ScienceScope

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SOUTH AFRICA'S COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

SEVENTY YEARS

IDEAS THAT WORK

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our future through science

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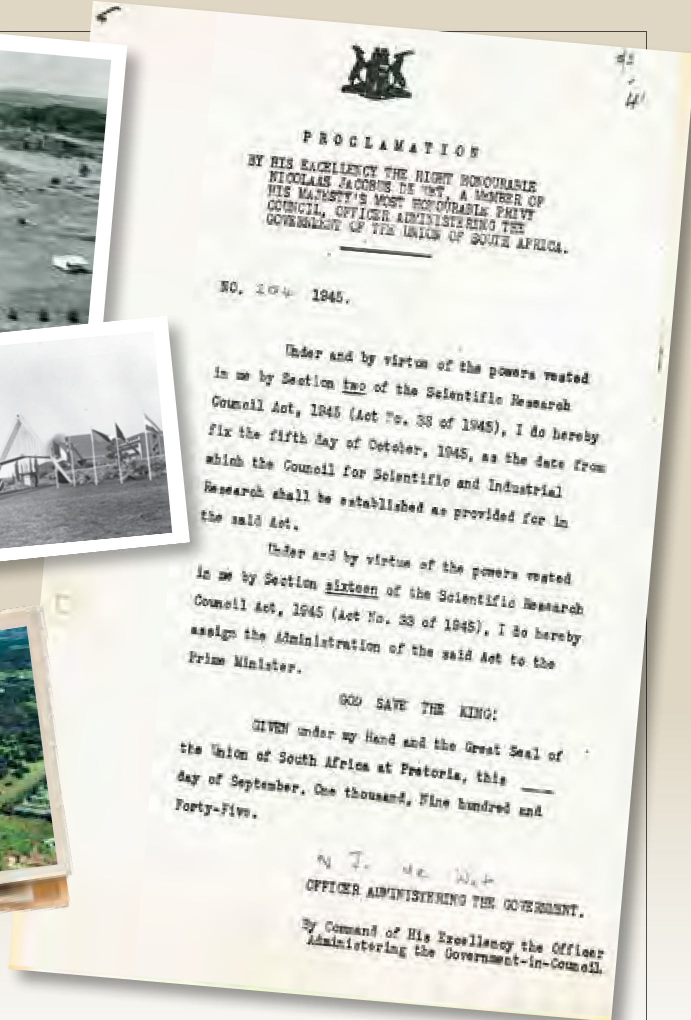


PROCLAMATION

BY HIS EXCELLENCY THE RIGHT HONOURABLE NICOLAAS JACOBUS DE WET, A MEMBER OF HIS MAJESTY'S MOST HONOURABLE PRIVY COUNCIL, OFFICER ADMINISTERING THE GOVERNMENT OF THE UNION OF SOUTH AFRICA.

NO. 204 1945.

Under and by virtue of the powers vested in me by Section two of the Scientific Research Council Act, 1945 (Act No. 33 of 1945), I do hereby fix the fifth day of October, 1945, as the date from which the Council for Scientific and Industrial Research shall be established as provided for in the said Act.

Under and by virtue of the powers vested in me by Section sixteen of the Scientific Research Council Act, 1945 (Act No. 33 of 1945), I do hereby assign the Administration of the said Act to the Prime Minister.

GOD SAVE THE KING!

GIVEN under my Hand and the Great Seal of the Union of South Africa at Pretoria, this ___ day of September, One thousand, Nine hundred and Forty-Five.

N. J. de Wet

OFFICER ADMINISTERING THE GOVERNMENT.

By Command of His Excellency the Officer Administering the Government-in-Council.

THE CSIR WAS ESTABLISHED 70 YEARS AGO in 1945. While this may appear to be a venerable age, we are – in the South African context – still something of a newcomer. By comparison some of our educational institutions have been around for quite a bit longer (the University of Cape Town is 126 years old, Rhodes University is 111 and even the upstart University of the Witwatersrand has been around for 93 years) as have some of our key industrial and developmental institutions – Eskom is 93 and Transnet is 99. Therefore, we may be justified in thinking that the CSIR is but a stripling, 70 years young and only now entering into our full maturity as a national institution. As with many long-lived South African organisations, we have something of a chequered history – apartheid and the systems that supported it have cast a long shadow over the CSIR's many scientific and technical accomplishments during its first half-century. It is perhaps emblematic of modern South Africa that we are able to reconcile this duality – that we can proudly reflect on the scientific achievements of our predecessors while recognising the fundamental injustice of the system within which those achievements took place.

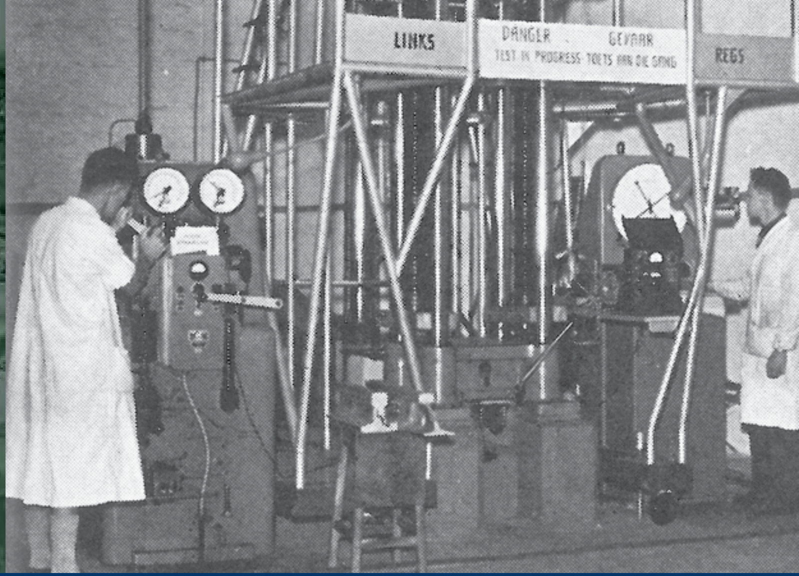
The last 20 years have seen a significant re-orientation of the CSIR, and while our larger aims (scientific and industrial development) remain the same, the context within which that work is conducted has changed. We now explicitly acknowledge that the ultimate aim of the CSIR is to improve the quality of life of all our people.

As we celebrate 70 years of research and development, I take pride in sharing with you in this edition of *ScienceScope* some of our recent and ongoing research and development. Also join me in reflecting on some aspects of the CSIR journey in an article on pages 2 to 5.

My hope for the future is that we will remain a society that uses science and technology for the common good.

Dr Sibusiso Sibisi,
CSIR CEO

The CSIR's main site in Pretoria, during the early years following the organisation being established by an Act of Parliament in 1945.



Researchers undertaking testing of wire ropes for the mining industry, a specialised service that is still being undertaken today.

70 YEARS OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH

One of the few constants in the 70-year history of the CSIR is the awareness of, and commitment to, the value that science and technology can deliver to the development of our country. Aside from this, not much else has remained the same. Within the political environment, the CSIR has experienced the upheavals associated with changes in administrations and policies, and of course the rather more significant changes that occurred when South Africa transitioned from an Apartheid to a democratic state.

SCIENTIFIC DISCIPLINES have grown, withered and been replaced by new areas of research, and the associated technologies have developed at a breathtaking rate. Internally we have seen our infrastructure built and then re-built from modest beginnings, our administrative structures have been designed and then re-designed, and the people who make up the core of this organisation have joined, grown, and departed.

There will certainly be many more such changes over the next 70 years, and no doubt our successors in this organisation will adapt as necessary. No matter what these changes are, we can be sure that the organisation will remain true to the idea that binds us all together – that investing in scientific and technological research is an effective way to ensure the well-being of current and future generations.

70 years ago

The world was a different place in 1945 with governments and industry reforming and transforming the postwar landscape. It is from the embers of World War II that the CSIR was established, although it had been in the minds of some visionaries years before. One such example is Dr HJ van der Bijl, head of the South African Advisory Board for Industry and Science in 1916, who argued that a government-funded central research institute was necessary.

In 1942, the Prime Minister of South Africa, Jan Smuts, set the wheels in motion for what would become the Council for Scientific and Industrial Research three years later. He discussed his intent to establish a scientific research institute to support industry with Dr Basil Schonland (later Sir Basil) who was at the time working on radar technology. The CSIR was modelled on international organisations, including the Australian and Canadian examples of science councils. Schonland believed that the right environment, such as the scenic garden settings found in Britain, would provide the necessary creative atmosphere in which researchers could flourish. Today, this sentiment still ranks high on CSIR employees' top reasons for enjoying their work, as the main campus perfectly amalgamates world-class scientific research infrastructure and natural beauty.

The legislative process to establish the CSIR followed, during which Acting Prime Minister Hofmeyer was quoted as saying, "A nation which neglects research is at the same time impairing its prospects of material welfare and weakening its status and dignity among the civilised nations of the world."

On 5 October 1945, the CSIR was legally constituted and work to refine its scope and structure followed immediately. Holding the view that industries should be responsible for funding technological research, but realising that an uphill battle lay ahead to instil such an imperative, and that it should therefore start off with focusing on research that would typically be neglected by industry, the CSIR established the National Physical Laboratory, the National Chemical Research Laboratory and the National Building Research Institute.

One of the newest buildings on site, the CSIR Knowledge Commons.

CSIR biotechnologist Zandile Nxumalo using modern equipment to develop digital pathology technology to train experts remotely.

Five years later these were joined by two national institutes focusing on telecommunications and personnel research (industrial psychology), as well as industrial research institutes for the leather, fishing, paint, and sugar milling industries.

Nearly 160 applied research projects were undertaken for industry and other funders in the first five years of the CSIR's existence. Research programmes included areas such as coal tar and bituminous materials, water treatment, low-cost and high-density housing, and the use of plant and animal products for industrial use. Scientific and technical cooperation in Africa aimed at addressing technological problems relevant to this continent was on the agenda as early as 1949 with the establishment of the Scientific Council for Africa South of the Sahara.

Growth amidst challenges

Of course, all was not smooth sailing; and in 1948, when the organisation's line department changed from the Office of the Prime Minister to the Ministry of Economic Affairs, the CSIR has had to strenuously advocate for the importance of science and technology in the national economy to be recognised by Parliament. This was realised to some extent decades later with the Department of Arts, Culture, Science and Technology and then, in 2002, the Department of Science and Technology.

In 1950, Schonland was succeeded by Dr PJ du Toit who presided for two years and formed the SA Wool Textile Research Institute and the Bituminous Binder Research Unit.

Dr Stefan Meiring Naudé was the third CSIR President and a prominent physicist. During his presidency of nearly two decades, the staff complement grew from 685 to more than 4 000 and additional research institutes were added in the fields of nutrition, mechanical and electrical engineering and defence.

The 1970s brought its own international challenges in the form of environmental lobbying, questions about the real value of science and technology, and disillusionment because the latter was seemingly not solving challenges faced by developing countries. It is in this period that Naudé's successor, Dr Chris van der Merwe Brink, made a concerted effort to bring his organisation, universities and industry together to coordinate research as well as to increase the emphasis on applied research.

The CSIR's collaboration with the French national centre for space studies, CNES and the American space agency, NASA, in tracking satellites raised its profile internationally and very soon the Hartebeesthoek tracking station – which later became the CSIR Satellite Applications Centre and which moved from the CSIR to form part of the South African National Space Agency in 2010 – was one of the busiest in the world.

In Brink's tenure, the CSIR International Convention Centre opened its doors and it remains one of the premier, award-winning conference centres in the country.

Increased isolation and organisational upheaval

It is also in this period that South Africa became an international pariah for its apartheid policies. The tenure of Dr Chris Garbers, Brink's successor in May 1980, was characterised by change on a national and organisational level. The South African economy was in recession and the national research laboratories were under pressure to pursue research that would be able to address immediate technological needs.

Garbers also had to navigate the storms caused by apartheid closer to home. The organisation formulated its equal opportunities policy in the mid-1980s while at the same time transforming its research and development focus – a necessity that received further impetus from the Kleu Report, an investigation ordered in 1977 that underscored the need for practical research that would be relevant to the country's economy, and that placed the spotlight on the transfer of technology.

Technology transfer emphasised

The White Paper promulgated as a result of the Kleu Report, stipulated that the CSIR had a vital role to play in technology transfer. Brian Clark was earmarked to lead the CSIR's technology transfer process. This renewed focus took place alongside efforts to rid the CSIR of bureaucracy imposed by the Commission of Administration. Then Minister of National Education, FW de Klerk, was instrumental in enabling the introduction of a system of framework autonomy, thereby helping the CSIR to chart its new course in line with the global shift in emphasis to implementation.

Patents were being registered since the early 1950s. In the mid-80s the venture capital company Technifin was established in collaboration

70 YEARS OF SCIENTIFIC AND TECHNOLOGICAL RESEARCH

with the Industrial Development Corporation to accommodate the expected investment in innovative technologies. By the mid-1990s, Technifin received some 2 000 patent applications per year – of which only three to five typically would have international potential. Among the most important was the CSIR-developed technology for lithium-ion batteries.

Winds of change continue

This and other decisions required a fundamental restructuring that was completed by 1 April 1988. The new Scientific Research Council Act specified that the organisation would be known by its acronym only. The Act also separated the offices of chairperson and chief executive, leading to Dr Louw Alberts becoming the first independent chairperson of the new CSIR. One of the many changes concerned the Foundation for Research Development (FRD), which formed part of the CSIR until its refocus to exclude its funding responsibility. The FRD became an independent organisation in 1990 and is now known as the National Research Foundation.

Clark assumed the position of President of the CSIR in September 1990. The CSIR now had to manage the expectations of stakeholders: government that saw it as its scientific arm and industry that recognised its critical role in advancing the country's technology base through technology transfer.

Times were changing yet again with the release of Nelson Mandela and South Africa's slow but determined redressing of apartheid ills. While European and American companies were showing interest in the CSIR, there were concerns regarding the state of its technology after its long isolation. At home, however, the distinct move from fundamental to applied research was paying off and the CSIR won the 1991 Technology Top 100 Prize and received the Safto Business Development Award in 1992.

A study commissioned by the African National Congress, the Congress of South African Trade Unions and the South African National Civics Organisation in 1991 to effect an appropriate science and technology policy for South Africa, described the CSIR as a "very significant South African investment in scientific research" with "modern facilities and a tradition of technical competence". It also recognised that the organisation's transformation enabled it to support large industries to compete internationally.

The value of the CSIR's multidisciplinary capability was apparent as different expertise could be employed to tackle national challenges. Sectors that especially benefited were the natural environment, the automotive industry and mining. Today, this multidisciplinary nature of the organisation remains one of its biggest assets.

With democracy progressing, the CSIR would be challenged even further – and a second major transformation was to start in 1993/94. Under the leadership of Dr Geoff Garrett, who succeeded Clark in 1995, it had to expand its view of relevant research to include the technological needs of the country for continued development, creating jobs and working towards a sustainable environment for posterity.

On the global front, the CSIR established cooperation agreements with international research institutions and participated in intergovernmental agreements. As the Regional Focal Point for Africa, appointed by the World Association of Industrial and Technological Research Organisations, the CSIR further strengthened its role on the continent.

The South African research landscape was also changing and, as in other sectors, transformation measures to realise a science, engineering and technology base representative of the country's population were implemented.

Refined focus, geared for relevance and impact

Current CEO Dr Sibusiso Sibisi, a mathematician, former Deputy Vice-Chancellor (Research and Innovation) at the University of Cape Town and also known for his role as the chairperson of the National Advisory Council on Innovation from 1998 to 2001, took office in January 2002 as President and CEO of the CSIR (the designation of 'President' in science councils has since been replaced by that of CEO).

Sibisi was to become the third President to guide the organisation along the path of repositioning and re-configuration. This, he stated in 2004, was to ensure "that the CSIR remains true to its commitment to the nation, namely to foster industrial and scientific development in South Africa, contribute to economic growth and competitiveness, and to ultimately improve the quality of life of South Africa's people".

In order to more effectively fulfil this mandate, the CSIR embarked on a transformation process, which was implemented in the course of 2005/06, to ensure that the organisation returned to its core science purpose.

This entailed a change in priorities, with increasing emphasis on performing relevant, knowledge-generating research, building and transforming human capital, strengthening the science and technology base and promoting excellence.

Its new corporate identity – with its modernised logo and updated positioning statement – made its debut on 27 February 2006 at the first CSIR Biennial Conference. In line with its mandate, the CSIR's reconfiguration aimed to embody the key brand concepts of scientific excellence; innovation and quality; skills development; leadership in science; working

Advanced facilities, such as those housed at the National Centre for Nanostructured Materials (above), have replaced older facilities and buildings as they existed some 70 years ago (left).

CELEBRATING 70 Years Ideas that work

through partnerships; ensuring transformation and making a difference through science to build a better South Africa.

In 2011, Sibisi also placed an emphasis on growth and impact, responding to calls for the organisation to achieve greater impact. Findings of more than one review panel pointed to the organisation spreading itself too thinly, and that it would benefit from sharpening its focus. In making a decision about focus, the organisation had to take numerous factors into consideration. International development priorities, as set out in the Millennium Development Goals; the country's development priorities as outlined in guiding documents such as the National Development Plan 2030; and the organisation's competence base were taken into consideration. Going forward, the organisation would focus its skills and resources on the natural environment, defence and security, industry, energy, health, and the built environment, while nurturing and developing enabling technologies such as information and communications technology, nanotechnology and photonics.

In 2011, Sibisi also introduced an additional mechanism, called flagships, as a measure to boost uptake of technologies and ultimately improve the impact of the organisation's work. The bulk of the activities of these delivery and implementation programmes take place in the development and implementation phase. The flagships are derived from research and development outputs generated over time and focus on interventions that transfer technological solutions to external stakeholders. The flagships have been refined in the past few years and today focus on health, water sustainability, safety and security as well as capability development for state-owned company Transnet.

Ongoing honing of its focus is strengthened by efforts to establish closer relationships with stakeholders and regularly investigating the relevance of its work as well as refining its systems and processes to more easily guide the outputs and outcomes of its science, engineering and technology base to positions of uptake and use by government or industry. South Africa's triple challenge of unemployment, inequality and poverty; African and global opportunities to collaborate; and a changing global landscape influenced by international socio-political events and economic uncertainties mean that there is no room for complacency.

In 2013, then Minister of Science and Technology, Mr Derek Hanekom, said, "The CSIR's approach of looking at challenges from a systems or whole-environment point of view means that it can draw successfully from its multidisciplinary base to deliver a holistic solution as opposed to addressing only symptoms."

Technology transfer remains a priority and has seen significant refinement in the past decade. A World Intellectual Property Organization report of 2009 featured the CSIR as the top institution by Patent Cooperation Treaty patent application with a South African priority; revenues generated through commercialisation; and the number of start-up companies established.

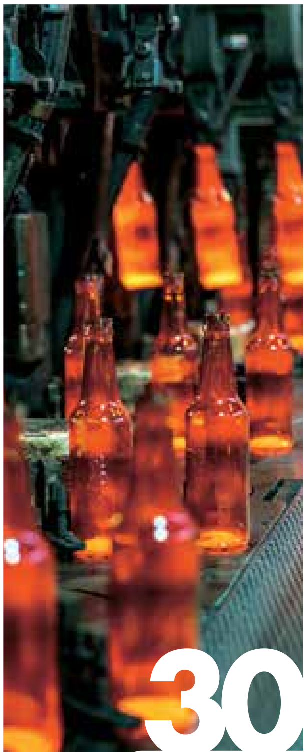
On the human capital front, the opinion of first CSIR President Schonland regarding the value of a dynamic and environmentally pleasing work place not only still rings true, but has been bolstered by solid and up-to-date work practices. So much so, that the organisation has been certified as a Top Employer based on independent research and international benchmarking of employee conditions of work.

Thus, while the CSIR has just come of age, it is also proud of its accomplishments. Any technology organisation would be pleased to count among its portfolio of achievements examples such as a camera that captures the invisible energy coming off a power line insulator and has captured some 50% of the world market, the lithium-ion battery powering the world's smart phones and laptop computers technology, and a mobile laboratory that simulates the traffic that a road would endure over 20 years in three months.

Minister of Science and Technology, Mrs Naledi Pandor, in the CSIR Annual Report for 2014/15, articulates it best, "Organisations like the CSIR must consciously marshal the evidence to demonstrate, in a compelling manner, that investments in research and innovation do, and will continue to, lead to greater prosperity, more jobs, and more entrepreneurs."

CONT


10 VISUAL SURVEYING PLATFORM


30 IEE INTERVENTIONS


36 INDIGENOUS FOODS ADDRESS MICRONUTRIENT DEFICIENCIES

BUILT ENVIRONMENT 8

ENERGY 20

HEALTH 32

INFORMATION SECURITY 44

ENTS

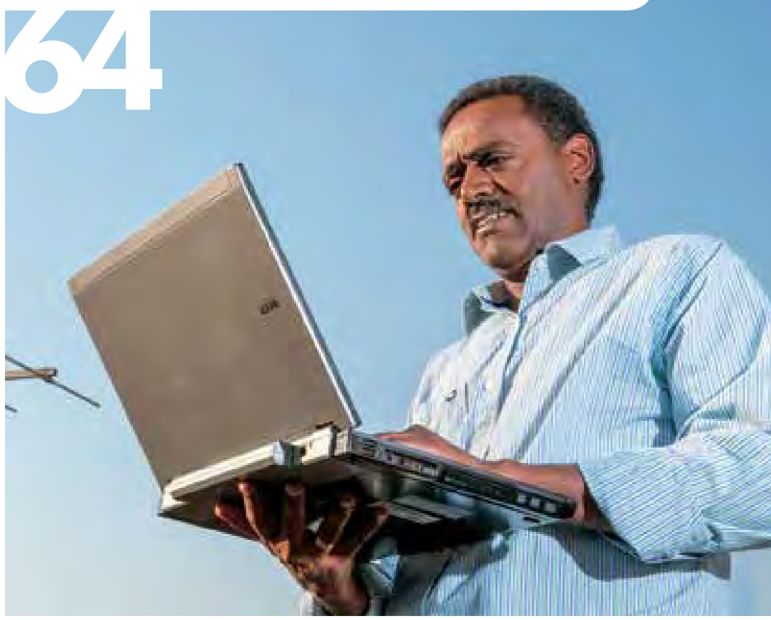
DEFENCE 50

ICT 62

INDUSTRY 74

NATURAL ENVIRONMENT 92

NEW BROADBAND OPPORTUNITIES THROUGH SMART SPECTRUM SHARING



PRODUCT DEVELOPMENT

MANAGING INVASIVE ALIEN PLANTS

Single rooms for patients with infectious diseases such as tuberculosis are fitted with multiple windows that can open to maximise the movement of air. Here, the warm air will rise to transport potentially infectious organisms through openings in the roof.

Doors on both sides of the room allow for maximum ventilation.

Health outcomes and service delivery are profoundly affected by the built infrastructure that supports them. Disease burdens and service response – which shape health buildings – change over time. Furthermore, these buildings are also required to be environmentally friendly and sustainable despite severe resource constraints in the public health sector. Taking these challenges into account, the CSIR has helped to develop norms, standards and guidelines to support the Department of Health in managing and expanding South Africa's public healthcare facilities in an efficient and sustainable way.

BUILDING TOWARDS GREEN AND EFFECTIVE HEALTHCARE INFRASTRUCTURE

By Peta de Jager

HEALTHCARE SERVICE DELIVERY relies on a complex interplay between a region's unique disease burden, the socio-economic challenges faced by its people and the availability of health resources, such as staff, scarce skills, equipment, supplies and infrastructure.

South Africa faces a compounded burden of disease which includes HIV/Aids, tuberculosis, maternal and child health challenges, violence and injuries, and emerging lifestyle diseases such as diabetes and hypertension. This is further complicated by a fragmented healthcare service where almost half of all healthcare spending is spent in the private sector – that only serves 16% of the population. This split has led to the duplication of service provision in some areas, while other areas have a lack or over-provision of services with institutions that are overburdened or not used optimally.

With South Africa already spending more than 8% of its gross domestic product on health, and other sectors competing for funding from a limited fiscus, spending on capital and operational projects is seriously constrained.

In addition, climate change and the pressure on the environment require that we increase efforts to limit energy consumption and manage waste and water use in facilities, while not compromising a safe and efficient healing environment needed for healthcare delivery.

Developing guidelines

Due to these unique challenges, the Department of Health cannot simply apply international guidelines in the South African context.

The CSIR was therefore commissioned to develop new norms, standards, guidelines and performance benchmarks that can be used to manage the acquisition, quality, delivery, operation and maintenance of all levels of public healthcare facilities in the country.

Multidisciplinary task teams with clinical and built environment expertise developed extensive guidance documentation and software tools, much of which has been gazetted as mandatory practice during the last two years.

Building design to prevent infection

An example of unique design requirements for South African healthcare facilities includes the solutions implemented to limit tuberculosis infection. Tuberculosis is transmitted through the air and is the leading cause of mortality in South Africa. Public health facilities can be adapted, designed and engineered to ensure that the risk of infection is limited, especially in high-burden settings where patients with infectious tuberculosis may come in contact with vulnerable individuals. Solutions include natural ventilation and careful spatial configuration.

The life cycle perspective and new approaches

The current replacement rate of South-Africa's healthcare infrastructure is approximately 40 years and in order to address building design from this perspective, a modification of traditional roles may be indicated to ensure sustainability. For example, optimising building ventilation is often assigned to the mechanical engineering discipline. Optimising natural ventilation, for example through rethinking building envelope design (thermal, air and water barriers), could redefine the traditional roles of architects and engineers. However, this approach needs to be considered during the pre-project stages of a building contract. Planners also need to take into account that the drivers of healthcare demand are dynamic. For example, a tuberculosis vaccine or new treatment could drastically reduce the need for an emphasis on prevention of this disease, while a worsening water crisis may shift the disease profile of certain regions to heat- and water-related conditions. Open building designs could provide more flexibility to adapt facilities in future.

A holistic approach

The guidelines consider clinical services as the key driver of health infrastructure and also cover support services such as waste management, central sterilising services, catering and laundry services, training and hospital administration, as well as guidelines for information and technology infrastructure, project planning, maintenance and the decommissioning of failing infrastructure.

The CSIR is now in a position to support government with structured capacity building and an implementation programme that will help to see a gradual replacement and improvement of healthcare building stock over time.

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Road defects such as cracks, edge breaks and potholes can have a negative economic and social impact. These road defects can damage motor vehicles, endanger the lives of motorists and pedestrians and lead to more costly road repairs. Timeous identification of road defects can help with the maintenance of road infrastructure. In response to this need, the CSIR developed a visual surveying platform to support road infrastructure inspections.

CSIR engineer Tumelo Motloutsi sets up the unit before operation.

VISUAL SURVEYING PLATFORM ASSISTS WITH ROAD MAINTENANCE

By Thegaran Naidoo

A CSIR-DEVELOPED VISUAL surveying platform assists with the maintenance of road infrastructure by timeously identifying and geo-locating road surface defects such as cracks, edge breaks and potholes.

The visual surveying platform consists of a vehicle-mounted sensor system along with an analysis and visualisation software suite. The sensor system comprises a high-resolution camera, a global positioning system (GPS) receiver and a computer with peripherals for wireless connectivity.

The sensor system is attached to a vehicle and driven through the area that is to be inspected. The system records synchronised video and GPS data which are then uploaded to a computer for analysis. The detections that are produced during the analysis stage are stored in a geographic information system (GIS) database where the defects may be viewed and validated by an operator. The operator can use the visualisation tool, which is a part of the system, to plan maintenance operations.

Current imported state-of-the-art systems that are used for road inspections cost more than R15m each. The visual surveying platform can be produced for an estimated R500 000. The lower cost implies that more units could be deployed, which would result in a higher area coverage at a higher frequency of updates. The visual surveying platform would thus provide decision-makers with a timeous first level estimate of the state of the road infrastructure to enable more effective planning of further maintenance operations.

The CSIR has issued a technology evaluation licence to Jetpatcher, a local repair company, to trial the visual surveying platform as part of its regular operations workflow. The Johannesburg Roads Agency has also expressed an interest in using the technology as part of its maintenance operations.

More about how it works: image processing and machine learning algorithms

The analysis module is a key component of the system and it uses a combination of image processing and machine learning algorithms to detect, classify and quantify road defects.

The visual surveying platform has three modes of operation – a manual mode, an autonomous mode and a hybrid mode.

In the manual mode the operator uses the software suite to watch the video stream and manually detect the defects from the video. Once detected, the size and geographic location of the defect are automatically calculated and stored in the database.

In the autonomous mode, the system automatically analyses the video stream to detect the defects before automatically calculating the size and location of the defect. During evaluation, the automated detection algorithm was able to detect a specified defect with an accuracy of 89%.

To improve the overall accuracy further, a human-in-the-loop or hybrid mode of operation was adopted. In the hybrid mode the system automatically analyses the video stream and suggests possible defects to an operator who then validates the detection.

The development team believes that the manual mode and hybrid mode would be suitable for integrating into the existing workflows of companies and municipalities that are involved in the maintenance of road infrastructure. Further improvements to the autonomous mode would be incorporated into the hybrid mode.

Future plans and applications

Although defects of different types can be extracted from the video stream, the current version of the visual surveying platform focuses on detecting and estimating the size of potholes. During one investigation the team also developed an algorithm to detect road signs. The team has since received requests from the South African Road Traffic Sign Manufacturers Association and a road defect repair company to further develop the road sign detector, as they have a need to geo-locate road signs to determine if they are placed correctly or if they may be missing.

Future development plans for the system include improvements on the detection and estimation accuracy of the system and the development of a backend that integrates the data over all deployments of the visual surveying platform.

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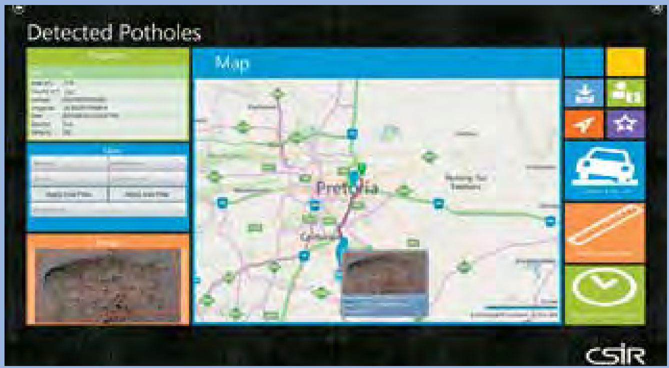

The visual interface for detected potholes.

The hardware system of the Visual Surveying Platform.

Creating safer coastal and port infrastructure with innovative physical and numerical modelling

By Kishan Tulsi

Recent innovations have allowed the CSIR coastal and hydraulics laboratory to create more accurate numerical and scaled physical models of coastal and port infrastructure. These models provide invaluable performance measurements of planned coastal infrastructure, such as the design life of a harbour or breakwater. They support infrastructure decisions and shipping operations within a port.

THE CSIR COASTAL and hydraulics laboratory team is able to create numerical models of planned port or coastal infrastructure as a result of a series of innovations developed and implemented. These models are then used to create accurate physical scale models of port layouts or breakwater designs that can be tested in the CSIR's advanced coastal and hydraulics model facility. Subsequent experiments and induced wave testing generate accurate datasets which allow us to understand the dynamics of waves, coastal structures and ship motions. This assist engineers to determine the force limitations and design life of planned infrastructure.

This innovative 'hybrid modelling' approach is typically applied to the monitoring and tracking of breakwater armour unit displacements to calculate damage to breakwater structures and the monitoring and measurement of moored vessels inside ports. Custom software in these experiments use physical model simulation data to accurately compute the forces exerted on mooring lines and fenders based on the motion of docked vessels.

Some of the innovations and systems routinely used by the CSIR coastal and hydraulics laboratory are outlined in this article.

Tracking movement in a physical model: The Armour Track System

The Armour Track System is a digital image processing system which is used to track movement in a physical model. This involves the capturing and processing of high-resolution digital images and high-definition laser scanning data of physical models, including the movement

Two of the technologies pioneered at the CSIR hydraulics laboratory are the Keofloat system, where the movement of small lightweight floats (seen top right) are studied to measure the effects of long waves on ships and the Armour Track System, that combines high-resolution images from mounted cameras (opposite page) with laser scanning data of physical models such as breakwater units to track the movement of physical models. The CSIR's Kishan Tulsi (left) at work during extensive tests on a detailed model of the Richards Bay breakwater.

of separate breakwater armour units, to visualise the extent of damage to prototype breakwaters as a result of wave impact on coastal structures.

Measuring long waves: The Keofloat and Keoship systems

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 300 seconds. This frequency resonates with a moored carrier and can result in disruption of harbour operations and even broken mooring lines. The second threat is high winds.

Both threats can be managed by adjusting the mooring systems, but also by installing early-warning systems based on real-time and stand-alone measurements of environmental parameters, such as waves, currents, tides and wind.

The CSIR has developed a system that allows the organisation to measure waves that are smaller than 10 mm in height. The system consists of small lightweight floating blocks, called Keofloats. These floats are tracked by a standard video camera and are insensitive to erratic gauge drift caused by temperature and resistivity in cables. With the Keofloats, noise levels are therefore very low and they do not require separate calibration. The Keofloat system complements the capacitance wave gauge equipment at the laboratory with the benefit of having focussed on multiple floats recording the wave climate surrounding the model ships in a physical model. The Keoship system allows for the monitoring of model ships, which includes mooring lines and fender force calculations.

Numerical models for ship motion: WAVESCAT, PASSCAT & QUAYSIM

Three numerical models for ship motion studies, moored ship response and wave-ship interaction are researched. The WAVESCAT model computes wave forces and hydrodynamic forces on a ship or other floating bodies. The ship's hull and the submerged surface of other nearby structures are covered with a large number of flat quadrilateral panels on which the pressure and the velocity in the fluid are computed. Combining the pressures over the submerged hull gives the total wave force on the ship.

The PASSCAT model computes hydrodynamic forces on a moored ship caused by another ship passing in a channel. Finally, the QUAYSIM model computes the ship motions and mooring line forces of a ship moored at a quay or a jetty due to waves, current and wind.

These models can be interconnected so that the results of PASSCAT and WAVESCAT feed into QUAYSIM to accurately determine the motions of a moored ship.

Monitoring nearshore conditions in bays: Virtual Buoy System and Harbour Watch

Until recently, national wave information was captured using waverider buoys deployed around the South African coastline. However, the CSIR is developing a virtual system that can monitor nearshore conditions in bays.

The Virtual Buoy System and Harbour Watch system have already been used in Table Bay, Saldanha Bay and Mossel Bay. The Virtual Buoy System uses numerical models to provide real-time forecasting of wave data at multiple locations – pilots use this information while navigating ships at these ports. Harbour Watch is a camera-assisted system that provides digital information ranging from user-friendly visual geo-referenced records to ship motion data for improving safety around port operations.

Calculating the maximum allowable safe draught of a ship: DMAX

DMAX is a numerical model decision-support system for the calculation of the maximum allowable safe draught of a ship entering or leaving a port. This decision-support system computes the ship's squat and vertical motion response in waves, and incorporates probabilistic safety criteria. These components are applied to a specific vessel under a particular sailing condition in the harbour channel. The DMAX computations can be made for present conditions and for up to three days in advance, by using measured and predicted tide levels and wave conditions.

The CSIR team of coastal engineers uses these systems and innovations to ensure that South Africa's coastal and port infrastructure is safe, reliable and protects people from harm.

Routinely, the CSIR coastal and hydraulics lab is also contracted to test planned port or coastal infrastructure projects from around the world and has built up a proud reputation of reliability and service excellence in this regard.

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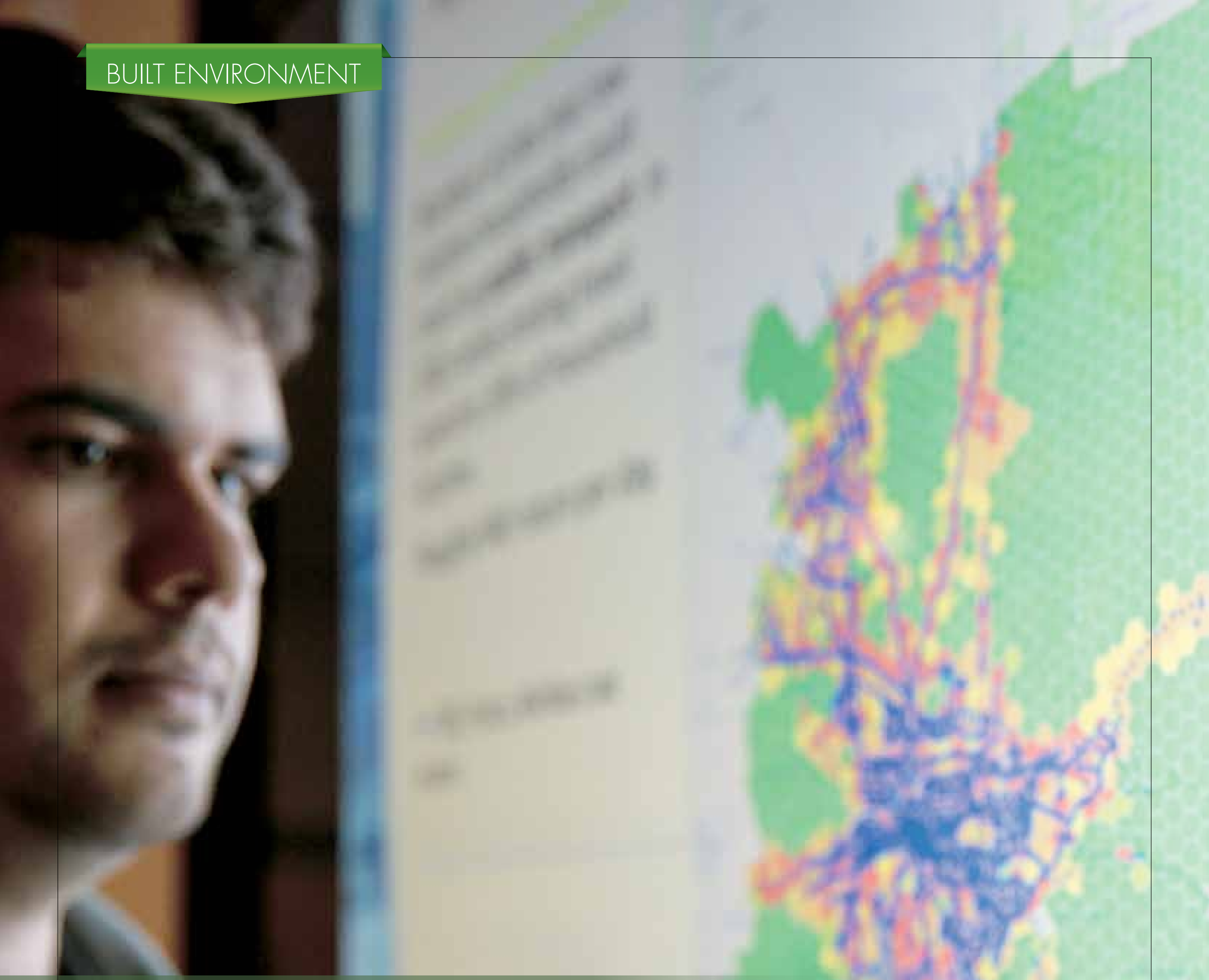
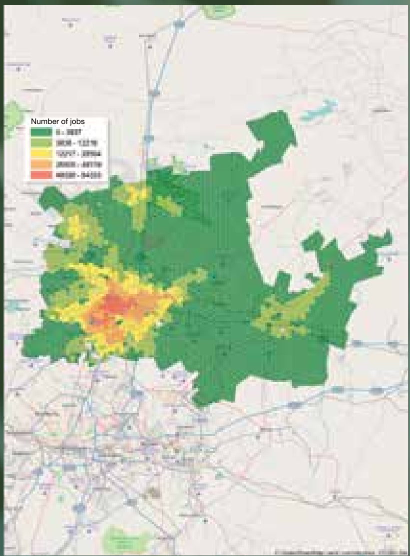
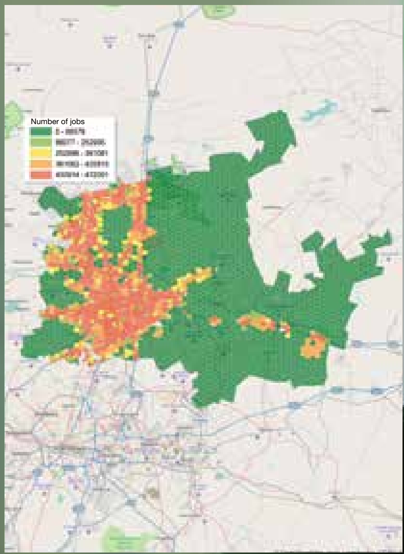


Access to jobs: Private transport



Access to jobs: Public transport



The CSIR's Quintin van Heerden and his colleagues have undertaken integrated land-use and transport modelling in which the link between public transport and increased accessibility to jobs was demonstrated. The graphs show the clear difference in the access to jobs that exist with only private transport, compared with public transport. Residents in the best located areas (shown in red) are able to access more than five times the number of jobs compared to what they would have been able to access without public transportation (in some cases more than a 100 times).

