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SOUTH AFRICA'S COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

Improving impact through licensing and ventures

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FOREWORD

Improving impact through licensing and venture creation

Beyond the CSIR's significant contribution to the global knowledge base, we are determined to ensure that our work has quantifiable economic, environmental and social benefits. One of the ways to attain this is to improve our transfer of technology and innovations to third parties.

We recognise that innovation implies dissemination and uptake and that for an invention to become an innovation, it needs to be implemented or used by the market and society. The term 'third parties' hints at the diversity of actors needed for innovation, and the implied interdependencies. These parties all hold knowledge that is essential for true innovation to occur.

In this edition of *ScienceScope*, we are giving you a glimpse into our efforts in licensing and venture creation as a mechanism of technology transfer. Details on the organisation's view in this regard are contained in an interview with Dr Sean Moolman, group manager: licensing and ventures, whom I appointed to this position a year ago.

In the first section of this publication, opportunities for uptake of technologies are outlined. High potential opportunities in sectors such as health, advanced manufacturing and defence have arisen from the collective efforts of our multidisciplinary competence base. In all of these cases the technology readiness is at an advanced stage. In some cases, such as the portable landing lights, the technology was first developed for a specific client with great uptake and success. It has since been modified, with exciting potential for application elsewhere.

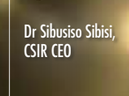
We also feature some success stories: outputs that have been successfully licensed or have become the basis for new companies. Some technologies have been in use for decades and their impacts are undeniable. The heavy vehicle simulator has earned South Africa more than R200 million in foreign revenue since 1994 while the PUDU sense-and-deploy system is regarded as a contributor to the continued decline in cash-in-transit heists. The development of a camera that visually displays the corona discharge around defective, high voltage electrical equipment and cabling has proven extremely useful for power utilities worldwide.

There are many examples of technologies and services with CSIR roots that have been transformed as technologies merged and grew. The CSIR hosted the very first Internet service provider in South Africa, for example. Today very little of that service is recognisable, but we take pride in having played a part in its evolution.

Arguably, one of the biggest impacts CSIR research has had on an industry, is in the development of the lithium ion battery, which has literally changed the world. All major lithium ion battery manufacturers have been licensees of CSIR patented intellectual property. The person behind the 1994 invention was world-renowned scientist, Dr Michael Thackeray.

A publication on venture creation would not be complete without reference to our organisation's activities in enterprise creation for development. These activities are in response to national imperatives such as the creation of decent employment through inclusive economic growth, poverty reduction and the development of vibrant, equitable and sustainable rural communities. In this publication, two such undertakings are featured.

We trust that you will enjoy this edition of *ScienceScope* and invite your feedback via **query@csir.co.za**.



Dr Sibusiso Sibisi,
CSIR CEO

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MOSQUITO REPELLENT CANDLE

Scientists, traditional healers and entrepreneurs pooled their skills and today consumers can reap the benefits by purchasing a new insect repellent candle with more effective repellent properties than comparable commercial products. Isaac Mohlamme, Business Development Manager at Zolhaus International (Pty) Ltd, with whom the CSIR signed a licensing agreement, spends time in-store at a major Gauteng retailer to discuss product sales with his General Manager, Gordon Muller. Read the full story on page 56.

Transforming ideas into innovations

"There are more CSIR technology opportunities in the early stages of maturity than there are resources to help mature and package them for commercialisation." But as he cites the plans and progress made in getting all the gems packaged and successfully transferred, it becomes clear that Dr Sean Moolman, CSIR group manager: licensing and ventures, is in serious pursuit of his vision – and that of his organisation – of securing as much impact from as many technologies as possible for the country. "Technological innovation is important for companies to remain competitive and we can help them. We want our technologies to be used. We want South Africa to benefit from it," he says.

Technology transfer: One route to impact

In the research, development and innovation (RDI) landscape, the term 'technology transfer' is widely used. It refers to the process of transferring new knowledge and innovations to third parties who can realise value from them by making them available to the market and society, for commercial gain and social good.

In the case of the CSIR, the organisation is committed to this aim through its mandate, which states that the organisation should use directed and particularly multidisciplinary research and technological innovation to foster industrial and scientific development to contribute to the improvement of the quality of life of the people of South Africa.

Of course, technology transfer is not the only way to heed this call. There are numerous pathways to achieving impact, says Moolman. One can develop skills through training, lecturing and secondment of staff. For the CSIR, this is a road well-travelled, with 245 CSIR staff members studying towards their Master's and PhDs, and the same number of studentships supported in the past financial year. Knowledge transfer is an equally well-trodden route to impact for the CSIR. The organisation produces a myriad of reports, findings and documents for stakeholders in the private sector and in government departments. New knowledge generation too is a familiar pathway for the organisation's 1 500-strong science, engineering and technology base, with research findings being published in conference proceedings and technical journals around the world. The CSIR's online repository of research publication records continues to see a growth in download numbers.

Moolman has been mandated to drive technology transfer, specifically through licensing and venture creation, even though he fervently opposes boxing these elements. In fact, he is making it his business to encourage colleagues to view what happens across the innovation chain as a single process. "Block thinking is not good for achieving maximum impact."

Technology transfer track record

The CSIR has a sound track record in transferring its technology through licensing and venture creation, points out Moolman. A World Intellectual Property Organization (WIPO) report published in 2009 and surveying local institutions in the period 2001-2007, featured the CSIR as the top institution by Patent Cooperation Treaty (PCT) patent application with a South African priority; revenues generated through commercialisation; and the number of start-up companies established. It should be taken into consideration that the CSIR was one of the first South African public research and development organisations that had established a technology transfer office, he says, and other institutions have caught up in recent years.

"The CSIR did quite well in the past, but the fact is that we can do much better. This is particularly evident when comparing ourselves to similar international organisations. Room for improvement is apparent in comparative figures such as number of start-ups as well as invention disclosures per Rand spent on research and development. When comparing ourselves to a similar organisation like VTT in Finland, that also receives

Dr Sean Moolman, CSIR group manager: licensing and ventures (top left) and his team (clockwise from left), Dr Janine Chantson, Bongani Masombuka, Rosemary Wolson, Brian Mphahlele and Wilma van Rooi.

30% direct government funding support, we are behind in several respects."

Probed about which CSIR innovations he would cite as the most successful to date, he points out that one would come to different conclusions when revenue is the proxy for success, compared to, for example, degree of industry adoption, social impact or impact on human health.

"With revenue as a proxy for success, contenders for the most successful innovation include a system that protects vehicles and its occupants from the effects of landmine explosions, and a heavy vehicle simulator that determines whether a road will have an acceptable life-span and which can simulate damage caused by 20 years of traffic, within three months.

"But you may come to an altogether different conclusion on success when learning about CSIR innovations that are keeping South African miners safe. In 2011, there were about 200 000 self-contained self-rescuers deployed in South African mines which provide the wearer with a supply of breathable oxygen, which will save lives in the event of, for example, an underground fire. A CSIR researcher has developed a noseclip that does not slip off when using these self-rescuers. Approximately half a million noseclips are now used throughout the world. He went on to develop a new mouthpiece that is more comfortable and does not irritate or stimulate the sublingual saliva glands and which allows you to verbally communicate while wearing the mouthpiece. The CSIR has now licensed this patented, rubber mouthpiece to Afrox. (The CSIR is also the only accredited facility in South Africa to test the performance of self-rescuers, testing in excess of 1 500 of these every year.)

If pervasiveness of adoption were the criterion for success, one should consider that all major lithium ion battery manufacturers – a sector still dominated by Japan – have been licensees of CSIR intellectual property.

Gearing up

Irrespective of the successes of the past, Moolman says the time has come to take technology transfer to the next level and that there are many things that can be done to achieve this. He says that worldwide (especially in the USA), technology transfer offices have become more sophisticated and efficient in their approaches and the CSIR is following suit.

Numerous steps are being taken to make it easier for researchers to see their innovations 'go all the way' – from awareness programmes to comprehensive new training modules and technology transfer operating manuals. A seed fund has been established to give technologies the extra momentum needed to get them into the final stretch of 'investor fundable' opportunities.
The organisation has also adopted a new intellectual property and technology transfer policy that is more streamlined and should better enable technology transfer activities in the CSIR.

The quest to develop batteries that are small, light and rechargeable ultimately resulted in the lithium-ion battery, which continues to be a major technology driver worldwide. Major lithium ion battery manufacturers licenced the CSIR's patented intellectual property in this regard.

Eleven of these CSIR-developed roadside laboratories have been exported to date.

CSIR innovations in mining safety are a nose-clip, used in self-contained, self-rescuers and an electronic sounding device to detect loose overhead rocks after blasting.

But arguably the most important improvement needed, is industry involvement in the RDI process, says Moolman. "In a small case study, I analysed the reasons for success and failure of 23 technologies developed at the polymers and composites group at the CSIR, a group I previously headed. It was not technical failure that was the number one reason for failure (only one out of 19 technologies failed due to technical issues); it was the failure to sufficiently engage with industry, stakeholders and end-users from the planning stages right through to transfer and implementation. If a fantastic system does not fit into the factory because researchers or developers never sufficiently engaged to understand the requirements, the most robust technology simply won't be taken up."

The CSIR's position on licensing and venture creation

Clarity in terms of one's own organisational drivers is key before going about the business of licensing technologies and creating businesses. If pursuing maximum revenues is the aim, one would typically pursue only opportunities with large commercial potential; tend to look internationally for bigger markets; concentrate on licensing at the expense of start-ups; and negotiate the best possible licensing terms. This is not the CSIR position, Moolman emphasises. Instead, the organisation's central motivation for its technology transfer activities is increasing the organisation's positive impact in South Africa and globally. This includes supporting opportunities for social and economic development, as well as having a service orientation.

Moolman says that this was aggravated in the past by the fact that generally only technical stage gates were used. Simplified, the only reason to stop research projects was technical failures. All of this has changed with the organisation's new growth and impact strategy. Planning for impact requires continuous stakeholder interaction, from the earliest planning stages up to the final stages of uptake and implementation.

"This means that we lean towards start-ups; local, regional and national opportunities; the development of local entrepreneurs; and opportunities with significant impact even if it has limited potential for returns to the CSIR. It also implies that we wish to assist innovators and staff who want to start companies; that we are keen to link technologies with entrepreneurs and funders, and that we will invest in transforming technologies into market-ready opportunities.

"We have some of the best researchers and engineers in the world. Generally, they solve the problems that they set out to. We just need to help them identify the right problems to solve, and provide the right support along the way," he concludes.

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Life-sciences research is about to become a whole different ball game with the CSIR's ReSyn™ microsphere technology. Microspheres are tiny beads onto which molecules can attach. ReSyn™ microspheres are unique in that they resemble a ball of wool rather than a solid sphere – this maximises surface area for the molecules to bind. They are also able to bind targets very specifically and are magnetic for easy purification. The technology is set to boost drug development, diagnostics, R&D and industrial processes.

