THE CSIR Dossier

OF SCIENCE AND TECHNOLOGY FOR DEFENCE AND SECURITY

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Understanding the explosive threat

Joining forces for growth and development

ROBOTIC DESIGN

RADAR AND ELECTRONIC WARFARE LABORATORY IN THE SKY

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CSIR

Touching lives through innovation

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About the CSIR

The Council for Scientific and Industrial Research (CSIR) is South Africa's foremost R&D organisation and a strategic national capability. It undertakes directed research and technology development across scientific domains in areas specifically linked to social and industrial development. The main focus areas are defence and security, health, industry & advanced manufacturing, the built environment and the natural environment, and energy. The CSIR is the biggest research council in Africa and its activities are supported by a variety of expert facilities and infrastructure, laboratories, virtual platforms and instrumentation for testing and evaluation, design and technology experimentation.

Key objectives for the CSIR are contributing towards technical skills development, healthy industrial growth, and forging strategic relationships where the shared aim is a positive impact on people and nations.

CSIR
Touching lives through innovation

JOINING FORCES

By Dr Rachel Chikwamba, CSIR Group Executive: Strategic Alliances and Communication

Science and technology has a substantial and critical role to play in the socio-economic development of any country. This is an inspiring opportunity that continues to drive the CSIR in its efforts to contribute towards improvement in the competitiveness and prosperity of South Africa and its people, and indeed people on the African continent.

Science does not effect change by itself. It requires committed contributors, and – importantly – robust, productive partnerships. Combining our wisdom and experience, discoveries and lessons, amplifies the impact we achieve in the improvement of our societies and industries. We share the imperative of contributing to the security of our countries. We also face similar adversaries in fundamental challenges such as poverty, rapid population growth and urbanisation, and the associated pressure on infrastructure, natural resources, efficient service delivery and job creation. These are challenges that can be causal to territorial disorder.

National partnerships in government aid the efficiency of state. Partnerships in industry open doors to create new enterprises in different sectors. International partnerships create platforms for learning. Partnerships in science fuel skills development and new thinking.

By showcasing a sample of our work in defence and security, the CSIR invites collaboration from current and new stakeholders. As allies we can amass a considerable force in the advancement of science and innovation.

FORCES FOR GROWTH AND DEVELOPMENT

By Erlank Pienaar, Acting Executive Director: CSIR Defence, Peace, Safety and Security

Technology is essential for achieving improvement and progress.

In the defence environment, technology development happens at a rapid pace, against significant stakes and to severe standards of precision. From the hotbed of innovation, these technologies are increasingly finding their way into other fields of application – both civilian and commercial. The technical skills underpinning these technologies need to develop concurrently.

The CSIR views science, engineering and technology as a gamemaker for progress and positive change and impact. Not only the direct benefit of the utilisation of a particular technology, but also to use technology development as a driver for growing skills and stimulating the sector by sparking new hi-tech enterprises and small businesses.

We are proud of the accomplishments of our core of scientists, engineers and technologists. Their ingenuity is our currency to achieve impact.

We are appreciative of the strong collaborative networks we have in government and industry in defence and security.

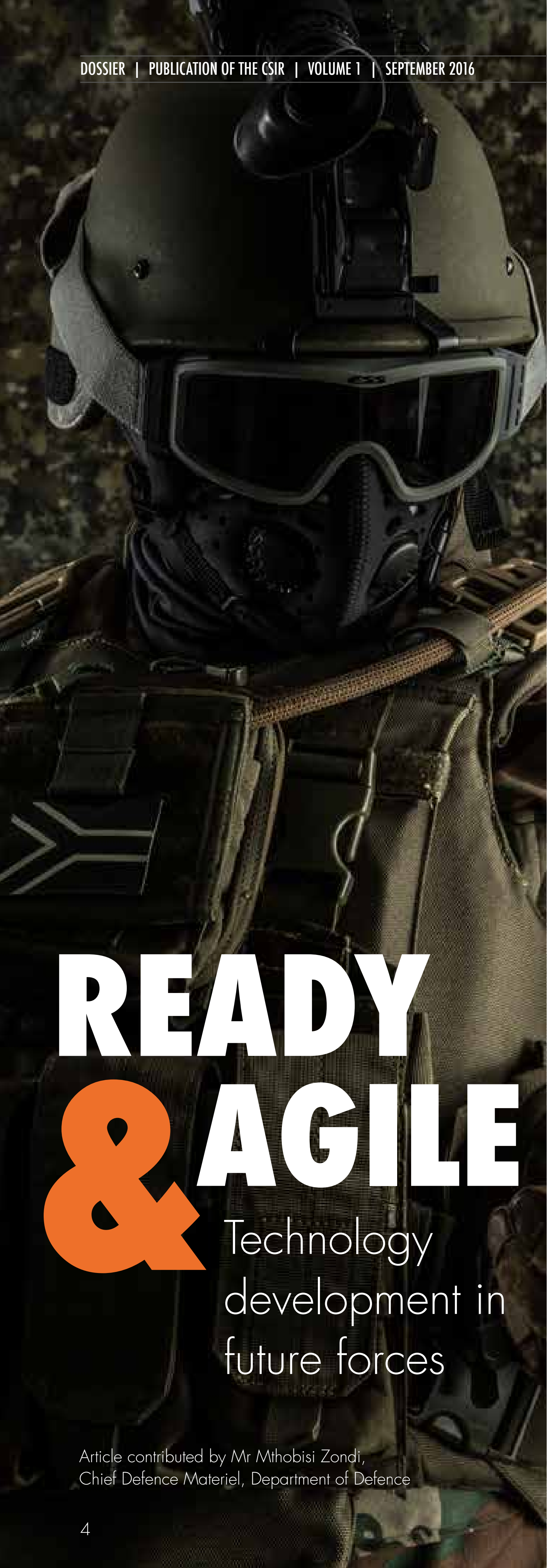
We are devoted to forming mutually beneficial international research and development partnerships within the framework of intergovernmental agreements.

We are committed to gear our technical pioneering towards stimulating business and providing platforms for entrepreneurs.

We are inspired by the opportunity to use technology to grow the next generation of scientists, engineers and new industry players to become leaders who will drive the growth and transformation of the local defence sector.

This is how we stand to contribute to the South African knowledge economy of the future as we join forces to fight poverty and inequality.

This collection of articles is a small sample of the thinking of experts, innovators and some of our partners in the field who live with technology decisions in their day-to-day operations. It offers a glimpse into what technology stands to achieve in government and industry, the opportunities for entrepreneurship and where our future opportunities for impact lie.



READY & AGILE

Technology development in future forces

Article contributed by Mr Mthobisi Zondi,
Chief Defence Materiel, Department of Defence

Conflict doesn't follow a predictable trajectory. It is a chaotic human activity that follows no rational process. To think we can fully predict the future battlespace, is naïve. We can assume it will be similar to the last war - or we could track the obvious trends. This is the habit of most militaries in order to uphold doctrine, tactics, techniques and procedures that were successful before. This traditional approach will no longer do. In the words of former US Secretary of Defence, Donald Rumsfeld: "We have to put aside the comfortable ways of thinking and planning, take risks and try new things so that we can prepare our forces to deter and defeat adversaries that have not yet emerged to challenge us."

How then, do we equip ourselves for the unknown? How can technology development provide us with a means to have 'a fighting chance' in the future?

Military institutions have come to understand the importance of investment in R&D as one means to gain the upper hand. Technological inequalities between adversaries can shape the 21st century battlespace and determine battle strategies. The underdog must be more innovative, versatile, and - importantly - adapt rapidly to challenge the "technologically superior" opponent. Adversaries can gain an operational edge based on how fast they move from defining the required technology to implementing it in theatre.

However, historically, technology development cycles are lengthy, costly and resource intensive. In fact, a root challenge to the military is the protracted planning processes – sometimes with horizons of 20 to 30 years, involving changes to policy and resources. Capability acquisition projects are similarly conducted over multi-year time spans. Long processes are typically costly processes. Subsequently, the major technology breakthroughs and development projects have been left to deep-pocketed multinational corporations and the more wealthy governments.

Understandably, more R&D takes place in the civil environment where commercial benefit is found. High consumption of technology products leads to shortened development cycles and reduced costs. It has also spurred demand for cutting-edge technologies to be easily available, reliable, convenient and efficient. Examples are Wi-Fi and several commercially-off-the-shelf (COTS) products for connectivity, communication and surveillance.

As the human habitat underwent a 'technofication', the modes of technology development and uptake have also shifted.

Despite challenges in the military ecosystem, the defence force needs to ensure full exploitation of its technology development capability to ensure it is equipped for operational campaigns of today and tomorrow.

In addition, the commercial industry provides opportunity for dual use technologies to go beyond the military into the civil domain. Another opportunity is establishing commercial partnerships with industry players to expand the capability and market involvement.

The technology edge has shifted from rich armies to the most innovative armies who can adapt civil technologies to their military operations. Unfortunately, adversaries are innovative too. Adaptation of easily-available technologies is contributing to the changing face of the threat.

The quantum of the challenge

Declining defence budgets have caused serious repercussions for militaries the world over. It has caused the erosion of defence industry capabilities, plus a diminishing capacity to support and maintain existing capabilities. Importantly, it has also refocussed acquisition strategies away from 'bespoke' products towards adaptable COTS products which are usually also cheaper and faster acquired.

The match between defence planning and capability acquisition is also important. Currently there is no alignment between the acquisition strategies and the 'defence planning assumptions', which are based on defence threat assessment. Forces acquire capabilities based on the 'might' they aspire to project. These end up collecting dust due to maintenance cost, lack of suitably trained staffing and misfit with prevailing operational requirements.

Agile capability

So, how do we visualise the future technology development process? How can technology development make our acquisition strategies more relevant and aligned to our mandate?

The answer lies in the two dimensions of technology development, namely the attainment of operational advantage and the achievement of strategic independence.

The operational advantage means having the upper hand and an increased chance of success and protection of assets. Mission-centric technologies must be considered, technology life-cycles must be short and development processes must be agile to match the volatile operational environment.

Coupled with this, the armed forces need to choose the niche technologies for strategic independence and invest in long-term technology development programmes that will result in technology demonstrators and technology products that are ready for uptake by industry to support their participation in acquisition projects.

Why is strategic independence important?

Strategic independence in this context includes the ability to apply capabilities to achieve national goals and preserve national interests without dependence on or intervention from third party states or entities;

Strategic independence affords the country the freedom to choose how, where, and when it applies its defence capabilities – while it enjoys the capacity to support, operate and maintain such capabilities independently. It creates opportunities to generate intellectual property at system or sub-system level of technology products, and have the freedom to decide on how to utilise it. Once strategically essential technologies have been defined and developed, they need to be protected and safeguarded from falling into the wrong hands.

Technology development: The strategic edge

Technology development is a systems effort that reduces risks within the acquisition strategy. It requires specific environmental components: For example, the ability (skills, knowledge, expertise) to understand capabilities of specific technologies, how best to apply and operate them, and what their underlying strengths and weaknesses are. This includes evaluating technologies in terms of performance, interoperability, cost and value-for-money before acquisition.

Technology development ultimately creates the 'smart buyer' approach. A smart buyer understands capabilities from sub-systems level to the system-of-systems level – plus ensures the capacity for life-cycle management. A defence force should maintain adequate in-house capability that can at least assess operational and safety risks of technology products.

Another important component is agility. The dynamism and uncertainty of the prevailing battlespace demands a defence capacity that is agile, adaptable and able to re-organise swiftly according to instantaneous operational requirements. Forces must be able to generate capabilities to solve an imminent security challenge as and when needed, with immediacy. The practical response to the uncertainty and unpredictability of future conflict is institutional and operational agility. Decision-making should be decentralised to levels that allow swift response with less bureaucracy.

Financing is a serious challenge. Initiatives to reduce cost across the development life-cycle can assist. Examples include using civil technologies, customising and modifying COTS technologies to be MOTS capabilities and co-funded, joint development programmes with allies. Allies across the system of innovation are important avenues for leading technology development. Consider the benefits of having access to blue sky research and in-depth research at universities, the evaluation and development at independent science authorities – all the way through to the partners in technology transfer, commercialisation and uptake.

Industry has a critical role to play in creating an enabling environment successful technology development. However, industry would only commit R&D resources where clear market uptake is evident. It is therefore prudent that government works with industry from the onset to identify such opportunities.

One approach could be a network of smaller companies with high technical density that are able to manufacture sophisticated technical products rapidly and in small quantities. This supports the agile acquisition environment driven by prototype production. Original equipment manufacturers should include SMMEs in the supply chains through complementary collaborations that benefit a sustainable defence industry.

Technology development is an area that can be leveraged to generate effective, suitable and relevant capabilities to deal with the asymmetric future combat scenario. This calls for agile and innovative institutions that efficiently combine human acumen and the right technology choices.

Land-based defence: IN THEIR SHOES

Landward operations are typified by a human-centric focus that has to show responsiveness and sensitivity towards the national imperative, the needs of societies, communities and individuals. With a duty such as this, land-based forces are no longer just a military component of the South African National Defence Force (SANDF) but an instrument of socio-economic development and peacekeeping in the country, the region and the larger African continent. Great opportunity exists for close cooperation with foreign national forces, and unprecedented levels of civil-military cooperation involving other government departments, foreign and local agencies, and the local civilian population.

The key figure remains the soldier. A solder that is well educated and trained in the realities of the task, fit and healthy, skilled, disciplined and professional. Not only does this figure contribute to the power of the force, but also serves as a role model of competent leadership in civil society.

Key 'hard core' technologies will be required to improve the soldier's situational awareness; night vision; man-portable drones; unattended ground sensors; data mining of other battlefield sensors like UAVs; communications (including smart phones); lethality that includes less-than-lethal means; the ability to call for fire support and designate targets to precision munitions; survivability through improved personal protection; detection of Improvised Explosive Devices; battlefield medical support; sustainability through better rations, hydration and power supplies; mobility and load reduction.

The increasing availability of these technologies as commercial-off-the-shelf can be exploited by the military. However, the challenge would be to adapt and integrate these 'commoditised' technologies to be fit-for-purpose, practical and effective. Ultimately, science, engineering and technology support is required to achieve the balance between high-tech and low-tech solutions and combinations thereof in a financially constrained environment.

The CSIR supports the approach of first understanding a problem or need through scenario development and analysis, working to develop the solution with operational concepts, architecture (processes, organisational and technical systems), effectiveness analysis and trade-off studies, as well as supporting implementation. The value of this approach lies in reduced risk through increased integration, more efficient, longer-lasting solutions due to more stringent consideration of options, and innovation in security and operating concepts at an inter-departmental level, plus architecture at a departmental level.

The complexity and dynamism of the future 'battle space' will require a dynamic and responsive landward force. To this end, the future landward force requires science, engineering and technology support to ensure smart strategy, smart operations, and a rightful place as a smart user and buyer. In short, have the power base to operate as a 'smart force'.

The complex realities of the landward operational threat environment include female and child soldiers, formal military forces, rebels, private security agencies, the occurrence of atrocities, genocide, terrorism, asymmetric warfare, famine, water scarcity, the scramble for precious minerals and resources, frustration and violence especially among the youth, refugees, illegal immigrants, natural and manmade disasters, civil disobedience, extremism, passive resistance, use of IEDs, to name a few. It is clear that our landward forces face an entirely new war. A war that requires combat on the one hand – and peace keeping and enforcement on the other. Yet, while the battle space has expanded considerably, resources – both human and financial – have not increased accordingly.

WHAT IF?

Experiments in reality

For South Africa, border safeguarding entails the challenge of an extensive borderline and several hundred ports of entry. The borderline comprises approximately 2 798 km of coastline, 4 471 km of land border and over 1.2 million km^2 of air space. There are approximately 730 registered airports of which 10 are recognised international airports, more than 52 formal land border posts and 111 seaports. Rich in valuable, sought-after natural assets (precious minerals and stones, rhino horn, abalone), located on an increasingly active trade route and with often non-existing, inefficient land border structures, the risk expands to economic losses through piracy, poaching, smuggling, illegal entry and the potential to unhinge regional safety and security.

Improved border safeguarding requires close cooperation and integration between a number of government departments responsible for defence, immigration and policing. Beyond safety and security, the phenomenon also has social, economic, education, health, transport and issues of migration.

In the practical implementation of effective border control, command, control, communications and surveillance technologies are key components. With limited scope for technology investment, the opportunity for novel and innovative thinking can lead to ways of doing more with what exists.

Data from aerial views, camera surveillance, called in on radio or cell and detected through sensors, are channelled through an interoperability gateway into a software system that gives the full border picture and can pinpoint incidents of concern. This means that improved surveillance – without sending armies of patrol staff – and the information as a deterrence mechanism or best-suited combatting tactics, is available to commanders.

A practical and affordable option is using an integrated concept development and experimentation process to surface optimal solutions. This entails incorporating existing infrastructure, using readily available surveillance technologies and ensuring better integration of different platforms.

Field experiments are conducted in border zones to rigorously test the use of sensors, communication mechanisms and networks in combination. The ultimate aim is to manage a solution as an interoperable system that adds scope to the detection and provides intelligence guide command decisions and patrols.

The right ingredients and the right combination

Challenges are created to add to the stringent testing – these include geographic spread, smart phone technology integrated with other communication platforms. Technology options include use of unmanned aerial systems capturing video views, cellular telephone intercepts, GPS jamming, video and audio conferencing and sharing of remote computer desktops.

Although not new tools in the military environment, the key is effective collaboration and synchronisation. The pivotal requirement is the means to facilitate and enable inter-departmental collaboration. This implies the important interplay between humans and processes – these also need to be interoperable for optimal and effective collaboration.

Experimental defence scenarios brought to life

The CSIR's concept development and evaluation centre becomes the nerve centre of a mission when various sources are integrated into one, comprehensive view. Information from diverse systems such as radar, satellites and video feeds acquired from unmanned aerial telemetry systems, communication devices, etc. can be displayed on screens to provide an invaluable integrated overview of a defence scenario. The centre is used for operations planning to create border security response strategies, centrally monitoring counter-poaching efforts and training.

The centre allows for a flexible environment with a strong networking, multimedia and server infrastructure in which different information display configurations can be easily and quickly prepared to be used for different experimental scenarios to aid in better planning. It employs equipment and software platforms that can support, display, analyse, integrate and interpret diverse sets of data quickly and efficiently.

As an example, in counter-poaching efforts, such an integrative 'war room' means officials and decision-makers can instantly see collated data, for instance on poaching incidents, mapped out in near real-time with statistics such as how many rhinos were killed, how many shots were fired, how many poachers were caught as well as game ranger and poacher movements. By integrating a large amount of information on a central platform, patterns can also be analysed and anticipated – for instance identifying when poachers routinely target a certain area or a specific part of a fence for easy access.

Other domains for experimentation includes border safeguarding – with interdepartmental participation, and supporting community policing forums and operations of the South African Police Service, which also includes crowd-control concept demonstration.

Smuggling, alien influx and illegal grazing across our borders are the results of lacking or vandalised fencing and insufficient capacity to deploy on patrols. By combining various surveillance and detection technologies in integrated communication and command systems, the CSIR works to assist its defence clients by expanding their ability to watch over our territories.

The CSIR works in a coalition with the South African National Defence Force and industry partners in the testing and evaluation of suitable solutions.

A BEHAVIOURAL SCIENCE APPROACH TO STRENGTHEN MILITARY RANKS

Article contributed by Adelai van Heerden, head of CSIR Behavioural Sciences research

The field of psychology has never been more important to the military than it is today

People are at the centre of all military efforts. People operate the weaponry and technology; they make the life and death decisions that guard our way of life in so many aspects. With this in mind, military thinkers are now starting to look at new approaches guided by behavioural sciences to assist in ensuring the combat readiness of soldiers.

The importance of having soldiers with the right combinations of knowledge, skills and abilities has become critical in a context where, according to the 2015 South African Defence Review, conventional and unconventional military operations will span the spectrum from participation in disaster relief and support to government departments to combat operations such as counter-terrorism and counterinsurgency operations, to lethal combat in responses to threats to national interests or threats found at multiple levels. Wide-ranging skills are required by the soldiers to fulfil their role as peacekeepers, as they experience stress on various levels.

The challenge posed within the South African behavioural science domain has been to proactively work towards combining theory building with practical knowledge application within the indigenous African context. Only through the exploration of contextually relevant research, can there be impact.

Behavioural science researchers at the CSIR have been working closely with the South African National Defence Force for more than a decade. Through applied military psychological research, the focus is on an African warrior expected to perform diverse roles in highly stressful circumstances. Specific attention is paid to the prediction and understanding of individual attributes and contextual factors that contribute to success within the military environment. In studying human attributes, the importance of including studies of contextual factors such as the influence of national culture on an individual's current behaviour is important, as the context often determines how they view and approach the world around them. Consequently, researching what motivates people within specific groups and deploying informed, testable interventions on the ground, is central to managing modern conflict on the African continent.

The CSIR's behavioural research develops methods and solutions to assist the South African National Defence Force in identifying candidates that show potential to succeed as qualifying soldiers early on in their training. The costs involved in training military candidates are high, with significant resources being invested in each person who signs up. The research focus is on organisational (contextual) and individual processes including methods of assessment, selection, instruction, development and reinforcement of core soldier behavioural attributes, such as mental toughness and performance motivation.

During recruitment and training phases, attention is given to physical, psychological and contextual factors that may have an influence on a candidate's ability and will to succeed in adverse circumstances. Research is focused on identifying the personal characteristics associated with success during military training, complemented by exploring the military candidates' values, beliefs and frames of reference as these relate to intrinsic motivation and coping abilities.

After the selection phase, the focus shifts towards the individual and group levels of analysis through research focused on specialised skills and abilities that support soldiers' military career progress in terms of personal life skills development, career development, leadership development as well as financial planning and retirement planning. On the organisational level of analysis, relevant research is conducted in support of contextual requirements.

What makes a good soldier?

A good soldier will possess a balanced combination of personal characteristics that include cognitive as well as non-cognitive skills and abilities.

Of critical importance in the complex era of modern warfare on the African continent, will be effective interpersonal skills, such as cultural and emotional intelligence, leadership, human relations and teamwork. In addition, technical, technological and tactical proficiency will always be important attributes in addition to having numerical comprehension and problem-solving skills.

The African philosophy of Ubuntu is famously explained as, "I am what I am because of who we all are." The good soldier in the modern era of war on the African continent is an individual with a strong moral compass that can switch roles between being a defender of the peace and an African warrior fighting for peace. Leadership and followership inspire both individual effectiveness and group co-operation. The CSIR's behavioural science researchers apply this principle from the perspective of focusing on all the important attributes that make up the whole individual while also developing teamwork skills. In many ways, this life philosophy can be applied to the camaraderie found within the military organisational culture where the individual and the group are interlinked during military operations, resulting in good soldiers becoming great soldiers.

Work being conducted by the CSIR defence-related behavioural science capability include:

- Creating an indigenous South African approach to behavioural science research through the evaluation and development of psychometric and other assessments, appropriate for South African populations;
- Selection, training and development of soldiers;
- Career development and retention of soldiers;
- Psychological profiling, focusing on matching personality dimensions with role requirements;
- Investigating positive psychology constructs in the context of resilience measurement and training;
- The development of leaders as well as life skills development that enables the soldier to function effectively on individual, group and societal levels; and
- The behavioural aspects of cyber warfare.

WITHSTANDING THE BLAST

In a war zone, improvised explosive devices (IEDs), land mines, grenade launchers and anti-aircraft, anti-vehicle or anti-personnel devices are used for their effectiveness against their target. A direct hit immobilises units faster than anything else.

Unicef stated in an online article that more than a million people have died since 1975 from landmines detonating beneath them. They estimate that landmines kill around 800 people per month, despite these mines being outlawed in the 1997 Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-personnel Mines. The treaty, known as the Ottawa Treaty, has since been signed by 162 nations.

There are two common types of landmines: anti-personnel and anti-vehicle explosive devices. Researchers at the CSIR specialise in studying the effects of these devices at a research facility in South Africa's Gauteng province. The Detonics, Ballistics and Explosive Laboratory (DBEL) caters for the testing and evaluation of vehicles, boots and other protective gear that aim to reduce the damage done to people exposed to explosive events. DBEL can handle explosive events of net explosive content from less than 100 g, up to 50 kg in open air.

Using a combination of high-speed or flash X-ray photography and CSIR-developed test-rigs, such as the lower-leg impactor, researchers can study the effects of a blast event in up to a million frames per second. Crash test dummies (or ATDs – anthropomorphic test devices) are used as surrogates for vehicle occupants and are fitted with data-collecting sensors that measure how the impact or shockwave of the explosion travel through the ATD. Data collected indicate where forces generated by an explosion do the most damage and where better protection is needed.

Buried blast threats are difficult to identify. Adding to the danger, is the fact that the soil they are buried in enhances the blast effects enormously. Having the focused DBEL available in conjunction with the specialised research equipment and processes, the CSIR has launched a number of research activities into the effects of soil on both concealing the explosive threat and the parameters that make the blast more effective. This leads to

The Emily blast chamber; previously a submarine hull.

better protection, as well as detection, which is ultimately better.

With the increased risk of civilians and soldiers being exposed to extremist threats in towns and cities, it is paramount to understand the effects of blasts in built-up areas. Emily, a section of a decommissioned submarine hull, was modified to offer the perfect conditions to study explosions that happen in confined spaces.

In addition to the larger facilities, DBEL also caters for small arms and automatic grenade launchers, cubicles for the testing of small charges, and a fenced area for research into the effects of landmines exposed to prolonged exposure to sunlight or soil.

Ballistic research is a fascinating career and many a young chemical, electrical and mechanical engineer have arrived at DBEL bright-eyed and ready to see some action (and learn a few things in the process). As a state-of-the-art training facility run by seasoned professionals, it offers forces, such as the South African Police Service and other special operational forces, a controlled environment to test and train on how to deal with IED disruption and explosive ordinance disposal. A custom-built human shelter on site offers a safe haven for clients and visitors from where the blasts can be viewed on video screens.

A critical aspect of explosive and ballistic impact research and protection is the ability to scientifically replicate both standard military threats as well as the ubiquitous and widely spread IEDs. DBEL has the equipment and methods to safely develop and test new explosive threats and unique IED-type applications, as well as provide a range of validated scientific surrogate threats.

A thorough knowledge and understanding of explosives is critical in developing technologies, systems and doctrines needed to offer effective protection. For example, effective foot protection when stepping on a landmine may provide enough of a shield that the soldier will still survive the blast with a functioning knee joint – vital when learning to walk with a surrogate leg. For this reason, the CSIR has enhanced the infrastructure, data and capabilities to offer explosive threat and protection research and development.

SIIMA

SIIMA is a Scientific Instrumented Impulse Measuring Apparatus used to measure the impulse generated by an explosive charge. Data collected from SIIMA are used to quantify the threats, characteristics and the protection capacity of the protection solutions under investigation; for example, the effect the depth of burial has on the impulsive loading the target will experience. Other variables studied include stand-off distance, the shape of the charge and the soil conditions. SIIMA is also used to compare the effectiveness of various protective structures on a scaled level.

By understanding the mechanisms that actually cause the injury, and researching human tolerances that indicate how much the human body can actually take, CSIR researchers can improve the design of vehicles or personal protection equipment aimed at reducing the damage humans suffer during blast events.

THE **EXPLOSIVE** THREAT:

Studying the human response to an explosive event

The primary threat to the human body is the overpressure from the blast. It exists for a few milliseconds but can cause immense damage to the internal organs. Soft, air-filled organs such as the lungs, ears and stomach, where tissues of differing densities meet, are the most at risk. Exposure to an explosive event may cause haemorrhaging and organ rupture. The second most dangerous effect is the impulse that can propel a body into surrounding obstacles. The body is further exposed to loading caused by velocity shock waves, structural impacts, and impulsive loading.








DRIVING IS BELIEVING:

ENHANCED MOBILITY, FIREPOWER AND PROTECTION

To properly demonstrate various applied technology outputs and their value on the battlefield, the CSIR is creating a test-bed military vehicle called the Landward Technology Demonstrator, or LTD, which promises to be a mean testing machine.

"Seeing is believing, as the saying goes," says Deon Malherbe, chief designer of the LTD at the CSIR.

"We want to allow our major stakeholder, the South African National Defence Force, to physically experience the impact of various defence-related technologies that have been and will be developed at the CSIR. This includes technologies to enhance mobility, firepower and protection, soldier systems, autonomous vehicle systems and other research.

"Seeing may be believing, but when it comes to proving the value of enhanced landwards defence technologies and capabilities, first-hand experience will trump 'seeing' every time. The LTD gives our stakeholders the opportunity to drive in a vehicle that is actually outfitted with these systems."

The mobility platform for the LTD has already been commissioned and various technologies that are in the pipeline will be fitted onto the vehicle in the next three to five years for testing and demonstrations.

"The LTD demonstrator platform is based on existing vehicle technologies and reflects a current six to eight-ton military vehicle to allow the South African National Defence Force to easily assimilate our technologies into their domain," says Malherbe.

The various 'bolt-on' technologies that will be fitted onto the LTD could include CSIR camouflage research, protection and firepower research (including augmented reality displays), and unmanned vehicle research technologies.

"To be clear, this is not a vehicle designed to replace any vehicle in the South African National Defence Force fleet; nor does it compete with industry in terms of being a military vehicle in and of itself. It is primarily a mobile laboratory to evaluate, demonstrate and leverage technologies developed as a result of applied research in protection and firepower systems, soldier systems, unmanned systems and various aspects of mobility."

Apart from being a mean machine in terms of demonstrating the value of enhanced landwards technologies to the defence industry, the LTD will also add value as a visible demonstrator of the country's innovative spirit.

THINKING TANK?

Creating autonomous vehicle navigation on the battlefield

One of the primary challenges in unmanned mobile ground systems is real-time path planning and navigation in the absence of global location information such as a GPS. The CSIR is developing such a system for potential use in military vehicles.

A lot of work is being done globally to develop vehicular or robotic unmanned mobile ground systems that can, for instance, navigate through hazardous environments such as earthquake rescue zones or that can haul military equipment over long distances or across rough terrain. Currently, most of these systems primarily make use of GPS, static radio frequency (RF) beacons or satellites to navigate.

"The problem is that in dangerous or hostile environments, these systems could either be absent or can often easily be compromised or disabled, and they also have very limited use indoors," says Danie de Villiers, a systems engineer at the CSIR.

"Reliance on these systems is therefore undesirable and there is a global need for a system capable of determining accurate location information using only local sensors such as cameras and inertial measurement systems."

This sentiment is supported by a Broad Agency Announcement of the USA Combating Terrorism Technical Support Office, issued in February 2015, where it requested international assistance in this area of research.

"This is why the CSIR is developing an advanced autonomous navigation system. The purpose of this project is to demonstrate autonomous navigation of an unmanned ground vehicle using on-board sensors only, without using GPS, RF beacons or other external active identifiers, with plans to demonstrate the capability by connecting it to a light military vehicle."

CSIR project manager, Nombulelo Soyifa says, "The autonomous navigation research project is currently training and developing researchers to enhance scientific and technological capabilities." The establishment of these capabilities will also allow the CSIR to support the strategic trajectory of the South African National Defence Force, as described in the 2014 Defence Review, as far as using the best that technological innovation can offer in pursuit of a safe and secure South Africa.

READY FOR A RAPID RESPONSE to Special Operational Force's needs

The men and women in the armed forces form the rapier of a nation's defence muscle. At the frontlines, operational efficiency is key. This includes access to the tools, tactics and technology interventions to deploy, engage, respond, regroup and make rapid decisions – tried and tested tools that are optimal for operational scenarios. No guessing.

A changing theatre of war means changing the arsenal of technology options and approaches. This is innovation with urgency.

The special operations capability of the South African Defence Force enlists a particular brand of soldier – able to operate under difficult and dangerous circumstances. These operatives are carefully selected and rely on equipment of particular sophistication and precision. Often this requires customisation. Often the operational need is extremely urgent. This is the challenge to creativity, invention and superfast product development.

The CSIR performs a number of so-called 'quick reaction tasks' throughout the year for the South African National Defence Force (SANDF), and the South African Special Forces specifically. These tasks have to be completed within 24 to 72 hours and typically require a customised, solid – yet cost-effective – solution to address an urgent force deployment need.

The CSIR is able to support these requirements not only due to its ready engineering and technical capability, but also because of its understanding of the importance of confidentiality on work performed for the SANDF. Hardly any of the project achievements can be publicly disclosed. Deployments range from hostage situations, anti-piracy or poaching, to safekeeping, rescue or other military operations such as those encountered on the African continent.

Requirements are wide ranging: from creating a custom object by 3D printing, to mobility solutions such as specialised GIS and map data for smart phone, or adaptations to existing technology tools or weaponry – making it smaller, bigger, collapsible, wearable, waterproof, airborne, limitless.

As an example, the CSIR was tasked to assist with the deployment of fully equipped field stations, needed at the time of the Soccer World Cup. These tented field command centres needed to be such that it could literally be packed up, dispatched anywhere and rapidly erected – including the required command and communication infrastructure such as screens, projection equipment, etc. The solution? Custom-made suitcasing and rigging, still used by operators for deployment anywhere, any time.

Despite the speed at which these tasks have to be performed, the CSIR follows a disciplined and formal engineering and design approach that is documented and quality controlled.

Longer-term projects for the Special Forces typically look at sustainment, custom weaponry and equipment. A power pack that charges multiple devices is one example. The mantra is: every kilogramme of weight reduced, means one more litre of water to take along.

'Halt! Who goes there!'

Mobile wireless field networks for connected soldiers

As part of its Soldier Technology Integration project, the CSIR is creating peer-to-peer wireless field network systems that will enable advanced early warning and friend-or-foe identification for modern soldiers.

The CSIR's wireless mesh network topology developed for industrial control and sensing, is a point-to-point or peer-to-peer system which essentially creates an ad hoc, multi-hop wireless network without the need for a central WiFi router. A node in these networks can send and receive messages, and can also function as a router to relay messages to its neighbours. These networks, in other words, communicate wirelessly without a fixed infrastructure.

"As such, these wireless mesh networks have valuable potential applications for modern soldiers, including being able to instantly distinguish between friend or foe, or the ability to create temporary base protection in the field through early warning, without having to set up traditional fixed WiFi infrastructure," said Danie de Villiers, a Systems Engineer for the CSIR's Soldier Technology Integration project.

"The objective of this work is to study wireless network technologies and sensors and integrate appropriate technologies into a system which can be used by a landwards soldier, who becomes a node in these networks.

"At this stage we are investigating the possibilities of using these ad hoc network technologies in the soldier environment. From that, some prototype concepts will be developed and tested."

The CSIR's Soldier Technology Integration project is used to test new soldier technology concepts by building prototype systems. The CSIR mandate in this regard is to develop a capability to assist the soldier through requirement analyses and the integration of new technologies. The systems and prototypes developed will be transferred to the industry for final development if accepted by the South African National Defence Force as the main client.

RAPIDLY REAL

3D printing is not a novel technology any longer. Much faster than manual or numerically controlled manufacturing, the process is also more cost-effective, reduces labour cost and increases turn-around time, reduces material waste associated with conventional forms of manufacture, plus lowers energy use, and allows for the design of unusual and more organic shapes and forms.

In the defence environment, the technology is used for scaled models of actual structures, terrains, areas, prototypes of parts, small volumes of items, patterns, moulds and tools.

It also enhances the advanced mechanical engineering capability, especially when complex mechanical engineering solutions are required. The designer can use direct manufacturing to produce the following: scaled models of actual structures, terrains, areas, prototypes of parts, actual items (if a small volume is required and the material is acceptable), and as a high production volume input to investment casting (for patterns), injection moulds (for hard tooling), sand moulds, and soft tooling (for cores).

Direct manufacture comprises the stereolithography apparatus where a laser sets a layer of wax or photosensitive material in a bath; 3D printing, which uses injection technology to create a thermos-plastic structure; and selective laser sintering that uses a laser to fuse powder (nylon, polycarbonate, polymer and metal). Because colour terrain models are a particular requirement of the client, the CSIR uses a 3D printer that uses colour ink jet technology. Similar to a normal printer that would print a photograph, this equipment prints layer after layer using a material that builds up on the previous layer of material. The input into the printer has to be created either in computer aided design software, or by using a 3D scanner to capture all dimensions of a particular object or shape.

How we work:

1. Clients request specialised mehanical parts or electronic housings or fitting to be printed.
2. The CSIR invents or formulates an idea of concept.
3. The CSIR creates a design using CAD software.
4. The client and the CSIR team review the design and upon agreement a prototype is printed.
5. The prototype is assembled and inspected, improved or finalised.
6. Delivered to client.

Keeping it *green*

South Africa's borders are as diverse as the people who live within them. The country shares fences with six other nations and has a massive exclusive economic zone in the oceans surrounding it. The size, penetrability and ecological risks, among others, require partnerships between the forces tasked with securing the borders and those responsible for the research and development of border safeguarding technologies.

Such a partnership exists between the Joint Operations Division of the South African National Defence Force (SANDF) and the CSIR. Since its establishment in 2010, the main focus of the collaboration has been operational border area deployments.

Projects vary from quick reaction tasks that address immediate operational needs, to medium- and long-term solution requirements.

Sustainable use of natural resources has a role to play in improving the deployment conditions, capabilities and effectiveness of the soldier, deployed on mission-specific tasks, where combat systems are not suitable for these unique deployment scenarios.

Large areas of the South African border run through conservation areas, such as the Kruger National Park. Soldiers deployed in these areas require protection from dangerous animals and the CSIR has invested significant research into finding solutions that protect both the soldier and the environment. Ranging from the most basic solutions such as air horns and mobile electric fences, to more advanced technologies.

Waste management

A CSIR waste management advisory committee was formed in 2015 and its aim is to assist the defence force's Environmental Management Office with waste management issues, specifically in matters relating to dismounted soldier deployment and upstream waste management. Multidisciplinary expertise provides waste management advice and guidance, as well as the development, testing and evaluation of custom technology solutions that will minimise the impact of long-term deployments in protected areas.

Power management

Power supply for deployed soldiers to remote positions remains a challenge as equipment critical to mission success, such as a GPS or communication systems, needs to be recharged. The CSIR has developed several technologies in this regard, one being 'Muscle', a power management system that uses available energy sources in the field, to replenish equipment batteries. By using Muscle, a soldier is able to recharge a radio using a vehicle battery, solar power, or power mains in countries with electrical outputs that differ from South African plugs.

Knowledge and experience gained will be applied to rolling out advances to other areas of deployments, expanding green deployments and managing and improving the environmental footprint of SANDF deployments. Longer-term research will look at introducing cost savings by making small remote deployments completely self-sustainable. The CSIR will further increase the scope of waste management to include water purification and the management of waste water.

POWER TO OPERATE

Power management systems require a holistic R&D approach to fully understand and optimise the power chain from the replenishers to the energy storage units, to the equipment to be powered. Each item in this chain has unique characteristics and requirements. Each item must be optimised for efficiency, performance, reliability and safety.

The dismounted soldier's equipment includes electronic equipment ranging from radios to navigation and situational awareness equipment. Typically powered by internal batteries, this means carrying different sets of batteries and replenishment items.

The CSIR's Muscle, an integrated power management system reduces the weight and space burden of the dismounted soldier significantly. It is also more reliable and more versatile, for example one solar panel could charge any of the equipment items. By testing and evaluating energy sources against the needs of deployed forces, a fit-for-purpose solution is found.

Muscle is a power management system that uses various sources of energy – mains power, vehicle batteries, solar panels – to charge battery packs that power electronic equipment in the field. The pack can support loads ranging from 10-32V.

MOVING ABOUT

The operational requirements of the future African battle space present the South African National Defence Force with additional mobility challenges. Confronted with a battle space environment that varies from desert to water-rich surfaces, will challenge the defence force to provide support in operational scenarios such as peacekeeping, border security and disaster relief. Although the defence force will have to retain some conventional capability, balancing those requirements for operations other than war with those necessary to sustain a conventional capability, will be challenging.

LIGHTING TO LAND

Codenamed 'Candle', a portable landing light system is rapidly set up to mark a drop zone or lay a landing strip – using either visible light or infrared, detectable only with night vision equipment. Light weight yet rugged, the system is operated remotely, either by a pilot or troops on the ground. Candle has been used in peacekeeping operations by pathfinding operatives who are dropped in areas where there is no landing strip.

The system consists of 12 lights, each fitted with a transmitter/receiver with a remote control effective up to 600 m and 200 m between lights. With six lights on either side, a landing strip of 1 000 m and longer can be marked out – space enough to land a transport aircraft the size of a Hercules.

PLANT BIOPHARMING OFFERS RAPID RESPONSE TO PANDEMIC AND BIO-TERROR THREATS

The world is on high alert with the threat of infectious diseases spreading through the entire human population. Emerging global pandemics include drug-resistant forms of tuberculosis, bird flu, swine flu, super staph, severe acute respiratory syndrome, drug-resistant malaria and the continuing major threat of HIV. The use of biological weapons in hostile quarters is also a threat not to be ignored. Pathogens of concern include various forms of plague; Ebola; anthrax; haemorrhagic fevers; and zoonotic diseases, such as Rift Valley fever.

Military personnel are particularly vulnerable as they form part of the first responder team. For the South African defence forces operating in peacekeeping missions in East, Central and West Africa, haemorrhagic fever-causing pathogens, such as Ebola and zoonotic diseases are real and present dangers.

At a global scale, there is a serious concern that should the outbreaks turn into a full scale pandemic, there would be desperate shortages of vaccines and treatments to protect citizens.

In response, governments have implemented strategies to tackle these threats through the establishment of vaccine and medicine stockpiles, as well as installing infrastructure and capacity to rapidly make and deploy biologics to counter the threats. To adequately deal with an outbreak, it is imperative that capacity exists to model the disease spread, and to have in place a strategic logistics plan for access to vaccines and other therapeutics.

Plant biopharming is the expression of therapeutics in plants. It is able to produce large amounts of protein in a short period of time, which makes it the perfect solution when a fast response to a pandemic disease outbreak (or bio-terror attacks) is needed.

Biopharming can rapidly produce preventative vaccines and antidotes for those already infected.

The production of effective bio-therapeutics in plants is no longer the stuff of science fiction, but rather a reality with the first high-value biopharmaceutical products already on the market. Plant-based pandemic influenza vaccines have completed Phase II human clinical development. The US Department of Defence's Defence Advanced Research Projects Agency has invested heavily in plant-based antigen expression technology as part of its rapid response strategy.

The CSIR and its international collaborators have established cutting-edge technologies to express functional therapeutics in plants. The consortium's first product, an antibody product against rabies, is undergoing preclinical development with highly positive indications to date. On the basis of this model, the CSIR and its collaborators already have the capability of producing other antibody antidotes and subunit vaccines for diseases (such as Ebola) for which antibody therapy is viable.

Nutri-drink for MISSION READINESS

A security force requires proper balanced nutrition for optimal physical performance and endurance. The CSIR has developed Nutri-drink, a nutritional drink formulated from a variety of leafy vegetables and indigenous gluten-free cereals and soya. It contains key nutrients required for physical stamina such as protein, iron, zinc and vitamin A. In addition, the drink alleviates hunger, and is high in energy and dietary fibre, which is important for healthy digestion.