Integrated land-use and transportation modelling in developing countries

By Quintin van Heerden • Co-author: Dr Louis Waldeck

Large cities are amongst the most complex production systems ever built. Land Use Transportation Interaction (LUTI) models are often used to support the equally complex urban planning processes that shape our cities. The CSIR has developed a LUTI model, based on adapted versions of UrbanSim and OpenTripPlanner, which has been used to simulate spatial growth patterns in South Africa to better understand the future demand for infrastructure and services. The model has proven that there is a clear and demonstrated link between public transport and increased accessibility to jobs.

IN THE DEVELOPING WORLD, mobility challenges and the role of government in providing infrastructure are significantly different from those in the developed world. Factors such as extreme poverty and income disparities as well as mounting demands for basic services such as clean water, sanitation and healthcare, result in daunting challenges for urban planners in developing countries.

Government also needs to balance investment in economic infrastructure and social infrastructure and services. On the one hand, transportation and energy supply systems would enhance economic competitiveness. On the other, no monetary return is expected when providing basic necessities such as access to water, sanitation, and healthcare or interventions such as grants/subsidies aimed at alleviating the plight of the poor.

To aid infrastructure decision-making and urban planning processes, urban planning models are often used to investigate the likely outcome of adopting various policy scenarios. A CSIR research group focusing on spatial planning and systems for urban and regional planning has developed a Land-Use Transportation Interaction (LUTI) model that can be used to evaluate the effect of policy scenarios on, for instance, densification in the city. The model is based on adapted versions of two open source software packages: OpenTripPlanner (OTP), a platform to plan multi-modal transport itineraries; and UrbanSim, a state-of-the-art platform to simulate the urban growth patterns resulting from the decisions made by the main actors in an urban system.

Poorer households spend a larger portion of their income on transportation than wealthier households. One would therefore expect the choices made by poorer households about where they live and work to be more sensitive to transport costs than travel time. This is one reason why accessibility measures based on monetary costs could be a more representative model for South Africa (and possibly other developing countries) than one based on travel times or generalised cost.

As an input to the model, we created a road network from OpenStreetMap, an open-source, crowd-sourced road network. The public transport services were specified using the General Transit Feed Specification (GTFS), which is a format developed by Google to publish public transportation schedules. We adapted OpenTripPlanner to calculate the lowest-cost commuting trips between all origin-destination pairs in the study area, taking into account different modes of transport that include private car usage, buses, trains and mini-bus taxis. These calculated costs are then used in UrbanSim to calculate measures of accessibility to jobs, which could in turn influence where households choose to live and work.

The benefit of public transportation to low-income households can be seen from the two maps of the City of Tshwane, illustrating the number of jobs (opposite page) that can be accessed by private and public modes of transport while limiting transport expenditure to 30% of household income, which equates to about R40 per day. Census data for 2011, as published by Statistics SA, were used to derive this cost for low-income households. Residents in the best located areas (shown in red) are able to access more than five times the number of jobs compared to what they would have been able to access without public transportation (in some cases more than a 100 times).

In addition, the number of jobs that can be reached as a percentage of the total available jobs also increases with the availability of public transportation.

The model was validated by comparing the household growth per analysis area (about 3km^2) obtained from the simulation model to the actual growth that occurred over the same period of time (2001 to 2011) according to two reputable sources: GeoTerraImage (GTI) and National Census. Some of the outliers in the comparisons could be explained by, for instance, the fact that the delays in legal processes experienced by real-life developers are not known to developers in the model. If these outliers are excluded, the predictive accuracy of the model is estimated at about two housing units per hectare.

About 10% of the GDP is invested annually into building and operating infrastructure and facilities in metropolitan municipalities alone. Many of these investments are aimed at enhancing the long-term sustainability of our cities and overcoming the spatial inefficiencies inherited from the past. This type of simulation can contribute significantly to the debate and eventual decisions aimed at stimulating the economy by way of increasing the efficiency of our cities and improving access to employment opportunities.

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Municipal service delivery SET for success

By Samantha Naidoo and Renee Rahaman

Numerous implementation challenges have led to poor and ineffective service delivery in South Africa. The CSIR assists local government to provide effective and efficient service delivery with the aim of improving the quality of life of South Africans. Its municipal strategic programme support group has developed a three-phased methodology that shapes the identification and implementation of integrated scientific, engineering and technological (SET) solutions to enhance current service delivery levels.

LOCAL GOVERNMENT has a mandate to deliver on key priorities to ensure visible, tangible and positive changes in all communities.

However, local government faces a number of implementation challenges, including aged and insufficient infrastructure; poor financial management and insufficient funding allocation; inefficient natural resource management; and lack of capacity building and skills transfer.

Implementation of innovative solutions

Piecemeal solutions are likely to prove ineffective in local government since problems with service delivery sectors are often interlinked. The CSIR is able to assist, mainly because of the organisation's ability to:

- Understand municipal problems at systems level through close interaction with local government, and
- Develop and execute integrated solutions by identifying and eliciting the required technical competence from within the CSIR as well as from collaborators and service providers, where necessary.

Continual innovation in the integrated application of science, engineering and technology allows for the design and implementation of the most appropriate solutions to address identified municipal challenges. The CSIR's methodology enables the identification of implementation challenges as well as the design and execution of integrated SET solutions.

The methodology has three broad phases, illustrated in Figure 1.

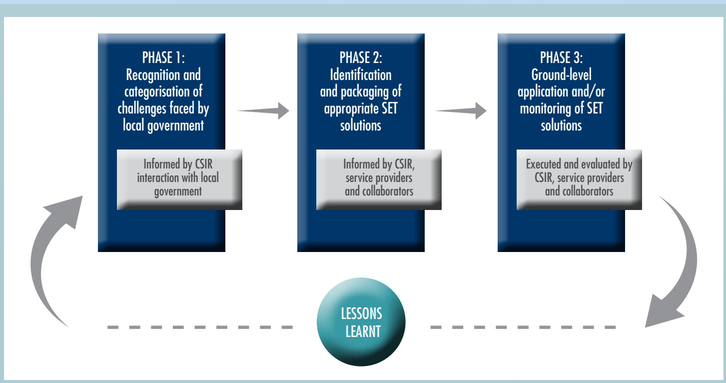

Figure 1: Methodology employed by the CSIR for developing and applying SET solutions

PHASE 1: RECOGNITION AND CATEGORISATION OF CHALLENGES FACED BY LOCAL GOVERNMENT

Three main drivers assist the CSIR in recognising and categorising high-level challenges: market pull, (public) sector partner mandate and business intelligence.

The dynamics between these three drivers influence the CSIR's services and feed into the local government's Municipal Financial and Performance Management System. This system monitors actual performance of municipalities against set targets and contractual obligations.

PHASE 2: IDENTIFICATION AND PACKAGING OF APPROPRIATE SET SOLUTIONS

The CSIR's multiplicity of competences and services as well as those of service providers and collaborators are interrogated, combined and discussed with the client to determine the most appropriate SET solutions.

Appropriate solutions are proposed to the municipality as a suite of projects. Assistance with implementation and/or monitoring of these projects is also offered.

Furthermore, the CSIR develops and transfers skills as part of proposed projects with the aim of increasing relevant competency and capacity within municipalities.

PHASE 3: GROUND-LEVEL APPLICATION AND/OR MONITORING OF SET SOLUTIONS

The implementation and monitoring of SET solutions are designed to meet legislative, technical and management requirements; this is spearheaded by the CSIR, in conjunction with service providers.

All lessons learnt are recorded and fed back into the methodology which may result in changes to the tasks or scope of tasks, or the development of an amended methodology.

The CSIR supplies specialised services to support municipalities at different stages of the water value chain. These pictures in KwaZulu-Natal show water quality monitoring and assistance with preparation for SANAS accreditation.

Case Studies: Municipalities within KwaZulu-Natal and Mpumalanga

The CSIR has applied the methodology to projects at particular stages of the water value chain for the City of uMhlathuze, Capricorn District Municipality and eThekwini Metropolitan Municipality. The CSIR, collaborators, service providers and relevant officials within these municipalities were involved in the design, implementation and monitoring of these projects.

The purpose of the projects was to assist the respective municipalities to effectively plan and manage water resources and wastewater within their jurisdiction and, where possible, build the required in-house skills and capacity. Integrated SET solutions were developed through the joint effort and input of all parties, and packaged and presented to each municipality.

A lake management plan for the City of uMhlathuze

The CSIR was appointed by the City of uMhlathuze to develop a lake management plan for Lake Mzingazi, near Richards Bay. The objectives of the project were to compile a plan based on relevant scientific studies and establish a forum to lead the implementation and periodic revision of the plan. This project drew on the expertise of freshwater and marine specialists. Inputs from external specialists as well as a social specialist were used to identify and prioritise potential environmental impacts, and recommend appropriate management and monitoring measures for implementation. A robust stakeholder engagement process was run in parallel.

Blue and Green Drop projects

Scientific analysis is conducted in both the Blue and Green Drop projects to improve overall water and wastewater management within the municipality. The Blue Drop project is currently being implemented in the Capricorn District Municipality, while the Green Drop project is being run in both this municipality and the City of uMhlathuze. The CSIR provides suitable site-specific recommendations to mitigate and manage process failures as well as improve general operations within the water and wastewater treatment plants. The lessons learnt and data gathered will be used to design and apply predictive modelling in future. This will allow the CSIR to predict the potential impacts of a range of effluents on various types of wastewater treatment works. Based on this, measures to ensure optimum functioning of the plants for desired results will be identified. Predictive modelling can also be used to inform the operations of water treatments works to ensure that water is treated to acceptable standards for its various uses.

Water quality monitoring

The CSIR has manufactured and installed a water quality monitoring system at water and wastewater treatment works in the City of uMhlathuze and the Capricorn District Municipality, and at a strategic location along the uMhlangane River in the eThekwini Municipality. This system measures the levels of specific water quality parameters and communicates measured data to a CSIR-hosted database and online platform, using a CSIR-developed telemetry system. Complementary CSIR laboratory analysis of collected water samples determines faecal coliform and *E. Coli* counts, which are not currently measured by the system.

The system is based on existing technology and includes real-time data transmission capability (software and hardware). As the focus of the system is management of water quality, the system is designed for the easy upload and interpretation of water quality data to highlight key issues of concern, and to direct efforts and resources effectively. The actual value of this system lies in its ability to enable the remote management of water quality and the implementation of real-time responses.

Accreditation by the South African National Accreditation System (SANAS)

A CSIR laboratory accreditation system specialist is assisting the City of uMhlathuze and the Capricorn District Municipality with preparations for SANAS accreditation by applying knowledge of ISO 17025. The project involves facilitating the implementation of pre-determined scientific methods to ensure the accuracy and reliability of laboratory analysis and compliance with the standard requirements and procedures. This reduces local government's reliance on external SANAS accredited laboratories and builds their in-house capacity.

Input into tertiary-level curriculum

The CSIR has provided the University of Limpopo with inputs on its water quality and sanitation curriculum. This was accomplished by conducting a gap analysis on existing courses and recommending possible additions. Capacitating students within the water and sanitation field will support skills development and transfer at municipal and provincial levels.

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The CSIR's Samantha Naidoo discusses a management plan for Lake Mzingazi, near Richards Bay, with Neeran Maharaj of the City of uMhlathuze.

MAKING SMARTER DECISIONS IN URBAN ENVIRONMENTS

By Dr Daan Velthausz

Making informed decisions for a city and its inhabitants is difficult since this complex environment is made up of many domains, actors, resources, asset pools, factors and performance criteria. Using smart information and communications technology-based empowered solutions, capable of making sense of the growing amount of data, enables well-informed decisions and sound planning (both in the short and long term).

INCREASING URBANISATION has introduced and exacerbated challenges related to the management of resources for service provision. Making informed decisions for a city and its inhabitants is difficult because it is a complex environment with many integrated and inter-related factors and actors to consider.

Making sense of the fine-grained usage data (e.g. via smart meters) allows for better decision-making, effective solutions, adequate actions (e.g. energy savings via demand-side and load management, dynamic street lightning, efficient buildings, reducing water losses by detecting water leakages, providing travellers with real-time traffic, and public transport information that culminates in reduced travel and commute times). This leads to predictive usage forecasting for the short and long term (e.g. using automated urban settlement classification and expansion detection; using acoustics indicating the stability of constructions). Being more aware of what is going on in the city, as well as accurately predicting what might be happening in the (near) future, allow the citizens and the city managers to be better prepared (e.g. via early hazard warning), to adapt and to make informed decisions (e.g. dealing with safety, resource usage, urban planning of infrastructure and proactive maintenance).

Urban planning of road, water and energy infrastructure requires knowledge of resource usage and the nature of growth of expanding areas (new settlements and changes in settlement types) in order to deal satisfactorily with the increasing and related demand for road use, water and electricity.

Using information from multiple domains in urban planning (such as projected energy demand based on short-term weather forecast, long-term settlement resource demands, and available energy capacity) provides better and early insight. As a result, targeted interventions based on the insights become possible. Similarly, more effective operational decisions affecting the current state become possible if data are available describing the current state of the environment, which can include near real-time measurements of consumption as well as current weather conditions.

Potential impact of smarter decision-making

Better understanding of the bigger picture would enable alleviating measures to be put in place to deal with water distribution, traffic congestion and power consumption as a whole, rather than dealing with the consequences, related issues and challenges in each domain individually.

However, making decisions in one domain by drawing upon insights from other domains is difficult. Currently, most decision-making processes are set up to operate exclusively within a single domain.

The challenges to enable smarter decision-making are:

- Sourcing, delivering, storing and integrating large-scale decision data from multiple domains
- Processing and interpreting data within the required time constraints and with the desired accuracy, and
- Influencing and creating impact through appropriate feedback channels and mechanisms.

The key aspects of these challenges relate to the integration of the required system componentry ('the binding glue'), the integration of the data needed for decision-making, the algorithms needed for decision-making, and lastly how to present and visualise it to the decision-maker tailored to his context and purpose.

Future proof solutions must be scalable (capable of handling and processing huge and rapidly increasing volumes of data), open (both technology and data-wise), interoperable, transparent (how a particular decision is derived), affordable and secure (trustworthiness of technology and data).

The CSIR's focus in this regard is to expand on current research and development and associated technologies through the Smart World Growth and Impact Initiative, to either extend existing platforms, combine it with similar offerings or to develop new components for an evolving platform that enables smarter decisions. The evolving platform will be scalable, open, interoperable, transparent and secure. It will be linked to appropriate data sources, with fit-for-purpose applications to assist in contextual decision-making in targeted domains.

The approach follows these principles:

1. Integrate existing, adapted/upgraded componentry into an evolving platform supporting – and concurrently researching – better planning and operational decision-making in urban environments.
2. Deploy and demonstrate the decision platform in contexts

that are already demonstrating challenges associated with mass migration to specific areas.

3. Use the Urban Living Lab approach to stimulate citizen engagement, as is adopted in the Smart City Strategy and Implementation Plan of City of Johannesburg (2014), by fast tracking and co-creating solutions in real life context.

The CSIR has developed a 'Smart Platform' and applied it in the energy, as well as the safety and security domains in the context of smart cities. The current version of the platform supports decision-making for energy-efficiency improvements and demand management for individual home and building owners with the ability to scale up the platform to service large utility distribution networks and aid decision-making for utility providers and city managers.

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Towards the development of hydrogen storage technologies for clean energy applications

By Dr Henrietta Langmi

Finding a way to more easily store hydrogen, at ambient temperatures and without too much added weight or cost, would set hydrogen free as a potential clean energy alternative to fossil fuels. The CSIR is examining three possible options for hydrogen storage, namely storage in high pressure gas cylinders, storage in the form of chemical carriers and materials-based storage.

WITH A GROWING HUMAN POPULATION and an increasing standard of living there is an increase in energy demand across the globe. In fact, energy is a vital requirement for the development of a modern society. Most of the energy consumed today comes from fossil fuels. However, the rapid depletion of fossil fuel reserves and the concomitant environmental impact of burning fossil fuels have led to the search for alternative sources of energy. The ideal energy source should be abundant, environmentally benign, affordable and safe.

For several reasons, hydrogen is considered an energy carrier that holds tremendous promise for vehicle, stationary and portable power applications. Hydrogen is the third most common element on the Earth's surface, although less than 1% occurs in its free form as molecular hydrogen gas. Hydrogen can be generated from clean and renewable sources, for example, by electrolysis of water linked to renewable energy like solar energy. Hydrogen is further considered clean because when combined with oxygen in fuel cells to generate electrical energy, the only by-product is water. Hydrogen has a high energy density on a mass basis, which is about three times higher than that of other liquid hydrocarbon fuels like petrol.

However, despite hydrogen being an attractive energy carrier, there are still technical challenges associated with its efficient production, storage and utilisation in fuel cells. Of these three areas, hydrogen storage presents the greatest challenge.

As a gas at ambient conditions, hydrogen has a low energy density by volume, which makes it very difficult to store or transport, and therefore requires a storage method which compacts it. At normal temperature and pressure, a volume of one litre of hydrogen gas has an energy content of only 0.011 MJ, while a litre of petrol for example, has an energy content of 32 MJ. Developing a viable hydrogen storage system is crucial. Generally, such a system should store a large amount of hydrogen on a mass and volume basis, have an excellent rate of hydrogen uptake and release, good recyclability and low cost. Due to volume and weight constraints, the requirements for on-board vehicle storage are particularly stringent.

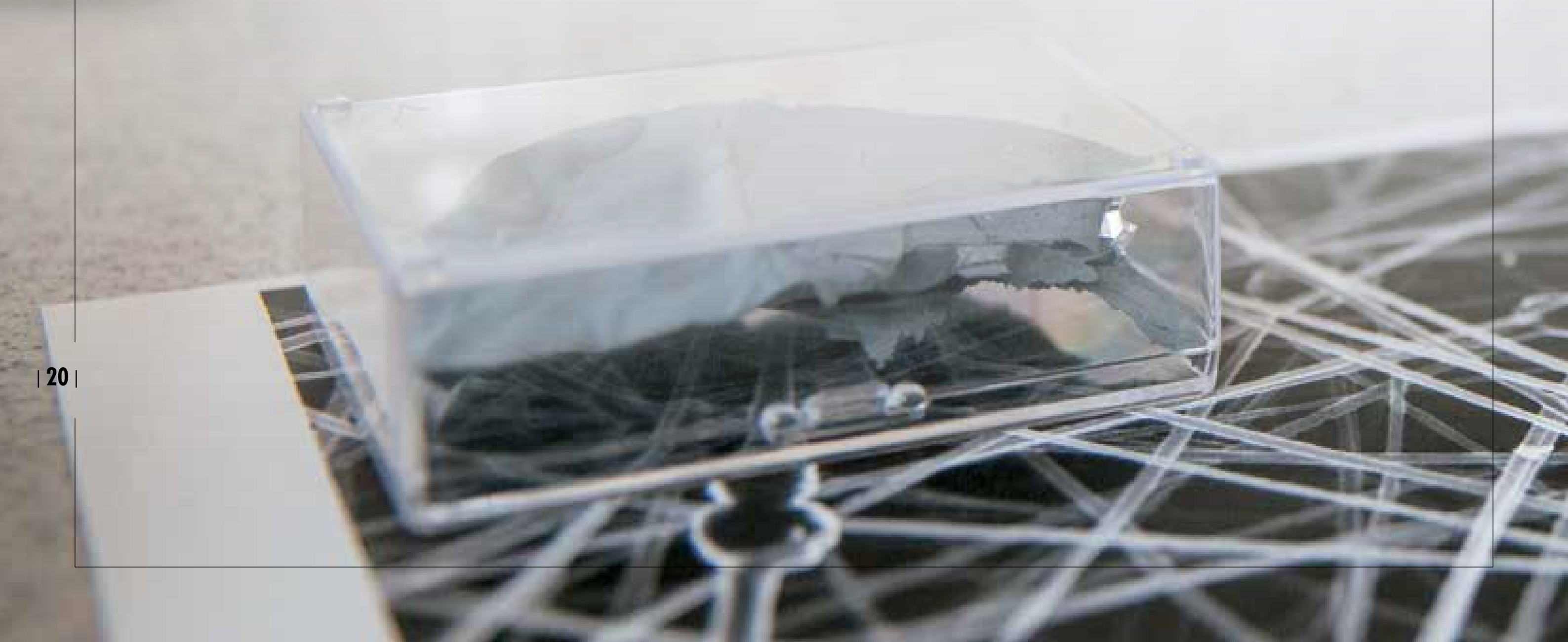
The Department of Science and Technology developed South Africa's national hydrogen and fuel cells strategy, branded as Hydrogen South Africa (HySA), which aims to develop and guide innovation along the value chain of hydrogen and fuel cells nationally. The HySA Infrastructure Centre of Competence – jointly hosted by the CSIR and North West University – is developing innovative solutions to the hydrogen storage challenge.

Currently the CSIR is examining three possible options for hydrogen storage, namely storage in high-pressure gas cylinders (called Type IV cylinders); storage in the form of chemical carriers, specifically formic acid; and materials-based storage (metal-organic frameworks and carbon nanostructures).

High-pressure composite cylinders

In terms of cylinder storage, the CSIR is examining ways of creating stronger, lighter cylinders at a reduced cost. Specifically, the research team is looking at the composition of the composite matrix used for the overwrap outer layer of the cylinders, which provides the cylinder's strength.

The effect of the incorporation of nanomaterials as a strength-



Key analytical instrumentation in the hydrogen storage laboratory.

Hydrogen storage material pellets for incorporation in a storage tank.

enhancer in the matrix is being investigated. The goal is to develop a better matrix, produce samples of this material for testing and produce full high-pressure composites for non-destructive and destructive testing and for use on-board a demonstration vehicle.

Chemical carriers

Parallel to the development of a composite matrix is the evaluation of liquid carriers like formic acid, as a means of storing and transporting hydrogen, and also the development of porous materials for hydrogen storage.

When formic acid is decomposed in the presence of a catalyst, hydrogen and CO_2 is generated. With a chemical carrier, a closed cycle is created because the CO_2 that is produced as by-product can be combined with hydrogen, in the presence of a catalyst, to regenerate formic acid. The CSIR is working on getting the decomposition reaction just right, by determining the optimum conditions, catalyst and reactor for this kind of process.

Materials-based storage

Materials-based storage involves storing hydrogen inside certain porous materials such as metal-organic frameworks. For this research, South African minerals like chromium, zirconium and platinum group metals are used. The advantages of storing hydrogen in porous materials are that storage takes place as a physical interaction, with no chemical bonding required, and the uptake and release rate (of stored hydrogen) is therefore faster. The main drawback is that this kind of storage can currently only be performed at cryogenic temperatures (typically, –196 degrees Celcius). The CSIR is therefore looking at improving the properties of these materials to make storage possible at closer to ambient temperatures.

The existing facilities enable the full characterisation of the materials being developed, and measurement of their hydrogen storage properties. To build prototype hydrogen storage units, the best powder materials developed are shaped to give them application-oriented configurations. The ultimate aim is to develop practical, affordable and safe hydrogen storage for use in selected clean energy applications.

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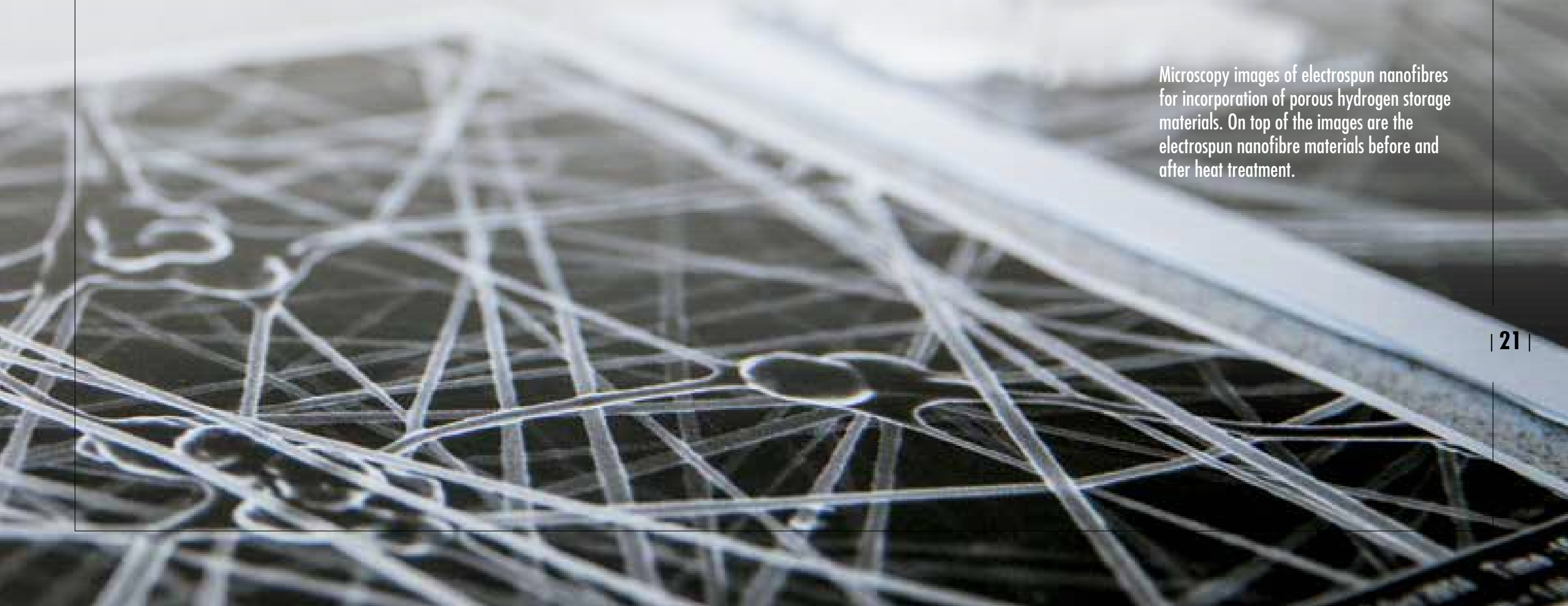

Microscopy images of electrospun nanofibres for incorporation of porous hydrogen storage materials. On top of the images are the electrospun nanofibre materials before and after heat treatment.

ADVANCED ENERGY STORAGE: Creating impact for next-generation lithium-ion batteries and supercapacitors

By Prof. Kenneth I. Ozoemena

CSIR chemist Funeka Nkosi testing coin cells.

Coin cell battery assembling and testing.

A reactor for the large-scale preparation of battery and super-capacitors materials.

A glovebox used for battery assembling. With this process, work is done inside the machine, protecting the cells from any harmful factors.

Lithium-ion batteries and supercapacitors are critical energy storage systems that power our smart phones, laptop computers, electric vehicles, smart grids and even our homes. They also play a role in decreasing the necessity for load shedding by alleviating the pressure on the national grid. The CSIR is developing the next-generation lithium-ion batteries and supercapacitors using some of the country's abundant mineral resources.

THE CSIR HAS DEVELOPED a novel method to produce high-voltage cathode material using lithium manganese nickel oxide. The organisation is currently producing this material at a kilogram scale as a precursor to pilot plant design, taking the work one step closer to commercialisation.

Ongoing pursuit for viable energy storage systems

Rechargeable lithium-ion batteries and supercapacitors continue to capture global attention as viable electrical energy storage systems. Market analyses continue to predict that lithium-ion batteries and supercapacitors will dominate electrical energy storage technologies for a plethora of applications, ranging from portable electronics to electric vehicles and smart grids.

The past five years have witnessed rapid developments in the global quest for clean and sustainable energy and seemingly endless releases of new technologies that use lithium-ion batteries and supercapacitors as main power source. These technologies include portable electronics and consumer products such as laptop computers, mobile phones, tablets and digital cameras; electric vehicles such as the Tesla Model S, BMW i3, Nissan Leaf and Chevrolet Volt; and home energy storage devices, notably Tesla's Powerwall® that was launched on 30 April this year.

Complementary energy storage

Batteries and supercapacitors are complementary energy storage systems and have become very useful in grid/utility-scale energy storage. They offer critical services such as security of electricity supply, mainly as power back-up or to avoid the problems of load shedding; price arbitrage (storing electricity during the off-peak periods when the cost of electricity is cheap and using it during expensive peak times); industrial peak-shaving or demand charge reduction (using stored electricity during peak periods to avoid penalties for breach of contractual peak demand), and for island and off-grid storage to augment renewable energy sources such as solar and wind power used by people who live or work in remote areas.

Research efforts amplified

Despite the increased importance of lithium-ion batteries and supercapacitors, the development of these energy storage systems has been slower than the rate of development of new technologies in need of these systems. To add to the challenge, existing lithium-ion batteries and supercapacitors still fall short of some critical requirements such as energy density (the ability to generate energy for a long period of time after being charged), power density (the ability to generate energy when needed at a very short time), extended system life (10-15 years) and safety to the user and the environment (not being prone to catch fire during use or the component materials being toxic to the environment). To mitigate these challenges, it is important to develop innovative materials and advance our understanding of the chemistries underlying their performance. Further breakthroughs in materials hold the key for developing the next generations of lithium-ion batteries and supercapacitors.

The CSIR has, in the past six years, been engaged in designing and synthesising several new materials for the development of manganese oxide-based lithium-ion batteries and supercapacitors. Improving lithium-ion batteries mostly centres on the choice of chemicals. One of the main benefits of the envisaged new lithium-ion batteries is low production cost, as its major raw material, manganese, is abundantly available in South Africa. Because it is a high-voltage material, it can be used to develop lithium-ion batteries with high energy. This gives the batteries the ability to be used over an extended period.

The chemical processing strategy that the CSIR has adopted to improve the performance of the materials for lithium-ion batteries and supercapacitors is what may be termed as *quadruple combination processes* which are (i) nanostructuring or nano-sizing of the product particles, (ii) doping or integrating small amounts of relevant chemicals into the parent structure, (iii) surface-modification of the parent structure with appropriate coating chemicals, and (iv) microwave irradiation as a key step in the synthesis scheme. Each of these processes plays a critical role in improving the performance of the final product. For example, the CSIR has found that nanostructuring improves the power performance of the batteries and supercapacitors by shortening the distance through which ions can travel within the chemical structure, while microwave irradiation can stabilise the structure against the untimely loss of energy during operation. Succeeding with this research will mean that local raw materials, such as manganese, can be utilised and beneficiated to create advanced, world-class energy materials at lower costs than would otherwise have been possible.

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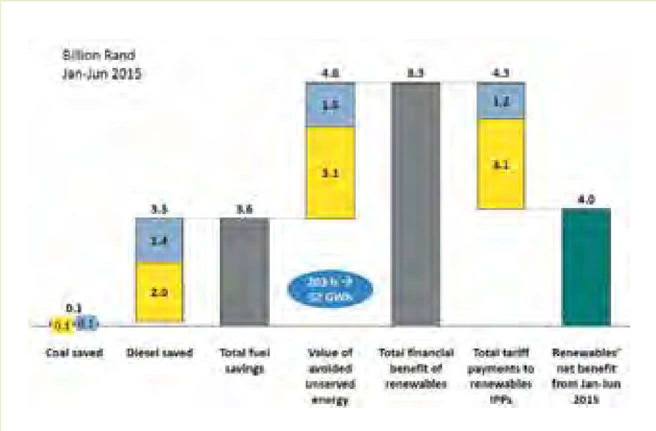
QUANTIFYING THE FINANCIAL BENEFITS OF WIND AND SOLAR ENERGY PROJECTS IN SOUTH AFRICA

By Joanne Calitz, Crescent Mushwana and Dr Tobias Bischof-Niemz

The first wind and solar photovoltaic projects that were connected to the South African national power grid in 2014 resulted in a net financial benefit to the country of R0.8 billion. In a subsequent study the CSIR has determined that in the first six months of 2015, wind and solar projects created R4 billion more financial benefits to the country than what these projects cost. This seems to indicate a trend where the financial benefit of renewables in South Africa far exceeds their cost.

The CSIR has quantified the financial benefits of the first solar and wind renewable energy projects (such as this wind farm in the Western Cape) that were connected to the South African national power grid in 2014. A subsequent study calculated the benefits of renewables from January to June of this year.



This graph shows how the total net benefit from renewable energy projects was calculated for the period from January to June 2015.

AN INDEPENDENT STUDY BY THE CSIR has found that renewable energy from South Africa's first wind and solar photovoltaic projects created R4 billion more financial benefits than what these projects cost during the first six months of 2015 (January to June). Without these wind and solar projects, South Africans would have had to endure a higher stage of load shedding during 15 extra days during this period.

The study is an update and continuation of an initial study that was published in January 2015 that covered the 2014 calendar year. In that initial study, it was shown that renewable energy projects generated 2.2 TWh (terawatt-hours) of electricity in 2014, which saved R3.6 billion worth of fuel for the conventional fleet (mainly coal and diesel fuel). The availability of renewables furthermore avoided the curtailment of customer load, with an additional macroeconomic value of R1.7 billion. The total financial benefit of renewables to the country was therefore R5.3 billion in 2014, compared to R4.5 billion in tariff payments to the owners of the wind and solar photovoltaic projects in the same year. This resulted in a net financial benefit to the country of R0.8 billion in 2014.

In the follow-up study, for the period from 1 January to 30 June 2015, the benefits earned from renewables were again two-fold. The first benefit, derived from diesel and coal fuel cost savings, is pinned at R3.6 billion (or R1.82 per kWh of renewable energy). This is because 2 TWh of wind and solar energy replaced the electricity that would have otherwise been generated from diesel and coal (1.5 TWh from diesel-fired open-cycled gas turbines and 0.5 TWh from coal power stations).

The second benefit of R4.6 billion (or R2.33 per kWh of renewable energy) is a saving to the economy derived from 203 hours of so-called 'unserved energy' (a total of 52 GWh = 0.05 TWh) that were avoided. During these hours the supply situation was so tight that some customers' energy supply would have had to be curtailed ('unserved') if it had not been for the renewables. As a consequence, during 15 days from January to June 2015, load shedding was either entirely avoided, delayed, or a higher stage of load shedding was prevented thanks to the contribution of the wind and solar photovoltaic projects.

These direct cash savings on fuel spending to Eskom and the macroeconomic benefits of having avoided 'unserved energy' are countered by the tariff payments to the independent power producers of the first wind and solar photovoltaic projects. They amounted to R4.3 billion from January to June 2015.

The CSIR's first solar photovoltaic (PV) power plant was constructed between June and August 2015 on its Pretoria campus. This one-hectare, ground-mounted 558kW PV facility feeds power directly into the CSIR's grid and provides for around 4% of the energy needs of the campus. It is one of the first steps taken in the CSIR's quest to become a leader in the era of distributed energy generation. The solar power generated by the facility will equate to an annual carbon dioxide saving of approximately 1 200 tonnes, which will significantly reduce the CSIR's carbon footprint.

Therefore, renewables contributed a total net benefit of R4.0 billion (or R2.0 per kWh of renewable energy) to the South African economy.

The study was based on actual hourly production data for the different supply categories of the South African power system (e.g. coal, diesel, wind, photovoltaics). The CSIR has developed a methodology to determine whether at any given hour of the year, renewables have replaced coal or diesel generators, or whether they have even prevented 'unserved energy'.

This CSIR methodology was fed with cost assumptions from publicly available sources, such as Eskom's 2015 financial results for coal and diesel costs, the Department of Energy's publications on the average tariffs of the first renewable energy projects and the Integrated Resource Plan on the cost of unserved energy.

Because the study is an 'outside-in' analysis of the system operations, conservative assumptions for the system effects and for the costs of coal were chosen. The actual cost savings that renewable energy sources brought during the first six months of 2015 may be higher than shown by the study.

The study shows that in the first six months of 2015, the trend that started in 2014 – that renewable energy provided a huge net financial benefit to the country – continued and accelerated.