A new microsphere technology set to overhaul life-sciences research and development

CSIR spin-off company, ReSyn™ Biosciences, will soon put a range of versatile tools on the life-sciences research and development (R&D) market. ReSyn™ is a 'microsphere technology'. A microsphere is a tiny, artificial bead onto which molecules like DNA and proteins can be attached. The technology has been around for a long time, but CSIR researchers have made some drastic improvements to it.

The first microspheres were solid balls that could bind molecules only on its outer surface. ReSyn™ microspheres are not solid; they are made up of many strands, coiled together like a ball of wool so that molecules can bind on the surface of individual strands. In other words, far more biological particles can stick to a ReSyn™ bead than to other beads on the market. Research group leader, Dr Justin Jordaan, says that binding more molecules at one time will allow scientists to work much faster than before.

Drug discovery and disease diagnosis

Such speedy workflow is useful, for example, in fast-tracking the discovery of drugs and specific molecules that are only present during disease. Such molecules are known as biological markers, and the ReSyn™ microspheres that bind them are thus valuable for diagnosis that leads to disease treatment.

In diagnostics, for instance, antibodies can be bound to the beads. These antibodies are attracted to specific disease-related proteins from the likes of viruses and bacteria. If these disease-causing agents are present in a blood sample, they will bind to the antibodies on the beads and the disease can then be positively diagnosed.

Custom design

Jordaan says that new diagnostic technologies are planned for the future, but for now they will have a range of R&D, off-the-shelf products and custom solutions to target different molecules. "It only takes four days to engineer the beads to meet the desired properties," he says.

Researchers can customise unique features of the beads to maximise the attraction between the beads and the target molecule. This makes for very specific targeting of molecules, which will allow scientists to improve the quality of their research.

A versatile technology

The beads are not just useful in pharmaceutical research and diagnostics. They can also be used to improve many routine lab processes such as DNA and protein purification, for the purpose of any biological research or even forensics. ReSyn™ microsphere technology can also be applied in industrial processes. For example, enzymes can be permanently attached to the beads for speeding up chemical reactions.

Magnetism: where the magic happens

A major feature of ReSyn™ microspheres is that they are magnetic. "Once the required molecule sticks onto the bead, the beads can be easily separated from a mixture, such as a blood sample, using only a magnet," says Dr Dusty Gardiner, a research manager.

While not a new idea, this simple property replaces the usual technique of spinning the solution at extreme speeds in a process called centrifugation. It takes much more time and effort to purify by centrifugation than it does to use a simple magnet. "Magnetism further adds to a much faster workflow," says Gardiner.

Both researchers say that they expect ReSyn™ products to hit the market within three months. They will initially focus on larger US and UK markets and will expand into Europe later on. The technology should prove highly competitive as it is cheaper, compatible with existing processes and equipment, easy to use, efficient and it speeds up workflow.

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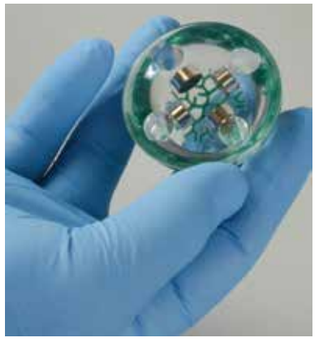
www.resynbio.com

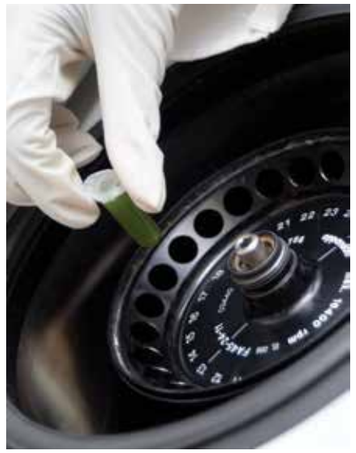
Dr Isak Gerber preparing microspheres.

Market-ready products for the life-sciences R&D sector. Shown in the centre is a magnetic separator which forms part of the product pack.



Plants are the most efficient producers of proteins on earth. The CSIR got involved in research on the use of plants as 'biological factories' in 2003 and has gained significant experience in this domain in subsequent years, specifically studying tobacco plants in biosciences laboratories, taking it all the way to the Rabivir product (bottom) that is ready for trials.

Genetically modified tobacco plants
deliver a cheaper, better rabies antidote



The tobacco plant family has turned over a new leaf – to save lives. CSIR researchers have genetically engineered a microfactory to produce the world's first injectable medicine from a plant: a rabies antidote 10 times cheaper and potentially far more effective than the currently available cure.

THE CSIR HAS PIONEERED the world's first injectable plant medicine. Researchers have genetically engineered the micromachinery of a leafy tobacco plant to churn out a cocktail of life-saving drugs.

Their flagship product is an antidote to the deadly bite of a rabid dog. It's called Rabivir and it doesn't just match the only other available product on the South African market against rabies, it betters it by far.

Why rabies?

Dr Ereck Chakauya leads the Rabivir research at the CSIR and says that deaths caused by rabies are vastly underestimated, especially since developing countries often have stray dog overpopulation.

"By my approximation there are about 9 million dogs in South Africa, and some researchers say there may be up to 2 000 bites per day, many [of the victims] kids." He believes many deaths caused by rabies may go unnoticed since diagnosing the disease after the victim has died requires laboratory tests. The disease can also be mistaken for cerebral malaria.

If the virus is not stopped in its tracks soon after the bite, death is virtually inevitable.

Victims need help before the flu-like symptoms of the disease start showing. Treatment involves taking preventative medication as soon as possible after suspected infection. This is known as post-exposure prophylaxis (PEP) and, in the case of rabies, consists of a cocktail of antibodies and a vaccine. Every year around 20 million people receive this treatment.

In South Africa, a single non-profit company currently produces the antibodies from human blood. An average adult male would need about five vials, setting him back about R3 000. He would also need four injections of the vaccine, which is more readily available but still costs about R300 per jab. If South Africa has trouble affording the drugs, other African countries are almost certainly worse off, says Chakauya.

Rabivir is an alternative to the antibody component of the PEP. What GreenPharm, the proposed spin-off company of this research has effectively done, is to reduce the cost of the antibody treatment from R3 000 to just R200, while still being profitable.

Simpler, better, faster

Apart from being both cheaper and more effective than current drugs, Rabivir could also solve a few other problems unique to developing countries.

For example, human blood donations are prioritised for life-saving transfusions, not for the production of anti-bodies. Blood is a scarce resource in the first place since much of it is infected with HIV and hepatitis B and must thus be discarded. Certain African countries make the anti-bodies from horse blood, but this may cause an allergic reaction in the patient. Some religions are against using blood-based products at all.

The CSIR scientists worked closely with the World Health Organization, and other partners like Kentucky BioProcessing and MAPP Biopharmaceuticals, to address these challenges. Since it was already known which antibodies worked against rabies, their genetic codes were engineered into *Nicotiana benthamiana* plants, a cousin of the commercial cigarette tobacco plant *Nicotiana tabacum*.

The research group's first attempts produced just below ten milligrams of antibody per kilogram of leaves. Now, after some clever genetic tweaking, they have increased the yield substantially.

GreenPharm is currently seeking funds to complete pre-clinical trials. The trials will test whether Rabivir is safe for healthy humans. The antibodies will also be further tested against rabies strains specific to Africa and Asia.

Potential partners include companies which currently only manufacture the vaccine component of the PEP.

Chakauya and his fellow inventors, Dr Rachel Chikwamba and Dr Tsepo Tsekoa, hope Rabivir will be on African and Asian markets within five to 10 years.

A steep curve to the top

"There's a lot of learning that came out of this," he says, referring to lessons in drug research and development from the CSIR's more experienced international partners.

Chakauya also highlighted the important role of funding from the Technology Innovation Agency.

Now, GreenPharm not only has a potential commercial product, it also has the tools and skills to create other drugs and vaccines using the same genetic engineering techniques. For GreenPharm, Rabivir is just the beginning.

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Five reasons why Rabivir is perfect for treating dog-bite victims in developing countries

1. Poorer countries have more stray dogs vulnerable to rabies
2. Not enough human-donated blood is available to make human antibodies
3. Antibodies from horse blood used in some African countries can cause allergic reactions
4. Some religions reject the use of blood-based products
5. At R200, Rabivir treatment will cost about 10 times less than current treatments.

Better primary health care services for pregnant women through Umbiflow

Technology that empowers nursing sisters, midwives and general practitioners (GPs) in mobile, rural and low-resource primary health care settings

CSIR RESEARCHERS, together with their counterparts at the Medical Research Council, have developed a low-cost Doppler ultrasound device that aims to place Doppler technology at the primary health care level. It is a simple yet effective device that can assess foetuses considered to be 'small for gestational age' (SGA) at the primary point of care, thereby greatly reducing the cases of mothers being referred with healthy-SGA foetuses.

Umbiflow, as the device is called, speaks directly to the Millennium Development Goals (4 & 5) around mother and child care. It also addresses three of the four priorities of the South African National Department of Health, namely, increasing life expectancy, decreasing mother and child mortality and strengthening the health system effectiveness.

"At present, we are working to establish Umbiflow's effectiveness in a clinic environment, following which we are looking to roll out the systems to the primary health care sector," says the CSIR's Jeremy Wallis, who heads up the team that developed the technology.

The CSIR is seeking to partner with NGOs or potential licensees that will assist with the distribution, marketing and sales of Umbiflow.

Filling a gap

Foetal size is used as a simple metric to assess the health of a growing foetus during pregnancy and concerns are raised whenever a foetus is considered to be below the growth curve. Such foetuses are termed 'small for gestational age' or SGA.

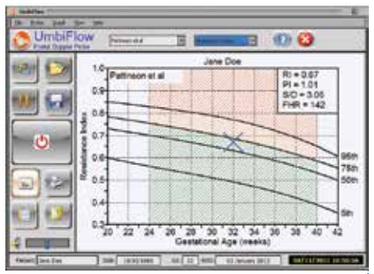
The current reality at the primary health care level is that foetuses are assessed regularly for SGA status using a tape measure measurement of the fundal height (measured from the pubic bone to the top of the uterus). This technique is able to correctly identify SGA foetuses (typically 10 in every 100 cases) but is unable to assess if the baby is "healthy-SGA" or "sick-SGA", the latter often being consistent with placental insufficiency. A condition of placental insufficiency implies that the placenta is not able to provide sufficient blood flow to maintain the foetus on the standard growth curve and hence an intervention such as an early Caesarean section may be indicated in order to save its life.

All SGA foetuses are referred to the secondary level of health care for a Doppler ultrasound measurement by a specialist. Up to nine out of 10 referred patients are found to have healthy-SGA foetuses and are referred back to the primary level for continued (standard) antenatal care.

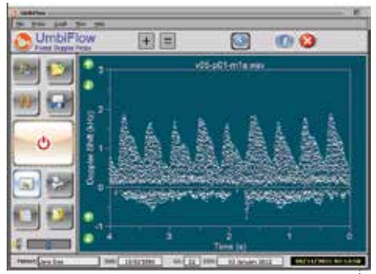
"With a hospital like Tygerberg in Cape Town currently doing 4500 such Doppler measurements per year, there is room for significantly reducing this figure for those cases linked specifically to the SGA condition," says Wallis.