Not requiring cooking, boiling or heating, Nutri-drink is the perfect meal on-the-go. It comes in a sachet of dry ingredients that is mixed with water.

POINT-OF-CARE DIAGNOSTICS FOR INFECTIOUS DISEASES

CSIR researcher Zandile Nxumalo holds a peripheral blood smear during the process of capturing the morphology of the blood cells onto a digital pathology database

The diagnosis of diseases at the point-of-care, for example, at farms and nature reserves, reduces long-term testing costs, improves sample viability and minimises the need for cold chain storage and transport of samples. In most cases, it reduces the turnaround time of test results, which is pivotal in the event of a disease outbreak.

The CSIR has developed an isothermal polymerase chain reaction (PCR) technology that enables complete point-of-care testing.

This gene-based technique allows for disease diagnosis from relatively crude samples that can be easily adapted for the detection of a specific pathogen.

The complete isothermal PCR technology includes a built-in communications system, that instantly disseminates test results to a laboratory for verification and database storage. The setup improves compliance and removes the possibility of testing bias. When a disease outbreak is detected, relevant authorities can be notified and testing results made available as required. A streamlined testing procedure will ensure that crucial results are available when needed, with a significant reduction in the risk of misplaced test results.

The scope for this diagnostics technology is vast and can be adapted for the diagnosis of specific human diseases following basic method development and relevant certification. The CSIR has already developed testing methods to detect zoonotic diseases, such as avian influenza.

At least 60% of human diseases are spread by animals and about 75% of emerging infectious diseases are zoonotic in nature. The emerging threat of the ability of relatively unknown diseases to infect and spread in humans highlights the importance of having diagnostic technology that can be readily modified and can be used to detect at the point-of-care with a rapid turnaround time for results.

Sectors such as defence and security can benefit greatly from the use of the PCR integrated diagnostics technology. Many personnel in this sector are at risk due to frequent travelling and deployment at various high-risk borders. Moreover, many biological agents can spread rapidly once introduced into society. The adaptable point-of-care diagnostics technology can be applied to mitigate the risk of both common and emerging disease outbreaks.

The military applications also become a serious consideration when dealing with the detection of bio-warfare agents at the point-of-care.

Polymerase chain reaction technology has been optimised at the CSIR for the diagnosis of livestock diseases, such as foot-and-mouth disease.

TECHNOLOGY-ENABLED HEALTHCARE

A spin-off application of this technology is the treatment of tumours by subjecting them to the intense heat with minimal damage to neighbouring tissue, unlike the damage encountered with radiation and chemo treatments. Due to the nature of sound waves, only the targeted region is exposed to the intense acoustic energy. Frequencies used are high so that precise control of the treatment region is possible and highly defined.

CSIR CELLNOSTICS: *ANALYSING BLOOD ON-SITE FOR QUICK DIAGNOSIS*

Diagnostic tools are required to identify the presence and cause of a disease, to suggest potential treatments and to monitor the effects of interventions. When healthcare centres are located far from centralised laboratories, the delays caused by transporting blood samples and test results may be detrimental to the quality of patient care.

The South African public health system provides healthcare services to the majority of its people. Many of its facilities are in remote locations and some face serious resource constraints, such as skills shortages and the lack of appropriate healthcare information at the point-of-care to facilitate diagnostic, treatment and referral decisions.

To address some of these challenges, the CSIR developed a device to perform quick and effective on-site blood tests to reduce the time between tests and diagnosis and subsequent treatment. The portable, wireless blood analyser named Cellnostics has an embedded electronic device providing two-way communication between the clinic and central laboratory. Users receive results without having to transport blood samples from remote areas to a laboratory for analysis. In addition to rapid blood-based diagnosis, Cellnostics is designed to support other diagnostic equipment that can benefit from the two-way wireless communication between healthcare workers and off-site specialists.

CSIR NHLS DATABASE: *IMPROVING THE TRAINING OF PATHOLOGISTS*

The CSIR and the National Health Laboratory Service (NHLS) have developed a national digital pathology database which is being used to improve the training of pathologists. It also extends expert pathology services to areas outside of major cities where specialists are mostly concentrated.

A CSIR NHLS team constructed a national digital pathology database containing 105 anonymous medical case studies. For each of these case studies, an expert pathologist from the NHLS recorded the clinical features and full blood counts of samples with detailed annolations that identify specific abnormalities. These database submissions were then reviewed by other experts to ensure that the information was accurate.

The database facilitates the training of pathologists, improves the number of accurate diagnoses in remote and under-resourced areas, and aids in reducing referrals. It is an up-to-date ‘digital textbook’ of cellular pathology specifically relevant to South Africa’s disease burden, which can be used as a reference database for comparing anomalies when detected. NHLS staff can use the information to further educate themselves and increase their accuracy in future diagnoses.

The CSIR monitors the activity and usage of the database.

CSIR HIFU: *HIGH INTENSITY, HIGH TEMPERATURE HEALING*

Ultrasound technology has been in use in medical fields for both imaging and treatments for many years. Physiotherapy and the disintegration of kidney stones are just two examples of major relief for patients.

High Intensity Focused Ultrasound (HIFU) is an exciting new application of ultrasound technology in the medical field. Now with advanced imaging and control, it is finding use in more precise targeted tissue procedures.

HIFU is based on high frequency, high energy sound radiation. International research has proven that HIFU technology, which uses a high-intensity ultrasonic beam, can stop internal bleeding successfully in a specific area. As a result, the temperature of this specific area is raised to above 70 °C.

Controlling internal bleeding of vital organs such as the liver, kidneys, spleen and arteries (deep tissue bleeding) has always been a challenge for medical personnel responding to an emergency or on the battlefield with almost no technology available to stabilise wounded soldiers or civilians. The current project, which is at conceptual demonstrator stage, can provide a means to stop bleeding in casualties in the ‘golden hour’ after a trauma. This is critical for life preservation and for limiting the blood loss and allowing time to evacuate the casualty from the scene to a more secure and prepared treatment centre.

The CSIR designed a unique transducer for the biomedical application of this technology making it suitable for use in the field. Moving out of the clinical environment and providing a portable solution suitable for casualty stabilisation has been a key driver of the project. Traditionally, researchers used a fixed focal length transducer using external water sacks to vary the depth of penetration according to the need – a rather clumsy and inaccurate approach. The CSIR’s HIFU demonstrator provides a very small footprint of energy at a controlled variable tissue depth which can then be used to precisely target specific areas.

MEDICAL CARE IN RESOURCE-LIMITED ENVIRONMENTS:

Laser-based drug delivery within HIV infected cells

The use of femtosecond laser pulses in the targeted introduction of genetic matter and drugs into mammalian cells is escalating rapidly. This novel optical technique achieved through a tightly focused laser light beam is called photo-poration.

Briefly, the process is described as the accumulation of numerous free electrons resulting from irradiating the plasma membrane on mammalian cells with ultrashort laser pulses. These generate electrons that react photo-chemically with the cell membrane, lead to the creation of transient pores that allow entry of a vast variety of extracellular media. For example, it has been recently shown that gold nanoparticles can be optically tweezed to a desired location and subsequently introduced into mammalian cells by such photo-poration methods. It has also been demonstrated that it is possible to optically transfect mammalian cells via an axicon tipped optical fibre, thus opening the future prospect of coupling this photo-poration methodology with endoscopes for a host of in vivo applications.

In the CSIR study, researchers specifically investigate in vitro targeted delivery of antiretroviral (ARV) drugs into human immunodeficiency virus (HIV-1) infected cells using femtosecond (fs) laser pulses. The main objective of this study is to optimise the in vitro drug photo-translocation parameters to allow future design of an efficient drug-delivery device with potential in in vivo drug delivery applications for HIV-1. Some applications include the development of a laser-based drug-delivery patch for individuals working in resource limited environments, such as military personnel.

The human immunodeficiency virus still remains one of the world's most serious health challenges even after years of in-depth research. A positive and successful intervention in the past decade uses powerful new tools to prevent people from becoming infected and from dying from acquired immunodeficiency syndrome (Aids)-related causes. This has led to a decline in the number of new reported infections globally, and a decline in the number of children dying from Aids-related causes and acquiring HIV infection. However, national epidemics still arise in many parts of the world, and the burden of the epidemic varies between countries.

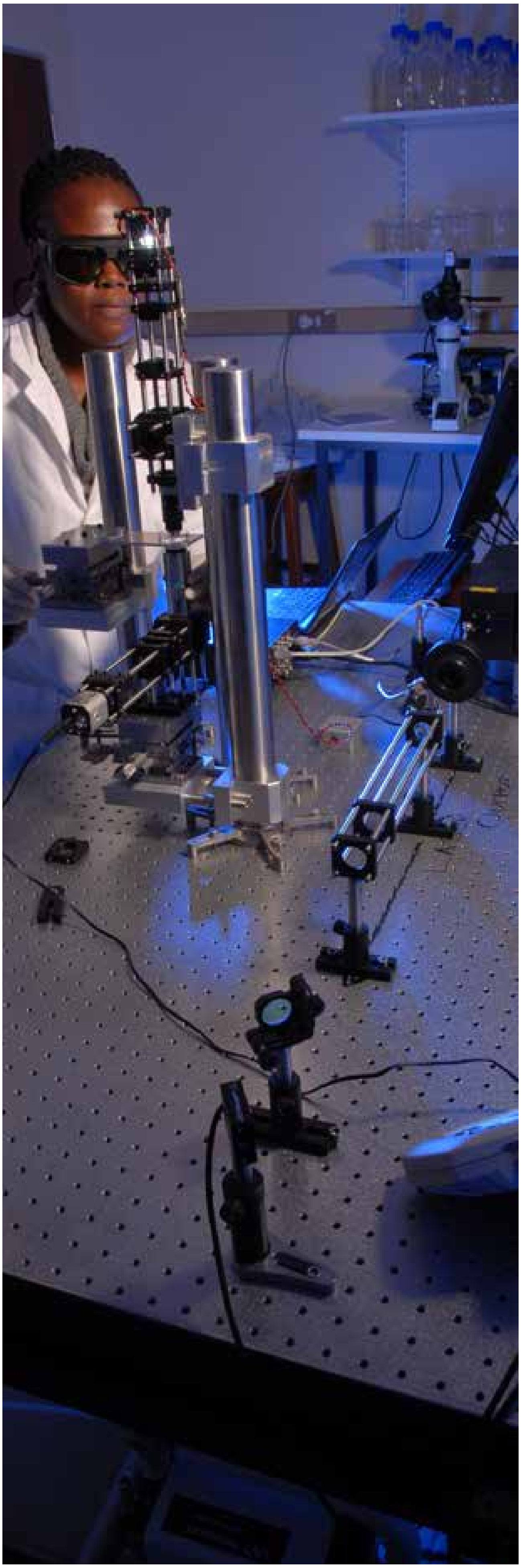
Antiretroviral therapy, taken orally, is the recommended treatment of choice for HIV infection. The use of highly active antiretroviral therapy (Haart) as a combination treatment prevents HIV from replicating and destroying the immune system, and therefore enables the body to fight off opportunistic life-threatening infections, cancers, and also arrests HIV infection from advancing to Aids. Each of the drugs used for Haart has adverse drug reactions which may vary from one patient to another and even be severe in some patients. This sometimes leads to non-conformance to medication which may further complicate the prognosis of the illness. The major challenge with Haart is the inability to reach the viral reservoirs where the HIV-1 remains latent and persistent, leading to inability to fully eradicate the virus.

Various methods including chemical, cationic polymers and lipids, viral, or physical approaches have been developed to promote uptake of foreign genes, drugs and other macromolecules into living mammalian cells. Each of these delivery systems carries specific limitations. However, for both in vitro as well as in vivo procedures, a drug delivery scheme possessing minimum cytotoxicity, which can be applied under sterile tissue culture protocols and can offer targeted treatment of a large number of individual cells, is highly desirable.

Optical drug delivery techniques using a fs-laser light source satisfies these criteria.

The most commonly used laser source in the area of laser-facilitated delivery is the fs-laser since it emits extremely short pulses and has a broad spectral range in the near infrared regime extending within the 700-1000 nm region. When focused to a diffraction limited spot, fs-laser pulses possess high peak powers and sufficient photon density to trigger non-linear effects such as multi-photon absorption of photons confined at the laser beam focus. Therefore, employment of fs-laser pulses for optical drug delivery in HIV-1 infected cells offers a high degree of spatial confinement of the deposited pulses leading to precise local disruptive effects at the targeted area and very minimum collateral damage.

The research uses fs-laser pulses to facilitate targeted optical drug delivery into HIV-1 infected cells. Additional benefits are that optical drug delivery setups are non-invasive and can be easily integrated with other optical techniques such as confocal laser scanning microscopy and optical tweezer systems.



The future high-level R&D relationship between CSIR & SAPS

The CSIR's role is to conduct science, research, technology and innovation in order to advance the wellbeing of the people of South Africa. Crime is an obvious challenge to the wellbeing of our people, communities and our economy. In keeping with that role – and with a track record in safety and security acquired over decades – the CSIR and the South African Police Services (SAPS) entered into a formal strategic agreement in 2013. The main driver is to provide the SAPS with access to the broad multidisciplinary skills base within the CSIR.

To further strengthen its technology-driven policing capabilities, the SAPS made the decision to amalgamate its R&D activities into a single, robust department.

The South African Police Service (SAPS) deemed necessary to establish Division: Research and Development under the leadership of Divisional Commissioner: Lieutenant General (Dr) Bongiwe Zulu.

The main function of the Division is to determine the SAPS Research Agenda and facilitate research execution within the SAPS. It focuses on the R&D matters with the purpose of:

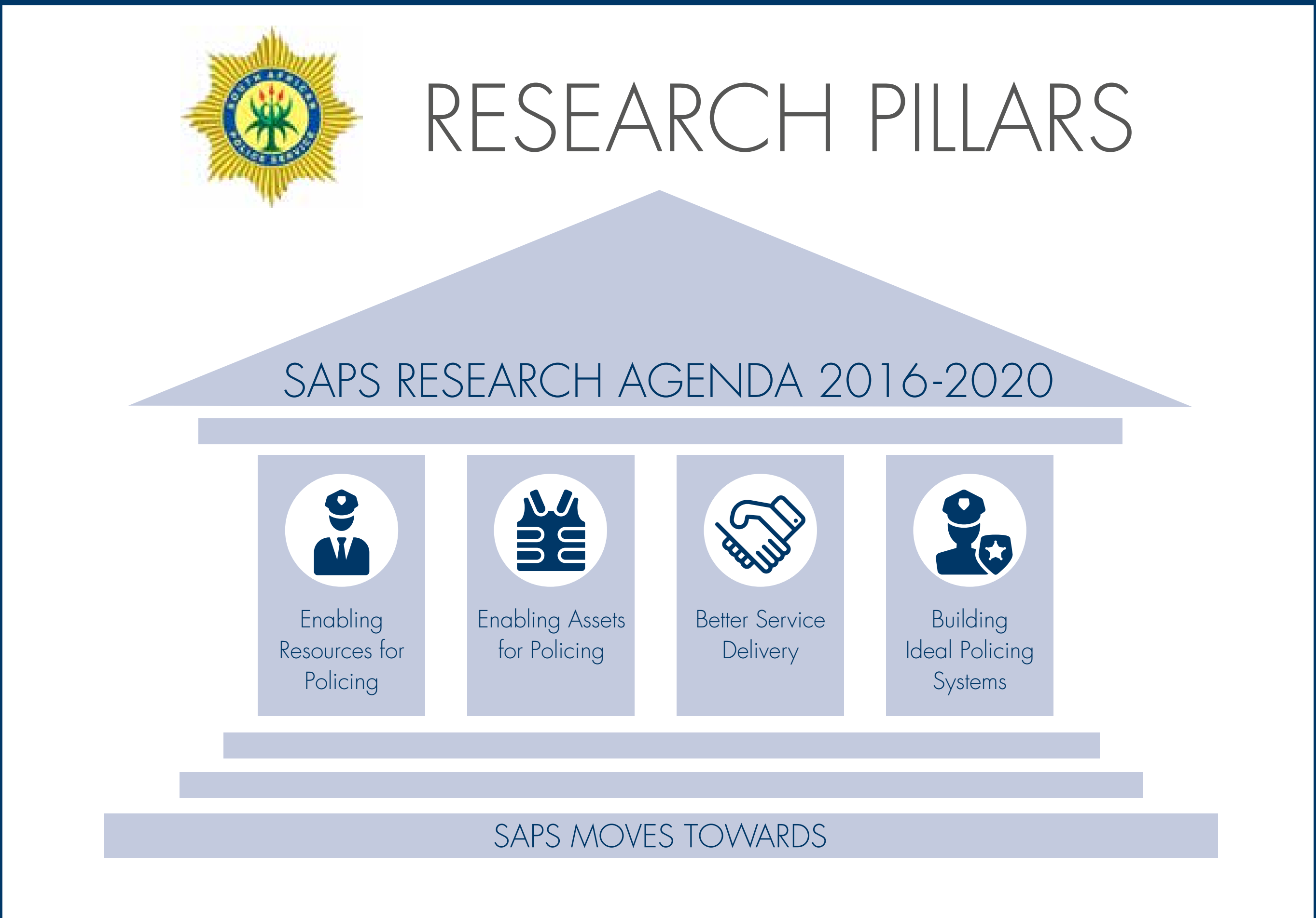
- Developing ideal policing systems, models and strategies.
- Improving service delivery.
- Enhancing innovation and modernisation in the SAPS.
- Infusing professionalism in policing.

The SAPS National Management Forum has recently adopted the SAPS Research Agenda for 2016-2020 which is premised on four pillars (Fig1). To institutionalise this Research Agenda, the SAPS will be working with different service providers including Tertiary institutions and NGOs. The SAPS will also be utilising the existing Memorandum of Understanding with the CSIR to execute this Research Agenda.

The R&D relationship between the CSIR and the SAPS will include the collaboration in conducting extensive research to support the review of the existing SAPS products and processes as well as designing and developing the new products and processes for the SAPS, which will enhance service delivery. The relationship will inter alia assist in:

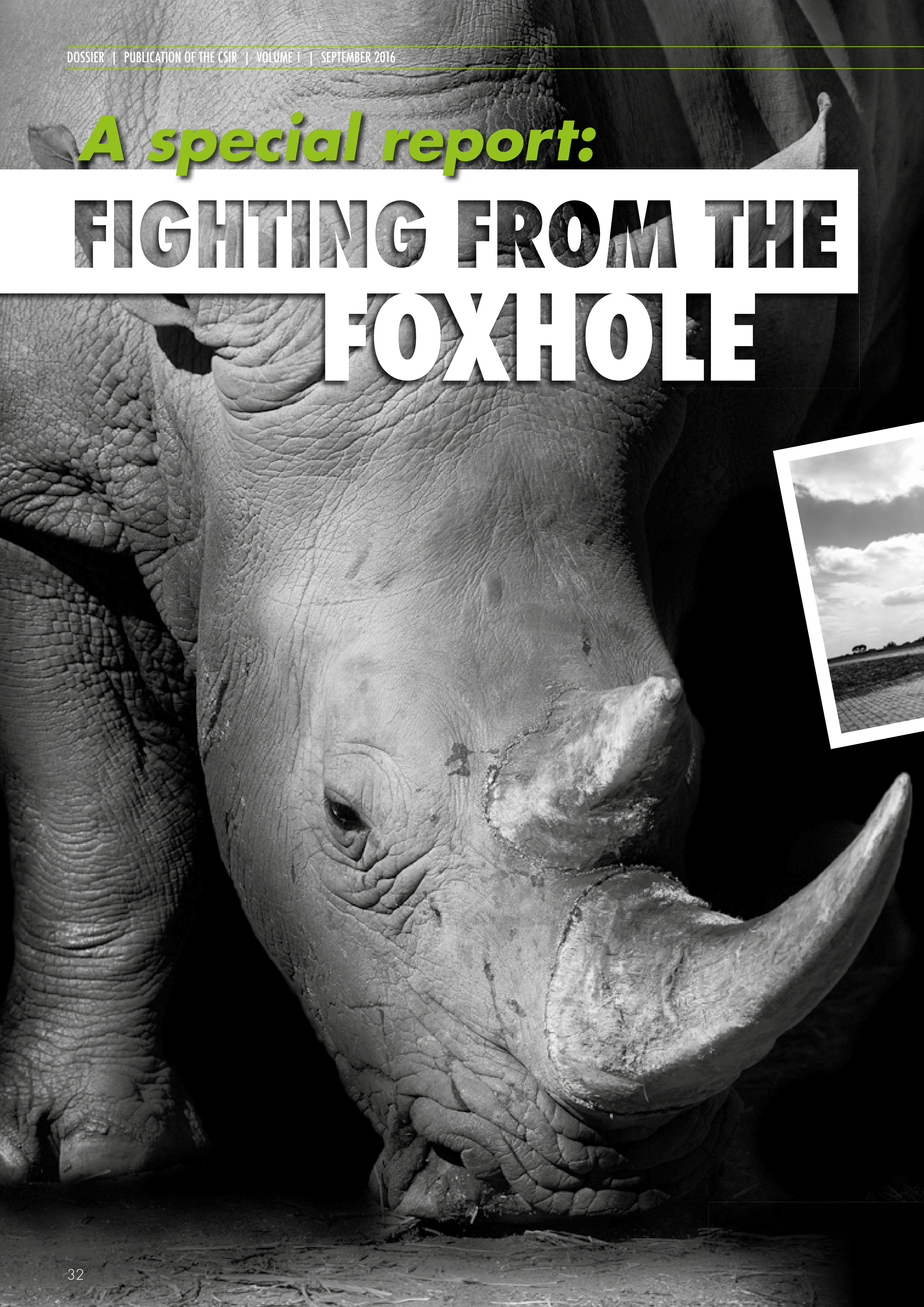
- Improving innovation and modernisation in policing.
- Determining the relevance of new products before development commences.
- Determining ideal specifications for the proposed products.
- Designing and development of new products.
- Validating that the developed products and processes meet regulatory requirements.
- Evaluating the return-on-investment on the SAPS assets and human resources with the aim of enhancing the SAPS products and processes, as well as introducing the new solutions to solve the pre-identified problems in the SAPS.

The SAPS and the CSIR are both excited by this challenging and brain teasing relationship.



A special report:

FIGHTING FROM THE FOXHOLE



A joint operation centre in Skukuza

By Gen Johan Jooste (ret), Commanding Officer Special Projects

A few years ago, the intensity of the campaign against poaching in the Kruger National Park, necessitated the establishment of a 'nerve centre' for joint operations and command and control. This centre houses the Ranger Services, the South African Police Service and the South African National Defence Force on a permanent basis, and up to six other departments from time to time. The centre deals with an average of nine poaching incidents per day.

Joint operations are conducted over two million hectares, an area roughly the size of Israel, defending a thousand-kilometre boundary. Foot, vehicle and air patrols are executed 24 hours a day, seven days a week with as many as 80 ground actions occurring at any one time. These operations are supported by up to ten helicopter and fixed wing aircraft sorties. All of this is well coordinated with neighbouring parks and other agencies in South Africa and Mozambique.

This task could not be executed without empowered staff with access to technology. The required situational awareness, well-packaged management information and means of communication is a prerequisite for proper planning and execution. That is why the South African National Parks (SANParks) selected an alliance with the CSIR. From this alliance, customised solutions were developed and applicable technologies applied.

Of specific note is the CSIR-developed Cmore system that serves as an innovative situation awareness and decision-support platform. It addresses the need for shared awareness among users, through the consolidation of information from various sensors and external systems, real-time analytics and the collaboration between multiple parties from various domains.

In addition, the CSIR's predictive modelling plays a significant role to assist counter-poaching units to deploy sensors and manpower at the right time, at the right place. This tool utilises both a statistical model and a data-driven model, which is used mainly for making predictions.

These systems are adding real value and contributed to the stabilisation of rhino losses. For the first time in a decade, 2015 showed a downward trend in rhino slaughtering. The alliance between the CSIR and SANParks will ensure the further pursuance of the technology roadmap that gave direction to counter-poaching efforts in 2013. This will ensure a joint operations centre operating as aware and wary as a fox – a facility that lives up to its name, Foxhole, always ready for any contingency.

Those who have been CALLED

Article contributed by Elise Daffue, founder of StopRhinoPoaching.com

South Africa stands as the last stronghold for rhinos on the African continent. The first rhino war, affecting the southern Africa region, diminished in the early 1980s but in 2008 new alarm bells started ringing in South Africa's conservation circles.

An unprecedented 83 rhinos had been poached for their horns, far more than in previous years. 2009 saw this figure rise to 122 animals killed and, by 2010, with the signs of the looming rhino poaching crisis increasingly apparent, South Africa started to mobilise.

A deep determination to 'save the rhino' took hold and while reserves in the harder hit areas started to fortify their defences to protect their animals, a wave of public outcry and support swept over South Africa. Numerous rhino initiatives – well-meaning, but fragmented – sprang to life.

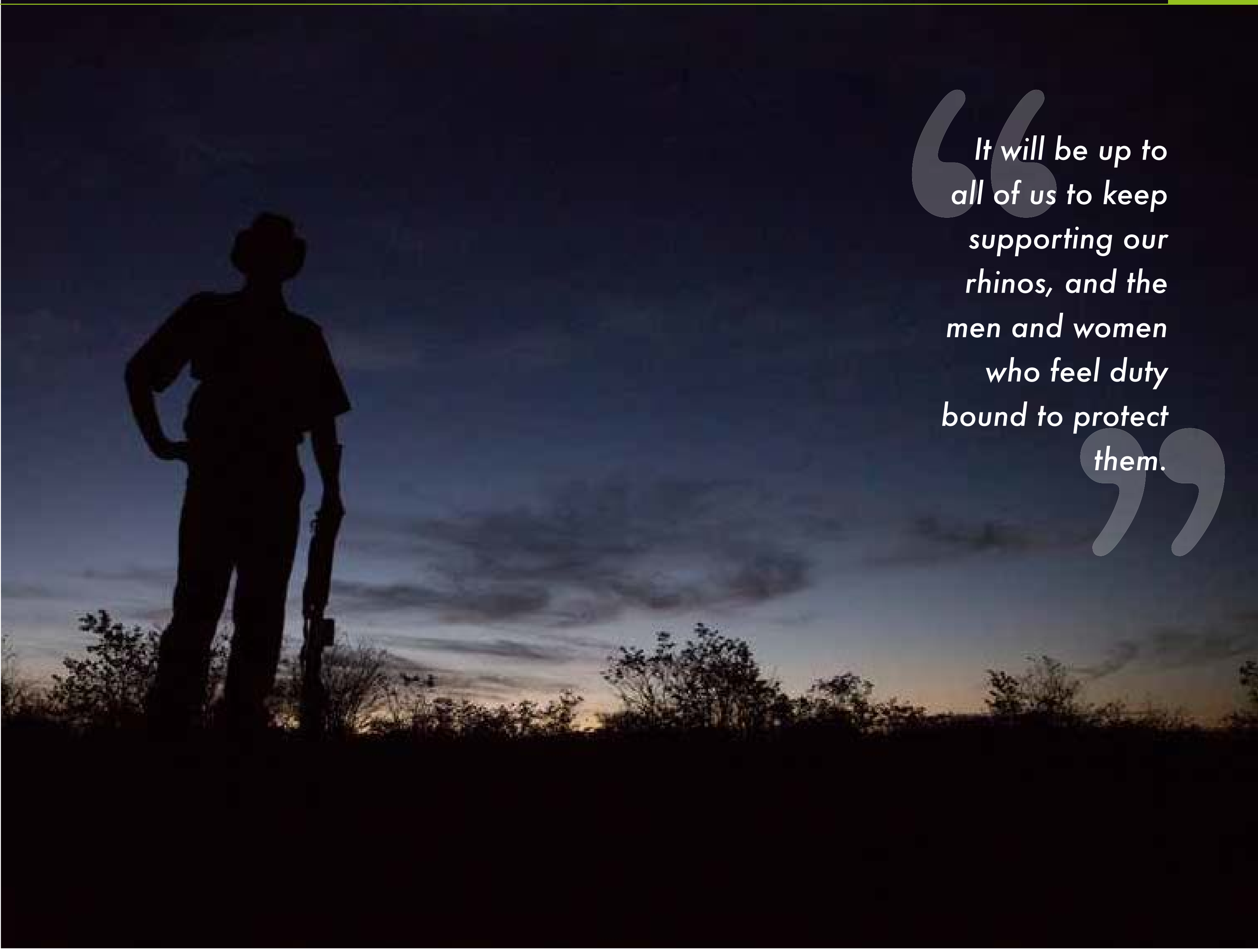
Correctly applied public funding boosted rhino protection efforts; field rangers underwent specialised training; security strategies and emergency response plans were drafted; law enforcement efforts kicked in; trust networks developed; and while a shared sense of dedication and urgency drove roleplayers forward it was clear that the poachers were many steps ahead. They simply moved to softer targets or changed their tactics.

Since 2008 over 6 000 (known) rhinos have been poached. In that time tens of millions of Rand have been invested into rhino security and protection initiatives.

As the years have passed we have learned more about poachers and the organised criminal networks that feed the illicit global wildlife trade, and with this knowledge has come the frightening realisation that the enemy is far more sinister than could ever have been anticipated.

A poaching syndicate is made up of a chain of individuals working within a complex structure that is ever evolving. A rhino poacher can take many forms. He can be, as is often perceived, a poor member of a local community desperate to put food on the table. He could be a man earning a legitimate wage – for example, an employee of the reserve with inside knowledge – recruited by those who profit from the rich spoils of poaching.

More often than not he could be a hardened criminal accustomed to committing aggressive acts of crime like vehicle hijacking, favouring the low-risk high-reward margins offered to a rhino poacher. Organised crime thrives in corrupt environments, which is exactly why the syndicates have infiltrated almost all levels of society, as well our rhino reserves. Be it by brute force (death threats to the individual or their families), through blackmail, or through the lure of wealth, a rhino poacher



It will be up to all of us to keep supporting our rhinos, and the men and women who feel duty bound to protect them.

can just as easily be a policeman or even a ranger. The syndicates have woven their tentacles into the once sacred heart of those sworn to defend and protect.

Conservation has always been seen as a calling. Tough, bush-wise rangers, weathered by years of experience under the African sun, committed to conserving our wildlife heritage. Brave men and women who were once responsible for entire eco-systems now barely get to focus on anything but the rhino. The cost to conservation has been high, the cost to these individuals even more so. Gone are the days of enjoying the bush, of a sense of achievement, of family-time or off days. The bush now symbolises poachers, relentless incursions, dead rhinos, anti-poaching patrols and the daily risk of encountering aggressive poaching groups who don't hesitate to shoot on sight.

Poachers have the upper hand, while the rangers are governed by strict rules of engagement and a split second decision to pull the trigger could result in a murder docket being opened. To be a ranger in a rhino reserve means that your life depends on the man covering your back, and it's when these individuals are exposed as being involved, that the depth of betrayal becomes an abyss.

What makes a ranger, heading home after a day of patrolling, stop to assess a human track crossing his path? He could just as easily have turned a blind eye, knowing that he is going home to his family and a warm bed. What makes him stop to assess that spoor and call it in, knowing that he has just committed himself and his team to hours of follow-up in the dark with a possible shoot-out awaiting them at the end? What makes a staff member on a reserve refuse a bribe? What makes a law enforcement officer stand up to the pressures of a corrupt system? What makes an investigator, or prosecutor, or reserve manager, or specialist consultant, or NGO, or the little girl selling cupcakes to save the rhino go that extra mile? Something in our moral fibre, and a deep sense of duty.

At the time of writing, rhino poaching has been stabilised in South Africa. Although every rhino life lost is one too many, and although these numbers remain high, huge efforts and collaboration at every level is ensuring that the escalation of incidents as seen in previous years has not re-occurred.

Right now, across a wide spectrum of roleplayers and amidst a complex web of wannabe's and people with either corrupt or misguided intentions, lies a group of individuals who stand between our rhinos and the poachers. They get along with what needs to be done in their quiet and humble way. They remain true to their word and to the sanctity of trust, and it is these individuals who will ultimately save the rhino.

It will be up to all of us to keep supporting our rhinos, and the men and women who feel duty bound to protect them…those who have been called.

CONNECTING THE DOTS IN WILDLIFE CRIME

Integrated approaches to dealing with security

Complexity theory differentiates between 'complicated' and 'complex' problems. The former is patterned and predictable. All you need is more information. The latter is fraught with multiplicity, its elements are diverse, in constant interaction, and ultimately, unpredictable.

The phenomenon of rhino poaching falls within the complex category. It is an entanglement of factors ranging from human greed and folklore, to fraud and differences between legal systems. All of which disrupt conservation and impact community security. Does this mean there is no solution to wildlife crime? Some argue that the crucial element lies in people and how they are engaged.

South Africa faces complex security challenges. None of these can be solved by a single actor or organisation. The key is the integration of efforts undertaken by the various players. The CSIR is providing interactive approaches at different levels to improve security in the national interest. This does not only mean developing another piece of equipment. Such thinking would ignore the importance of sharing and agreeing to objectives and goals, shared approaches and strategies to get synchronisation and avoid groups working against each other.

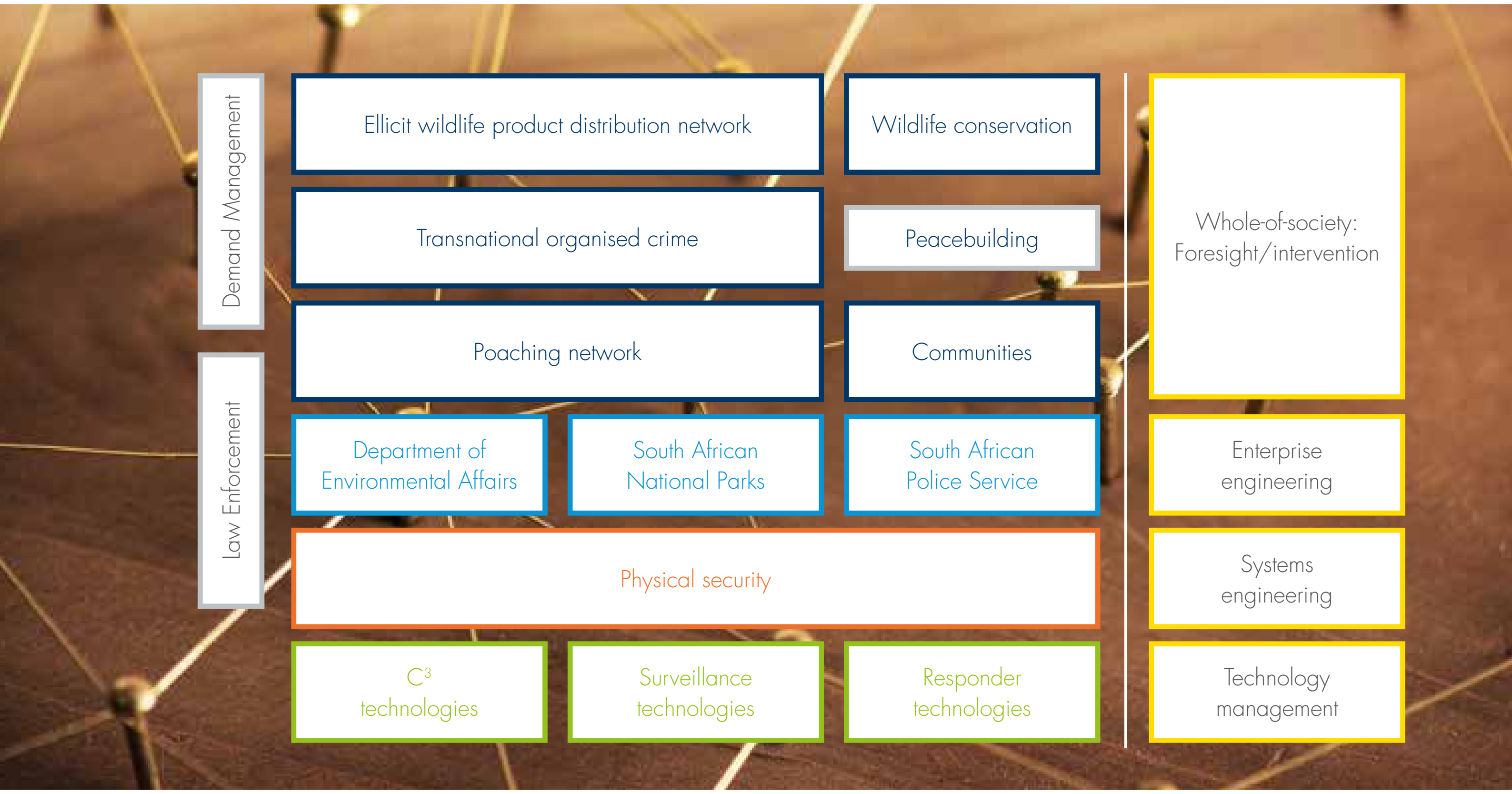
However, collaboration alone does not create deep change nor does it surface paradigms. It might improve tactical and operational level situations but it does not address problems which require strategic interventions. In the case of complex problems, all levels need to be addressed simultaneously. The paradigm underlying the problem must be changed. Furthermore, superficial collaboration ignores the importance of power which could disrupt, stall or undermine any effort.

Hence, the CSIR's approach of vertical and horizontal integration – from a whole-of-society approach to enterprise engineering, systems engineering and technology management for complex problems. This approach deals with matters at a broader scope.

In the case of wildlife crime, different aspects of the problem are interconnected, but stakeholders are tempted to address the problem in parts, consequently creating new problems. For example, while law enforcement is understandably frustrated by its inability to get ahead of wildlife crime, it cannot refer to its efforts as a "war on poaching" and then hope to work with communities. As another example; in as much as parks are necessary for conservation, parks fragment land and people.

Peacebuilding as a community intervention that addresses stakeholder needs, contributes to the constitutional imperative of "peace and harmony" while dealing with specific root causes. With peacebuilding as one of the interventions, it offers an important alternative to "militarisation of conservation". Also, by including stakeholders in the development of interventions increases the chance of these interventions being successful.

The complexity of wildlife crime requires a vertically and horizontally integrated approach with the problem context and interventions on one side, and methodology on the other.



Refer to the image above for a graphic presentation of this concept.

A number of levels are of concern and one level should not be assumed to be more important than another. Activities occur on all levels simultaneously:

- The context level is important in terms of understanding the problem. One of the temptations is to ignore the context and jump towards a solution quickly. In the case of poaching, the context level includes the end-users of wildlife products in Southeast Asia, the illicit product distribution network, the syndicates involved in transnational organised crime, poaching networks in southern Africa, wildlife parks, and communities around parks.
- The second level includes the government departments and other organisations involved in interventions. One of the interventions is law enforcement which includes the South African Police Services, the Department of Environmental Affairs, South African National Parks and NGOs, among others. This level provides capabilities for the intervention. Other interventions might include demand management, or community interventions such as peacebuilding.
- The third level is a particular capability within an organisation, such as physically securing the Intensive Protection Zone in the Kruger National Park.
- The fourth level includes the technologies for a particular capability, such as command, control and communications, surveillance technologies and responder technologies.

The integrating methodologies corresponding to the various levels above are:

- A whole-of-society approach is concerned with developing interventions outside of departmental mandates, individual organisations and communities based on foresight and drawing on different disciplines.
- Enterprise engineering (single departments and interoperability between these) focuses on capability evaluation and assessment against strategic requirements. This is not just about ICT but includes organisational design (leadership, rewards and recognition, and culture).
- Systems engineering concerns technical systems and capabilities.
- The technology management level develops, acquires and matures new technologies.

Each of these make use of discipline-specific methodologies, such as scenarios in the context level. The approach is problem focused as opposed to discipline focused or organisation centric, and vertically integrated with enterprise engineering/ architecture and technical systems. The timeous flow of information in both directions along the vertical and horizontal dimensions is critical for appropriate responses to security risks.

What is being learnt by the CSIR in the context of wildlife crime can also be applied in cyber security, water and energy infrastructure security, and disaster management, among others.

UAVs IN COUNTER POACHING

Many industry roleplayers, as well as the public are asking why unmanned aerial vehicles (UAVs) or drones are not applied to counter-poaching. Many think it is the ultimate solution, yet there are also those who feel the technology is a waste of time in this domain. CSIR test and evaluation experts conducted extensive field trials to determine the answer.

Partnerships formed

Peace Parks Foundation (PPF), through generous funding from the Dutch Postcode Lottery, initiated the UAV evaluation project under the auspices of the Rhino Protection Programme. The programme places substantial focus on developing advanced technology solutions through which to combat wildlife crime and protecting South Africa's rhino in the wild. A partnership was formed between the CSIR, PPF and the South African National Parks (SANParks) to determine if and how UAVs can be applied in operations dealing with environmental asset protection, for example countering rhino poaching; or environmental asset management, for example aerial environmental surveys.

The CSIR applied knowledge gained from the defence environment to formulate three concepts of operations for the use of UAVs in counter-poaching and five concepts for conservation management. Tests and evaluations looked at how UAVs can be applied effectively to enhance the current operational capabilities within SANParks. Further analysis aimed to determine which functionalities are required from an Unmanned Aerial System (UAS) for successful implementation.

The challenge put to the technology: For counter-poaching operations, UAVs can be applied for reconnaissance flights; to search, locate, track and follow potential poachers before and directly after an incident as well as a deterrence tool. For conservation management the systems can be used to study temporal and spatial dynamics of savannah elephants, as a survey tool for rhino guardian strategies, for fire management, the monitoring of aquatic systems and for the detection of radio frequency collared animals.

The UAV platform provided was a fixed wing electric powered aircraft with a mean take-off mass of 4.5 kg and a wing span of 2.4 m. The mean take-off mass includes a maximum payload weighing no more than 500 g that consisted of a night vision, or colour, or low-light black and white camera gimbal. The UAV is operated by two operators from a command and control vehicle.

How they tested it

For this project, the test and evaluation process was developed in such a way that it can be applied for the test and evaluation of several types of UASs.

UAV and Drone Solutions (UDS) was selected by PPF as the UAS supplier. They provided an unmanned aircraft with its supporting sub-systems for the duration of the testing.

The system was optimised by UDS and tested by the CSIR in three national parks located in South Africa over a period of nine months. Phase one looked at whether the system can operate stealthily and if so, at which altitude above ground level would it need to fly to not be heard. In phase two, the optic sensors were tested to determine if objects of interest could be located at varying altitudes. The objects included people, vehicles, flashing lights and human size high-resolution test targets. The tests were conducted in three different veld types that represented savannah, bush and mountainous areas. Optic surveillance systems were also tested at different times of the day in a 24-hour cycle. Different scenarios were created during the third phase to represent the operational concepts to assess the functions, features and performance under representative operating conditions that are required for locating objects of interest in the Kruger National Park environment.

And now to implement

From the test results it was clear that UAVs are a remarkable support tool if included into the arsenal of counter-poaching technologies and capabilities already hard at work. To optimally use this technology, the study further found that success will lie in developing operational procedures of how to integrate a UAS into current concepts of operations as well as to employ these capabilities on actionable intelligence of poacher activities threatening protected areas.

The CSIR will continue to support SANParks in the testing and evaluation of proposed UASs to be used in environmental asset management and protection operations.