Without the first solar and wind projects, the country would have spent significant additional amounts on diesel, and energy would have had to be 'unserved' during more than 200 additional hours from January to June 2015. What is more, the cost per kWh of renewable energy for new projects is now close to 80c for solar photovoltaics and between 60c and 70c for wind projects. That will keep the net financial benefits of renewables positive, even in a future with a less constrained power system.

Energy generated by any new wind and photovoltaics project will generate electricity at approximately 65% less than the first projects that came online during 2014. The drop in the prices of wind and photovoltaics is in line with global observed trends over the past five to ten years, which can be attributed to mass manufacturing, improved production processes and technological advancements.

By quantifying for the first time the financial costs and benefits of renewables in South Africa, based on actual hourly production data, the CSIR's ongoing study is contributing to the discussion around the power-system capacity expansion for the future. The CSIR will continue to monitor the fuel-saving and security-of-supply benefits of renewable energy in the country.

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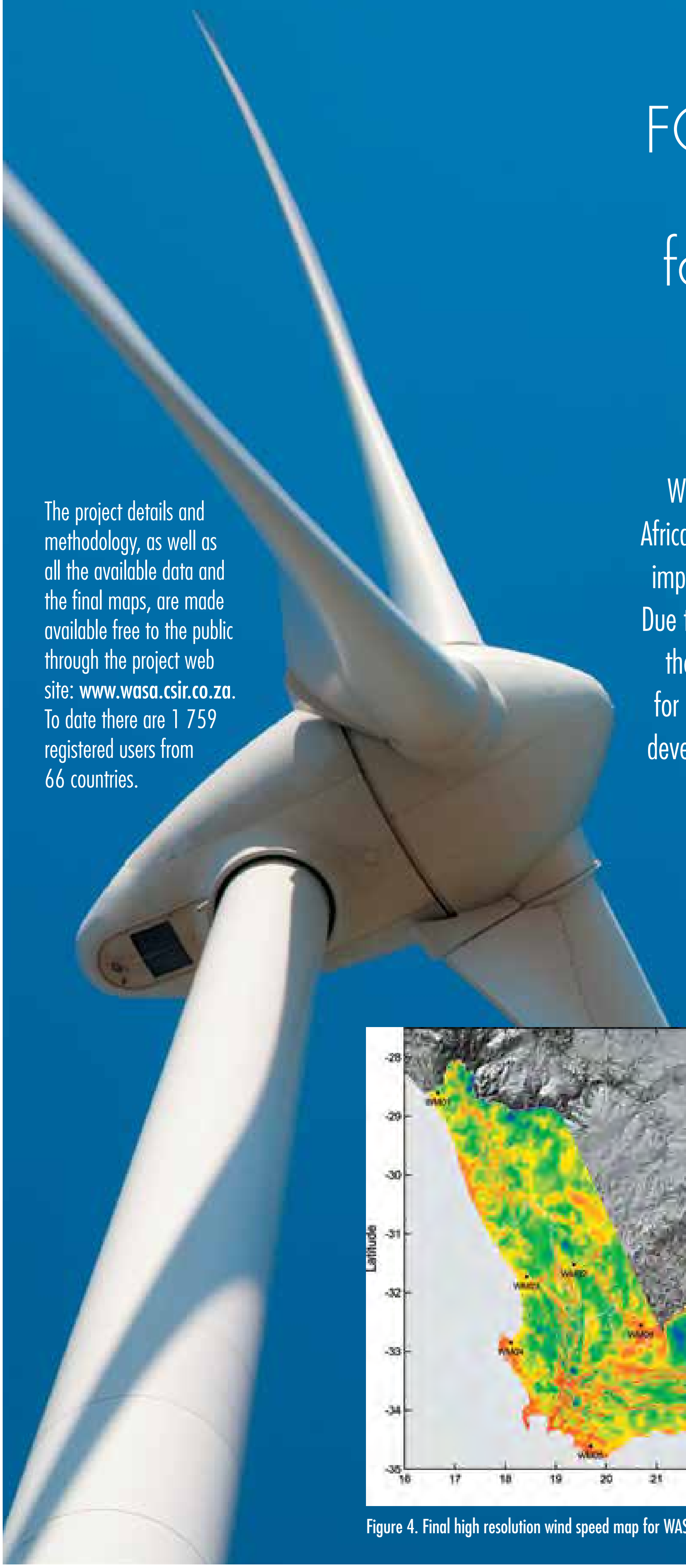

THE WIND ATLAS FOR SOUTH AFRICA: A tool to aid wind farm developers and decision-makers

By Eugéne Mabille

With the increasing development of wind farms in South Africa as a renewable energy source, it has become ever more important to identify and map the country's wind resources. Due to the lack of this information, the Department of Energy, the CSIR and other partners embarked on the Wind Atlas for South Africa project, intended to be an aid to wind farm developers as well as for decision-makers in government and entities such as Eskom regarding grid planning as well as for industrial development.

The project details and methodology, as well as all the available data and the final maps, are made available free to the public through the project web site: **www.wasa.csir.co.za**. To date there are 1 759 registered users from 66 countries.

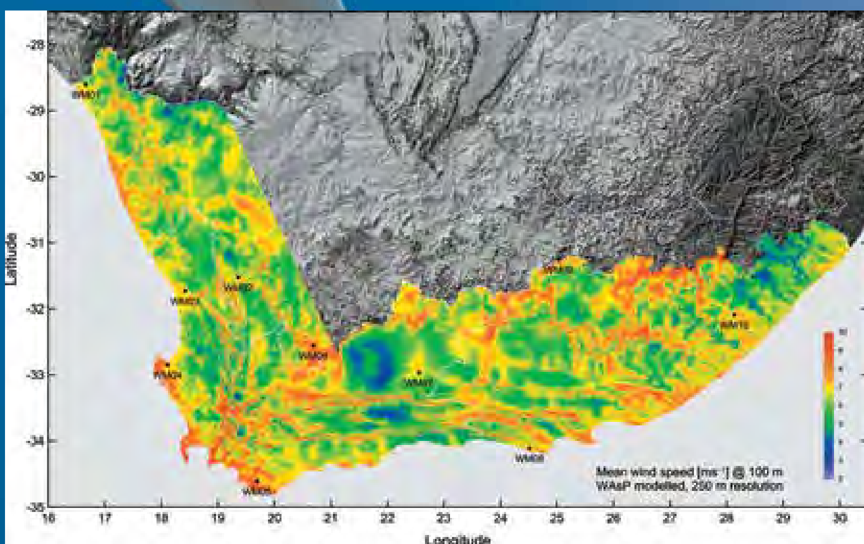

Figure 4. Final high resolution wind speed map for WASA Phase 1.

THE WIND ATLAS FOR SOUTH AFRICA (WASA) is an initiative of the Department of Energy, funded by the Royal Danish Embassy in South Africa and the Global Environmental Facility with support from the United Nations Development Programme. The executing partner is the South African National Energy Development Institute and the implementation partners in South Africa are the University of Cape Town, the South African Weather Service, the CSIR and the Technical University of Denmark's (DTU) Wind Energy centre (formerly Risø). The aim of WASA is to create a final high-resolution wind resource map for parts of the Northern Cape, the Eastern Cape and entire Western Cape, as well as several additional supplementary maps to assist wind farm developers, stakeholders and decision-makers in government to make more informed wind-related decisions.

In 2003, a study commissioned by the then Department of Minerals and Energy identified a problem with the existing wind atlases as a result of poor input data. The study concluded that the accuracy of the wind resource estimates could be significantly improved through the establishment of a network of high-quality wind measurement sites.

So does it matter if wind measurements are not made as accurately as possible for the purposes of assessing the wind resource? The answer lies in the power equation: $P= ½ \rho U^3$ [W/m^2] where ρ = the air density and U = the wind speed. In the equation the wind speed (U) is cubed, therefore any inaccuracies in the wind speed measurement result in large inaccuracies in the possible wind power available. As an example, if the inaccuracies in the wind speed are only ± 5%, then the inaccuracies in the power (P) will be ± 15%. The wind power available at a particular site might therefore be dramatically over or under-estimated if accurate wind measurements are not available.

The WASA project commenced in 2009. The methodology employed was to make use of numerical modelling and to verify the model results using data from wind measurements. The process made use of global mesoscale models (which have been developed for weather prediction) and data to produce a regional wind climate for the WASA domain. This regional wind climate was then used in the microscale model (which takes topography and ground cover into account) to produce a high resolution wind resource map.

Due to the fact that the 2003 study identified a lack of high-quality measurement data, the WASA project included ten high-quality measurement sites. The locations of these sites within the project domain were defined using very specific criteria that were focused on the verification of the modelling output.

The CSIR focused on measurements, microscale modelling and application. The work was undertaken in partnership with DTU Wind Energy who was also the lead agency on the microscale modelling and application of the outputs.

The final verified Wind Atlas for South Africa (Phase 1) was published in April 2014 at a resolution of 250 x 250 metres. This was only made possible through innovative development work done by DTU Wind Energy in automating the use of the microscale model so that it could be applied to large areas. It is the first time ever that such a large area (approximately 350 000 km^2) has been microscale modelled to such a high resolution.

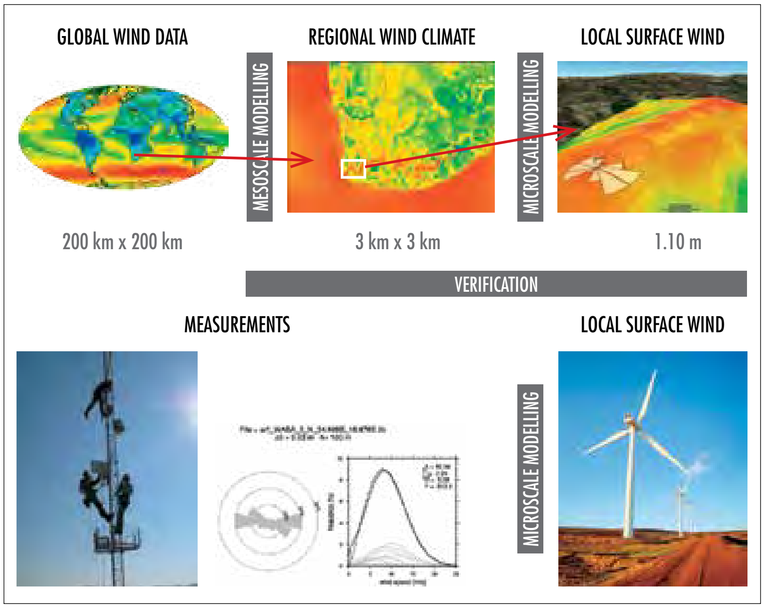

Figure 1: The WASA methodology

Figure 2: Location of measurement sites within the project domain. The project required three years of measurement data from the ten measurement sites for the verification. Each site consisted of a 60 m mast with anemometry at 62 m, 60 m, 40 m, 20 m and 10 m as well as other meteorological sensors. The data from the sites were sent to the CSIR where it was quality controlled and made available on the WASA web site.

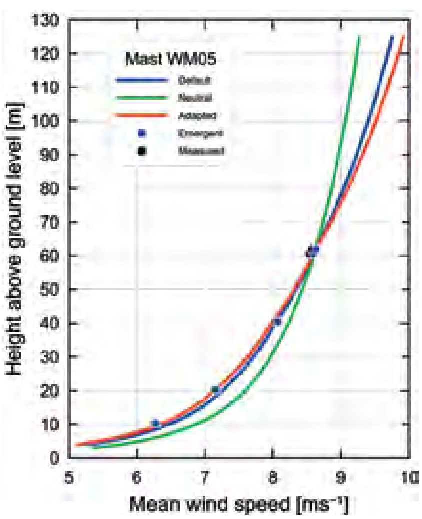

Figure 3 illustrates the good correlation between the modelled output (red and blue) and the measurements (blue dots) from one of the sites. All the other sites have a similar correlation.

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Smoothing out the volatility of South Africa's wind and solar photovoltaic energy resources

By Crescent Mushwana[1]

Co-authors: Dr Tobias Bischof-Niemz[1], Britta Zimmermann[2], Ann-Katrin Gerlach[2], Dr Stefan Bofinger[2], Andre Otto[3]

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Wind speeds can vary greatly from minute to minute, and cloud cover/movement can cause the output of solar photovoltaic (PV) energy sources to vary. As a result, solar and wind power naturally and continuously fluctuates. The CSIR has embarked on research focusing on smoothing out the inherent volatility and fluctuations from wind and PV energy resources in South Africa. A key finding has been that when wind and PV plants are spatially distributed, it can result in a smoothing effect on the power output and also be made predictable.

Solar and wind resource potential in South Africa

South Africa has abundant wind and solar resource potential as shown in Figure 1. Solar PV potential is excellent countrywide with some of the best wind sites located in the Western and Eastern Cape. Wind and PV resources have not been fully exploited for the country's economic benefit. The wind and PV target of 17.6 GW by 2030 as stipulated by the Integrated Resource Plan of the Department of Energy, also remains low in comparison to the abundant resource potential. In 2030, wind and PV will only amount to 8% of the energy supplied in South Africa.

Figure 1: Wind

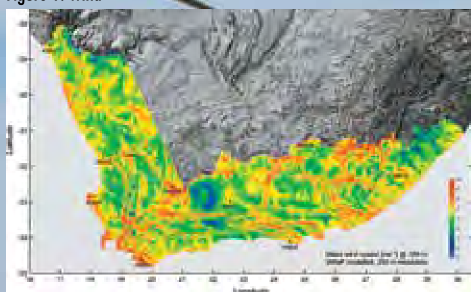

Figure 2: Solar

Figures 1 and 2: Wind (top) and solar (bottom) resource maps *(sources: WASA and GeoModel Solar).*

Understanding the variability of wind and PV power supply

In general, large-scale PV power supply is well understood in South Africa (based on a study titled, *Cloud cover impact on PV production in South Africa* by GeoModel Solar and the University of Stellenbosch).

Figure 3 shows smoothing effect and the increased predictability of PV when spatially distributed based on the GeoModel Solar study. However, the combined effect of wind and PV has not been quantified, and to do this, the following aspects relating to wind power supply need to be studied:

The predictability (or forecasting) of wind supply

It is important to understand how much, when and where the wind supply is available, and this information must be accessible at relatively short notice. With a good forecast there will be less need to reserve power from the conventional generation to balance the load.

The gradients (or ramp rates) of wind supply

How quickly the wind supply changes can pose a challenge for the conventional generation plants as they also need to adjust for the system to remain stable. Spatially distributed wind plants will result in a reduction of ramp rates.

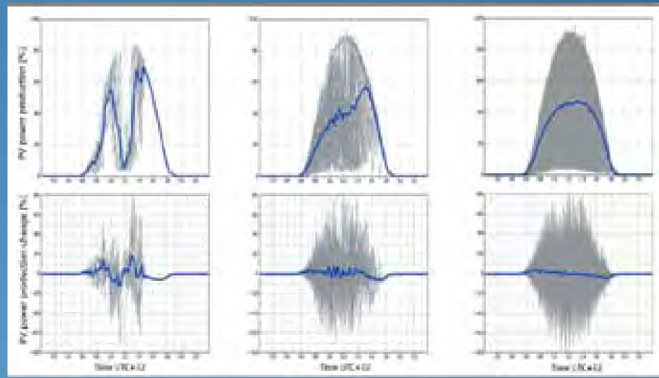

Figure 3: PV power production and ramps for 9, 49, and 225 plants respectively; grey lines show the output of individual power plants, and the blue line shows the combined output of all the plants.

Availability (under or over) of wind supply

When sufficient wind supply is not available for long periods of time (days/weeks), the lower-than-expected supply must be compensated for by conventional generation plants.

The impact of spatial distribution on wind and PV power output

The selected area to illustrate the spatial distribution is Port Elizabeth in the Eastern Cape (Figure 4). Figures 5 and 6 show the normalised power output for wind and PV in five locations within the Port Elizabeth supply area (light) and the aggregate for the entire area (bold). Figure 5 shows that even for a day with fluctuating PV output, which could be due to intermittent clouds, the aggregated output for the whole area remains smooth. In Figure 6, it is shown that even for a day with extreme variations in wind power outputs from individual sites, the aggregated output for the whole area evens out the ramps. These are the initial results of the ongoing study. Final results are expected by December 2015.

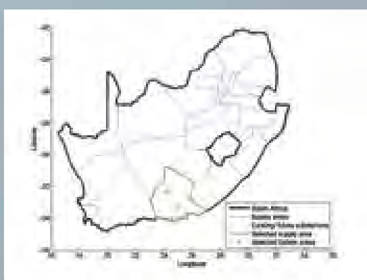

Figure 4: Port Elizabeth supply area

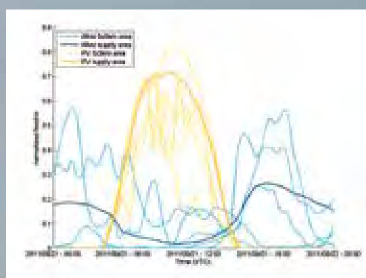

Figure 5: Aggregation for wind and PV power in Port Elizabeth supply area – 21 September 2011

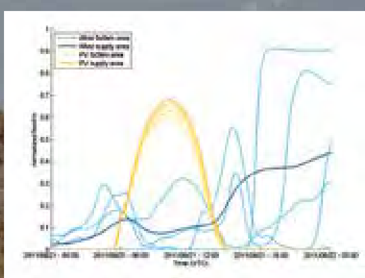

Figure 6: Aggregation for wind and PV in Port Elizabeth supply area – 21 June 2011

Spatially distributed wind and PV plants are beneficial

The initial results clearly indicate the benefits of spatial distribution in terms of increasing the predictability of power output from wind and PV plants. The ramps or gradients are also reduced, thus making it easier for conventional generation plants to respond to the residual load to ensure a more stable power system.

The datasets produced by this study can be used for a variety of further studies to quantify the amount of renewables that can be integrated at power system level to responsibly move towards an energy system with lower carbon emissions with renewables being the primary generation source.

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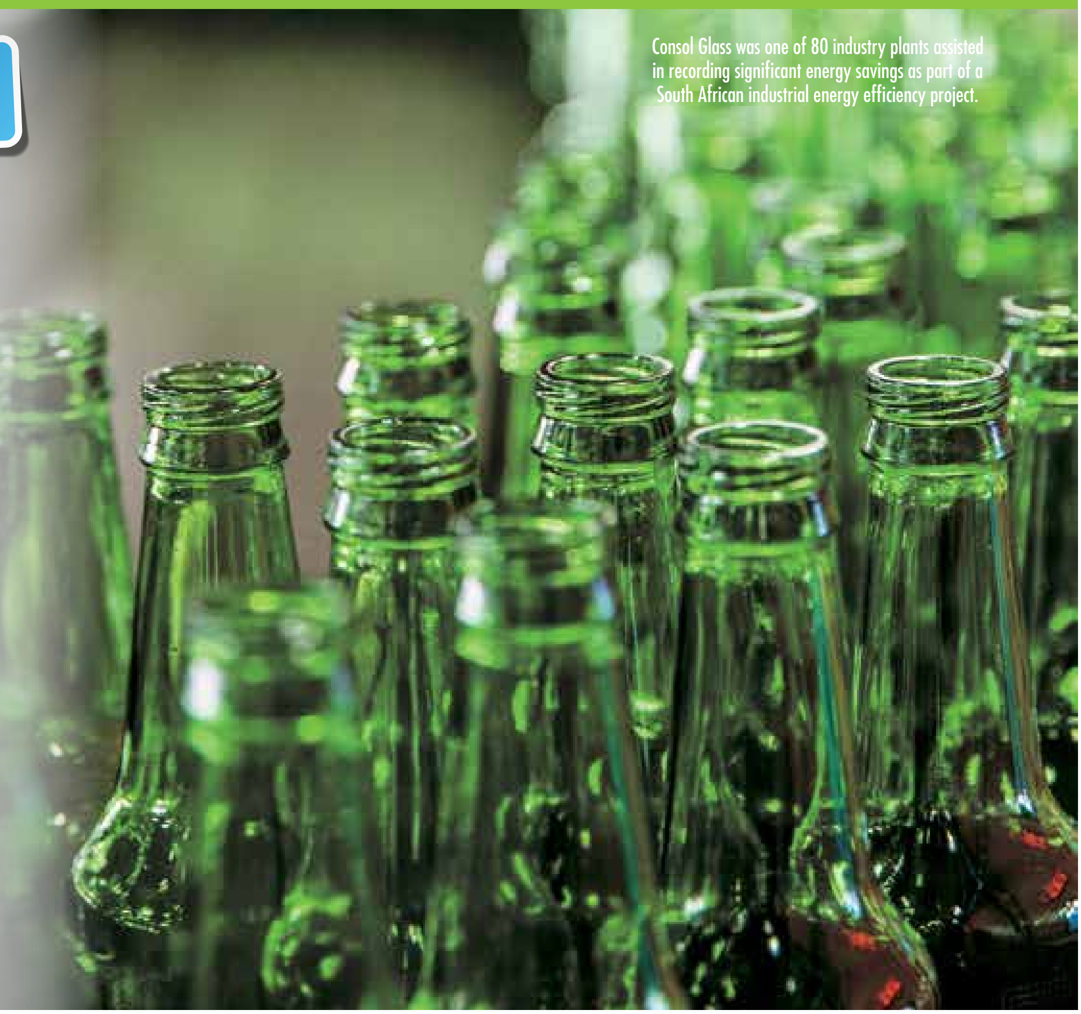
Industrial energy efficiency interventions reap monetary and environmental rewards

By Alfred Hartzenburg

DID YOU KNOW?

Implemented by the National Cleaner Production Centre of South Africa (NCPC-SA) and the United Nations Industrial Development Organisation (UNIDO), the Industrial Energy Efficiency (IEE) Project was set up to help transform the energy use patterns of South African industry to realise sustained energy savings for the nation. The NCPC-SA is hosted by the CSIR on behalf of the Department of Trade and Industry.



Consol Glass was one of 80 industry plants assisted in recording significant energy savings as part of a South African industrial energy efficiency project.

The National Development Plan, when focusing on environmental matters, calls for South Africa to foster economic development with the least impact on the environment; move to a low carbon economy with less dependence on fossil fuels; introduce mixed sources of energy; and make communities more resilient to the impacts of climate change and less socio-economically vulnerable. In response to this, the Industrial Energy Efficiency Project has, between mid-2010 and July 2015, helped participating companies save 1 340 GWh of energy and R1.1 billion in energy costs. It has created or preserved an estimated 5 704 jobs within local communities with investment payback periods of generally less than two years.

INDUSTRIAL ENERGY efficiency has been proven to save firms money, increase the reliability of operations, improve security of supply and offer attractive financial and economic returns, while promoting job creation and reducing carbon dioxide emissions. With its growing importance in global trade it also has a positive effect on productivity and competitiveness.

Against this background, the IEE Project was introduced in 2010 to contribute to the sustainable transformation of energy-use practices in South African industry and enhance national energy security. While the project officially ended on 31 March 2015, its success and importance as a driver for future economic growth has led to the approval of a second phase. In addition, the work of Phase I was extended to allow the project to run uninterrupted. Phase II commenced in October 2015.

A contributing factor to the IEE Project's success is the fact that companies do not have to spend a lot of money to save energy. It is often not necessary to invest in technology upgrades to effect significant energy savings. In fact, some companies use the money they save through their energy management system to fund technology upgrades.

Phase 1 elements and successes

The IEE Project's participation options range from three-day audits for small and medium-sized enterprises to becoming demonstration plants where measurable and verifiable impacts of recommended energy system optimisation interventions may be showcased. Phase 1 had four components:

Enabling policy environment

It firstly encouraged the creation of an enabling policy environment and played an active role in creating awareness and supporting the development, implementation and review of the South African National Energy Efficiency Strategy.

Energy management standards

Secondly, the project supported the adoption and promotion of energy management standards, especially SANS/ISO 50001 where a lead auditor training course was developed and South Africa's first lead auditors trained. Initial interest has been surprisingly slow and to date South Africa has nine companies ISO 50001 certified; the IEE Project played an influencing and capacitating role in all nine certifications. ISO certification guides and enables any organisation to manage energy in a sustainable way. Previously, companies that wanted to manage energy did so by implementing ad hoc interventions with little sustained rewards or impact.

Building local capacity

A significant contribution of the IEE Project focused on the building of local capacity to implement energy management systems and energy systems optimisation in industrial enterprises through specialised training and extensive in-plant implementation support. The energy-efficiency courses trained plant personnel and consultants to implement energy efficiency at an advanced and expert level. During the training of experts, candidates underwent practical in-plant training by international experts and had to implement their own energy-efficiency interventions in an industry plant to attain their certificates. These interventions resulted in actual energy savings in plants. Some R1.1 billion in energy costs was saved by participating companies.

Companies that implemented energy management systems as a direct result of their engineers being trained as IEE experts include Toyota South Africa in Prospectun, ArcelorMittal Saldanha and Tenneco Automotive. The latter achieved monetary savings of R2 million, energy savings of 2 540 000 kWh, and a reduction in greenhouse gas emissions of 2 428 tonnes. It was also the first automotive Original Equipment Manufacturer in South Africa to achieve ISO 50001 certification.

The training programme has equipped local professionals with the expertise to support energy efficiency in industry as well as to train more experts. More than 2 600 individuals were trained in our advanced end user level courses of which 101 experts were qualified. Moreover, 43 national trainers in energy management and energy systems have been trained, replacing the international experts recruited at the start of the project.

During 2014/15, the NCPC-SA began a process to develop these training courses into national occupational trade qualifications, which will allow training institutions to offer the courses and further increase the impact of the project.

Demonstrating potential and impact

The fourth component aims to demonstrate the potential and impact of IEE on the bottom line of a business through case studies, demonstration plants and awareness-raising. Some 35 case studies have been documented and 29 are under development.

Energy audits for small and medium enterprises were conducted to illustrate the savings potential in their companies. A total of 231 audits were undertaken and identified potential energy savings of R111.5 million per annum.

TOYOTA AND THE IEE PROJECT "We have completed 103 projects since April 2010 and have identified 11 more for the financial year, ending March 2015. Fifty of the 103 projects required no additional financial investment. Projects varied and had both financial and energy savings. One of the 103 projects, gas supply conversion, had many additional benefits. We converted from liquid petroleum gas to compressed natural gas. Apart from financial savings, we are also reaping safety benefits. The tank can be filled while the driver is on the vehicle, filling time is quicker, and CO_2 emissions are lower. But the real success story is that Toyota SA has shown a year-on-year decrease in energy consumption while also achieving a year-on-year increase in building vehicles." Arden Wessels, Toyota Senior Manager: Environmental Engineering and Compliance.

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Point-of-care diagnostic and screening tools for resource-limited settings

Patient data being displayed on the Cellnostics web-interface.

Examples of silver inkjet-printed paper-based sensing electrodes.

A wax-printed paper-based microfluidic device. Reactions implemented on the device result in a colour change.

The shortage of expert skills and limited access to diagnostic tools and equipment are challenges in parts of South Africa's healthcare system. The CSIR collaborates with government to develop point-of-care diagnostic and screening tools which allow healthcare workers to efficiently and timeously diagnose a patient at a clinic or in the community.

By Busisiwe Vilakazi, Pieter Roux, Ureshnie Govender, Kevin Land and Jeremy Wallis

THE SOUTH AFRICAN public health system provides healthcare services to the majority of people. Many of its facilities are in remote locations and some face serious resource constraints – these include 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 has developed a number of medical devices and sensors to improve test turnaround time, quality of care and health information for primary healthcare facilities. These technologies include the Umbiflow fetal health evaluation system, the Cellnostics device as well as paper-based sensors for on-site blood testing.

The importance of diagnostic tools

Diagnostic tools are required to identify the presence and cause of disease, to suggest potential treatments and to monitor the effect of any interventions. When healthcare centres are located far from centralised laboratories, the delays caused by the transport of blood samples and test results may detrimentally affect the quality of patient care.

Cellnostics

CSIR researchers have developed the Cellnostics 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 has an embedded electronic device that allows for two-way communication between the clinic and a central laboratory, providing results without having to transport blood samples from remote areas to this laboratory for analysis. In addition to rapid blood-based diagnostics, Cellnostics is designed to support other diagnostic equipment that can benefit from the two-way wireless communication between healthcare workers and off-site specialists.

Paper-based technologies

A team of researchers has also developed paper-based sensors for point-of-care testing. They selected paper as the platform for biological reactions as paper is a low-cost, easily-disposed-of material which can be modified to detect biological material such as glucose for diabetes tests.

The team has successfully modified the paper using specialised wax and conductive ink printers. In doing so they created microfluidic sensors to control the flow of small volumes of biological material on paper, and printed electrodes and circuits on paper to detect biological material. In a clinic setting, healthcare workers will place a drop of biological material (e.g. blood) on the paper and will have a positive or negative result within minutes.

The design is based on the World Health Organization's ASSURED criteria (affordable, sensitive, specific, user-friendly, rapid and robust, equipment free, and deliverable to those who need it) for point-of-care tests.

The Umbiflow system is used in a clinic to determine the blood flow in the umbilical cord. The device is able to determine when the placenta is no longer providing sufficient nutrients and oxygen for the baby to reach its growth potential.

Umbiflow

The South African Medical Research Council's ninth *Saving Babies Report* (2012-2013) found that the top causes of perinatal deaths in the state health sector included unexplained stillbirth and spontaneous preterm birth. In the report it was speculated that undiagnosed fetal growth restriction could be one of the major contributors.

During the mother's visit to a prenatal clinic, fetal growth restriction is normally detected by using a tape measure to measure the distance across the mother's abdomen, called the symphysis-fundal height. When fetal growth restriction is suspected, a clinic-based nurse must refer the pregnant woman to a higher level of care, where a conventional Doppler ultrasound test can be done using an expensive imaging device.

CSIR researchers have developed an ultrasound device called Umbiflow which can be used at a clinic to reduce unnecessary referrals. By measuring the blood flow in the umbilical cord, the device detects when the placenta is no longer providing sufficient nutrients and oxygen for the baby to reach its growth potential.

A recent field trial conducted in Kraaifontein in the Western Cape showed that referrals of patients with suspected fetal growth restriction can be reduced by 43% if the Umbiflow technology is made available at the primary care level. The field trial also showed that 9% of late bookers (women who have their first antenatal visit after 28 weeks) had abnormal Doppler results and smaller babies which would not have been detected. Conducting Umbiflow measurement at a clinic was shown to be more cost-effective than referral to a secondary hospital for a Doppler test.

Empowering nurses to make decisions at the point of care with technologies such as these has the potential to significantly impact healthcare delivery and to address the challenges of health disparities in South Africa.

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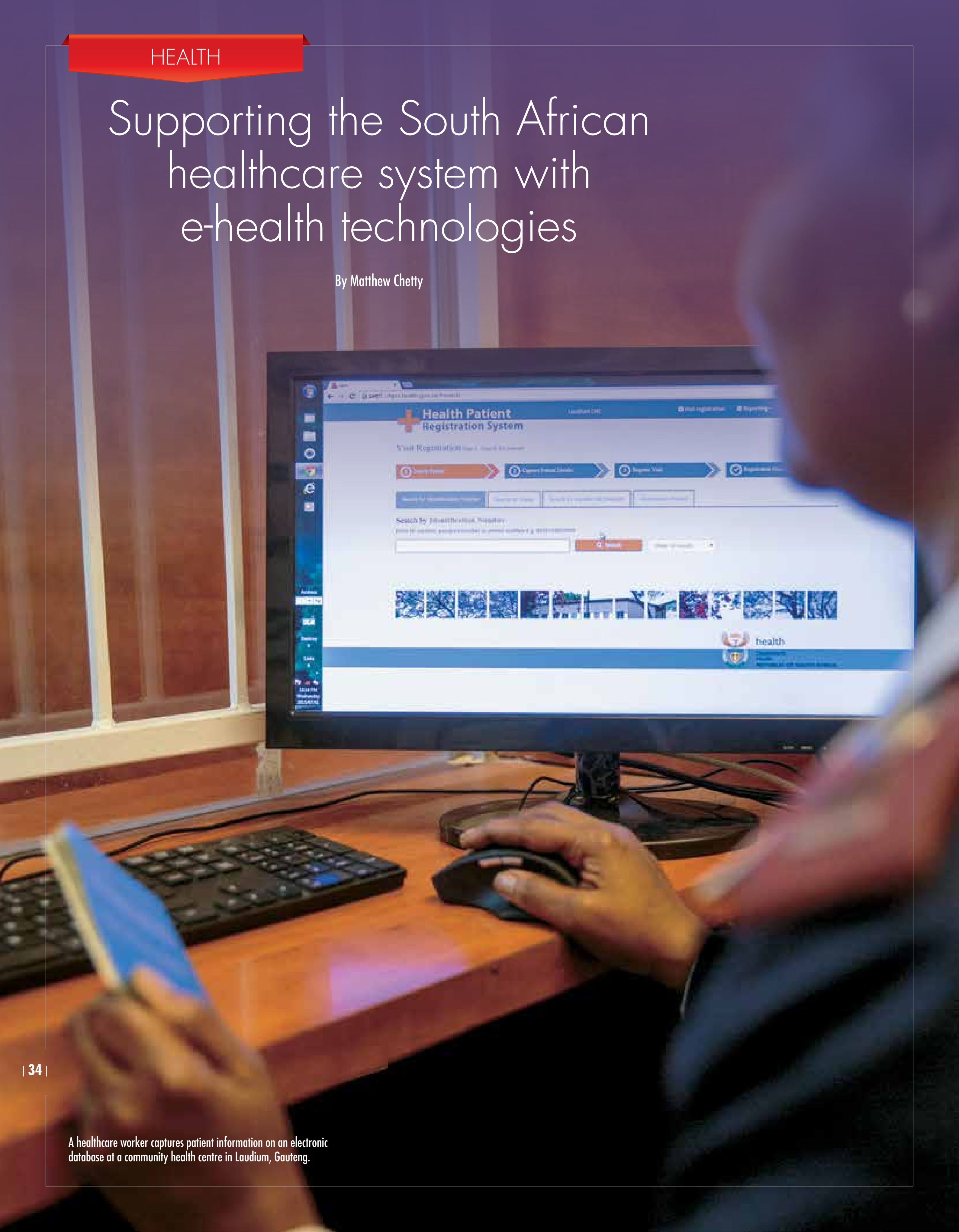
Supporting the South African healthcare system with e-health technologies

By Matthew Chetty



A healthcare worker captures patient information on an electronic database at a community health centre in Laudium, Gauteng.

E-health – the use of information and communications technology in healthcare – is imperative for South Africa's re-engineering of its primary healthcare system and the development of a National Health Insurance system. The CSIR has been actively involved in various e-health initiatives, including the development of norms and standards for e-health, the implementation of a national patient registration system and the assessment of existing health information systems.

THE DEPARTMENT OF HEALTH (DoH) published the *National eHealth Strategy* in 2012 in which it emphasised the critical role of e-health technology and provided a framework for improving e-health systems within the national public health system.

Dr Aaron Motsoaledi, Minister of Health, expressed his concern about the prevalence of manual health information systems in the public sector. He was also concerned about the lack of interoperability between existing electronic systems. Efficient healthcare systems need reliable electronic systems to keep patient records, facilitate fast clinical decision-making and to ensure efficient communication between healthcare professionals and patients. These systems are also vital for efficient procurement and other hospital administrative functions.

Assessing the current status of e-health infrastructure

In 2012, the CSIR conducted an analysis of the health information systems deployed in public hospitals and found at least 42 different systems deployed across the country. All of these were essentially stand-alone systems with minimal levels of interoperability, which made it difficult to deliver an integrated health service to patients. For example, when systems are not integrated it can be a challenge to retrieve patient information when the patient visits another health facility. This may result in duplication of prescriptions or – in a case where a patient is unable to communicate – an incomplete record of previous treatment and underlying conditions which a doctor needs for optimal diagnosis and care.

In 2013, the DoH commissioned the CSIR to establish a set of standards for interoperability of e-health systems. The standards would advocate a common 'language' for health systems, thereby ensuring that information could be shared and used effectively across different systems and in different health facilities. In coming up with the standards for South Africa, the CSIR and the DoH considered case studies of e-health standards developed internationally and considered South Africa's burden of disease scenarios. *The Health Normative Standards Framework for Interoperability in eHealth* was gazetted on 23 April 2014. It stipulates six categories of standards with which all e-health systems deployed in the country should comply, including standards for the type of content they must contain, terminology used, how the messaging works and security features.

Assessment of patient information systems

The CSIR was also commissioned by the DoH to perform an assessment of all patient information systems that are deployed in both private and public sector clinics in South Africa. These contained patients' demographic, clinical and administrative data. The information was voluntarily provided by vendors who provide ICT solutions to clinics and hospitals and assessed against functional requirements and adherence to the *Health Normative Standards Framework for Interoperability in eHealth*. The CSIR also conducted a costing analysis of these systems and presented the results to the National Health Council, where they were favourably received. The assessment is being extended to hospital information systems. The work will assist provinces to understand the types of healthcare information systems solutions deployed across the country and the important principles on which the procurement decisions of health information systems should be based.

Implementing a patient registration system

Knowledge of patient demographics and a record of their movement through health facilities are fundamental in delivering integrated healthcare services and are also required for planning aspects of the National Health Insurance (NHI). The CSIR and the DoH have partnered to develop a national patient registration system, which allows for the registration and identity verification of patients at public health facilities. The system has thus far been deployed in 38 NHI pilot clinics, and has registered more than 400 000 patients. The system is considered as the national authoritative source of patient demographic data in the country. The deployment of the system continues.

The road ahead

On 10 July 2015, the DoH issued a Government Gazette that established a ministerial advisory committee on e-health. This committee is expected to advise the Minister on the implementation, monitoring and evaluation of the department's e-health strategy, covering pertinent areas such as strategy and leadership, stakeholder engagement, standards and interoperability, capacity and workforce, and e-health foundations. The CSIR is ready to provide its ongoing support to this committee.

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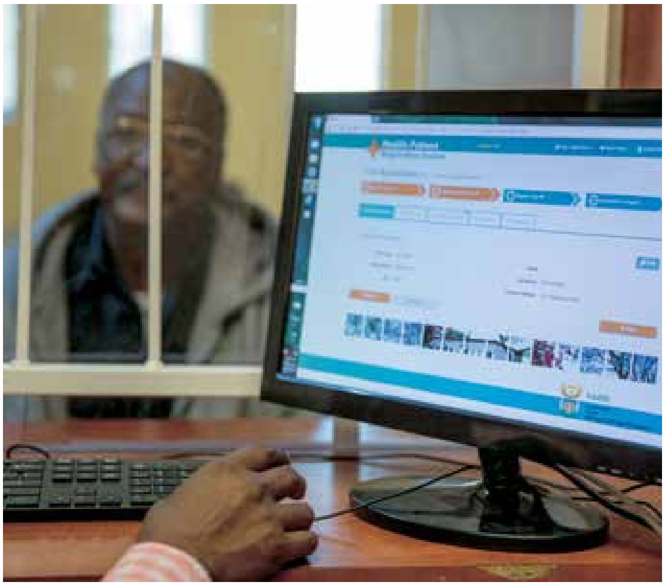

Electronic capturing of patient data ensures fast and efficient communication between patients and healthcare professionals.