The plan is therefore to implement the Umbiflow technology which will permit such Doppler measurements to be done at the primary health care level by nursing sisters and midwives, without the need for a specialist to operate the equipment.

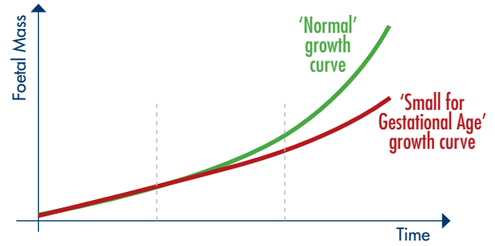
Jeremy Wallis manages the CSIR's research in sensor science and technology.



A screen grab from the current Umbiflow system showing the image that provides the operator (typically a nursing sister or midwife) with diagnostic support. Foetuses that fall within the red zone will be referred to secondary health care providers.



A screen grab from the current Umbiflow system showing a typical Doppler ultrasound image of the blood flow through the umbilical artery.



Foetal size is used as a simple metric to assess the health of the growing foetus during pregnancy. Concerns are raised whenever a foetus is considered to be below the growth curve, as per this figure. Such foetuses are termed "small for gestational age" or SGA.

The infant mortality rate of a country is often used as a metric of that nation's health care status. It is defined as the number of infants under the age of one who die per 1 000 live births. South Africa's Infant Mortality Rate places it 164th out of 220 countries.

How Umbiflow can help

Umbiflow aims to reduce the number of pregnant women who are referred to the secondary level for a Doppler ultrasound test to assess placental sufficiency as a result of having a SGA foetus. This will reduce the costs associated with Doppler measurements at the secondary level through the greatly reduced patient load.

Through improved access to the Doppler measurement, Umbiflow can reduce the perinatal mortality rate. Literature suggests the mortality rate of sick-SGA foetuses can be reduced by, on average, 38% compared to a health care system that does not have access to Doppler ultrasound.

"Umbiflow will also reduce the cost, inconvenience and emotional burden to pregnant women by avoiding referrals. Such referrals generally means that they need to book days off from work, arrange for costly transport and spend long waiting times in queues, all the while worrying about the health of their unborn babies," says Wallis.

Through connectivity, Umbiflow will furthermore be able to provide accurate and up to date statistics on the medical conditions being assessed at the point-of-care (primary level), and on the quality of data measurements being done by staff at this level.

The effectiveness of the Doppler measurement has been shown at the secondary level to have considerable benefits, including reduced numbers of hospital admissions (e.g. by 44%), reduced numbers of induced labour (e.g. 20%) and reduced numbers of caesarean sections for foetal distress (e.g. 52%). This is according to studies published in the American Journal of Obstetrics and Gynaecology.

"Umbiflow's introduction at the primary level will see reduced referral numbers between the primary and secondary levels and, if implemented at secondary level facilities that do not currently have access to the Doppler measurement, could have the additionally mentioned impact," says Wallis.

A cost-effective, easy-to-use system

The Umbiflow system uses Doppler ultrasound to measure blood flow in the umbilical artery of a third trimester foetus as a means to assessing placental sufficiency or insufficiency.

Wallis explains that, in South Africa, an umbilical blood flow measurement is only available in the secondary level of health care and above, as it requires a specialist to operate the conventional equipment.

"Cost is also a prohibiting factor. At the time development for Umbiflow started, stand-alone Doppler ultrasound units for umbilical blood flow analysis were available at more than R200 000 each. High-end ultrasound imaging systems, requiring a higher level of training, cost around R1,5 million. Prices for these devices have since dropped, but they are still not employed in the primary health care sector, with cost being a significant factor," he says.

Umbiflow is a PC-based or hand-held / tablet based system with an ultrasonic transducer. It displays data on a screen and provides diagnostic support, which means operators require very little training.

"Other than the probe, the system uses a commercially available PC or tablet as display and processing device for the Umbiflow software to run on. This reduces time to market and development costs," says Wallis. "This truly is technology that can empower every nursing sister, midwife or rural GP based in mobile clinics or resource-poor primary health care settings. It has the potential for great impact in our health care system."

Up to nine out of 10 pregnant women referred to secondary care can be referred back. Umbiflow aims to reduce this number.

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The Umbiflow system is being tested by a registered nurse and midwife, on a patient at Tygerberg provincial hospital in Cape Town.

Using biological expression systems to manufacture therapeutic peptides

A proprietary biological expression system to manufacture therapeutic peptides is one of the latest CSIR inventions in life sciences. These peptides are generally manufactured by pharmaceutical companies through chemical synthesis and this route can be complex, costly and inefficient. Globally, the use of biological expression systems is finding favour as a low-cost, environmentally friendly alternative to traditional chemical processes. The HaloBiologix™ technology is being further developed at the CSIR and incubated as a potential new start-up venture.

HALOBIOLOGIX™ is the brand name given to a grouping of technologies used for the production of pharmaceutically relevant peptides and proteins. The name was derived from the development of a proprietary expression host, *Bacillus halodurans* Alk36, as a potential expression system for the production of therapeutic peptides.

The proprietary *Bacillus halodurans* Alk36 strain of bacteria was found to produce flagellin protein at high levels. The flagellin protein is the main building block of flagella, a surface-exposed appendage, used for motility. The ability to produce large numbers of flagella (and flagellin) was utilised to develop a surface display system. Surface display technologies are used in applications such as biosensors, vaccines, nanotechnology, biosorbants, and whole cell biocatalysis. Furthermore, through genetic inactivation of genes on the chromosome involved in the production of flagella, the flagellin secretion pathway, also known as the type III secretion system, was genetically engineered to successfully secrete recombinant therapeutic peptides into the supernatant.

Dr Michael Crampton, a senior researcher at the CSIR says: "Currently, therapeutic peptides are produced using chemical synthesis procedures. This process is expensive and results in the production of large quantities of toxic waste. The number of steps required for the synthesis of larger peptides (>35 amino acids) is also excessive and adds to the high cost of production. Through the use of the CSIR-patented expression technologies, we hope to produce such peptides at a much lower cost. This will result in drugs being made available to lower income patients, especially in Africa.

"South Africa's entire active pharmaceutical ingredient (API) requirements for the anti-retroviral treatment programmes are imported, mainly from India and China, but also from other countries. We cannot continue to rely on other countries to supply products for which we require a high level of quality and security of supply for the antiretroviral treatment programme. Secondly, the pharmaceutical sector has for good reason been identified as one of four lead sectors which could be used to diversify South Africa's industry (away from its predominantly resource-based nature) and to address a worsening trade balance problem (present trade imbalance for the pharmaceutical sector alone is R11.8 billion)," says Crampton.

In further genetic modifications of the *Bacillus* strain involving the inactivation of five protease genes, protein secretion was enhanced, giving rise to peptide concentrations in the range of mg/L as opposed to the previous µg/L. Actual concentrations vary depending on the nature of the peptide. The peptides are secreted into the medium as protein fusions with built-in cleavage sites and affinity tags, thereby facilitating purification. The cleavage sites are amino acid sequences which are recognised by specific proteases and allow for the separation of the carrier protein from the therapeutic peptide of interest. The affinity tag is also a specific amino acid sequence, six histidine amino acids, and facilitates the binding of the produced protein to a metal based affinity resin for purification (IMAC, immobilised metal ion affinity chromatography). Peptides of up to 80 amino acids and small proteins have been secreted in this way without the need for expensive inducer chemicals.

In 2009, the Cape Biotech Trust (now Technology Innovation Agency) invested in the development of the expression system. The CSIR agreed to incubate the HaloBiologix™ technology with a view to spinning it out as a new start-up venture to commercialise the biological route to recombinant peptide production. In doing this, the CSIR team is collaborating with the chemical engineering department of the University of Cape Town and the Technical University of Berlin.

"Recently, government has called for the rapid implementation of sectorial strategies and for leveraging of the state's pharmaceutical procurement programme in order to stimulate the local production of APIs. Finally, new ARV drugs, such as Enfuvirtide, that are highly effective, are also very costly and as such will forever be out of reach of African patients unless alternative, cost-effective manufacturing methods are found that will lower the cost of production," adds Crampton.

Evaluating the proprietary HaloBiologix™ technology has resulted in the successful expression of antigenic peptides (useful for vaccine development), anti-microbial peptides (useful as a topical antibiotic) and anti-viral pre-curser peptides (useful in antiretroviral therapy). Many of these peptides need post-translational modifications such as amidation and/or acetylation to improve efficiency. Chemical and biological approaches to address this are being evaluated and developed.

In addition to the biological production of peptides, a number of alternative applications for the technology are being explored. These include vaccine development for both veterinary and human applications; surface display of peptides for applications in metal binding; biocatalysis, biosensors and synthetic biology applications in artificial scaffolding development and nanotechnology.

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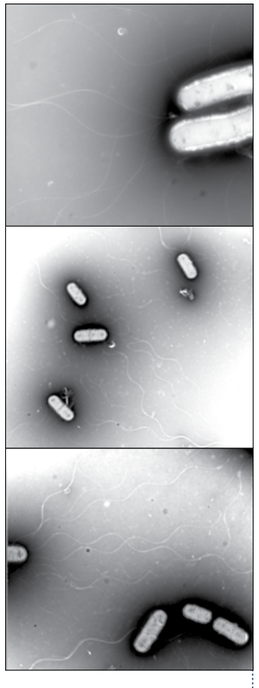
Dr Michael Crampton purifying chimeric flagellin from the recombinant soil isolate, *B. holadurans* BhFL05S, harbouring the optimised flagellin expression vector.



Transmission electron micrographs of *Bacillus halodurans* Alk36 demonstrating the abundance of flagella on the cell surface.

Challenging the tradition of 2D cell culturing

Cells are cultured in laboratories around the world every day. They are typically used in a large number of applications, including screening of new drug-leads, cytotoxicity testing of new biomaterials or chemicals, cancer research, stem cell research, tissue engineering, gene therapy, and for the production of cell culture products such as vaccines, hormones, enzymes, antibodies, and other therapeutics. Can it be done reliably in 3D, on a large scale, with minimal damage to harvested cells?

Avashnee Chetty and Claire Rossouw both completed their PhDs on 3D culturing of cells.

CULTURING CELLS in a laboratory is conventionally done using a two-dimensional (2D) cell culture tray. It has some pitfalls though. It is highly labour-intensive and does not replicate the complexity of the three-dimensional (3D) environment of natural tissues.

"Cells grown on 2D surfaces tend to lose their native characteristics and display vast differences to their in vivo counterparts. The methods used to remove these cells from the surface that they have grown on are also damaging to the cells," explains Avashnee Chetty, who heads up the CSIR's team developing an automated cell culturing system.

From 2D to 3D

Chetty says that the need existed to develop a system for culturing cells that would allow them to grow in 3D, as they would do in their natural environment, without too much human intervention. This would reduce the chances of contaminating the cells. The system also needed to spontaneously release the cells from the surface they have grown on without damaging them. This was achieved through the CSIR's cell culturing bioreactor, a cost-effective bench-top system that allows for non-invasive, high-density, 3D culture of adherent cells.

