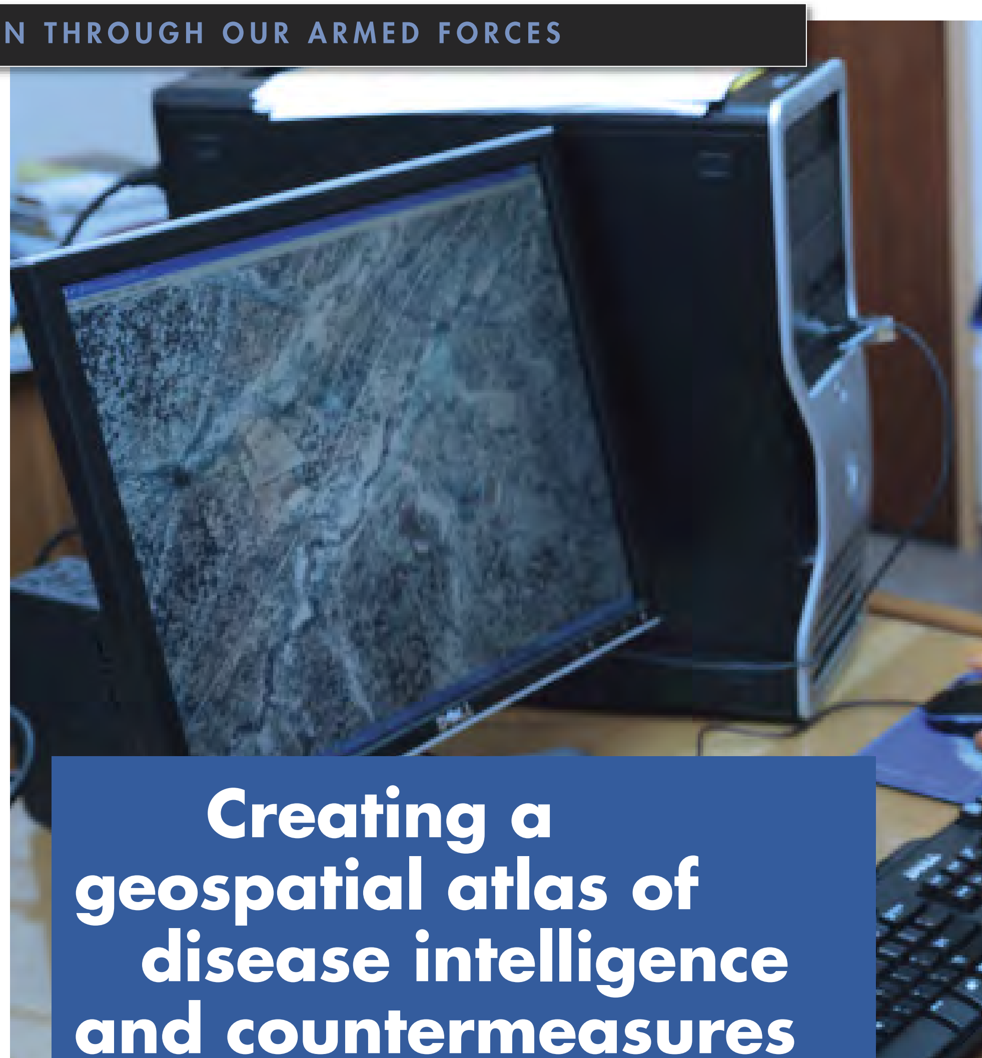


Creating a geospatial atlas of disease intelligence and countermeasures

MILITARY APPLICATIONS OF MEDICAL GEOGRAPHY IN SUB-SAHARAN AFRICA

MEDICAL GEOGRAPHY is an area of research that incorporates geographic factors with studies of health and disease, examining the impact of climate and location on health. The first example of medical geography dates as far back as the 4th century BC, when physicians observed that certain diseases occurred in some places and not others. For example, they perceived that malaria was more prevalent among people who lived at low elevations near waterways than those living at higher elevations.

Since then, the field of medical geography has advanced dramatically, with new technologies greatly increasing its level of sophistication and variety of applications.