The CSIR's Dr Zodwa Mbambo pours a sample of the nutritional drink that consists of various food products such as sorghum, soya and indigenous leafy vegetables.

The drink is made by mixing a dried-ground powder with water.

A sample of the powder being weighed.

Indigenous foods used to address micronutrient deficiencies in rural Eastern Cape

By Dr Zodwa Mbambo

The CSIR embarked on an integrated nutrition intervention pilot programme in five schools in Cofimvaba in the Eastern Cape with the aim of supporting government to provide nutrient rich food-stuff to improve the learning ability of learners. Researchers developed a nutritional drink from a combination of food products such as sorghum, soya, milk as well as local and indigenous leafy vegetables. CSIR researchers are currently evaluating the bio-accessibility of the micronutrients in the drink to the human body to determine the nutritional value of the drink.

THE SOUTH AFRICAN National Health and Nutrition Examination Survey conducted in 2012 found that nutritional deficiencies are still prevalent in children in rural and urban areas with an average of 43% children being vitamin A-deficient and 11% iron-deficient. Although these figures show slight improvement from the previous surveys (1999 and 2008), they still point to a health challenge that requires a long-term sustainable solution. In an effort to improve dietary intake of vitamin A and iron, among other micronutrients, the Department of Health implemented a mandatory national food fortification programme in 2013, which requires that selected micronutrients are added to local maize and wheat flour.

However, despite considerable efforts to improve dietary intake and a commitment from the government to provide quality education, a significant number of students across rural South Africa still have diets lacking in micronutrients. Nutrient-poor diets can lead to nutritional problems, such as iron-deficiency anaemia, that can adversely affect attention and learning in school.

Assessing nutrition

Baseline studies involving five schools in Cofimvaba were conducted in August 2013 with a focus on three micronutrients (vitamin A, iron and zinc) which had been identified by a national survey on nutrition as being inadequate in children living in rural areas. The assessment of nutrient intake included a 24-hour recall of food intake, food frequency, biochemical tests and anthropometrics (body measurements).

The baseline studies indicated that chronic and acute malnutrition was mainly prevalent in girls, with the incidence of underweight recorded as 8.3%, wasting (too thin for their height) as 2.8% and stunting (too short for their age) as 5.6%. Overweight and obesity was not prevalent. Only 2.3% of the boys suffered from chronic malnutrition (growth stunting) and no acute malnutrition (underweight) was observed, but overweight was observed in 4.7% of the boys. Based on the children's serum ferritin levels, a protein that stores and releases iron in the body, more than 90% of the children were diagnosed with low iron levels in their blood. Overall, these results indicate that the diets of households were not diversified, and lacked nutritious food items from some food groups, like fruits and vegetables, a key source of micronutrients.

A science-based intervention

The CSIR embarked on an integrated and comprehensive food and nutrition intervention in the selected schools to enhance nutrient intake of food provided in schools. The intervention included providing a nutritious breakfast drink, functional school garden and training and education for food handlers, learners and teachers. Over 1 800 students, mostly aged 7-12, from five schools in the poorest regions of the Eastern Cape received the breakfast drink.

The breakfast drink is made from a combination of various pre-cooked food products such as sorghum, soya, milk as well as four other vegetables, including indigenous leafy vegetables which are dried-ground to a powdered form and blended. The pre-mix powder is then mixed with water and served to the children each morning. The breakfast drink is a good source of vitamin A, zinc and iron and the researchers are currently testing the nutritional impact of the drink as part of the ongoing project.

Studying bio-accessibility

Bio-accessibility can be defined as the quantity or fraction of food components which is released in the gastrointestinal tract and becomes available for absorption by the human body. The determination of nutritional content directly from foodstuff through laboratory testing is not enough for the accurate prediction of its potential absorption in the human body. Metabolites reaching the blood system may be different from the original compounds found in food as a result of metabolic activity (the breakdown of food into smaller absorbable constituents) that takes place during absorption. CSIR researchers are testing the bio-accessibility of micronutrients in the human body to establish the true nutritional efficacy of the food products used in this programme. This data will be used to improve the formula of the nutritional drink and can provide valuable information to determine the right amount for daily intake and the optimal food sources for better nutrition.

Measuring the nutritional drink in its mixed form.

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DID YOU KNOW?

What does RNA stand for?
Ribonucleic Acid, and it is similar to DNA.

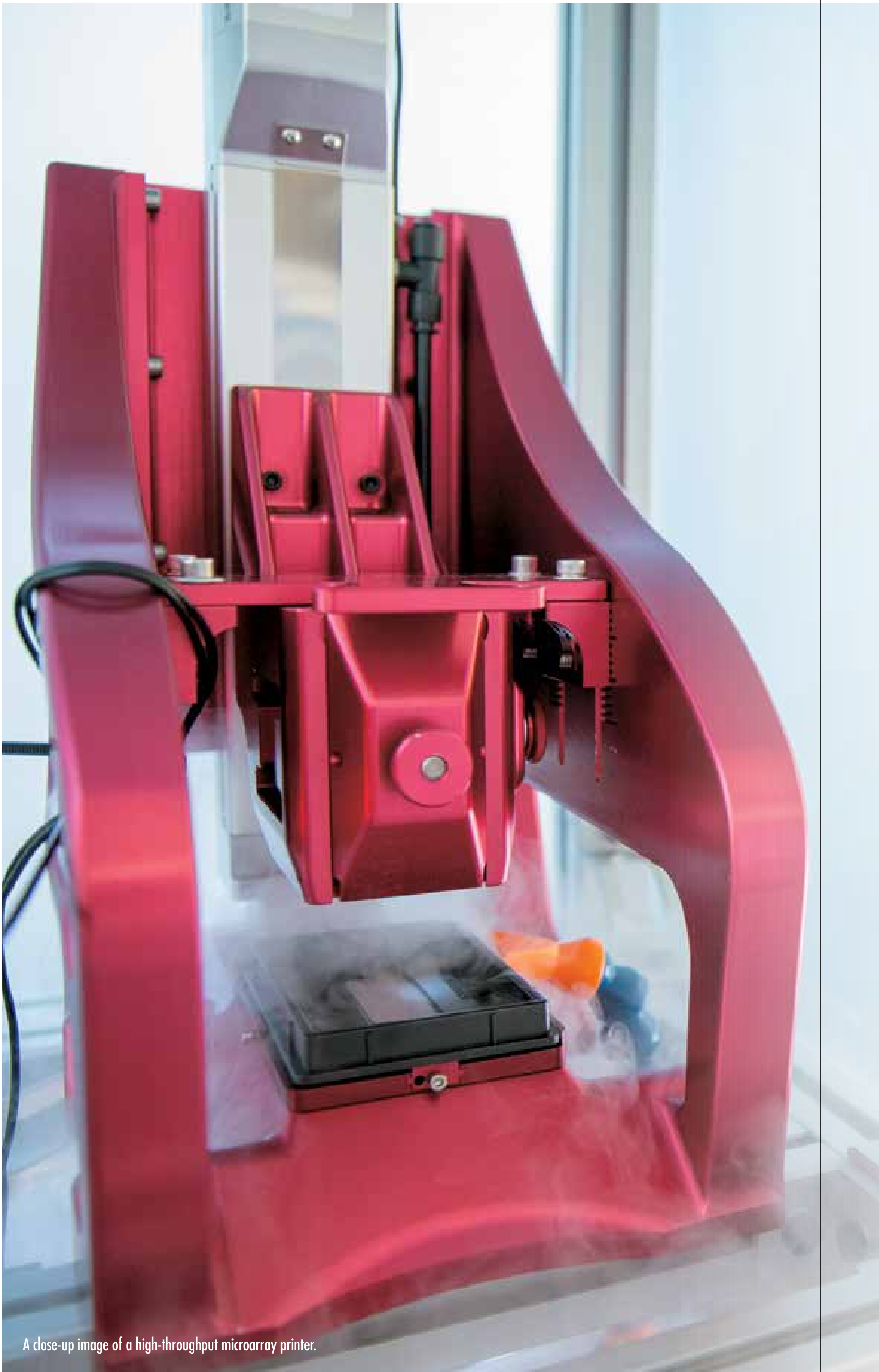
Ribo – This is short for ribose and it is a pentose sugar. The sugar group in DNA is dexoyribose.

Nucleic – Refers to the fact that it originates in the nucleus.

Acid – It is an acidic compound.

RNA is an intermediary between DNA, which houses the instructions to make a protein, and the ribosomes, which are a cell's protein making factory. It carries out its role by transcribing the genetic instructions inside the nucleus by producing a complementary strand of RNA. It is a copy of a segment of DNA.

From: www.brighthub.com



A close-up image of a high-throughput microarray printer.

STUDYING GENE EXPRESSION: An improved RNAi screening technology

By Dr Asongwe Tantoh

Discovering more, faster, cost-effectively

The CSIR has developed a 'movable type' high-throughput microarray printing technology that can compress several individual RNA-interference (RNAi) experiments onto a single glass slide. The technology, which has been licensed to Persomics AB, is characterised by its simplicity, low cost, rapidness and high efficiency. The state-of-the-art printing platform is geared at providing a miniaturised high-density RNAi microarray product that will enable researchers to screen a large number of genes with relative ease and in a short time.

What is RNAi?

RNAi interference is a natural process used by cells to inhibit the expression of unwanted or harmful genes. RNAi works typically by causing the destruction of specific mRNA molecules that carry instructions coded in a gene which is the blueprint for individual proteins. By destroying the RNA messenger, the RNAi shuts off a gene's activity by ensuring that the corresponding protein is not synthesised.

So many genes, so little time

The human genome is made up of 20 000 to 30 000 genes that form the blueprint for every human cell, and 200 different cell types form the trillions of cells that make up a human being. The process of testing these genes individually against cellular functions or pathogen-ligand interactions is an enormous challenge. Researchers are currently harnessing the RNAi mechanism to shut off individual genes, one at a time, in order to figure out which function they control in normal cellular processes or during disease progression. With the sheer volume of genes, there is a global need for a high-throughput high-content RNAi screening approach to easily sift through them.

Our screening facility

Adapting the RNAi mechanism, the microarray printing technology creates a scaffold which allows the screening of thousands of genes in parallel. The technology works through printing up to 3 150 distinct RNAi molecules encapsulated in an optimised printing solution. Each printing solution contains the RNAi molecule, a transfection lipid, a marker to identify each spot and an extra-cellular matrix protein. The different RNAi encapsulation mixtures are loaded by capillarity into separate 230μm inner and 300μm outer glass tubing supported by a metal plate. Using a highly-engineered microarray movable Z-axis printer, the entire 3 150 RNAi spots are printed onto a chemically modified glass slide in one contact. With just 4μl of the print solution, more than 1 500 copies of the microarray can be produce in a single print cycle.

With this technology, genome-wide screening can be achieved for a fraction of the investment required for conventional technologies. Traditional high-throughput screening methods, such as systematic well-plate based screening using high-end robotics, automation and a team of skilled operators, take six weeks of full-time work to complete one screening experiment. Using this array screening platform, screening time is reduced from six weeks to six hours for a single screen and this technology therefore commoditises genome-wide experimentation and allows scientists to explore many more research questions that were previously inaccessible and costly.

Other applications of the technology

With the growing pool of chemical-compound libraries, there is an urgent need to find new quick and easy ways to profile the activity of these chemical compounds against hundreds of biological targets. The CSIR is currently in the process of adapting this high-content high-throughput screening technology to allow the printing of compounds on similar arrays that will enable researchers to meet the challenge of screening through hundreds of compounds against different disease models in a relatively short period of time.

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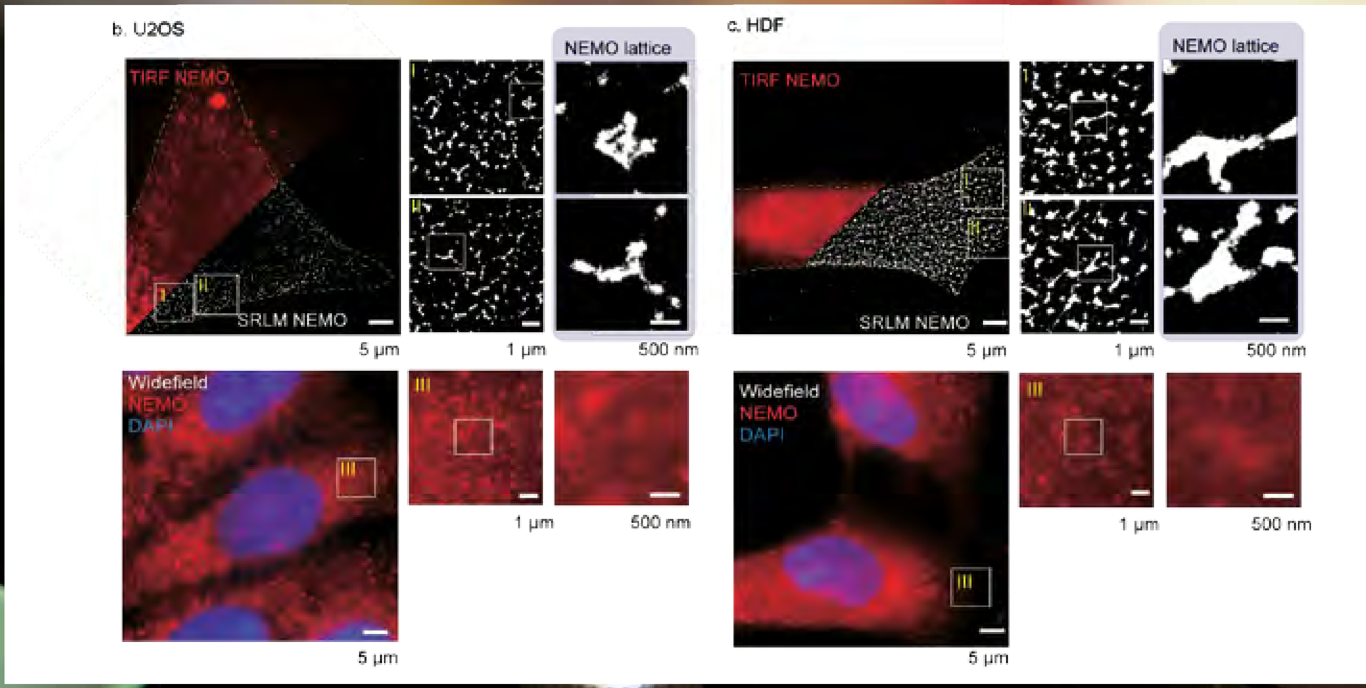
A CSIR researcher using high-throughput microarray printing technology to compress an RNAi experiment onto a glass slide.

FINDING NEMO:
Using super-resolution microscopy to diagnose disease-in-a-dish

By Dr Janine Scholefield

Scientists at the CSIR, in collaboration with scientists at Institut Pasteur and the Université Paris-Descartes, have identified the first visual proof of complex intra-cellular structures acting as pre-formed regulators of the immune response. The work emphasises how super-resolution microscopy can provide novel insights into the single-molecule mechanisms of genetic disorders, as well as crucial cellular interactions.



Super-resolution microscopy reveals the presence of an extensive lattice-like structure of NEMO (upper panels, in magnified insets) which cannot be observed in conventional microscopy (lower panels)

UNTIL RECENTLY, there were no simple approaches to prove the existence of complex intra-cellular structures – and thus, little means of understanding basic molecular pathways as a stepping stone to unravelling mechanisms of disease. This is largely due to the very basic physical properties of light itself, which cannot be resolved below 200 nm. Since many structures in the cell may be smaller than this, they cannot be visualised with conventional microscopy.

Fortunately, through extensive research over the past decade, and by combining the fields of physics, biology and chemistry, scientists have been able to overcome this problem. So extraordinary was this discovery that a year ago, Eric Betzig, Stefan W. Hell and William E. Moerner were awarded a Nobel Prize in chemistry for developing super-resolved fluorescence microscopy. The CSIR has custom-designed the very first and to date, only such microscope in South Africa. Using this technology, scientists have been able to identify the first visual proof of these higher-order structures.

Knowing how disease works

Understanding the biological mechanisms of disease has never been more important in the pursuit of developing treatments and cures for both infectious and non-communicable diseases. But to better understand how pathogens are able to hijack our cellular processes for their own benefit, we must unravel the basic molecular pathways themselves. It is becoming increasingly apparent that a multi-layered complexity in the architecture of our cells dictates our response to cellular attack or damage. Yet, there is arguably less known about the details of the invisible responses of our own cellular pathways than the depths of our oceans.

Historically, we have disingenuously conjured the image of a cell akin to a 'bag' of stochastic protein interactions. However, a developing hypothesis in the field of signal transduction proposes that there is a high degree of architectural order in the cell which reduces such randomness and biological noise, instead creating a biological binary on/off switch. The answer was thought to lie in the multimerisation of proteins; but how to demonstrate this phenomenon remained unclear.

One of the critical pathways in our cells is called the nuclear factor kappa-light-chain-enhancer of activated B cells (NFkB) signalling cascade – perhaps the most important one we have. This is because every cell in the body must have an innate ability to respond to an outside stimulus or attack. Whatever form that signal may take, essentially our healthy cells will respond by moving the protein, NFkB from the cell body (cytoplasm) to the DNA storage area (the nucleus). There, it will activate many genes that lead to the cell's protection. Although extremely simplified, in this way, we stay healthy.

Finding Nemo

A recently proposed theory suggests that the intermediate protein (NEMO), which links the signal from the outside of the cell to the successful movement of NFkB to the nucleus, might be able to do this by forming complex structures that would be able to act as a finely tuned regulator – waiting for a minimum signal threshold to arise before switching on a green light of activation.

We used super-resolution microscopy to reveal the complex structure of NEMO in non-stimulated cells and have identified how this structure is held together in cellulo.

DID YOU KNOW?

NEMO: The NEMO protein is the regulatory subunit of a complex, which is involved in the activation of a complex suite of genes involved in inflammation, immunity, and cell survival. The gene coding for NEMO is located on the X chromosome, and mutations lead to severe clinical defects.

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ERADICATING MALARIA:

Exploiting advances in disease modelling to develop new generation drugs against malaria transmission

By Dr Dalu Mancama

The CSIR, in collaboration with several partner institutions, has begun screening vast libraries of synthetic compounds that could be used in a new generation of antimalarial drugs. These drugs will disrupt the life cycle of the parasite (that causes malaria), paving the way for the eradication of the disease. Compounds have already been identified that meet the criteria and exhibit the ideal characteristics required for further development.

Processing of a malaria parasite culture (above and below).

Testing novel compounds to block malaria transmission.

NEARLY HALF THE WORLD'S population continues to be at risk of contracting malaria, with *Plasmodium falciparum* representing the most prevalent parasite species of the disease. Despite recent gains in reducing the disease's morbidity and mortality, malaria's global burden remains high, with 200 million cases and 600 000 deaths reported in 2013 alone.

Apart from tremendous human suffering, the cost to the African continent is a loss in gross domestic product estimated to exceed USD$12 billion per year, and this impact is compounded by an ever-increasing parasite resistance to virtually all the existing anti-malarials. This is mirrored by increasingly widespread mosquito resistance to insecticides, including those used for long-lasting insecticide treated bed-nets. The unrelenting malaria burden has placed pressure on scientists to develop more effective interventions to reduce the disease's impact, and has led to renewed efforts to eliminate and eventually eradicate the disease.

The Malaria Eradication Agenda represents the key global framework for defining innovative strategies to reduce the malaria burden and eventually achieve eradication. The top priority is to develop a new generation of antimalarial drugs that not only act to expeditiously clear parasite infection, but also provide long-acting post-treatment protection, possess the ability to block the transmission cycle and result in a radical single-exposure cure of all the malaria species that affect humans.

The need to identify such antimalarials, capable of inhibiting parasite growth at multiple stages of development, is the focus of the CSIR team's current research efforts. In particular, researchers are focused on developing and deploying technologies that rapidly identify transmission-blocking compounds that prevent specific forms of malaria (gametocytes) from being transmitted from humans to the mosquito vector.

Significant challenges exist in finding such compounds. Among these are major shortcomings associated with accurately replicating, in vitro, the endogenous host environment and key gametocyte development stages associated with disease transmission; the unique metabolic homeostatis of malaria during these stages, whereby many of the parasite's normal metabolic functions are developmentally arrested; and the significant bottlenecks associated with producing sufficient biomass representing the parasite during transmission.

Despite these challenges, the CSIR team has successfully developed a highly efficient gametocyte generation technology, and through collaboration with local and international research groups, has been exploiting this to deploy robust bioassays that permit rapid screening of up to thousands of compounds per week to identify transmission-blocking antimalarial compounds.

After an extensive process of technology validation, the team's efforts are currently focused on rapidly screening large new compound library collections, in order to identify a novel, diverse compendium of compounds that possess potent transmission-blocking antimalarial activity. Several thousand compounds have been interrogated; typically less than 20% of these compounds meet the criteria and exhibit the ideal characteristics required for further development.

Dr Dalu Mancama conducting a visual assessment of a malaria culture.

These and other compounds identified in future will form the basis of drug development efforts aimed ultimately at creating drugs that combat and reduce malaria's transmission. This project also offers other benefits. Highly skilled local expertise in developing and implementing high-throughput compound screening infrastructure and knowledge and process management in high-throughput screening are being developed and will strengthen the country's nascent drug discovery and development capacity.

This initiative is being performed in collaboration with the universities of Pretoria and the Witwatersrand/NHLS, the Cape Town H3D Centre, and the Medicines for Malaria Venture through funding provided by the MRC Strategic Health Innovation Partnerships programme and the CSIR.

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Ensuring safe networks through virtualisation

By Dr Suné von Solms

Advances in technology have transformed today's society. Technology is so deeply embedded in society that we cannot imagine our lives without gadgets like mobile phones, tablets, computers, air conditioners, navigation systems and alarm systems. Technology keeps us connected to our friends and family, helps us get through our work and makes everyday tasks easier. Owing to the pervasiveness of cyberspace, the protection of our digital assets and activities is crucial. To ensure that technology only makes our lives better, cybersecurity research is of critical importance.

THE UTILISATION OF TECHNOLOGY in our daily lives provides countless opportunities for the introduction of flaws that could allow the deliberate compromise of a user's confidentiality, integrity or availability. Although cybercrime is a global phenomenon, the rapid increase in bandwidth and increased use of wireless/mobile devices in South Africa make us highly vulnerable to cyberattacks.

Cybercrime is growing at a faster rate in Africa than in other continents and according to Microsoft's security report of 2011, malware infections in Africa are higher than the global average. This is due to the fact that growing economies are often tracked by cybercriminals for potential targeting. As more people in Africa rely on these technologies, cybercriminals are developing their strategies to exploit cybersecurity gaps and users' trusting nature towards these technologies.

Legislation relating to cybercrime, cybersafety initiatives, computer literacy and education are critical factors in the process to secure our cyberspace. However, in many respects, these factors are failing to maintain the desired pace to keep up with the rapid development of technology use. Research and development is a component that can greatly assist in making government, businesses and citizens more resilient to cyberattacks through the development of innovative solutions and enhancement of skills to combat cybercrime and other cyber-related issues.

Cybersecurity research and development is hampered by the fact that network vulnerabilities and new cybersecurity tools and technologies cannot be tested on live deployed networks, as it can compromise network stability or create even larger network vulnerabilities. Therefore, one of the best approaches is to create virtual replicas of the networks and do the tests on these virtual counterparts. With the recent advancements in the field of computing technologies, research and development in the field of cybersecurity is greatly aided. A decade ago, large network testing infrastructure was limited only to the few corporations with massive server rooms and even larger budgets. However, with the recent advances in simulation and emulation (virtualisation) technology, building large network research facilities is now possible.

The CSIR is establishing various network testing platforms for network performance and behaviour testing, cybertools and technique evaluation as well as network equipment capability verification. These platforms utilise live malware, security strikes, realistic user traffic and high-fidelity network virtualisation to provide an integrated testing environment for networks, networking equipment and cybertools. The ability to conduct research and development in a contained environment under real-life circumstances assists researchers to study and address critical network security weaknesses.

One of the platforms built by the CSIR, in collaboration with the Department of Science and Technology, is the network emulation and simulation laboratory that aims to facilitate cooperation between cybersecurity researchers and experts from various universities across South Africa and industry. It is the first web-accessible, open-source platform in South Africa where emulation, simulation, virtualisation and physical platforms will be integrated for large-scale cybersecurity testing and research. Postgraduate students will be able to access the facility through the internet or can visit the facility to run full tests and implementations. They can use the platform to research network vulnerabilities and develop new cybersecurity products.

By enabling these research and development activities, the CSIR assists in the advancement of South Africa's cyber knowledge base through original research and the provision of top quality graduates in the field of cybersecurity. These network virtualisation platforms will drive developments in the theory and practice of cybersecurity to help in the creation of a safe, secure and prosperous cyberspace.

The CSIR's network emulation platform acts as a testing environment for network and device security. The system is used for cybersecurity training, network modelling and advanced analytics to assist the private sector and government departments.

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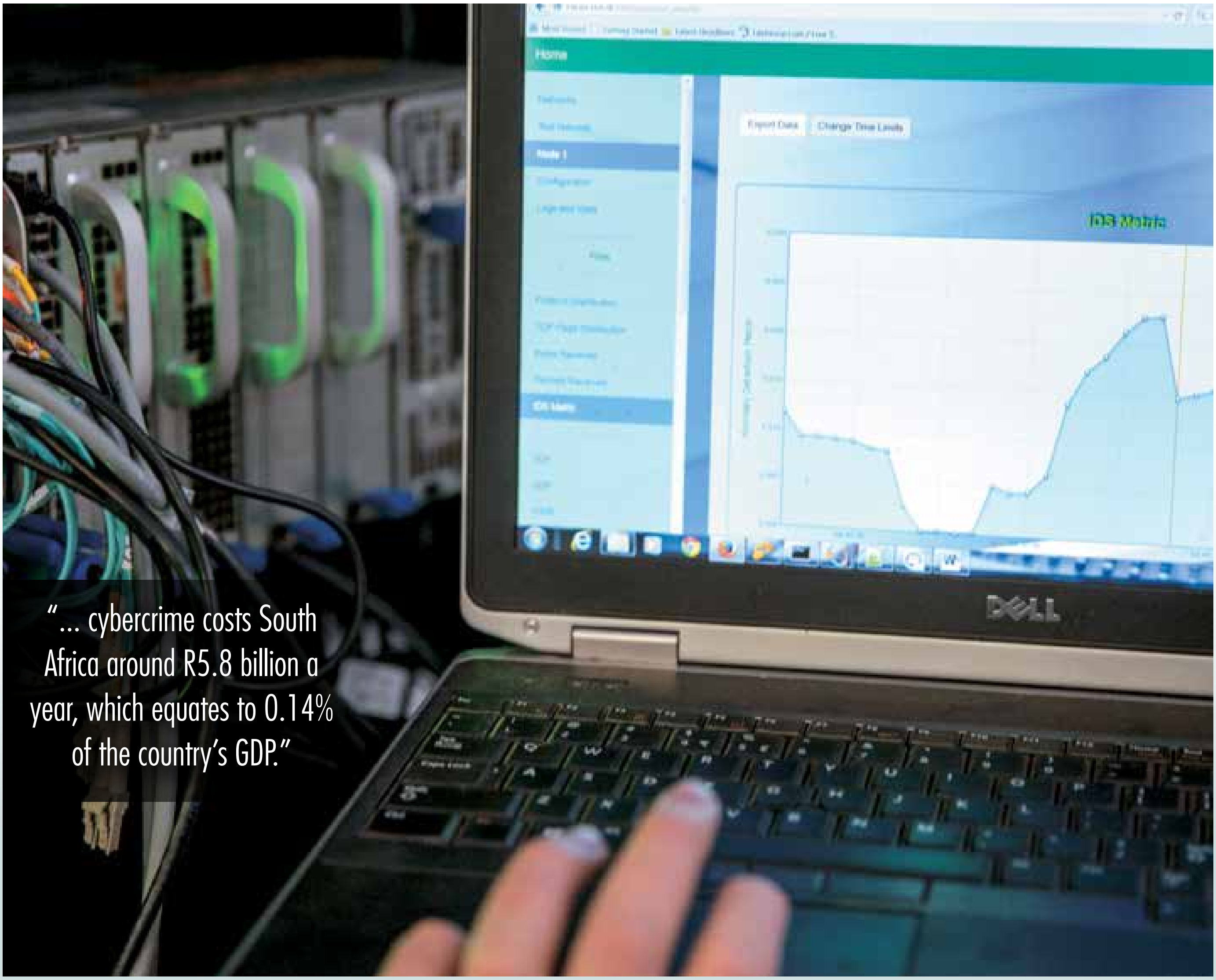
ACCURATE DETECTION OF INTRUSIONS IN INFORMATION NETWORKS

By Andre McDonald

Cybercrime is a significant problem in South Africa and it is slowing down the growth of our economy. Researchers at the CSIR are contributing towards cybercrime prevention by developing new and more accurate systems for detecting intrusions in information networks.



"... cybercrime costs South Africa around R5.8 billion a year, which equates to 0.14% of the country's GDP."

Researchers at the CSIR are developing novel software for accurately detecting network intrusions. The novel detectors used by the software operate by scanning for unusual or unexpected network traffic patterns or anomalies in the characteristics of network traffic. Traffic patterns that do not conform to what is expected are often indicative of malicious activity in a network, and can be successfully used to identify likely intrusions.

SOUTH AFRICA is growing increasingly reliant on information and communications technology to provide access to information and services. Greater connectivity and progress towards bridging the digital divide are adding significant value to society and to the economy, but at the price of greater exposure to cybercrime and an evolving host of increasingly sophisticated threats against personal and confidential information of organisations and individuals.

The cybercrime problem

Defining cybercrime

Cybercrime constitutes a wide spectrum of illegitimate activity that involves networked information systems. Examples of cybercrime include the illegitimate access to personal or sensitive information which may lead to financial loss and identity theft, fraud and extortion, and the disruption of online services to bring about a loss in revenue.

An independent study by computer security company McAfee in 2014, estimates that cybercrime costs South Africa around R5.8 billion a year, which equates to 0.14% of the country's GDP. Cybercrime is not limited to large organisations and business institutions, but also extends to individual users of the Internet. A 2013 report by Symantec estimates that over one million South African citizens fall victim to cybercrime each year, ranking South Africa as third on a list of countries hardest hit by cybercrime.

Cybercrime often involves illegitimate access to networked information systems and resources, which leads to a breach in the confidentiality, integrity or availability of information, or the unauthorised use of these resources. Despite their maturity and widespread use, conventional network security mechanisms such as firewalls are often insufficient to safeguard against these intrusions. The reasons behind this deficiency include misconfiguration or lack of sufficient security mechanisms, infrequent updating of software to fix known vulnerabilities, and so-called zero day exploits, which take advantage of previously unknown flaws in information and communications technology systems.

Network intrusion detection

The inability of conventional network security mechanisms to reliably prevent intrusions in networked information systems has revealed the need for an additional layer of security in computer networks. The purpose of this additional layer is to prevent or limit the extent of any malicious activity involving the network and its resources, as may result from an intrusion. It involves the accurate and timely detection of intrusions as they occur, and the subsequent blocking of illegitimate access to the network. This security layer relies on the assumption that an intruder's behaviour or usage patterns will be noticeably different from that of a legitimate user.

The CSIR's Brenwen Ntlangu and Andre McDonald develop software that is able to accurately detect network intrusions.

The detection of intrusions in computer networks, or network intrusion detection, is a problem that has received attention from researchers in the field of information security for more than 30 years. Progress in this area has led to the commercialisation of network intrusion detection technology. This technology consists of hardware and software systems that are deployed in a computer network to monitor network traffic, with the purpose of detecting intrusions in an automated fashion. These misuse detection systems are able to accurately detect known patterns or signatures of malicious activity, but they are limited in the scope of malicious activity that can be detected.

Solutions in progress

Novel techniques for detecting intrusions

Researchers at the CSIR are developing novel, more accurate detectors of intrusions that do not rely on predefined signatures of malicious activity. This is a key advantage over misuse detection systems, as signatures for new or recent exploits are frequently unavailable – they are created by specialists only after malicious behaviour has been identified and analysed. The novel detectors are able to detect a wide spectrum of malicious activity, as there is no requirement to accurately capture every possible permutation of malicious activity in a signature.

The novel detectors operate by scanning for unusual or unexpected network traffic patterns, or anomalies in the characteristics of network traffic. Traffic patterns that do not conform to what is expected are often indicative of malicious activity in a network, and can be successfully used to identify likely intrusions. The anomaly detectors developed at the CSIR provide real-time detection, which provides a larger window of opportunity for responding to the intrusion and limiting the extent of the malicious activity. They also require little computational power, which is an important practical consideration.

Collaboration with the University of Cape Town

The CSIR is collaborating with the Faculty of Engineering and the Built Environment at the University of Cape Town in joint research in the area of network intrusion detection, and the co-supervision of postgraduate students in related topics. The objective is to expand the scope of the research currently undertaken at the CSIR; specifically, to develop a range of detectors that operate in synergy to further suppress false positives, which is a key practical limitation of anomaly-based network intrusion detection systems.

A system for network intrusion detection

CSIR researchers have developed a software system that can be used to deploy the novel detectors throughout a computer network, thereby providing a consolidated view of the network and any threats to its security. The system enables the security expert to configure the detectors and to focus on specific types of malicious activity, depending on the nature of the network. The situational awareness provided by the software system contributes to the early detection of threats, and is a key component in preventing intrusions.

The CSIR is currently exploring partnership options with industry towards further development and commercialisation of the network intrusion detection system. By partnering with industry, the CSIR creates an avenue for research uptake and impact through a jointly-developed product. Consultation and joint development with industry also improves the relevancy of the software, thereby promoting its uptake in the marketplace.

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FIGHTING IDENTITY THEFT WITH ADVANCES IN FINGERPRINT RECOGNITION

Dick Mathekga

Fingerprint recognition is a powerful tool to combat identity theft, which is costing the South African economy billions of rands. In an effort to make fingerprint recognition accessible for use by more South African companies to help prevent fraud resulting from identity theft, CSIR researchers have developed a software library with functions required to perform fingerprint recognition. Areas that require improvement have been identified and development continues in order to optimise the fingerprint recognition functions.

IDENTIFY THEFT occurs when someone assumes the identity of some other person, using their identifying information, usually in order to commit some crime. It occurs because:

- Most people's identifying information is readily available to criminals, for example, our names and ID numbers are recorded each time we enter venues or organisations with security. More often than not, we do not know how the information is managed and if information protection laws are applied.
- Methods that are commonly used to confirm identity can be circumvented by criminals. The South African ID document, for example, is the most used method of confirming identity in South Africa, but is easy to forge.

Given the above, fraud resulting from identity theft can be prevented through a more reliable method of confirming identity. Biometric recognition, which is the use of a biometric to automatically determine or confirm identity, is such a method; where a biometric is a measurable biological or behavioural characteristic that can be used for automated recognition, such as a fingerprint.

Identity can be reliably verified by comparing the biometric of a person claiming an identity, to a biometric stored against the claimed identity in a trusted database. A trusted database, when using fingerprints as a biometric, is that of the Department of Home Affairs and it can be used as a basis for creating other trusted databases; by only entering fingerprints and identifying information of people whose identities can be confirmed using the department's fingerprint database. Therefore, companies affected by fraud resulting from identity theft can procure their own biometric recognition systems for use to confirm client identities; creating a trusted database.

Biometric recognition systems are made mostly with technologies that are developed overseas and although the cost of the systems is affordable, it is believed that the use of local technologies could reduce costs and therefore make the systems accessible to more companies. Therefore the CSIR, in-line with its mandate, performs biometric research and development to contribute to the creation of local technologies. Initial efforts have been directed at developing fingerprint processing software with the following functions, which are required for fingerprint recognition: fingerprint feature extraction, fingerprint feature comparison and fingerprint classification.

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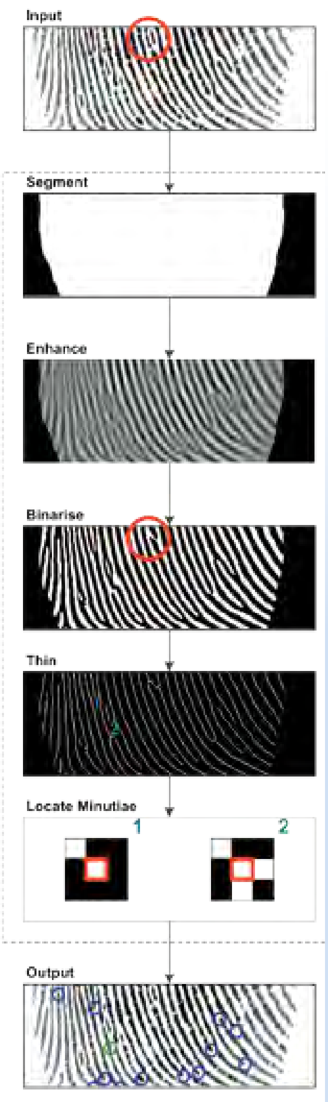

Figure 1: Minutiae point identification algorithm steps, with ridge endings and a ridge bifurcation inside blue circles and a green circle, respectively.

Fingerprint feature extraction

The mostly commonly used fingerprint features are minutiae points, which are the locations on a fingerprint where the ridge lines, in other words, the black lines on the fingerprints and fingerprint sections – shown in Figures 1 to 3 – end or bifurcate. The function to extract minutiae points implements the algorithm shown in Figure 1, where each step, except the *locate minutiae* step, was implemented using published methods.

Figure 1 shows that the minutiae points can be extracted from a fingerprint using the function. However, not all minutiae points are always correctly identified as shown in Figure 1. This is mainly because of the poor performance of the methods for performing the *enhance and binarise steps;* their outputs are not a true representation of the input as shown by the regions encircled by a red line in Figure 1. The methods are being improved.