Chetty describes the bioreactor: "It is a small cylindrical glass vessel housed in a stainless steel casing, which is perfused with oxygenated media with a peristaltic pump allowing sufficient oxygen and nutrient delivery to the cells. It contains stacked scaffolds – highly porous 3D non-woven matrices onto which the cells are seeded and where they grow."

Non-destructive cell harvesting mechanism

The scaffolds are made from a 3D, highly porous, non-woven material that was manufactured at the CSIR's facilities in Port Elizabeth. The non-woven material has been treated with a thermoresponsive polymer. The polymer changes from a hydrophilic (water-loving) to a hydrophobic state depending on the temperature. At temperatures above 32°C, cells happily attach to the polymer-covered scaffolds and grow in 3D into all the spaces of the porous scaffold. If the temperature is lowered to around 20°C, the polymer that they have attached to, changes its state and releases the cells in clusters from the scaffolds without damaging it.

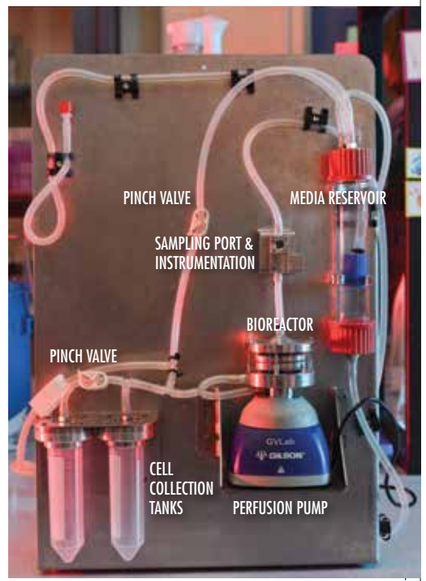
"What is important is that the bioreactor delivers large numbers of 3D cell clusters by simply cooling the culture media, and without damaging the cell membrane," says Chetty. "These cells also have enhanced metabolic activity and gene expression, which we have demonstrated in our labs and would be far more valuable for use in, for example, drug screening," says CSIR candidate researcher, Claire Rossouw.

Proven technology

A perfused bioreactor system containing a 3D thermoresponsive scaffold allowing for high-density, non-invasive culture of adherent cells does not exist anywhere in the world. The novelty of the CSIR's system is the combination of three key components into one device, that is, the thermo-responsive cell release mechanism, the use of a 3D scaffold, and a perfused bioreactor.

The CSIR's cell culturing bioreactor has been tested using mammalian hepatocyte cells (liver cells). It has demonstrated that cells attach and grow on the scaffold, easily yielding high-density cultures (approximately 45 million cells were achieved after 14 days of continuous culture with 10 times increase in cell number).

Says Chetty: "We have also proven the bioreactor's ability to release the cells spontaneously without requiring enzymes, and we have shown that even after 21 days of continuous culture, the cells remain healthy and viable."



The bench-top thermoresponsive 3D cell culture device, containing a media reservoir, a pump for perfusing media, a bioreactor containing the scaffolds, and a collection unit for released cells.

Patent filed

The CSIR's cell culture system received a positive International Preliminary Report on Patentability from the EPO (European Patent Office), and is patented in South Africa (2010/02052), with a patent application pending in the USA (12,678,450).

"With respect to bioreactors and automated systems, there are several types commercially available. However, destructive cell release methods are often still used to release confluent cells. The CSIR's cell culturing bioreactor combines the advantages of the use of a 3D scaffold, the thermoresponsive polymer and a perfused bioreactor to provide a superior system for cell culture which currently is not available," explains Chetty.

Work to be done

According to Chetty, the CSIR hopes to sell the cell culturing bioreactor in its final form as an automated cell culture system.

"We can develop the bioreactor further so that it becomes an automated cell culture system. To get it to this final form, we would need to optimise the system for high-density cell culture and optimal cell release, and automate it. This will include incorporating a programmable logic control system to automate the manual steps, as well as a user interface."

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From raw plant material (right front) to extracts (centre) to product formulations such as capsules and scalp serum. Dashnie Naidoo has closely managed the scientific research and development for this product to retard hair loss.

Harnessing the power of nature for better health

Knowledge of the healing powers of South Africa's abundant flora has been passed down through generations of traditional health care practitioners for centuries. Although few products derived from these botanical specimens are registered treatments, there is a definite place for them on retail shelves stocking complementary medicines and cosmetic preparations. To bring more of these products to market, the CSIR has entered into a partnership with Afriplex, a leading manufacturer of botanicals for the complementary health, cosmetics and food markets.

WITH THE SLOGAN 'From source to shelf', Afriplex produces more than 5 million pharmaceutical units a year to serve the demand for wellness products. Using raw materials harvested from sustainable sources, and then transforming these into innovative, client-specific products.

The CSIR-Afriplex partnership aims to see three new botanical preparations being launched in South Africa and, ultimately, internationally. It taps into plants that hold the promise of efficacy and the potential for commercialisation, and is seeking solutions for the management of colds, flus and allergies; male pattern baldness and hair loss; and sexual dysfunction.

The CSIR has a long history of working with traditional health practitioners, tapping into South Africa's rich biodiversity of more than 24 000 plants to identify candidates for development into commercial preparations. With more than 200 000 such healers – catering for about 70% of the population – the knowledge base is immense.

Frontrunner for the market is BP5, an active ingredient from a South African indigenous plant for managing hair loss. The plant is traditionally used for a wide range of ailments, including diarrhoea, stomach disorders and haemorrhoids.

During the BP5 research cycle, the CSIR produced plant extracts in the specialised botanical and clinical supplies facility, from which formulations such as topical creams were developed. The extracts and compounds were shown to have significant activity against the enzyme steroid 5-alpha reductase. This enzyme – which converts testosterone to dihydrotestosterone – is seen as a causative factor in the progression of prostatic hyperplasia and male pattern baldness. Current commercial treatment of these indications is based on the inhibition of this enzyme.

The extract also showed potent anti-oxidant activity – greater than that of green tea extract – when tested in several comparable anti-oxidant assays.

The clinical study to confirm product efficacy involved more than 40 individuals and spanned three months. Results have been extremely encouraging and point to a successful product launch within the next two years, says the CSIR's Dr Dashnie Naidoo, cosmetics business area leader. "Our partnership with Afriplex will come to the fore now, with that company's vast knowledge and understanding of registration processes, supply chain management and market sectors."

BP5, with its capacity to retard hair loss and its anti-oxidant properties, is well positioned for the cosmetics market and Afriplex is currently finalising the development programme for marketing and distribution.

Before the product is launched, the CSIR will meet with stakeholders, including the traditional health practitioners and communities from which the raw material will be sourced, to agree on a benefit-sharing model involving financial support and non-monetary benefits such as expanding cultivation, which will create jobs and provide skills development opportunities.

In the months to come, the CSIR, with Afriplex, will evaluate thoroughly the commercial feasibility of BP5 for other applications, assessing the cost of manufacturing and performing clinical evaluations of selected formulations.

In the meantime, work is advancing well on the second product of the Afriplex agreement. BP4 has as its principal component *Siphonochilus aethiopicus*, or African ginger, a traditional treatment for mild asthma, colds, influenza and sinus problems. With only anecdotal information on the plant's effectiveness, the CSIR demonstrated that extracts from the plant significantly suppressed the increase of inflammatory cells in bronchoalveolar lavage fluid when measured in an in vivo anti-asthmatic ovalbumin-sensitised mice assay.

BP4 has reached the stage of industrial manufacturing that precedes preparations for commercialisation. The CSIR is currently sourcing funds for clinical trials on the product.

Depending on availability of finance, the formulation could go to market within two years, says Dr Vinesh Maharaj, CSIR manager of the natural products technology platform.

Work on the final product, to manage sexual dysfunction, is at an early stage, with the development of a manufacturing process.

The road to market is not always short or direct, says Maharaj, with anything from five years for an improvement to an established formulation, to 10 years for the development of a novel ingredient. "Research into hoodia started in the 1960s and it was licensed only in 1998," he says. "Still, after further investment by licensees of close to half a billion Rand, we do not have the ideal product."

The collaboration between the CSIR and Afriplex is important from an import replacement perspective. He adds, "By adding value to the country's natural remedies and applying local know-how and technology, South Africa can produce and register high-quality herbal medicines instead of buying them, while creating formulations that can compete very favourably on international markets."

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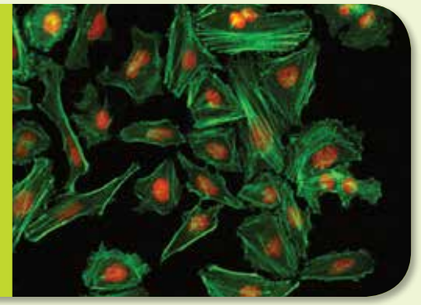
Low-cost technology for mass production of arrayed miniaturised experiments



Actin stained cells – We are built of billions of cells, just like these shown in the image above. These are human cells that can be grown and looked at to understand the mechanisms of disease. In this case, the cells have been stained so as to see the cell interior skeleton (green) and the DNA packed into the nucleus (red). Each one of these cells is around 10-millionth of a metre across, and advances in Persomics technology and high throughput imaging makes it possible to look at thousands of experiments per hour to find genes and drugs that can be used to treat illness.

Life is complex. Tens of thousands of genes form the blueprint for every human cell, and 200 cell types form the thousand billion cells that make up a human being. Life's complexity is the reason why the CSIR has developed technology to investigate cells themselves, faster than ever previously possible.

RESEARCHERS AND PHARMACEUTICAL COMPANIES are interested in knowing how cells work, how they interact and how pathogens interact with them. These interactions form the basis of most diseases afflicting society. If they can be understood and ultimately treated, then our quality of life will improve. But this is challenging – any one of thousands of human genes can fail and cause disease, yet a pathogen can find its way into cells using only a handful of genes. This article describes new miniaturised technology to confront this challenge and that is being spun out from the CSIR.

Complexity comes at a price. Having 20 000 genes to study means many times the number of genes in experiments. This means that human beings can no longer do all these experiments. Biologists have adopted automation technology and robotics from the pharmaceutical industry to do all these experiments and now large industrial and academic centres worldwide are performing these screens, looking to find new understanding and new drugs.

The current technology is powerful, but that comes with the corollary of how long a single screening experiment takes. Even with robotics, automation and a team of scientists, one screening experiment takes from four to six weeks of full-time work. Screening is also limited to a handful of research centres – mostly in the developed world – and requires a complex, fixed infrastructure. This makes the technology limited in application and technologically demanding. Given how hard this is, our approach is to miniaturise it all and fit thousands of experiments into a handheld device.

Miniaturisation permeates our lives – we all understand the benefits. Miniaturisation of devices dates to the invention of the pocket watch in the 16th century by Peter Heinlein.

While driven by necessity, miniaturisation's greater impact came with mass production. Large-scale production gave us lots of relatively inexpensive devices – such as the pocket calculator. The twin impact of miniaturisation and mass production impacts all aspects of modern life, business and research.

The CSIR's high throughput biology group, under leadership of Dr Neil Emans, has developed new technology that miniaturises experiments and makes the task of finding new cures easier. This technology is incorporated in Persomics, a new technology start-up company.