Critical requirements to take note of before operating this type of technology are:

- SACAA regulatory compliance for licensing of the area of operations, systems and pilots;
- Sustained budget (owning vs renting the system);
- Life cycle and running costs;
- Integration with enforcement capabilities; and
- Integration with other sensors and technology solutions.

Types of unmanned aerial systems to consider:

- Fixed wing;
- Rotary wing; and
- Multi rotor.

Classes of unmanned aerial systems to consider:

- 1A (<1.5 kg);
- 1B (<7 kg);
- 1C (<20 kg);
- Refer to SACAA RPAS regulation 101

Prevention is better than countering

Predictive modelling assists in counter-poaching

CSIR researchers specialising in data fusion and mathematics plan to extend a predictive modelling tool currently implemented in the Kruger National Park to private nature reserves. This newly implemented model assists counter-poaching units to deploy sensors and manpower at the right time, at the right place.

In collaboration with the Endangered Wildlife Trust (EWT), researchers will extend and contextualise the tool to be of use in the private and provincial nature reserves surrounding the Kruger National Park.

Dr Pieter de Villiers, a principal CSIR researcher, said that the predictive modelling tool was originally developed to assist the South African National Parks (SANParks) with better decision-making in the deployment of technologies. "The Kruger National Park is vast in terms of surface area with a limited number of rangers available for patrols. This tool will help them better direct rangers and deploy technologies such as radars, perimeter surveillance systems and other sensors used to detect poachers. If you have resources to cover a small percentage of the park, you have to know where to focus your efforts.

"Smaller private reserves typically have more accurate information on ranger and rhino positions. The tool will be optimised to predict poacher positions more accurately, using historic and recent poacher tracks, natural terrain features and other sources of contextual data. In this way rangers can be deployed to intercept poachers. Another plan is for rhino behaviour to be analysed in real-time to detect anomalous behaviour. Once strange behaviour is detected, a ranger or unmanned aerial vehicle (UAV) can be tasked to investigate."

CSIR software engineer Pieter Botha is the project leader of the social network-inspired collaborative command and control platform, Cmore. Botha states that poacher prediction and rhino behaviour anomaly detection will form a part of their analytics service offering, "Predictive modelling, tracking and anomaly detection are examples of services that can be easily integrated into the Cmore platform with modest development effort. This provides a mature front-end and graphical user interface with a vast collection of geo-spatial analysis and collaboration tools to host, display and utilise analytics results."

CSIR applied mathematician, Hildegarde Koen, started working on a concept of a tool that could potentially tip the balance back in the favour of

CANINES TO RHINO RESCUE

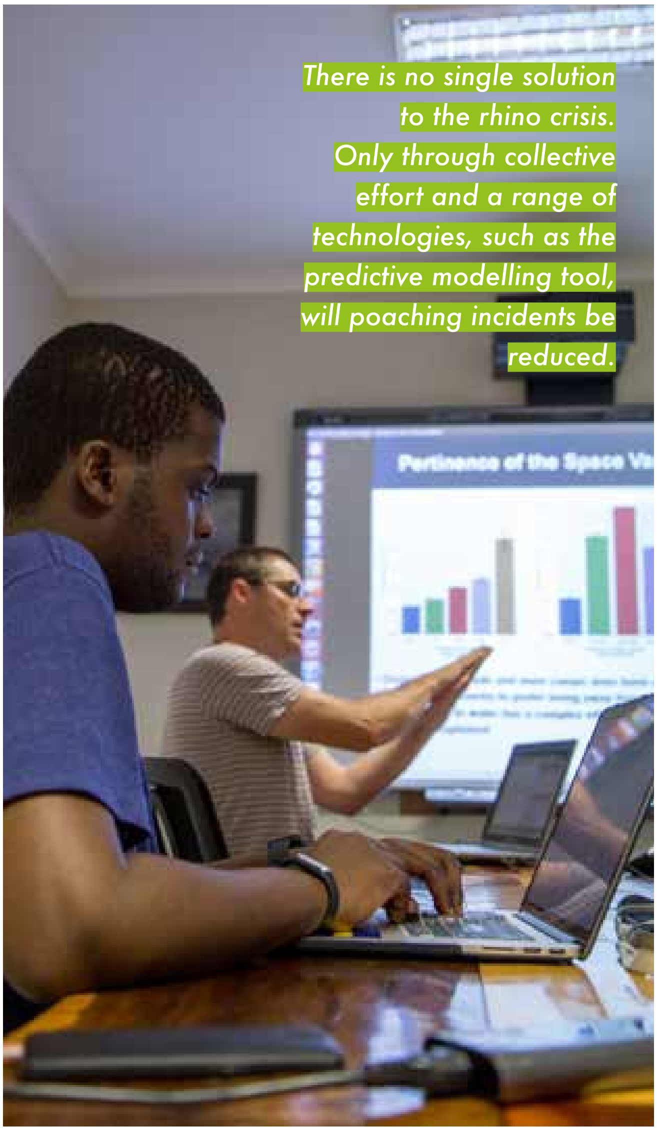
The canine unit, functioning as part of the Kruger National Park's counter-poaching operations, has proven itself as one of the most effective groups in the war on rhino poaching. Dogs like Killer have become household names – known and loved by many South Africans, and feared by the poaching syndicates. The CSIR assisted South African National Parks with determining specifications for dogs to be acquired, and aided in the deployment of the dogs and handlers. Inherent health, willingness to work, and an outstanding ability to track were among the top qualities sought in the highly trained dogs chosen for this challenging task.

the rangers. "When the poaching problem flared up in 2010, I decided to focus my PhD study on developing a model that could theoretically predict poaching incidents. As I started working on it I quickly realised that there were no existing rhino poaching models and very limited information available. We decided to build an expert knowledge model based on the experience and information provided by experts working on counter-poaching programmes in the Kruger National Park. We try to consider the variables that would influence poaching events, such as proximity to water, vegetation density, or moon cycles," said Koen.

A complex problem such as wildlife crime requires innovative solutions built through collaboration. In addition to the EWT, CSIR safety and security experts, as well as data mining and data science researchers are working together with the University of Pretoria's Statistics Department and researchers from the Thales Research and Technology group of laboratories based in the Netherlands.

Data science researcher and project team member, Dr Vukosi Marivate, commented on the possible implications of a successful prediction, "At the moment there are many experts working on the poaching problem. By adding computers that are continuously crunching numbers and providing possible locations to the team, you can give forces on the ground a better chance of catching poachers."

The benefit lies in assisting SANParks and neighbouring private reserves in decision-making and it helps key roleplayers to better understand the causal contextual factors that promote or reduce poaching. It will also directly impact the arrest rate by directing rangers and air support that are in hot pursuit of poachers, with the help of smartphones carried by rangers that are integrated into the system. It is much easier chasing someone if you have an idea of where they are heading.



There is no single solution to the rhino crisis. Only through collective effort and a range of technologies, such as the predictive modelling tool, will poaching incidents be reduced.

TACTICAL RANGER TRAILER

The Mpumalanga Tourism and Parks Agency's special counter-poaching team, which operates clandestinely in rhino reserves, received a tactical ranger trailer re-designed and optimised by CSIR engineers seasoned in adapting existing equipment according to mission specification. Rangers, in groups of five, are often deployed for days at a time in areas without any infrastructure. The standard Jurgens trailer (originally donated to StopRhinoPoaching.com by Jacaranda FM's Purple Rhino Project, who then donated it to the Mpumalanga Tourism and Parks Agency) needed to be modified to offer specialised support for these teams. The requirements included a mobile electric fence that would offer protection from wild animals, accommodation, shower facilities, water and storage for cooked food for five days. A silent fossil fuel generator and solar panels were further included for power generation, energy storage and the charging of batteries for command and control systems, as well as camouflage for concealment and safe storage space for sensitive equipment.

A SUPER-ADVANCED 'SPYGLASS' FOR ENHANCED MODERN SECURITY

Ever watched a crime drama or spy film and marvelled at those scenes where a team of technicians are sitting in a darkened room full of big, fancy monitors that enable them to constantly track and follow a Jason Bourne-like assailant with great precision, in real-time, while being in constant communication with a team of operatives and controlling traffic lights and surveillance cameras seemingly at will? That is the kind of advanced shared situational awareness that the Cmore system can enable. Recently, it's been making life a lot tougher for rhino poachers in the Kruger National Park.

"It all started with the CSIR's preparations to support the 2010 Soccer World Cup, where the idea of creating web-based applications for command and control purposes originated," says Pieter Botha, Senior Software Engineer.

"Those applications did not result in the Cmore we know today, it was simply some standalone applications for roll call, operations, and resource tracking and management, with some added systems integration. All of these concept demonstrators and ideas then found their way, through the CSIR, into supporting border safeguarding experiments in joint operations with the South African National Defence Force (SANDF), where interdepartmental and multinational agencies are required to collaborate. The idea was to use smartphones as sensors and collaboration devices in a network. After a couple of tries, Cmore was born."

One of the first versions of Cmore was demonstrated during the SANDF's Musina Border Safeguarding experiment in February 2013. A big change in approach for developing Cmore came when it was decided to deploy the technology in the Kruger National Park in support of counter-poaching activities, from July 2014 onwards. Currently, Cmore is used by many organisations and users in the environment asset protection domain.

See more, do more

Basically, Cmore is an advanced, innovative situation awareness and decision-support platform that exploits modern web and mobile technologies to address the need for shared awareness among users. It consolidates information from various sensors and external systems, uses real-time analytics and enables collaboration between multiple parties from various domains.

Situation awareness is the ability to perceive and comprehend a situation and being able to predict how a situation may unfold – similar to where Jason Bourne (or his terrorist or poacher counterpart) might be going next, and how to stop him.

Cmore is able to exchange information with a diverse set of services and sensors, such as detection systems and various other entity tracking systems. Cmore also allows for the secure distribution of information with the ability to share and collaborate with other users in the community from anywhere in the world.

During complex operations, many different sensors can therefore be deployed, for example radar, optronic, electronic warfare, tracking or detection systems. Cmore allows for the filtering of information to mitigate information overload. It allows users to only see the information that is relevant to them at a specific point in time. This assists in decision-making and provides useful shared situation awareness to all members involved.

Cmore's flexible information model and focus on simplicity of use makes it suited for domains such as conservation, disaster response and management, public services, as well as safety and security. The system has the ability to fully exploit the geographic nature of events and real-world entities, and eloquently facilitates interoperability.

"Most people are amazed at what is possible with Cmore and how good it looks compared to the conventional shared awareness systems they've been exposed to," says Alex Turlunen, Senior Software Engineer.

"Cmore takes interoperability a level up. It provides the ability to integrate diverse data and information sources. This also holds for external applications and services. All of this combined with the appealing visual design language and user experience-based design make for a compelling case in security and defence application. It also simplifies and enhances the use of smartphones for gathering real-time information and enabling useful data sharing."

Currently, Cmore is a web and mobile application enabled for use on smartphones using the Google Chrome web browser and Android 4.1 or later. iOS support is also in the pipeline, which will significantly broaden the potential user base.

According to another of the CSIR's Cmore experts, Shazia Vawda, lots of systems exist that can do bits and pieces of what Cmore can do, but the system is unique in that it does everything in one place.

"The most important aspects missing from comparable systems are secure sharing and collaboration support. Cmore also sports a flexible data model, but still provides the benefits of a common static data model, without prescribing a specific domain. It is in essence 'domain agnostic', making it applicable in a variety of domains and applications," says Vawda.

The other aspect where Cmore shines, according to Botha, is in consolidating various kinds of sensor inputs in a single place.

>> Continued on following page

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"We can bring in information about the movement of ships, aircraft, vehicles and people through the various systems that track them. We can bring in detections made by smart devices such as motion cameras and licence plate detection too."

"Finally we have a section dedicated to the interfacing with services external to Cmore done by third parties. Some examples are systems that perform analytics or predictive models on Cmore and other data and then send results back to Cmore. External databases can also be queried to augment information about captured events in Cmore, for example a number plate may be queried against the national stolen vehicle database and the outcome recorded in Cmore."

In terms of information security, all network communications are encrypted. Cmore was conceptualised with security in mind, right from the start.

"We've had other units in the CSIR perform black and grey box penetration testing to ensure system integrity. As with most other web-based systems, the greatest risk lies with the individual users that are given access to Cmore and don't take care when safeguarding passwords," said Botha.

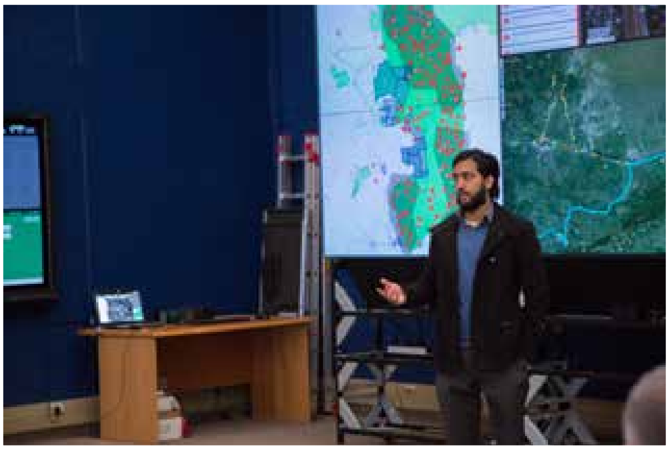
Collaboration efforts have started with the South African Police Force (SAPS) to incorporate Cmore into community policing forums for improved crime prevention and reaction. However, the main tests of Cmore's mettle to date have centred on counter-poaching efforts in the Kruger National Park.

Comprehensive counter-poaching capabilities

The number of rhino poaching incidents has escalated dramatically in the past decade as the demand for poached rhino horn increased. Housing the largest concentration of rhinos in South Africa, and also worst hit by poachers, the Kruger National Park has become the focus of a number of interventions to protect these vulnerable animals and improve the ability of park officials to deal with poachers.

Cmore is currently being used as the core shared awareness platform in the fight against rhino poaching. Cmore

"It really puts you in the field, as it were, even though you may be in an air-conditioned office outside of the park. We can see in real time which rangers are where in the park and what they have encountered on patrols," says Swart.



assists the Mission Area Joint Operations Centre to plan and run anti-poaching operations and provides the capability to manage events, report on the current situation and, crucially, to work jointly with neighbouring parks, reserves and partner organisations to combat poaching. A number of related organisations have started to collaborate on Cmore and contribute to the platform as a result of the successes achieved in the Kruger National Park.

The CSIR's chief Cmore coordinator and operational analyst in the Kruger National Park is Charmaine Swart, who has been involved in the rollout of Cmore as a counter-poaching measure and the training of game rangers in the use of the technology.

According to Swart, the biggest advantage of Cmore is that it gives users the ability to have a complete picture of what is happening in the park at any given moment, and from anywhere.

"With Cmore we can plot trends and identify patterns to get ahead of the poachers. We plot where carcasses were reported or where poachers or suspicious persons or vehicles were spotted, or where poacher tracks or scent were picked up. Over time a picture emerges of problem areas and how poachers are moving in the park and, importantly, where they may be getting into the park.

"This helps us to better plan our patrols based on where Cmore shows poachers may strike next or what times of the month poachers might be more active, and so forth."

Swart says Cmore has undoubtedly increased the effectiveness of counter-poaching efforts in the Kruger National Park.

"Specific cases are still sub judice but it has made a massive difference in the park. Also, by adding sensors and new data streams, the system just keeps getting stronger and more useful. The rangers have also gotten used to how Cmore works and have truly embraced the technology."

Cmore is already, apart from the Kruger National Park, being used to cover about 50% of the rhino population in South Africa, with limited participation from Mozambique and Namibia. These efforts will be replicated in the Southern African Development Community region to serve as a collaboration platform for conservation groups and partners for the purpose of providing a South African, African, and ultimately a global view of conservation.

The CSIR continues to refine and expand Cmore's capabilities by collaborating with diverse stakeholders, such as the SAPS, Eskom, Denel, and the Department of Environmental Affairs. More than 77 organisations are already registered users of the Cmore system.

Taking the guesswork out of GUNSHOT DETECTION

Public gatherings pose a security challenge to the services tasked with maintaining law and order and, most importantly, safety. The chaos that can emanate from crowd unrest or protest situations necessitates fast, accurate information. For example, being able to pinpoint if a gunshot originated and from where will assist safety forces to respond in a controlled, measured manner. Information such as the source coordinates, the type and range of the shot is key data in assisting authorities to provide a fast, effective and informed response that can save lives.

A prototype acoustic gunshot detection system, recently developed by the CSIR, is able to identify (or dismiss) if an impulse noise (such as a sharp, loud bang) was a real gunshot and can identify where the shot came from.

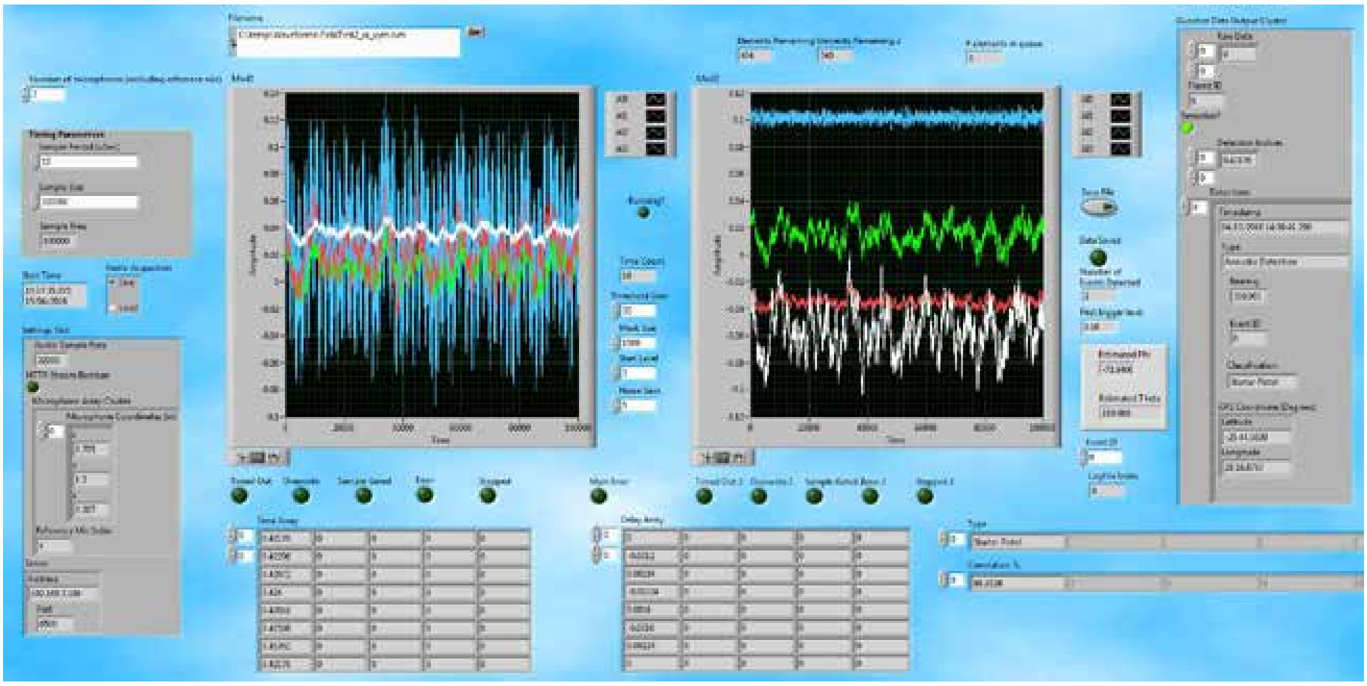
The demonstrator comprises sensors in a unique three-dimensional array, related analogue and digital electronics with a dedicated processing unit running custom algorithms that provide the real-time signal processing. A sudden noise triggers the transfer of the detection and localisation information to a software platform running on an auxiliary computer. This graphical user interface displays the signal and gunshot information to the user in a real-time polar form indicating relative and actual bearing. It is possible for the system to identify the calibre of the gun from the signature of the shot. All the data parameters are recorded and available for post-analysis, if required.

The system can interface with command centres via Cmore, an advanced, innovative situation and decision support platform, providing tactical information and situation records. The potential to coordinate with other systems and provide common feedback will provide both field and command centre operatives live data and situational feedback. This ability to rapidly dispatch information to a designated control room or operations centre will provide the situation commanders with the agility to respond tactically to evolving events – key data that the authorities require to formulate and execute a response equal and appropriate to the threat.

Previous page: Prototype sensor array mounted on a car

Right: Processing electronics

Bottom: Operator's interface



Out in the field

The system is small and cost-effective to produce. It has the potential to operate from both static and mobile installations and from varied power sources such as batteries and solar power, rendering it adaptable to local environments.

The mobile system can be vehicle mounted and used in applications such as crowd control operations by the SAPS, peacekeeping missions and in border patrols to detect and localise hostile activity.

A static installation is ideal at strategic points in game reserves or border areas for intelligence gathering. In a distributed configuration, the system can also support neighbourhood security.

The system could also be mounted for naval use when patrolling rivers.

Aerospace:

HIGHER ORDER

Supporting strategic air power

In conventional or asymmetric warfare, the adage that "he who has the best toys, wins" seems to remain true. Aeronautics has arguably been the beneficiary of the most rapid rate of technological advance of all sectors.

Air forces globally agree that 'going high-tech' in air defence is tempting, can be cost-effective and certainly provides a competitive edge. Smaller air forces that argue against the cost of new technologies are in danger of finding themselves outmanoeuvred by better equipped opponents. Still, technology choices have to be taken judiciously on a case-by-case basis and must be well-supported by superior technology testing, evaluation and development. This is where scientific testing and evaluation ensure competitiveness by enabling smart buying, smart usage and smart management of capabilities.

Effective air defence depends on detecting, identifying, tracking, intercepting and destroying potential air threats. This requires well-integrated airspace surveillance and command and control systems. While static systems provide much of this capability, South Africa's deployed forces can also rely on mobile, organic air, land and sea systems for protection.

South Africa's range of airborne assets is used to protect the country against air threats, provide fire-support to our forces and infrastructure protection through interdiction and close-air support. Our key air capabilities are also used in peacekeeping missions and combined security operations, as well as providing air transport for ordered and diplomatic commitments and air support to civil authority and for South Africa's international obligations.

The use of our air capabilities has, in fact, become indispensable to defence support operations. Our air force is often called up to assist in military evacuation and rapid deployment, strategic lift, air supply and airborne operations or civil society operations such as search and rescue, support to other security services, diplomatic interventions, humanitarian assistance and disaster relief.

As part of a joint defence responsibility, an integrated air defence system is critical to providing collaborative intelligence from air assets and electronic sensor data. This is where innovative engineering can best deliver real-time intelligence and threat analysis.

The CSIR supports the South African Air Force in its efforts to operate as a strategic defence capability, to support force development and air operations; support industrial initiatives and the growth of a healthy base of aeronautics engineers and innovators.

The ultimate aim is to ensure that South Africa's Defence Force is configured and equipped to defend and secure its national interests and protect its people, as well as participate in peacekeeping missions and render military assistance to other nations.

Technology choices must be well-supported by superior testing, evaluation and development capabilities.

WIND TUNNEL TESTING: RELEVANT OR RELIC?

Mauro Morelli, facilities manager at the CSIR's wind tunnels

Modern times have seen significant advances in the modelling and simulation of structures and their responses in various scenarios. It saves developers and designers massive amounts of resources, including time and money, when a newly developed structure can be tested in a virtual world that simulates reality to perfection.

This begs the question, are wind tunnels with their huge infrastructure and high running costs still relevant?

Mauro Morelli, the facilities manager at the CSIR's wind tunnels, has been part of the aeronautics team for as long as it has been in existence. Well, almost. He has spent the better part of two and a half decades testing and evaluating numerous airframes in the CSIR's suite of wind tunnels.

"25 years ago I was guaranteed that digital technology and mathematical modelling was going to render the wind tunnels obsolete. 'Soon' they said. I am still waiting. In March this year we conducted an important transonic wind tunnel test for an international client that manufactures aircraft. We are expecting more to come," says Morelli. He is not ignorant of the advantages the digital world can offer, "We are striving to improve our integration with digital technology that will surely enhance our offering to the clients."

When questioned about the most interesting test Morelli and his team conducted in a wind tunnel, he said, "It must be the tomato plants we tested in the seven-metre wind tunnel. This was conducted for a study on the resistance created by tomato plants to the airflow in the hot-house where they were growing. We really did it! We placed the plants in pots, on shelves in the tunnel!"

In terms of engineering, he stated that the NOVEMOR project was of particular interest. The CSIR's aeronautic team collaborated with a European consortium to test a passenger transport airframe with morphing control surfaces. In this project, researchers and engineers are studying the possibility of moving the control surfaces of an aircraft, mainly the wings, during flight, by using smart, flexible materials and adaptive technologies to enable the aircraft to fly at a large number of operating points while maintaining maximum efficiency. This will make flight more efficient and cost-effective. The international team is also developing the tools that will allow the analyses and simulations necessary to evaluate the effectiveness of these proposed solutions.

The CSIR's suite of wind tunnels includes the previously mentioned seven-metre tunnel, a low-speed tunnel, a high-speed tunnel and Morelli's favourite, the medium-speed wind tunnel. "If I must choose a wind tunnel that I like more than the others, it must be the medium-speed wind tunnel. Not because it is imposing, transonic, expensive and the youngest, but because I got my degree through it. I grew professionally through it, spent blood, sweat and tears in it. Being now the manager of the whole suite of tunnels has endeared all of them to me. I have learned the strengths of each and how to broaden the scope of our wind tunnel testing services."

The challenge is to keep these industrial facilities operational and available to the local and international industry within a scientifically poised community and funding agencies. The CSIR and the South African Department of Defence have done their fair share to make this task easier.

Morelli has had a long and successful career at the CSIR. He has mentored many young and aspiring aeronautical engineers who now have successful careers of their own. Reflecting on his time at the CSIR, he states that he a has deep appreciation for his colleagues who are specialists in their respective fields. Together they form a dedicated experimental aerodynamics research group. The experience and expertise can be invested in technologies that are rare in the world and exclusive in South Africa.

THE CSIR'S SUITE OF TUNNELS

LOW-SPEED WIND TUNNEL

The low-speed wind tunnel is a continuous, single return wind tunnel with a closed test section. Strut-mounted models are suspended from an overhead six-component virtual-centre balance. An auxiliary pitch sector allows sting-supported models to be mounted on a variety of internal strain gauge balances.
Low-speed wind tunnel test capabilities include:

- Scaled aircraft loads and static stability;
- Pressure distribution;
- Air data probe calibration;
- Flutter;
- Two-dimensional oscillating aerofoil;
- Scaled racing vehicle tests;
- Flow visualisation (oil flow, tufts, liquid crystals);
- Helicopter intake characterisation; and
- Propeller tests.

Low-speed wind tunnel specifications:

- Speed range: 5 m/s to 120 m/s;
- Test section: 2.1 m x 1.5 m rectangular with corner fillets;
- Atmospheric tunnel; and
- Reynolds number: 6 x 10^6/m.

MEDIUM-SPEED WIND TUNNEL

The medium-speed wind tunnel is one of the best-equipped and most sophisticated tunnels of its kind in the southern hemisphere. A 20 MW electric motor drives a three-stage axial compressor with variable guide vanes and stator blade angles for accurate Mach number control. This variable density transonic tunnel operates continuously for optimum productivity and accuracy. The square test section is slotted, with a porosity of 5% for the best possible flow at transonic Mach numbers.The test types in the medium-speed wind tunnel include:

- Captive trajectory (store separation) tests;
- High angle of attack tests;
- Force and pressure measurement;
- Flow visualisation;
- Flutter testing;
- Dynamic testing capability; and
- Aerodynamic damping tests.

Medium-speed wind tunnel specifications:

- Mach no. range: M 0.2 to M 1.4;
- Test section: 1.5 m x 1.5 m x 4.5 m;
- Reynolds number: 31 x 10^6/m (M 0.8);
- Closed circuit, variable pressure, continuous wind tunnel; and
- Stagnation pressure: 20 to 250 kPa

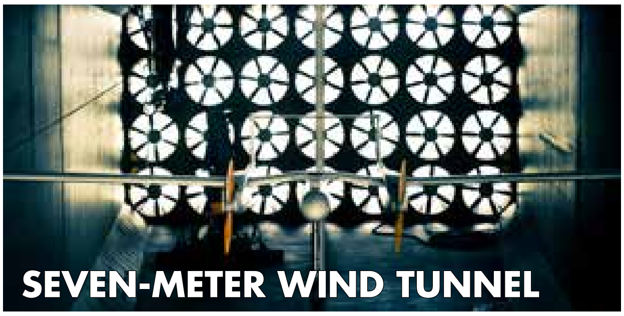
HIGH-SPEED WIND TUNNEL

The high-speed wind tunnel is a trisonic, blowdown wind tunnel equipped with a colour Schlieren system for flow visualisation. Subsonic and supersonic Mach numbers are tested using the standard wind tunnel setup, while tests in the transonic regime employ an extra cart that is fitted with a plenum evacuation system and porous walls. Typical test types in the high-speed wind tunnel include:

- Force measurement;
- Pressure measurement;
- Inlet flow measurement; and
- Flow visualisation (colour Schlieren).

High-speed wind tunnel specifications:

- Mach no. range: M 0.6 to M 4.0;
- Test section: 0.45 m x 0.45 m;
- Run time: 10 to 30 seconds;
- Reynolds number: 6 to 50 x 10^6/m;
- Stagnation pressure range: 70 to 950 kPa; and
- Trisonic intermittent blowdown wind tunnel.



SEVEN-METER WIND TUNNEL

The seven-meter wind tunnel is a continuous, open circuit tunnel powered by 28 axial flow fans of 30 kW each. Uniform flow distribution across the speed range of the tunnel is given by running the fans in one of 13 different symmetrical patterns. The test capabilities in the seven-meter wind tunnel include:

- Force measurement (internal balance, platform balance and rotor balance);
- Pressure measurement (Scanivalve system);
- Flow visualisation (tufts, oil flow, smoke);
- Flow field measurement (multi-hole probes);
- UAV test rigs; and
- Propeller test rigs.

Seven-meter wind tunnel specifications:

- Speed: 2 to 32 m/s in discreet steps;
- Test section: 7,5 m x 6,5 m x 13 m; and
- Continuous, open circuit.

Fast, faster, *supersonic!*

Three young female aeronautical engineers are helping to push the envelope at the CSIR's medium-speed wind tunnel with research across the whole subsonic-supersonic spectrum that will significantly expand South Africa's aeronautics expertise and testing capabilities.

From left to right, Janine Schoombie, Lara Nel and Alesha Saligram at Mach speed: In aeronautics, the Mach number refers to the ratio of flow speed (such as wind speed) past a boundary compared to the local speed of sound. Mach 1 is equal to once the local speed of sound, Mach 2 is twice the speed of sound, etc.

FAST

Up to Mach 0.3

Janine Schoombie, an aeronautical engineer at the CSIR, is currently working on testing and adapting a conceptual design engineering method, which focuses on non-linear effects of wing-body interference for missiles with low aspect ratio wings.

"The method was developed in 2013 by Dr Sean Tulling for use at supersonic speeds, but my main objective is to extend the application of the method to incompressible subsonic speeds (below Mach 0.3). This will also aid in exposing limitations of the method," said Schoombie.

The method is used during the conceptual design phase of missiles to calculate the lee side flow characteristics for the particular configuration and other properties such as lift, pitching moment, centre of pressure position and vortex positions.

Some of these engineering level codes exist, but are not readily available in South Africa and many are not applicable to missiles with very low aspect ratio wings. The benefit of using an engineering level method is that it is very quick and cost-effective at a reasonable accuracy.

Janine Schoombie, whose father is a commercial pilot and who grew up around aircraft, initially wanted to become a pilot herself. Her parents wanted her to first earn a degree and she naturally chose aeronautics. "I fell in love with engineering and now I don't want to do anything else," she said. She enjoys working on defence aircraft because she has found it to be "much more complex than standard aircraft, and the scope is vast".

FASTER

Mach 0.8 to Mach 1.4

A Master's student in aeronautics from the University of the Witwatersrand (Wits) and CSIR bursar, Alesha Saligram, is developing an electronically controlled induced mass flow system for aircraft inlet speeds between Mach 0.8 and Mach 1.4 testing at the CSIR's medium-speed wind tunnel.

"We currently only have the ability to perform full aircraft aerodynamic testing. The medium-speed wind tunnel facility therefore requires the ability to also perform testing on aircraft inlets," said Saligram.

"My system will allow for the careful control of mass flow through inlets at speeds of between Mach 0.8 to Mach 1.4. In other words, the system will allow the air flow characteristics of aircraft inlets to be verified, thereby allowing for optimised designs."

With such a system in place, engineers will be able to study not just the air flow around an aircraft, but will also be able to predict the aerodynamic characteristics of the aircraft inlet under investigation. When completed, the capability to test aircraft inlets will be added to the suite of capabilities available at the CSIR's wind tunnels.

Alesha Saligram's father is a lecturer in electronic engineering and her two older sisters are computer science engineers. So when it was her turn to choose a career, she wanted to do something different and to challenge herself. She chose aeronautics, and hasn't ever regretted her decision.

SUPERSONIC

Mach 1 to Mach 5

Lara Nel, another Wits student and CSIR bursar currently busy with her PhD in aeronautics, is studying shockwave/expansion fan interactions between bodies in close proximity at supersonic speeds (between Mach 1 and Mach 5). She's looking at how shockwaves and expansion fans interact with each other when aircraft are flying in close proximity or when aircraft are carrying or releasing weapon systems at supersonic speeds.

"There hasn't been a lot of research that looks at shockwave/expansion fan interactions at supersonic speeds. On the one hand I'm looking at the basic physics involved, and I'm also working on developing aeronautics models that will assist with supersonic engine inlet design or the testing of store carriage and release from aircraft (missiles, bombs, fuel tanks, etc.), and formation flying," said Nel.

"Other researchers have mostly looked at shockwave/shockwave interactions, but very little research has focused on shockwave/expansion fan interactions. My research will help to fill that gap."

Where similar research studies have mostly relied on two-dimensional modelling, Nel's work combines data from wind tunnel tests with computer-generated flow visualisations to create three-dimensional models of the interactions observed.

By understanding how shockwaves and expansion fans interact when aircraft and aircraft, or aircraft and weapons systems, are in close proximity at supersonic speeds will greatly assist in the design of supersonic engine inlets and aircraft store carriage and release mechanisms.

Lara Nel has always loved science and finding out how things work, especially when it comes to flight and flying. "At the Wits open day there was a Mirage F1 on display during the aeronautics laboratory tour and I was sold!" Studying supersonic aeronautics appealed to her for a simple reason: "The faster, the better! It's amazing that we can travel that fast. At those speeds the shockwaves become very interesting and the flow visualisations make for amazing pictures that can even be considered art."

Longer endurance unmanned aerial systems

The CSIR flagship Modular Unmanned Aerial System (UAS), first flown in 2009, has been under continuous developed. Serving as a research platform, it is used to validate advanced novel technology components and basic sub systems by integration and demonstration in a relevant flight environment. The Modular UAS is unique in that is has a twin-fuselage, electrically powered modular design. The two fuselages are spaced sufficiently far apart that the wing joining them plays a significant role in the performance and handling characteristics of the airframe.

The latest modifications are to extend the span to 6 m to provide a longer endurance capability. This version utilises a small internal combustion engine to provide the flight duration required for a through-the-night mission, and electric motors that can be turned on intermittently for up to an hour of almost silent surveillance. A locally developed stabilised camera system is fitted to the central payload pod.

FAR AND AWAY:

Extending guided missile range and UAV capabilities with advanced gas turbines

Advances in electronics and other developments have seen gas turbines and micro gas turbines becoming some of the most promising technologies for powering unmanned aerial vehicles (UAVs or drones) and extending the range of guided missile systems. The CSIR has significantly expanded its activities in gas turbine design, building on developments that were made in the 1980s and 1990s.

With the lack of a propulsion systems capability in South Africa having been identified as a deficiency in the aerospace industry, and with a clear market for an emerging gas propulsion sector, an ideal opportunity was presented to create a local gas turbine industry and enable the continued development of South Africa's considerable capability in guided weapons development.

The CSIR, in collaboration with Cape Aerospace Technologies (CAT) and Stellenbosch University, is currently working on both a 200N (Newton) micro gas turbine engine for the hobby market, UAVs and potential small diameter precision guided weapons. The CSIR is also developing a 1 000N turbojet engine capable of vastly extending the range of large guided missile systems.

"With ground-based air defence systems becoming more capable, long-range stand-off weapons are becoming increasingly attractive to air forces worldwide." says CSIR principal engineer of gas turbines, Dr Glen Snedden.

"Extending the range of these types of weapons is the focus for building the next generation of such systems. The correct gas turbines have the potential to extend the range of these types of weapons to over 200 km."

The 200N engine is currently being assembled for testing, while the larger 1 000N engine is in the detailed design phase with specific sub-systems being manufactured for component testing. According to Snedden, the core for both designs are based on mixed flow compressor design, simultaneously enabling high mass flow and pressure ratios in single stages. The compressors that have been tested thus far all show that the designs should meet their targets. The technology has many potential applications and spin-offs.

"Apart from the turbojets currently envisaged, which themselves have spin-off potential in the self-launch glider market, there are many variant designs possible; for instance, by adding turbine stages or converting the engine to bypass engines with higher thrust for helicopter applications and UAVs, respectively," says Snedden.

The work being done on these engines, with assistance from the Aerospace Industry Support Initiative (AISI) of the Department of Trade and Industry, is helping to launch a local gas turbine industry that could be of great economical value to the country.

"Gas turbines are extremely high value-added sub-systems," concludes Snedden. "The potential to create a high value export commodity, combined with the skilled jobs that will be created for our manufacturing sector, make it a very attractive project for South Africa."

INFRARED ELECTRONIC WARFARE:
Getting to know the enemy on-screen first

Infrared (IR)-guided man portable air defence systems (or shoulder launched surface-to-air missiles) pose a serious threat to both civilian and military airborne platforms. This is especially true on the African continent, where terrorist and insurgent groups are suspected to possess thousands of such systems.

Understanding the threat and its capabilities is critical for any research, development and effective deployment of infrared countermeasures to ensure the survivability of the platform and aircrew.

The characterisation of IR-guided threats started in the 1960s and over the years the CSIR has built up strong capabilities and facilities to enable the characterisation and analysis of threats. The result of the characterisation process is a model of the missile both from infrared seeker and aerodynamic perspectives.

This process progresses further with the infrared measurements of the potential target (the aircraft) carried out using imaging radiometers, as well as an imaging Fourier Transform Infrared Spectroscopy (FTIR) spectrometer. The FTIR collects spectral data to characterise objects spectrally, spatially and temporally. Measurements, using the imaging radiometers, are executed in the short-, medium- and long-wave infrared bands.

Using these measurements, accurate computer models are developed of the aircraft and countermeasure flares for use in the modelling and simulation environment.

In the past, to test a design, hardware was built and tested in the field. In many cases prototypes were damaged beyond repair or, in the case of electronic warfare missiles, completely destroyed. This build-and-break experimental method has almost been completely replaced by simulation-based design and testing.

The modelling and simulation approach provides earlier understanding and validation, as well as the opportunity for refinement and improvement.

This approach is particularly relevant for the development and evaluation of complex systems, such as aircraft self-protection countermeasures against missile attacks. The use of simulation also extends the evaluation to beyond that which is feasible with hardware-only evaluations.

Using the results of the simulation runs, field trials are then undertaken by the CSIR with the client to provide further validation, enabling the client to compare the actual hardware (aircraft and flares) operating as recommended by the simulations.

Air safety starts on the ground

A specialised weapons integration capability provides the required aero-mechanical knowledge and expertise to help define the aircraft carriage and release armed envelopes. Naturally, the performance and handling of aircraft is impacted with the addition of fire power because its flexibility and aerodynamics are adversely affected. Stores that are individually stable, could react differently in the flow field of an aircraft. Aerodynamics can adversely affect the trajectory of a weapon when released. This means it may not be delivered accurately and may strike the operator's aircraft.

Flying MACHINES
The great automation debate

Arguably, innovative engineering and technological advances have increased aviation efficiency and safety at a higher rate than in any other domain. However, how the benefits of advanced technology are directed, is raising concern.

Civil aviation regulators, aircraft design engineers, pilots and test pilots form a growing community that recognise the irony of technological advances in aviation over the past 113 years of powered flight. Based on accident statistics, the technology revolution has become a serious challenge to the aviation community at large.

Have training regimens kept pace with innovative technologies and engineering? Do pilots of highly-automated aircraft get sufficient 'hands-on' flying experience? And, importantly: Could automation error be the new 'human factors' contribution to accidents?

Internationally, the pilot community is registering a general concern regarding the lack of basic situational awareness and handling capabilities in the cockpit because of the attraction of automated flight. In several accident cases, the causes could be traced back to a pilot's inadequate 'hands-on' abilities or loss of situational awareness operating the latest generation aircraft. It is no secret that engineers seized upon the fickleness of pilot judgement to deliberately design 'pilot error' out of the cockpit.

The universally accepted 72% of accidents attributed to 'human factors', spurred engineers to introduce automation technology to ameliorate pilot handling and judgement inadequacies. In fact, in an effort to improve the flight experience of paying passengers, some airlines generally prohibit manual flying of an aircraft, except the take-off and landing.

Over the years, regulators have exercised their mandate in directing safety conventions in accordance with existing knowledge and experience. Today, however, personnel staffing the regulatory bodies are mainly 'old school', with little or no understanding of the impact of modern technologies. The problem stems from the fact that smart avionics, smart aerodynamics and smart flight control systems have made modern aircraft a lot easier to fly and, consequently, pilot workload has decreased significantly – to the extent that the 'pilot out of the loop' philosophy increasingly poses a threat in the decay of piloting skills.

Engineers have led pilots to the point where trust in technology has overwhelmed their faith in their own ability to recover from a 'bad situation'. Also, to a certain extent, the pilots themselves are complicit in this situation; the luxury of automation is turning pilots into 'better informed passengers' with inadequate physical cues to handle emergency situations in some cases.


Article contributed by Maj Gen Des Barker (SAAF ret) who is a military experimental test pilot assigned to the CSIRs Aeronautics Systems.

Very little seems to be made of the fact that engineers have not yet succeeded in designing zero-defect equipment. In addition, their backup of quadruple redundancies statistically reducing failure to better than 10^9, have not lived up to expectations in the real world.

The loss of the Air France Flight 447 Airbus over the Atlantic in 2009, saw a series of 24 Aircraft Communications and Reporting System messages sent automatically for a duration of four minutes, indicating – among others – speed measurement inconsistencies, the disconnection of the autopilot and the airplane going into 'alternate law' flight control mode indicating multiple failures of redundant systems.

228 people died. Previously considered a minor failure – namely an airspeed indication due to icing – left the pilots with information overload and a total lack of situational awareness, resulting in loss of control of the aircraft manually under the adverse weather conditions. Preliminary findings by the accident board indicate the serviceable aircraft stalling and impacting the ocean at nearly 11 000 ft/min rate of descent. The question, "How was this possible?", resounded across the aviation community.