Fingerprint feature comparison

The comparison of minutiae points from two fingerprints is performed through a two-step approach:

1. Matching minutiae points, i.e. minutiae points with the same relative spatial locations such as those in Figure 2, are identified.
2. A similarity score, i.e. the likelihood that minutiae points being compared where extracted from fingerprints of the same image, is computed.

The above steps are performed using methods that were developed at the CSIR and matching minutiae points can be identified as shown in Figure 2. However, the performance is below that of similar commercial products, mainly because the method for implementing step 1 does not always identify correct matching minutiae points as in the case of the minutiae points encircled by red line in Figure 2. Current efforts are directed at improving the methods for implementing both steps above.

Figure 2: Two representations of the same fingerprint with matching minutiae points that have been identified, using the CSIR software, connected by yellow lines.

Fingerprint classification

Classification is performed to determine which of the five different types of fingerprint patterns shown in Figure 3, match a given fingerprint. This is usually done to speed up the process of comparing a large number of fingerprints by only comparing fingerprints of similar patterns.

The classification function performs classification based on the number of singular points on the fingerprint image and their relative positions. Singular points are the locations on a fingerprint image where ridge lines make a sharp U-turn (loop) or form a triangular shape (delta) as shown in Figure 3. However, fingerprints are often captured with one or more singular points missing and the classification method implemented in the function can account for such cases.

Classification accuracies of over 90% have been obtained when classifying fingerprints in Database 1 for the 2002 and 2004 fingerprint verification competitions using manually identified singular points. However, accurate identification of singular points is not always possible, especially on poor quality fingerprints. Current efforts are on improving the methods for identifying singular points and also experimenting with a different non-singular point feature for classification.

Figure 3: Five main types of fingerprints with singular points marked.

DEFENCE

NOVEL CSIR TECHNOLOGIES REDUCE THE TIME AND COSTS OF AERONAUTICAL SYSTEMS TESTING

By Dr Kaven Naidoo

Global aerospace and defence budgets are increasingly under pressure, with a resulting need to optimise resources. Ever more complex problems have to be solved in shorter periods of time. The CSIR has developed a range of novel technologies for modern aerodynamic design, testing and evaluation in support of our aerospace and defence industries.

IN THE CURRENT CLIMATE of restricted research and development spending there is a need to solve ever more complex problems in shorter time scales and at reduced costs. Typically, aircraft design programmes and weapons integration efforts need to characterise the effect of a large number of problem variables, and require large programmes and resources spanning thousands of hours of wind tunnel testing and simulations. This is not feasible in a cost and time-constrained environment.

In South Africa, the need to maintain competitiveness with leading aerospace nations has generated innovation in the form of several novel technologies developed at the CSIR. These help to reduce the time and budgets needed to complete aeronautical design as well as testing and evaluation programmes. Brief descriptions of some of these technologies follow.

Simulation of airborne system concepts

The CSIR developed a mission simulator for unmanned aerial vehicles (UAVs) that allows for the simulation of various UAVs with mission-specific payloads in any kind of operational theatre. This wargame-like software system can evaluate the performance of the UAVs in a number of scenarios with variations in terrain, environmental factors and threat systems. This allows for improved tailoring of designs to fit mission-specific requirements in the simulation environment, reducing the number of demonstration prototypes. It also provides UAV operators and commanders with the opportunity to easily test UAVs and operational concepts in a simulation environment so that they may be operated optimally.

Similarly, the simulation environment can be used to test the operational capabilities, limitations and design requirements of missile systems in various operational scenarios.

Faster, less costly testing of weapon systems integration

Testing the integration of a new weapon system onto a fighter aircraft to ensure that missiles can be safely flown and deployed within the aircraft's flight envelope (the limits of its altitude, speed and manoeuvring capabilities) entails thousands of hours of computer simulations and wind tunnel tests. This is necessary as the impact of adding a weapon system has to be tested at every point within the flight envelope, while testing a number of critical aerodynamic variables to ensure a consistently safe operating envelope.

The CSIR developed a mathematical method to select a limited number of points within the flight envelope for testing and simulation, allowing for the data to be interpolated at different points within the envelope.

The first image-plane tests carried out in the CSIR medium-speed wind tunnel, using the half model of the airframe used in a project that investigated the use of joined-wing configurations and morphing wing solutions.

In essence, the CSIR has explored the development of hybrid methods that combine the speed and low cost of traditional, fast, well-established aerodynamic prediction methods with the high accuracy of new, higher fidelity methods coupled with wind tunnel simulation to reduce solution time for complex aerodynamic problems. This results in significant savings in terms of the cost and the time it takes to perform a weapons integration. The method has already been successfully validated against traditional testing methods.

High angle-of-attack test rig designed

Using the same mathematical method mentioned above, the CSIR was also able to expedite the design for a test rig for the CSIR's large transonic wind tunnel facility that will be used for the aerodynamic characterisation of high angle-of-attack missile aerodynamics.

Normally, designing such a rig is time and cost-intensive, because the rig design has to be tested at various attitudes and roll angles to ensure that the rig itself will in no way affect the aerodynamics of the missiles tested.

With the use of an optimised test matrix as well as flow simulations the design for the proposed, high angle-of-attack test rig could be completed at a fraction of the time and cost it would otherwise have needed.

Testing 'morphing wing' designs to reduce carbon footprint and cost-of-travel of future aircraft

Traditional aircraft wing designs, of the kind that is prevalent on most aircraft, are constrained by traditional structural design methods, materials, material strength and current manufacturing processes.

The CSIR is currently investigating the effect of so-called morphing wings (wings that can change their shape in flight to reduce aircraft drag at different aircraft speeds) for possible use on future commercial aircraft. The exact method of morphing is still to be determined by industry, but the CSIR is exploring the efficiency of different morphed wing test shapes in wind tunnel testing to determine the design requirements for such futuristic wing designs. These wings would allow for a dramatic reduction in the carbon footprint (fuel efficiency coupled with a reduction in greenhouse gas emissions) and cost-of-travel per passenger on the aircraft.

With the above-listed technologies, the CSIR has again shown that the challenge of intensive resource constraints, in this case in the aerospace and defence industries, can often produce unique and innovative solutions.

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Finding the right technology solutions to secure our borders

By Cobus Venter

Ensuring the safety and security of our combined land, air and sea borders is a complex challenge for which there is no single, simple solution. From a science and technology perspective, the CSIR has played an important role by creating a process that identifies the deficiencies and shapes scenarios to test feasible solutions.

WORKING WITH A RANGE of government and industry stakeholders, operational conditions were simulated during border-safeguarding field trials to test technical tools and combinations of technologies as well as the effectiveness of processes and doctrine. These tests contributed to a better understanding of the comprehensive approach needed to address border safeguarding and those technologies that would positively contribute to it.

South Africa's coastal border stretches along 2 700 km from Namibia on the Atlantic ocean, around the tip of the continent and upwards to Mozambique on the Indian Ocean. The terrestrial border runs along 5 200 km shared with five neighbouring countries and with Lesotho ensconced within the country. Transborder crimes – ranging from poaching and smuggling to illegal crossings – are a major challenge. Also, border zones have different, but equally challenging, environmental profiles – from dangerous and unpredictable oceans, to semi-desert areas, and pockets of extremely high humidity and rough terrains.

Adding to the complexity of border management is the requirement to coordinate or consolidate the roles and activities of a multitude of parties involved. These include agencies such as the SA Police Services and Revenue Services, as well as more than 10 government departments including Agriculture, Fisheries and Forestry, Home Affairs and Environmental Affairs. The CSIR's efforts are mainly focused on supporting the Department of Defence – and the SA National Defence Force in particular – as lead agency tasked with border safeguarding.

Finding focus in complexity

Given the complexities and the broader context of challenges, government philosophies and policies, and the different interests of involved parties, the CSIR developed a process that considers all aspects, but narrows it down to specific objectives to target with technical interventions.

Through consultation, parties agreed to an experiment definition that used maritime safeguarding as the operational scenario in which to conduct field deployments to 'play out' typical incidents. Specific scenarios were planned that would test or demonstrate technical and tactical capabilities. On the technical side

Evaluation under real conditions: Several technologies and different role players formed part of a field experiment at Saldanha in the Western Cape to evaluate optimal approaches to maritime border safeguarding.

it included detection and effective synthesis of situation awareness data, and at command level, the challenges of joint, interagency and intergovernmental multinational participation.

From the lab to real life

It is essential that the options are verified as technically achievable before embarking on the expensive field experiment phase. This verification takes place during small-scale laboratory experimentation. During this phase, various elements are tested independently to verify individual feasibility as well as its integrated operation. What fails in the lab does not go into the field. This ensures that time and money is not wasted on trying out elements that cannot contribute positively. The next test happens during the actual experiment; experience has shown that the experiment elements usually change after a day or two in the field. These lessons are taken into the next experiment.

Maritime and harbour protection in the Saldanha area became the scenario for deployment. The safeguarding challenges include refugee influx, intertidal poaching, vessel interception for contraband and maritime sabotage.

Specific 'injects' – plausible events that could occur in real life, but simulated for purposes of the experiment – were planned to occur over a two-week period in November 2014. These included piracy attempts, poaching incidents and illegal crossings, and made use of different surface craft and submarines. Technologies used in the monitoring and response included radar and electronic warfare systems, optronic systems, unmanned aerial systems, databases, software and communication networks. The preparation time spanned eight months and involved all Arms of Services, government departments and private agencies who participated actively in the 'injects' and contributed technologies for the deployment or manned command centres.

Working with real results

After the field experiment, the overall and technical objectives are evaluated. The evaluation gauges if the objectives were achieved fully, partially or not at all. The reasons for not achieving an objective are noted and used to improve the process.

The most important outputs of the experiment are the recommendations generated against each objective. These recommendations are used by the relevant department to improve a process or implement a technical solution or to develop a new capability.

During the past four years, the CSIR has conducted five major experiments related to border safeguarding. Each of these experiments identified process improvements and verified the feasibility of technical solutions. Based on these results, the Department of Defence has initiated doctrinal changes as well as acquisition and procurement processes to ensure they are equipped to deal with border-safeguarding challenges and security of state.

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Priaash Ramadeen of the CSIR demonstrates a platform that integrates and processes data from different sensors and communications devices at the organisation's concept development and experimentation centre.

TECHNOLOGY TO COMBAT POACHING: From the lab to the Park

By Priaash Ramadeen

South African National Parks (SANParks) has partnered with the CSIR on the use of technology to combat rhino poaching. The CSIR supports SANParks with technology evaluation and advice, improved systems for surveillance and detection as well as secure tools for the collection and analysis of data pertaining to poaching tactics and trends. The CSIR's Cmore platform is currently being used as the Kruger National Park's core command and control system in the fight against poaching.

THE NUMBER OF rhino poaching incidents has escalated drastically 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 the animals and improve the ability of park officials to deal with poachers.

Within the complex and dynamic world of safety and security, information is the key towards gaining insight and understanding of a situation.

Real-time information enables timeous and informed decisions, while subsequent analysis of the information enables an organisation to become proactive.

Border safeguarding sets the scene

The CSIR first started work on a system to facilitate inter-agency collaboration in supporting border-safeguarding initiatives in South Africa. The team considered social networking technologies and the emergence of wireless and mobile communications and combined that with traditional command and control functions (tracking, threat detection, situation awareness, etc.) to create the initial Cmore technology demonstrator. Cmore is a cloud-based shared situation awareness platform that facilitates inter-agency collaboration and the integration of a diverse set of services and sensors.

A screenshot showing real-time location tracking on a smart device which is running Cmore.

Major General (retired) Johan Jooste, SANParks Commanding Officer Special Projects, (left) and Dr Sibusiso Sibisi, CSIR Chief Executive Officer, at the Mission Area Joint Operations Centre in Skukuza in the Kruger National Park.

The Cmore user interface.

The system fully exploits the geographic nature of events and real-world entities. Its flexible information model makes it suited for various domains, ranging from conservation to public services to safety and security.

The technology platform was initially tested in laboratory type scenarios, before an opportunity arose for it to be put to the test in border-safeguarding experiments.

These experiments involved a number of organisations and systems being deployed within an operational defence force scenario.

Between 2013 and 2014, experiments were held in Ladybrand, Musina, Macadamia and Saldanha. The latter focused on maritime activity. These experiments highlighted real-world requirements that were used to further improve the Cmore system.

From the lab to the Park

In June 2014, the Kruger National Park's anti-poaching personnel visited the CSIR's concept demonstration and experimentation centre for a demonstration of the technology platform. Since then, the CSIR team has been working to support the anti-poaching campaign by developing new requirements, conducting training and improving current processes.

The CSIR and its collaborators established a facility that serves as a nerve centre, where surveillance reports and data about poaching events, country-wide border crossings and other operational information are collated, shared and analysed. It also serves as a command post for immediate-reaction task forces that are dispatched from a nearby airstrip.

Rangers and other parties involved in combatting rhino poaching – from private game rangers and tourists to the South African Air Force – all log incident data of various types. By forming a holistic picture of incidents and trends, SANParks' staff members are able to understand the behaviour patterns of poachers and develop pro-active response strategies.

Continuous, shared awareness

Cmore's portal and mobile applications allow the commanders and rangers to have real-time shared awareness of events, planning and tracking (rangers, aircraft) wherever there is an internet connection. The mobile applications have a full offline capability allowing use when not connected. Within the operations room, multiple organisations have access to a common operating picture.

Progress has been made to the extent that data being gathered can be used by researchers to develop algorithms to assist the Kruger National Park with its operations. Opportunities include predictive modelling to anticipate the next poaching event and optimising interdiction patrol routes.

Through Cmore, the team is working on linking all of the parks within South Africa as well as getting all the major anti-poaching stakeholders and organisations to collaborate. These efforts will then be replicated in the SADC region through conservation partners for the purpose of providing a South African, African, and ultimately a global view of conservation.

Project team: Alex Terlunen, Pieter Botha, Priaash Ramadeen, Shazia Vawda, Minrie van Ellewee, Herman le Roux, Cobus Venter, Arno Duvenhage, Jaco van den Bergh. Supported by Braam Greeff and Charl Petzer.

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Research and development to protect soldiers from landmines and improvised explosive devices

By Rayeesa Ahmed

Nicolas Tsila, a CSIR explosive technician, setting up an experiment involving an explosively formed projectile surrogate.

An add-on protection package is tested at the CSIR's detonics, ballistics and explosives laboratory.

Typical damage or penetration caused due to an improvised explosive device projectile on an unprotected target.

Landmines and Improvised Explosive Devices (IEDs) remain a major threat for military vehicles, their occupants and other assets. Due to the improvised nature of the current threats, the shift from conventional to unconventional warfare and the use of improvised weapons and terrorism, traditional methods of protection need to be adapted or new technologies developed. In one research project addressing this challenge, the CSIR developed a vehicle add-on protection package to interrupt explosively formed projectile IEDs.

PROTECTION SOLUTIONS for the South African National Defence Force has resulted from several processes of research, development and innovation.

A clearer understanding of the problem (threat) is built on a combination of encounters in the field, trends and theoretic calculations. The main elements that must be understood in the case of landmines and IEDs are the damage mechanisms of the threat. For landmines, this mechanism can be defined in terms of the blast loading. For IEDs, it can be blast loading, fragmentation penetration or a combination of both. With make-shift explosives devices, such as IEDs, the threat characterisation phase is critical, because each weapon is different and poses different threats.

Case study: Explosively formed projectile

For this case study, the threat was an explosively formed projectile IED. These are generally characterised by the projectile that is formed during the detonation, in terms of its mass, the speed it attains and the shape it forms (including whether a single coherent slug is formed or several smaller slugs). These three parameters are key in determining the performance of the projectile (based on its kinetic energy over a distance) and thus also indicate the required protection needed to prevent penetration.

Because of the improvised nature of IEDs, a representation of the threat, or surrogate, is needed to simulate repeatable behaviour, against which any protection solution can be evaluated.

CSIR researchers modelled a surrogate explosively formed projectile IED concept design using specialised software to simulate the performance of the projectile. The concept design was modified based on the computational results and a prototype was built. This was experimentally tested, using specialised equipment, against a simple steel plate target.

The equipment used during the tests included a Flash X-ray and high-speed video cameras to measure the speed and morphology of the projectile as well as the interaction thereof with the target.

This initial surrogate design was then fine-tuned to get the desired performance output (based on projectile mass, speed and shape). The modification, modelling and subsequent retesting was an iterative process until the correct behaviour was attained. Several tests were conducted on the final version to ensure that the performance of the surrogate was consistent and repeatable.

A good protection solution against an explosively formed projectile threat should ideally break up the projectile or slow it down. This reduces the kinetic energy of the projectile sufficiently for it to be unable to penetrate the occupant compartment of the vehicle or final layer of the target.

The protection solution should, however, also not add too much weight to the target and thus the mass per area of the solution is an important criterion to consider. Similarly, the dimensions of the solution should not be such that the total width of the vehicle becomes impractical. These weight and dimension budget limitations are assessed by that which would provide the same protection levels as the equivalent mass and thickness of a plate of Rolled Homogenous Armour.

Several concepts for an add-on protection package that can be fitted onto a vehicle were devised based on research, including threat/target interactions, material behaviour under impact loading and new materials or novel material combinations. Each concept was modelled and prototype panels of those that showed potential were manufactured. These were each tested against the surrogate projectile, and the speed and morphology of the projectile was measured before and after interaction with the panels to evaluate whether the panels had the predicted effect in slowing down or interrupting the projectiles.

Based on the results of the tests, the concepts were modified and retested until a final design was reached. This case study is an example of how the research, development and innovation process was successfully followed to reach a solution that would provide the required protection, within the specified mass and dimension restrictions.

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Providing state-of-the-art modelling and simulation support for the South African Air Force

By Kevin Jamison

Air warfare in the 21st century is dominated by advanced technology and it is increasingly difficult to intuitively discern the optimal solutions, doctrines and tactics to adopt. Modelling and simulation can be used to simplify complex scenarios to the point that they can be analysed and learning derived. Often the process of modelling and simulating these scenarios uncover non-intuitive insights as the interactions between the elements in the simulation are investigated. The CSIR has developed advanced modelling and simulation software that adds real value to the operations of the South African Air Force.

IN DECADES PAST, air warfare mostly involved single aircraft in line-of-sight combat, or 'dogfights', and the use of very similar weapons for air-to-air or air-to-ground attacks. These days, with advanced modern radar and sensing technologies, a myriad of advanced weaponry and countermeasures, and the use of unmanned aerial vehicles (UAVs) and long-range missiles, air warfare has become faster, more unpredictable and a lot more complex. This makes the acquisition and adoption of the right aircraft, systems, technologies and tactics a difficult task for any air force. The same is true for the South African Air Force (SAAF), which has to anticipate increasingly advanced and unpredictable threats on the continent.

The 2014 Defence Review makes it clear that peace enforcement operations outside of South Africa are very much part of its mission. At the same time, sub-Saharan Africa continues to grow economically (it is one of the fastest growing regions in the world) with spending on defence acquisitions increasingly resulting in some very advanced munition systems proliferating across the region. This means that the South African National Defence Force is likely to encounter very advanced adversary systems being utilised. As the SAAF is a small air force, there is a great premium on fighting 'smarter' and on making the best possible use of the limited resources available. At the same time, the introduction of systems to cope with the increasingly complex combat scenarios, for example the introduction of the SAAB Gripen into the SAAF, has presented a range of new capabilities such as datalinks, helmet-mounted displays, ultra-agile missiles and long-range multi-mode radars. These facets add to the challenge of accurate planning, well-informed acquisitions and the selection of the best tactics.

Addressing complexity through modelling

One of the best ways to address complexity is to model it. Nowadays models can utilise the dramatic increases in computational power and innovations in software architecture and algorithms to address complex systems. Simulating complex nonlinear systems is important for avoiding the unintended consequences that often arise when issues are studied in isolation. The CSIR has long provided modelling and simulation support to the SAAF, drawing on the organisation's diverse expertise in areas such as aeronautics, radar, optronics, electronic warfare and command and control.

The CSIR has assisted the SAAF over many years, using modelling and simulation, in a range of different missions and acquisitions. This led to the development of the Mission Simulation Framework, used by the CSIR in modelling and simulating scenarios for the SAAF. Some of these projects are outlined on page 59.

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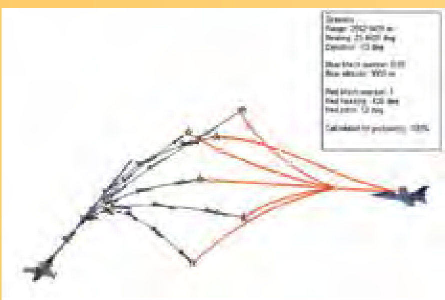
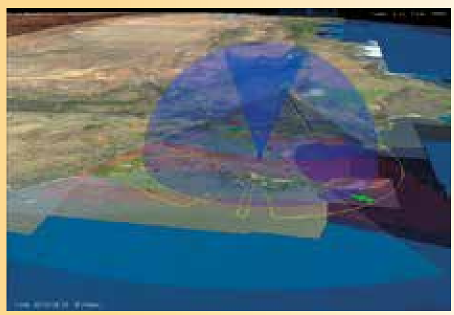


Analysing missile hit probability for engagement scenarios.

Helmet-mounted display.



Air defence planning during the Soccer World Cup in 2010.

Photograph: Frans Dely

New fighter aircraft acquisition

Before the acquisition of the SAAB Gripen fighters in 1999, the CSIR used modelling and simulation to help determine the minimum performance requirements for the acquisition of a new fighter aircraft in the southern African operational environment. These simulations showed what speed, range and manoeuvrability would optimally be required, even before aircraft were shortlisted for selection.

Planning air defences for the 2010 Soccer World Cup

FIFA – the International Federation of Association Football – required that South Africa protects all the stadiums and surrounding airspace from unauthorised intruders. This task was assigned to the SAAF and was challenging for a small air force due to the number of stadiums across the country. Modelling and simulation was used to study the positioning of radars and sensors, and to optimise the flight paths for aircraft patrols to complement the ground-based sensor coverage while still being able to respond rapidly to threats.

Short range air-to-air missiles and helmet-mounted display

With the advent of helmet-mounted display targeting technology and ultra-agile short range missiles, certain 'rules of thumb' had to be developed, with the aid of simulations, to ensure the safe use of such advanced weaponry – for instance to avoid a fighter pilot accidentally shooting down his/her wingman.

Anticipating new stand-off weapon technologies

Stand-off weapons are missiles or bombs which may be launched at a distance beyond the range of defensive fire from the target area. With the increasing proliferation globally and also in Africa of advanced air defence systems, the SAAF needed to clearly understand what performance to specify for the new stand-off weapon technology. Modelling and simulation was used to determine what ranges and capabilities were required from different launch profiles to succeed against these threats.

Beyond-visual-range air-to-air combat

With the advent of long-range airborne radar technologies and beyond-visual-range weapons systems, this mode of air-to-air combat has become increasingly important. Beyond-visual-range combat is very complex with a large number of factors that can influence the outcome of an engagement. Some of these factors include the capabilities of the aircraft on both sides, the missiles, the presence of datalinks, the use of ground controllers and electronic warfare. Beyond-visual-range technology is proliferating in Africa and the SAAF asked the CSIR to develop a modelling and simulation environment to support acquisition decisions on such systems and to evaluate tactics and doctrines.

These projects show that modelling and simulation is playing a key role in assisting the SAAF to address the complexities of modern air warfare, to anticipate threats, to make smarter acquisitions, and to enable it to cost-effectively adapt to changing needs and capabilities in the air defence sphere.

OPTICS AND RADAR: Your eyes and ears in the battle field

By Simphiwe Mkwelo

The ability to detect and identify a possible threat is critical in the military context where rapid reaction, deployment of countermeasures and self-protection tactics can mean the difference between life and death. The CSIR's work in combining radar and optical sensors into fully integrated systems supports the South African National Defence Force as it conducts peace-keeping missions in African combat zones and protects our land, air and sea borders.

MODERN WARFARE takes place in an asymmetric environment where different forces have different military capabilities and use unconventional weapons or tactics to gain the upper hand. Improvised explosive devices and shoulder-launched missiles are examples of weapons that may be used in the African combat scenario.

These are typical problem areas where integrated optical sensor and radar technology can be used to characterise the threat, countermeasures and the environment under which engagements take place.

Optical surveillance

Optical surveillance and sensor networks provide one method of detecting, tracking and recognising enemy threats. CSIR research in this area deals with both the sensing and processing components. This requires a wide range of skills including electronic engineering, mechanical engineering, software engineering and optical physics. Optical systems are imaging systems designed to image the scene, using radiation from the environment and self-generated heat from objects. Optical sensors operate at the small end of the electromagnetic spectrum in terms of wavelength – i.e. wavelengths spanning 100 nm to 1 mm. At these small wavelengths, these sensor systems encounter challenges with weather and lighting conditions, which limits visibility. One of the challenges is to develop image processing algorithms to mitigate these effects and improve image quality.

Radar surveillance

Radar is a short term for 'radio frequency detection and ranging'. This has been a core research domain at the CSIR since the organisation's establishment in 1945. In fact, South Africa's history in radar technology stems from its use during the World War in 1939 when systems were deployed along the coast as part of the British campaign in Africa. Radar sensors

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Field trials performed using a mobile, integrated dynamic radar cross-section measurement facility.

A stand-alone tracker incorporating a multi-spectral high-resolution digital sensor suite that tracks potential threats, and simulates the ocean's movement (or motion) to allow the evaluation of the sensor suite on land.

typically operate in the microwave portion of the electromagnetic spectrum with wavelengths from 1 mm to 100 m.

Radar in general are not naturally suited to performing imaging, identification and recognition functions. This is because the basic radar operates based on received echoes from the surrounding environment – the target appears as a blip on the radar display. Much more sophisticated hardware and processing are required to produce images of the target using synthetic aperture radar techniques. Even these images require a trained human operator to best interpret them.

Integrated infrared and radio frequency capability

Combining these two technology types has benefits which include long-range target detection and tracking, coupled with imaging and recognition of targets at close range. The normal scenario is to use radar as a designation source for the optical sensor. The optical sensor then images the scene and allows for automatic identification and recognition of the target from image features.

A proof of concept was demonstrated at the Paardefontein site in 2013, when the CSIR-developed radar cross section systems were tested in the field together with a number of optical sensors in infrared and visual bands. A command and control centre was set up where the feeds from the various sensors were received through a GiGE switch and displayed to give situational awareness to the operators. The radars were used as a primary source for designation on target aircraft because of longer range detection performance. When the targets were estimated to be within range for imaging, angular coordinates of the targets were sent to the optical control system to steer the sensors in the appropriate direction for imaging. The images at various optical bands and radar signals were then recorded and time-stamped for off-line analysis. In a real scenario, the processing would have had to run in real time to track and classify imaged targets automatically. This deployment was a major success and a baseline for further opportunities for collaborative and integrative exercises.

On the receiving end: Dealing with modern missiles

Performing research into self-protection aims to improve the effectiveness of countermeasures and survival of aircraft against specific missile threats. Vulnerability of aircraft is a matter of concern for the public/passengers, airliners, aircraft manufacturers, owners and operators. All aircraft, including civilian aircraft, are at risk of being attacked. The most common threat has for a long time been MANPADS (Man-Portable Air Defence System) with an infrared seeker head. An integrated infrared electronic warfare capability is required that uses testing and evaluation field measurements, modelling and simulation, and hardware-in-the-loop systems in a laboratory environment to characterise the behaviour and performance of the threat. The objective is seeing the world through 'the eyes of the missile' and understanding the processes that take place within the missile during an engagement with an aircraft.

Modern missiles now have integrated infrared and radio frequency capability to increase the probability of a hit. The integrated nature of the threat requires a countermeasure research capability that seeks to understand the integrated threat fully – a relatively new domain for threat testing and evaluation research. The fundamental requirement is to have infrastructure including integrated infrared and radio frequency threat exploitation and countermeasure effectiveness evaluation.

Cutting-edge technologies for modern warfare

Radar and optical sensors operate in the electromagnetic spectrum and are key technologies for survival in the asymmetric war environment, where early warning, situation awareness and recognition of allies and enemy forces are critical. An infrared/radio frequency integrated capability in terms of surveillance and platform self-protection is set to be a game changer in this dynamic and unpredictable combat environment. The CSIR is well placed to support the Department of Defence in tackling modern warfare challenges.

Infrared images of a C-130 Aircraft in the three different infrared bands: short wave (top), medium wave (middle) and long wave (bottom) depicting the contributions made to the aircraft signature within the various bands. These images were captured using imaging radiometers.

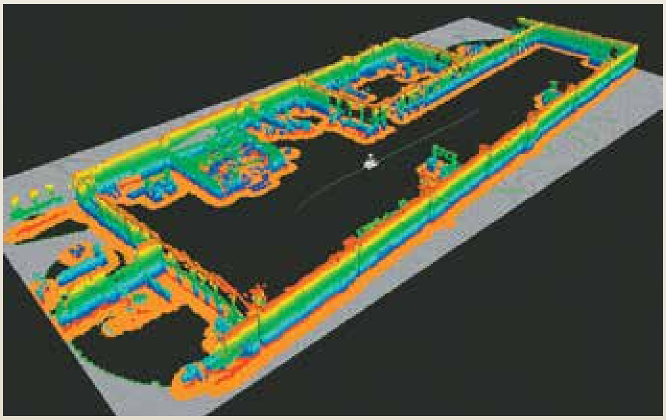
COMPUTER VISION FOR AN AUTONOMOUS MOBILE ROBOT

By Dr Daniel Withey

Mobile robots are well suited for remote reconnaissance and remote inspections, especially in environments that are dangerous or difficult for people. Examples include the remote investigation of damaged or contaminated buildings; remote inspections of, for example, the breakwater dolosse at coastal ports; and the inspection of large liquid storage tanks, which may present space constraints and harbour chemical vapours. Autonomous mobile robotics is an active and growing research area internationally. CSIR researchers in mobile intelligent autonomous systems are working on ways to improve a robot's visual interpretation of its environment for autonomous movement and intelligent inspection.

COMPUTER VISION SYSTEMS are essential for practical, autonomous, mobile robots; machines that employ artificial intelligence and can control their own motion within relatively unconstrained environments.

Analogous to the human visual system, which includes sense organs and processing centres for interpretation of visual information, a computer vision system includes one or more primary vision sensors, such as a set of cameras or a laser scanner, as well as sophisticated computer algorithms for extracting information from the raw sensor data.



The CSIR developed an experimental system for exploration and mapping using autonomous robots. The primary vision sensor for the system is a laser scanner that was mounted atop a generic robotic platform (right). The scan information is collected by an on-board computer to form a three-dimensional map. An example (above) shows the map produced from a 40m x 15m indoor area. A representation of the robot is shown in white following its self-generated path, indicated by a green line.

Platform design

An autonomous, mobile robot platform typically consists of a frame with wheels and gears, driven by electric motors. The design of the platform allows the machine a wide range of movement, including combinations of translational and rotational motion. One or more vision sensors are mounted on the robot frame and an on-board computer runs software that takes input from the sensors and determines the required motor control.

Suitable computer vision sensors include cameras, typically passive sensors that form an image of the environment; laser scanners, which emit a light beam and measure the distance to objects based on the travel time of the reflected light; and sonar scanners, which emit and receive sound waves.

Computer vision algorithms allow an autonomous, mobile robot to form a map of its environment. A key class of algorithms used in providing this information is Simultaneous Localisation and Mapping (SLAM), where sensed data are used to form the map and simultaneously determine the location of the robot within the map. When the robot is moving, computer vision algorithms are also used to detect obstructions that may appear in the robot's path, allowing appropriate action to be taken to avoid potential collisions.

Experimental system

A CSIR-developed experimental system for autonomous exploration and mapping demonstrates computer vision for an autonomous mobile robot. The primary computer vision sensor in this system is a laser scanner that provides a representation of the environment as a point cloud, identifying locations where returns have been received from the laser scans. Point clouds are produced by the laser scanner at a rate of several times per second and a SLAM algorithm is used to accumulate successive point clouds into a single representation of the environment, forming a map.

To autonomously move from one point to another, the robot uses its map to plan an obstacle-free path from its current position to the destination point. It then computes the motor drive controls that will allow it to follow the path. As the robot moves, the laser scanner input is used for location estimation and also for collision detection. If a blocked path is detected, the robot plans and follows a new, obstacle-free path.

For autonomous exploration, the robot uses its map to identify a region which has not yet been viewed with the laser scanner. It then moves to a position where the region can be observed and accumulates the scanned information into its map. This process is continued until the robot has mapped all accessible regions of the environment.

The map created by the robot, along with video from two forward-looking cameras, is supplied to an operator console via a wireless communications link. From this console, an operator has control to start, stop, or redirect the robot.

This experimental system demonstrates capability in the design and development of computer vision systems and of autonomous systems, in general. It lays the foundation for directed research in these areas and for the development of systems for specific, industrial applications.

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ENABLING NEW BROADBAND OPPORTUNITIES THROUGH SMART SPECTRUM SHARING

By Dr Fisseha Mekuria

Wireless devices connected to our daily lives, such as smartphones and laptops, are increasingly demanding more bandwidth and services. At the same time, a large proportion of the population in developing countries is still waiting for wireless broadband internet connectivity and services. The CSIR has developed an innovative, smart spectrum management tool that allows optimal sharing and utilisation of currently wasted and scarce spectrum resources to improve the reach of broadband internet services.

THE EFFECTIVE USE OF national radio frequency spectrum resources is important to meet the increasing bandwidth and service demand from current devices as well as responding to the enormous need in developing countries for wireless broadband internet connectivity and services.

Access to efficient broadband internet communication plays a pivotal role in the socio-economic development and functioning of societies hoping to progress to a knowledge economy.

As the number of wireless devices and associated bandwidth-hungry services is rapidly increasing, the existing static allocation of frequency channels to wireless networks and devices will soon inevitably give way to a system for 'on-demand', dynamic spectrum allocation. Taking the lead in this domain, the CSIR developed a national spectrum database covering the whole of South Africa. The spectrum database is coupled with a patented location-based dynamic spectrum allocation tool for easy, on-demand spectrum allocation. Together they provide an efficient spectrum management system and co-existent monitoring tool for telecommunications regulatory authorities (like ICASA).

Radio frequency spectrum is an important national resource for information and communications technology (ICT) infrastructure that needs to be managed effectively to cater for the increasing service demand from ubiquitous wireless devices. Better, smarter management of spectrum resources will assist a large proportion of the population in South Africa and developing countries where the majority of the population is still waiting for broadband internet connectivity through wireless communication technologies. The CSIR's wireless research team, as a result of consistent research, development and innovation in ICT and future wireless communications for several years, has developed a cloud-based dynamic spectrum allocation system that enables spectrum sharing between secondary TV white space broadband networks and licensed TV broadcasting networks.

Secondary broadband wireless networks use dormant or unused white space channel frequencies in TV broadcasting frequency bands. Furthermore, with the ability to accurately and continuously see which spectrum spaces are unused and which networks and broadcasters are using which frequency ranges, the system can provide spectrum regulators with a helpful smart spectrum management tool.

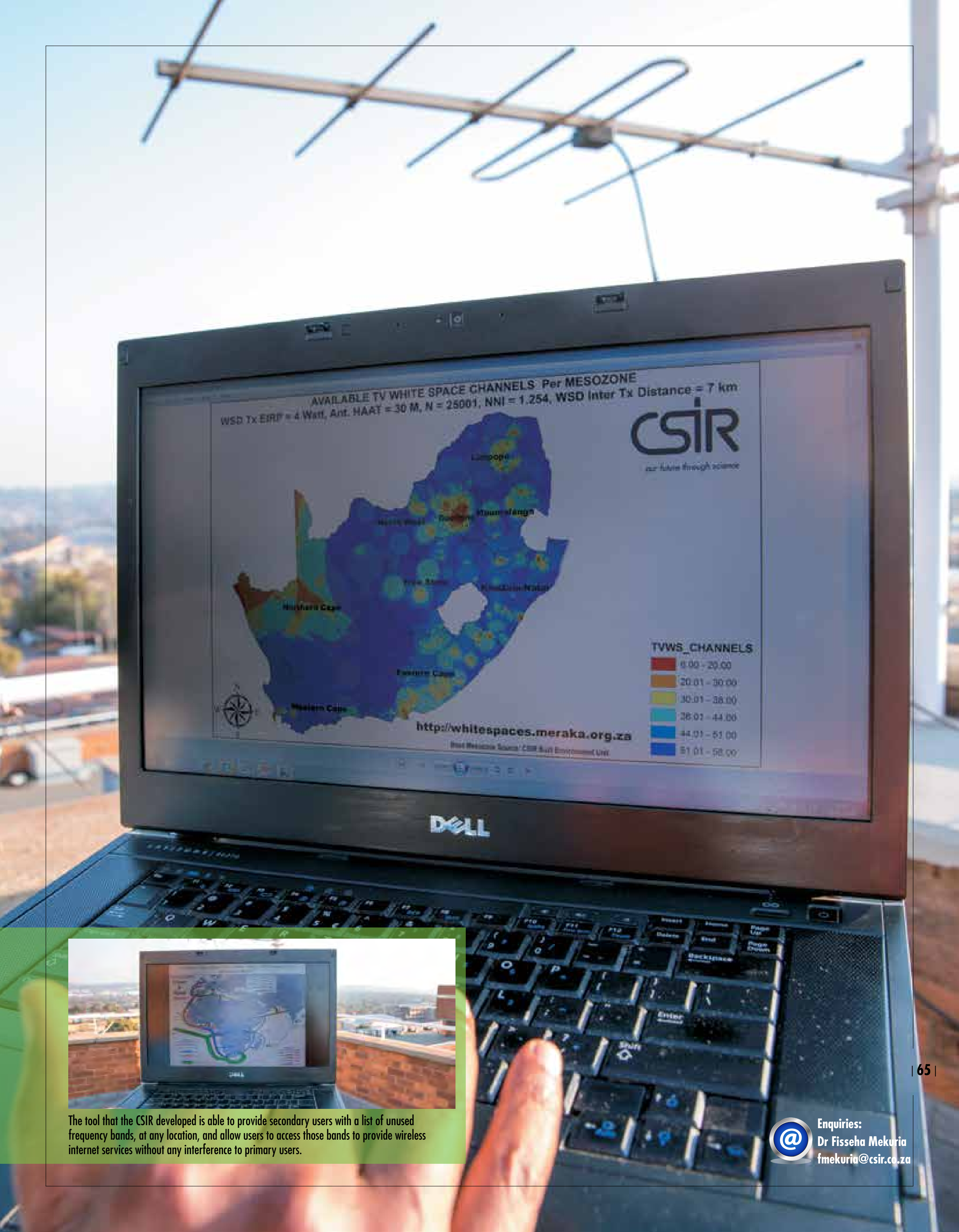
This technology has led to the emergence of new wireless broadband communications technologies, termed white space communications. Future wireless white space communications technologies will add to improved broadband service availability, and are expected to be affordable and easy to deploy in rural underserved communities. The CSIR is involved in deploying two experimental network test-beds based on spectrum sharing, which are now operational at two locations in South Africa (the Western Cape and Limpopo) where broadband internet services are provided to several schools.