Persomics technology works through array printing technology, which prints thousands of experiments onto a device. Each experiment is tiny – the width of a pencil tip – and yet each one is one of thousands of experiments, and these are enough to use to screen how cells work and understand how disease progresses. Screening thousands of experiments with cells this way is at least a hundred fold faster than previous technology and can be mass produced for the first time.

Fanie Marais, CSIR commercialisation manager in the biosciences domain, says: "This novel technology enables the printing of an entire array of experiments at the same time, reducing the time and cost of cell-based screening through miniaturisation, literally creating a mass production pipeline."

Mass miniaturisation

Miniaturisation is used to shrink gene silencing experiments from the macroscale to the miniature. Each experiment is printed onto a glass wafer, as a spot of gene-silencing chemistry only 300 millionths of a metre wide. A single printed experiment recapitulates all the features of a macro-experiment. The partner technology used focuses on scaling this up – producing thousands of these experiments printed as arrays on a glass wafer.

Life sciences and medicine are moving towards large-scale biology, high-content, cell-based screening. Miniaturised, commoditised screening tools access this space without the need for complex robotics on a wider customer base.

"The technology provides the means to bring libraries and experiments from plates to an imaging-ready microtiter plate packed with 3 000 experiments for clients. Clients will get these ready for screening and at an industrial scale of thousands," says Marais.

The currently available solutions involve high-throughput, plate-based screening of large-scale installations, producing screening at a high cost with limited access and impact. It also involves the use of arrayed screens with no commercial solution; has a labour-intensive set-up; and is miniaturised, but not scaled to market or personalised medicine needs.

"The fact that we are able to produce these devices provides us with an opportunity to further investigate diseases to better understand how infection proceeds and how exactly it can be cured," concludes Marais.

Creating new markets

The human genome is at the leading edge of modern life sciences, enabled by genome-scaled experiments. But the size of the human genome is a bottleneck, slowing the introduction of screening which creates an opportunity for making array screening technology available to the market. It is believed that miniaturisation, and mass production of Omic devices will create new markets in research and health care.

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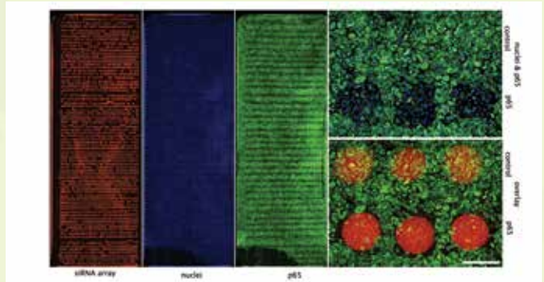
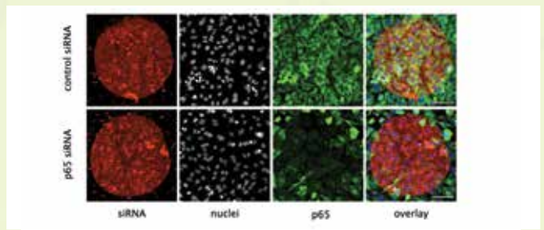
The technology was developed and patented by the CSIR. A spin-out company, Persomics, is being formed to make the technology available commercially. Persomics offers its clients the ability to convert their libraries into miniaturised arrays and produce them in a ready-to-go plate as a commodity. Its product portfolio offers miniaturisation and mass production of personalised arrays across all Omic domains. For more information, visit www.persomics.com.



Persomics array figure – There are thousands of genes and millions of potential drugs to treat disease. Persomics miniaturises experiments into arrays of tiny spots of chemistry on a glass chip. Many thousands of these experiments can be seen as red dots on the left panel (siRNA array). Small RNA molecules have been delivered into human cells; these siRNAs silence genes, stopping them from making any of the protein they code for within 48 hours. Each red spot contains one of these siRNAs and the thousands of spots on the array enable thousands of genes to be turned off in cells. The way this works, cells on the siRNA array are grown; siRNA enters the cells and stops production of a protein. If that protein is involved in a disease, it is found by image analysis of cells on every spot on the array.

The right panel shows human cells growing on 6 siRNA spots, where the production of a gene called p65 are detected. The more p65 there is in the cells, the greener they are. The bottom three spots contain a siRNA-silencing p65 – and unlike in the upper spots – the gene is turned off and the cells go dark.



Silencing the genome, by silencing the genes – The panels show the p65 gene being silenced in cells using a p65 siRNA (lower panel) and no effect in a control (upper panel). Persomics technology miniaturises and commoditises screening for the first time, enabling industry and researchers to screen for new therapies faster than ever before.

An innovative way of delivering broadband to rural South Africa

Using wireless mesh networks, the CSIR has devised an innovative way of delivering broadband to rural communities in South Africa with partnership potential for social entrepreneurs.

BB4All initiative progress to date

Nkangala and Sekhukhune network

- Wireless mesh network with 16 village operators and 200 schools connected
- Backbone to CSIR linked on to SANReN
- Test-bed for further research and development
- Operations with call centre implemented.

John Taolo Gaetsewe wireless mesh network

- Detailed plans for connecting 59 schools using wireless mesh network in the Northern Cape
- Funding from DST to build network (backbone and mesh) in the Northern Cape
- Grant from Sishen Iron Ore Company to construct 12 m towers at 25 schools for each of the 59 schools to 'see' at least two other schools in the mesh network
- Commitment from the Northern Cape Education Department to fund school connectivity.

Neil Oosthuizen, field operations manager for the BB4All project and Timothy Segopolo, the village operator for the Marapong cluster in the Sekhukhune District Municipality of Limpopo discuss the installation of the high-performance node which links the village operator office with the other sites (schools and nutritional units of the Ndlovu care group) in the cluster.

Learners of the Zenzeleni Primary School (the gateway school for this cluster) in KwaMhlanga in the Nkangala District Municipality of Mpumalanga during a computer literacy class using the BB4All broadband wireless mesh network to access the Internet.

Village operator Timothy Segopolo checks up on a network monitoring tool for his cluster. Segopolo purchased the land and built suitable offices using his own funds.

Nombulelo Molumaela (left), village operator for the Vezubuhle cluster in Nkangala, Mpumalanga, with an employee tasked with overseeing the office when Molumaela is away visiting the schools in her cluster.

THE INTERNET has come to represent societal connections, co-creation, knowledge sharing, a gateway to new markets and ultimately a new economy. It has the same impact on society as the railway, post office and telecommunications networks of days long gone by; such that those not connected are left behind in what is now termed the knowledge economy.

Take South Africa for instance; it has approximately 26 500 primary and secondary schools, of which at least 17 000 are in remote rural villages, according to a research paper by CSIR researchers Kobus Roux and Mario Marais. None of these rural schools have any form of Internet connectivity, the paper states. The same rural villages may have one health facility for every 20 schools and very few other public or community service centres.

Intervening to bridge the digital divide

If all of those in remote villages and on the rural-urban fringe could have affordable access to broadband, they could have access to the wealth of knowledge and information that abounds on the Internet as well as the potential to link up to health facilities and to share know-how. Thus, broadband access could aid in alleviating some of the challenges in terms of educating and developing an informed, knowledgeable and healthy citizenry. A digital divide is caused by the fact that building large scale networks in these remote areas is not economically viable. Without intervention, the digital divide will continue to polarise South African society into those that are connected and those not connected.

This is one of the main drivers behind the CSIR's Broadband for all (BB4All) initiative, which is funded by the European Union through the Sector Budget Support programme of South Africa's Department of Science and Technology. The initiative aims to build low-cost infrastructure to ultimately bridge this digital divide. At the heart of the initiative is the Wireless Mesh Network project, a collaborative project started in 2009. This project is based on using wireless mesh communication, a way of communicating information using unconventional methods.

Making it work

The CSIR, in collaboration with non-governmental organisations, government and industry, has deployed a novel ecosystem using wireless mesh networks for delivering broadband infrastructure in under-served areas. Instead of the traditional point-to-multi-point communication, it is based on peer-to-peer communication between network nodes. The CSIR makes use of high performance nodes to establish peer-to-peer communication within the network. Imagine a community with these nodes installed at certain points. If a person in one house wishes to relay a message to a person in another house that is not adjacent nor close to it, the message will go through other nodes between the two houses until it reaches its destination. So-called village operators, young local entrepreneurs with a keen interest in information and communications technology and who want to be self-employed, are then trained to provide support and manage the BB4All network. These operators are the key success factor in the BB4All initiative. They are sourced from the targeted communities to service their own communities.

An opportunity for partnerships

An opportunity exists for partners to take the BB4All initiative to other regions of the country and the CSIR is currently engaged in talks with some potential partners. Partner opportunities exist in the design and development of the wireless mesh technology as well as the design of wireless mesh network infrastructure; the installation, support and maintenance of the networks and measuring and monitoring performance of such networks. Non-governmental organisations and social entrepreneurs are also welcome to contact the CSIR.

– Bandile Sikwane

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Preventing derailments caused by broken rails

CSIR research conducted in the domain of guided wave ultrasound has supported the development of an Ultrasonic Broken Rail Detector (UBRD) system that reliably detects rail breaks on heavy-duty continuously welded railway lines, preventing derailments that are estimated to cost over R50 million per incident.

Operating concept and initial development

The concept of rail integrity monitoring by using long-range ultrasound was selected by Transnet Freight Rail to address the problem of the country's ageing railway infrastructure, where breaks in continuously welded rails can cause derailments to occur, at an enormous cost to the economy. The Institute for Maritime Technology (IMT) was contracted to develop the system and the CSIR was subcontracted to develop the ultrasonic transducers.

The operation of the system is based on the concept of ultrasonic waves that are transmitted along the rail between a transmitter and a receiver that are placed alternately along the length of the rail. If the required ultrasound signals are not received, an alarm is activated to indicate that there is a broken rail. This means that the entire length of rail can be monitored remotely and continuously, and it also allows the railway operator to know in which section of the rail the break has occurred. This system is a world-first for monitoring tracks and detecting rail breaks. It is designed to operate with solar power; is not maintenance intensive; is easy to install; and does not interfere with train operation.

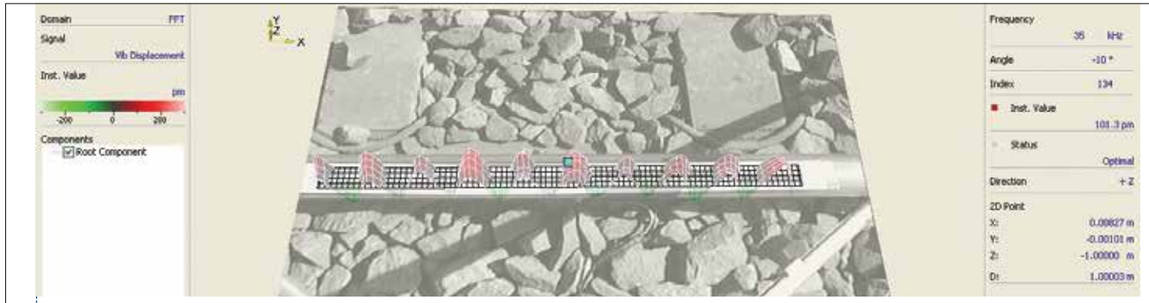
The initial development of an ultrasonic transducer to detect broken rails was led by the CSIR's Dr Philip Loveday in the late 1990s. Loveday is a technical expert in piezoelectric actuators and transducers in the CSIR's sensor science and technology area. In addition to the design of patented high-displacement piezoelectric actuators and ultrasonic transducers for the integrity monitoring of railway tracks, he has also conducted research on vibratory gyroscope dynamics and control, the analysis and design of sonar transducers and the optimisation of piezoelectric actuators for smart applications.