>> Continued on following page

Flying MACHINES
The great automation debate

>> **Continued from previous page**

The simple failure of a radio altimeter led to the delayed attempts at stall recovery of the Turkish Airlines Boeing 737 Flight 951, in which the investigators' preliminary report confirmed that the pilots allowed the automatic systems to decelerate the aircraft to a dangerously low speed as it approached Schiphol Airport. With very late detection and pilot response at only 450 ft above ground level, the pilots scrambled to accelerate out of the stall before it crashed to the ground, killing the three flight deck crew and six others on board. The radio altimeter had 'informed' the automatic flight system that the aircraft was eight feet below the surface when it was still actually 2 000 feet above ground level, which caused the auto-throttle to pull back the power to idle, as if the plane were flaring for the landing.

The Amsterdam incident was at least the fourth in a 13-month period in which pilot error caused an airliner to stall and crash. The accident findings intensified the debate over the dangers of pilots losing their basic flying skills and situational awareness as a result of relying on the sophisticated electronics that control airliners through most of their flights.

Amazingly, following the accident, Boeing was prompted to issue an unusual worldwide alert covering procedures that should be second nature to aviators: "to carefully monitor primary flight instruments during critical phases of flight", such as take-offs and landings.

Coupled with the threat of technology and engineering, the emphasis on 'paper licences' by civil aviation authorities, without an equivalent focus on handling skills and decision-making – typically transferred from classroom to cockpit – is also of concern with the 'old hands'.

The removal of stalling and spinning from the basic flying training syllabus as a mandatory basic handling requirement, has been debated for many years and is being accepted by civil aviation authorities in some cases. Add to this engineers offering stall- and spin-free handling qualities in their latest products to reduce accident risks, are in fact, indirectly, producing 'handling' deficient pilots. The result? Pilots with a lack of recognition of high angle-of-attack characteristics and low confidence in handling aircraft at high angles-of-attack; accidents that should not occur.

A recent Federal Aviation Administration (FAA) study found serious flaws in pilot training and suggested that flight crew were not properly trained for operating highly automated aircraft, and that for many of the problems they have to deal with, there are no checklists, leaving the pilots to rely on ingenuity and airmanship. Inadequate crew knowledge of automated systems was a factor in more than 40% of accidents and 30% of serious incidents between 2001 and 2009 worldwide.

Research undertaken by FAA human factors specialist Dr Kathy Abbott published in 2014, catalogued the evidence of disharmony between crews and their highly automated aircraft. Recurring handling problems that pilots demonstrated included lack of recognition of autopilot/ auto-throttle disconnect, lack of monitoring and failure to maintain energy/speed, incorrect upset recovery and inappropriate control inputs.

Abbot delivered a telling judgement on the impact of automation on pilots, stating that failure assessment of the automation was difficult, failure recovery was difficult, and that the failure modes were not adequately anticipated by the designers.

The issue of 'automation addiction' has been intensely deliberated and debated within the airline industry and aircraft manufacturers. They conceded that the rapid pace of engineering innovation held the potential for a regression in pilots' handling skills and situational awareness.

However, there is no going back on technological progress. It would also be impractical and unrealistic, given the significant positive contributions of technology to aviation safety.

Fact remains that the threat is real; automation is getting ahead of, and out of sync with the pilot's abilities and regulator knowledge. Advanced technologies instituted to ameliorate human deficiencies could turn out to be a bigger threat to safety than the human factor, unless methods of reconciliation can be found between test pilots, aircraft design engineers and regulators.

The pertinent question seems to be how to manage the challenge of integrating human factors with automation. Certainly, a compromise solution would require closer collaboration between design engineers, test pilots, line pilots and regulators to better understand the impact of technological innovation on the fickleness of the human psyche.

Regulators need to ensure that training regimens adequately address the human factors, issues of skills regression and reduced situational awareness. Design engineers and test pilots need to allow for cognitive saturation and pilot workload following failures. By the same token, test pilots need to play a stronger role in ensuring better understanding between engineering and the line pilot. Airlines, charter companies and flying schools should acknowledge the extent of the challenge of integrating the next generation of pilots safely into technologically advanced cockpits through adequate training on automation.

Finally, pilots of the automation generation (otherwise known as 'children of the magenta line'), will be required to more fully understand the matrix of failures linked to integrated systems. In fact, pilots need to grow their levels of technical knowledge almost to the level of aviation engineers. Automated systems are complex. Without fully understanding the intricacies and multiple permutations of complicated matrix systems, failures will leave pilots at the mercy of automation.

As US Airways Capt. Chesley "Sully" Sullenberger[1] said: "We cannot afford pilots and the technology failing together! If we only look at the pilots – the human factor – then we are ignoring other important factors; we have to look at how they work together."

1 Automation in the air dulls pilot skill, by Kells Hetherington, The Daily Caller, 30 August 2011. http://dailycaller.com/2011/08/30/automation-in-the-air-dulls-pilot-skill/

NUMERICAL MODELLING TO UNDERSTAND VIOLENT FLUID SLOSHING IN AEROSPACE VEHICLES

Violent fluid sloshing in large fuel tanks causes impact loading on structures and can threaten the dynamic stability of the vehicle they are contained in – typically airliners and space launch rockets.

A tool that efficiently predicts these structural and dynamic effects, is of great value in the design of such platforms, as well as for evaluating the effectiveness of different approaches for reducing sloshing.

The new methods were implemented into an open-source computational fluid dynamics framework and demonstrated improved accuracy in realistic aerospace sloshing scenarios compared to industry-standard methods. It has proven to be particularly efficient and accurate in modelling exceptionally violent sloshing cases, such as those experienced inside aircraft wing fuel tanks and liquid rocket fuel tanks.

The tool enables the modelling of the flow dynamics of two immiscible fluids (fluids that cannot be mixed). The fluids may be separate phases, such as liquid and gas, or the same phase (gas-gas or liquid-liquid). The code calculates the evolution of the position of the interfaces between the two fluids, the velocity field throughout the domain and the pressure field. These detailed calculated fields form the output, from which any derived quantities may be obtained – for example loading of baffles, damping ratios, centre of mass, mixing ratios, etc.

The code has been extensively applied and benchmarked in simulating the sloshing of liquid-gas mixtures in tanks. The intellectual property was developed at the CSIR within the open source 'OpenFOAM®' framework.

Some of the new algorithms are:

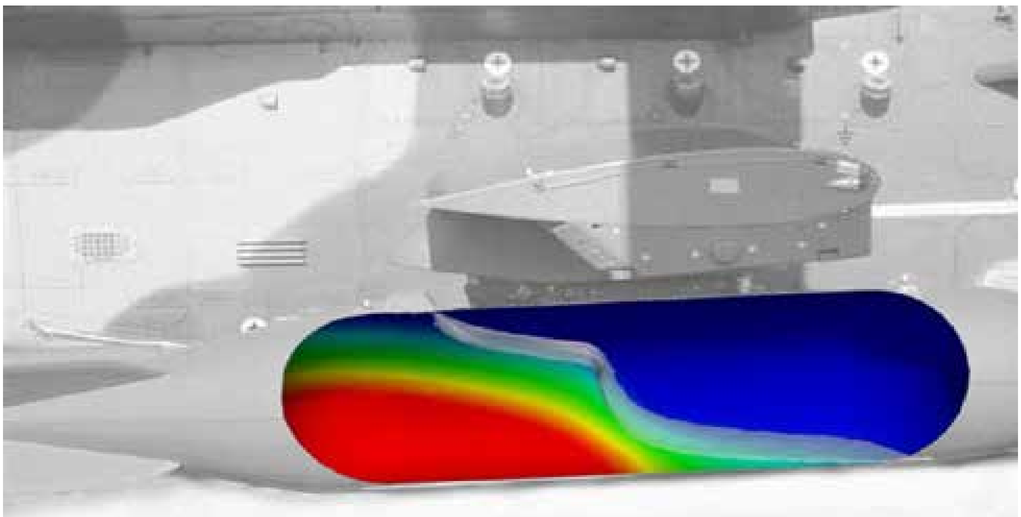
- A compressive surface capturing formulation for modelling free-surface flow using the volume-of-fluid approach;
- A weakly compressible free-surface flow solver for liquid-gas systems; and
- An improved pressure discretisation scheme for non-orthogonal computational meshes.

The CFD laboratory

The CSIR's computational fluid dynamics laboratory consists of 325 powerful computers working in parallel for integrated wind tunnel and experimental fluid dynamics studies.

The facility is used to perform complicated mathematical modelling and simulation for a variety of applications such as store integration and transonic flows, industrial flows, coastal defences, ventilation analysis, space science and launchers, two-phase flow analysis and molten metal flows. These applications are used to fulfil requirements across a number of sectors including aerospace, manufacturing, building designs, ventilation for mines or hospitals, and the automotive sector.

The CSIR uses both commercial and customised in-house computational codes to address complex aerodynamic, fluid-dynamic, multi-physics and fluid-structure problems.



An artist's impression of the SAAFs Gripen, launching Denel Dynamic's 5th generation air-to-air missile. (Image: Denel Dynamics)

AIR-TO-AIR MISSILE DEVELOPMENT: Fighter pilots at the forefront

Article contributed by Maj Gen Des Barker (SAAF ret) who is a military experimental test pilot assigned to the CSIRs Aeronautics Systems.

The South African air combat capability got an additional sting in its technology power with the coupling of a 5th-generation air-to-air missile (AAM) with a 4th-generation fighter and the benefit of a helmet sighting system.

Currently under joint development, the South Africa/Brazil/Denel Dynamics' A-Darter air-to-air missile gives South Africa and Brazil independence in a key area of defence technology. This is a programme of some significance since it demonstrates southern hemisphere cooperation in cutting-edge technology whereby we supply our air forces with an AAM capability.

The two countries have invested considerable effort into establishing the framework for cooperation. The partnership is well supported by commonalities in their national objectives and defence posture.

Some 30 engineers from the Brazilian Air Force and civilian defence companies are involved in the programme together with counterparts from the Denel team. They are involved both in the development of the missile as well as in technology transfer to Brazil – representing an excellent match between the two countries, the two air forces, and the two departments of defence.

The new missile is geared for use by the South African Airforce's (SAAF) Gripen fighters and Hawk lead-in fighter-trainers, and the Brazilian Air Force's modernised F-5M fighters and its Gripen NG.

As a 5th-generation missile, the A-Darter missile is highly agile and able to manoeuvre at high angles of incidence. Its agility is supported significantly by thrust vector control, similar to that found on the latest military aircraft. The A-Darter missile is able to operate in an environment saturated with enemy electronic countermeasures (ECMs) and –

in order to do that successfully – it is equipped with a number of ECM techniques to counter any hostile advances. The A-Darter missile will be guided by a highly sensitive thermal imaging seeker, with a large field of regard.

The fighter pilot is able to designate a target for the missile in one of three ways: If the target is outside visual and infrared (IR) homing range, it will be designated using the aircraft radar, and the missile launched on the requisite intercept course, with the seeker head locking onto the target once it comes within range. This is called 'lock-on-after-launch'. Even if the target is within visual and IR-homing range, the radar could still be used to designate the target – the seeker head would 'lock-on-before-launch'.

'Lock-on-before-launch' would also be the mode in the other two methods of target designation. These are designation by the pilot using the helmet sight, or using the missile seeker head to scan for targets itself. This mode allows the aircraft to hunt for targets while maintaining radar silence (radar transmissions can be detected by hostile forces using electronic support measures).

The missile's large-look angles, added to its considerable agility, will make it possible for the pilot to launch it at high off-boresight angles (boresight is a narrow cone of vision straight ahead of the fighter, using the helmet sight). In other words, the pilot will not have to turn his aircraft towards the enemy in order to engage him.

The A-Darter design is a low-drag wingless airframe which gives it an extended range in comparison to previous-generation IR-homing AAMs.

It is generally accepted that technological superiority is the deciding factor in modern warfare. Denel Dynamics' A-Darter missile gives the SAAFs Gripen pilots 'the edge' and puts them on course for mastery of the skies.

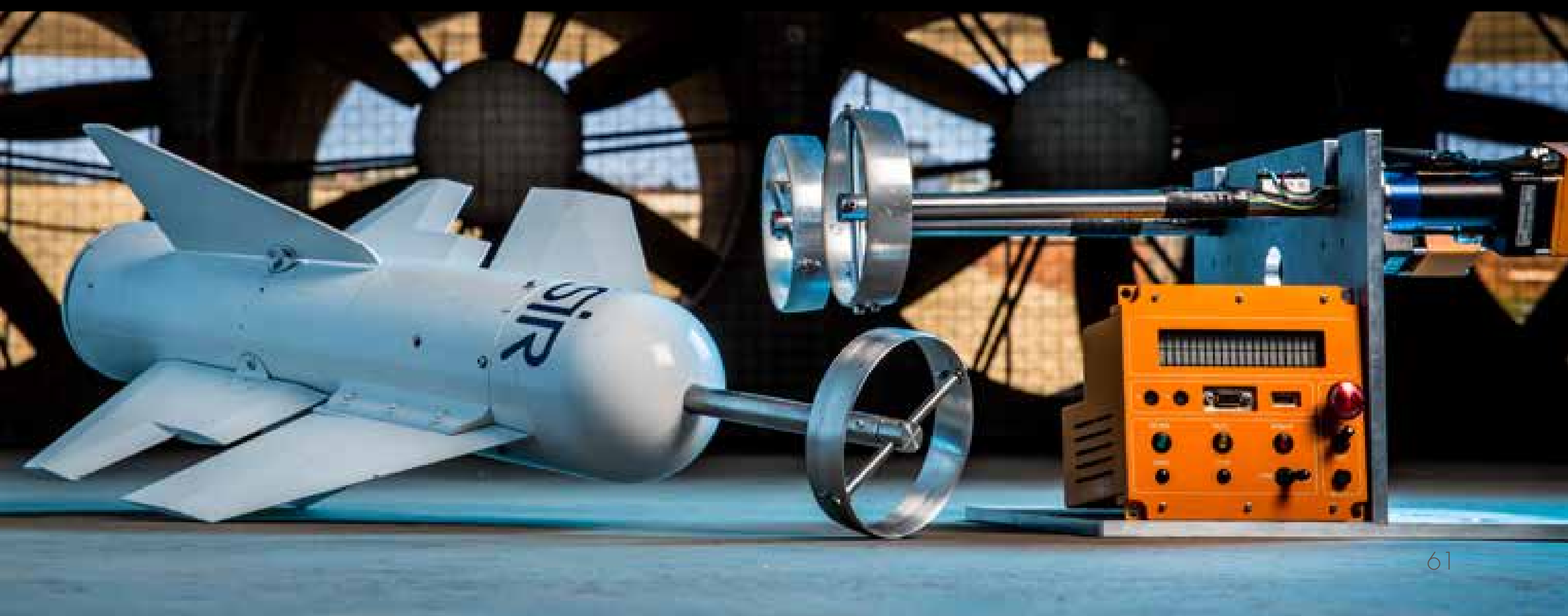
Shake it off: FLUTTER EXCITATION

Flutter is a very dangerous dynamic instability that all aircraft can encounter. The purpose of a flutter exciter is to impart a vibration into a structure. Carried by the flight test aircraft, it distributes energy into the aircraft structure to excite all the natural modes. Structural vibrations are measured by accelerometers and the responses are used to determine if flutter onset is likely or not.

The technology comprises two flutter exciters (port and starboard side) and a cockpit control unit. The exciter unit is incorporated into selected stores that the particular aircraft will carry (be it bombs or missiles) and has to be cleared. Being store mounted, the aircraft configuration is not changed significantly.

The flutter exciters used by the CSIR include:

- Bonkers: An explosive charge that provides a single excitation. This was used on Buccaneers, Impalas, Mirage F1s, etc.
- Rotation cylinder exciters: The CSIR co-developed this type of flutter exciter. The rotating cylinder provides excitation over a programmable frequency range and duration. The picture shows the system as fitted to a SAAF Cheetah.
- Annular wing exciters: This type of system is currently used on civilian and high speed military aircraft. The annular wing excitation system provides excitation over a programmable frequency range and duration.



ANGLE OF ATTACK INDICATOR:

Panacea for Safe Handling and Performance?

"You will write out 1000 times by tomorrow morning: "The AoA indicator is not only a stall warning indicator"; these were the orders of the ground instructor to a student pilot during an aerodynamics lecture at Flight School."

Origins of the AoA indicator

Historically, angle of attack (AoA) indicators were regarded as the sole domain of flight testing and then, later on, in third generation fighters as an aid to pilots during combat manoeuvring. In the world of flight testing, AoA has always been one of the most critical measurement parameters. In fact, the Wright brothers had only one instrument on their first aircraft: A protrusion from the nose of their aircraft with a piece of yarn attached to it from which they could estimate AoA.

The century series fighters such as the F-100 to F-106 types with relatively low aspect ratios, plus those with delta wing planforms such as the Mirage III, generated drag curves in which minimum drag speeds were typically 300 KIAS and managing the aircraft energy was the single biggest contributor to pilot workload. Surprisingly, 100 years later, it is still not a common instrument on general aviation aircraft, despite the Federal Aviation Administration (FAA) requiring stall warning devices on certificated aircraft.

FAA push

Due to the number of loss-of-control accidents in general aviation, both the National Transportation Safety Board and the FAA have recommended an increased use of AoA indicators. The latest push focused on bringing this technology to general aviation aircraft. The FAA's Advisory Circular AC23.1309-1C states: "To improve the safety of the aircraft fleet by fostering the incorporation of both new technologies that address pilot-error and weather-related accidents and those technologies that can be certified affordably."

The Advisory Circular emphasised that AoA gauges allow pilots to quickly assess their stall margin, and went on to declare affordable AoA instruments one of its most-wanted safety improvements. The Aircraft Owners and Pilots Association (AOPA) Air Safety Institute also enthusiastically supported the cause.

Weight as a performance parameter

Every pilot worth his wings knows that a wing will stall at a specific angle and that the stall airspeed is a direct function of aircraft weight. Since aircraft efficiency is an indirect function of weight, by logical deduction, to maximise efficiency, one would need to fly the aircraft at a specific optimal AoA for specific flight/weight profiles to produce maximum efficiency.

Article contributed by Maj Gen Des Barker (SAAF ret) who is a military experimental test pilot assigned to the CSIRs Aeronautics Systems.

In fighter combat missions, large weight differentials of 50% between take-off and landing depend on maximising critical performance parameters for successful mission accomplishment, namely:

- Maximising range and endurance;
- Maximising turn performance during air combat (a survival tool); and
- Optimising speed control on approach for landing at airspeeds of up to 200 KIAS and stopping the aircraft in the available runway length (drag chutes required to stop).

Optimising energy was, and still is, a primary control parameter for fighter pilots. The single, most important indicator of aircraft efficiency, is AoA. However, the collateral benefits of AoA go beyond performance enhancements. In 1957 the United States Navy and Marines reportedly cut their fatality rate in half in one year after they perfected using AoA as the primary management of energy in carrier landings.

Times have changed

The cost of fuel is a critical factor in aviation, and cause for optimising performance to be able to afford flying. Also, general aviation accidents worldwide have remained in roughly proportionally consistent levels in the statistics for each phase of flight over the years.

Most accidents occur during take-off or landing, followed closely by manoeuvring flight. An AoA indicator could help prevent such accidents.

According to the FAA, the final 'killing event' is uncontrolled flight into the ground due to stalls and spins. The AOPA's Air Safety Foundation (ASF) states that "stall/spin accidents tend to be more deadly than other types of GA [General Aviation] accidents, accounting for 10% of all accidents, but 13.7% of fatal accidents".

The ASF study also found that stalls/spins are most likely to occur in manoeuvring flight such as aerobatics, 'shoot ups' with steep vertical pull-ups, agricultural flight steep turns to reverse directions, engine failures after take-off with the pilot trying to return to the runway, and steep turns to final approach ('hammerhead') when trying to correct an overshoot from base to finals. A NASA study in the late 1970s found that GA aircraft typically require about 1 200 ft to fully recover from a spin, which would be undoable in most GA aircraft.

Most airliners have AoA sensors, but output is only through to the flight management systems and not readily visible to the pilot. Corporate aircraft have had AoA indications available for years and general aviation now also has an affordable indicator. General aviation can no longer sit back thinking it does not need an AoA indicator because of the audio stall warning that is scanned in conjunction with the airspeed indicator (ASI). The AoA benefits go beyond than just stall warning.

ASI vs AoA indicator

The AoA sensors in GA aircraft are rare and therefore airspeed is used as a proxy to get the approximate angles for various flight profiles. However, the ASI has its own unique inherent inadequacies such as lag and sideslip over/under read errors due to asymmetric input to the static vents. Unfortunately, pitot-static errors increase with airspeed decrease and provide very little information about the lift conditions of the wing; that is what an AoA indicator does.

Add to that the idiosyncrasy that pilots generally only know the correct approach airspeed for gross weight at sea level on a standard day – which means that if the aircraft is light, they tend to come in fast and curse the 'floating' landing, the bounce or the excessive braking required to stop on the shorter runways. At the other end of the scale, the problem is getting too slow, resulting in a 'hard landing'.

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Benefits of AoA indications

An AoA indication can provide the pilot with information to increase the safety and efficacy of the aircraft:

- The indications are valid under any flight condition, at any airspeed, altitude wing loading and density altitude.
- The indicator is sensitive at any airspeed and changes in AoA are immediately apparent.
- There is a specific AoA that provides maximum range and endurance and even the minimum sink speed.
- Vx and Vy are all functions of AoA and occur at the given AoA. Using the same pitch attitude for low and high density take-offs may place the aircraft in the 'region of reverse command' but by flying the proper AoA on rotation, will ensure a proper attitude regardless of density altitude or gross weight.
- All approaches should be flown using a specific AoA regardless of gross weight, bank angle, turbulence or density altitude.
- Provides a stall indication/number that is correct whether straight and level or in a turn.

Real-world applications

Some AoA advocates point to the recent Asiana 214 incident in San Francisco as an example of the type of accident that could have been prevented. However, it also demonstrated exactly why AoA is not the panacea for control woes. Obviously pilots have to look at the instrument for it to be of any use. In the case of the Asiana accident, the crew ignored the airspeed indicator, and got almost 30 knots slow on final approach. Another instrument would not have prevented this disaster.

Besides looking at the instrument, pilots have to know how to react to its indications. For the GA pilot struggling to log 25 hours in a year, the physical stick and rudder skills will be more important than the recognition skills. Furthermore, an AoA indicator won't help a pilot who does a 'shoot-up' at 20 feet, or prevent a stall caused by over-gross weight take-off on a hot day or other scenarios in the category of 'loss of control'.

Fighter pilots readily sing the plaudits of an AoA system because it's a religion in the military. Many of them are therefore surprised that general aviation pilots are still flying solely on airspeed. However, a counter argument from GA pilots is that an AoA indicator is most probably required when landing on the pitching deck of an aircraft carrier at night. For the average GA pilot, however, landing on a 5000 ft runway, the situation is quite different – airspeed control on final approach matters a lot more than a new instrument in the panel.

The simple fact is that airspeed is an effective proxy for AoA most of the time and general aviation pilots fly in a very small envelope of +/- 10º in pitch and 30º of bank in most cases. Within those boundaries, monitoring airspeed is sufficient to avoid stalling.

Most of the base-to-final stall/spin scenarios occur because the pilot got too slow. Basic air speed control would therefore improve safety more than a new instrument in the cockpit. However, accuracy of speed control on final approach remains a challenge to the GA community at large; naysayers will claim that: "We don't have an instrument problem, we have a stick and rudder skills problem. Instead of spending a lot of money on new instruments, let's teach pilots how to maintain the proper airspeed on final. Now, that would be revolutionary."

Tangible benefits

Is the system worth the expense? There's more to consider than just some extra protection against becoming a stall-spin statistic or floating a bit on landing, although that may be enough for many pilots. Every landing at the right speed is that much less wear and tear on brakes, tires and undercarriage. Increased efficiencies are achieved by flying at the correct angles for best rate, best angle of climb, maximum range, etc., all for an investment of under $1500 for most light aircraft. Stall warning, increased precision of flight, improved stall/spin situational awareness, fuel conservation and building confidence in pilot's handling, are just some of the benefits.

A visible AoA indicator is similar to 'monitoring' the wings' lifting potential at any stage of flight. This in turn enhances the safety and efficacy of the flight.

For this reason, the FAA/industry panel recommended the use of AoA-based systems by GA to reduce fatal loss-of-control accidents in the approach and landing phases of flight. Bolstering that conclusion, FAA Administrator Michael Huerta has called for the addition of AoA systems and other potentially life-saving equipment to GA aircraft. Kirk Hawkins, former Air Force F-16 Pilot supported the directive: "Angle of attack well executed, is a game changer in any aircraft – and it's long overdue."

Any air tactics manual should warn: "Speed is Life." A good mantra for fighter pilots, but time lessons have taught us that in GA, it is probably more appropriate to remember "Angle of attack is life."[1]

BETTER DESIGN OF AIRPORT PAVEMENTS

Roads are the lifeblood of an economy; at a cost of between R15 million and R8 million for a kilometre of highway with a relatively short lifespan of 20 to 40 years, a country's roads infrastructure has to be scientifically constructed and maintained to maximise cost-effectiveness.

The CSIR-developed Heavy Vehicle Simulator (HVS) is a high-tech accelerated road-testing field lab with unique instruments that measure and analyse the engineering performance of runways or road structures and material layers to test whether a specific road will have an acceptable lifespan. With the accelerated testing and laboratory-associated research, researchers can simulate the damage over 20 years caused by heavy traffic volumes to road structures within a short time span of up to three months. These results are invaluable to taking corrective action in road design and selecting the best construction materials and methods when planning the construction of long stretches of new roads.

The simulator can also be used to evaluate new or improved pavement materials, structural designs, and construction techniques that extend pavement life and expedite construction to minimise the impact on users. Evaluations include the impact of increased tyre loads and tyre pressures on existing and proposed pavement structures.

Runway applications

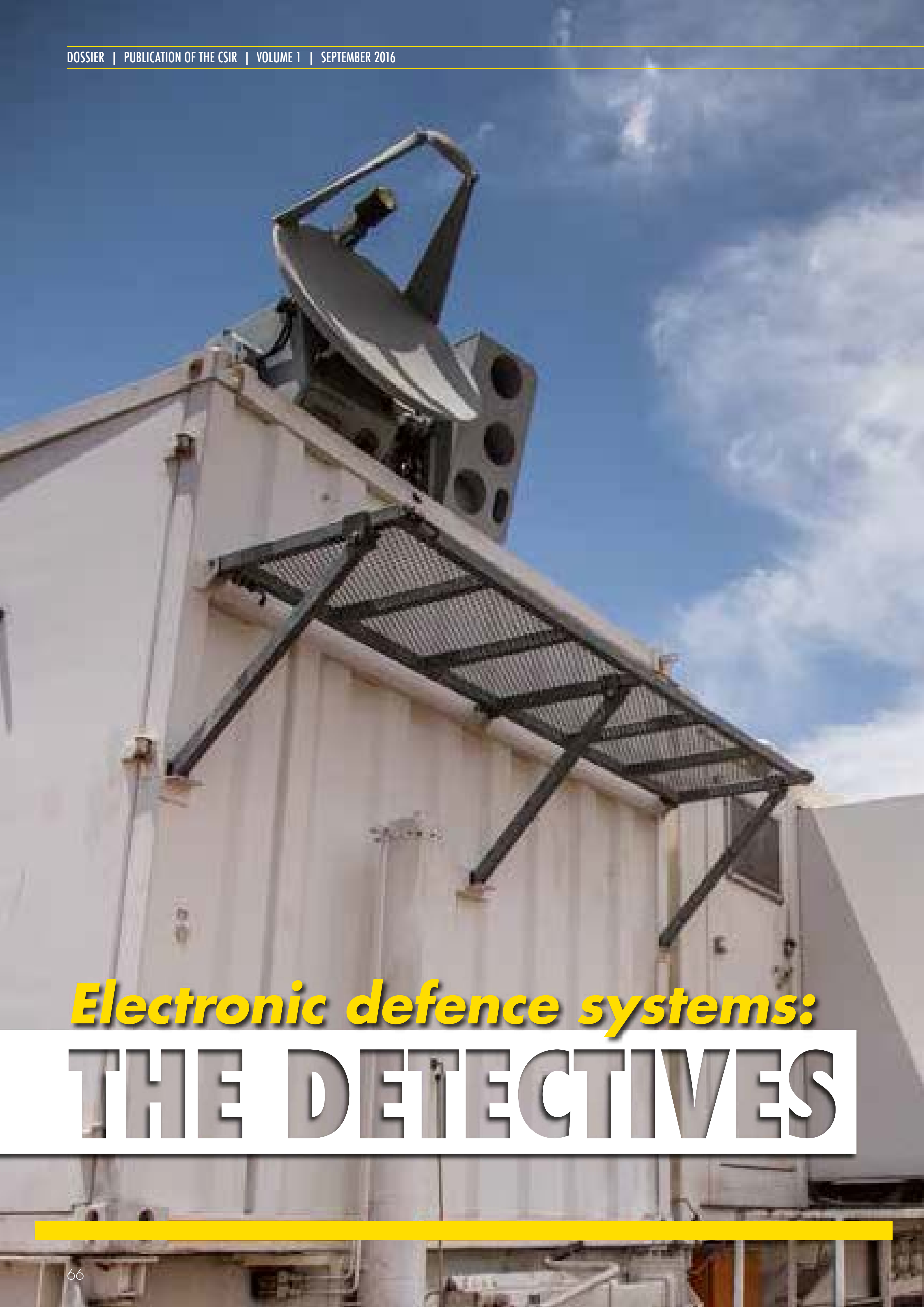
The newer generation of large aircraft have complex gear configurations and high wheel loads. To assess the damage caused by these 'monster' aircraft, the standard HVS was upsized to test airport pavement structures to a maximum wheel load of 450 kN. The two HVS-A machines currently in use are 37 m long, 5 m wide and can test pavements using full-size aircraft landing bogies and their wheel configurations. The latest one was delivered to the Federal Aviation Administration in Atlantic City, in the USA in 2012.

Environmental effects on roads also under investigation

Apart from simulating the damaged caused by tyre loads, the HVS is able to simulate environmental damage. Using a specially designed heating/cooling chamber, the surface of the pavement can be cooled down to below zero or heated to above 60 °C to access the structural performance of the pavement under extreme temperature conditions. Water can also be introduced onto or inside the pavement.

The CSIR-developed HVS platform holds the key to better design of civilian and military airport pavements. The HVS has been the pillar of the CSIR's comprehensive research programme carried out in conjunction with provincial, national, and international transport authorities.

This platform has had a significant impact on pavement engineering in South Africa and internationally over the past four decades and as a result, the CSIR is recognised as one of the global leaders in pavement design and evaluation. At present, 18 of these massive roadside laboratories have been exported to active duty in the USA, Sweden, China, South Korea, Indonesia, Mexico, India, Saudi Arabia and Costa Rica. The HVS has also been used for research in Finland, Slovenia and Poland, with two units available in South Africa, one belonging to the Gauteng Provincial Department of Roads and Transport and the other to the CSIR. Over the past 18 years, the international programme has generated significant direct foreign income for the country – brought home as a result of quality research and technology development and sound commercial decision-making.



Electronic defence systems: THE DETECTIVES

RADAR DEVELOPMENT: 70 YEARS AND COUNTING

Article contributed by Francois Anderson, a CSIR Chief Radar and Electronic Warfare Systems Engineer

The first radar echo in South Africa was received on the 16th of December in 1939. It signalled the beginning of a field of science and technology that has since blossomed into a modern, strategically important radar capability in South Africa to an extent unexpected in a relatively small, developing country. The capability is increasingly being utilised to help satisfy the country's defence and security requirements. In this way, the local radar capability is contributing to increased peace, safety and security in southern Africa while helping save foreign exchange and contributing to South Africa's talent-based industrial development and job creation.

JB0 was the first South African radar demonstrator developed by a team consisting of seven South African engineers and scientists from South African universities. At the start of World War II, the team was drafted into the South African Army Corps of Signals to form the core of the Special Signal Services (SSS), a wartime codename for the radar capability of the South African Defence Force (SADF). Led by Dr Basil Schonland at the Bernard Price Institute for Geophysics (BPI) on the campus of the University of the Witwatersrand, the team based their work on information transferred from the United Kingdom.

The war years

During the war years, radar expertise in Africa grew exponentially and within a remarkably short period of time, the wartime radar network included 30 coastal radar stations in South Africa as well as mobile radars deployed and operated in East Africa and near the Suez Canal. The team grew to consist of 60 radar professionals at the BPI and 200 radar technicians. A staggering 500 female graduates were employed as radar operators.

In 1945 Schonland established the CSIR at the request of Prime Minister Jan Smuts, who saw science and technology as crucial to the post-war reconstruction and growth of South Africa and its fledgling industrial base. Schonland was subsequently appointed as both CSIR President and scientific advisor to the Prime Minister. In 1946 he formed the Telecommunications Research Laboratory as one of the founding institutions of the CSIR with nine core members drafted in from the SSS Radar Team. One of them, Dr Trevor Wadley and his staff went on to apply their wartime knowledge and experience in radar to the invention and development of the now famous Wadley Loop HF Receiver and the Tellurometer, the first microwave electronic distance measuring instrument in the world. It was first demonstrated in 1955, patented, industrialised and produced as the worldwide golden standard in long distance surveying applications for decades, to be replaced only in the 1990s by GPS-based surveying methods. However, even today Tellurometers are still being used in a number of specialised applications, for example inside mines.

After WWII, Schonland campaigned hard for continued military related R&D at the CSIR and succeeded in 1947 with the establishment of the South African Corps of Scientists at the TRL. They continued supporting the SADF with propagation predictions in support of HF radio communications as well as radar acquisition, site selection and data network planning for the new air defence surveillance radar network established under Operation Nassau to help protect the industrial heart land of South Africa against air attack.

1950s and 1960s

1951 saw the beginning of the development at the CSIR of the JB51, a next-generation long-range surveillance radar for the South African Air Force (SAAF). In 1957 a prototype of this radar was deployed at Pienaars River north of Pretoria. For many years it was used by the SAAF in air defence training. Unfortunately, when selecting the long-range surveillance radars to be used as part of their modernised air defence radar network in the early 1960s, the SAAF project team decided against the use of South African radars in favour of radars produced in the UK. This subsequently led to the demise of the original radar team's work on surveillance radars in South Africa.

However, this was not the end of radar at the CSIR. In the early 1960s, the military authorities in South Africa concluded that the country had a strategic need to follow the example of other militaries at the time and develop a capability in missile design, development, test and production. They approached the CSIR to establish such a capability. In 1963, this led to the establishment of the National Institute for Rocket Research, to be greatly extended in 1965 into the National Institute for Defence Research (NIDR).

The NIDR established R&D groups focusing on the design and development of the subsystems of modern missile systems at the time, including missile seeker radars, altimeters and proximity fuses as well as Ground Based Air Defence System (GBADS) surveillance and fire control radars. This renewed radar capability at the CSIR was extended by another technology transfer, this time from France as part of the acquisition of a low-level GBADS missile system for the South African Army. In March 1964, 20 NIDR engineers were sent to France to take part in the development of the system called the Crotale in France (renamed the Cactus system in South Africa). The target acquisition radar was an S-band pulse Doppler radar while the target tracker used for command-to-line-of-sight missile guidance was a Ku-band monopulse tracking radar.

1970s

During the early 1970s local teams at the NIDR designed, built and tested technology demonstrators of missile-related radars including an X-band seeker and radar altimeter for a sea skimmer missile and an X-band, coherent pulse compression surveillance radar, intended for the modernisation of the Super Fledermaus air defence gunnery system of the South African Army. Requirements for detecting armed people in woody savannah foliage on the northern borders led to a number of experiments and the development of early versions of VHF foliage penetration radars.

From the mid-1970s onwards this technology base in radar was used to develop another capability that was seen as strategically important in the light of the increasing threat perception caused by the introduction of Soviet weapons systems into southern Africa. This was the local design and development of electronic countermeasures (ECM) against radars and of electronic counter-counter measures (ECCMs) in radars against such ECMs. During the next decade, a range of locally designed microwave and antenna components and first generation digital processors were developed from first principles in support of ECCM hardening programmes of SAAF and South African Navy (SAN) radars. In addition, increasingly capable radar warning receivers, self-protection chaff and flare dispensers and ELINT receivers were developed for use on South African aircraft and ships.

Towards the end of the '70s, the South African missile industry was finally established. Missile R&D, production facilities and staff were transferred from the CSIR to form Kentron (Pty) Ltd, a new company established by Armscor that later became Denel Dynamics. They nowadays perform the design and development of radar-based missile seekers in-house. Meanwhile, national defence R&D and test and evaluation remained at the CSIR with a continuing focus on radar and electronic warfare (EW) research, development, test and evaluation (RDT&E).

1980s and 1990s

The 1980s saw an escalation in the requirements for the modernisation of both the South African Army and South African

Air Force GBADS. The radar team at the CSIR utilised some of the latest developments in Ka-band technology to build an experimental development model of a range-only tracking radar called NIMBUS, which was followed by the FYNKYK pseudo-coherent monopulse tracking radar. FYNKYK became quite famous in the South African Defence Force (SADF) when, deployed as part of the Red Forces during force preparation exercises, it defeated SAAF countermeasures and flying tactics and was credited with as many as 27 'kills' of ground attack fighter aircraft during a single week of intensive 'operations'. FYNKYK digital monopulse tracking radar technology was transferred to industry during the late 1980s and formed the basis of the newly created tracking radar division at ESD, now known as Reutech Radar Systems (RRS).

During the 1980s and 1990s the CSIR developed, built, maintained and operated a range of national facilities in support of radar and EW RDT&E. Besides specialised microwave, RF, digital and radar integration laboratories at their buildings on the Pretoria campus of the CSIR, these included the national antenna measurement range at Paardefontein, a transportable wideband radar cross-section (RCS) measurement radar called FYNMEET, a reference tracker based on the FYNKYK tracking radar technology demonstrator, the STATIC inverse synthetic aperture RCS measurement facility at Air Force Base Waterkloof and an increasingly more capable range of digital RF memory-based EW T&E facilities called ENIGMA. In the 2000s these facilities were extended to include the transportable MECORT pulse Doppler tracking and measurement radar facility, its outdoor integration and testing environment on the CSIR campus and a transportable sensor RDT&E command centre.

Starting with training courses in the early 1980s, digital pulsed Doppler radar knowhow was established at the CSIR throughout the 1980s and 1990s. Some of this new-found capability was used to provide technical support to the SAAF and Armscor during the acquisition of the airborne multifunction radar for the Cheetah C fighter aircraft upgrade programme during the 1990s and the radar for the Gripen fighter during the 2000s. The MECCANO digital, pulsed Doppler, monopulse tracking radar technology development programme was contracted at the CSIR in 1989 and culminated in the early 2000s with technology transfer to and joint production with RRS of high-performance naval tracking radars. These radars formed part of the optronic radar trackers (ORTs) that became operational in 2006 as part of the air defence fire control system on the Valour Class Frigates of the SAN.

In the late 1990s and up to the early 2000s the CSIR collaborated with UCT to develop a VHF polarimetric Synthetic Aperture Radar (SAR) system and fly it on a SAAF Dakota. The focus was on exploring foliage and ground penetration applications.

More recently

Besides the development of further enhancements of the tracking radar technology base in support of performance improvements of the ORTs during the 2000s and early 2010s, the focus of the CSIR radar area shifted to the development of cost-effective wide area persistent surveillance solutions for safeguarding the vast areas around South Africa's maritime, air and land border lines as part of a programme called AwareNet. To cover such wide areas effectively, radars need to be located on high sites looking down on the terrain or, where such sites are not available, airborne radar technology is required. One option being explored is the use of aerostats as airborne radar platforms that can be flown at low operating cost for periods as long as 30 days at a time.

In order to detect the small objects of interest in the AwareNet programme, (including small boats at sea; small, low-flying aircraft and individual people on foot crossing the land borders); track them; classify them and estimate which of the thousands of similar looking objects represent threats to which the country's defence and security forces need to react, a range of new pulse Doppler radar detection, tracking, classification and data fusion technologies are being developed.

The CSIR also recently restarted its SAR capability that had been on ice since the early 2000's. It plans to develop and fly a SAR demonstrator in 2016 and use it to investigate the use of high resolution, polarimetric and interferometric SAR imaging, moving target detection and radar target recognition for civilian and military applications. The programme envisages the development of SAR systems for UAVs and in the longer term for satellites.

Other modern technologies being developed include monostatic and multistatic phased array radar systems, radar reflectivity calculations and radar performance modelling and calculations. All of these are supported by a capability to validate the models and calculations by means of full-scale measurements in the field.

A radar capability to be proud of

In his overview of the history of radar in South Africa at the IEEE Radar Conference held in Johannesburg in October 2015, Francois Anderson, Chief Radar and EW Systems Engineer at the CSIR, remarked that over the past 75 years a surprisingly strong radar capability for a small, developing country had been built in South Africa.

Nowadays the country educates its own radar engineers with a dedicated postgraduate radar course being presented at the University of Cape Town. It performs independent radar RDT&E at the CSIR and IMT. It has a number of mature radar industries supported by a large number of small, medium and micro enterprises (SMMEs) that together are capable of developing, industrialising, producing, integrating and maintaining radar systems locally. Finally, at Armscor the country has people specialising in the professional acquisition of radar systems on behalf of the South African government. These South African radar-related organisations are represented in an officially registered body, the South African Radar Interest Group (SARIG).

Anderson concluded his presentation with the following statement: "Our research is being published internationally and South African radar engineers have a strong international network and partners. It is a wonderful time to be a radar engineer in South Africa and we are looking forward to an increasingly vibrant radar industry in the country, capable of satisfying important defence and security-related needs in Africa with systems optimised for the conditions and requirements of our continent."

The elusive radar, baffled experts and an unlucky politician:

A SHORT STORY ON RADAR WARNING RECEIVERS

Article contributed by Christo Cloete, CSIR Electronic Warfare Systems Engineer

In the 1970s the CSIR was requested to design a Radar Warning Receiver to protect South African Air Force aircraft from Soviet Union-supplied surface-to-air missiles and fighters. In response, the CSIR designed the Radar Warning Receiver III, one of the first of its kind in Africa.

The system consisted of a four channel (spiral receiving antennas) 500 MHz to 18 GHz, crystal detection receiver. Two extra channels were later added to enable the detection of the Spoon Rest radars A and B, these worked in the 80 MHz and 150 to 170 MHz region. The channels were received by two large omnidirectional antennas that were fitted in the existing wooden section of the Canberra aircraft's tail. The display had eight lamps to indicate the direction of the radar detected. To reduce radar signals being heard on the intercom, each sector had a push button to disable the radar's sounds from that sector. An audio recorder captured the necessary intelligence of all the intercepts.