The CSIR has received several international requests, based on the recognition of its excellent research and real-world experimental network test-beds. Requests range from development of a national dynamic spectrum allocation tool from other African countries, to help them in effective utilisation of their own national spectrum resources, to designing television white space broadband networks for increased broadband service provisioning. As a result, the CSIR also developed a cloud-based spectrum database framework, on which many national spectrum databases of various different African countries can be hosted. Countries that have thus far shown an interest in making use of this platform include Ghana, Botswana and Tanzania.

The CSIR wireless research team is the only team from Africa to take part in the recent global white space spectrum database qualification project organised by the EU Ofcom-UK telecom regulator. The outcome will give the CSIR's smart spectrum management tool international recognition, as well as open up global business opportunities.

Going forward, the CSIR aims to remain a leader in the smart sharing and use of spectrum resources on the continent, to accelerate wireless broadband internet services and improve socio-economic development.

Dr Fisseha Mekuria, Litsietsi Montsi and Luzango Mfupe are three of the researchers working on the CSIR's geo-location based dynamic spectrum allocation system.



The tool that the CSIR developed is able to provide secondary users with a list of unused frequency bands, at any location, and allow users to access those bands to provide wireless internet services without any interference to primary users.

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CYBERINFRASTRUCTURE FOR INTERNATIONAL COMPETITIVENESS

By Dr Happy Sithole

Figure 1: SANReN network roll-out.

Figure 2: A sample of data for ALICE projects showing the number of jobs processed at the CHPC from April to June 2015.

Cyberinfrastructure refers to information technology systems that provide particularly powerful and advanced capabilities. It encompasses a combination of massive processing capability, high-speed connectivity, massive storage facilities and highly skilled personnel. Leading nations have invested significantly in these facilities and closely aligned them with their economic activities. South Africa has in the past decade invested in national cyberinfrastructure to enable cutting-edge research and development within its academic and research institutions as well as industry. The CSIR, through the relevant centres and initiatives it hosts, plays a key role in developing South Africa's cyberinfrastructure landscape to ensure maximum impact from its various services.

THE CENTRE FOR HIGH PERFORMANCE COMPUTING (CHPC), hosted by the CSIR, is one of three primary pillars of the national cyberinfrastructure intervention supported by the Department of Science and Technology.

The CHPC provides massive parallel processing capabilities and services to researchers in industry and academia. The South African National Research Network (SANReN) provides high-speed connectivity to academic institutions and research councils around the country, while the Data Intensive Research Initiative of South Africa implements tools and facilities to enable efficient data-driven scientific and engineering discoveries.

To facilitate cutting-edge research, a wide range of skills development initiatives and support services ensure efficient utilisation of these facilities.

The performance of research activities in South Africa when compared to the rest of the world is used as a measurement of the outputs from these interventions. In addition, adoption of cyberinfrastructure in industry and other science and engineering domains is accelerating discoveries and development.

Cyberinfrastructure achievements in South Africa

The Department of Science and Technology has invested in cyberinfrastructure entities since 2006 and much has been achieved to date.

- The list of initiatives and organisations benefitting from connectivity from SANReN continues to grow and includes 25 universities; most statutory science and research councils; selected Technical Vocational Training and Education and Training colleges; and some schools. The 204 connected sites (with over 1 million users connected) receive between 1 Gigabit per second (Gb/s) and 10 Gb/s, with an average bandwidth availability of 2.82 Gb/s per site. The connectivity status is depicted in Figure 1.
- High performance computing (HPC) infrastructure has grown from 2.5 TFLOPS in 2007 to 61.4 TFLOPS, and is being upgraded to 1 PFLOPS (that is a thousand trillion operations per second) in the current year.
- A 4 PBytes-storage system split between the Pretoria and Cape Town campuses of the CSIR has been designed for data-driven applications and near-real time synchronisation to provide for full disaster recovery of all research data. This facility provides storage for big data resources in support of data intensive research activities.

Furthermore, these cyberinfrastructure entities also provide value-add services:

- The eduroam wireless roaming service allows researchers, students and educators to seamlessly connect to eduroam-enabled sites globally using their home organisation credentials.
- A combination of HPC-related training initiatives, which includes winter schools and a student cluster challenge, to develop high-end skills in the country.
- An annual meeting that attracts over 400 participants from all over the world with renowned cyberinfrastructure personalities giving keynote lectures.

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The successful implementation of cyberinfrastructure in South Africa has enabled competitiveness of the country in many aspects, notably:

- The reduction of bandwidth costs for the South African higher education and research communities from R43 000 for 1 Mbps per month to R6 100 for 1Gbps per month for local connectivity, and from R52 425 to R880 per month for 1 Mbps for international connectivity.
- The critical contribution made to the Square Kilometre Array bid by demonstrating efficient connectivity and processing capability that led to the successful award of the hosting rights for South Africa.
- South Africa is rated among the leading countries to provide support for the Large Hadron Collider experiments of the European Organization for Nuclear Research (CERN) with recognition for a Tier-2 facility producing 2 400 jobs per day for project ALICE (A Large Ion Collider Experiment). See Figure 2.
- The human capital development programme, through the Student Cluster Challenge, has proven to be world-class with South African students crowned champions two years in a row at the international competition hosted by the International Supercomputing Conference.
- The HPC system in South Africa has been rated among the TOP500 supercomputers in the world – number 311 in 2012.
- South African industries are adopting HPC for their research and development competitiveness.
- A multinational corporation, Johnson Matthey, established its research centre in South Africa in 2013, mainly attracted by the expertise in modelling and simulation in this country, and the existence of high-speed connectivity and HPC resources. The company is currently one of the leading industrial users of the CHPC.
- There has been an increase in publications from South African researchers in high impact journals, coupled with an increase in postgraduate qualifications in HPC-related fields.

It is evident that South Africa's ability to compete globally is receiving a substantial boost through significant bandwidth; massive processing facilities and data storage systems, driven by high-end skills.

BROADBAND FOR ALL: Towards closing the broadband infrastructure gap

By Kobus Roux

Government has long realised the immense potential of universal and accessible broadband to fight the triple threats of unemployment, poverty and inequality. According to Minister of Telecommunications and Postal Services, Siyabonga Cwele, government is planning supply and demand-side broadband interventions to address the gap between those who have access to digital services, and those who do not. The CSIR conducted research to better understand the nature of this gap and to identify the best approach to close it.

BROADBAND ACCESS is largely an infrastructure challenge: the lack of infrastructure in some regions and the cost of communications, are what keeps us from a digital future in which the majority of households benefit from access to broadband technologies, services and content.

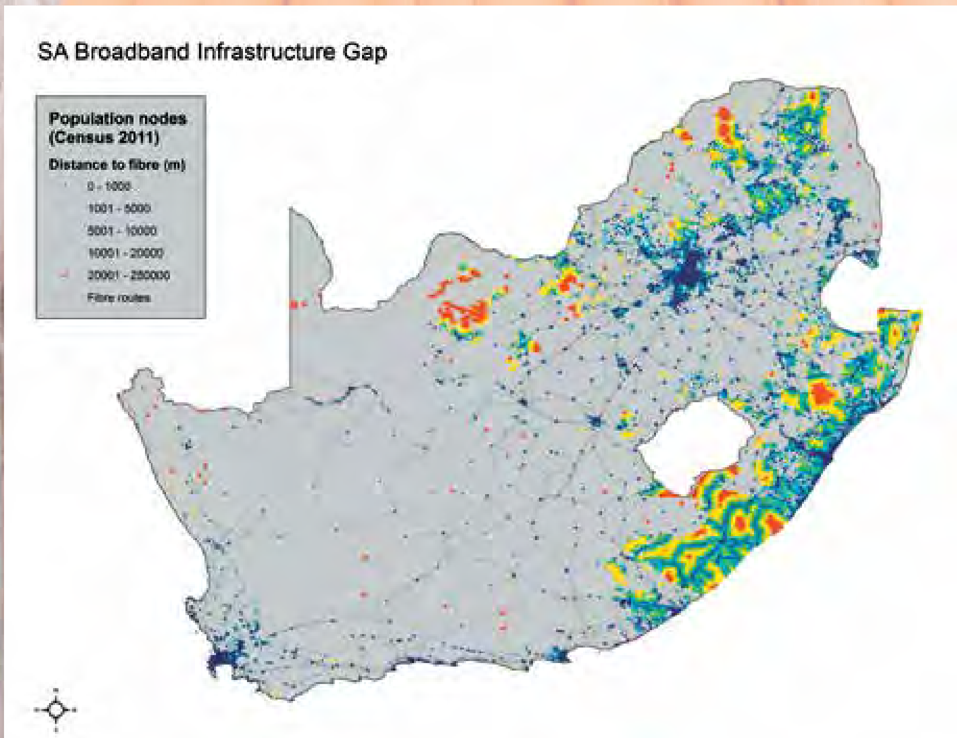
What is the nature of this gap? How many kilometres of fibre are needed? How will new technology developments impact on the national plans?

What is the nature of this gap?

The CSIR's infrastructure gap-analysis study identified a gap between the high-capacity backbone infrastructures and access to this network infrastructure. This gap is greatest in rural areas and, in particular, in former homeland states where the most marginalised communities live.

Gap-analysis started with understanding the proximity of people and buildings to the nearest broadband fibre infrastructure. Census 2011 data were used to calculate the general gap to the nearest broadband fibre infrastructure. We further calculated the specific gap to school buildings: Schools are at specified geographical points, allowing measurement of the distance to the nearest fibre infrastructure; they are also located close to where people live and therefore have been identified as a priority for broadband connectivity.

This study contributed to a shift in broadband policy thinking, away from developing long distance networks, towards measures for closing specific gaps in regions where local distribution remained a problem. The approach is complemented with more integrated measures across the broadband value chain, such as demand stimulation ("Digital



Opportunities"); government acting as an anchor user in under-serviced areas ("Digital Development"); and greater infrastructure sharing ("Digital Future") [SA Connect, Dec 2013].

Initially, gaps were classified into regions by grouping the places where the gaps and concentration of people were simultaneously the highest. However, the results were too difficult to plan and implement, as fiscal funding is applied and managed along municipal demarcations. Using the municipal demarcations, it was found that each of the 232 local municipalities in South Africa is covered with one or more nodes on the existing fibre infrastructure. This underlines the nature of the infrastructure challenge: it isn't in the long distance network, but in the local distribution.

A weighted measure of the gap is introduced as the distance from the nearest broadband fibre multiplied by the number of people affected. Using this, South Africa has an overall gap of 101 554 kilo-people-km. The following table lists the ten district municipalities with the largest gap, representing 44% of the overall national gap.

For continued contribution to decision-making in support of the National Development Plan and the National Infrastructure Plan as championed by the Presidential Infrastructure Coordinating Commission, the CSIR is continuously improving the mapping, analysis and monitoring of infrastructure development. As a result, South Africa can better leverage the synergies between road, rail, power-line, water and broadband infrastructures.

How many kilometres of fibre are required?

Government is about to spend a great deal of money to subsidise broadband construction. Since more than 70% of the total investment is related to civil works involved in laying fibre, it is imperative to have an accurate assessment on the minimum number of kilometres of fibre required to connect the country.

The CSIR is developing models to quantify the distance of fibre-routes required in under-serviced areas and although infrastructure providers will have their own detailed plans and network operators will add requirements such as redundancy through ring architectures, a sound starting point is important. The following have been considered for the models:

District municipality	Weighted gap
O.R.Tambo, Eastern Cape	7 204
Alfred Nzo, Eastern Cape	5 864
Capricorn, Limpopo	5 210
Chris Hani, Eastern Cape	4 203
Vhembe, Limpopo	4 185
Ngaka Modiri Molema, North West	4 093
Amathole, Eastern Cape	4 035
Uthungulu, KwaZulu-Natal	3 735
Dr Ruth Segomotsi Mompati, North West	3 376
Mopani, Limpopo	3 267

- The fibre network footprint could follow one or more of the road, rail, power-line and pipeline networks;
- A point of presence/fibre access is required in every local municipality, mesozone, or census enumeration area;
- The access network technology can be wired (fibre) or wireless; and
- Anchor users, such as universities, hospitals, government offices and schools should be on the fibre network.

The initial estimate is that South Africa needs at least 159 000 km of fibre routes to connect all settlements. The following table illustrates the estimated fibre need, fibre present and remaining weighted gap for the fifteen local municipalities with the largest weighted gap.

Ultimately, by effectively closing the broadband access gap as it relates to infrastructure and the cost of communications, every dwelling in South Africa can be connected.

Local municipality	Minimum fibre need (km)	Fibre present	Weighted gap (kilo-people-km)
Ngquza Hill, O.R.Tambo, Eastern Cape	788	9%	2 435
Blouberg, Capricorn, Limpopo	698	10%	2 407
Joe Morolong, John Taolo Gaetsewe, Northern Cape	989	12%	2 318
Nkandla, uThungulu, KwaZulu-Natal	471	1%	2 076
eThekwini, KwaZulu-Natal	1 888	185%	2 054
Thulamela, Vhembe, Limpopo	957	29%	2 004
Matatiele, Alfred Nzo, Eastern Cape	682	13%	1 977
Kagisano/Molopo, Dr Ruth Segomotsi Mompati, North West	1 065	7%	1 852
Ekurhuleni, Gauteng	1 551	271%	1 750
Mhlontlo, O.R. Tambo, Eastern Cape	756	21%	1 664
City of Johannesburg, Gauteng	1 805	416%	1 612
Mbizana, Alfred Nzo, Eastern Cape	793	17%	1 544
Mbhashe, Amathole, Eastern Cape	1 130	13%	1 492
City of Tshwane, Gauteng	1 997	242%	1 444
Engcobo, Chris Hani, Eastern Cape	778	6%	1 345

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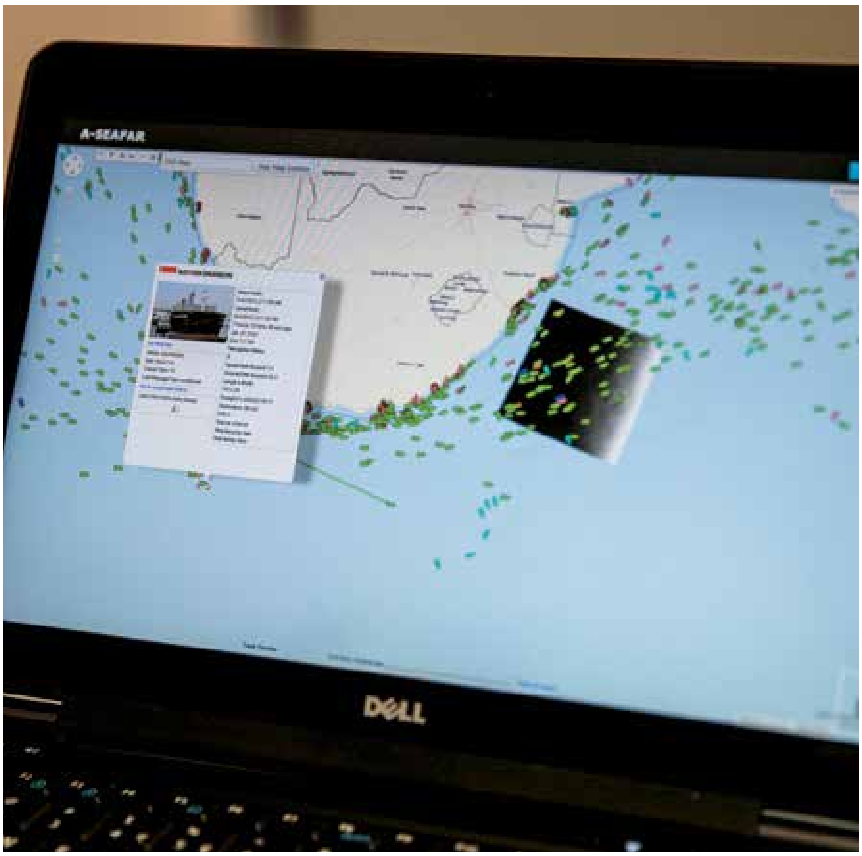
The CSIR-developed monitoring system for large-area surface deformation.



SeaFAR realtime display of maritime information.

Our ability to understand the world, to measure and change perceptions, is facing a new challenge – how to draw insights, to forecast and to act on the massive datasets being delivered at ever-increasing speed and variety from thousands of satellites and millions of sensors. The CSIR's multidisciplinary skills set and the integration of these skills sets enable it to support the processing, analysis and application of this data.

THE PRESERVATION OF OUR ENVIRONMENT and natural resources is imperative if humankind is to achieve – and enjoy – a sustainable future.

Earth observation scientists understand that measurement of the world, of the Earth system, is critical to bring into clear perspective the changes that are going on around us. Thus, in the 21st century we have come to understand our world spatially through a technical lens. Satellites and remote sensing transformed the way the planet is observed and understood; and the Internet and social media opened up new ways of thinking about human expression and activity.

In-situ measurements, with the advent of connected devices, could grow to over one billion devices collecting data and measuring almost every conceivable parameter around us.

New satellite systems and constellations are increasing their collection capacity, their persistence and spectral range and their spatial coverage. A new Silicon Valley start-up will, by the end of 2016, image the entire planet every day! Historic data, collected from multi-decadal missions, are now becoming more accessible through online portals. We now face the data deluge.

The data deluge

Our ability to understand the world, to measure and change perceptions, is facing a new challenge – how to draw insights, forecast and act on the massive amounts of data being delivered at ever-increasing speed and variety.

Such is the paradigm shift, that traditional remote sensing and spatial analysis – the purview of geographers and geo-informatists

Increasing spatial awareness through the convergence of space and ICT

By Lee Annamalai • Co-authors: Waldo Kleynhans and Janine Engelbrecht

– is changing into an information and communications technology (ICT) solution space. It is now widely accepted that remote and in-situ sensing is an important pillar of the information society. However, there is still the need for the associated information processing, algorithm development, innovative analytical techniques and management philosophies for large data sets to keep pace with the advances made in sensing capabilities.

Over the past 15 years, convergence between space technology and ICT has seen significant maturity. While this convergence was led by satellite-based communications, information processing techniques from the ICT domain have demonstrated an increasing convergence with the processing techniques used on the terabytes of data collected from the constellation of satellites orbiting and monitoring the Earth's surface. Unlocking information from the masses of satellite data currently available is a major ICT challenge.

Currently the emphasis is on moving Earth observation applications from experimental or intermittent use to everyday use – a process generally referred to as operationalisation. It is within this new focus that CSIR researchers believe ICT advancements will show the most potential and enable the unlocking of much more tangible socio-economic benefits.

Three broad trends in ICT propelled these Earth observation advancements. The first was convergence, wherein the boundary between ICT and space technology disappeared; secondly, broadband emerged and enhanced the capacities for the delivery of services; and thirdly, a new wave of global transparency and information empowerment arose.

As ICT penetration continues to influence global culture, politics and the economy, seven modern day advances are seen:

- Digitisation, especially of the environment and Earth sensing equipment, and the creation of increasingly powerful and intelligent digital sensing technologies and applications.
- Continued miniaturisation and the mainstreaming of nanotechnology in manufacturing and telecommunications.
- The growth of wireless computing.
- The growth of cloud computing and big data analytics.
- The continued development of technologies based on open standards that ensure interoperability.
- Wireless technologies, which have led to the development of the concept of ubiquitous or pervasive computing known as the 'Internet of Things' whereby all manner of objects in the built and natural environment are tagged, equipped with a microchip and have the ability to send and receive wireless signals.
- The growth in broadband diffusion and adoption.

Convergence

The CSIR's Earth observation and ICT research and development work has tracked, researched and applied these trends over the past few years. It has resulted in the creation of highly innovative market-aligned solutions like AFIS – the advanced fire information system, Azimuth – a systematic subsidence detection and monitoring system and SEAFAR – a wide-area maritime domain awareness system.

The research built on the existing knowledge in signal processing and machine learning; middleware concepts used in networked application development and web service provisioning – which has been applied to remote and in-situ Earth observation data, creating the paradigm shifting results in these Earth observation operational solutions.

Azimuth

In South Africa, large areas are affected by surface deformation associated with underground mining or natural geological processes. It poses a significant threat to the safety of humans and damage to economic infrastructure. Proving the stability of undermined areas is important for post-mining rehabilitation. The Azimuth system analyses data captured by orbiting satellites to map surface deformation over large areas (up to 150 x 150 km) at very fine scales (down to 1 mm) and monitors the evolution of areas where deformation occurs over time. The deformation measurements are provided on a secure web accessible platform. The system overcomes the limitations of traditional monitoring, such as labour-intensiveness as well as working in potentially unsafe areas.

SeaFAR

SeaFAR is designed for use in the identification and reporting (sms and email alerts) on maritime activities and events, for example, foreign flagged fishing vessels activities in South Africa's exclusive economic zone (EEZ) as well as cargo vessels moving into and out of port holding areas. The system utilises location and ancillary vessel information transmitted from the automatic identification system (AIS) receivers on-board the vessels. Vessels that are not carrying AIS transponders, which are required by international law, are identified through the automated processing of Satellite Synthetic Aperture Radar imagery. One satellite observation can typically cover up to 250 000 km^2 of the 1.5 million km^2 South African marine EEZ. This means that the entire EEZ can be covered in less than a week. SeaFAR has several algorithms developed within the system which are also able to detect maritime pollution events (like bilge dumps) and identify culprit vessels through vessel track forecasts and correlations.

Towards the future

The CSIR is partnering with numerous ICT innovators on the continent; linking up the geospatial community into an ecosystem creating interesting and useful ICT-centric geospatial applications with modern communication devices providing the primary user interfaces. Our understanding of ICT in developing worlds is enabling African technology to penetrate international markets and create lasting impacts.

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THE SCIENCE OF DATA: FREEDOM TO THINK

By Quentin Williams

Reference: [1] Gantz, J. and Reinsel, D. 2012. THE DIGITAL UNIVERSE IN 2020: Big Data , Bigger Digital Shadows,and Biggest Growth in the Far East. EMC Corporation.

Freedom to think is what computers were supposed to provide to human beings. It is the reason why the calculator and indeed computers were invented. Instead of humans manually doing calculations on paper, number crunching gets done by the computer, freeing up humans to do the more complex and creative type of thinking. It is at this cusp of interactivity between human insight and computing analytics that data science truly comes alive and amazing benefits can be realised by extracting value, products and insights from messy and unstructured data.

THE 2014 EMC DIGITAL UNIVERSE STUDY VIEW claims that the digital universe, which is a measure of all data generated, replicated and consumed, will grow by a factor of 300, from 130 exabyte to 40 000 exabyte (40 trillion gigabytes) from 2005 to 2020 [1]. This digital universe has several characteristics that change the current technology landscape. Our ability to manage and manipulate data becomes increasingly challenging because of the volume, variety, veracity and several other factors such as ownership, ethics and distribution.

The substantial growth in data has gone alongside the ability to instrument almost any 'thing' with requisite sensors, computing capabilities and connectivity. We can now collect data from humans via bio-sensors, from cars and household appliances like fridges remotely and from any device we can imagine, while being able to send instructions to be executed through these devices.

Data science thus adopts a scope that deals end-to-end with everything data-related, including data acquisition, capturing and recording, integration, storage, manipulation, governance, analysis and mining, the visualisation and the final deployment to and use of the data products by the relevant stakeholders.

The key to data science is however the extraction of value or insight from data. This can only be achieved by closely involving the human being who has the ability for complex thinking and problem solving: Finding causes (complex thinking – human) rather than just correlations (number crunching – machine); creatively imagining new future scenarios rather than just predicting; and gaining insight beyond just merely finding patterns.

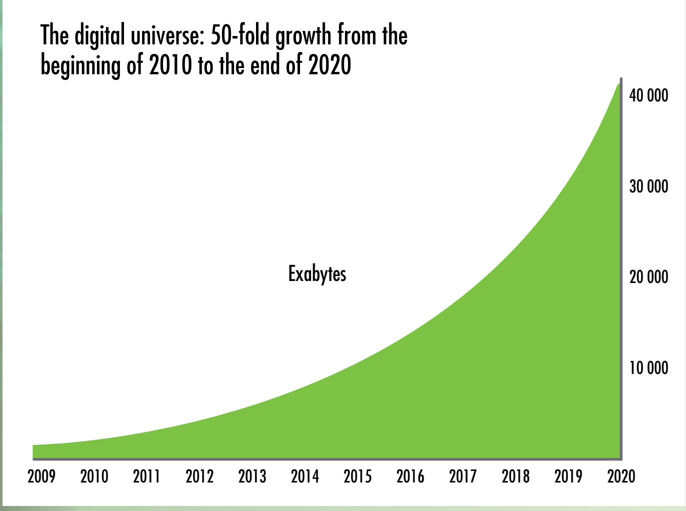

Figure 1: Source – 2014 EMC Digital Universe study

In the last couple of years, the CSIR conducted extensive research and development throughout the full data value chain. In partnership with the Tshwane University of Technology, the CSIR developed a low-cost technology demonstrator (smart sensor) to monitor water-quantity in pipes and display information in near real-time. These sensors, equipped with a communications hub, can be deployed across water pipe distribution systems to monitor water flow and identify potential leakages and loss of treated water. Information displayed in real time allows decision makers to quickly identify problem areas and optimally manage maintenance tasks on the pipes, leading to better utilisation of one of our most critical resources.

The CSIR also developed the Smart Cities platform that has the ability to collect data from a multitude of heterogeneous sources, send instructions to devices connected to real physical objects and intelligently allow different applications to analyse the data. The data sources could be static data collected from past observations (e.g. weather data); real-time data from water distribution sensors, traffic sensors, mobile devices or energy loads from household devices and distribution networks; or even data from services such as Twitter and Facebook. The technology was piloted in 10 households, showing the ability to monitor and control energy loads at a device level within the household as well as within the macro distribution network. This led to cost savings through more efficient management of energy loads.

A text analytics platform for extraction of actionable insights from customer service complaints and compliments sourced from the Web is another CSIR data-science technology. There are currently over 350 000 samples of customer service reports for various industries in South Africa. SerViz is a cutting-edge interactive infographic platform where consumers can extract brand and product insights powered by research in machine learning and visual analytics.

The outputs from all these technologies are expected to trigger actions towards better decision-making. It has shown that data science provides humans with the ability to explore, analyse and understand data, and to promote real-time value generation on the basis of very large and complex data. It is thus truly about allowing decision makers the freedom to think and act more creatively and from a more informed basis.

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Marius Vermeulen, project manager: additive manufacturing at the Aerosud Innovation and Training Centre inspects the Aeroswift additive manufacturing system built in collaboration with the CSIR.

TITANIUM METAL PRODUCTION AND ADDITIVE MANUFACTURING – contributing to a vibrant new industry

Dr Dawie van Vuuren, Hardus Greyling

South Africa is the second largest producer of titanium-bearing mineral concentrate in the world and exports the bulk of the mineral in the form of titanium-bearing slag. Although the potential to further beneficiate the mineral to either titanium dioxide pigment or titanium metal existed for a long time, very little was done because of technical and market constraints. However, in 2007 the Department of Science and Technology (DST) and representatives from industry and different research councils developed a strategic plan covering the full industry chain from titanium metal production to value added manufacturing technologies, including additive manufacturing technology. As part of this plan, the CSIR plays a key role in contributing to the creation of a local titanium and additive manufacturing industry.

STRATEGIC ANALYSES of South Africa's competitive position with regard to the establishment of an internationally competitive titanium industry showed that it was unlikely that such an industry could be established without the development of new technology.

Beneficiating titanium

Titanium is the alloy of choice in the aerospace industry where the quest for lighter aircraft continues. By developing technologies to add value to titanium-bearing raw materials, the country can become a significant contributor to the global aerospace market. Cost-effective methods for producing titanium metal and its alloys, followed by the conversion of these into net and near-net products, offer the potential of a vibrant new South African industry sector.

To facilitate the development of a titanium metal industry in South Africa, the DST tasked the CSIR to establish a Titanium Centre of Competence. The role of the Titanium Centre of Competence is to develop capacity and technologies across the full titanium beneficiation value chain, from primary metal production to the development and manufacturing of final titanium parts.

Two of the technologies that are being scaled-up with financial support from the DST within the titanium beneficiation value chain are primary titanium metal production and high-speed additive manufacturing. The latter is conducted in collaboration with Aerosud ITC, a private sector technology development company in the commercial aerospace sector.

Titanium metal production: Pilot plant

The DST awarded a contract to the CSIR towards the end of 2011 to build a suitable pilot plant to scale up a novel titanium metal production process. This followed the successful laboratory-scale demonstration of the technology. The pilot plant was inaugurated in June 2013 and construction was completed early in 2014.

The change in going from a batch-wise (± 1 kilogram titanium per batch) – and to a limited extent semi-batch wise – operation on a laboratory scale to a fully automated, continuous 2kg/h titanium production plant, is substantial. The design of the pilot plant, construction, commissioning and operational experiences have all offered immense learning opportunities. Challenges related to construction materials, the reliability of mechanical and electrical equipment in extremely harsh process conditions, the measurement of process parameters and the control thereof, as well as underlying chemical phenomena.

While every unforeseen challenge and subsequent lesson learnt impact on the operations, the work is steadily progressing.

Additive manufacturing: Aeroswift

Cost containment is a key driver in the commercial aerospace sector, with fuel consumption and the operational cost of aircraft being the two main cost contributors. By reducing the weight of aircraft, fuel consumption can be drastically reduced. Composite materials have proven to be effective in reducing the weight of aircraft, which have traditionally been manufactured from aluminium-based material. The latest commercial aircraft designed by the world's two biggest commercial aerospace original equipment manufacturers, Boeing and Airbus, contain significant quantities of composite material. Composites in the airframes of these aircraft make up more than 50% of the total structural weight of the aircraft.

The challenge with composite material is that it cannot be joined to aluminium – joining the two materials results in galvanic corrosion. This challenge forces companies to look at new metal materials such as titanium alloys. However, titanium alloy is more expensive to produce and difficult to machine.

South Africa's rich titanium mineral deposits and the advantages that additive manufacturing offers with respect to part geometry optimisation and reduced material utilisation, position the country to develop an additive manufacturing industry with a focus on titanium alloys to produce high-value components for the aerospace industry.

Project Aeroswift started in 2008 when Aerosud and the CSIR demonstrated a new approach to laser-based metal powder fusion, which could potentially be applied to the 3D-printing of metal components for various industry sectors.

In 2011, the DST awarded a contract to the CSIR to design and construct a high-speed large-area laser-based powder fusion platform capable of producing titanium alloy components with dimensions of 2 m x 0.6 m x 0.6 m.

The Aeroswift platform demanded several new technology developments. Any optical system requires laser switching and beam delivery technologies, but with the Aeroswift platform various additional factors came into play, such as how to handle large amounts of metal powders, how to protect the optics inside the processing environment, how to handle generated heat and the stresses induced during the melting of the powder, and how to prevent oxidation of the powder during the printing processes.

The team designed, developed, tested and implemented a range of new technologies to cater for all these challenges and built demonstrators to verify processes, culminating in the full Aeroswift platform at the end of 2014. In parallel with the Aeroswift platform development, the team successfully demonstrated the technology's increased metal build rates, which are higher than commercial powder-bed fusion systems available on the market.

Phase 2 of the Aeroswift project started in late 2014 and focuses on process development and optimisation. This phase will culminate in the production of the first large flight ready demonstrator part for the commercial aerospace industry.

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The titanium pilot plant at the CSIR.

TECHNOLOGY LOCALISATION: making South Africa's manufacturing industry more capable and competitive

By Ashley Bhugwandin

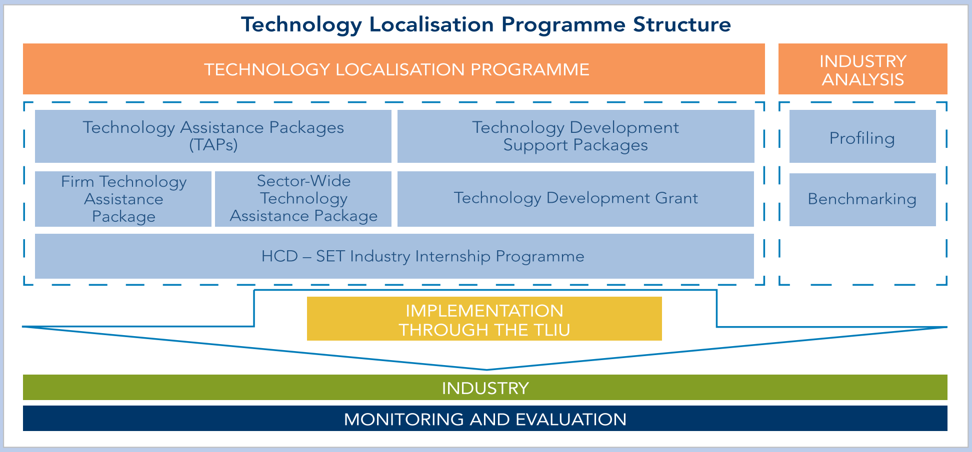
The Technology Localisation Implementation Unit (TLIU) is an initiative of the Department of Science and Technology, established by and hosted at the CSIR. The unit has been supporting manufacturing companies since 2012. To date, more than 150 South African manufacturing companies have benefited from the unit's interventions. It has primarily supported companies that are linked to the localisation objectives of Transnet and Eskom. The unit has a national footprint and supports industry in five provinces: Gauteng, KwaZulu-Natal, Western Cape, Eastern Cape and Mpumalanga.

THE TECHNOLOGY LOCALISATION IMPLEMENTATION UNIT was created to support the South African manufacturing industry to enhance the capacity and capability of companies in this sector, enabling them to participate in the infrastructure rebuild programme of South Africa.

Through the investment in these industries, the unit has supported the transfer of technologies, development of local products and intellectual property, and creation of jobs.

Since 2012 the unit has grown and expanded. It has had three instruments added to the bouquet of support solutions for the development of industry. The instruments that are used for implementation are illustrated in the diagram to the right.

Understanding that there is a need to support industry holistically, the unit was provided with an instrument to develop solutions to support common needs for an entire sector or sectors. The unit has thus far supported a total of three sector-wide initiatives and is currently developing a further two sector-wide support initiatives.



A FIRM TECHNOLOGY ASSISTANCE PACKAGE is aimed at providing assistance to an individual company. The companies that participate in this programme are linked to either Eskom or Transnet and are therefore recognised as companies that are currently producing or have the potential to produce a component or commodity linked to the localisation plan by the state-owned companies (SOCs) or an original equipment manufacturer (OEM). The companies are then subjected to a technology capability assessment. This process is conducted independently and provides the TLIU and the SOC or OEM with a gap analysis for the company in terms of the capability and capacity that exists within the company.

A SECTOR-WIDE TECHNOLOGY ASSISTANCE PACKAGE creates an environment where specialised services or common products can be developed so that the various companies in the particular sector can be supported. This could lead to the development of a new enterprise or a shared facility that can then be utilised by industry stakeholders to complement their normal operations. Identifying these packages will require the identification of areas where currently expertise or facilities do not exist in the country or where there are common products being imported into the country that have applications across a variety of applications.

Through the **TECHNOLOGY DEVELOPMENT GRANT,** the TLIU assists the SOCs to identify key and strategic commodities, which should be developed in the country. There is a need to partner with key foreign OEMs that will commit to a programme of technology and skills transfer. The TLIU creates a partnership between the OEMs, SOCs and relevant research and development bodies to launch a platform for the development of local IP. The TLIU uses the strategic partnerships that exist within the DST to engage local OEMs as well as research and development bodies related to the foreign OEM. In this way an environment of continuous knowledge transfer between the institutions is created, resulting in the latest technology being available for the continuous development of IP.

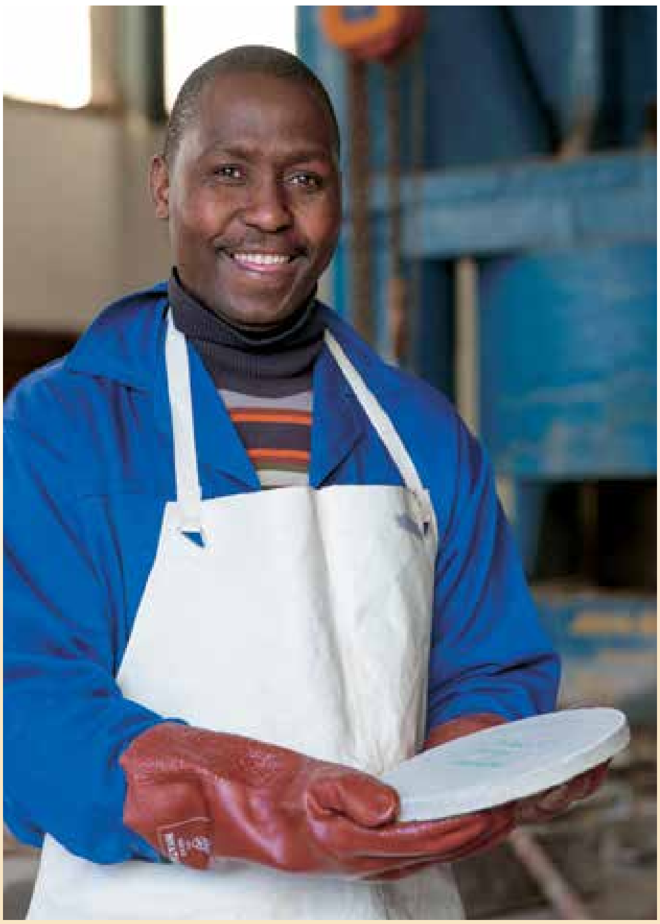
The aim of the **SET INDUSTRY INTERNSHIP PROGRAMME** is to provide industry placement of students within the science, engineering and technology fields. Students assisted in this programme are sourced from a University of Technology and are placed at companies that are participating in the Firm Technology Assistance Package programme. Students require 12 months' placement into industry to complete their Practical 1 and Practical 2 training, which will ultimately allow them to achieve their qualification.