Over the years numerous improvements to the transducers and the system have been made to achieve reliable operation without false alarms. Extensive field qualification has been performed by IMT to meet Transnet's requirements. The broken rail detector system is currently installed on sections of Transnet's heavy-duty iron ore Orex line (860 km of track between Sishen and Saldanha Bay) and sections of their coal line (460 km of double track from Ermelo to Richards Bay). During 2010 alone, it prevented two definite derailments, saving the economy an estimated R100 million. A contract has been awarded to install the system on another 800 km of the Orex line.

Improving the system through research and development

After the initial development of the system, a number of questions remained around the physical operation of the system and the possibility of improved operation either in terms of distance between transmit and receive stations or detection of cracks before complete breakage without false alarms.

A capability in guided wave ultrasound was established at the CSIR through strategic research projects led by Loveday. These projects developed original numerical modelling techniques for simulating the transmission of elastic guided waves by piezoelectric transducers and measurement techniques based on scanning laser vibrometry.



Field measurement of ultrasonic waves travelling in the rail head at a distance of 500m from the transducer.

First generation (left) and second generation (right) rail transducers.

The insights obtained from field measurements and the modelling capability were used to develop a second generation ultrasonic transducer. A transducer has been demonstrated that is significantly smaller than the original version but can transmit and receive ultrasound over greater distances, thereby reducing the number of transducers required for the total length of the railway line. This makes the new version not only more cost-effective, but also easily adaptable to operate on a variety of rail profiles, which are used internationally.

The CSIR is currently industrialising the new transducer and IMT is developing the next version of the system, which will exploit the new transducer along with modern signal processing techniques. These developments are being funded by the Department of Science and Technology. It is anticipated that this future system will achieve twice the distance of the current system.

The CSIR has started longer term research aimed at using the new transducers to detect and locate cracks in the rail head before complete breakage occurs.

Commercialisation of the innovation

The new-generation transducer is in the application stage of commercialisation, and a PCT patent application has been filed for the new transducer in the UBRD system.

The system has attracted a great deal of international interest thanks to the unique solution it offers for a problem that is experienced all over the world. It has already been tested in the New York City Subway, and is currently being tested at two sites in Japan.

According to Delon Mudaly, manager of intellectual property and technology transfer for materials science and manufacturing at the CSIR, the development of the new generation model is accompanied by business development and commercialisation planning. The commercialisation task team will need to investigate the best way of taking the device to market, which may be via a spin-off company or licensing to a going concern.

The scope of commercialisation will include the manufacture of the transducer devices, as well as the assembly of the system, the installation of the units and ongoing maintenance. "Although the current focus is on Transnet and the freight industry," says Mudaly, "the commercial feasibility of the device will need to speak to a broader market, which could even include high-speed passenger trains across the world."

Global market

To put the international market of the broken rail detection system into perspective, it can be assumed that more than 60% of all rail worldwide is suitable for the current system. This means that at least a total of 673 554 km is suitable. At a conservative estimate of 1.75 km per unit, the total global market is estimated to be more than 384 888 units. With the improved version, the system should also become applicable to the other 40% of the world's continuous welded railway lines, expanding the market by a further 450 000 km of rail.

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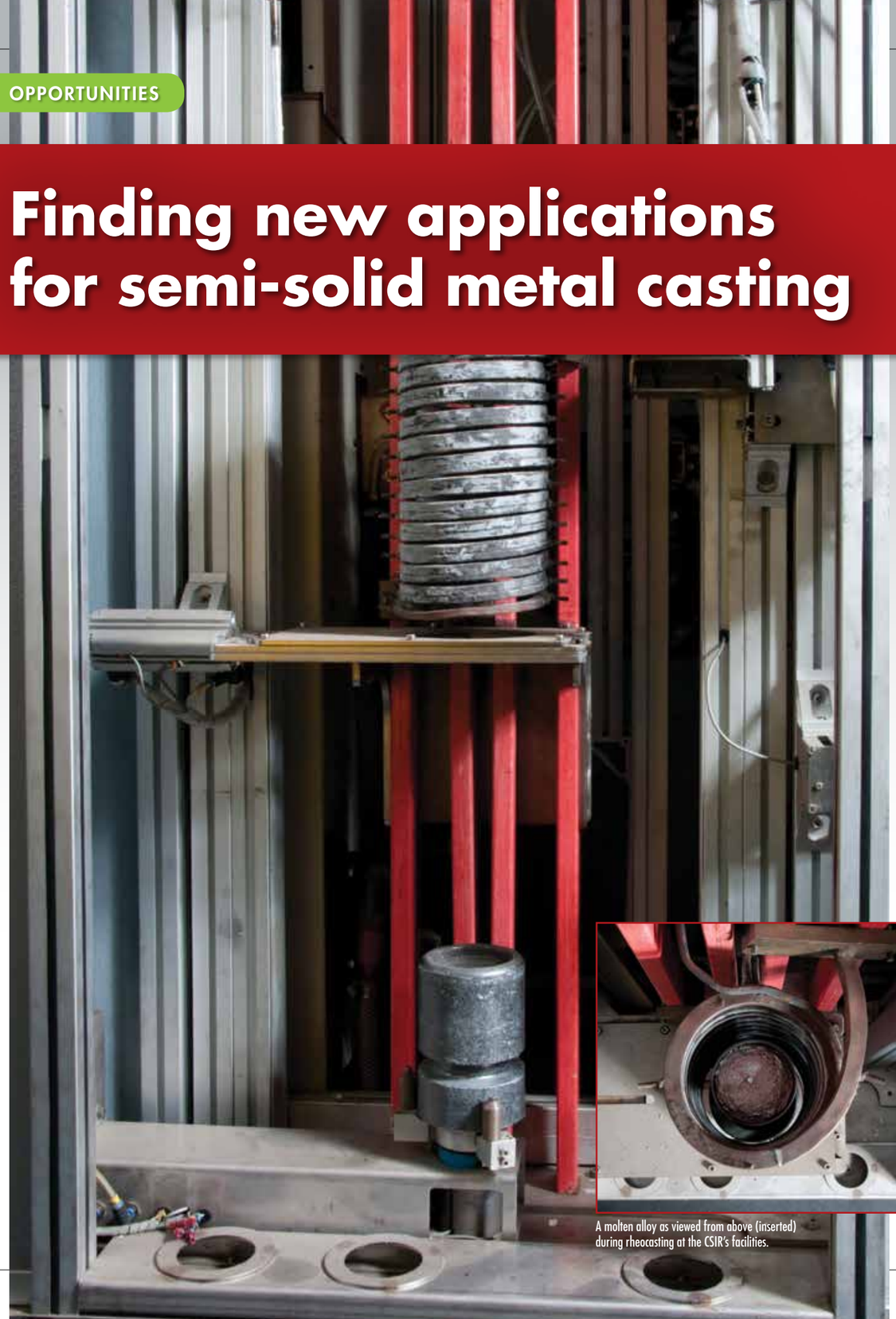
Finding new applications for semi-solid metal casting

Although the casting of semi-solid metal alloys was developed at the Massachusetts Institute of Technology (MIT) in the early 1970s, the challenge for the CSIR was to develop a technique that consistently produces high-quality products and can be used in cost-sensitive niche markets, such as the automotive industry.



A molten alloy as viewed from above (inserted) during rheocasting at the CSIR's facilities.

A part produced using semi-solid metal casting.

FOLLOWING RESEARCH conducted at the University of KwaZulu-Natal in the mid 1990s, the CSIR, in collaboration with its research partners, secured an Innovation Fund project to develop a rheocasting system in 2000. This resulted in the patented CSIR rheocasting system for the preparation of semi-solid slurries.

This process stems from a recent trend in the automotive industry to produce fuel-efficient vehicles through the use of aluminium and magnesium alloys. The bulk of the automotive industry's needs in this regard are satisfied through the use of liquid metal, high-pressure die casting (HPDC). The growing demand for improved quality and weight reduction is driving the development of new processing technologies. The problems inherently associated with liquid metal HPDC led to increased interest in semi-solid metal casting processes, which in turn led to the development of rheocasting.

There are two technologies that can produce metal slurries at a temperature at which semi-solid casting can take place, namely, thixocasting and rheocasting. Thixocasting is a two-step process, the main disadvantages being the higher cost of the process compared to conventional casting processes. Special feedstock material is purchased at a much higher cost and reheated to a semi-solid state – which is highly capital and energy-intensive – before being formed into a final component. The scrap material from the manufacturing process cannot be recycled on site and is sold as conventional scrap. With rheocasting, in contrast, the molten metal is cooled and cast into a solid shape in one step. The biggest advantage of this process is that the slurry can be made on demand and 'in-house'. The chemical composition of the cast metal can also be modified and tailored to meet the quality and property specifications of the components, and scrap and other used metal can be directly re-melted for subsequent rheocasting, which contributes to the lower production costs, and hence growing interest by industry.

The rheo-high pressure die casting (R-HPDC) technology developed by the CSIR, which incorporates its rheocasting system, is both flexible and capable of processing just about any alloy or metal with a melting temperature below 1000°C.

The current focus is on the commercialisation of the R-HPDC technology. In order to achieve this, an advanced research and testing laboratory has been established at the CSIR, comprising two HPDC machines: a research scale facility (130 tons) and an industrial scale facility (630 tons). Both machines have real-time shot control and monitoring capabilities, and will ensure that component research and testing can be done effectively before being tested on an industrial scale. It will also enable the research team to simulate industry conditions to cast components on an industrial scale.

Similar systems have been developed in other countries, using semi-solid metal and high-pressure die casting techniques, but by taking these devices to market before being thoroughly tested, high failure rates were experienced. According to Dr Sagren Govender, leader of the CSIR's advanced casting technologies group, it is essential that the manufacture of components using this process should be proven to be consistent and reliable, and should not produce more than 5-10% scrap metal, preferably less than 5%. Only then can it be taken to market.

Before commercialising the R-HPDC technology, it is essential to ensure that the process can provide high-quality components at a competitive price. Because the automotive industry is cost-driven and highly regulated, the focus of the research group is on demonstrating the technology on a product that is less regulated, and which can enter the market much sooner than would be the case with automotive components. Once its feasibility is proven in a less regulated market, e.g. the recreational market, it would be possible to expand the application of the technology to other market sectors.

"We are currently in the final stages of development and are entering the commercialisation phase," says Ulyate Curle, a senior metallurgical engineer and member of the research group. With the establishment of the industrial-scale facility at the CSIR, the patented rheocasting device can be tested on a commercial scale to optimise the process.