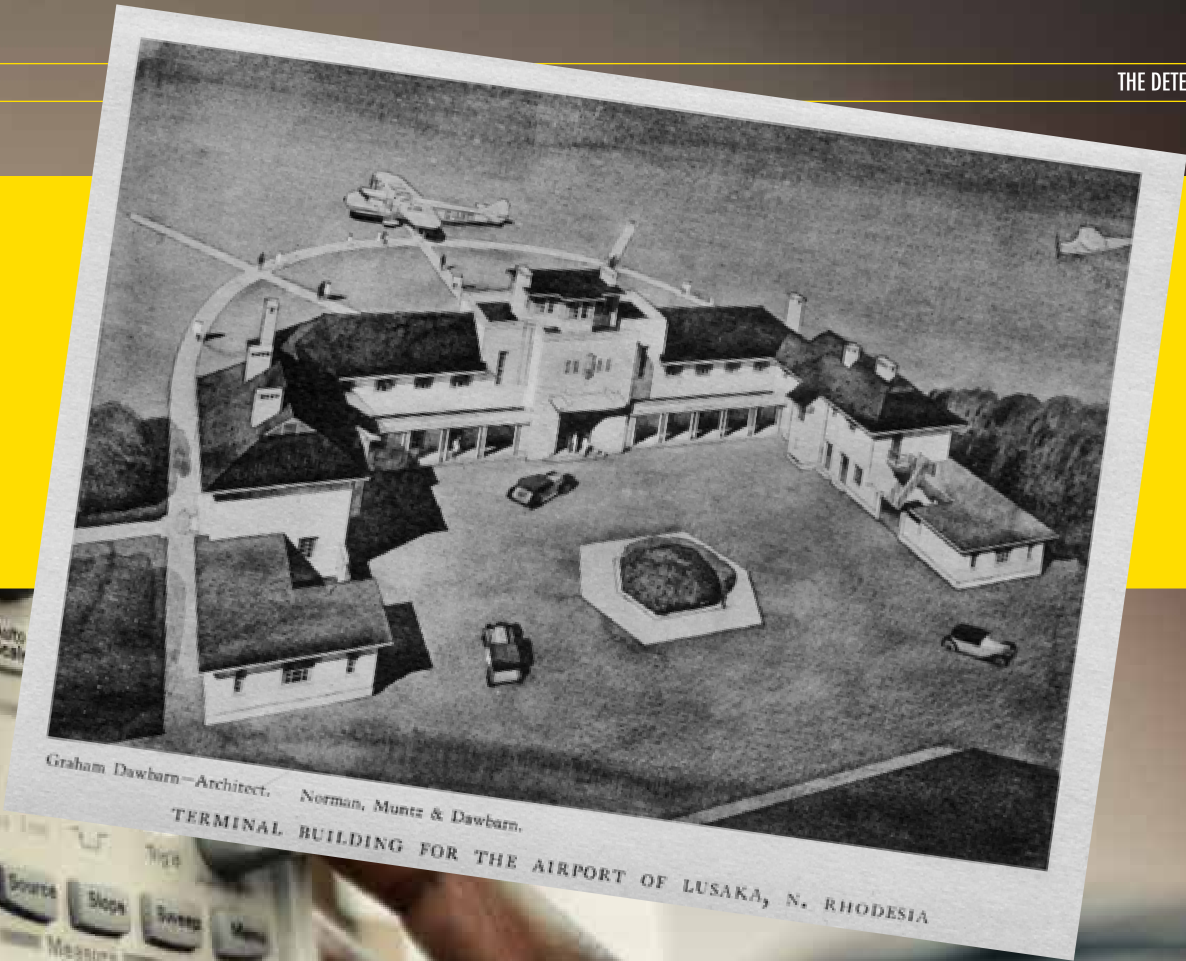
During that time all the known radars' detection parameters were defined, and as test flights were conducted, the system proved to work exceptionally well.

However, one specific radar being used at Lusaka Airport in Zambia remained unknown. To detect and define that radar, permission was given by Rhodesia (now Zimbabwe) to fly to the Kariba Dam, about 150 km south of Lusaka. The mission proved unsuccessful as the team was unable to detect the radar at Lusaka. A brave pilot then decided to risk flying closer to Lusaka at 45 000 feet, which is above the maximum height of Zambia's Rapier missiles. This too was unsuccessful as they still could not detect the illusive radar. The next day intelligence sources reported that the reason they could not detect the radar was because it was unserviceable and in the process of being repaired. The South African Air Force then used the opportunity to conduct photo reconnaissance missions with the knowledge that there was no search radar working. The team remained hopeful that when the radar was switched on again, they would be able to detect it.

In 1975 South Africans saw television broadcasting in their homes for the first time. One evening a news broadcast aired an interview with a politician at Lusaka Airport. Radar researchers watching recognised the familiar 'buzz' of a search radar interfering with the audio recorder. This sound was promptly recorded on an audio recorder when the news broadcast was later repeated. The recording was then analysed on a specialised computer system used to control a vibration test station. This computer was able to run a Fast Fourier Transform that determined the Pulse Repetition Interval and scanning pattern of the radar. This provided enough information to establish the make, model and manufacturer of the radar. The unfortunate politician remained unaware of the fact that he unknowingly shared state secrets while being interviewed and never knew the secrets he was giving away that night.

South African electronic warfare researchers celebrated their first victory through the electromagnetic spectrum. A lot has changed since 1970 with technological advances in the electronic warfare environment being achieved every year. The CSIR radar and electronic warfare teams continue to push R&D boundaries through collaboration, innovation and excellence.

RWR3's electronic box and display as fitted to the Canberra.


Graham Dawbarn—Architect. Norman, Muntz & Dawbarn.
TERMINAL BUILDING FOR THE AIRPORT OF LUSAKA, N. RHODESIA

AEROSTATS – TAKING A SECOND LOOK

Article contributed by Francois Anderson, a CSIR Chief Radar and Electronic Warfare Systems Engineer

Criminals and adversaries are well versed in avoiding detection. They know, for example, to operate at night or in poor visibility, fly low using small aircraft or sail out from deserted beaches or small harbours to big ships using small inflatable boats. Even the most sophisticated wide area sensor systems will have a hard time finding them when they operate among similar, non-threatening entities and at some unknown location along South Africa's 4 471 km of land border line, 2 798 km of maritime border line and the air border extending 7 660 km over both of these.

The CSIR started its AwareNet programme in 2004 in response to the border safeguarding requirements formulated by the Joint Operations Division of the South African National Defence Force, the South African Army, South African Navy and South African Air Force, as well as other members of the Justice, Crime Prevention and Security Cluster of government. The programme aims to develop technology required for much improved situation awareness over vast areas to increase the efficiency and reduce the costs of these stakeholders' operations.

The AwareNet programme has been looking into the use of advanced, integrated sensor systems, including Doppler processing radars and multispectral cameras to detect and track surface and low level air targets-of-interest and separate them from targets-not-of-interest using a range of non-cooperative target classification and threat estimation techniques. To obtain continuous low level coverage over undulating terrain and to ranges beyond the normal radar horizon, such sensors need to be based on high ground, or in areas without access to appropriate mountains, on airborne platforms.

The CSIR AwareNet team became aware of the increasing use of modern Aerostats in security and 4th-generation warfare operations. For example, the United States and Britain used them extensively in Irak and Afghanistan to provide situational awareness and targeting information to commanders. The team included an investigation into the possibility of utilising aerostats and air ships as low-cost, long-endurance airborne sensor platforms into the AwareNet programme.

Aerostats are lighter-than-air aerial platforms using helium or hydrogen as a lifting gas. Medium size aerostats can remain airborne at heights up to 1 500 m above the ground for periods up to 30 days at a time while carrying payload masses in the 300 kg to 500 kg range, thanks to a combination of buoyancy and lift generated by an aerodynamically shaped body. This enables them to remain within 13 degrees of the vertical above the mooring platform, even in winds as high as 130 km/h. Aerostats are stabilised by tailfins and tethered to the surface with a composite tether that not only anchors the aerostat to its mooring platform, but also provides fibre-optic communications links to its payload, three-phase power and an earth conductor for lightning protection and the prevention of static electricity build-up.

Aerostats and air ships have been in use as observation platforms since the French Revolution, including during the United States Civil War, the 1899 South African War, as well as during both the first and second world wars. However, a number of well published accidents including the Hindenburg disaster, the tremendous surge in heavier-than-air aircraft development, and successes in air defence weapon systems during the Cold War period resulted in the phasing out of most aerostats and airships during the latter half of the 20th century.

Over the past two decades the need for long endurance airborne platforms with much lower operating costs than fixed wing aircraft, helicopters and even unmanned aerial vehicles have seen aerostats regaining prominence in 4th-generation warfare, counter-insurgency, counter-terrorism and border safeguarding operations. Improved aerostat envelope and tether materials combined with better lighting protection, more stable aerodynamic designs and enhanced standard operating procedures have dramatically reduced the risks involved in deploying and operating aerostats.

The USA, UK, Brazil, Russia and China, among others, currently own operational aerostat systems and have deployed them to provide situation awareness along land and coastal borderlines, near forward operations bases and to help guard assets including national strategic installations such as power stations, oil platforms, dams, and harbours as well as targets for terrorists such as high visibility events at stadiums and convention centres. Ship-based aerostats flying at 1 500 m above the surface and providing up to 70 000 km² coverage of the sea surface around a ship can dramatically increase the efficiency of a maritime patrol vessel.

Aerostats are particularly well suited for ship-based operations as the air over the sea is usually quite stable and provides for easy flying conditions. They can operate in up to 130 km/h winds which even allows for operations from fast-moving vessels. Aerostats can be deployed from a helicopter flight deck on a ship and then be tethered to another area of the ship to allow helicopter operations to continue while the aerostat is flying.

Potential advantages of Aerostat-borne radars

Airborne radars operating from aerostat platforms are being developed internationally to detect low-flying aircraft and cruise missiles as well as micro-light aircraft and helicopters over both land and sea. Some are designed as gap fillers for ground-based air defences and for airspace control radars. Others are designed to safeguard maritime economic exclusion zones from the coast to ranges that would be over-the-horizon for a normal coastal radar network. Increasingly, aerostat radars are also being used to help safeguard land borders against illegal immigrants, smugglers, traffickers and terrorists.

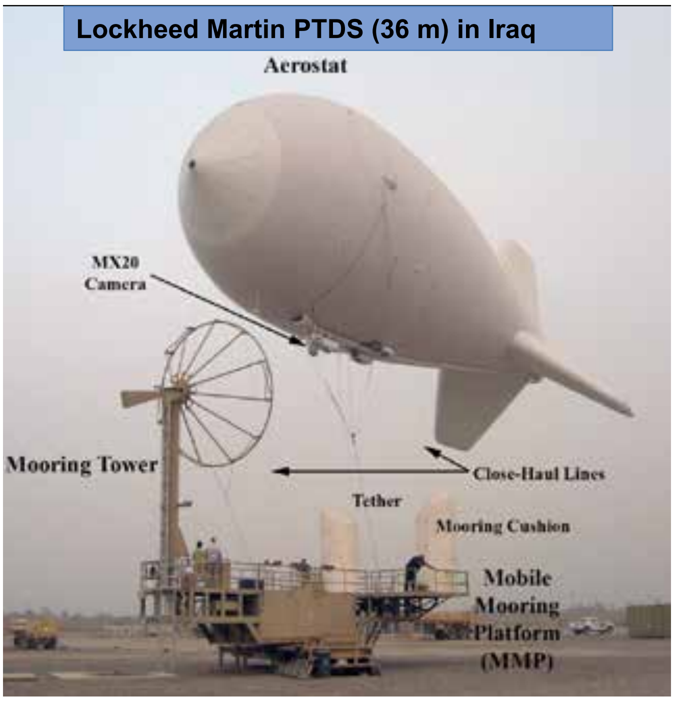
Aerostat-borne radars share many of the advantages of radars on surveillance aircraft and satellites. These include the much-increased ranges to the radar horizon, the reduced height of the null caused at low elevation angles by reflections off the surface and greatly reduced effects of terrain shadowing. However, unlike aircraft- and satellite-borne radars, an aerostat-borne radar is virtually stationary relative to the terrain below it. This allows more persistent surveillance over large areas than is possible with aircraft-based radars. Relative to satellite radars, the higher update rates (seconds, rather than days) and higher sensitivity as required to detect small targets, are some of the advantages. In addition, also because they are relatively stationary above the terrain below it, aerostat-borne radars can achieve superior suppression of interfering echoes from the terrain and detect targets at very low speeds while using relatively low-cost radar antennas and signal processing techniques. Integrating avionics on an aerostat is also easier and much less costly than doing so on normal aircraft.

Modern aerostats in South Africa

Aerostats of the sizes and flying heights required for the operations described above have not yet been flown in South Africa. As a result, it is not known to what extent environmental and logistical issues may affect the availability of systems based on them. The potential described above had not yet been verified by means of tests conducted under South African conditions and against current threats. Acquisition project teams for wide area surveillance and communications projects in South Africa have therefore been hesitant to include aerostat-based systems as part of their solution options.

The CSIR in its role as science and technology partner of the departments of Science and Technology and Defence is currently planning an aerostat evaluation programme. This is planned to continue for two years from early 2017. It includes the development of the required capability to deploy and fly aerostats safely and in South Africa legally. It also includes experiments to measure their movements and determine the performance of sensors and communications systems integrated on them. The project targets six locations in the South African maritime, land and air border areas as well as in a wildlife park.

If this programme proves successful, aerostats and the specialised sensors and communications developed to exploit their unique characteristics could become important and relatively affordable force multipliers for peace support and crime fighting operations in South Africa and in sub-Saharan Africa.



INUNDU

Inundu is an isiZulu word for tiger moth – an insect that uses clicking sounds to disrupt and confuse the finely tuned echolocation ability of bats, making it nature's own cunning 'acoustic warfare expert'. It is therefore a fitting monicker for a smart radar deception capability.

Channeling the ingenious radar mimicry of the cunning tiger moth

The CSIR has developed an innovative airborne electronic warfare capability that allows any aircraft to mimic the radar signatures of other aircraft, either to test new radar technologies or to fool opposing radar systems. Fitted with an Inundu pod an aircraft can pose as any type of friend or foe aircraft, as an incoming missile or even as a squadron of aircraft, making it possible to test electronic warfare systems in-flight, to intimidate enemies or to pass by opposing forces undetected and unhindered.

The Inundu technology demonstrator pod was recently fitted onto Denel's Cheetah fighter jet for an important test flight as part of the trials for this exciting new technology.

Erlank Pienaar, Acting Executive Director at the CSIR unit for Defence, Peace, Safety and Security, views the recent successful test flight as a historical event.

"The platform will play a crucial role in our technology development effort in advanced electronic warfare, as well as in our efforts to support the growth and transformation of the local industry."

'Look mom, I'm a missile!'

The CSIR's Inundu pod can be viewed as a novel system for conducting airborne evaluation and testing of radar and electronic defence capabilities. The modular payload can be reconfigured for various research, development, test, evaluation and training scenarios. Inundu has the unique ability to perform experimentation and testing live, in the air.

"Apart from the obvious benefit of being able to easily fit a modular pod onto a plane and being able to fool enemy radar into thinking you are a friendly aircraft, Inundu has massive potential for the testing of new radar systems in real-life scenarios."

Radar and electronic warfare are critical elements of a defence capability. It requires specialist infrastructure to accurately measure and analyse targets and to test the effectiveness of countermeasures. While laboratory tests are useful indicators of a system's performance, the ultimate test of systems for aircraft, is in-flight performance validation.

"Imagine you want to test an electronic warfare system designed to confuse the tracking radar of a missile in order to divert the missile, as a countermeasure. With Inundu, an aircraft can make itself 'look' like a missile and the effectiveness of the new system to identify and disrupt a missile can be tested in-flight, live, without actually having to fire a real missile at the test bed."

The Inundu system is the product of a collaboration between aeronautical and radar and electronic warfare engineers at the CSIR – plus a team of partners from industry.

The pod is similar in look, size and mass to the BL-755 store, which was a popular choice on fighter aircraft. This means that many fast jet types such as the BAE Systems Hawk, Alpha Jet, Hawker Hunter, F-16, Tornado, F-4 Phantom and the Mirage III can carry the system without requiring a costly store integration programme.

The technical details

The radome in the front of the pod supports radio frequency transmission and reception. Inundu underwent stringent weather and wind testing during 2015. By September of that year, it was ready for its first flight trials to evaluate the effect of fast-jet flight on the pod structure and to characterise its internal environment before the final electronics payload was added. The electronics payload was subsequently flown and successfully demonstrated at the 2015 Paardefontein deployment that coincided with the Electronic Warfare South Africa conference.

Over the past few months, the focus has been on developing a ram-air turbine that allows the pod to generate its own power, independently of the parent aircraft. This upgrade will greatly facilitate aircraft integration.

The main use of Inundu will be to evaluate the effectiveness of electronic warfare interventions. It also allows engineers to experiment with different electronic warfare techniques and is an excellent platform for the training of young electronic engineers.

Inundu has become a mechanism for the establishment of much needed small enterprises in the radar and electronic warfare sector. Through the establishment of a Defence Transformative Enterprise Development Programme, the CSIR and the Department of Defence are using this opportunity to transfer technology to a set of small, medium and micro enterprises (SMMEs) and to train their engineering base.

The Inundu pod interfaces with a base station via a telemetry link for in-flight control. The pod's on-board equipment includes an inertial measurement unit used for determining position and velocity in space and time, as well as a global positioning system, which enables scripted, waypoint programming of modes and techniques. This means that the pod can perform according to pre-established behaviour based on defined conditions. For example, the pod will automatically switch on at a certain distance from the target base stations and switch off at another predefined distance. All of this happens automatically.

Testing scenarios using Inundu can also be used to train electronic warfare and radar operators against airborne threats. Such exercises assist with operational support for doctrine development and optimisation, as well as acceptance testing of new systems.

The payload is temperature controlled and isolated from shock and vibration. A platform-independent power supply is currently being developed. The simulator hardware in the pod is based on high-resolution digital radio frequency memory, radar signal processing, and data capturing and radio frequency technology developed by the CSIR.

Valuable training platform

As part of an industry development project that aims to allow engineers who own or are employed by SMMEs to work alongside seasoned CSIR engineers to further develop their skills, two engineers from Sovereignty Systems joined the CSIR team during the development of the Inundu pod. Yanga Tekane and Mcebisi Solilo gained valuable, practical knowledge in the radar and electronic warfare domain. The duo have started working with CSIR engineers to apply their skills by developing the Inundu's CSIR-designed ram air turbine, to serve as an energy source to replace the current battery-driven power pod.

Special focus is placed on developing the radar and electronic warfare sector in South Africa as it has been identified as a sovereign capability in the 2014 Defence Review. The CSIR aims to contribute to this capability by developing the country's intellectual and skills capital in the radar and electronic warfare domain.

All along the watchtower

The South African National Defence Force has an extensive and diverse border to protect from land, air and maritime threats. Radar and electronic warfare measures and counter-measures can provide armed forces with much needed information during safety and security operations along national borders. Technology such as the Inundu pod can significantly contribute to the training of operators and the development of technologies used in border safeguarding.

ADVANCING TOWARDS NEXT GENERATION RADAR:

NON-COOPERATIVE TARGET RECOGNITION

Since World War II radar has played an essential role in the detection of objects that pose possible threats to nations. This has proved to be immensely valuable. However, merely knowing that something is present and not being able to identify it, limits the ability to respond appropriately. In military operations the inability to correctly identify an object can be the source of significant problems that include fratricide, deception by decoys and acting on tracks originating from objects that are not of interest. In operations other than war, unidentified objects cause inefficiency or even failure in the policing of poaching, smuggling, piracy and terrorism.

As a result, radar-based non-cooperative target recognition has received widespread attention from researchers globally working in both the military and civilian environments. As a sensor, radar offers significant advantages through its long-range performance; the ability to operate in diverse weather conditions, and during the day or night.

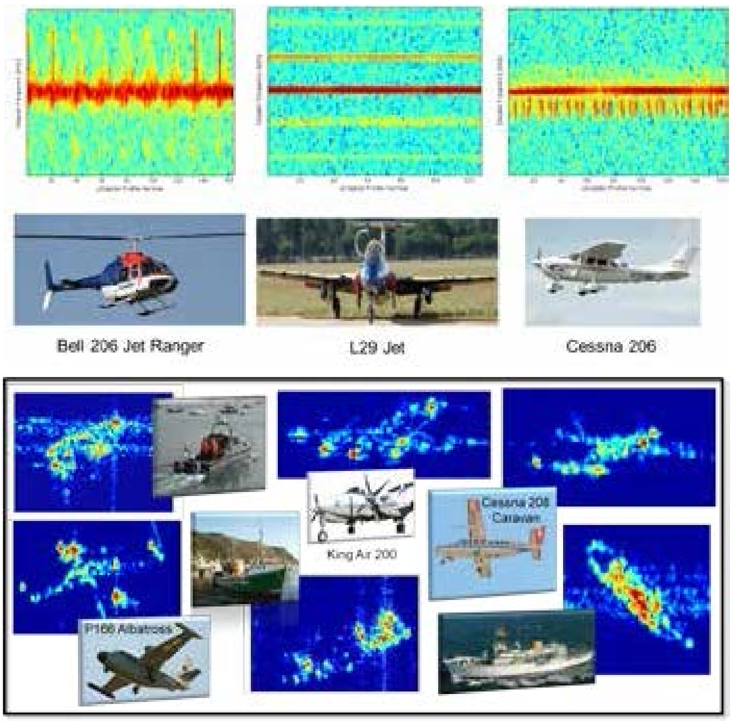
As a well-respected radar sensor research and development institution, the CSIR has developed technology that enables early information gathering for object identification. These radar target recognition techniques make use of information related to a target's physical characteristics, such as shape, length, width, or wingspan. These characteristics are measured using high-range resolution measurements, which when combined with a target's movement can be used to produce two-dimensional Inverse Synthetic Aperture Radar (ISAR) images. Other recognition technologies developed include micro-Doppler techniques that exploit information provided by the method of propulsion of a target, such as rotors, propellers, turbine blades, wheels, tracks, or limbs.

With the increasing threat of terrorists using drones as weapon delivery platforms, non-cooperative target recognition can contribute greatly to building defences against these threats.

Many of the smaller drones are specifically chosen by terrorists because they are difficult to detect visually. Radar systems able to detect objects that are small will also detect targets that are not of interest, such as birds. Detecting and tracking these targets places strain on data processing resources and makes it nearly impossible for a human operator monitoring the radar display to pay close attention to all of the information presented. Consequently, detections and tracks that are of interest may go unnoticed and unexamined, leaving areas to be protected exposed.

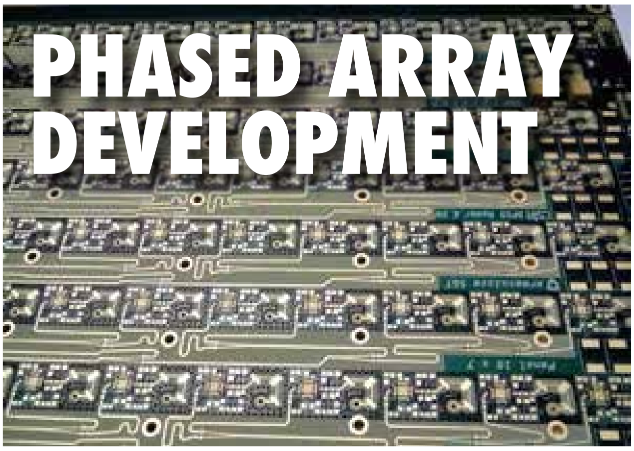
As threats reduce in size, radar recognition technology can assist by classifying detections as birds or UAVs, providing the operator with a more filtered, uncluttered view that allows focused attention on objects that are actually of interest.

The development of a target recognition capability at the CSIR started in 2001. Over more than a decade, the team has produced results and technology that have been increasingly recognised globally. This is evidenced by a number of local and international collaborations on the topic as well as tutorial presentations at IEEE Radar Conferences. Aided by the recent well-publicised advancements in machine learning, radar recognition is going to be a critical component in the new generation of intelligent radar systems. The CSIR has an established competence base from which to impact the development of these systems through partnerships with industry.



Radar target recognition signatures: (Top) ISAR images of aircraft and maritime vessels and (Bottom) Micro-Doppler modulation from different classes of aircraft.

PHASED ARRAY DEVELOPMENT



The CSIR recently developed affordable and cost-effective phased array radar technology. The innovative design allows for low-cost, steerable phased array transmit antennas. Coupled with multi-channel digitally beam-formed receive arrays using low-cost compact receivers developed in collaboration with Lochtron, these exciting technology developments will pave the way to reduced size, weight and power for next generation radar concept demonstrators and measurement facilities.

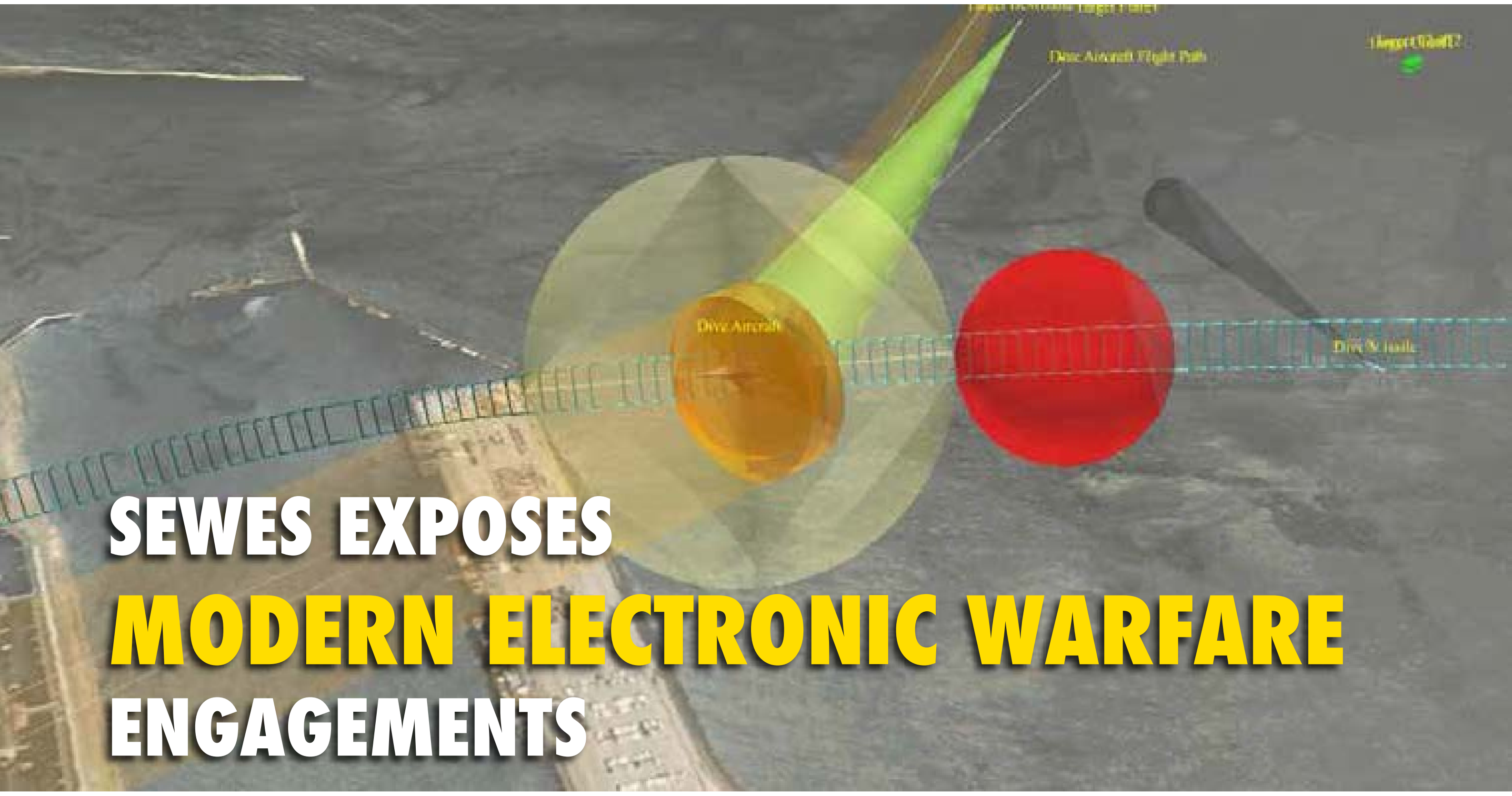
After 20 years

STILL THE PULSE OF NATIONAL RADAR CAPABILITY

Enigma 4 is a multi-channel electronic warfare simulation system used for target characterisation.

Information technology consists of two subsystems, namely the Radio Frequency Environment Simulator (RFES) and the Electronic Warfare System (EWS). The RFES has two channels that can be used to simulate two independent radars simultaneously. It is used to simulate moving target echoes with correct frequency, power modulation as well as accurate return time. The RFES can also receive the instantaneous target distance data and simulate a variety of different jamming modes. The EWS makes use of instantaneous frequency measurement technology that provides the system with an immediate situational awareness capability of the electromagnetic spectrum.

Users of the technology include the South African Air Force and Navy, local research institutes as well as international research institutes where the CSIR has the opportunity for skills and technology transfer and joint technology development. At the CSIR, such a system is used for ongoing research. The CSIR radar and EWS outputs are built to be used in combinations to establish robust, complex, integrated electronic defence platforms.



SEWES EXPOSES MODERN ELECTRONIC WARFARE ENGAGEMENTS

Fifteen years ago, the approach of 'know your enemy' was all a pilot needed on the battlefield. He or she had a ready plan of action for certain predictable outcomes, he even had a few minutes to implement new manoeuvres when challenged with unforeseen and life-threatening conditions. The complexities of modern radar and electronic warfare systems, coupled with an increasing number of unknown threats, however, presents significant challenges to the modern pilot.

SEWES (Sensors and Electronic Warfare Engagement Simulation) is a few-on-few electronic warfare simulation environment. Any number of platforms, consisting of any number of sensors and warfare simulation systems can engage each other in a simulated environment. The platform is used by defence research institutes for research and development and by defence contractors for system development and optimisation.

Developed in the early 2000s SEWES has proven itself to the extent that it is an internationally recognised electronic warfare engagement tool. It is a key capability in the radar and electronic warfare research groups within the CSIR, for a number of reasons.

It is pivotal in planning, training and effectiveness evaluation that ensures mission success. The simulated environment gives future buyers the opportunity to simulate systems of interest to predict performances, aiding in acquisition decision-making.

Modelling and simulation is the preferred scientific approach to developing computational models of the platforms or systems of interest. For instance, knowing how to respond to threats can be tackled by modelling the threat and simulating it against a model of one's own system.

The Matlab and Simulink environments provide an advantage in terms of rapid prototyping, readability and understandability of implemented models. The parameter level simulation of the systems and interactions are modelled to a detailed level. All relevant system parameters in the simulation can be displayed and stored while the engagement scenario is visualised in 3D.

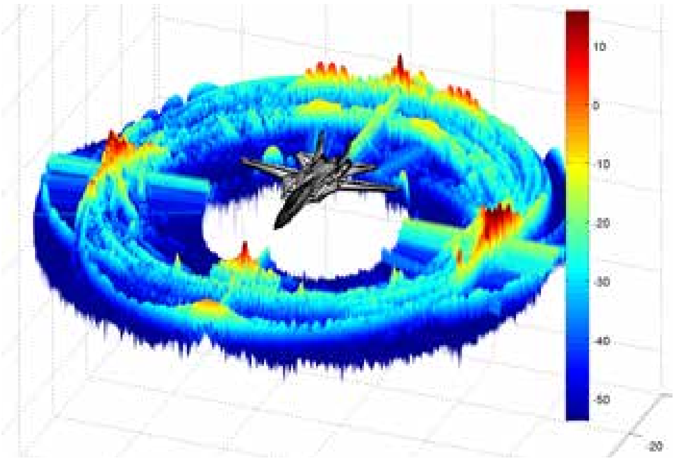
Architecture

The innovative architecture enables the user to easily modify the simulation to specific requirements and to interoperate with other simulations. It allows for a fully scalable distributed simulation in terms of the number of platforms in the simulation, the number of systems that can be added to the various platforms and the number of processing units in the cluster. Naval, air or ground platforms can be selected. Each platform has its own command and control function which manages all interactions between the various system models. It is also responsible for the logging and display of the timeline behaviour of the systems.

Visual dislay and management of the simulation enable quick and easy operation. Generated outputs are export ready and user-friendly for other applications as well as display and visualisation.

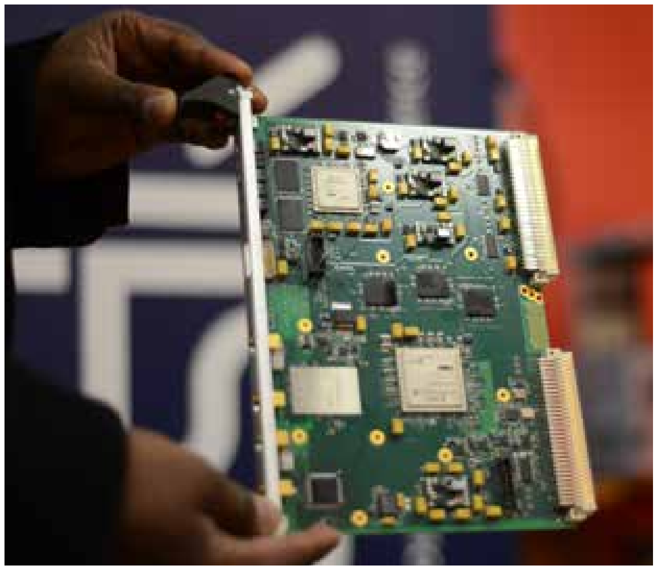
A plan of action should be established before entering the battlefield, due to the sophistication of present-day electronic warfare engagement environments. The ability to develop elaborative scenarios and evaluating key factors improves the protection of platforms, such as aircraft. SEWES offers fundamental system parameters that aid in the development of electronic warfare. The platform also provides information, such as the distance at which an aircraft is detectable, or how effective a particular jammer is against electronic counter measures. It is able to ensure the best performance of electronic warfare systems against unfamiliar threats.

With the strong modelling and simulation capability of SEWES, the survivability of pilots is enhanced.

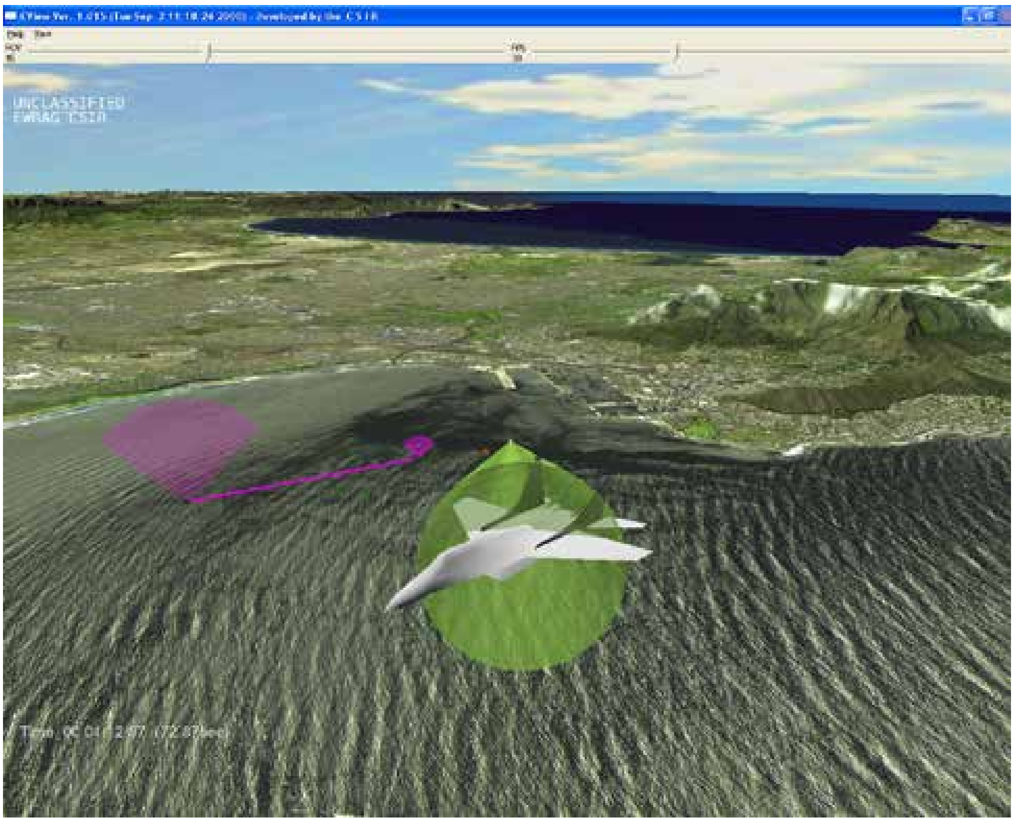


SigmaHat is a radar scattering prediction tool for large complex objects. It can provide estimates of the RCS of naval, air or ground platforms. In the integrated setup, platform-profile information from SEWES can be used by SigmaHat to calculate the RCS for all target aspect angles in a profile.

The RCS data are then used to extract dominant scattering points of the platform for each frame in the profile. The parameters of these scattering points are exported to SEWES, which integrates the data into the scenario simulation. SigmaHat's real-beam image shows the distribution of the platform's scattered field intensity, indicated as varying colour profiles. SigmaHat is based on innovative calculation techniques which provide a blend of scale, speed and accuracy, perfectly suited to radar and electronic warfare applications.



The digital radio frequency memory (DRFM) is the hardware closing the loop with the radar under test that responds in real time to radar signals. The DRFM records pulses received from the radar system, and then plays the recorded pulses back towards the radar, which now perceives these pulses as reflections from a target. Traditionally, DRFMs simulate targets as single point reflections with only one pulse played back per target. The latest module simulates targets as a collection of point scatterers. It is essentially multiple DRFMs in one. This DRFM represents a high standard of capabilities in high-speed mixed signal hardware, firmware and digital signal processing.



SEWES' visualisation and analysis tool depicting a ground platform with a tracking radar and surface-to-air missile against an airborne aircraft with jammer on board. The aircraft jammer responds by jamming the tracking radar, successfully evading the tank's surface-to-air missile. The detailed graphs display the power of the targets in the radar tracking gate allowing for in-depth analysis.

Passive radar research makes a comeback

Research in passive radar technology development is a joint effort between the CSIR, Armscor, the University of Cape Town and Peralex Electronics.

Passive radars do not transmit any signals, they only receive. They exploit illuminators of opportunity as their source of electromagnetic illumination, which means they receive signals that are already in the air. This is in contrast to active radars that do their own heavy lifting by emitting and receiving signals.

Passive radar architecture was the first step in the development of active radars, taking a backseat when active radar research became prominent. "Interest in passive radars experienced a recent resurgence due to the increasing congestion of the electromagnetic spectrum over the last decade," says Francois Maasdorp, a CSIR radar specialist.

Apart from being a low-cost alternative, passive radar systems offer other benefits as well. They are smaller and more mobile, a perfect fit for covert operations in both the military and civil domains.

As a result, radar R&D giants Lockheed Martin, Thales, Cassidian, BAE and Selex, as well as academic and research institutions are enthusiastically investing great effort into studying passive radar technology.

Passive radars are still seen as an emerging technology in the international radar community and are yet to gain market acceptance for industrialisation. A factor not on the side of industrialisation is the lack of the performance characteristics of such systems (over an extended period of time) as opposed to traditional active radars that are well characterised. To address this technology gap, the CSIR's radar and electronic warfare research groups are developing a national multi-static passive radar facility to gather sufficient data for the characterisation of the detection and tracking performance of a locally developed frequency modulation (FM) based passive radar. They aim to complete the performance characterisations (this includes varying weather conditions) in the next three years.

Knowledge gained could then be used to motivate passive radar technology as a reliable and cost-effective sensor to be used in situational awareness applications. Three possible applications may include air traffic control in areas where there is a lack of infrastructure (specifically in Africa), peacekeeping mission support and to fill the current gaps in active radar networks in the border safeguarding environment.

Established in 2011, the Paardefontein satellite radiometric calibration site was developed with Department of Science and Technology funding. Located far away from the ocean and other immediate sources of atmospheric aerosols (in northern Gauteng), it is perfectly suited for CalVal operations.

Optronic sensor systems

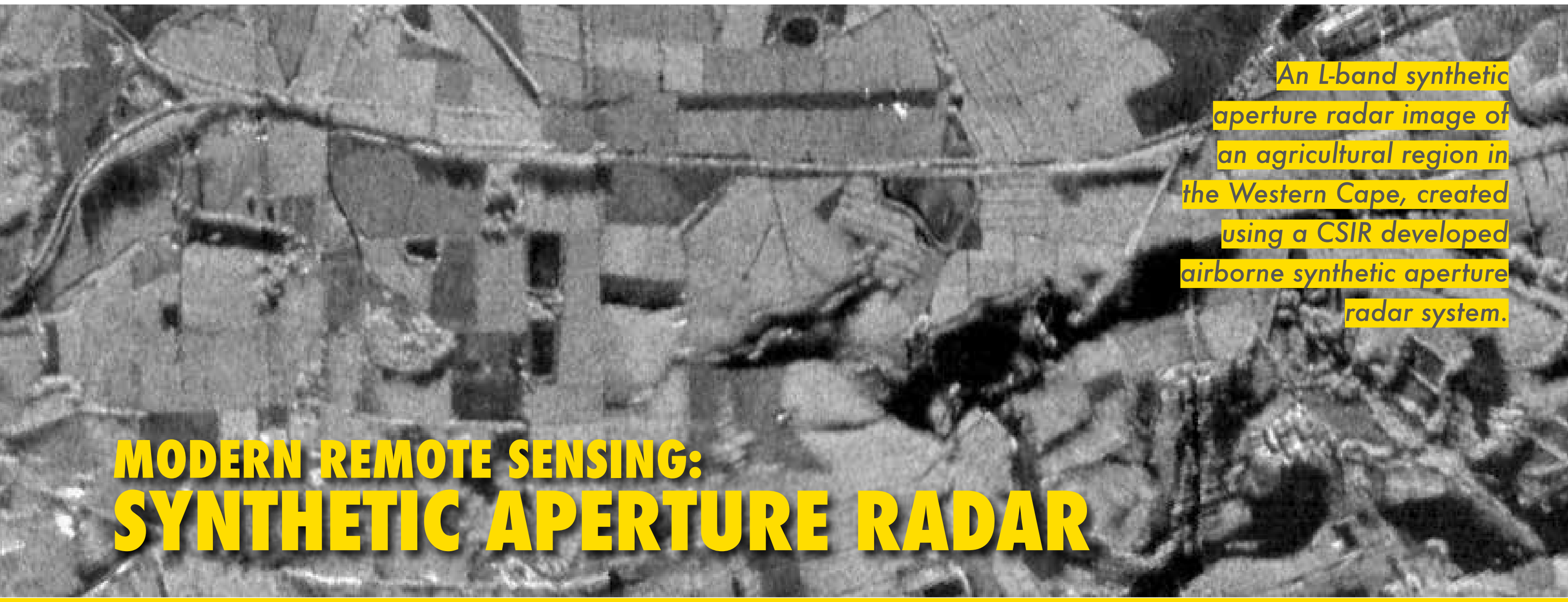
SATELLITE CALIBRATION AND VALIDATION

Space technology increasingly provides essential information for socio-economic areas, such as sustainable water, food security, biodiversity, logistics and renewable energy. Applications of satellite data will make key contributions to innovative services and significantly improve the international market position of these sectors. When the provision of data from space is guaranteed, many more smart applications can be developed.