The approach is to work with the sector-specific bodies and understand the constraints to the sector becoming globally competitive. These solutions often involve the establishment or enhancement of a shared centre or centre of excellence. Through such focused interventions, industry is able to gain access to high-end technology that would generally be inaccessible or unaffordable. This approach is particularly beneficial to SMMEs which form a large portion of the South African manufacturing sector. These shared centres also provide a platform wherein research and development can be supported for the sector and this will allow local manufacturers to introduce or improve products.

'Design for local' picks up momentum

The unit is also supporting the development of local products. This is in an effort to support the 'design for local' drive of government. Working with state-owned companies and original equipment manufacturers, the unit identifies products that have a potential to be localised. This process starts with designing the local systems within which these products will operate. This effort will be coordinated with the science councils and higher education institutions. Through this initiative, the TLIU aims to ensure that more manufacturing is conducted locally.

However, to support manufacturing, there is a need to ensure that the system integrators within the manufacturing sector are local and therefore the designs of the systems will have to be localised. This requires extensive research and development as well as an environment where testing and prototyping can be supported. This support from the unit carries entrepreneurs and inventors through the so-called 'valley of death' in the development life cycle of ideas and innovations.



Charlie Inama, an operator at Interohm, with a sample of the asbestos-free cement board insulator.

Case study 1: Asbestos-free cement insulators for industry

The CSIR has assisted original equipment manufacturer Insulectric (Pty) Ltd with the development of an asbestos-free cement board insulator.

Insulectric specialises in high-temperature electrical insulation. Following South African legislation in 2008 prohibiting production and import of asbestos-containing products, Insulectric had to import asbestos-free cement board insulators as no locally manufactured products were available.

The TLIU and the CSIR assisted Insulectric with the development of an asbestos-free cement board insulator.

The product has been tested and now enters the commercialisation phase as advanced research and testing are matched to requirements of the industry, and local and international demand.

The re-commissioned manufacturing plant Insulectric-Interohm will become the only manufacturer of asbestos-free cement board insulators in South Africa. This ensures future import replacement of seven different foreign-sourced products and job creation through introduction of extra shifts.

Case study 2: Promoting casting simulation benefits to South Africa's foundry industry

The Casting Simulation Network (CSN) is a network supported by the TLIU through a sector-wide technology assistance package.

Simulation software improves and confirms casting processes and tools, thereby providing the South African foundry sector with advanced technology to equip it in its role to provide critical inputs to the South African manufacturing industry.

The CSN provides access to casting simulation software for the foundry industry through a network of support centres. The hub of the CSN is located at the Vaal University of Technology's Southern Gauteng Science & Technology Park, Sebokeng.

The hub connects with the satellite sites within the technology stations at the Durban University of Technology, the Nelson Mandela Metropolitan University, Stellenbosch University and the University of Johannesburg. Other higher education institutions will be added in subsequent phases. This provides foundries, including SMMEs, with access to simulation software and skills.

Dr Joe Molete, Executive Director: VUT Science and Technology Park; Prof. Irene Moutlana, Vice-Chancellor: VUT; Erik Zimmermann, CSN; Mrs Naledi Pandor, Minister of Science and Technology; Dr Sibusiso Sibisi, CEO: CSIR; and Thabani Nene, Technical Manager (SA): Speedcraft Manufacturing.

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Towards a South African bio-economy: Agile product development

By Dr Dusty Gardiner • Co-authors: Dr Raj Lalloo and Dr Justin Jordaan

The CSIR Biomanufacturing Industry Development (BIDC) Programme supports small, medium and micro enterprises (SMMEs) to translate research into market-ready products. An agile approach to product development has been adopted to meet customer requirements and to significantly reduce the time and cost of product development. The agile approach has been applied with two spin-out companies from the CSIR and is now realising value in product development for 12 SMMEs in the BIDC Programme.

Products developed by three enterprises supported by the BIDC. (From the top) Phepisa Natural Resources Institute produces extracts for soaps and skin-care products and the company is based in Mpumalanga. Elvema Nutrition produces nutritional porridges and is based in North West. (Left) Ubitron-manufactured candles.

THE DEVELOPMENT OF a South African biomanufacturing economic sector is clearly outlined in several national strategies. The CSIR has been involved in developing biomanufacturing technologies for a long period of time, and has developed a strong skills and infrastructure base in this sector.

The BIDC Programme was established in 2013 to increase access to this competence. The programme has a strong emphasis on supporting SMMEs to develop processes and products that meet customer requirements within short time-frames to exploit existing market opportunities. The typical product development process in the biomanufacturing sector follows a sequential path from early-stage research at small scale to process development, piloting and ultimately transfer of technology into manufacturing duty. This classical approach has limitations for the development of high-value, low-volume performance products in the biomanufacturing sector. An alternative agile manufacturing approach to process and product development was thus implemented and tested using real-world examples.

Two excellent examples illustrating the benefit of the agile product development approach can be found in ReSyn Biosciences and OptimusBio, two recent spin-out companies from the CSIR.

Going forward

The agile approach is being continually adapted and improved as more products are developed under the banner of the BIDC programme. Twelve SMMEs are currently being supported through this programme and a range of products for the biotechnology, cosmetics, food and water and sanitation markets are under development.

Key requirements for implementing an agile methodology include close relationships with customers and end-users; a dynamic, innovative and responsive work force; appropriate infrastructure and a well-established technology platform. If any of these elements are missing, the risk of product failure increases.

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OPTIMUSBIO manufactures biological products that contain active, beneficial bacteria from the genus Bacillus. The CSIR has been developing Bacillus-containing products for a number of years and has built up a database of Bacillus organisms, and knowledge on the production and formulation of the bacteria. To optimise value creation from this platform, a decision was taken to commercialise the technology through a spin-out company, OptimusBio. Application of the agile development methodology is paying dividends for the fledgling company, which was spun out of the CSIR in 2014. The company already offers five product lines consisting of more than 30 products. Products have applications in the water and sanitation, aquaculture, automotive and personal care markets. Product development cycles have been reduced to between three and six months from a previous 18 to 24 months. Customers and end users are closely involved in the development cycle, often in a co-development model, which builds customer loyalty and ensures that products are fit for purpose.

OPTIMUSBIO
GREENER TOGETHER

ReSyn Biosciences

RESYN BIOSCIENCES manufactures and sells microsphere-based research reagents to the international biosciences research and development market. The company offers at least 12 product lines with different functionalities, and also provides custom development of solutions meeting customer needs. Initially, development cycles for the ReSyn products were around 12 months. These have now been reduced to around three months. The short product development cycles are particularly important to meet the demands of international customers requiring the development of custom products. Lengthy development cycles would result in lost business, as the window of opportunity in this market is often extremely short. ReSyn Biosciences has been in business since 2013 and counts among its clients and collaborators Cancer Research UK, the Institute of Cancer Research, Syngenta, Novartis, the Broad Institute, Scripps and Stanford University. The company recently won a New Product Award at the prestigious Society for Lab Automation and Screening Conference held in Washington, USA.

DID YOU KNOW?

Originally developed and pioneered in the software development industry, agile methodology is finding application in other industries. The iterative approach provides opportunities to assess the direction of a project throughout the product development lifecycle.

Each iterative cycle involves rapid development of a prototype that is tested by customers or end users in the marketplace. This allows the project team to continually gather information on customer requirements, and assess product performance in parallel to the actual technical development aspects of the process.

The results of this approach greatly reduce development costs and time to market and ensure that products meet customer requirements. Over-optimisation of products is also eliminated.

MAKING THE INVISIBLE VISIBLE: UViRCO, an innovation success story

By Jeremy Wallis

In 1991, when Eskom contacted the CSIR with its need to visualise corona discharges on power distribution networks, no one could guess that two decades later the new start-up company resulting from this research would capture some 50% of the world market with total sales of R180 million, and would be exporting high-tech camera inspection systems to 40 countries. Apart from the technical excellence of the research team, key success factors included the tenacity and full participation of every stakeholder in the innovation chain.

The CoroCAM 6 and MultiCAM, two high-voltage power line inspection cameras.

(From left) Demonstrating the latest CoroCAM 8, inspecting a power substation in Russia and collecting corona discharge data.

INNOVATION CAN BE SEEN as the successful implementation of a creative new solution. Inherent in this is 'a need' and 'a solution'. Bringing these two together though is not always easy and requires considerable tenacity from many people, at different stages of the innovation chain, all with different roles, working together to make it happen.

In 1991, when Eskom contacted the CSIR with its need to visualise corona discharges on power distribution networks, who would have guessed that, twenty years later, South Africa would be successfully exporting high-tech camera inspection systems to 40 countries from a new start-up company, having captured some 50% of the world market with total sales of R180 million?

There were times when team members cheered a new camera order and times when they wondered if the road ahead was closed. But with a strong belief in what they were doing, the storms were weathered and a multidisciplinary team of CSIR and Eskom people saw the original need converted into technology, then a product, then another and then UViRCO was born, a CSIR spin-out company operating since 2008 as a licensed venture.

Such an achievement requires the talents of many people at different stages, but one lesson learnt was that it also requires people who believe enough in what they are doing to keep the dream alive, to motivate for funding, to solve the technical challenges and to bring in the additional skills as these are needed. In this particular case, some of those people chose to make this journey their careers, a passion for solving industrial challenges driving them on.

UViRCO manufactures the CoroCAM and MultiCAM range of inspection systems that allow an operator to visualise not just what we see with the naked eye but also what we can't see, namely energy coming off a power line insulator that is in the infra-red or ultra-violet (UV) wavelength bands. It is in these additional wavelength bands that the information to prevent an unplanned power outage is contained.

CSIR researchers focusing on sensor science and technology use their expertise in developing sensor innovations to respond to South Africa's challenges. For example, work by these researchers has led to such inventions as the world-first ultrasonic broken rail detection system that is saving our economy more than R100 million per annum by avoiding freight train derailments. They are also responsible for developing the technologies and products that are licensed under the CoroCAM and MultiCAM trademarks.

What makes these cameras special in the technical sense is their ability to detect even small amounts of UV energy in competition with much larger levels of UV energy that stream continuously from the sun. By solving this challenge with solar-blind filter technology, workers no longer needed to conduct inspections at night time and hence the world's first daylight inspection systems were born.

Thus, we find ourselves in 2015 with an innovation success story, one that saw a 'need' and a 'solution' brought together over more than a decade by numerous passionate people, to create the successful camera exporter that is UViRCO.

We wish UViRCO well as it now enters the next stage of its own growth as the CSIR sells its share to a Black Economic Empowerment investor, while we step back and celebrate the realisation of a dream and the creation of a South African brand on the world stage.

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DID YOU KNOW?

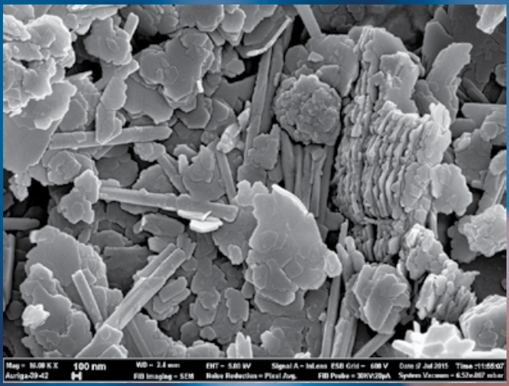
Over and above the technical excellence of the research team, key success factors included:

- Having passionate people in both the 'need space' at Eskom as well as the 'solution space' at the CSIR who believed that they could succeed and who were willing to tie their personal reputations to achieving success.
- Having a research and development team that was prepared to shoulder the responsibility for moving their creations along the innovation chain, constantly having to motivate for continued funding. They are often the single constant in the whole journey.
- Having a partner in Eskom who were willing to entertain risk by funding research and development but who also showed international leadership by seeing a bigger picture around creating an enterprise that could take its sponsored technologies to a world market.
- The ability of the CSIR as an organisation to bring together skills across the innovation chain to create a new business venture based on cutting-edge engineering development.

NANOCLAY MINERALS AND PLASTICS: Tiny particles deliver big impact

By Prof. Suprakas Sinha Ray

Modern technology continuously requires new, enhanced materials with special combinations of properties. In recent years, researchers have managed to develop new materials at the nanoscale with excellent combinations of properties. These new materials, called nanocomposites, possess enhanced properties (for instance plastics that are much lighter, stronger, smoother and also scratch, ultraviolet and even fire-resistant) and promise to soon replace classical materials used in industry. The CSIR has been involved in the development of nanocomposites that can be used in the plastics, cosmetics and paint industries.



Scanning electron microscopy image of a typical nanoclay. Image: Sharon Eggers, CSIR

Five South African clay samples mounted on holders prior to examination using scanning electron microscopy. Infrastructure at the National Centre for Nanostructured materials translates seemingly uninformative details to the naked eye into valuable information about the nanostructure, chemistry and industrial application of clays in the manufacture of polymer nanocomposites.

NANOCLAYS ARE NANOPARTICLES of layered mineral silicates with unique, enhanced properties that could have a big impact on various industries. The CSIR is looking at how best to beneficiate South Africa's nanoclay minerals with the aim of creating nanocomposites that can enhance the properties of plastics, cosmetics and paints.

Over the past few years, various types of nanoparticles have been used for the development of nanocomposites with almost all types of polymer matrices. However, clay mineral-containing polymer nanocomposites (PNCs) have attracted the greatest interest in current materials research because a small weight percentage of nanoclay can greatly enhance the manageability and the properties of treated composites. Moreover, clay minerals are naturally abundant, economical, and most importantly, benign to the environment and humans. In nanocomposites, the increased total surface area becomes the critical characteristic which can not only expand the performance of traditional materials, but also introduces completely new combinations of properties.

With nanoclay minerals, it becomes possible to create plastics, for instance, that are not only stronger and lighter, but are also scratch, ultraviolet and fire-resistant. This enables various advanced modern uses for plastics, such as lighter, stronger plastic parts for motor vehicles. The CSIR is also working on enhanced bio-compatible, biodegradable plastic bone scaffolding for repairing broken bones. These will be implanted surgically like traditional titanium bolts or plates, but won't have to be removed again due to the plastic being 'programmed' to degrade over the course of a year or so, with the plastic naturally breaking down into lactic acid over time. Another application is using enhanced plastics for meat and other food packaging. Traditionally packaging plastic is made up of up to nine thin layers. With nanocomposite plastics, only three layers are needed, which dramatically reduces the amount of plastic required.

The CSIR has also made use of nanoclays for application in the cosmetics and paint industries. One example is the creation of a new, improved petroleum jelly that does not discolour or degrade over time and has better application properties on the skin and that feels smoother. For the paint industry, nanoclay-enhanced paints have been developed that act as corrosion-inhibitors when applied to metal surfaces such as in the automotive or aerospace industries. The paint, in other words, prevents rust and corrosion of the metal it is painted on.

During nanocomposite formulation, nano-level dispersion is the most important characteristic to achieve, in order to have increased surface area for polymer-filler interaction, improved co-operative phenomena among dispersed particles, and/or a higher degree of confinement effects. However, the primary challenge is to find the right chemistry to provide a favourable driving force to disperse fillers at a nano-level. What this means is that one needs to determine the right temperature, pressure and environmental conditions needed to successfully and optimally allow a nanoclay to mix with a polymer.

The Department of Science and Technology and the CSIR have realised the potential of polymer nanocomposites and have built capabilities and world-class facilities in the synthesis and modification of nanoparticles and structures as well as in nanocomposites. The CSIR is continuing to investigate the use of nanocomposites to create enhanced plastics, enhanced cosmetics and enhanced paints.

The CSIR's work in nanoclay minerals focuses primarily on South African nanoclay mineral-enhanced plastics and efforts to create awareness of PNCs in industry as well as the development of products that will benefit the industry. The CSIR is also putting further research efforts into processing and characterisation techniques, properties and applications, and key research challenges and future outlooks in the development of South African nanoclay minerals-based multifunctional PNCs.

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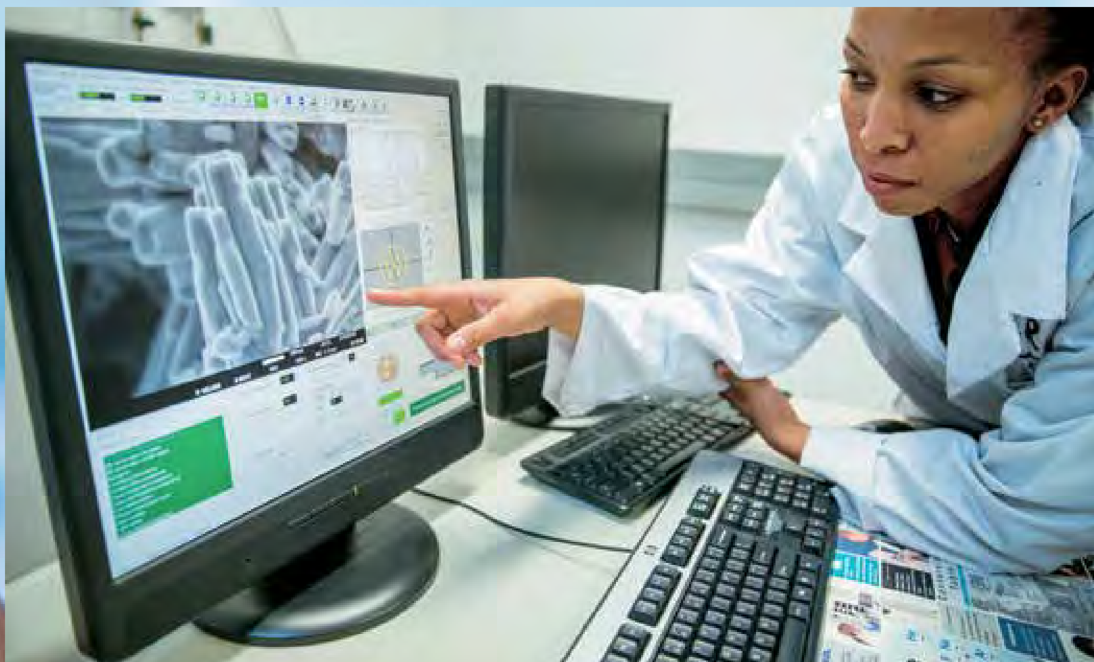

Researchers are able to study the nano-structures of materials using a scanning electron-microscope.

Collaborative engineering platform for globally competitive South African products

By Jonnro Erasmus

The CSIR is developing a platform that will enable small, medium and micro enterprises in South Africa to work together to create eco-friendly and regulatory compliant products and deliver those products to the global market.

VARIOUS FACTORS are contributing to the rapid increase in product complexity. One of the most obvious is the increasing presence of electronic components and embedded software, to the extent that even household appliances are becoming 'smart' and connected. Globalisation is introducing new competitors in all industries, accelerating the need for product innovation. Globalisation also makes it possible to reach new customers, each with individual needs and expectations. In fact, even traditionally simple industries are experiencing major change due to customisation and personalisation requirements. Furthermore, regulatory, environmental and sustainability requirements are becoming ever more restrictive.

Most modern products are aggregates of many different parts, necessitating collaboration between several parties. This rapid increase in product complexity drives a new approach to product engineering. More specialised techniques and tools are needed to create components and deliver services that fulfil a very specific purpose. The trend presents new opportunities for small, medium and micro enterprises to play a vital role in large and complicated supply chains.

While the entrepreneurial spirit in South African industry is beyond question, the challenge lies in connecting the entrepreneurs with each other and with clients. Products are no longer developed and manufactured in one enterprise alone, but through the successive addition of value by several parties. The responsibility of integrating the ultimate product now sits with the original equipment manufacturer, but it also allows the latter to dictate to the supply chain.

Product lifecycle management

Collaboration breeds innovation and the CSIR is taking the lead to show how new technologies and practices are deployed and used to enable collaboration. The research firstly investigates the adoption of product lifecycle management (PLM) technology to understand what can be done to assist small, medium and micro enterprises. Secondly, it is developing a platform that will allow South African enterprises to collaboratively create globally competitive and regulatory compliant products. The vision is that this platform will ultimately become a digital marketplace where large and small enterprises make products and services available and organise themselves into optimised supply chains.

The PLM is a set of technologies and practices that aims to streamline the flow of information about the product and related processes throughout the product's lifecycle such that the right information in the right context at the right time can be made available. It applies a consistent set of business solutions in support of the collaborative creation, management, dissemination and use of product information, spanning from the initial idea to the eventual phase-out. The PLM aligns people, information, processes and business systems and provides a product information backbone for companies and their extended enterprises. By adopting PLM as a complete business approach, local engineering and manufacturing enterprises can participate in global industry by achieving improved product control, quality and regulatory compliance.

However, apart from adoption by some of the largest companies in the world, PLM has seen very limited adoption in South African industry. By understanding and removing the obstacles that hinder adoption, the CSIR aims to give South African organisations a competitive advantage. It is proposed that the burden of the implementation of the technology itself should be taken away from industry, allowing companies to focus on the necessary practices and competences. Thus a cloud platform is needed with sufficient functionality to enable industry participants to design and develop modern products. By making a neutral platform available to industry, the burden on the original equipment manufacturer and its ability to dictate to smaller companies are reduced.

As more companies join in, such a platform can facilitate the relationship between the various participants in the supply chain by enabling the exchange of the information that describes the product, its configuration and intended use. The functionality and features of the platform can be progressively improved to enable new ways to connect and collaborate. Eventually, a procurer should be able to use the system to find either the exact, or similar products, components or services of 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. It may even become a national marketplace for engineering services and manufactured products.

This is certainly an ambitious, long-term initiative, but the CSIR is well able to pursue ambitious goals for the benefit of South Africa.

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The CSIR is developing a product lifecycle management facility where the organisation will help industry to develop its products and experience the value of product lifecycle management; provide advice and support on engineering and product lifecycle management; and provide training and practice-based knowledge transfer.

Supporting the industrialisation of aerospace technologies

By Marié Botha

Due to South Africa's unique history, the South African aerospace industry developed and implemented the capability to design, develop and produce aerospace technologies and products. The support of stakeholders in the National System of Innovation and government is vital to ensure that this industry remains viable.

THE SOUTH AFRICAN AEROSPACE INDUSTRY has followed a development path unlike any other national models as a result of the unique history of the country. This development path resulted in a wide scope of capabilities and infrastructure for complete vertical product integration, far in excess of what would be commercially sustainable in the global market today. It entails integration and technological capabilities that span a significant portion of the aerospace product and technology stream segmentation as defined in the South African aerospace sector development plan. With high levels of revenue, access to global markets and level of support required to successfully bring products to market and continue development, the structure of the industry is neither economically nor commercially sustainable. Government coordination and support are critical to ensure that the aerospace industry remains economically viable and contributes to broadening participation of organisations that, under normal circumstances, would not have been able to become suppliers to an industry with such high barriers to entry.

Government's role in supporting South Africa's aerospace industry

Various government departments currently play an active and significant role in the development of the South African aerospace industry. They are the departments of Science and Technology (DST), Defence (DOD) and Trade and Industry (**the dti**). These departments have invested significantly in the industry and have partnered with the CSIR, as per international models where research institutions act as implementation bodies for government, to establish initiatives which aim to support, uplift and enable the local South African aerospace industry. Government departments across the NSI utilise the CSIR's infrastructure and expertise to improve the competitiveness and offerings of the local aerospace industry, through the development and implementation of strategies, and the development and transfer of technologies.

Access to national infrastructure

Internationally, research institutions and science councils act as the implementation body for national government. National infrastructure is essential to direct and lead research. This ensures that the industry is kept current with technology injections and that the research appropriate to industry needs is timeously performed.

This provides an enabling platform for skills development planning, resourcing and coordination with industry, which in turn develops national facilities and capabilities. Higher education institutions align themselves with the strategic direction provided by science councils and address the skills requirement for industry growth. This mechanism is the outcome of the effective operation of the NSI, where each role player fulfils a specific mandate and ultimately benefits the industry. The CSIR is utilised by the various South African government departments to improve and validate technologies and improve the competitiveness to the local aerospace industry.

Development of the Rooivalk helicopter through government support

The Rooivalk national programme is an example of why it is important for government to sustain an advanced manufacturing industry such as aerospace. It demonstrates benefits multiplied into peripheral industries, as well as the development and improvement of company-specific capabilities as value addition to other products and offerings of the organisations. The Rooivalk programme has resulted in numerous successful technologies which have been

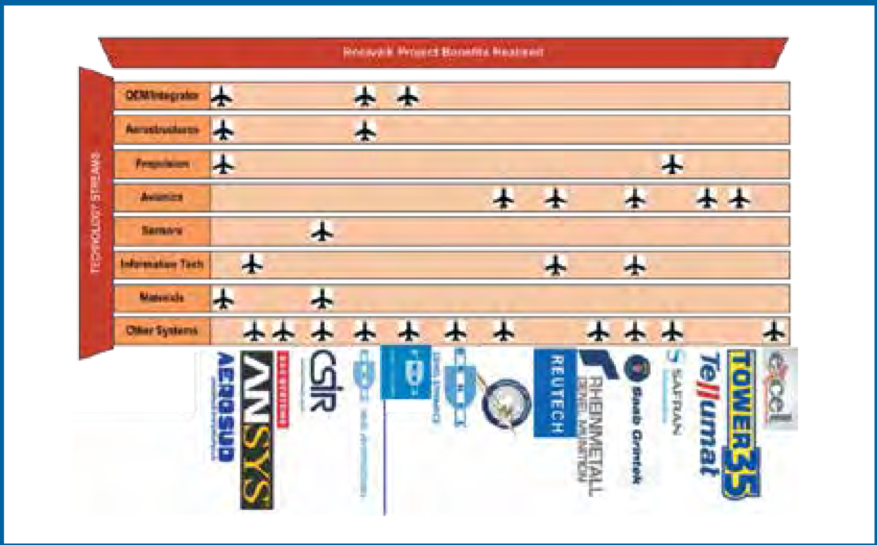
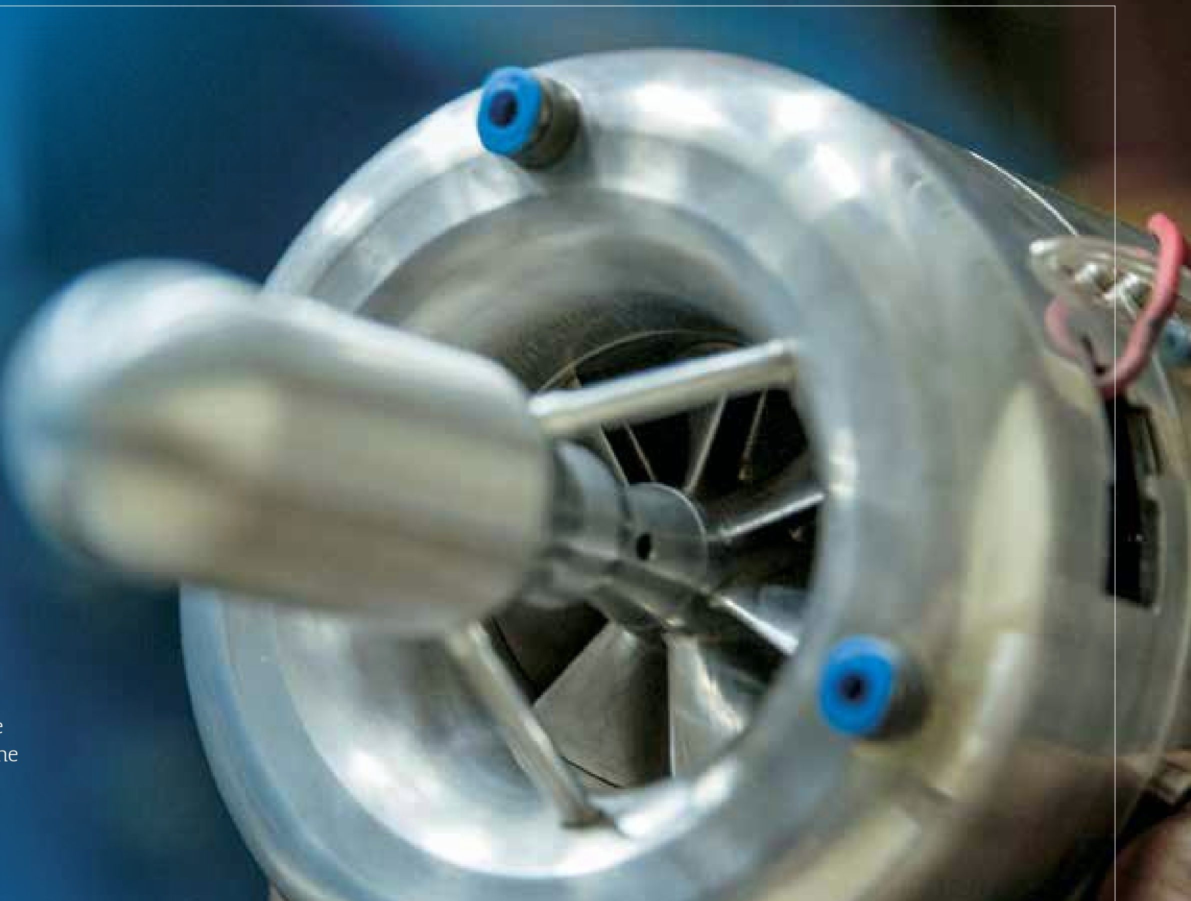


Figure 1: Rooivalk spin-off technologies in South African industry



The CAT 200 KS, a micro gas turbine engine developed by Cape Aerospace Technologies.

commercialised and which continue to serve the South African aerospace industry. Some of these commercialised capabilities are illustrated in Figure 1. The actualisation of these spill-over benefits into the South African industry shows the importance of industrialisation in an advanced manufacturing industry, and more importantly, substantiates the governmental support provided.

Industrialisation of aerospace technologies

The Aerospace Industry Support Initiative (AISI), an initiative of **the dti**, hosted and managed at the CSIR, aims to improve the local aerospace industry's capability through focused interventions and support. Taking into account global trends, the CSIR assists **the dti** in identifying key thematic areas of support to address its strategic requirements.

Industry development and technology support is one such intervention. This support has led to the emergence of three highly innovative local aerospace technologies with great promise for successful commercialisation. The technology-based SMMEs in question include a company that is the first in South Africa to be able to provide radiation screening and mitigation services for satellite components; a company that employs a unique stellar gyroscope to function as a reliable attitude control system for nanosatellites; and a company that has developed a micro gas turbine engine that has the potential to be used in unmanned aerial vehicles.

Supplier development through the AISI

Supplier development is directed at including small, medium and micro enterprises in the economic activity and supply chains of the industry, which under normal circumstances would not have been able to participate in the economy. The AISI supplier development programme focuses on three aspects, namely; technology transfer, skills development related to manufacturing processes and supplier development enablers.

The design and manufacture of aerospace fuel tank structures is one example of technology transfer and skills development. This project, a joint collaboration between the CSIR (software development), Denel Aerostructures (manufacturing) and the University of Pretoria (experimental analysis), proposes the establishment of a specialised capability for the loads analysis of aerospace fuel tank structures (fuel sloshing analysis). It aims to obtain a competitive advantage in the international market by leveraging locally developed technology to attract foreign investment and grow its footprint in the global supply chain.

The dti utilises the CSIR, through the AISI, to bolster the local aerospace industry through the support of viable technologies that can be industrialised through effective supplier development and to identify niche areas where South African aerospace companies can become global leaders.

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ENERGY, WATER, WASTE: Salvage and synergy for a sustainable environment and industry

By Ndivhuho Raphulu

The National Cleaner Production Centre of South Africa continues to enhance industry competitiveness through resource efficiency and cleaner production methodologies, helping industry do more with less.

SOUTH AFRICAN INDUSTRY'S efforts to improve competitiveness, save costs and reduce its environmental footprint have, over the past few years, received a significant boost in the form of a national resource efficiency and cleaner production (RECP) programme. This is implemented by the National Cleaner Production Centre of South Africa (NCPC-SA), which was established by the Department of Trade and Industry and is hosted by the CSIR.

The NCPC-SA is a member of the global RECP network managed by the United Nations Industrial Development Organization and the United Nations Environment Programme. It also plays a leading role in the African Roundtable on Sustainable Consumption and Production.

Resource efficiency and cleaner production

The RECP services – all subsidised – offered to companies begin with an in-plant assessment to identify areas for improvement in the fields of energy, water and material consumption. Interventions follow a 'doing more with less' approach, ensuring sustainability as well as efficient allocation of resources.

Based on the findings of the assessments, companies are provided with recommendations on cost-saving options and resource efficiency improvements that can assist them in their efforts to become environmentally responsible, productive, low-carbon, and competitive businesses.

NCPC-SA specialists undertaking a resource efficiency and cleaner production assessment for a participating company.

Energy

Focusing on energy, the NCPC-SA's Industrial Energy Efficiency (IEE) Project contributes to the sustainable transformation of energy use practices in South African industry to enhance national energy security.

This is done through the promotion and implementation of energy management systems and energy systems optimisation in plants, as well as building the capacity of industry to implement these methodologies.

Since mid-2010, some 153 companies have participated in the IEE Project, effecting a saving of 1 340 GWh of energy, mitigating 1.2 million tonnes of CO_2, and saving R1.1 billion in energy costs. An estimated 5 704 jobs were created and preserved within the local community because of IEE interventions. Read more about the IEE Project on page 30.

Waste

Implementation of RECP methodologies over the past 10 years has shown that South African industry is increasingly concerned by not only energy and water usage, but also by the amount of waste generated by their businesses.

Industrial symbiosis is one approach to waste minimisation that makes both environmental and business sense. An industrial symbiosis programme connects companies so that they can identify potential synergies for 'waste swapping'. Industrial symbiosis reduces carbon dioxide emissions, landfill costs, use of virgin resources, industrial water usage, hazardous waste, pollution, transport, risks and costs.

Industrial symbiosis programmes are currently run in the Western Cape (by GreenCape), Gauteng and KwaZulu-Natal, both managed by the NCPC-SA. All three programmes collaborate and share information to connect the businesses that have waste to business that can use that waste.

One such case study involves a Western Cape company, ComboTimber Structures, a pallet manufacturer. The company saw an opportunity for recycling old, discarded or broken pallets and a synergy with waste management companies. One of these, for example, was sending 30 tonnes of wood waste to landfill every couple of days. ComboTimber provided a service by removing this waste, gaining materials with only labour and transport costs, reducing their input costs by 60%. Labour costs have increased by 40%, creating new jobs, and the business no longer produces new pallets.

This new initiative has also led to the company developing specialised machines to break down and manufacture recycled pallets. This year alone, ComboTimber has diverted more than 500 tonnes from landfill.

Water

Efficiency

Water scarcity is one of the most important environmental problems, aggravated by an increasing population. Public pressure and operational risk make it relevant for businesses to assess their physical, regulatory and reputational risks by moving beyond being 'green pioneers' to making sustainable water use the status quo.

In one case study, Sundale Free Range Dairy in the Eastern Cape has implemented audit recommendations with a long-term potential reduction in municipal water supply of 75% and projected direct savings of R1.35 million per annum.

Sundale takes in over 120 000 L of milk a day, making it the biggest milk buyer processing fresh products in the Eastern Cape. An RECP audit assessed the usage of energy and water to comply with municipal regulations. Key focus areas were identified, and an ozonated water filtration plant with ultra violet was installed. This resulted in a more than 50% steam reduction, more than 20% reduction in electrical energy, and more than 50% reduction in water. While the investment in the plant was substantial, the immediate savings mean that the company will recoup their investment in only 18 months. A next step for Sundale will be the re-use of water without the installation of a new, costly system.

The NCPC-SA has begun capacity building in water efficiency and management for industry and is in initial discussion with other stakeholders to initiate an industrial water efficiency project, based largely on the model and learnings of the IEE Project. Implementation of the project will begin during 2016.

Footprinting

According to ISO 14046, a water footprint is determined by one or more metrics that quantify the potential environmental impact on water of a product, process or organisation. It uses a life-cycle approach to allow companies to assess, scientifically and objectively, the impacts on water associated with a product or an organisation.

The NCPC-SA is one of the implementers of the United Nations Environmental Programme's life cycle assessments, which aims to provide practitioners from both industry and academia, with a consensual and consistent framework to assess, compare and disclose the environmental performance of products and operations regarding freshwater use.

DID YOU KNOW?

Global water use life cycle assessments determined hidden water use in the supply chain and found it takes:

- 120 L of water to make one glass of wine
- 15 500 L to produce 1 kg of beef
- 140 L for one cup of coffee.

Delegates at the 2015 Gauteng Industrial Symbiosis Programme hosted by the NCPC-SA.

Capacity and advocacy

Two fundamental principles of any initiative that involves changed behaviour and practices are that business has to be made aware of the need and benefit of the changes; and they need to have the necessary skills and human capacity to make the change a sustained effort.

To address these issues, the NCPC-SA is active in industry and government, advocating and making business and legislators aware of the need for resource reduction through RECP.

In terms of capacity building, the Centre has developed and presents training courses on energy and resource efficiency and is leading a national initiative to have these skill sets formalised into occupational qualifications and to establish a professional body for resource efficiency professionals.

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Localised automation and robotics solutions, using a lean and agile R&D innovation process

By Riaan Coetzee

South Africa faces a number of challenges in its manufacturing industry. Some of the competitive advantages which existed previously, like cheap electricity and low labour costs, have been eroded by rolling blackouts and increases in electricity costs. In addition, product stagnation and rising logistics costs have also negatively impacted the competitiveness of South African industry. The development of robotics, using the right innovation process to support automation in local industries, will do much to improve the country's competitiveness.

Background

Robotics and automation covers a broad range of technologies in manufacturing. It can be used in developing countries to automate a machine or a process and in developed countries it can be a humanoid that supports and care for the elderly. It forms the basis for smart machines and machine-to-machine interaction and if the wrong technology is applied in the wrong scenario it could amplify problems instead of solving them. Robotics and automation is an interconnected technology that will only work if a proper systems approach is considered and all the stakeholders are aware of the value proposition.

Changes to the innovation process are required to ensure there is a proper solution fit for the problem space. The following innovation process draws on a number of well-established management and innovation practices to create a seamless process for rapid product development and uptake by industry.

The innovation process is called lean and agile research and development (LARD). LARD is a non-linear innovation process that is iterative and parallel at the same time and resembles a spiral with four quadrants. The process is highlighted in Figure 1.

The key objective of LARD is to ensure that the business model, market and regulatory requirements are met and taken into account before the research and development starts. It further ensures that the technology development is done in tandem with the relevant stakeholders and are implemented and validated by the market as soon as possible. This reduces the time to market and increases the valuation of the technology for future funding from venture capitalists. It further ensures that there is always a take-up of technology from industry and research is not conducted for the sake of research.