The research group has already identified several potential products on which to demonstrate the technology, which would enable them to cast components and put them onto a platform to prove that it works. The technology can be used to develop components for a number of end-users, from the aerospace industry to prosthetics. The aim is now to find a commercial partner for which a component can be produced using the R-HPDC technology. Discussions of this nature are currently underway with bicycle manufacturers.

Govender believes that the ideal route would be to incubate the technology within the CSIR and, once it is found to be financially sustainable, to develop it into an independent company or transfer the technology to a local casting company that is willing to adopt this technology. By setting up a central manufacturing facility, it would be possible to create jobs and produce components that can be marketed locally and internationally.

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Josias Nonyama of the CSIR installing an AziSA communication link in a deep gold mine.

CSIR develops a protocol for underground mine networks

A common communication technology protocol for South African mines

South African platinum and gold mines are a maze of noise, dust, and darkness and are generally hazardous. The conditions make it quite difficult for mine operation managers to know what exactly is happening in the environment as the mining face advances. They are often forced to react to internal environmental changes rather than be proactive.

Having a consolidated view of the environment could make mines safer, and more profitable as managers would plan better – having knowledge of what is happening or likely to happen. For mineworkers, communication is difficult as in most cases it is non-mediated verbal communication, meaning that they constantly have to shout over the noise to communicate instructions to each other. With all other dangerous factors added, this is a precarious state of affairs for mineworkers.

Much has been tried in a bid to improve communication and environmental analysis in mines. The problem is that because conditions vary greatly inside a mine, the equipment used may not work. Thus, you might find disparate systems being used in different environments within the same mine. These variations often lead to the systems not being interoperable or data rendered useless as they are too context specific. These are precisely the problems that the CSIR is trying to solve with AziSA.

AziSA (IsiZulu for 'make known') is not a product as such, but a series of protocols that facilitate data acquisition and underground control. The system serves as a backbone for standardised wireless sensor networks. It is an open protocol for connecting to sensors, getting measurements and controlling actuators. It is also a data communication system that uses already installed mine power cabling (power line carrier). It can support data mining tools by using computational intelligence to distil the input from a vast array of sensors into knowledge that can be mustered for real-time decision-making.

AziSA is designed to enable mining companies to have a dynamic, continuous risk assessment of potential dangers during mining operations. For example, it allows for early warning systems for potential rock-falls. With AziSA, mine operators will be able to easily quantify dust and noise levels, aiding in making decisions in the best interest of the health of workers. Ultimately, it will enable tighter operational control and aid in creating safer and healthier working conditions for miners.

In addition to the AziSA protocol, the CSIR has a number of reference designs available to allow equipment manufacturers to produce compliant equipment, and to convert their current equipment. Currently, the CSIR is in talks with potential commercialisation partners who are interested in distributing the standard, as well as aiding mine houses to customise and apply the standard in their environments.

– Bandile Sikwane

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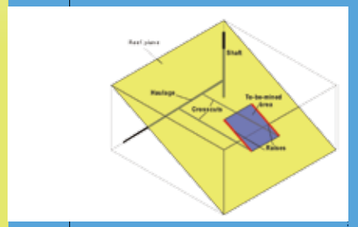
Home-grown borehole radar system

South Africa has its own system to delineate ore-body geometry.

Josias Nonyna, CSIR electronic engineering technologist, holding a receiver printed circuit board housed in a pipe-like probe.

A receiver of the borehole radar system which measures reflections from targets that are illuminated by the transmitter.



The geometry of a typical deep-level conventional gold or platinum mine.

IN DEEP-LEVEL South African gold and platinum mines, the standard way of mining is by developing footwall or hanging wall drives parallel to strike (the line formed by the intersection of a bed or vein with the horizontal plane). Cross-cuts are then developed perpendicular to strike until they intersect the reef. Mining then proceeds up the reef plane from level to level.

The geophysical challenge this presents is to define the reef plane in sufficient detail that once mining starts, it can proceed without any unexpected disruptions. Classically, geologists have mapped the reef plane from boreholes, outcrops and excavations. It is theoretically possible to achieve any desired resolution of the reef plane using higher densities of boreholes, but the cost is almost always prohibitive. Large dislocations that influence overall mine design are usually identified using the normal drilling pattern and from 3D seismic data. Knowledge of smaller dislocations can greatly improve short term tactical planning: typically, if a dislocation in the reef is less than three meters, it is possible to continue without redevelopment, while dislocations of more than 3m require redevelopment. Redevelopment takes time, and production is stopped during the process. If small dislocations can be mapped, miners can plan for the dislocations, lowering the cost of dislocations by lowering the extent of uncertainty about the rockmass.

Enter borehole radar

Borehole radar, an electromagnetic, geophysical tool that creates images of the subsurface by using short pulses of radio energy, is the best tool to identify production-stopping dislocations. It is quick and easy to apply, and images dislocations in Witwatersrand gold mines and Bushveld platinum mines up to 60m from the borehole. It is most economically applied from boreholes like haulage and crosscut cover boreholes that would be drilled in any event.

Go Team South Africa

South African mines are deep and hot. Any tool used in our mines must be designed to withstand these conditions. Also, designing, building and utilising a tool locally has many other socio-economic spinoffs, like job creation, human capital development and the building of scientific expertise.

This was the thinking behind the design and building of a home-grown borehole radar system at the CSIR in 2001. The development and testing was done at such a rate that by 2002, it was a complete commercial system used in routine surveys. It was named the Aardwolf BR40 borehole radar system. The system is still in use to this day.

Designed for standard underground exploration holes (so it fits comfortably in a 48mm borehole), the radar is robust enough for routine work underground and is easy to use. It works in boreholes with high temperatures, which sometimes exceed 70 degrees Celsius. The Aardwolf BR40 borehole radar system has a frequency (40 MHz) that offers the best compromise between range and resolution for geological targets in the Bushveld platinum and Wits gold environment. With rapid data turn-around (one week from provision) and novel interpretation software to augment mine geologist know-how, the system can be deployed without needing support from the mine or its drillers.

The system is currently operated commercially by the CSIR, which is seeking partners for its survey business.

– Bandile Sikwane

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Lighting for safer landing

The special operations capability of the South African National Defence Force enlists a particular brand of soldier to operate under difficult circumstances. These operatives often require technology solutions of particular sophistication and precision. The scene is set for heightened creativity, discovery and invention.

CHRIS BOTHA is a project manager and technician at the CSIR's technology for special operations group. Together with his team, he designed and developed a product named CANDLE, a portable landing light system which won them international acclaim.

The system is lightweight and can be carried as part of a paratrooper's kit. It is rapidly set up to either mark a drop zone for paratroopers or to lay out a landing strip for aircraft with infrared or normal visible light. Its innovativeness lies in the fact that the lights are remote-controlled and can be switched on and off either by operators on the ground or the pilot from as far away as 10 kilometres.

CANDLE is most often used by paratroopers in peacekeeping operations, who perform a path-finding function, and who are dropped in areas where there is no landing strip.

The system consists of 12 lights, each fitted with a transmitter/receiver with a remote control effective up to 600 metres and 200 metres between lights. With six lights on either side, a landing strip of a km and longer can be marked out. This means a plane the size of a Hercules transport aircraft can be guided with this system.

When the aircraft approaches, the lights are switched on, and then switched off immediately once it has landed safely.

Because it is infrared-enabled, the lights are only detected by night vision equipment and thus remain unseen with the naked eye.

Initially required to assist defence force personnel in areas without sufficient air transport infrastructure, the system has also found civilian application among mining companies both in South Africa and elsewhere on the continent. The CSIR is in the process of upgrading the landing light system to include landward-based sensor systems to serve as an early warning system for protection, as well as a detection capability for intrusion into secure environments.

The portable landing light system was awarded a coveted International Soldier Technology Award in 2006, selected from a number of soldier modernisation programmes from around the world.

The upgrading of this capability will ensure that the CSIR has an updated version ready for industrialisation with a partner under a licensing agreement.

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The CSIR's Ernst Smit with a prototype mine boot.

Surrogate lower legs with mine boot concepts fitted – ready for explosive testing.

The mine boots protect against anti-personnel mines (front).

Boots to limit landmine injury

Landmines have been branded the ultimate indiscriminate killer. They have claimed or impacted the lives of many people in mine-affected countries throughout the world – regardless of age, gender or race.

ACCORDING TO the 2011 Landmine Monitor Report by the International Campaign to Ban Landmines (ICBL), there were over 4 000 landmine-related casualties recorded worldwide in 2010. Furthermore, the ICBL stated that while the Mine Ban Treaty has 160 signatory parties, there are still three countries actively laying antipersonnel mines, while 12 countries have been identified as active antipersonnel mine producers. At last review in August 2011, twenty countries within the African continent remain mine affected.

Against this backdrop of the severity of the threat, the CSIR has undertaken work to investigate and quantify the injury mechanisms resulting from the detonation of antipersonnel blast mines. The research resulted in the development of a human surrogate lower leg which approximates an actual human leg in terms of geometry and the type of materials selected for its construction. The surrogate leg is intended for destructive testing to assess the degree of tissue and bone damage sustained, as well as to estimate the potential levels of amputation. It differs from other surrogate legs in that it employs a unique sensor system capable of measuring the shock or stress wave progression through the leg in microseconds. The sensor system is under ongoing development and refinement.

Using the surrogate lower leg with a newly developed test and evaluation system, the CSIR is in the process of developing a prototype 'mine boot'. The intention is to develop a boot that can prevent any amputation in the event of small antipersonnel mine detonations as well as to mitigate tissue and bone damage during larger antipersonnel mine detonations, as far as possible. The prototype mine boot is in the final stages of testing and development. It is envisioned that the final product will be available in both full boot and strap-on-sole user options, making it applicable to commercial demining activities as well as military use where mobility cannot be restricted with permanent heavy equipment. Potential commercial partners are welcome to contact the CSIR.

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Increased food and beverage shelf-life through polymer technology

Having food or beverages stay fresher and last longer on the shelf is one ideal that everyone in the food and beverage industries should invest in. The CSIR invented a way for this ideal to become a reality, with proven success.

DURING THE NORMAL COURSE of the research process at the CSIR's encapsulation and delivery research group, new polymer systems with special properties are created. It was the special nature of these newly created polymer systems that led researcher Dr Philip Labuschagne and his team to discover new uses for it. What they found was a very handy new technology specifically geared towards the food and beverages industries.

Their invention, which is now patented, is an oxygen barrier technology. It has the potential to considerably lengthen the shelf-life of food and beverages stored in plastic containers.

Labuschagne explains how the invention happened: "We regularly use a process called inter-polymer complexation in our drug delivery research. The result is a polymeric product with unique properties – one of which is that the polymer has a high density (or a close-knit polymer network formed by hydrogen bonds). This property led us to investigate its effect on the permeability of gasses."

Not letting oxygen through

His group did several trials on various inter-polymer complexation systems until a system was found that reduces oxygen permeability by a factor of about 20 (for polyester-based plastics) and by a factor of around 150 (for polyolefin-based plastics). "The consequence is that you can increase the shelf-life of any oxygen-sensitive beverage in plastic containers by up to 150 times," he says.