Calibration and validation (CalVal) processes for earth observations form the foundation of quality data products, fit for purpose and trusted by the scientific user community.

Calibration is defined as the process of determining the quantitative response of a system or measuring instrument, to known and controlled inputs. It is the fundamental process by which an instrument is given the capability to perform measurements that are traceable to international standards, therefore giving credibility to measurements performed with the calibrated instrument. CalVal activities span the complete lifecycle of a satellite mission from conception through to de-orbiting or disposal.

The CSIR, in collaboration with the South African National Space Agency and other partners, has developed a first-of-its-kind capability in southern Africa to effectively perform CalVal operations for earth observation systems. The first South African satellite radiometric calibration field campaign using the Paardefontein site, took place in July 2014 for a two-week period. A resounding success, the campaign proved that the South African space community is a world leader in this field and should pave the way for the eventual establishment of a complete space capability in the country.



An L-band synthetic aperture radar image of an agricultural region in the Western Cape, created using a CSIR developed airborne synthetic aperture radar system.

MODERN REMOTE SENSING: SYNTHETIC APERTURE RADAR

Article contributed by Dr Jaco de Witt, CSIR Principal Radar Engineer

Synthetic aperture radar has been established globally as a key remote sensing technology with applications in both the military and civil domains. The CSIR has been using synthetic aperture radar imagery collected by foreign sensors in a variety of applications ranging from marine domain awareness to the mapping and monitoring of forested biomes. The CSIR is also developing synthetic aperture radar sensor technology aimed at manned and unmanned airborne platforms in order to exploit lower cost synthetic aperture imagery in selected applications.

Modern remote sensing has come a long way since the advent of photography by Joseph Nicéphore Niépce in the nineteenth century. Today, a multitude of highly advanced sensors are being used both on satellite and airborne platforms to enable the monitoring and understanding of our planet and the universe in which it exists. These sensors are not limited to only optical sensors and include both passive and active sensors operating within other regions of the electromagnetic frequency spectrum. All of these provide unique benefits for particular applications.

Synthetic aperture radar has been established as a key remote sensing technology for both civil and military applications, with an ever-increasing presence in the airborne and space-borne arena. This technology employs radio waves that are emitted from an antenna placed on a moving platform to form an image of the illuminated area. The end result resembles a grayscale aerial photograph (with some significant differences). As a remote sensing technology, synthetic aperture radar complements and offers substantial advantages over passive sensors, such as cameras or telescopes currently operating in the optical domain.

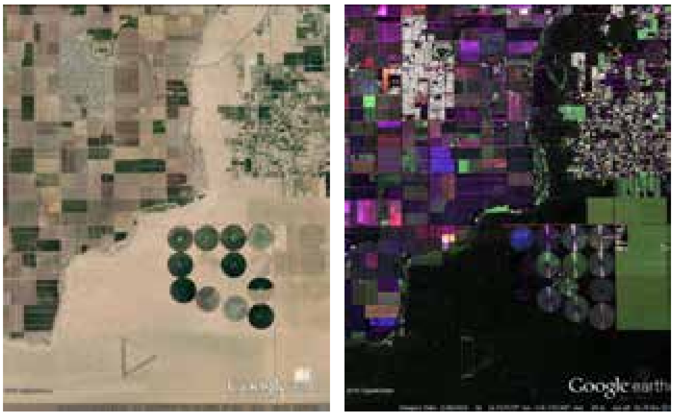
Synthetic aperture radar sensors are active sensors that transmit their own energy, comparable to an optical imaging sensor employing a powerful flashlight to illuminate an area of interest. This characteristic enables both day and night use.

The sensors are also unaffected by most weather phenomena because of the technology's typical operating frequencies. Cloud cover, mist or dust will however negatively affect optical systems.

Synthetic aperture radar imaging contains intensity information (strength of the received signal) as well as phase information (the specific position in the cycle of the waveform) for each pixel in the scene. This means that it is possible to detect changes between two images of a scene which may be as small as a fraction of the transmit signal wavelength (typically a few centimetres), even though the resolution of the image may be much coarser. This allows for example the detection of newly formed tyre tracks in sand or the detection of the cutting of vegetation in an area.

The number of possible synthetic aperture radar remote sensing applications are growing at a rapid rate, ranging from mapping, disaster management and precision agriculture, to military and security applications.

One of the most well-known applications of synthetic aperture radar is land-cover and land-use classification. This provides a description of the physical material that covers the surface of a particular area, for example, grasslands, forest, water or bare soil. In addition to standard features in the radar image that relate to shape or texture, land cover or land use applications may also analyse the polarisation information of each image pixel. This polarisation information reveals clues relating to the scattering mechanisms that



An optical (left) and synthetic aperture radar image (right) over Salton Trough, Mexico. The SAR image has the polarisation information of the scene embedded as false colour, providing a clear distinction between different crop types and growth stages, as well as man-made structures and the natural environment. Optical data courtesy of Google, UAVSAR data courtesy of NASA/JPL-Caltech.

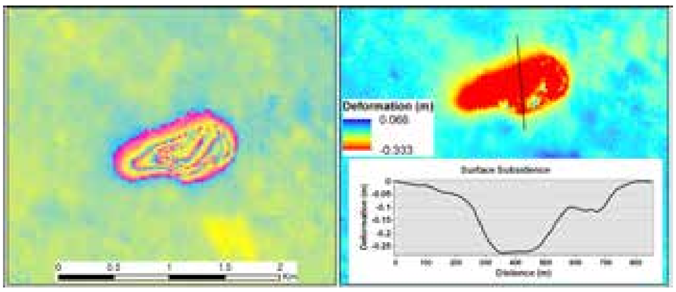
were responsible for the return, making it, for instance, possible to more clearly discern man-made objects such as buildings from trees, fields or crops in the natural environment.

Synthetic aperture radar images can also be used to generate digital terrain models by comparing the phase information from two images of the same scene recorded at different heights. If repeated over time, it is possible to construct a differential synthetic aperture radar interferogram able to detect small, centimetre-scale height changes in the areas of interest. This capability becomes extremely useful in applications concerned with monitoring subsidence, for instance in areas of mining activity.

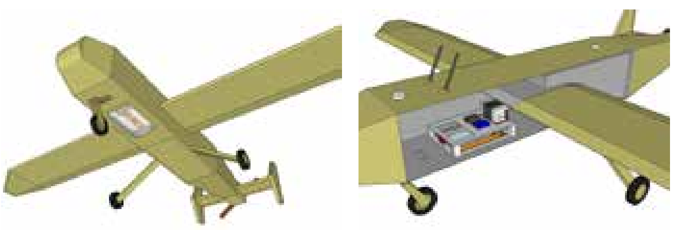
The CSIR makes use of synthetic aperture radar data collected by foreign sensors in various research and development activities, such as maritime domain awareness, surface subsidence monitoring (a downward shift of the earth's surface over time) in mining areas, and sink holes in urban areas. The CSIR is also exploiting data to map forested biomes in order to estimate woody biomass on a national scale.

In the marine environment, the CSIR uses synthetic aperture radar data to derive high-resolution ocean wind, wave and surface-current information to investigate physical processes in coastal and shelf regions. A three-year strategic research programme is currently focused on the combined use of synthetic aperture radar technology and optical systems to monitor key planning parameters in urban and peri-urban environments.

To unlock lower-cost exploitation of synthetic aperture radar imagery, the CSIR is developing airborne synthetic aperture radar sensor technology aimed at unmanned aerial vehicles and further down the line, satellites. This local sensor, image formation and application capability will benefit local industry, academic institutions and various government departments, including the South African National Defence Force. Ultimately, the CSIR would like to apply synthetic aperture radar technology to improve the quality of life of people in South Africa and Africa.



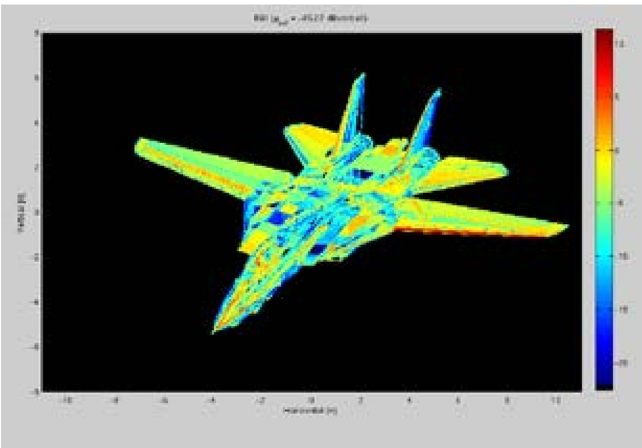
A differential synthetic aperture radar interferogram (left) generated by the CSIR shows an area undergoing surface subsidence due to shallow underground mining. The associated deformation map (right) reveals that almost 33 cm of deformation took place over the 46-day period.



A CSIR concept design for an X-band synthetic aperture radar sensor payload for an unmanned aerial vehicle, enabling left or right-looking imaging geometries.

***Remote sensing:* Extracting information from an object without making physical contact with it. In the context of this article, remote sensing refers to gathering information about the earth or our universe by means of sensors on-board aircraft and satellites.**

***Typical operating frequencies of synthetic aperture radar systems:* Most satellite-based Synthetic Aperture Radar systems operate at frequencies ranging between L-band (1-2 GHz) and X-band (8-12GHz), while airborne Synthetic Aperture Radar sensors may operate as low as VHF (30-300MHz)or as high as Ka-band (27-40 GHz), with extreme examples operating at even higher frequencies.**



An example of a standard output of SigmaHat, called a real beam image (RBI) shows the distribution of the platform's scattered field intensity, indicated as varying colour profiles.

BEYOND the radar:

Making the most of measurements

The advantage of radar cross section (RCS) measurement is that the output represents 'the real world'. Measurements are of actual, known platforms – be that a chopper or fighter aircraft; making use of purpose designed measurement Radar.

The downside? Firstly, measuring platforms is an expensive exercise. Also, the calibration of radar sensors is complicated and measuring a platform from all aspects can be problematic. It is difficult to get full coverage, including frequency, angle, resolutions, etc. In this process of flight measurement campaigns, the costs escalate quickly.

Enter the world of simulated reality. Creating a modelling and simulation environment enables greater control and flexibility because the software and model can be reconfigured. Modelling enables details investigation into dominant contributors to the RCS of a platform. (For example, investigating an aircraft with various payloads.)

This approach rules out many of the challenges of measurement – including making it easier to obtain extensive coverage in a cost effective way.

When it comes to targets, RCS provides signature data to evaluate detectability, classification and management performance of sensor systems, develop doctrine, specify or develop new radar sensors for specific targets – again with the benefit of ongoing testing and evaluation to ensure an optimal capability.

In this way, the true benefits of RCS data can be realised: The owner of platforms can better manage radar signatures and test detectability and classification by enemy sensors. This also means the ability to develop improved self-protection systems and amending doctrine. All of these can then again be tested and evaluated.

This does not imply the modelling solution is simple. It is critical to obtain highly accurate, electromagnetically representative CAD models of the platform and results need to be validated. With a suite of electromagnetic modelling tools – many of these self-designed – the CSIR has established a mature capability in platform modelling and RCS calculation.

This is the result of research in RCS conducted since the 1980s. Measurement facilities developed and employed by the CSIR include:

- Ground based dynamic RCS measurement facilities: Systems used to perform RCS in a number of operational, test and evaluation exercises, on acquisition decision support and to support several research programmes. Second generation facilities are also capable of performing high resolution RCS, evaluation of countermeasure (chaff and jammer), training on radar systems, acceptance testing and evaluation of electronic attack and platform protection systems.
- Ground based static turntable RCS measurement facility: Used in more controlled environment a RCS range is used to measure an airborne platform where the target is in the near field of the radar, and corrections for the distance is made, using sophisticated software.
- Airborne dynamic RCS measurement system: A modular radar system designed to be used for RCS measurements of objects from an airborne platform. The capability can be used to measure the RCS of large objects such as ships and record radar research data such as environment returns as recorded from an airborne platform.

Since 2008, the CSIR has actively been involved in the development of custom Radar signature calculation software. The tools originated from a specific requirement for generation of Radar signature data that could not be satisfied with the existing products on the market. The resultant software toolbox, named SigmaHat, is used for the calculation and analysis of the radar cross section (RCS) and other electromagnetic (EM) scattering features of objects of interest in radar and electronic warfare (EW) engineering. It is based on asymptotic (high frequency) EM calculation techniques and can be used to calculate and predict the RCS of electrically large complex 3D objects such as aircraft, land vehicles and ships. The innovative implementation of the calculation techniques provides a blend of scale, speed and accuracy, perfectly suited to radar and electronic warfare (EW) applications.

Building a stronger NATIONAL CYBER INTELLIGENCE NETWORK

Cyber attacks are on the increase in severity, complexity and frequency, negatively affecting citizens, government and businesses. Security and defence stakeholders in many developing countries are short of the required capacity and capability to adequately defend and protect the national cyberspace against fast moving and persistent threats and attacks.

Within the cyber domain, the various defence force roleplayers can no longer rely on traditional solutions to detect, defend and respond to the forever changing cyber threats and cyber attacks. In order to improve cybersecurity risks and strengthen the cyber resilience of the nation, strategic cybersecurity information sharing in the defence environment must take priority.

Threat intelligence

Threat intelligence is not a new phenomenon; it has been in existence ever since defence forces have sought for actionable intelligence information to give their army the upper hand, either in decision-making when weighing attack against evading or when information can be used to detect and prevent attacks.

Threat intelligence services analyses information about the intent, opportunity and capability of malicious actors. The challenge, however, lies in the collection, analysis and interpretation of raw data used in creating threat intelligence. Raw data can be difficult to understand, which makes basing an actionable decision on it complicated.

In order to combat fast-moving cyber threats, cyberattacks and cybercrimes, organisations need to have the most immediate threat intelligence information available. This is only possible if organisations have the ability to quickly gather, analyse and turn raw data from different sources into usable actionable threat intelligence essential to cyber defence. As cybersecurity challenges are multi-disciplinary by nature, no single organisation can address them on their own.

Partnerships in cyber defence

Stakeholders in the defence and security environment need to start sharing cybersecurity threat intelligence in an inherently collaborative manner that requires cooperation among members of the cybersecurity community. Since sharing of threat intelligence can also occur at strategic, tactical and operational levels, it is important that an appropriate sharing model is formulated and agreed upon by those involved.

The model needs to first focus on stakeholders' involved understanding of their operating environments; if an organisation does not understand its assets, infrastructure, personnel and business operations, it cannot understand if it is presenting opportunities to malicious actors. The information being shared among the stakeholders in the defence environment must also be at the level higher than cyber information, which is mostly useful in reactive operations (e.g. cyber incidents, observables, and indicators of compromise). The cybersecurity threat intelligence involved should be contextual and actionable, and enable proactive and predictive responses to cyberattacks and cybercrimes. It should be possible to provide operational information about threat actors, their campaigns, cyber behaviours, and their tools, techniques and procedures. This information shared between various stakeholders in the military environment could prove vital in threat intelligence.

Sharing lessons learned and cybersecurity best practices between allies will yield a resilient and better protected cyberspace.

The CSIR is currently in the process of the establishing a custom cyber threat intelligence platform for the exchange of threat information to support South Africa and other SADC countries. This platform will consist of several threat sources as well as the opportunity to anonymously add threats identified in participants networks. The threat intelligence platform will make it easier for South African organisations to proactively respond to cyber incidents and at the same time prevent cyber-attacks before they occur.

The Network Emulation and Simulation Laboratory can be accessed via the Internet or through a facility located at the CSIR Pretoria campus in South Africa's Gauteng province. The facility allows for the physical testing of IT security devices.

NETWORK EMULATION AND SIMULATION VIRTUAL LABORATORY FOR IT SECURITY TESTING

Information technology is ingrained in every aspect of modern life. However, the duality of cyberspace has been highlighted by daily criminal activities targeting not only organisations but also individuals.

The evolution of technology has given birth to two new concepts whereby these technologies will further advance cyberspace into the physical space of society: The Internet of Things (IoT) and Smart Cities. Both these technologies are in their infant phase and are inherently insecure for various reasons, including miss configuration and vulnerabilities in computer networks.

As a country's critical infrastructure can be exposed through the integration of IoT and Smart Cities implementations, the need exists to develop a platform to conduct various tests focusing on securing the implementations before deployment. Time and funding required to develop these mechanisms has proven costly and ineffective. One reason for this is attributed to the fact that the development of these mechanisms takes place in an environment that does not resemble the operational environment.

In response, the CSIR developed a Network Emulation and Simulation Laboratory that provides a platform for the high fidelity replication of existing or planned networks through a mixture of physical and virtual devices.

The platform caters for the design, development and deployment of cybersecurity processes and tools which resemble the production environment. These processes and tools test the concepts with the simulation of real-world legitimate traffic that includes malware, resulting in the identification of security vulnerabilities and ineffectiveness in computer networks. Therefore, the laboratory provides cybersecurity researchers with the ability to perform network bandwidth modelling, cybersecurity training, device research and advanced analytics to study cyber risks in an environment that mirrors reality.

This enables the delivery of tested, proven, effective and practical security solutions. The platform is ideal for use by researchers, including postgraduate students in cybersecurity as well as companies developing cybersecurity products.

Network Emulation Simulation Laboratory capabilities include:

- ***Configuration validation***
- ***Network performance and behaviour testing***
- ***Security and testing***
- ***User experience and training***
- ***Emulation of environments for advanced cybersecurity product research***

HACKING 101

Cyber defence expert Schalk Peach shares some insights about the hacking world.

Hacking is not a bad or dark art. It only really becomes something to fear when the hacker decides to exploit stolen information for personal gain or to advance an ideal. If you really feel that you have a knack for computers and computer systems, you should consider a career as a cyber defence expert. In my line of work I get access to some of the most technologically advanced network and security systems in the world. An added benefit is that I get to work for the good guys.

Hacker idealism has stolen the hearts and minds of many IT enthusiasts. Global headlines have named the practice as a formidable force when conventional methods of gaining access to information have failed. For example, the hacker group, Anonymous, has exposed corruption in multi-national organisations and governments it perceives as 'false' or corrupt.

Let us start at the very beginning, call it hacking 101. What is it?

Hacking is the art of gaining access to systems and information that is considered private. This may include personal data stored on home computers or sensitive information stored on secure network servers owned by massive organisations such as banks, government agencies or industries. The threat of hacking lies in the potential to exploit information gained for profit or political advancement.

In the wider term of the word, any person that modifies a component or exploits a process to gain access to features previously hidden can be considered a hacker.

How did you first come into contact with hacking?

Unfortunately, mine is not a unique story. The 1995 movie, Hackers, and its over-stylisation of hacking played a big part. That, coupled with my interest in computers, made following a career in all things cyber logical. I think I specifically became a cyber defence expert because my mom instilled a deep respect of the law in me. It will always outweigh any perceived reward illegal hacking may offer.

Stieg Larsson's The Girl with the Dragon Tattoo portrayed hackers as dark, mysterious individuals who simply cannot follow the rules. Is that, in your opinion, the average personality of a hacker?

The typical hacker has an inquisitive nature. They feel a need to know what information is being hidden and why it is hidden.

'The Mentor', a famous hacker who made a name for himself back in 1983, wrote an article titled 'The Conscience of a Hacker' shortly after he was arrested. In it he offered an interesting insight into the type of personality that would be drawn to hacking.

"I'm in junior high or high school. I've listened to teachers explain for the fifteenth time how to reduce a fraction. I understand it. "No, Ms Smith, I didn't show my work. I did it in my head…" Damn kid. Probably copied it. They're all alike."

Since its publication the article has been widely published and accepted by many as the hacker's manifesto.

Who is the most impressive hacker in your opinion?

The most formidable hackers in my mind are those who labour for passion and not for gain or notoriety. If the hacker's real identity is known he or she is definitely not formidable.

One of the most interesting hacking incidents I've come across is a group of Russian hardware hackers who are busy reverse engineering the original PlayStation's central processing unit to build a better emulation system.

The hacking group Anonymous has made headlines all over the world. A friend to value or foe to fear?

It really depends on who you are. If you are hiding information that can potentially expose you, especially in areas where you are endangering human rights, animal rights, are a danger to the environment or plan acts of terrorism, Anonymous is definitely not your friend. If, however, you abide by the law, you need not fear them directly. Their acts may indirectly affect you if they target a company they perceive to be 'evil' and gain access to your personal information.

SOCIAL MEDIA

A GATEWAY FOR CYBER WARFARE?

How to stay safe when using social media:

- Restrict the people who can view your profile by selecting the strongest parameters in the security settings on Facebook;
- Limit the amount of personal information available on social media platforms such as Facebook, Twitter and Instagram;
- Frequently monitor your Facebook security settings – Facebook is known to make regular changes; and
- Test that you are protected by using graph search on other profiles to check what personal information on your account is available to friends and strangers.

Arguably one of the greatest threats to personal, national and international security, cyber-conflict has also become part of modern-day warfare. The interconnection of communications systems in cyberspace is the backbone of the information exchange that integrates and synchronises national infrastructure in most countries in the world today. A backbone that is critical to the economy and national security of a country.

While there is great benefit from fast connectivity and vastly increased data storage space of Internet broadband, it has also increased exposure to the threat of cyber attacks – an attack that could delete personal wealth, disrupt economies, destroy critical infrastructure or affect military capability. Cyber weapons – mostly malicious software launched through computers – are being described as weapons of mass disruption for individuals in society, businesses, governments and countries alike. Originally designed for communication between researchers, the Internet has become a global tool with a proliferation of devices, from laptops to smartphones, connecting to it. This means that cyberspace – all the parts of the World Wide Web – has become virtually uncontrollable.

Social media has been widely adopted as part of everyday life in society. By using social media, users are meeting like-minded people, discussing ideas, making new friends and keeping up to date with trending news.

Cyber criminals have added social media to their arsenal, subsequently targeting innocent users with a wide variety of attacks. Many social media users are not aware of these attacks and do not understand how these platforms could be used against them.

Facebook's graph search

With over a billion active users, Facebook is one of the biggest social media sites in the world. It encourages friends and people with similar interests to share information such as messages, pictures, videos, website links and other digital media. With a large number of active users, Facebook upgraded its searching capability to enable a graph search. The feature allows users to search Facebook using queries phrased in simple English. When a query is executed, the results from the search can reveal personal information of friends as well as strangers.

The security threat dimensions violated by the graph search feature includes privacy, confidentiality and authentication that leaves the digital door open for identity theft, vandalism, harassment, stalking and spam.

Facebook's graph search could also be used for cyber warfare purposes. Terrorists and 'hacktivists' can use it to identify a targeted group of people with specialised criteria, such as location, interests, age and political views. The information could be used to recruit potential members for an organisation, or to plan attacks targeting a particular group. Conversely, government and law enforcement agencies could use the graph search to assist with crime and terrorism investigations by designing specialised queries to locate criminals.

Maritime research: THE BIG BLUE

AN INTRODUCTION TO
Defending our seas

With over 95% of South Africa's trade reliant on sea-borne trade, the freedom of the seas, the right of innocent passage and the protection of the trade routes for merchant shipping have made the maritime domain a fundamental matter of national security.

South Africa has one of the longest coastlines in Africa stretching for about 3 924 km at the high water line, with an exclusive economic zone exceeding 1.5 million km^2 of which the areas around Marion and Prince Edward Islands comprise 474 400 km^2. This implies that South Africa is obligated to control and enforce state authority over 4 340 000 km^2 of maritime territory. In this, it also requires strong inter-related linkages with neighbouring land-locked countries – especially in the Southern African Development Community (SADC) – also dependent on maritime trade for economic prosperity.

South Africa's dependence on maritime transport is a factor of its being an island economy: The bulk of the country's gross domestic product is generated through trade which is conducted via seaborne transport or merchant shipping. For example, 75% of oil importation – a critical economic resource – reaches South Africa from the Middle East via the sea. Not only a trade route, our oceans also underpin an important fishing industry and a wealth of natural resources (minerals, energy and marine life) requiring protection against irresponsible harvesting and poaching.

A considerable rise in piracy along Africa's coastline, has caused concern for the peace, security and stability of the continent and is seen as a direct threat against the international sea-lines of communication from the Americas and Europe to the Middle East and Asia.

The South African Defence Force has the responsibility to ensure the security of South Africa, its people, sovereignty, territory and national interests. This means having the ability to anticipate, deter, prevent, intervene and stabilise any potential threatening occurrences. Within our joint maritime defence capability involving surface, sub-surface and air dimensions, a major component of responsibility rests with the navy.

This requires a superior level of technological sophistication and being equipped to be responsive, effective and have the robustness to sustain a powerful marine security capability. For immediate urgent action, and for the longer term, robust technologies are critical – as is the means of providing an integrated maritime domain awareness capability. A combination of static and mobile platforms and sensors, off-shore and seaborne command and control mechanisms need to form part of this.

Once anticipated or detected, a surface combat capability is required to prevent, deter and counter conflict as well as surface and sub-surface threats. Typically, this capability is vested in Frigate-type vehicles and vessels. However, the challenge is that perpetrators use both conventional threats (missiles, guns, torpedoes, mines, etc.) as well as asymmetric threats, not only at sea, but also in the littorals and the confines of anchorages and harbours.

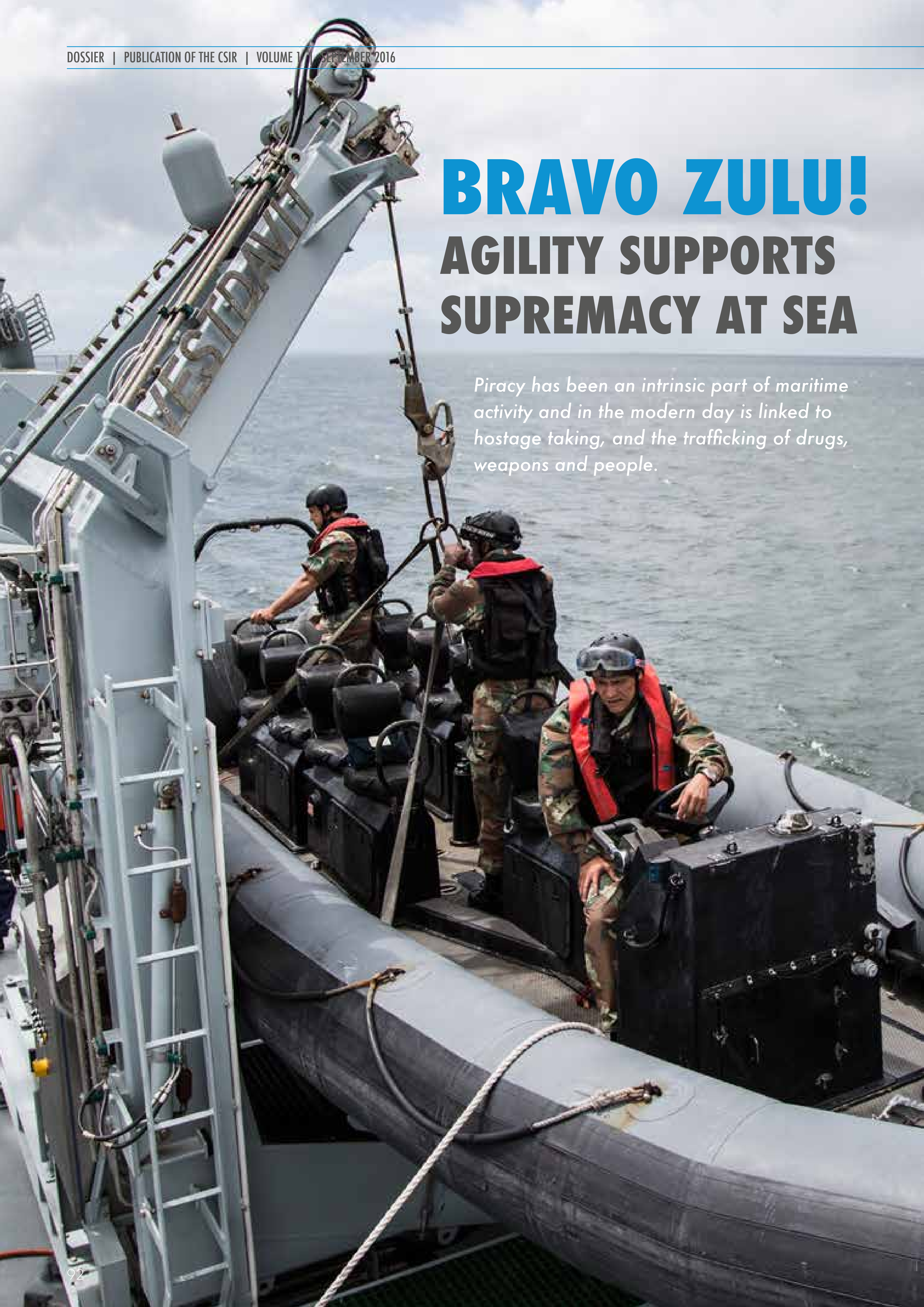
Detection technologies include radar for long and close-in detection from both ships and ashore. Oftentimes the targets are mainly small contacts, such as fishing boats used by abalone poachers. In addition, electro optics and infrared sensors provide the means to detect and also classify and evaluate the hostility of a threat.

Underwater, sonar technologies provide a means of detection. The electronic warfare domain has gone to sea as vessel acoustics, communications and electromagnetic signals fall prey to interception and analysis.

The question is not whether the required technologies exist and whether South Africa has the capability to engineer these into robust defence and security systems. The critical issue is the integration of various detection systems, interoperability in the extreme with the means to rapidly respond, deploy counter measures, launch operations to effectively deal with threats and sustain the combat. The commander needs a situational picture that is transferred between different command centres and deployed forces. This includes compatible data links and associated equipment that are able to transfer the situational picture to other users in real time. At present, the CSIR houses an active interoperability centre on behalf of the South African National Defence Force, which is continuously further developed as command and control needs evolve.

Even where technology solutions exist, time is the enemy and obsolescence and reliability become problematic. Research into upgrading technology to newer generations, enhanced sustainment and support to smart acquisition are some means of addressing this. Increasingly, ersatz tools are playing a role in preparing for real threats: simulation and modelling are affordable means of testing scenarios – for doctrine development, training and enhancing standard operating procedures, and are developed at ever increasing levels of complexity.

The CSIR has been involved in maritime security since South Africa required capabilities to project maritime force, and this force remains critical to maintain.



BRAVO ZULU!

AGILITY SUPPORTS SUPREMACY AT SEA

Piracy has been an intrinsic part of maritime activity and in the modern day is linked to hostage taking, and the trafficking of drugs, weapons and people.

Following an escalation in seaborne piracy along the East African coastline, the Cape of Good Hope has become a preferred option for shipping companies. This offers a multitude of benefits to South Africa's economy and its own import-based commodities and sectors. The challenge is to ensure the integrity of this maritime territory and assure shipping agents of the safety of the waters around the tip of Africa.

One component of counter piracy operations is the speed at which the navy can respond to suspected or reported maritime crime. If the majority patrol vessels in the fleet are frigates, options are limited.

Enter a simple solution...

Davit systems are used as cranes in the suspension or lowering of lifeboats. Turning such a system into a platform for rapid surface craft created a way to add faster force response than what frigates could manage.

CSIR maritime engineers were quick to devise a mobile system that could rapidly be fitted into an ISO container footprint mounted and adapted on the ship's deck. The system comprises a wave compensating hydraulic davit system mounted on a load vector compensating base. The base also houses the hydraulic drive system with its electronic and manual controls; stored energy to move the boat between the stowage point and the water; as well as the logistic support equipment needed for the boat. The davit system can accommodate boats of various hull shapes weighing up to five tons. The boats as well as crew can be lowered and retrieved safely by the davit system with the hosting ship underway. Two of these davit systems are normally fitted to a ship, with another two boats housed in the ships' boat bay on CSIR-developed cradle systems.

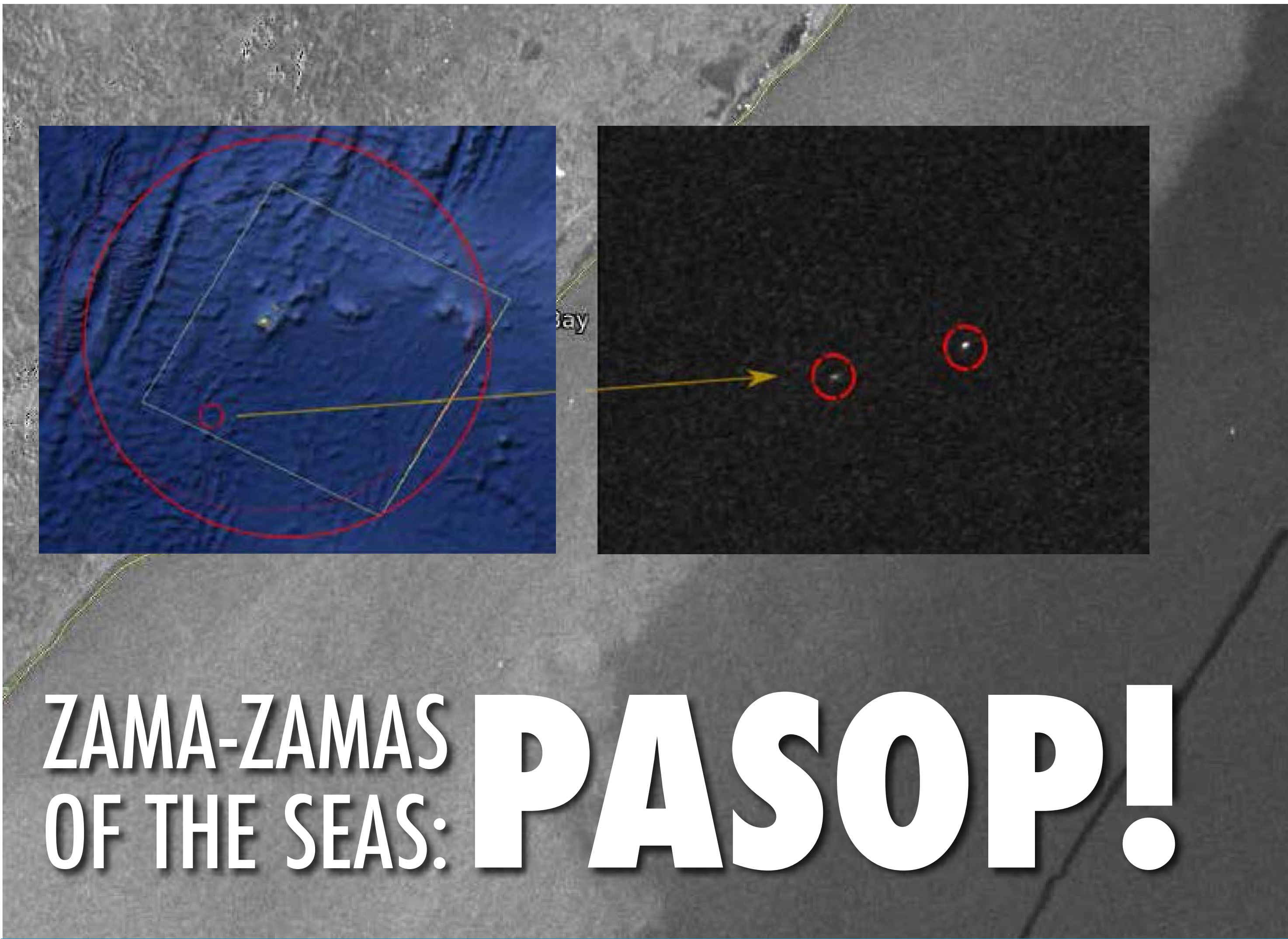
The system was put to stringent sea trials along the Cape Peninsula with various different boats from the Maritime Reaction Squadron, South African Special Forces as well as the South African Navy. During trials it was successfully used in an actual counter-piracy operation, earning the project team a Bravo Zulu from the commander – Navy-speak for a job well done.

Apart from successfully supporting integrated naval operations on the east coast of Africa, it also supports extended naval operations up the west coast of Africa, fulfilling the South African National Defence Force's mandated responsibilities within the SADC and African Union security environments.

The extended off-board capability further supports visit, board, search and seizure missions, interdiction, insertion and recovery over beaches, as well as augmenting search and rescue capabilities.

The hoisting systems have attracted international attention for licensing partnerships. It also creates business opportunities for small and medium enterprises in engineering and manufacturing to become part of the lucrative and fast growing ship building sector in South Africa.

With such technology as a building block to a highly mobile, integrated maritime capability, the South African Navy is in a stronger position to counter maritime threats, protect maritime assets, including natural resources, as well as the economic sea-lines of communication against multi-national crime syndicates and safeguarding the integrity of waters along the South African – and broader African – coasts.



ZAMA-ZAMAS OF THE SEAS: PASOP!

A technology to monitor large-scale illegal fishing in South Africa's exclusive economic zone

South Africa's coastline and beyond is teeming with all sorts of fish. And therein lies the problem. Our abundant fish are an allure to 'scaly' chancers of the deep.

Illegal fishing vessels lurk in the fringes of our exclusive economic zone. This is an area beyond our coastline mandated to us for our fishing and marine exploration activities.

The perpetrators turn off their transponders – a mandatory tracking signal transmitted to receivers mounted on satellites or onshore base stations – to hide their ignoble intentions. They lie in wait in the cold harsh sea, and for months on end if necessary. When the time is right; and they are sure they are not being watched, they slink into our exclusive economic zone.

They plunder our fish by the tons, make off with the loot, and cash in on their nefarious activities, always hiding in the vastness of the deep blue.

They are the Zama-zamas of the seas.

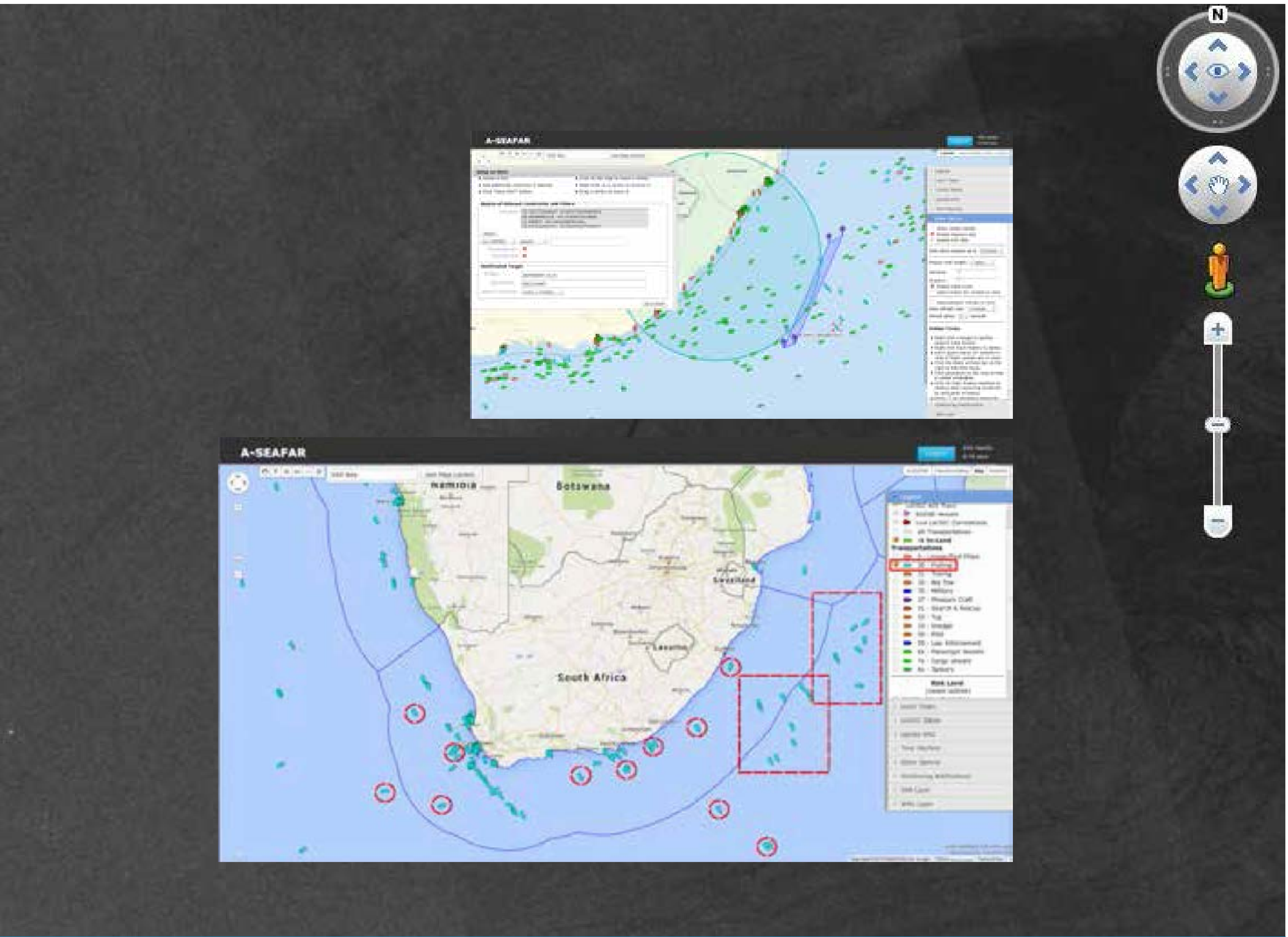
The panopticon in space – we are watching

Authorities cannot constantly be on the look-out for these poachers. It is near impossible to constantly police a 1.5 million km^2 area. To date, South Africa relies on catching these vessels in the act. However, with the help of technology from the CSIR, authorities can now anticipate with a high degree of certainty where illegal vessels will be, and police those areas. This is because the CSIR's technology is able to spot and identify vessels bent on theft by analysing their behaviour, says Dr Waldo Kleynhans, a research engineer. "We use satellite-based synthetic aperture radars to monitor the deep ocean in order to detect and identify vessels that exhibit suspicious behaviour," he states. "We are particularly looking for vessels that are where they are not supposed to be and whose transponders are off," he explains.

"These are large vessels that we are talking about, weighing over 300 tons. They are all legally mandated to have their transponders on," he says. "But if they are in a holding pattern just outside our exclusive economic zone or moving through our marine protected areas, with their transponders off, we know these vessels are up to something," he adds.

Chancers be warned

The CSIR has just completed a test case of the platform in Marion Island. "We observed Marion Island over a period six weeks. A satellite would



take images of the area, twice a week," says Kleynhans. "Image data were then fused with automatic information system data from transponders. We used our bespoke algorithms for detection and estimation," he adds. "Through this exercise, we managed to detect ten suspicious vessels within our exclusive economic zone."

The CSIR is already in talks with the South African Navy; the South African Maritime Safety Authority; the Department of Agriculture, Forestry and Fisheries; as well as the Department of Environmental Affairs to report the results of the Marion Island test and to further demonstrate the platform's effectiveness. "Our platform, dubbed SeaFAR, is an alerting tool that warns authorities about vessels moving through our exclusive economic zone and marine protected waters. We can also detect bilge dumps," he adds. Vessels sometimes dump their pollution or bilge in our exclusive economic zone as it is cheaper than pumping it out at their port of origin.