LARD draws upon a number of product development

Figure 3: MVP1

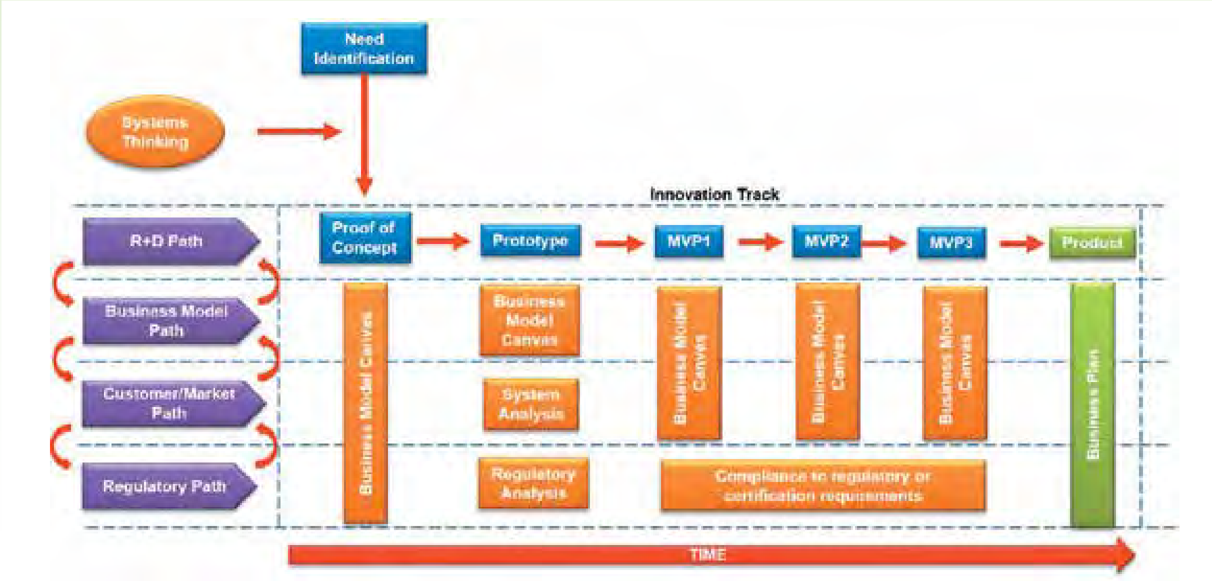

Figure 1: LARD Innovation Process

methodologies like the minimum viable product (MVP) concept.

In essence the focus is to rather have an iterative process of building various forms of the product and testing it in the market, get feedback and then build again rather than building the final product without testing or getting feedback during the process. This will reduce the cost and ensure take-up of the product in the market.

Case Study

In South Africa the gold seam that is being mined is 0.3 m high, but roughly 1.4 m of rock is taken out, therefore diluting the gold and reducing the efficiency and profitability of the mine. If it were possible to only mine the size of the gold seam, it will have a huge impact on the mining industry.

Besides the regulatory, business model and technology adoption issues, the LARD innovation process has identified significant challenges in terms of technology development for automation of mining. The ideal solution is to develop a swarm of robots that will work like a colony of ants to mine the thin gold seam. Figure 2 displays the concept.

We then followed the minimum viable product concept and developed the MVP1 robot, with the focus on mobility in underground slopes characterised by loose rocks. A prototype was built and tested in the mining environment and the learning was used to build MVP2.

The focus of MVP2 was to combine solutions for mobility and sensor data so that the value for the mining sector would be a mine safety platform that can be sent to dangerous areas and survey the environment prior to human entry. MVP2 is displayed in Figure 4.

MVP2 has sparked a number of enquiries from the mining sector and has opened up a new development path in terms of sensors packs and surveying of underground mines. Once industry was made aware of the capability, the value in getting more data to do better planning and improve safety became obvious.

While the building of a swarm of robots that can mine may be some years off, using the LARD process, we understand the problem space a lot better, continuously engage with industry and have created some impact in terms of safety. The new innovation process helps us to ensure that we create relevant solutions, work closely with industry to ensure that we understand the problem space and unlock incremental value by testing and validating solutions.

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Figure 2: Swarm of robots mining

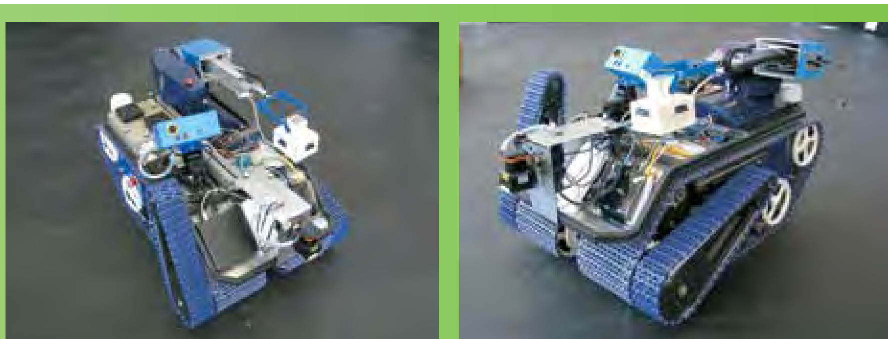


Figure 4: MVP2

"One of the most immediate uses of the study results is the determination of location-specific setback lines for South Africa... Another application is the development of a wave-energy atlas for the South African coast."

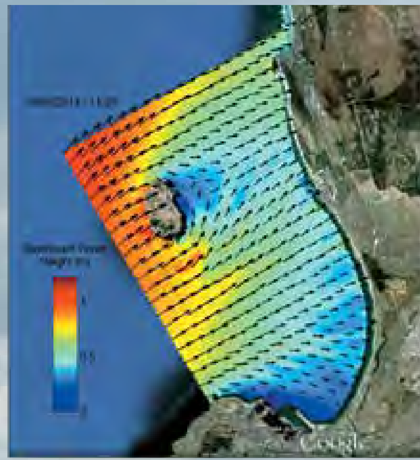
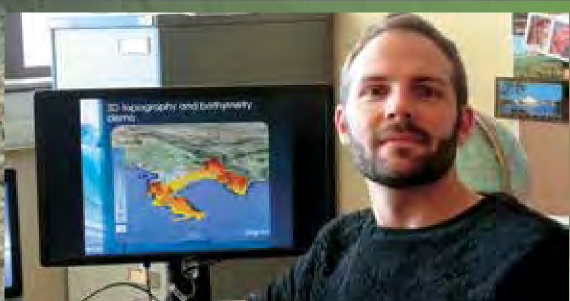


Figure 1: Example of wave simulation results produced for Table Bay, South Africa.



ASSESSING THE VULNERABILITY OF SOUTH AFRICA'S COASTS

By Dr Christo Rautenbach

CSIR researchers used mathematical modelling and engineering technologies to better understand the unpredictable nature and possible consequences of events in the ocean environment. The results from the study can now be used to harness wave energy, provide operational oceanographic forecasting (early-notification systems) and shed light on coastal erosion and sedimentation. It also provides decision-makers with information needed for coastal development planning and mitigation strategies.

TO HELP PROVIDE decision-support in the area of coastal management, the Department of Environmental Affairs needs well-researched information on aspects of coastal safety and vulnerability, climate change and setback lines.

As part of the South African coastal hazard and vulnerability assessment, CSIR researchers set out to determine South Africa's inshore wave climate and to quantify the wave run-up and coastal flooding elevations.

The modelling approach

A detailed wave analysis was undertaken by setting up numerical wave models for a number of regions along the South African coast. In total, 23 numerical models were set up, stretching from Port Nolloth on the West coast to St Lucia on the East coast. These numerical models made it possible to derive nearshore wave climates for locations at about 500 m intervals in each modelled area. Figure 1 gives an example of the results from a wave simulation of a combination of off-shore ocean conditions. The derivation process basically entailed the transformation of approximately 15 years of offshore data to the nearshore locations using transformation coefficients obtained from numerical models for each location. For the purposes of this study, validations with measured wave data indicated that the nearshore wave climates were well represented by the modelled data.

Based on the modelled nearshore data, scientists could conduct statistical analysis to determine the influence of extreme wave conditions on the shore, in other words, the 1-in-1 year and 1-in-30 year return period conditions for big storm events.

Wave run-up

Significant drivers of high inshore seawater levels are tides, wind setup, hydrostatic setup, wave setup and sea level rise (due to climate change), which all affect the still-water level at the shoreline. An additional significant driver of extreme inshore seawater levels in the South African context is the wave run-up, the maximum vertical extent of wave uprush on a beach or structure above the still water level. High flooding levels along the South African coast were simulated by combining modelled wave run-up heights at each shoreline point (at 500 m alongshore intervals or less) with tides, water level setups and sea-level rise components. A range of plausible and realistic scenarios was selected.

A wave-energy atlas and location specific setback lines

One of the most immediate uses of the study results is the determination of the location-specific setback lines for South Africa. These lines will determine the physical lines behind which land development should be allowed to protect coastal development from climate change and extreme weather events. Another application is the development of a wave-energy atlas for the South African coast. This atlas can be used for the determination of possible sites for wave-energy extraction. The South African coastline has a massive potential for wave energy extraction and such an atlas will enable energy providers to set up their pilot scale systems in the appropriate locations around the coast. This information together with the setback lines and coastal flooding elevations are crucial for coastal development planning and vulnerability assessments.

Updated forecasts of ocean conditions

In a further development, the project now also provides real-time updated forecasts of the ocean conditions. False Bay was chosen as a pilot study site. The study has proved to be effective in accurately predicting the unpredictable weather in False Bay. This aspect of the high-resolution numerical models provide full 3D information, including wind magnitude and direction, wave height, period and direction and full 3D ocean current conditions. The aim of the current research is to roll out these high-resolution studies and forecasts to other sites around the South African coast. To this effect, the 3D model for Algoa Bay is almost completed.

Far left: CSIR senior researcher, Dr Christo Rautenbach specialises in coastal vulnerability and erosion, forecasting and oceanographic numerical modelling.

Storm events in Kalk Bay in the Western Cape, often resulting in extreme damage along the coast.

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The first African-based Earth system model

By Prof. Francois Engelbrecht

The CSIR is developing the first African-based Earth system model towards more reliable projections of future climate change over Africa and the Southern Ocean. This is taking place in collaboration with partners in Australia, Japan and France.

CLIMATE CHANGE is the most serious collective environmental challenge ever faced by humankind. It is a problem of global reach, yet the research effort to address it is disproportionately concentrated in the northern hemisphere and in developed countries. Of the about 30 coupled ocean-atmosphere global circulation models and Earth system models suitable for the projection of future climate change, only one model, which was developed by the Commonwealth Scientific and Industrial Research Organisation in Australia, had its genesis in the southern hemisphere.

Relevant to Africa

However, southern hemisphere and African climate issues differ from those that drive the research and modelling effort in the north. In particular, oceans dominate the southern hemisphere and the land is largely occupied by semi-arid systems and tropical forests. It is against this background that the CSIR has in recent years embarked on the development of the first African-based Earth system model. This multidisciplinary effort is driven by CSIR experts in the fields of global change, high-performance computing and modelling and digital science. International partners in Australia, Japan and France are making key contributions to the development of this new model.

The African continent is highly vulnerable to future climate change, partially because of its relatively low adaptive capacity. Moreover, CSIR research indicates that temperatures are rising rapidly over the continent, particularly in the subtropics, at more than twice the global rate of temperature increase – with drastic further warming projected for the 21st century (Figure 1). Nevertheless, model projections of future climate change over Africa, and in particular

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future rainfall patterns, are uncertain. It is therefore critical to obtain more reliable projections of future changes in temperature, rainfall and extreme events over the continent through enhanced model development efforts. Africa is the only continent for which climate model simulations have not shown significant improvements between the Fourth (2007) and Fifth (2013) Assessment Reports of the Intergovernmental Panel on Climate Change. Clearly, such improvements can only be achieved by the development of an Earth system model through an African lens.

Continent-specific data to consider

Key focus areas of the development of the new model are the simulation of convective rainfall (short intense rainfall or thunderstorms) over Africa, aerosol-climate feedbacks over Africa, dynamic land-surface modelling of the African savannah and regional ocean-atmosphere feedbacks over the Atlantic and Indian Oceans. Of particular interest is upwelling – the movement of dense, cooler and usually nutrient-rich water towards the surface on the African west coast, and the dynamics of the warm Agulhas current on the east coast. It is also important to understand and better model the role of the Southern Ocean in regulating African and global climate. The role of the Southern Ocean in the global carbon cycle is a focus area – should the Southern Ocean's ability to absorb carbon dioxide decrease significantly under climate change, the rate of warming over Africa and globally may be even higher than currently expected. The CSIR's extensive Southern Ocean Carbon and Climate Observatory observational programme is aimed at better understanding the relevant Southern Ocean physical processes and biochemistry. Development of the new Earth system model will consolidate the CSIR's unique observational and domain expertise in Southern Ocean processes, and African atmospheric and land-surface processes, leading to a model with world-leading capability to simulate African climate change.

The new model is based on novel numerical features, including a quasi-uniform cube-based grid (Figure 2) ideally suited for parallel processing on the Centre for High Performance Computing's supercomputers. It offers stretched-grid capabilities for high-resolution regional downscaling, and has been termed the Variable-resolution Earth System Model. This model's development is taking place with the immediate objective of generating the first African-based projections of future global climate change as a contribution to the Intergovernmental Panel on Climate Change's Assessment Report Six.

The development and application of this model is expected to be associated with a new cadre of climate modellers, working and living in South Africa and Africa. This will imply a complete makeover of the climate modelling landscape in Africa and the developing world.

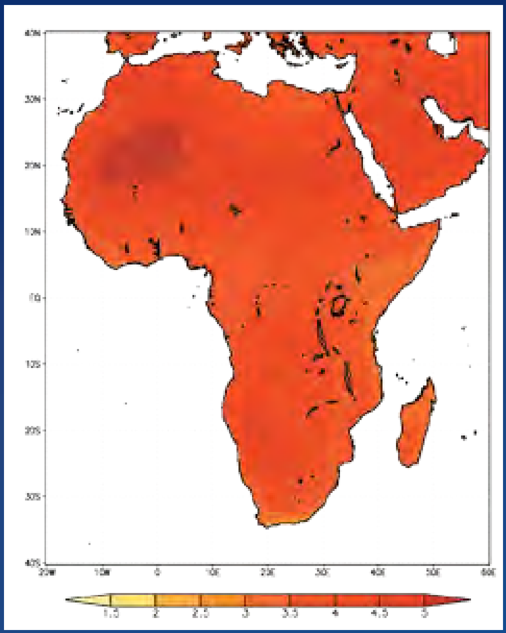

Figure 1: A CSIR climate model projection of changing temperatures (degrees Celcius) over Africa under climate change, for the end of the 21st century under low mitigation, compared to present-day temperatures. Temperatures are projected to rise rapidly in the African subtropics.

Figure 2: The cubic grid used by the Variable-resolution Earth System Model, the first African-based Earth system model. The grid is common between the ocean and atmosphere model components, simplifies model coupling and improves efficiency for eddy permitting simulations of the Southern Ocean circulation and will improve scaling on the Centre for High Performance Computing's super-computers.

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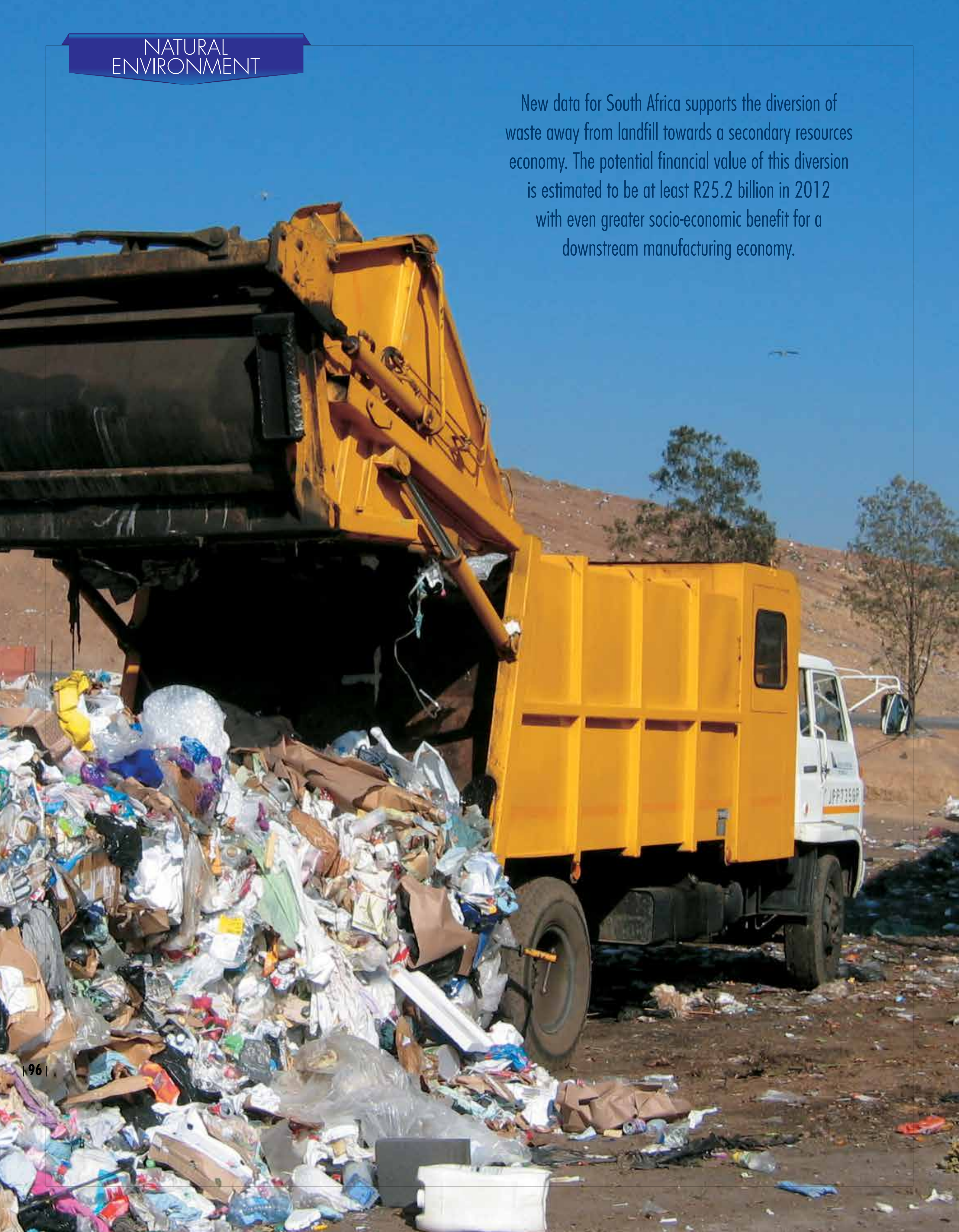
New data for South Africa supports the diversion of waste away from landfill towards a secondary resources economy. The potential financial value of this diversion is estimated to be at least R25.2 billion in 2012 with even greater socio-economic benefit for a downstream manufacturing economy.



FINDING VALUE IN WASTE:

CSIR-generated data shapes the South African waste sector and identifies opportunities for growth in a secondary resources economy

By Prof. Linda Godfrey

IN SOUTH AFRICA, considerable opportunity exists to reduce the generation of waste and divert the remaining waste away from landfill towards a secondary resources economy, which recovers valuable materials back into the economy, thereby creating opportunities for job creation and enterprise development. Through research partnerships with key national government departments, including the Departments of Environmental Affairs, Science and Technology, and Trade and Industry, the CSIR has been able to generate much of the data that has been used in quantifying the South African waste sector.

Finding value in waste

The social, environmental and economic opportunities that waste provides as a secondary resource are well acknowledged, locally and internationally. Driving waste away from landfilling towards reuse, recycling and recovery creates value-adding opportunities both in the waste and secondary resources sector as well as in the downstream manufacturing economy. Furthermore, in transitioning to a green economy, the waste sector provides opportunities in addition to secondary resources recovery, through the implementation of waste prevention or cleaner production measures, aimed at preventing the generation of waste. In so doing, an economy is able to decouple economic development from waste generation and disposal.

The financial value of the formal South African waste sector was estimated to be at least R15.3 billion in 2012, or 0.5% of gross domestic product (GDP). This sector was estimated to employ some 30 000 people in the public and private sectors. This is in line with developed and developing economies, where the waste sectors are typically responsible for between 0.2 and 0.4% of GDP. However, countries actively driving a green economy agenda, including a number of European Union member states, have been able to grow this secondary resources economy to as high as 1.0-1.5% of GDP, a two- to three-fold increase in the value of the waste sector.

The diversion of waste away from landfill ushers in the opportunity to create a large number of low- and high-skilled jobs, across the waste hierarchy and across the waste value chain, including the downstream manufacturing economy. However, much remains to be done to increase the recovery of valuables from the waste streams at source, through for example source separation measures, while simultaneously growing local end-use markets for the refurbishment or reprocessing of recovered materials. In this way, the economic and social value is not lost to landfill, or to overseas markets where growing quantities of recyclables are now exported for reprocessing.

While the waste hierarchy is strongly entrenched in South African policy, government, industry and society continue to send an estimated 90% of all waste generated to landfill, conservatively estimated at R17 billion's worth of secondary resources lost to the economy per annum through landfilling.

Waste meets policy

The South African Government is actively pursuing a secondary resources agenda through the implementation of new policy instruments. These include traditional command-and-control instruments such as the Waste Act, Waste Amendment Act and supporting Regulations, as well as alternative policy instruments, such as the National Pricing Strategy for Waste Management, that aims to introduce economic instruments (incentives and disincentives) into the South African waste sector, and the introduction of Extended Producer Responsibility.

The National Pricing Strategy provides an opportunity to address both the supply and demand side of a secondary resources economy.

Correcting the current under-pricing of landfilling among most municipalities by ensuring full-cost recovery of waste operations would make alternative waste treatment options more financially viable relative to landfilling. This would, in turn, support increased investment in the recovery of valuable materials from waste. Furthermore, opportunities are provided for incentivising end-use markets, thereby increasing the investment in downstream end-use markets.

The formal South African waste sector is estimated to employ some 30 000 people in the public and private sectors.

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PRODUCING MORE WITH LESS: Water-use efficiency is the key

By Dr Mark Gush, Dr David Le Maitre, Dr Sebinasi Dzikiti and Dr Nebo Jovanovic

With virtually all the water resources of South Africa already allocated to the various sectors of the economy, the best option for continued development of agriculture and forestry is to improve the water-use efficiency of crops and trees.

SOUTH AFRICA faces increasing water scarcity and competition for water due to its limited supply of water and growing population, economy and climatic uncertainty. Agriculture and forestry are thus faced with a major challenge: how do we produce more crops and tree products with less water?

At first glance it seems that this is impossible, because research shows that there is a direct relationship between production (yield) and water use. As the one increases, so will the other. However, we are not really sure whether the water that is supplied to the tree or crop is in fact all being used to produce what we want: utilisable food and wood. Another term for this is 'beneficial water use'. In reality there is a lot of 'wastage' of water, or 'non-beneficial water use'. The solution is to maximise the use and minimise the waste. This essentially means improving water productivity or water-use efficiency, particularly in the irrigated agriculture and forestry industries of South Africa. These two industries already use approximately two-thirds of the river water in the country and are not likely to be allocated any more.

Understanding crop water requirements

Irrigation is necessary for the production of key crops such as vegetables and fruit because of the low, erratic or unreliable rainfall in many parts of the country. It also produces high-value exports which are important economically. If this industry is to grow, the only option is to improve our understanding of crop water requirements and how to schedule irrigation most effectively and efficiently. This knowledge must be shared with farmers to enable them to apply only what the crops require, minimising wastage and producing more 'crop per drop'. While plantation forestry in South Africa is critical for timber and fibre production, income generation and job provision, the plantations have environmental costs, especially their impacts on water resources. This is because commercial tree plantations generally use more water than the natural vegetation that they replace. The ongoing spread of invasive alien plant species likewise reduces water availability. Their continued removal, particularly from stream channels, is imperative for conserving water.

In line with the maxim, 'To be able to manage, it is important to be able to measure', the CSIR has undertaken a number of research projects to improve our understanding of the actual water requirements and use by crops and trees, including quantifying the water-use of irrigated crops, trees, natural vegetation and invasive alien plants.

The methods include in-field vegetation water-use monitoring techniques, remote sensing methods for estimating evapotranspiration, modelling approaches and water-use impact indices and tools (e.g. water use efficiency/water productivity, water footprints and life cycle analysis) for agriculture, forestry, alien invasive plants and indigenous vegetation.

Measuring the water use of crops and trees

Techniques that are used to measure vegetation water use in the field include those that measure how fast water is travelling through the stem of a plant (sap flow monitoring techniques using probes inserted into individual stems), and those that measure the water use (total evaporation) of an entire field or stand of trees (energy balance techniques using equipment mounted above the vegetation).

Technologically advanced measurement systems such as these have dramatically improved our ability to measure the water use of crops and trees, not only how much they use and when they use it, but (in conjunction with additional instruments) what factors affect water use and how best to model and predict likely water-use scenarios under different conditions.

For example, field measurements have shown that a 14-year old 'Pink Lady' apple tree, growing in an apple orchard in the Western Cape, uses between 20 and 30 L water per day in summer (max 42 L). This amounts to approximately 4 000 L water per tree over the growing season, and means that it requires about 27 L water to produce an apple. Contrast this with mature Pecan nut trees in Mpumalanga that use over 200 L per day (54 000 L per season) and consequently require 5 000 L to produce a kilogram of pecan nuts. On the other hand, a water-thrifty indigenous tree such as the Sneezewood uses around 6 L per day (2 000 L per year), producing approximately 1.5 g of wood per L of water used.

The increasing availability and refinement of remotely-sensed data (from satellites, aircraft or drones) is also adding an exciting new spatial dimension, allowing us to see how water-use varies within fields and farms, or across landscapes. Application of the improved understanding and predictive ability provided by these techniques will improve the efficiency of water-use in the agricultural and forestry sectors, and free up water for other uses – a critical requirement in a water-competitive country such as South Africa.

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Crop water models were developed for selected fruit trees from data collected at seven different sites, also in the Western Cape.

Two decades of managing invasive alien plants: Exploring Working for Water success stories

By Dr Phumza Ntshotsho • Co-authors: Greg Forsyth, Dr David Le Maitre, Dr Nadia Sitas and Thozamile Yapi.

Invasive alien plants pose a significant threat to South Africa's biodiversity and human well-being. For 20 years, the Working for Water programme (WfW) has been tackling this problem. CSIR researchers are assessing three WfW projects to identify factors critical for success.

Why manage invasive alien plants?

Invasion by alien plants poses a significant threat to South Africa's biodiversity and human well-being. Ecosystem services, which are the benefits people get from nature, such as the provision of water and grazing, are under pressure, largely due to this threat. As the guardian of the nation's natural environment, the Department of Environmental Affairs is tasked with bringing the invasion threat under control and its WfW programme is tackling the problem head-on. (The programme was initially started by the then Department of Water Affairs and Forestry). The WfW programme was specifically set up in 1995 for the management of invasive alien plants in order to conserve water and to provide employment for marginalised sectors of South African society. The programme has been criticised for not bringing the invasion problem under control, despite having been in operation for nearly two decades, with associated total expenditure in the region of billions of rand – as stated by Van Wilgen et al. in an article published in the journal *Biological Conservation* in 2012.

However, there are some projects that have resulted in previously heavily invaded ecosystems being returned to a state nearing pre-invasion conditions. Such successes are rarely adequately reported, which is unfortunate as they demonstrate that control interventions can achieve the desired results, and help to identify critical factors for success.

Is WfW making a difference?

Applying a case study design, CSIR researchers show what WfW has achieved and why the chosen examples have been successful. Three projects selected in consultation with WfW managers are assessed, each representing an example of the different implementation models used in WfW (Table 1).

Critical success factors

The starting point is careful and strategic planning that takes into consideration the magnitude of the problem and the resources available to tackle it. Of critical importance is the allocation of funds for follow-up work and monitoring. Proper planning also involves choosing and prioritising operations based on their potential to achieve the stated objectives. For example, the Berg River Dam project and the Upper uMzimvubu project are of strategic importance for water security. Both projects lie within two of South Africa's 21 strategic water source areas. These are areas that occupy 8% of South Africa's land area and supply 50% of our surface water. Thus, the high stakes involved engender a high degree of commitment.

Commitment in terms of financial resources as well as buy-in and support of a shared vision by stakeholders are crucial. Buy-in is essential for a landscape approach to clearing, with private landowners often having to commit funds to clear invasive alien plants on their land, to reduce the threat of reinvasion of adjoining public land that has been cleared under the mandate of WfW.

Passion for the job is another critical success factor. Getting the right people, with the necessary understanding of the mandate of the programme, is vital for success. As one manager interviewed by the research team put it, "You have to be able to understand the human side of the project as well, because this project is meant to assist people, create jobs and develop them. If you don't have that passion, it's not going to work."

Time for reflection

As the WfW programme celebrates twenty years in operation, it is an opportune moment to reflect and celebrate the successes, but also flag potential pitfalls and highlight opportunities for how the programme could enhance its impact. Planning, commitment and passion are all essential success factors. While significant ground has been gained in the fight against invasive alien plants overall, it is crucial to hold on to those gains. To this end, planning for post-clearing sustainability, including making adequate provision for follow-up work, cannot be overemphasised. Additionally, distilling of lessons is imperative if the gains achieved are to be scaled up.

Table 1

Model	Implementing agent	Herbicide assistance	Land user incentive
Brief description	WfW appoints a government agent (e.g. a municipality) to manage the day-to-day operations of a clearing project while WfW funds and oversees (e.g. through periodic verification) the project.	Typically used to help private landowners manage invasive alien plants on their property. WfW supplies the herbicide/s needed to control invasive alien plants, but the operations are handled by the landowner.	Interested land users and land owners participate in a competitive bidding process for funds to control invasive alien plants. Applicants have to demonstrate the availability of co-funding from stakeholders of the proposed project.
Case study	Berg River Dam	Phinda Private Game Reserve	Upper uMzimvubu Catchment
Extent of project (ha)	11 600	13 000	4 000
Project duration	2001-present The Berg River Dam project has undergone several changes in management since its inception.	2001-present	2013-present
Major problem species	*Acacia* spp.; *Eucalyptus* spp.; *Pinus* spp.	*Chromolaena odorata; Lantana camara*	*Acacia mearnsii*
Land ownership	State and private	Private	Communal
Biophysical benefits gained	Increase in water quality and quantity; biodiversity	Increase in tourism potential	Increase in grazing capacity; soil retention


Photos taken at the Berg River Dam project site during initial clearing in 2008 (left) and in June 2015 (right).


There is anecdotal evidence of improvements in biodiversity as well as water quality and quantity. The photo on the left shows natural vegetation recovery in an area that was once covered by a pine plantation in the Berg River Dam project area. The other photo depicts project member Dr Phumza Ntshotsho drinking from a stream in the same area.


Photos taken before (left) and after (right) clearing of a dense stand of *Chromolaena odorata* at Phinda Private Game Reserve. Clearing of invasive alien plants such as *Chromolaena* does not only improve the tourism potential of the area by increasing the aesthetic appearance of the reserve, as well as game visibility, but it also contributes to the availability of grazing areas for game. *Pictures courtesy Cilla Pickering.*


(Left) A group of local women employed in the Upper uMzimvubu Catchment LUI project, clearing *Acacia mearnsii* (black wattle) to restore grazing land near Matatiele, Eastern Cape. Employment creation is an important imperative of the WfW programme. (Right) Veld recovery after clearing of black wattle is accelerated through trampling by livestock. There is a clear contrast between an area where trampling was implemented (green arrow) and where it was not (red arrow). *Picture on left courtesy Sinegugu Zukulu.*

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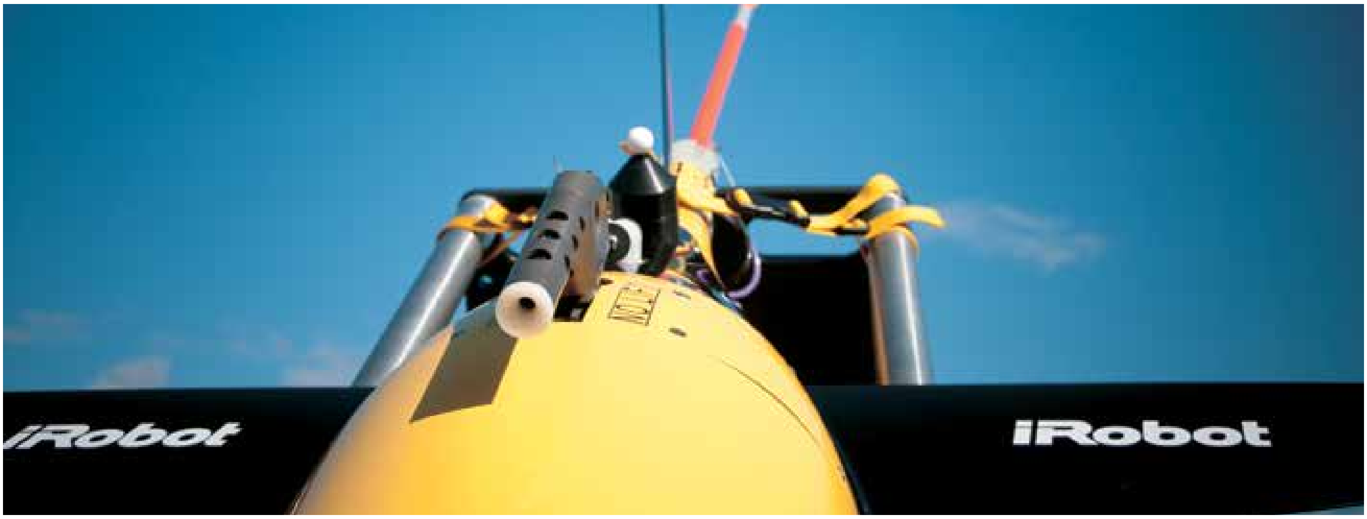


Top: A long-range autonomous iRobot Seaglider. Middle and bottom: A wave glider, pictured off the Western Cape coast between Dassen and Robben Islands with an acoustic echo sounder to determine fish stock levels.

Ocean robotics for sustainable, long-range marine resource and ecosystem management in the 21st century

By Dr Sebastiaan Swart, Hannes J Zietsman, Niel D Goslett and Dr Pedro MS Monteiro

Multi-month ocean glider deployments in the Southern Ocean have resulted in the collection of unprecedented ocean-climate data from the remotest and harshest ocean environments. Now we are beginning to use this technology to enhance our marine resource and ecosystem governance in South Africa's exclusive economic zone and beyond.

High reward ocean experiments

The Southern Ocean Carbon and Climate Observatory (SOCCO.org.za) at the CSIR has been undertaking extended ocean glider deployments in the remote Southern Ocean every year since 2012. These initially high-risk deployments have formed part of what is called the Southern Ocean Seasonal Cycle Experiments, aimed at providing continuous and high-resolution ocean observations between South Africa and Antarctica. Roughly 2 000 km south-west of Cape Town, glider pilots have been steering these gliders in the ocean to collect unprecedented oceanographic and biogeochemical datasets that are revealing new aspects about the health and functioning of the ocean carbon-climate system of the Southern Ocean.

SOCCO is regarded as a global pioneer in the use of ocean robotics in the Southern Ocean, which has significantly contributed to the development of a research niche in a new understanding of the role of fine scales in linking CO_2 between the ocean and the atmosphere.

Continuous presence in our exclusive economic zone

Repeated successful glider missions offshore of South Africa's coast, and particularly in the Southern Ocean, is enabling SOCCO, in collaboration with CSIR partners, to begin to innovate in respect of the use of ocean robotics beyond research and into ocean services areas.

These services have the potential to play an active role in supporting new domains for Operation Phakisa, an initiative of the South African Government, which was designed to fast track the implementation of solutions on critical development issues. The first implementation of Operation Phakisa, led by the Department of Environmental Affairs, focuses on unlocking the economical potential of the country's oceans.

Ocean services areas include ocean governance, fisheries management and marine safety, as well as developing a national carbon dioxide (CO_2) facility in support of South Africa's mitigation policy requirements. The challenge that exists is South Africa's exclusive economic zone, which extends over an enormous 1.5 million km^2 and also includes the remote waters around the Prince Edward Islands (including Marion Island) in the Southern Ocean. Along with the benefits of this zone comes the immense responsibility of managing its resources, one of which is its commercial fish stocks.

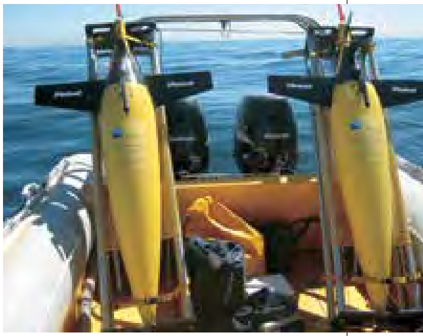
Protecting our valuable marine resources

Currently, fish stocks around South Africa are assessed via acoustic surveys using manned survey vessels. These fisheries research ships and surveys, currently managed by the Department of Agriculture, Forestry and Fisheries, are extremely expensive to undertake, limiting the amount of ship time available. This restricts the magnitude of fish stock assessment data being collected annually that are ultimately used to present fishing quotas to the fishing industry.

Wave gliders, by using wave and solar energy to propel and power on-board sensors, are able to operate autonomously for months at a time, while transmitting real-time data to researchers and ecosystem managers back on land. The fish acoustic and ocean environmental data being collected on a continuous basis and over larger spatial domains by gliders have been shown to be of comparable quality to data collected by ship. This means gliders could dramatically improve the temporal and spatial coverage of fish stock assessments, which will allow for fisheries managers to set quotas that may improve yields and reduce the probability of overfishing. The enhanced observational capabilities enable scientists to monitor the response of fish stocks to environmental variability and climate change that is already being seen to drive long-term change in our fish stocks.

The much lower operational cost and improved range of gliders versus ships mean that unmanned glider platforms are beginning to play an important role in obtaining ocean observations and having a presence in the marine domain. We envision new approaches in which the CSIR's current fleet of ocean gliders would monitor the ocean environment continuously and even year-round. Subsequent larger volumes of temporally and spatially coherent data providing unprecedented approaches to manage the ecosystems, strengthen ocean governance and support robust climate projections. This will support the development objectives of our country, specifically those set out in Operation Phakisa.

Glider pilots based in Cape Town steer the ocean robots in the remote Southern Ocean.



Unmanned ocean robots deployed in the ocean are revealing new aspects about the health and functioning of the ocean carbon-climate system of the Southern Ocean.

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