Medical geography today

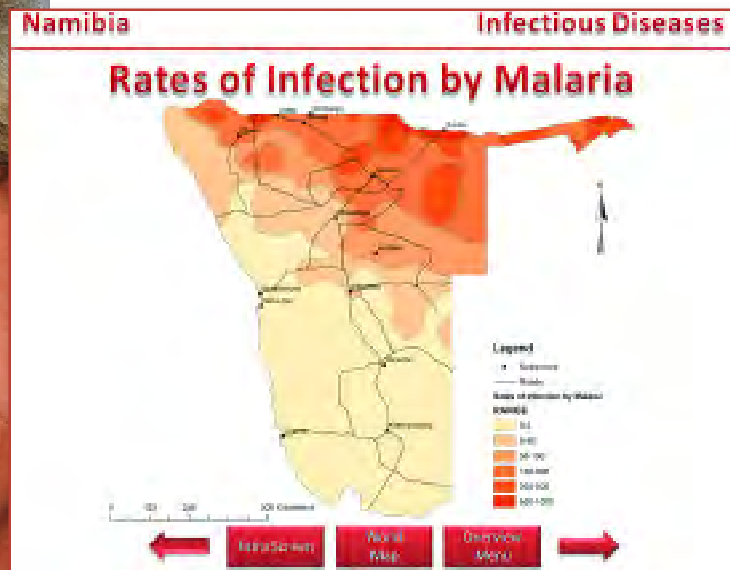
Geographic information systems (GIS) and related technologies such as remote sensing are playing increasingly greater roles in analysing the 'geography of disease'. In particular, they are used to clarify the relationship between pathological factors, such as causative agents, vectors (such as mosquitoes carrying malaria) and people, and their geographical environments.

GIS assists in improving understanding of the link between environmental, demographic and temporal factors with health issues increasing awareness of causes of health hazards within particular areas.

The CSIR is currently using GIS to create medical atlas software, the Geospatial Atlas of Disease Intelligence and Countermeasures, for the South African Military Health Services (SAMHS).

A medical atlas for the SAMHS

The medical atlas will greatly benefit military medics, troops and intelligence personnel. The interface of the atlas depicts a world map, and users can then click on countries of interest to learn relevant regional information, ranging from weather conditions to medical facilities.



A sample page from the medical atlas that will greatly benefit our armed forces. Pictured left is Minette Lubbe, military geospatial analyst, who says the completed product will be a goldmine of information

Minette Lubbe, a former lieutenant colonel and current military geospatial analyst at the CSIR states, "Unlike civilians, military health-care providers must be ready to deploy at a moment's notice. Their primary mission is military readiness, which means being able to respond effectively in times of conflict. Missions may also involve military operations other than war, such as humanitarian assistance and peacekeeping operations."

She goes on to explain that a medical atlas will provide military health professionals with instant and easy access to a wide range of medical reference data, giving them situation awareness. She explains, "This will enable medics to review environmental risks and conditions in their area of responsibility. Medical geography can also be used to support the readiness of soldiers by keeping them fit to fight before, during and after deployment. GIS can aid decision-makers in overcoming spatial issues of a medical nature."

Applications and benefits

Learning about an area of deployment prior to missions will greatly assist medics and troops in their preparations. The medical atlas enables them to research important factors such as environmental health, diseases and climate. Climatic factors such as temperature, humidity and rainfall affect what clothing and equipment are necessary, and also affect how artillery is set up. Troops and medics can prepare further by researching topography, population, water supply, living and sanitary conditions, pollution and hazardous animals and plants in areas of deployment.

Before deployment, medics can ascertain which diseases are common to a country and advise if inoculations are necessary for military personnel. During deployment, it is crucial to know what medical facilities are available in the region. Medics can research locations and capabilities of hospitals and clinics in an area sothat they know which equipment to take with them. For example, if there are poisonous snakes and no poison centres nearby, anti-venom kits must be added to supplies.

The atlas is also relevant for intelligence officers, and will increase chances of successful missions while minimising risk to troops. The more information a tactical commander has access to going into any operational area, the better he can understand mission complexities and prepare his troops. Once contingencies are known they can be planned for, and appropriate manpower and supplies can be taken to reduce loss of life and improve battle efficiency.

Furthermore, the atlas is applicable to emergency situations. If there is an evacuation or rescue situation requiring helicopters, it is important to know where helicopters can land. This can be determined by using different layers of GIS maps. By overlaying maps containing topographical information, clear-cut areas, transmission lines and soil type, a helicopter landing zone map can be created. Thus, depending on user-defined queries, GIS can be used for problem solving as well as preparation.

Lubbe concludes, "Although we're developing the atlas with military issues in mind, it will certainly be beneficial to all medical professionals and civilians who do field work in Africa. The atlas will continue to grow and develop as we collect more information and build up country profiles. Although we still need to gather a lot of data, the final result will be a goldmine of information for a range of user-defined queries."

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