"Our aim is to show that suspicious vessels follow a pattern and can be found in specific areas within the exclusive economic zone at specific times because they are following the fish. With better data, authorities can police those areas and put plans in place to curb the illegal fishing of our marine resources," says Kleynhans.

Contributing to Operation Phakisa

"We are able to monitor the vast areas that form the exclusive economic zone in this manner," says Lee Annamalai, the competence area manager where SeaFAR is being developed. "If they sail into our territory again, we will be on to them," he states.

Annamalai is also the contract manager for the development of the Department of Environmental Affairs Oceans and Coasts Information Management System (OCIMS). The system is a component of the Phakisa Oceans Economy Programme and SeaFAR is one of the prioritised decision-support tools for OCIMS.

"We are exploring the export potential of the SeaFAR system. We already have an interest from several African coastal nations who are also combating illegal fishing in their exclusive economic zones."

NO PLACE TO HIDE

The SeaFAR system is able to detect vessels without Automatic Identification Systems – a genuine leap for South African maritime domain awareness monitoring. When used together with the CSIR-equipped wave glider, it will quickly become a significant cause for concern for those who exploit South African waters.

South Africa's exclusive economic zone extends beyond 1.5 million km^2. Over a third of that is the remote waters around Prince Edward Island in the Southern Ocean – a distinctly valuable stretch of ocean, rich in natural resources. As a fishing mecca, this area needs to be effectively managed to prevent overfishing and subsequent severe economic and ecological consequences, such as the extinction of fish species.

To safeguard an oceanic area of this size, the custodians require domain awareness, a proper understanding of the area's climate, ecosystem and weather conditions, as well as the ability to manage the much sought-after resources. Traditionally, this has been done via satellite coverage and ship-based monitoring, but this is hampered by excessive costs, manpower demands, and limited time-space presence.

A possible solution in the form of a wave glider – an autonomous marine vehicle carrying sensors – is currently under investigation by maritime domain awareness specialists at the CSIR.

Equipped with suitable sensors, it addresses key shortcomings of other technologies. A fleet of these marine robots can gather maritime domain awareness, as well as climatic data on a level that is unprecedented.

SeaFAR, another maritime awareness platform, is a CSIR-developed satellite-based surveillance system that makes use of synthetic aperture radar, optical satellites and satellite automatic identification systems using algorithms that detect vessels exhibiting suspicious behaviour to locate 'dark targets' on the ocean. These dark targets are typically vessels without the lawfully required Automatic Identification Systems (AIS). With increased poaching, smuggling and human trafficking infecting South Africa, the need to identify dark targets quickly and accurately is critical. When a dark target is detected, a vessel from the Department of Agriculture, Forestry and Fisheries or the South African Navy is tasked to intersect – a costly response to what can easily be a legitimate fishing boat with a faulty transponder.

A wave glider fitted with acoustic and optical sensors could offer an alternative solution as it would be able to positively identify a dark target at a fraction of the cost, while providing valuable ecosystem information at the same time.

The ecological data alone offer insight into governance, ecosystem management, and climate change challenges at a fraction of the cost of conventional methods.

The CSIR's wave gliders will be able to detect, identify and relay positional information of shipping activities to other CSIR-developed platforms for shared awareness, such as SeaFAR and Cmore. Information gained will offer decision support in command and control in the maritime environment.

Radar technology for the detection & tracking of small boats at sea

Radar is one of the only technologies capable of providing wide area surveillance over ranges in excess of 100 km, day and night and in poor visibility. Detection and tracking of maritime surface vessels has been an important research topic at the CSIR for the past number of years. This is a demanding problem as the radar returns from small boats are often comparable to radar returns from the sea surface itself.

In addition, the characteristics of the environment in which the surveillance radar must operate are continually changing, and the radar is required to adapt to this changing environment to maximise its detection and tracking performance.

During the development and evaluation of an effective radar target detector, signal models are required for both the small maritime vessels and the environment in which these vessels operate. These models should span the expected range of environment conditions, geometries, radar system parameters as well as target manoeuvres and radar cross section characteristics. It is important that the modelling and simulation results be verified through real-world measurements, at least at a number of critical samples in the multi-dimensional parameter space. Once results have been verified, trade-offs between various radar system design parameters, such as the radar operating frequency, dwell time and revisit time can be performed.

To verify a number of such models available from the literature, and to evaluate the performance of some proposed detection and tracking algorithms under realistic conditions, the CSIR conducted a number of measurement campaigns at various locations in South Africa. Three large campaigns specifically aimed at recording comprehensive datasets of the radar reflectivity from the sea surface and small maritime vessels were held in 2006, 2007 and 2010 at Overberg, near Arniston, on Signal Hill in Cape Town and in Simon's Town, respectively.

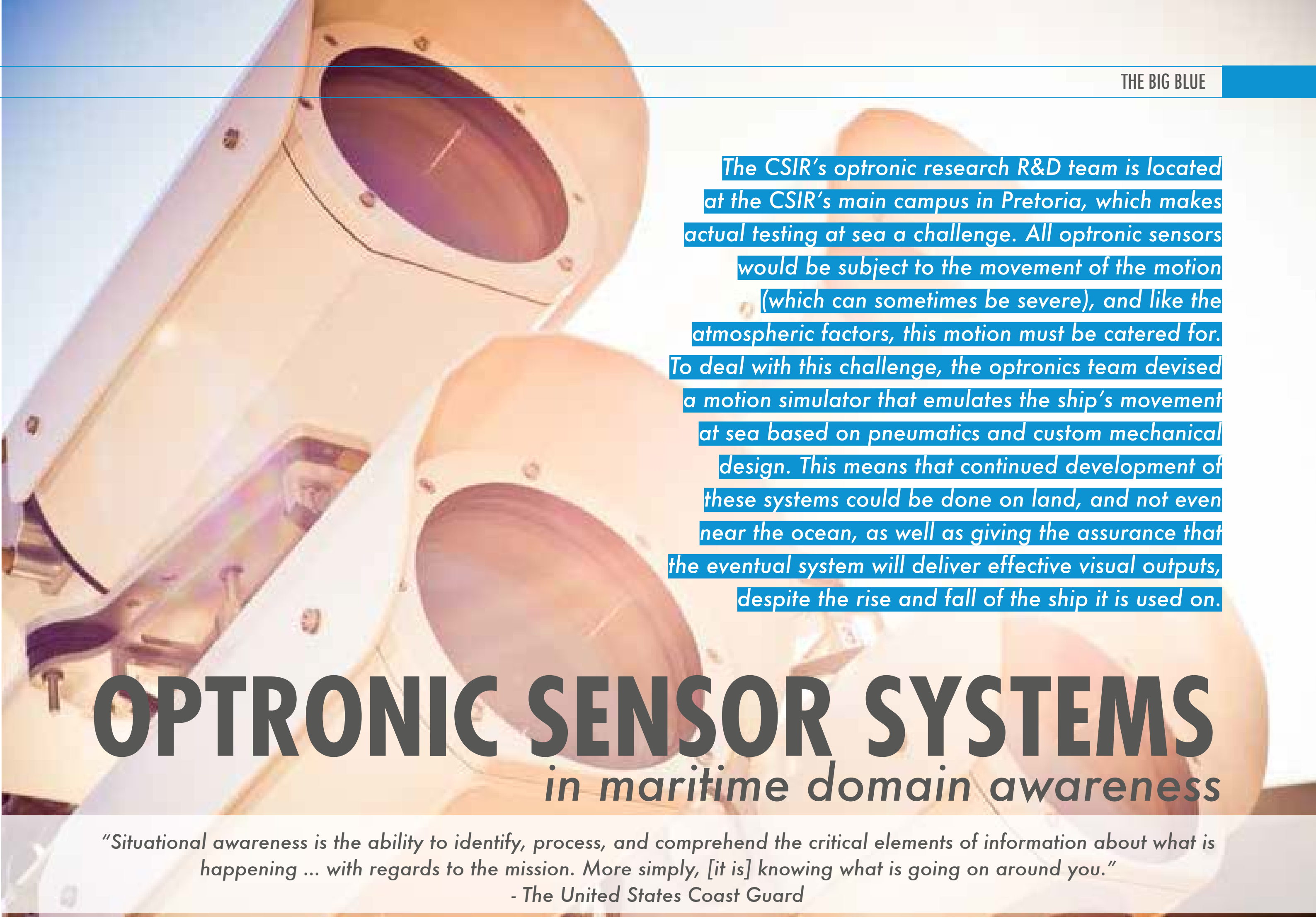
These measurements enabled the CSIR to develop a number of validated mathematical models of the amplitude, temporal and spatial statistics of the radar reflectivity of small boats as well as of sea clutter under conditions relevant to those that can be expected in some of the application domains of the AwareNet system in southern Africa. The datasets also enable the development and evaluation of detection and tracking algorithms on recorded data of a relevant environment. The detection algorithms were designed specifically to discern between the return from sea clutter and the return from other objects. These objects include targets of interest such as small boats, as well as objects not of interest such as birds. Detections that are deemed to be of interest (based on position, radial speed or amplitude, for example) may be extracted from the output of the detection algorithm whereby spurious and interfering signals are discarded. Tracks are then formed on the detections of interest. This tracking involves the association of detections with existing tracks or creating new tracks with detections that cannot be associated with any existing track, smoothing/filtering of all the tracks, estimating the speed and heading of the targets, predicting their future positions and calculating estimates of the errors in these estimates and predictions.

Following the suggestion of radar specialists in the United Kingdom who considered the recorded datasets to be some of the best of their kind in the world, the CSIR decided to make the data accessible via an online database at www.csir.co.za/small_boat_detection. This provides researchers from all over the world with much needed data to validate their models and algorithms, and creates opportunities for collaborative research.

The CSIR completed its first MATLAB-based technology demonstrator capable of the real-time detection and tracking of multiple radar targets in 2012. During the first phase of the development of this technology demonstrator, the focus was on developing the framework and algorithms required to detect and track maritime surface vessels only. The final objective is to be able to detect and track surface-based (land and sea) as well as airborne targets.

The future will see additional measurement campaigns and the continued exploitation of the recorded datasets to improve on existing models and algorithms.

The research focus will also include topics such as the simultaneous detection, tracking and classifying of targets, the feedback of tracking and classification information to detection algorithms and the enhancement of tracking algorithms when target classification information is also measured by the radar. The results of this research will be incorporated in future technology demonstrators.



The CSIR's optronic research R&D team is located at the CSIR's main campus in Pretoria, which makes actual testing at sea a challenge. All optronic sensors would be subject to the movement of the motion (which can sometimes be severe), and like the atmospheric factors, this motion must be catered for. To deal with this challenge, the optronics team devised a motion simulator that emulates the ship's movement at sea based on pneumatics and custom mechanical design. This means that continued development of these systems could be done on land, and not even near the ocean, as well as giving the assurance that the eventual system will deliver effective visual outputs, despite the rise and fall of the ship it is used on.

OPTRONIC SENSOR SYSTEMS

in maritime domain awareness

"Situational awareness is the ability to identify, process, and comprehend the critical elements of information about what is happening ... with regards to the mission. More simply, [it is] knowing what is going on around you."
- The United States Coast Guard

Not knowing what is going on around you in the maritime domain is akin to being blind, and in the military world this could mean the difference between life and death, winning the battle or suffering defeat.

To provide an effective situational awareness capability for the South African National Defence Force, as well as for any other stakeholder operating in the maritime domain, the CSIR undertakes R&D activities using radar systems, sensor technology and rapid response mechanisms to monitor or defend any oceanic terrain.

One specific area of interest is the use of optronics for improved surveillance at sea. This technology can act in a stand-alone capacity, or as part of a system of sensors that could include radar systems. The stand-alone capacity can, in turn, be composed of a variety of different sensor types (visual cameras, infrared cameras, night and/or day cameras) with the expertise required to integrate these technologies present within the CSIR. It is obvious that such systems need to be rugged, incorporate power and communications considerations and involve multiple elements of opto-mechatronics design.

Real-time, 360-degree surveillance is the 'golden chalice' in security; having that 'all seeing eye' to detect clearly what is happening in the full spectrum of your surrounds in order to respond rapidly and appropriately.

Optronic sensors offer an important complementary choice of surveillance to the generally used radar systems on ships. It is better able to detect even small objects, such as smaller wooden boats often used by poachers, against the highly cluttered background of waves and white caps. The CSIR's camera-based surveillance system consists of five high-resolution cameras (4000 x 1000 pixels at 20 frames per second), each capturing a section of the surrounds instantaneously. Footage is then 'stitched together' to create a real-time, 360-degree video-based view of the entire area surrounding a vessel. Calibration of these cameras is carried out using the CSIR's patented Automatic Photogrammetric Camera Calibration System.

Atmospheric factors play a role in affecting the quality of the image that the sensor 'sees'. These factors include atmospheric turbulence, mist or rain, and platform motion, for example when an optronic system is mounted on a ship in stormy weather. To this end, several algorithms have been developed by the CSIR's optronic experts for tone mapping, low light image enhancement, image de-warping, image stabilisation, motion de-blur and super resolution. The real-time implementation is achieved using multiple central processing units or graphics processing units. This capability is particularly useful when looking at real-time video during surveillance missions.

In the maritime domain, being able to see an object at a distance and to then ensure that the atmospheric effects are mitigated, are the initial steps in ensuring situational awareness is achieved. This capability is taken further by being able to detect a particular target of interest, track that target, as well as identify and classify it. For example, the commander of a maritime surveillance campaign would be able to positively identity a vessel as a pirate vessel and would then be able to track the movement of this threat. This can be carried out in real time, ensuring quick and sound decision-making.

A SIMULATOR

FOR SAFER LANDINGS ON VESSELS

The CSIR and Cybicom Atlas Defence have jointly developed a prototype helicopter simulator primarily to help the South African Navy with helicopter flight deck training.

A helicopter flight deck trainer was designed to provide training for flight deck controllers and marine helicopter pilots. It provides a safe, cost-effective solution to train personnel in a realistic and controlled environment. The flight deck trainer is a flexible, modular system that can be supplied in various levels, from a simple, portable, desktop trainer, to a multichannel, high-performance tracking system that can accommodate multiple trainees and provide a 360-degree, high-fidelity simulation with full-environment simulation.

"The success of this project illustrates the advantages of the collaboration between industry and the CSIR – the team operated as a single entity with a common purpose. Each role-player brought its own expertise to the project and the team was able to ensure seamless integration between hardware and software as well as between image generation, control software and highly realistic flight dynamics," says Dave Viljoen, Managing Director of Cybicom Atlas Defence.

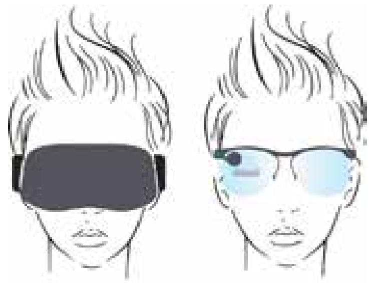
"The South African aerospace industry can only benefit from the introduction of Cybicom Atlas Defence as a new manufacturer of locally developed simulator products. We have also succeeded in replacing an imported component through the local manufacture of the display cladding and mounting," he says.

Cybicom Atlas Defence and the CSIR are also working towards industrialising the training system.

The product envisaged will be suitable for small-scale production and will cater to both the commercial and defence markets. This is being undertaken with the support of the Aerospace Industry Support Initiative (AISI). The AISI is an initiative of the Department of Trade and Industry hosted and managed within the CSIR.

The distributed simulation environment integrates three man-in-the-loop simulator stations:

- A helicopter flight simulator with a pilot interface that models the helicopter, the airflow over the deck and the ship interaction dynamics complete with an image-generation system that displays the external world view to the pilot.
- A ship bridge simulator that includes sea-state, rain and cloud-cover models with a bridge interface for the captain.
- A deck landing officer station.



AUGMENTED REALITY
not just for catching Pikachu

The recent Pokemon Go craze distracting the general geek population, brings to mind the defence applications of augmented reality.

Article contributed by Natalie Ausmeier, CSIR Image Processing Researcher.

Augmented reality allows developers (or commanders, in due time) to send sensory information, such as a video feed, to someone's viewer. This allows soldiers to see in the dark, around corners or through fog.

The CSIR's augmented reality researchers are investigating further training applications in a military, specifically naval, environment. Research is currently focused on developing platforms that will allow trainees to test their manoeuvring skills using a real water-borne vessel against virtual vessels. Using augmented reality in this way creates a safe training environment that is as close to the real thing as possible.

Training simulators using mixed reality

The world has seen significant developments in virtual reality technologies. The Oculus Rift and HTC Vive, once magical technologies found only on the silver screen, is suddenly on your son's Christmas wish-list. Developers have taken virtual reality even further by combining virtual worlds with the real world, creating a mixed reality, or an augmented reality. A world where real and virtual objects co-exist. Users are able to interact with virtual objects in real time. Imagine sitting in a virtual cockpit controlling an aircraft with real controls or driving a virtual car with a real steering wheel.

Augmented reality for situational awareness

Augmented reality allows developers (or commanders, in due time) to send sensory information, such as a video feed, to someone's viewer. This allows soldiers to see in the dark, around corners or through fog. Points of interest, waypoints or readings from wearables, such has heart monitors, can be overlaid on a semi-transparent display, allowing full awareness of the current surroundings – an enhanced reality.

Augmented reality out in the field, or not

Augmented reality applications are nearly limitless. By combining image recognition and augmented reality, experts or developers can assist technicians with dismantling and repairing complicated equipment in the field from anywhere in the world. The developer will be able to see the technician's view in real time, give verbal instructions, as well as draw and annotate directly into their view while wearing an augmented reality headset.

SONAR UNDERWATER MONITORING AND SURVEILLANCE

A recent development at the CSIR has been the work on an underwater, 3D imaging technology demonstrator. The current 3D array development includes extensive research into processing to enable a reduction of the array transducers and improved clarity of the image. Increased computing availability has now reduced the execution time to a few seconds of processing to allow faster image composition. The layout and wide bandwidth of transducers enable a virtual array of thousands of transducers to be created from just a small 32 x 64 array. Optimised electronics and processing platforms have also reduced the costs without losing functionality or resolution.

Instead of single-frequency 'pings', the broadband transducers use 'chirps', swept across a wide frequency band. The advanced processing enables the building of 3D pictures over a range in excess of 500 m. Sonar images cannot be accurately termed 'real-time' due to the time of flight delay of the acoustic signal, as determined by the speed of sound. However, the received signals are processed and displayed within seconds, still creating the 'realist' time acoustic picture of the sub-surface scene. The imaging is not restricted to only static features but the potential exists for moving targets to be resolved with speed and heading. Another advantage of the multi-frequency array is the image clarity whereby millimeter level resolution has been obtained compared to the more conventional tens of centimetres.

This brings a new dimension to object recognition and image perception.

The system, currently at technology readiness level six, is undergoing trials in dams and harbours. It is set to be exploited in numerous scenarios including national port and coastal security, detecting threats and navigational dangers, as well as sub-sea profiling from ships and Autonomous Underwater Vehicle Systems.

The research and development is at the cutting edge of developments in sonar imaging and the innovations are attracting interest from the international maritime environment.

Ultrasonic sensor manufacturing

The South African naval acquisition programme has used foreign-sourced sonar technologies for its frigates and submarines. Collaboration with international partners in the field of wet-end sonar transducers has facilitated local manufacture of these transducers, lowering the production and maintenance costs.

The specialised sonar transducer manufacturing and test facility has been accredited by European sonar institutions. This facility is capable of supporting the South African naval sonar systems as well as foreign navies with their maintenance and testing requirements. An additional capability of this facility is the ability to modify or redevelop legacy sonar transducers for clients.

Numerical models contribute to **safer fishing in False Bay**

By leveraging existing environmental and oceanographic numerical models and data, oceanographers have created an early-warning SMS system to provide three-hourly forecasts aimed at preventing drowning along the Western Cape coast.

"We no longer have to go to sea, over long distances and then decide that we will not fish due to the strong currents," says Charmaine Daniels who has been fishing for line and cray fish for the past 19 years.

The SMS Coastal Early Warning System combines climate, weather and ocean current and wave data sets to create detailed nine-hour, short-term forecasts of use to fishermen on small fishing vessels. Information includes current strength and direction; wave height, direction and frequency; as well as wind speed and direction.

The National Sea Rescue Institute advised CSIR researchers of the many drowning incidents involving swimmers and rock fishermen, who often knowingly take big risks when fishing on exposed rocky areas. The tool is designed for those individuals and small commercial fishing vessels that are particularly vulnerable to sudden worsening sea conditions. False Bay was chosen as a pilot site for the system because it has a thriving commercial fishing community. "We use the SMS information often, it is useful especially in our area where the weather changes very fast," says Daniels.

The CSIR has created a mathematical, numerical model that uses satellite and model data from the United States' National Center for Environmental Prediction as boundary conditions. It incorporates CSIR spatial varying wind forecasts and existing CSIR oceanographic models to create an accurate, holistic spatial wave and flow climate model for the entire False Bay area.

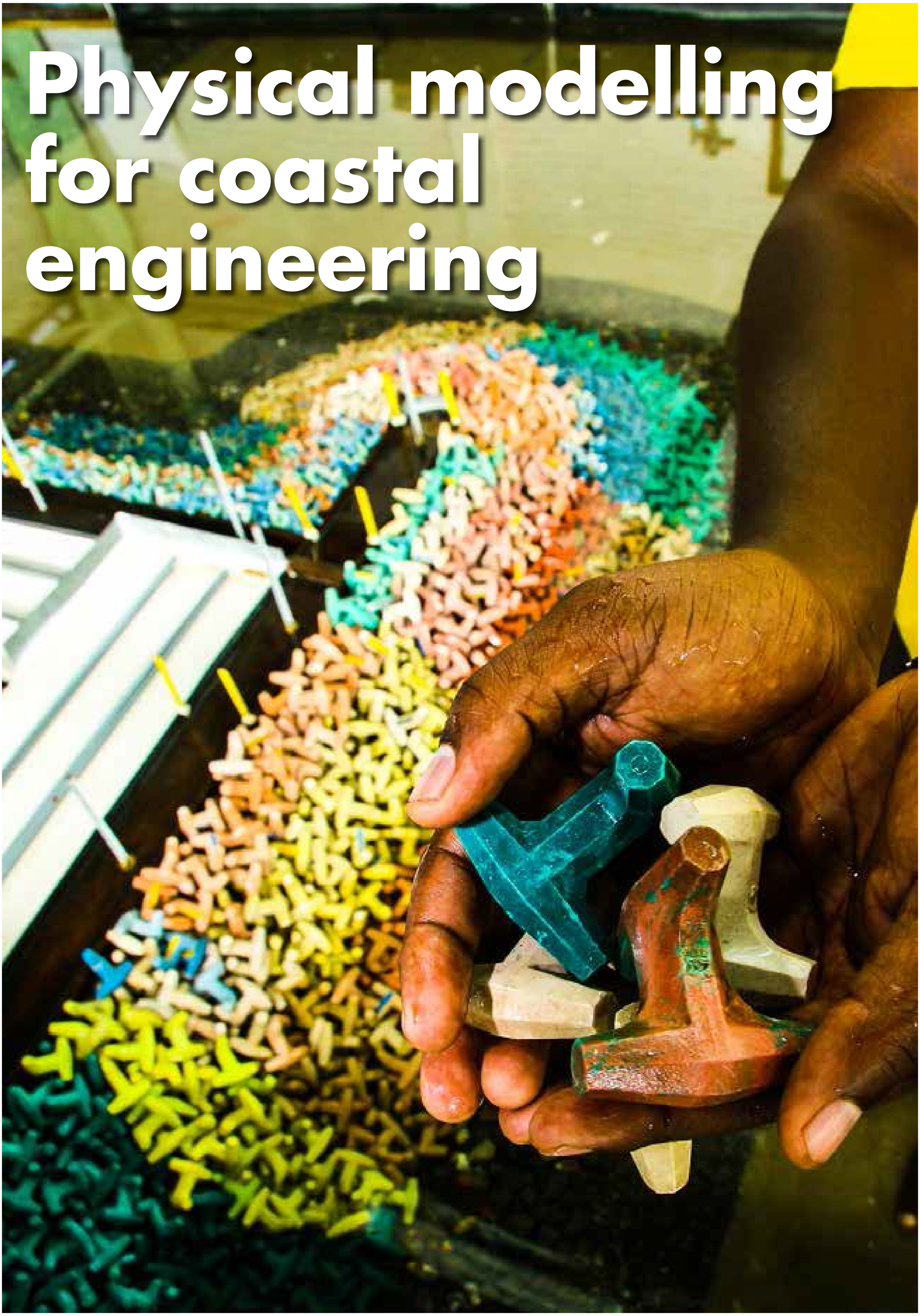
The model takes most abiotic environmental, weather and oceanographic data into account, is therefore quite comprehensive, and has so far proven to be reasonably reliable. New information on wave, current and wind measurements are received every three hours. Therefore, every three hours the model can provide a new nine-hour forecast for ocean and wind conditions in False Bay.

Easy to use

The SMS format was chosen because it creates a simple, affordable and quick communication system – and because fishermen do not typially take smartphones or tablets out on the ocean.

The fishermen simply send an SMS code to a specific number and within seconds they receive an SMS reply with the latest nine-hour forecast for False Bay's current strength and direction, wave heights and direction, and wind conditions.

The CSIR met with members of the Department of Agriculture, Forestry and Fisheries and local fishermen from False Bay, where fishermen were briefed and trained on how to use the system. CSIR researchers also used this opportunity to gain insight from the fishermen.


Physical modelling for coastal engineering

An exposed coastline, frequent violent storm surges, coastal erosion and the volatility caused by climate change factors, create constant waves of onslaught on the marine life and maritime structures along the South African coast.

The CSIR hydraulics laboratory is the only one of its size and capability in Africa and is used for hydraulic research and development on breakwaters, ports, and other maritime engineering domains such as vessel motion and mooring forces.

The laboratory has attained an international reputation and has worked on contracts as far afield as Australia and the Gulf.

Locally, investigations are done on national commercial ports for clients such as Transnet Capital Projects and Transnet National Ports Authority, to provide infrastructure assessments, input on rehabilitation and future expansion plans.

Numerical models are created of port or coastal infrastructure and then used to create accurate physical scale models that are tested in the hydraulics model facility. Subsequent experiments and induced wave testing generate accurate datasets which provide an understanding of the dynamics of waves, coastal structures and ship motions. In this way, it is possible to determine force limitations and design life of planned infrastructure.

Numerical modelling

Long waves represent one of the two major threats to moored ships. Visible only as surges of up to 35 cm on a harbour wall, long waves build up at sea and have a peak period of between 100 and 200 seconds. This frequency resonates with a moored carrier and can result in disruption of harbour operations and even broken mooring lines, especially if combined with high winds. These threats to harbour operations can be managed by adjusting the mooring systems, and by installing early warning systems which are based on real-time, stand-alone measurements of environmental parameters.

The CSIR has numerical models for different mooring scenarios – wave forces and hydrodynamics impacting on a vessel or floating structures, forces impacting on a moored ship caused by the passing of another ship in a channel, and the ship motions and mooring line forces at a quay or jetty due to waves, current and wind.

Human capital development

The engineers and technologists, backed by programmers, technicians and applied mathematicians, are exposed to international scrutiny in terms of service provision, work quality and overall innovative design and execution. This requires that the best international standards are applied while creating novel technologies that are on par with, or even outperform other laboratories in the world. At the same time, the CSIR's Coastal Engineering & Port Infrastructure research group actively participates in international and local working groups (the World Association for Waterborne Transport Infrastructure, the South African Institution of Civil Engineering and the Engineering Council of SA), and supports the University of Stellenbosch to provide academic training of Transnet coastal and port engineers, and cooperates with other world-class international engineering institutions (e.g. in the Netherlands and Denmark). The eight commercial harbours on South Africa's 2 798 km coastline – Richards Bay, Durban, East London, Ngqura, Port Elizabeth, Mossel Bay, Cape Town and Saldanha – are managed by Transnet National Ports Authority, with expert support as and when needed from the CSIR's research group on coastal engineering and port infrastructure.

Industrialisation: GROWING SOUTH AFRICAN INDUSTRIES

Ready for take-off:

TECHNOLOGY-BASED ENTERPRISES GROWN AT THE CSIR

The CSIR and the Department of Defence (DoD) launched a commercialisation programme to support black industrialists and entrepreneurs in the defence sector with technology development, enterprise development and technical human capital development.

The Defence Transformative Enterprise Development programme is funded by the DoD and implemented by the CSIR. The primary goal of the programme is to create and support sustainable and competitive black-owned small medium and micro enterprises (SMMEs) in line with objectives of the Defence Review of 2015, the National Development Plan - Vision 2030, and the Department of Trade and Industry (the dti) Black Industrialist Policy 2015.

The first three small businesses were identified through a process. Inclusion of their technical teams in project activities have already commenced and the process is underway to supply the necessary business and administrative support the companies would require. An additional two SMMEs will be added to the programme.

The defence sector – as many others – faces the challenge of enlisting scarce skills in high-technology domains as well as to transform its landscape to represent a fully inclusive, active South African economy. At a

higher level, the sector aims to contribute to positive economic growth and addresses national challenges of unemployment, poverty and inequality.

According to Bernad Mangwane, programme leader at the CSIR, the programme allows the science and entrepreneurship system to contribute directly to techno-industrial development. "This is a focused and directed programme for effective technology commercialisation that will support black business development – and support its sustainment," he says. "This is one of the CSIR's key focus areas, namely supporting industrial development." He adds, "The other is to make a real and lasting contribution to our defence industry transformation and growth and enhancing the technical skills base to foster industry competitiveness. In this case, it is an injection into the field of radar and electronic warfare which is a critical and undersubscribed field of engineering."

The CSIR and DoD will be seeking means to expand the programme into fields such as optronics, aeronautics, landwards, maritime, cyber, secure communication, and modelling and simulation. The intention is also to grow the programme involvement with other national departments such as Science and Technology, **the dti**, and Small Business Development.

SMALL BUSINESS: OPPORTUNITY ON THE RADAR

What does it take to start and run a small, medium and micro enterprise (SMME) in the defence industry? After 16 years of holding top positions for some of the big hitters in the defence sector and having co-founded Floida Engineering Services, Florence Musengi is more equipped than most to tackle the question.

"After a stint working for the United Nations I got head-hunted into the defence industry. It was quite a culture shock at first, but the ever-evolving technologies that drive the industry make it unique, challenging and also exciting," says Musengi, an MBA graduate who is currently CEO of Floida Engineering Services and owner of WAYAM Communications Consulting and WAYAM Clothing, as well as a seasoned empowerment coach.

"I've worked for multinational Saab South Africa as Vice President and Head of Communications and Public Affairs, for Reutech Pty Ltd as Executive Director and I was CEO of Paramount South Africa within the Paramount Group.

"The defence space is unique because you often work for organisations that manufacture state-of-the-art technologies and equipment that help to keep the peace and keep people safe. The sophistication of the technology makes one want to be part of the solution to the global defence challenge."

Floida Engineering Services is a 100% black female-owned company that primarily does research and technology development for the radar cross section (RSC) facility. The company receives funding from the Department of Defence as part of a collaboration programme with the CSIR.

Musengi decided to co-found Floida Engineering Services as a natural extension of her career in defence.

"Having been in the industry for so long it felt natural for my partner and I to start Floida. Our main aim was to help grow the scarce skills so needed in the industry in South Africa, and to put mechanisms in place to retain those skills," she says.

"Beyond that, it's always been my goal to own a technology development entity. I find it extremely fulfilling to design, develop and commercialise a new product."

So what does it take to start and run an SMME in the defence industry? Musengi lists the following valuable tips:

Find a niche

If you want to start any successful business you need to find a gap where there is a need for a product or service. The same applies to the defence environment.

Collaborate

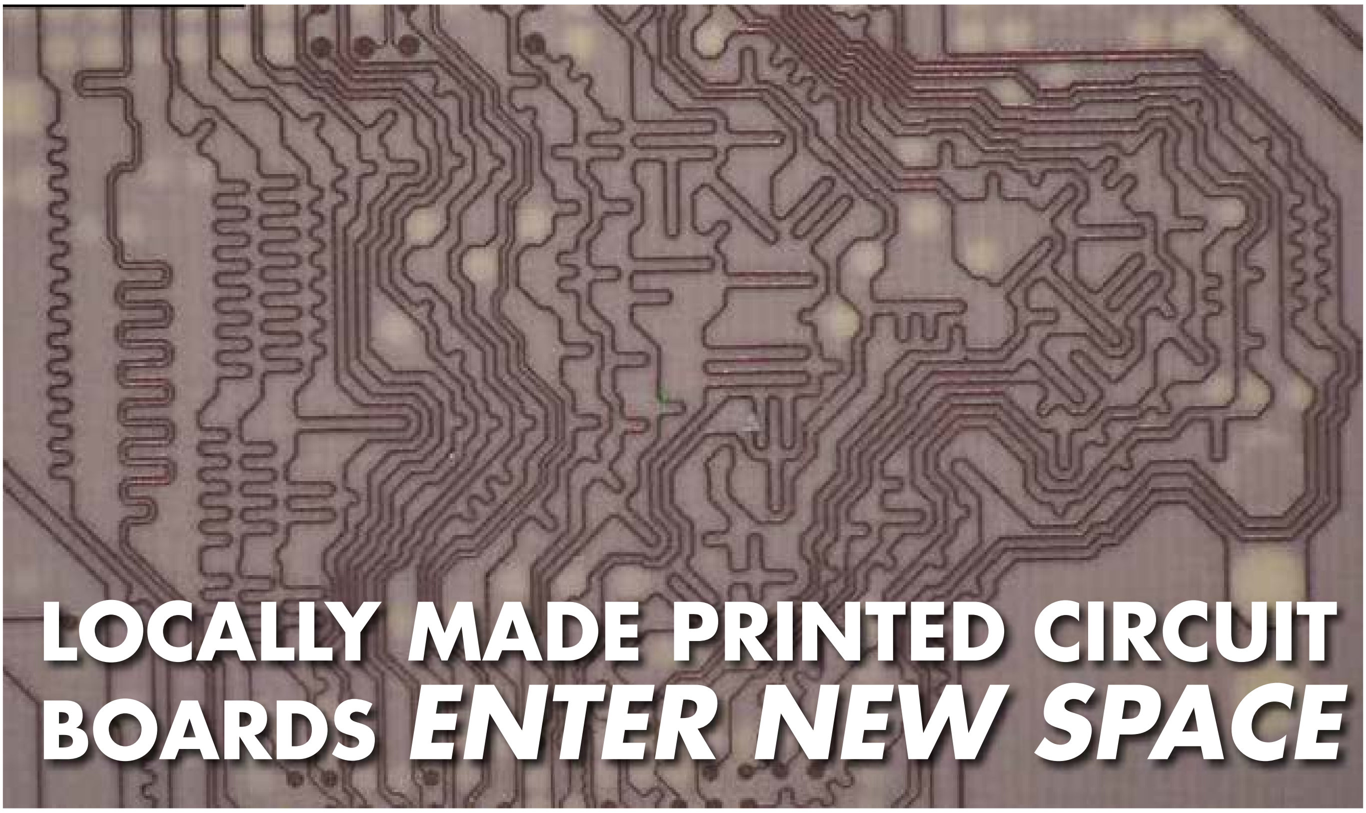
Making contact with the right people and fostering strong strategic partnerships is essential in order to grow. You need to pair up with people who have been around the block and who know the industry and its players.

Focus on your strength

You know what you do well and what you can bring to the table that others can't, so focus on that and just go for it.

Wise up

The defence sector is an extremely sophisticated industry. Get to know the relevant products, research and future technologies for the market you are trying to enter into. You have to apply a bit of a different mindset and skillset than in most other industries, simply because of the technical advances involved, but it's all doable.



LOCALLY MADE PRINTED CIRCUIT BOARDS *ENTER NEW SPACE*

A localisation project initiated by the Aerospace Industry Support Initiative (AISI) and supported by the CSIR's Technology Localisation Implementation unit is set to benefit the Square Kilometre Array (SKA) and the broader aerospace industry by increasing local capability to develop high-end electronics and mechanical systems, accelerating product development and time to market. At the same time, it will protect South African intellectual property.

Among others, this project concerns upgrading and enhancing the capabilities of printed circuit board (PCB) manufacturer, TraX Interconnect. The company will be positioned as a supplier of Class 3 PCBs to the aerospace and defence industries in South Africa.

Although not a stranger to institutions in these industries, TraX realised that to be able to manufacture the many PCBs currently made offshore, it had to upscale its manufacturing capability to meet Class 3/A performance requirements – the industry standard with the toughest requirements for high-reliability electronic products.

Meeting Class 3 standards will also require development of new ISO documentation, quality assurance reports and traceability reports. Apart from training of laboratory personnel, specialised training of computer-aided manufacturing engineers is necessary. Training will be provided by two engineers from NCS in India as this expertise is not yet available in South Africa.

With regards to technology upgrades, TraX was assisted to acquire a new direct imaging machine, probe testers as well as reverse pulse plating technology. This strategic upgrade of its plant enabled TraX to meet the ever increasing technology demands of its customers

In the longer term, higher education institutions will benefit from the training, process and software improvements as part of TraX's ongoing partnership with these institutions.

While the project is not yet completed, TraX has started to reap the benefits. Apart from work requests from the SKA, it has also received work from the European organisation for nuclear research, CERN, and locally from the Gauteng Department of Education.

Once the project is completed, TraX will not only meet Class 3 acceptance requirements and provide the necessary first article inspection reports, but it will also be able to deliver a number of services to the SKA and the broader aerospace and defence sectors, including manufacturing all of the SKA's PCBs as well as multilayer PCBs with varying, complex specifications.

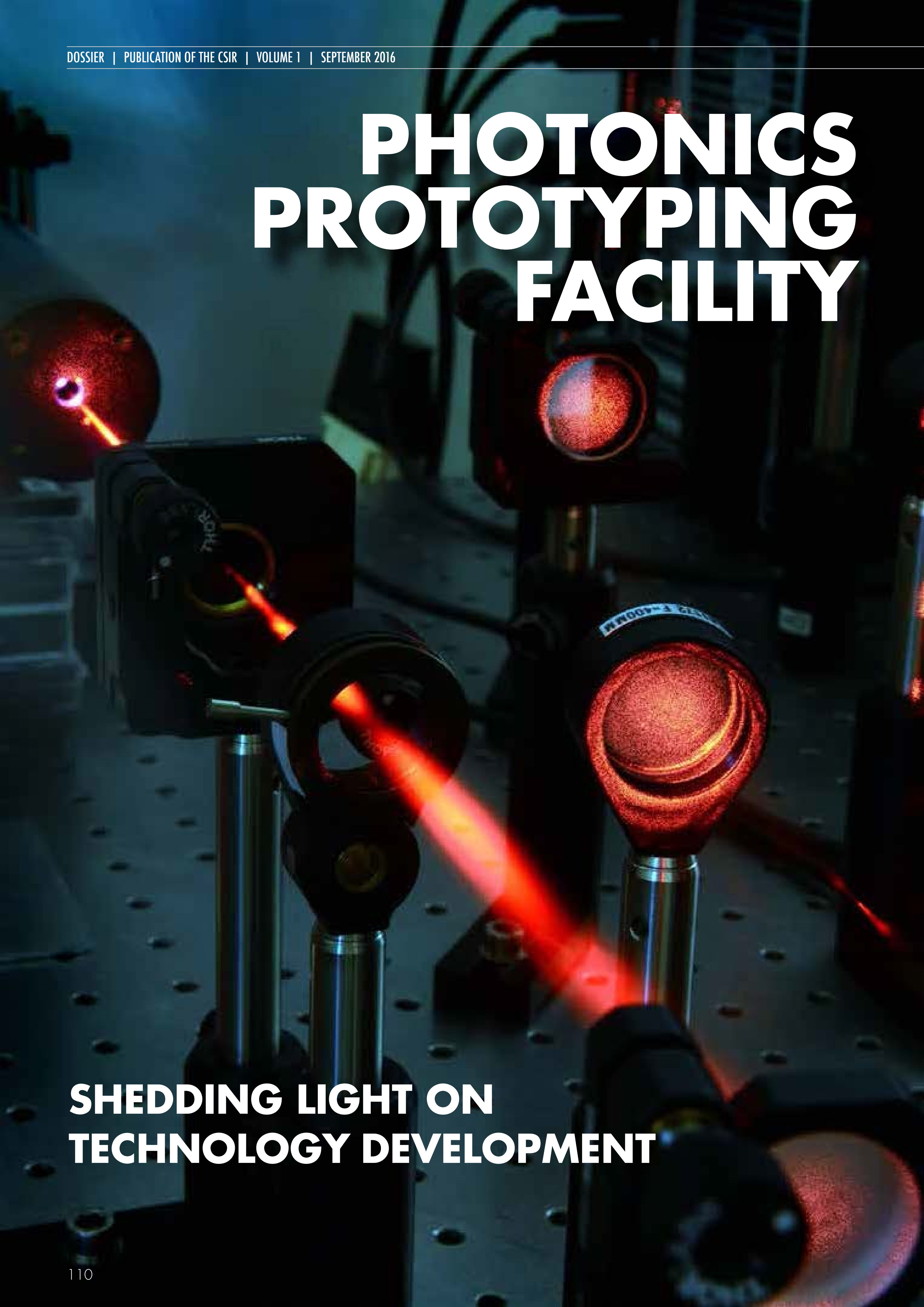
This investment will position TraX to tender for other PCBs making up the sub-systems of the MeerKat telescope.

TraX has already processed more than 600 PCB designs and improved its quotation turnaround time as well as quotation accuracy. A number of other software upgrades were also completed.

Special attention was given to continuous improvement of processes to ensure that any future requirements of the SKA can be catered for. Component manufacturers are a big driving force in this technological evolution as they create smaller and more complex components, requiring more intricate interconnects and complicated stack ups within the PCB design. In particular, TraX required key process improvements in resin-, copper-, and thermally conductive paste-filled vias (vertical interconnect access), in pad via, and mechanically drilled micro vias.

Marié Botha, AISI Project Manager, explains, "Part of our goal is to increase impact by supporting and implementing supplier development enablers, transferring technologies to improve SMME capabilities, and ensuring the appropriate skills and knowledge have been transferred to sustain SMME economic participation. TraX Interconnect was an ideal SMME for this purpose. The project will prepare local industry to offer more significant contributions to the international SKA project once it starts construction in 2018."

PHOTONICS PROTOTYPING FACILITY



SHEDDING LIGHT ON TECHNOLOGY DEVELOPMENT

Photonics is the science of light, describing a research field that aims to generate, manipulate and detect particles of light called photons. It is an essential component of everyday technologies including medical instruments, lighting sources, such as lasers or LEDs, and telecommunications and information processing.

Just as the invention of the transistor and integrated circuits revolutionised the 20th century with electronics, so the invention of the laser and optical fibres is at the centre of the next technology revolution. The 21st century is becoming the era of photonics.

The global photonics market is currently worth 300 billion euros, with a projected market value of over 600 billion euros in 2020. Apart from implementing photonics-based technologies to address societal challenges such as energy generation, healthcare and security, it is a driving force in accelerating economic growth to which South Africa has a minuscule market share of less than 0.3%.

One of the major contributing factors to this lack of impact is the fact that photonics-based technologies developed in South Africa are typically never commercialised or prototyped. This is caused by a lack of scientific and business expertise needed to industrialise technologies, as well as a lack of funding needed to develop the necessary infrastructure and facilities.

To address these challenges, a photonics prototyping facility, funded by the Department of Science and Technology and the CSIR, has been developed to stimulate the growth and competitiveness of the South African photonics industry. The facility is established within the CSIR's National Laser Centre, an innovative research environment in close proximity to several universities that serves as a nexus for industrialisation.

As the name suggests, the principal function of the photonics prototyping facility is to facilitate the development of prototypes, which results in products that satisfy a market need associated with photonics-based technologies and devices. It aims to address the current 'innovation chasm' experienced in the South African photonics industry by providing the necessary skills and facilities to support the industrialisation and commercialisation of photonics-based technologies. This will help develop South Africa's expertise in photonics product development and prototyping, stimulating the growth of the country's photonics industry by forming small, medium and micro-sized enterprises and creating sustainable jobs.

The photonics prototyping facility offers a world-class facility that houses Class 1 000 clean rooms and technical and optical equipment ranging from electronic, mechanical and diagnostic equipment for a variety of wavelengths. The facility will also house scarce skills such as knowledge and experience in optics and photonics and offer assistance with photonics-related prototype design and testing.

There are six key economic sectors that have been identified within photonics in South Africa that would benefit from prototype development. These include defence, security and sensors; industrial manufacturing; energy; lighting and displays; information and communications; and life sciences.

The photonics prototyping facility welcomes industry, entrepreneurs and public research institutions to participate in innovative prototype development projects of photonics-based technologies.

The facility:

- *Premier facilities: Three Class 1 000 clean rooms.*
- *Access to skilled resources: Optical engineers, industrial engineers and photonic scientists.*
- *Characterisation equipment: Diagnostic equipment, optical components and laser sources.*
- *Technical support: Mechanical, electronic and industrial design.*

Robotics for rails, crops and mining

In an ever changing and evolving world, scientists are paying closer attention to automation solutions. Automated and robotic systems are ideal for situations where safety and endurance are key considerations. The CSIR has undertaken research and development on automation solutions to improve the competitiveness of various industries in South Africa and has developed a number of cost-effective platforms for various sectors.

Autonomous solutions for farming

Dassie is a CSIR-developed robotic system that can inspect and monitor horticultural crops on local farms. The automated, intelligent robotic system has the potential to improve the monitoring, production, harvesting and processing of produce.

Following the successful development of a prototype that was tested in laboratory conditions, field trials of this precision-farming tool were undertaken to monitor vineyards in collaboration with the Department of Viticulture and Oenology and the Institute for Wine Biotechnology at Stellenbosch University.

One of the key considerations in developing the technology was durability, as the harsh South African climate and landscape have in the past prevented advanced robotic technologies of this nature from being put to work. The researchers developed the platform to be both capable and durable by ensuring that it had more than the required weight carrying capacity and energy to drive the machinery. Computer-aided design allowed for the simulation of performance before construction and deployment of the platform.

Robotic in the mines to ensure safe environment

Another robotic solution contributed by the CSIR is the Mine Safety Platform, which uses a novel thermal imagery system to help prevent uncontrolled rock fall. The mine safety platform makes use of infrared technology to create images of the heat of the hanging wall, thereby highlighting possible points of loose hanging rock. The platform can be used to reduce fatalities in South African mines.

Autonomous railway inspectors

SID (Survey and Inspection Device), was developed by the CSIR and is tasked with inspecting railways. A set of predetermined parameters allows SID to identify points of interest on rails and surrounding infrastructure that could pose threats to passing trains. The autonomous vehicle is capable of travelling vast distances on very little fuel between depots and sidings.

SID sends the information it gathers via a mixed set of wireless communications as they become available along the route. It captures a real-time view of the environment using on-board cameras. SID can be used for inspection missions in areas where platforms that run on wheels operate.

The vehicle can also operate as an early warning system when it travels ahead of trains, sending back alerts on track obstacles and level crossings.

Supporting SMMEs in the biomanufacturing sector

Science and technology has a key role to play in developing industries that support economic growth and address unemployment, inequality and poverty.

The development of a South African biomanufacturing sector is contained in several national strategies. In 2013, Cabinet adopted the National Bioeconomy Strategy tabled by the Department of Science and Technology.

The vision for South Africa's bioeconomy is to be a significant contributor to the gross domestic product of the South African economy by 2030 through the creation and growth of novel industries that generate and develop bio-based services, products and innovations, with a corresponding increase in new and existing companies that provide and utilise these solutions.

In 2013, the CSIR established a Biomanufacturing Industry Development Centre (BIDC) to support small, medium and micro enterprises (SMMEs) involved in biomanufacturing. Since its inception, the BIDC programme has supported 19 enterprises, of which 16 are owned by black entrepreneurs, including 10 black women-owned enterprises. To date, 42 products with applications in the cosmetics, nutrition, water and sanitation, and biotechnology industries have been developed and transferred to enterprises.

One of the SMMEs in the programme, OptimusBio's chief technical officer, Dr Raj Lalloo, points out that the BIDC's market pull approach has enabled companies in the programme to identify market opportunities. This, in turn, has allowed the companies to use the science and technology platforms of the BIDC to rapidly develop product prototypes to offer solutions to large industry partners.

Supporting SANDF deployments in environmentally sensitive areas

A CSIR team recently visited South African National Defence Force (SANDF) deployments at the Kruger National Park as part of its ongoing support to the SANDF. The aim of the visit was to assess conditions found in these remote deployments so as to propose the development of an environmentally friendly deployment solution.

It was found that eco-friendly products and practises were one of the requirements needed to assist the SANDF in remote operations. Examples include biological cleaning products, biodegradable personal care products, water treatment products, ablution, waste treatment and recycling solutions.

One such solution was found in OptimusBio, a CSIR spin-out company that specialises in eco-friendly biological products and solutions. OptimusBio uses technology developed at the CSIR's BIDC for product manufacturing. These next generation products use the concept of biomimicry to put 'nature's machines (active bacteria) to work' in cleaning, water treatment, sanitation, agriculture, aquaculture, environmental bioremediation and solid waste treatment.

"Our propriety technology has been tested to liquefy and degrade solid waste material, industrial and domestic effluents, reduce odour and reduce prevalence of disease-causing pathogens, while preserving the sustainability of natural environments," says Lalloo. Core components of the technology include biological screening and selection, applications testing, high-density bacterial fermentation, downstream processing and formulation, which yield highly engineered products through biotechnology.

The products feature microbial enzymes produced in a self-regulating system, coupled to biodegradable surfactants and mimic the look and feel of conventional products. The technology is an enabler to start the waste treatment process at source, thus reducing the burden on waste management, improving the well-being of people and preserving the environment.

Products are currently available in Botswana and Namibia and there is ongoing impetus to share these products with other countries in the African region. Because of the BIDC support, OptimusBio is currently setting up its own manufacturing facility and creating jobs in a new biotechnology sector of the economy.

AVOIDING RISKY BUSINESS

The 'how to' of growing an engineering business with reduced risk

Business owners know that a main element for hedging against internal and external risk is by having the right systems for your enterprise. The benefits of this become obvious when the business grows in a sustainable and consistent manner.

Substantial, even exponential, growth can be achieved in a low-risk environment if it is carefully planned and systematically executed; and one of the easiest ways to achieve this is by integrating your product set into the product portfolio of a larger, national or international manufacturer. The benefits are obvious – a larger market for your solutions, a more certain and steady order book, a smaller sales effort for larger order volumes, etc.

However, embarking on a programme of 'running with the big dogs' can be very daunting for a small business. Three steps can make a world of difference in growing your small business: a desire to win; a mindset that says, 'I can do this', and leveraging national programmes created for giving small businesses a boost.

The Programme Lifecycle Management (PLM) initiative, is established to address this, and is a way to connect participants of the engineering and manufacturing industry with each other on a national and international level.

With products becoming ever more sophisticated and complicated, more specialised producers are necessary. This results in large supply chains with many participants, often spanning the globe. Products that are designed and manufactured by many different organisations represent a huge integration problem, because the information that describes the components are typically inaccessible.

The initiative will help South African businesses to participate in these supply chains, by providing the tools and techniques to deliver designs and products with the right set of information, allowing products and solutions to be integrated and used by national and global manufacturing organisations.

The initiative also enables industry participants to co-create globally competitive products and services using a PLM platform that streamlines the flow of multidisciplinary information about products, services and related processes throughout a complete lifecycle, to ensure that the right information is available in the right context and at the right time.

Through this platform, industry can leverage CSIR skills and knowledge to develop sophisticated products and services. The PLM platform will also be made available as a cloud service, allowing industry participants to use the technology to develop and enhance their own products and make their engineering services globally available. This will significantly lower the barrier for South African small, medium and micro enterprises to enter large modern supply chains and expand their distribution and market share. Additionally, gaining access to the latest engineering software and systems; with appropriate assistance and training readily available, and a way to easily deliver their designs and product specifications to their national and international customers.

As a long-term initiative with the potential for huge impact on your business and the South African economy, the CSIR offers the following:

- A PLM facility to serve multiple goals. It showcases the value of PLM, provides practice-based training, tests technical capabilities and serves as a work space where CSIR experts can help clients to solve complicated problems with the latest engineering tools and techniques.
- The facility can be used by South African companies to design their products, and exchange ideas and product information with clients and partners. This is a way to streamline the supply chain and make it easier for the various participants to deliver their products and services.
- As more organisations use the PLM platform, the CSIR will facilitate relationships between businesses, investors and government, contributing to supplier development and localisation programmes.
- Finally, the initiative will become the modern version of the components catalogue. A procurer could use the system to find products, components and services or at least something similar to what is required. The contact information of the supplier of those items or services will be available, making it that much easier to build a supply chain.

The message is simple: scientifically based systems for growth and development are the best ways to ensure success and minimise the risk.

LENS shapes the future of local manufacturing of parts

Refurbishment of industrial components is particularly important in the South African context. South Africa's manufacturing industry relies on imported equipment, and critical spares have to be kept in stock or be imported from overseas. Where high-value parts are involved, manufacturing companies have to choose between expensive spare part inventories or the possible loss of production due to downtime while spare parts are being imported.

The CSIR, along with its partners, the National Research Foundations (NRF) and the Aerospace Industry Support Initiative (AISI), has invested in a research and development facility to help companies avoid such scenarios. The facility comprises an Otomec LENS 850R metal additive manufacturing system.

The laser-engineered net-shaping (LENS) technology focuses on blown-powder laser metals deposition additive manufacturing.

With LENS technology, companies can rebuild their existing parts, and thus realise substantial time and cost savings.

This facility is unique in the southern hemisphere, and is housed at the CSIR National Laser Centre's laboratories. In addition to refurbishment of existing parts, LENS technology also creates three-dimensional parts without the need for any specialised tooling. It offers the designer new freedom to design geometries which are not possible to realise using conventional manufacturing techniques. The technology supports the concept of time compression in product development, in that no hard tooling is required, and that product updates can be made by simply updating the computer-aided design models used to define the component build. LENS also supports the upgrading or refurbishment of components. It feeds blown powder from a nozzle into a laser-generated melt pool, which rapidly solidifies into the designed computer-aided design model shape. The part is thus fabricated layer by layer to achieve the final built part.

The CSIR has teamed up with Eskom as an industry partner to further investige the use of the LENS system as a technology platform of choice in its refurbishment processes. R&D activities are focused on the refurbishment of high value steam turbine blades. The first success came in the form of a process which enables the restoration of tenons on the tips of blades which had to be removed from the rotor shaft. Previously, these blades had to be scrapped regardless of the condition of the blade, but by rebuilding the tenons it is now possible to reinstall the blade if needed.

Unique technology platform, Aeroswift, set to revolutionise *ADDITIVE MANUFACTURING*

Additive manufacturing is a relatively new manufacturing technology, and is generally considered as one of the key technologies to support the production of complex, high value and low volume parts for industry.

The technology allows the processing of difficult-to-machine materials, and can produce parts with little material wastage. Research and development work is continuing globally to mature additive manufacturing as an accepted manufacturing technology.

A consortium consisting of the CSIR National Laser Centre and Aerosud identified a number of shortcomings with present commercially available metal additive manufacturing technology. At present, processing speed is still relatively slow, and there are limitations on the size of parts that can be produced.

An innovative way to address these limitations was demonstrated by the consortium in 2009, which led to the establishment of the Aeroswift programme in 2011 to develop the Aeroswift High Speed Large Area Laser-based Additive Manufacturing technology platform.

This technology platform is unique in the world. It will be the biggest laser-based 3D printer of metal components for the manufacturing industry. The technology is focused on titanium metal, and the commercial aerospace manufacturing sector will be one of the primary industry sectors on which the consortium partners will focus. The system allows the printing of components up to 2 m long, 600 mm in width, and 600 mm in height. It will also utilise a hot and inert processing environment, which will ensure that the components produced comply with strict aerospace manufacturing standards.

Aeroswift is based on the processes of selective laser melting, in which an object is produced from powder which is arranged in layers and fused by a high-power laser. In general, additive manufacturing lends itself to the development of unique components from a range of materials.

Compared to conventional manufacturing technologies which are often subtractive (i.e. materials are removed via a cutting or milling processes), additive manufacturing relies on various energy depositing technologies to fuse materials into three-dimensional functional near-net-shape parts. It accelerates the manufacturing cycle, reduces waste, minimises cost, reduces energy use and can reshape supply chains.

This technology will allow the production of large geometrically complex items, typically focusing on parts which are prohibitively expensive or impossible to make using traditional methods.

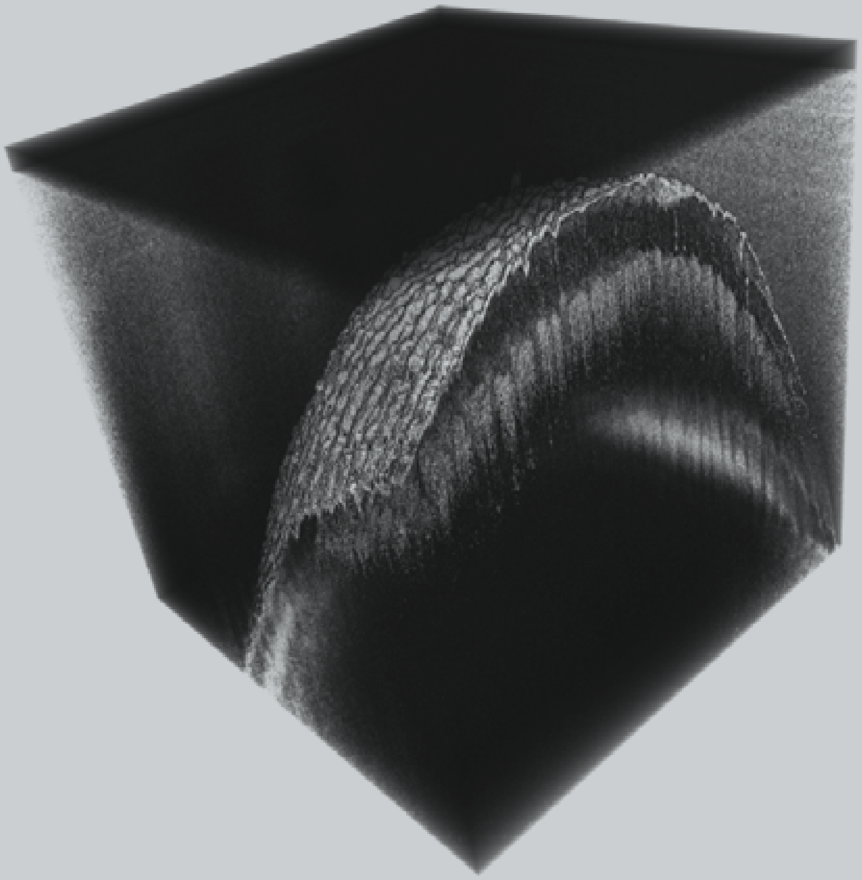
This development is at present being funded through a grant from the Department of Science and Technology. The project is central to South Africa's national titanium beneficiation strategy, which aims to transform the country from an exporter of raw materials to an exporter of semi-finished or finished goods, which can be sold at a premium compared with the material in its raw state.

The consortium has already achieved production speeds greater than currently available commercial selective laser melting machines. Phase 1 of Project Aeroswift was to design and construct the system. The system is currently still in the commissioning phase, which is running in parallel with Phase 2, which focuses on process development and optimisation. During this phase, the processing parameters will be optimised, all hardware systems will be tested and improved, and system reliability will be tested to ready the technology for adoption as a standard manufacturing technology. It is important to ensure that the technology becomes mature and that there is confidence in the manufacturing technology before manufacturing procedures and part qualification processes are developed for targeted aerospace components, commencing during Phase 3 of the programme. A commercialisation strategy for the technology is also being implemented.

Aeroswift will revolutionise additive manufacturing, in that it will be able to produce components in a cost-effective way, with minimal waste. New design approaches made possible by the design freedom that this technology offers, combined with the fact that material utilisation can be optimised, has the potential to dramatically cut aircraft component production costs.

LASER TECHNOLOGY

for biometric and biomedical applications



As part of a Department of Science and Technology-funded project, the CSIR has developed a high-speed, large-area optical coherence tomography (OCT) system for fingerprint biometrics.

The OCT system is capable of acquiring both external and internal fingerprints, thus enhancing fingerprint acquisition and providing fake detection.

Researchers have demonstrated the ability to acquire live and latent (forensic) fingerprints using the system. Light-based techniques are popular in different spheres of diagnostic and therapeutic applications due to their non-invasive, non-contact properties. The OCT technique was first reported by Huang in 1991 and has since made significant strides in different fields such as dermatology, ophthalmology, polymer characterisation and biometrics. Lasers permeate the world in a myriad of ways. Optical coherence tomography (OCT) is a non-invasive, non-contact imaging technique, capable of yielding both surface and sub-surface morphology (in 2D and 3D). High-speed, high-precision OCT systems employ lasers as the optical source. In addition to numerous applications in the biomedical imaging field, OCT can also be used for biometric acquisition and be a useful tool in the safety and security industries as well.

The technique is considered the optical analogue of ultrasound and works on the principle of low coherence interferometry. A broadband or tuneable light source is split between a sample and a reference mirror (reference path). When the difference between the distance travelled for the light, sample and the reference path is within the coherence length of the light, then interference will occur at the detector. This then generates an image after processing the resultant interference signal. OCT measures the echo time delay and intensity of backscattered light. Unlike conventional microscopy, the depth and lateral resolution are separated. The depth (axial) resolution is dependent on the spectral bandwidth of the light source, the broader the bandwidth, the lower the coherence length and the higher the depth resolution. The lateral resolution depends on the optics used.

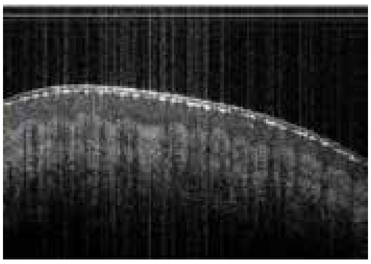
There are different configurations of OCT but all are based on the same principle. These configurations are Time Domain OCT and Fourier Domain OCT. The former involves scanning the reference mirror back and forth to match different depths in the sample to within the coherence length of the light source. Fourier Domain OCT uses a fixed reference mirror and measures the spectral response of the resultant interferogram. The interferogram is encoded in optical frequency space and undergoes a Fourier transform to yield the reflectivity profile of the sample. Fourier Domain can be further divided into Spectral Domain OCT and Swept Source OCT.

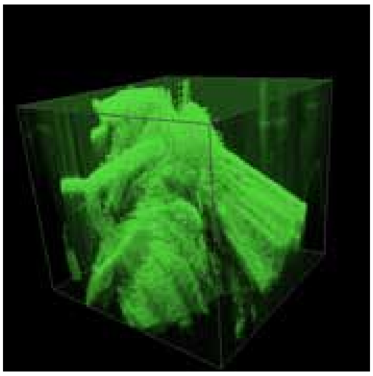
Spectral Domain requires a broadband light source for illumination and separates the spectral components with a spectrometer. Swept Source uses a light source which probes the sample with different optical frequencies sequentially. The power is then measured with a single photo detector.

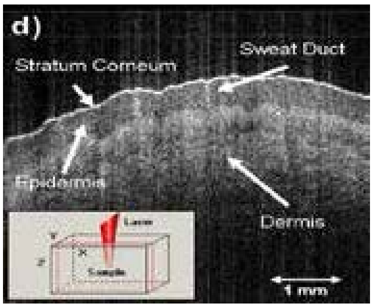
The OCT systems operate at different wavelengths (depending on the application) either in the infrared (800-900 nm) or in the near infrared (NIR) band (1250–1350 nm). The NIR wavelengths are preferable when imaging non-transparent tissue due to the better penetration depth. Ophthalmology is performed at 800-850 nm due to the transparent nature of the eye in this band. High-resolution applications require shorter wavelengths. Longer wavelengths are considered for samples with higher scattering properties.

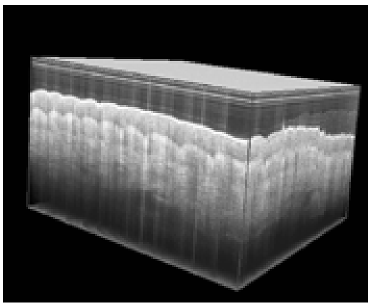
The type of OCT system employed can be a simple, cost effective solution or a complex, highly specific and fast system depending on the application. The CSIR's OCT system is not limited to this one application. The system can image a large surface area (25 mm by 25 mm) to a depth of 11 mm (sample dependant). Resultant 3D images (512 x 512 x 2048 pixels; XYZ) are acquired in less than three seconds. The heart of the system is a 200 kHz swept laser source and two-axis galvanometer-based scanner. Signal acquisition is made possible through a high-speed analogue-to-digital converter capable of speeds greater than 1GS/s.

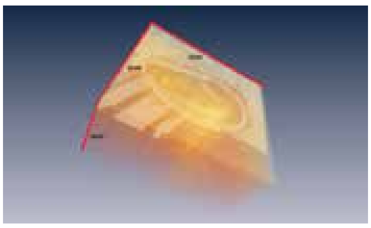
Due to the contactless nature of OCT, this technology can acquire latent fingerprints without destroying potential useful DNA material for forensics thus allowing multiple uses for one piece of evidence. The 3D capability of OCT also means it can be used to get both the internal and external fingerprints of a person thus protecting against fake fingerprints. It also has the ability to detect sweat glands and thus detect liveness. These are important features that enhance biometric security features for high-end applications such as military, national security points and forensics.











About the AISI

USING NATIONAL INFRASTRUCTURE FOR INDUSTRY DEVELOPMENT

The South African government, through the Department of Trade and Industry (the dti), is addressing the barriers to industrialisation, and upscaling and sustaining the aerospace and defence industry by using different instruments which include policies and regulation, and the implementation of strategic programmes.

Part of its overall approach relies on using national infrastructure to reach its objectives. One such strategic programme of the dti is the Aerospace Industry Support Initiative (AISI), which has been managed and hosted by the CSIR for more than a decade.

In line with government key objectives and national development imperatives, the goal of the AISI is to assist in integrating the South African aerospace and defence industry into the global supply chain. The AISI's programmes recognise that SMME development and BBBEE/ transformation-focused projects (specifically industrialisation of technologies) are a prerequisite for successfully supporting the national imperatives.

It places a premium on industry development and technology support by investing in key technologies and partnerships, technology platforms and the use of national experts and facilities, located at the CSIR. Economic benefits and related impact include job creation, job retention, skills development, transformation, cost savings, technology localisation and improved technology offerings.

Marié Botha, AISI manager, says, "South Africa has an impressive history in the aerospace industry. This background, along with its flexible and innovative engineering expertise, places the industry in an ideal position to establish itself as a reliable, cost-effective manufacturing partner.

"We strive to position the local aerospace and defence-related industry as a global leader in niche areas and accordingly, South African industry is encouraged to advance niche capabilities and technologies through industrialisation.

Interdepartmental participation and collaboration forms a crucial part of realising this vision."

Key national policies that give impetus to the continuation of initiatives such as the AISI include the National Industrial Policy Framework (NIPF). The NIPF specifically focuses on the diversification of the economy away from its traditional reliance on increased value-add per capita. It is characterised by increased downstream participation in higher value activities and value chain segments; and technological leadership in specific technologies.

Serving as the foundation for the Industrial Policy Action Plan (IPAP), it also supports the growth and diversification of South Africa's defence industry.

AISI programmes

Supplier development

The strategic focus remains on SMMEs with the objective of ensuring industry transformation, and the broadening of the economic base participating in the industry. The AISI supports and implements supplier development enablers, transferring technologies to improve SMME capabilities, and ensuring the appropriate skills and knowledge have been transferred to sustain SMME economic participation. Some projects in this programme include supply chain improvement and optimisation, and the process design of titanium fluid-cell forming.

Industry development and technology support

The programme focuses on advancing the involvement of industry in sectors reliant on advanced manufacturing for aerospace and defence. Original equipment manufacturers are encouraged to include SMMEs as well as lower-tier suppliers, to ensure the continuous transfer of knowledge, expertise, capability and technology, and in doing so, broaden the industrialisation base. Manufacturing processes developed as part of this programme include additive manufacturing and laser shock peening; and project beneficiaries include the South African National Space Agency, the Square Kilometre Array and unmanned aerial vehicles.

Sector strategic support initiatives

The AISI acts on behalf of the dti and the DST, as custodians of the Joint Aerospace Steering Committee (JASC), by hosting the JASC secretariat. The AISI also contributes to national flagship projects identified by the JASC and implemented by the AISI. Unmanned aerial vehicles, and in particular, ground control stations, have been beneficiaries of this programme.

Special projects

Hosted by the CSIR to address technology challenges, the AISI is also tasked with giving industry access to national expertise and infrastructure. Projects undertaken are technology advancement projects. In one example of technology transfer to an original equipment manufacturer and validation through the use of national infrastructure, a collaboration between Denel Aerostructures, the CSIR and the University of Pretoria will establish a specialised capability for the loads analysis of aerospace fuel tank structures.

Coordination, promotion and awareness

The AISI plays a pivotal role in coordinating information on the aerospace sector in South Africa. Its work enables it to connect and share world-class, home-grown technology solutions with a myriad of companies – from SMMEs, original equipment manufacturers, international leaders in the sector, to South African higher education institutions, science councils, government departments and like-minded support programmes. Awareness creation is achieved through a number of mechanisms such as print, electronic media and selected events and networking opportunities.

DEVELOPING INDUSTRY SUPPLIERS *LEVELS THE PLAYING FIELD*

Benefits derived through supplier development projects are many and include competitiveness improvement, productivity improvement, improved lead times, improved quality, cost savings, compliance to environmental standards, improved delivery performance, increased customer satisfaction and job creation and retention.

Two specific initiatives of the Department of Trade and Industry, and hosted by the CSIR, are great proponents of supplier development.

Aerospace industry support

Of its five programmes, the Aerospace Industry Support Initiative (AISI) places by far the biggest emphasis on technology based supplier development. It is through the enabling mechanisms inherent to this programme that industry is assisted to improve its competitiveness, productivity and quality management systems and in doing so, optimise its operations and procedures to ensure South African industry integration into global supply chains.

Sinjana Engineering, a black-owned SMME, is one such company that required help with its production planning and quality management systems. A needs analysis showed that it lacked a production planning system and a revised and updated quality management system.

Apart from creating jobs, this project has increased Denel Dynamics' confidence in Sinjana Engineering because it now works according to the processes it has created. It is also able to manufacture critical components.

Another project focuses on the good strength-to-weight ratio offered by natural fibres. This, with the growing popularity of green technologies and the need to reduce manufacturing costs, contributes to natural fibres being seen as a substitute for synthetic glass fibres. The capability developed within this project is linked to the use of natural fibres in the development of South African Regional Aircraft, a national flagship programme by Denel Aerostructures. The aim of the project is to take natural fibres from research to production.

Denel Aerostructures, with the support of the AISI, is characterising the material properties of an epoxy resin/flax fibre composite laminate with the purpose of using this material in the interior liners of the new regional aircraft developed under the SARA project. Two SMMEs were used to develop the local woven flax fibre fabrics: Herdman's spins the long fibre flax yarn and supplies Svenmill, who weaves it and supplies the flax fabric to Denel Aerostructures.

A third example of supplier development concerns an Aerosud project to supply insulation blankets for the Airbus military transport aircraft, A400M. These blankets are currently acquired from a company in Canada. Aerosud sought to increase the local content in the parts it manufactures. The manufacture of insulation assemblies was industrialised at an Aerosud certified location, as mandated by aerospace manufacture certifications. The intention was to create a long-term sustainable platform in partnership with local SMME Dreamhouse to manufacture insulation assemblies for delivery to Airbus for the duration of the A400M project. Other supply opportunities will be investigated in parallel with the current supply chain. Aerosud has formed new relationships with its suppliers and customers around the topic of insulation blankets. The project is now entering production phase.

National cleaner production

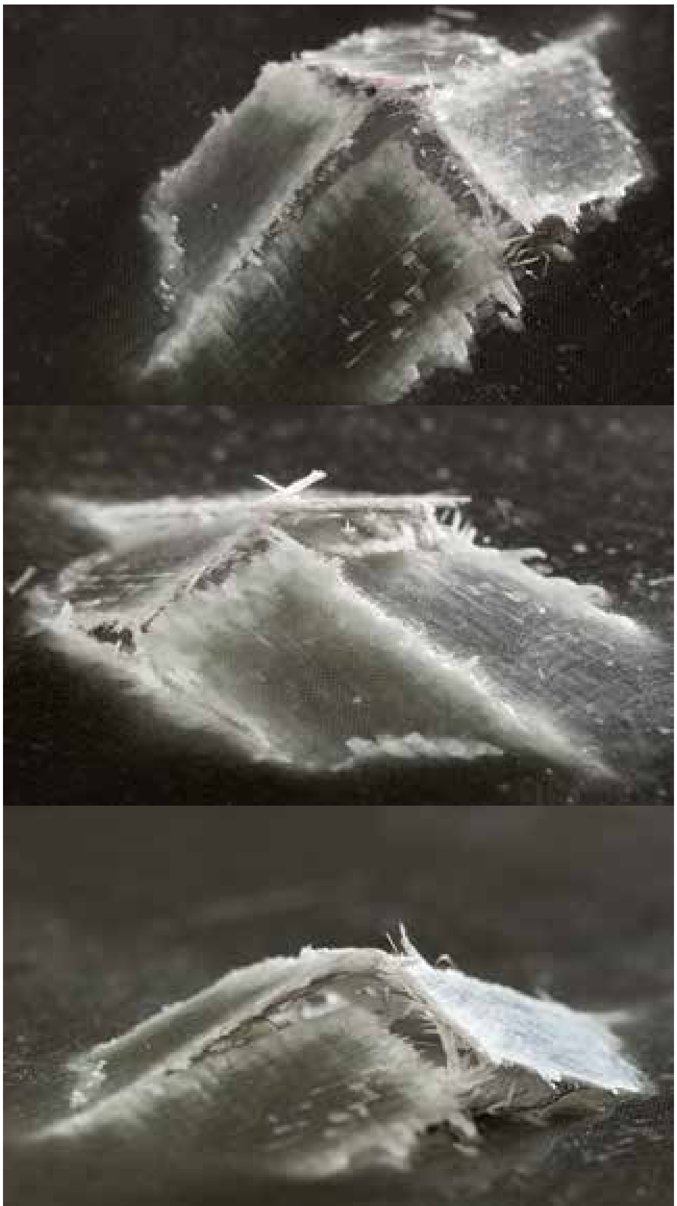
The National Cleaner Production Centre of South Africa (NCPC-SA) enhances the South African industry's efforts to improve competitiveness and reduce its environmental footprint by identifying areas where energy, water and raw-material efficiency and waste management practices can be improved through the implementation of highly subsidised resource efficiency and cleaner production (RECP) methodologies.

The automotive sector has shown noteworthy results from its participation in the NCPC-SA's Industrial Energy Efficiency (IEE) Project. International pressure is mounting for all sectors to reduce environmental risks and ecological scarcities through sustainable development.

Tenneco Automotive is one example of success. An international automotive supplier with more than 90 production facilities worldwide, Tenneco South Africa became aware of the IEE project at a two-day Energy Management Systems training session. Following a decision to join the full expert course, Tenneco was selected as the host company to showcase the implementation of the ISO 50001 Energy Management Standard.

Interventions focused on compressed air systems, lighting initiatives, automatic metering and emission control, among others. Apart from being one of the first companies in the sector to receive ISO 50001 certification, Tenneco also achieved financial savings of nearly R2 million and energy savings of 2 537 179 kWh.

Overall, since 2009, R653 million in potential savings have been identified through RECP assessments. Through the IEE Project, 80 companies have saved 866 GWh of energy and R759 million.



The South African composites industry

geared to compete globally

Industry players have come to realise the need to move to 'green' technologies, reduce the cost of manufacturing and move away from using conventional materials. In the composites industry, natural fibres are seen as an attractive alternative – particularly due to its good strength to weight ratio.

The CSIR manages the Collaborative Fibre Composites R&D and Innovation Programme, on behalf of the Department of Science and Technology.

The programme contributes to transportation in the automotive, rail and aerospace sectors. The focus is on structural applications (e.g. roof sheets) and marine applications, such as boat building, as well as renewable energy technologies (e.g. wind turbine blades).

"The goal is to take natural fibres from a research environment and industrialise it in the aerospace manufacturing environment, with specific focus on locally produced fibres. The outcome will be a ready-to-use design and manufacturing process for the selected fibres in an aerospace structural environment," says Aerospace Industry Support Initiative (AISI) programme manager, Marié Botha. The AISI is a programme of the dti, housed at and managed by the CSIR.

"One of the benefits for the local aerospace industry will be a cheaper alternative to synthetic fibres, with the design and manufacturing data for aerospace-related composite structures," Botha says.

The CSIR plays a coordinating role by facilitating and formalising the collaboration with research and academic institutions, and initiating industry collaborations.

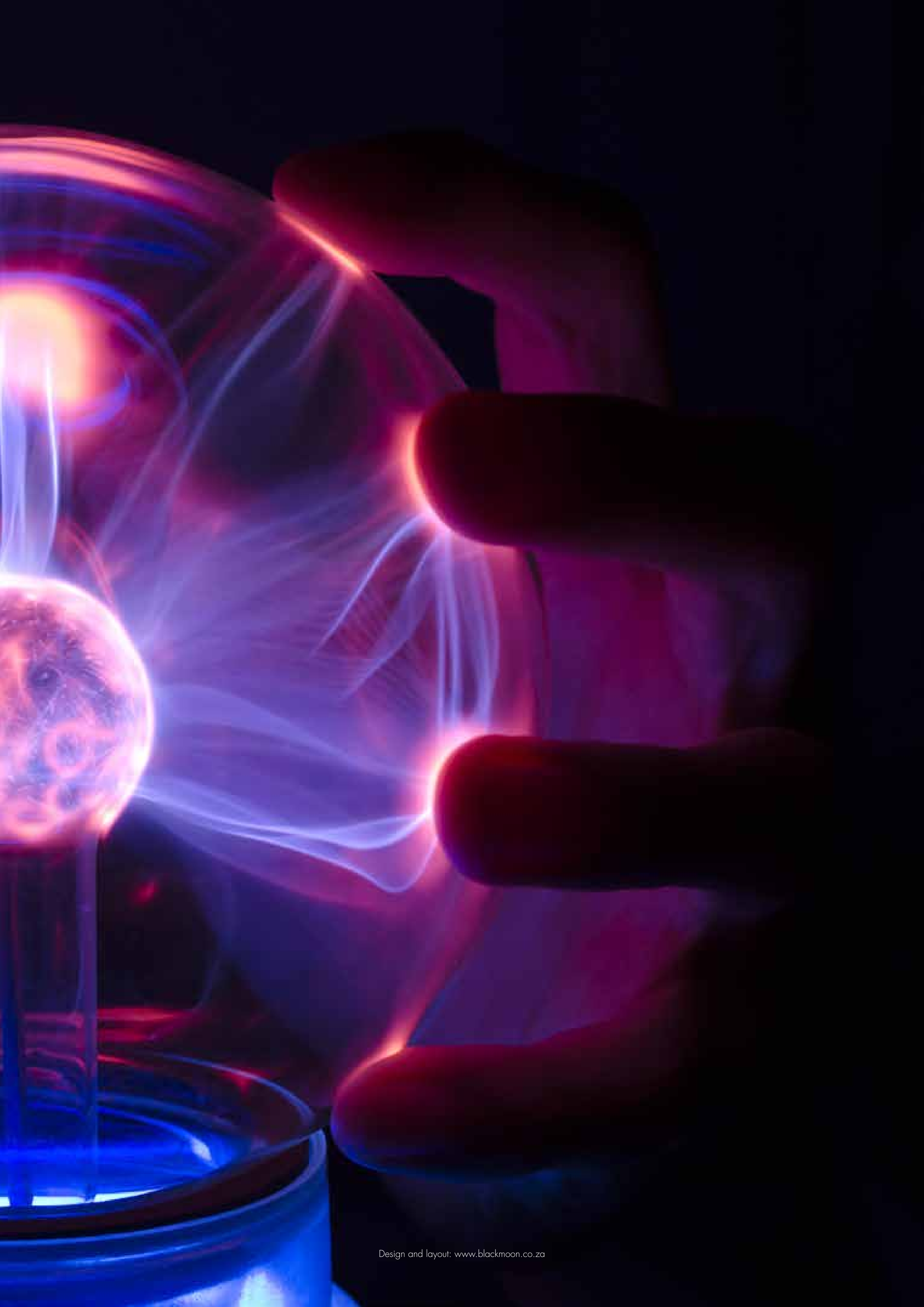
The scope of work is large, ranging from the growing of natural fibres (kenaf), to the development of prototypes for measurements, testing and evaluation, as well as industrial product development. This has intrinsic benefits to both the agriculture and manufacturing sectors. Engagement with industrial partners is ongoing to ensure alignment of research topics with the true development priorities in industry.

A number of students also benefit from the programme at various levels – from National Diploma level through to post-doctoral research – as another means for the CSIR to support the local aerospace industry.

The programme comprises eight projects:

- Natural fibre quality
- Marine eco-composites
- Natural fibre-reinforced roof sheet
- Bio-composites rail panels
- Interior trim for Volkswagen and Mercedes
- Bio-composites for mass transit applications
- Weight reduction on composites structures
- Residual stress measurement in composites.

Joining forces for growth and development



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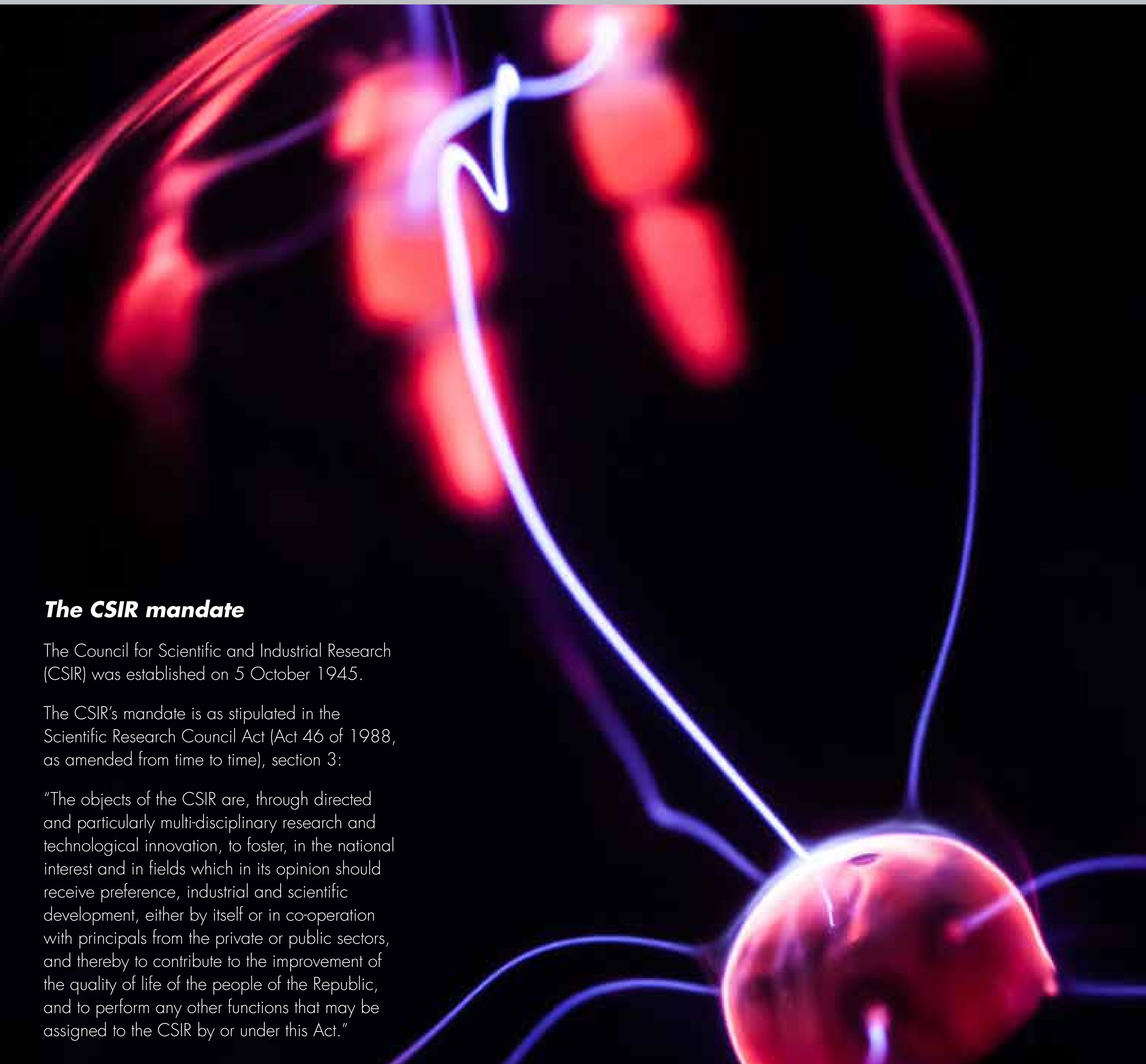

The CSIR mandate

The Council for Scientific and Industrial Research (CSIR) was established on 5 October 1945.

The CSIR's mandate is as stipulated in the Scientific Research Council Act (Act 46 of 1988, as amended from time to time), section 3:

"The objects of the CSIR are, through directed and particularly multi-disciplinary research and technological innovation, to foster, in the national interest and in fields which in its opinion should receive preference, industrial and scientific development, either by itself or in co-operation with principals from the private or public sectors, and thereby to contribute to the improvement of the quality of life of the people of the Republic, and to perform any other functions that may be assigned to the CSIR by or under this Act."

CSIR

Touching lives through innovation