"Another advantage of this technology is that it is a polymer solution that can easily be applied to a plastic surface, such as a beverage container, using a simple dip-coating process. The polymers used are also suitable for pharmaceutical use, thus they are completely non-toxic," he says.

Beverages that are typically sensitive to oxygen are beer or ciders, juices and any tomato-based products. Traditionally these products are stored in glass containers to ensure sufficient shelf-life. However, with this barrier technology, new opportunities for plastic packaging are possible. Plastic packaging is desirable because it reduces the enormous cost (and carbon emissions) resulting from the transport of heavy materials, such as glass.

An external coating

Labuschagne continues: "The coating is applied on the outside of the container using a dip-coating process. Because it has some degree of moisture susceptibility, a second protective UV-curable overcoat is applied over the barrier coating. Both these layers have achieved approval for use as external coating on food containers by the American Food and Drug Administration."

Cost-wise, the barrier technology compares favourably to other barrier technologies, but is superior to them in certain aspects. For example, metal-oxide coatings are expensive and suffer from brittleness; oxygen scavenger technology has a limited life span; and multi-layer technology is not only prone to delamination, but also difficult to recycle. "The containers can also be produced locally which can lead to considerable cost savings," says Labuschagne.

With local inventions such as this barrier technology, it is just a matter of time before we will be able to buy fruit juices that can stay in the fridge for at least a month. Or beer sold in plastic recyclable bottles rather than glass.

"The food processing sector is the country's largest manufacturing sector in employment terms with some 160 000 employees. South Africa has a competitive advantage in a number of fruit and beverage sub-sectors which, if fully exploited, could place it among the top 10 export producers in high-value agricultural products. I believe that the oxygen barrier technology has the potential to improve the competitiveness of this sector," concludes Labuschagne.

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An invention in bomb disposal continues to **make an impact**

A CSIR invention in bomb disposal has made its mark over three decades and continues to generate international interest. Recently, the CSIR signed two non-exclusive licensing agreements for this invention with Electrochemical Machining Technology (ECM) and Hausler Engineering.

A CSIR INVENTION in bomb disposal has made its mark over three decades and continues to generate international interest. Recently, the CSIR signed two non-exclusive licensing agreements for this invention with Electrochemical Machining Technology (ECM) and Hausler Engineering.

Four disruptors were licensed to ECM and one to Hausler. These companies will sell the technology to end-users such as the police and the army. The disruptors are used by bomb technicians to disrupt an improvised explosive device (IED) from a safe distance by delivering sufficient kinetic energy by way of a projected water jet to neutralise the device.

Senior researcher Philip Roach says that the range of small to large volume disruptors were developed to counter the range of IEDs confronting local bomb disposal operators. "These disruptors were successfully used by the South African Police Service (SAPS) and South African National Defence Force operators and are still in use today.

"With Hausler, we licensed only one of the disruptors called the Cobra, specifically for deployment by the SAPS bomb disposal unit," Roach remarks.

The disruptor technology was first developed in the mid 1980s and Roach has worked on them since its inception. "This technology is over two decades old, but it is still as effective – it remains the primary technology used for the neutralisation of suspicious IEDs. We are constantly looking at ways of improving the methods and the result of our efforts is the newer disruptor in the family: the Square cap uses coarse salt instead of water to disrupt the IED," Roach states.

Licensee ECM is in the process of securing an order from the United Arab Emirates to sell the disruptors.

"We are developing world-class technologies and by licensing them, we are aiding in building and supporting local industries that are able to sell to South African and international clients," says Dr Nivan Moodley, a CSIR research and development outcomes manager.

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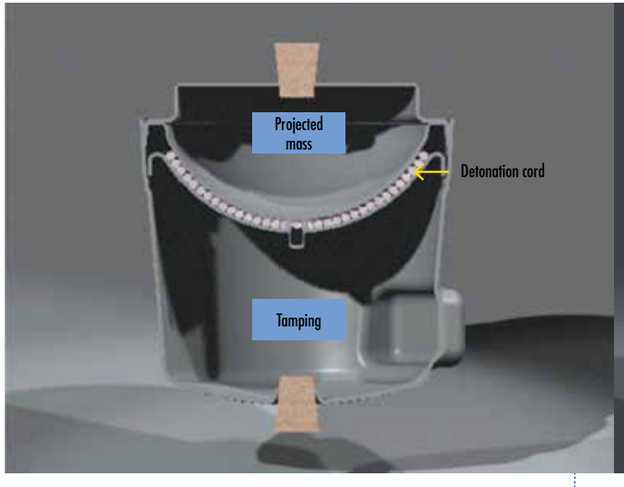
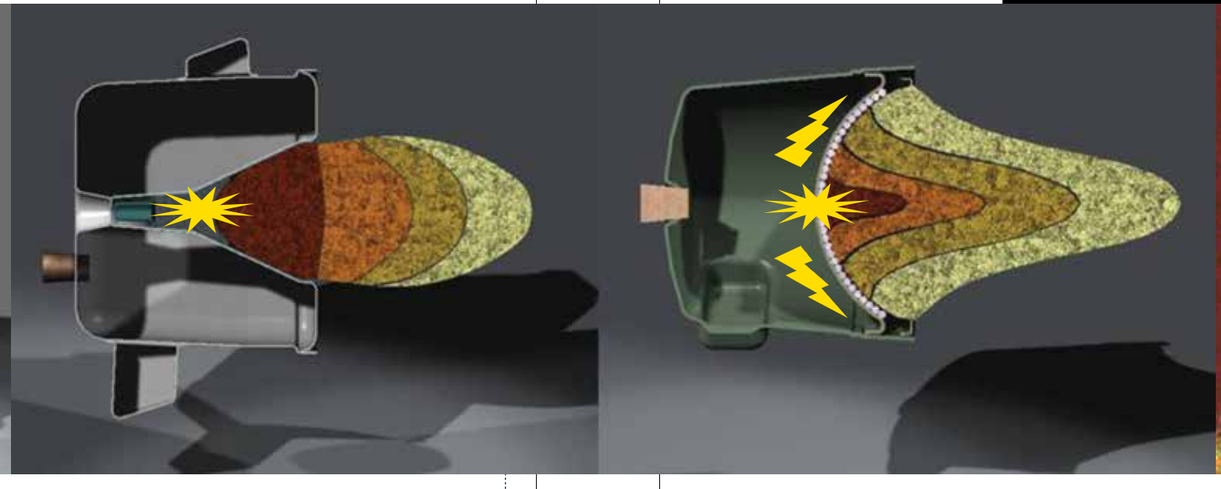
Simple in design, but highly effective. The basic operating principle of these devices used to disrupt improvised explosive devices is to form a high-speed water jet by winding detonating cord around a hemispherical form. A larger tamping volume (3:1 ratio) fits over the smaller, to-be-projected volume with the explosive cord contained between the two containers. The detonating cord is initiated in the centre of the convex form; a high speed water jet is generated and projected towards the explosive device. The water jet, on impact with the improvised explosive device, penetrates the container and disrupts the electronic circuitry before the switches or triggers can close. Velocities in the region of 550 m/s can be obtained – a velocity that exceeds the speed of sound.

A range of disruptors has been tailor-made for specific purposes. The 'Whole cap' for example, is suitable to disrupt explosive devices in cars, steel drums or wooden boxes, while a Mini cap can be used where collateral damage needs to be limited, for example, when it is close to sensitive equipment, instrumentation or inside buildings.



Cross-section of a Quarter cap (conical).



The functioning of radial (left) and conical (right) cap disruptors.

A single frame showing the use of a Quarter cap used in a disruption from 3.1 m

Heavy Vehicle Simulator – an enduring legacy with a trajectory well into the future

Impressive impact

The quantifiable direct benefits of the HVS are significant: at a discount rate of 8%, between R3-R6 are returned for every R1 invested.

Impressively, the HVS:

- earns foreign revenue for South Africa – more than R200 million since 1994;
- enables the improvement of road design and construction practices;
- provides a high-tech field lab for accelerated road-testing;
- simulates damage caused by traffic over 20 years in three months; and
- has been exported to a number of countries, with 11 units active worldwide.

Transport engineer Louw du Plessis

Proudly home-grown – the CSIR's accelerated pavement testing facility – the Heavy Vehicle Simulator (HVS) is a success story with global impact and one that has had a major impact on the design, construction and maintenance of roads locally and abroad for more than 40 years.

THERE IS NO DOUBT that the results obtained from the HVS programme over the past four decades will influence all road design undertaken currently in South Africa, and well into the future.

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

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

The latest model – the HVS Mk VI – is the result of continuous upgrades over the past two decades by the CSIR and its technology and commercialisation partner, Dynatest. Sporting numerous advantages over its predecessors, the new version costs less, is lighter and easier to tow on public roads and is less complex with increased wheel speed and test beam length.

Eleven of these massive road-side laboratories have been exported to active duty in the USA, Sweden, China, India and Costa Rica. The HVS has also been used for research in Finland, Slovenia and Poland. Over the past 18 years, the international programme has generated significant direct foreign income for the country – brought home as a result of quality research and technology development and sound commercial decision-making.

The largest and longest machine ever designed and built is under construction currently for the US Federal Aviation Administration.

The contribution of the two machines in use locally – one owned by the CSIR and the other by the Gauteng Provincial Department of Roads and Transport (GPDRT) – to our basic understanding of pavement material behaviour and advanced pavement engineering in South Africa has been immeasurable. GPDRT studies indicate that the quantifiable direct benefits of the HVS programme have been up to ten times more than the investment in the technology.

A benefit cost ratio of 10:1 was measured for the South African HVS programme in 2006. Every country that participates in the HVS programme has benefitted from improved, more cost-effective roads and a far better understanding of its road structure engineering and road materials behaviour.

More recently, the CSIR-developed HVS has been used locally to test the technology for using ultra-thin concrete technology for application in high-volume roads in South Africa. The original road design was imported from Denmark and adapted for local conditions. Working with the University of Pretoria, the Cement and Concrete Institute and local consultants, the CSIR used the HVS to test the final design and fast-track the implementation of the technology.

According to the CSIR's Louw du Plessis, an international expert in accelerated pavement (road) testing, "The ultra-thin, high-performance concrete is reinforced considerably for application in high-volume roads – seven times more steel is used than in ordinary continuously reinforced concrete."

The South African National Roads Agency Limited has implemented the technology for high-volume roads on the N12 near the Gillooly's interchange in Gauteng. In the Western Cape, the technology has been used on the N1 freeway between the Klip River Toll Plaza and the Huguenot Tunnel. The technology has also been used on an apron at the Oliver Tambo International Airport.

Over the next few years, CSIR research using the HVS will be aligned with the GPDRT's strategy to cost-effectively and efficiently rehabilitate and upgrade Gauteng's road network – one where more than 70% of the roads have reached the end of their design life-spans. Attention will be given specifically to public transport routes, freight corridors and the upgrading of unpaved roads.

It is foreseen that the local and international HVS programmes will continue to thrive, with other countries and research groups likely to order HVS machines.

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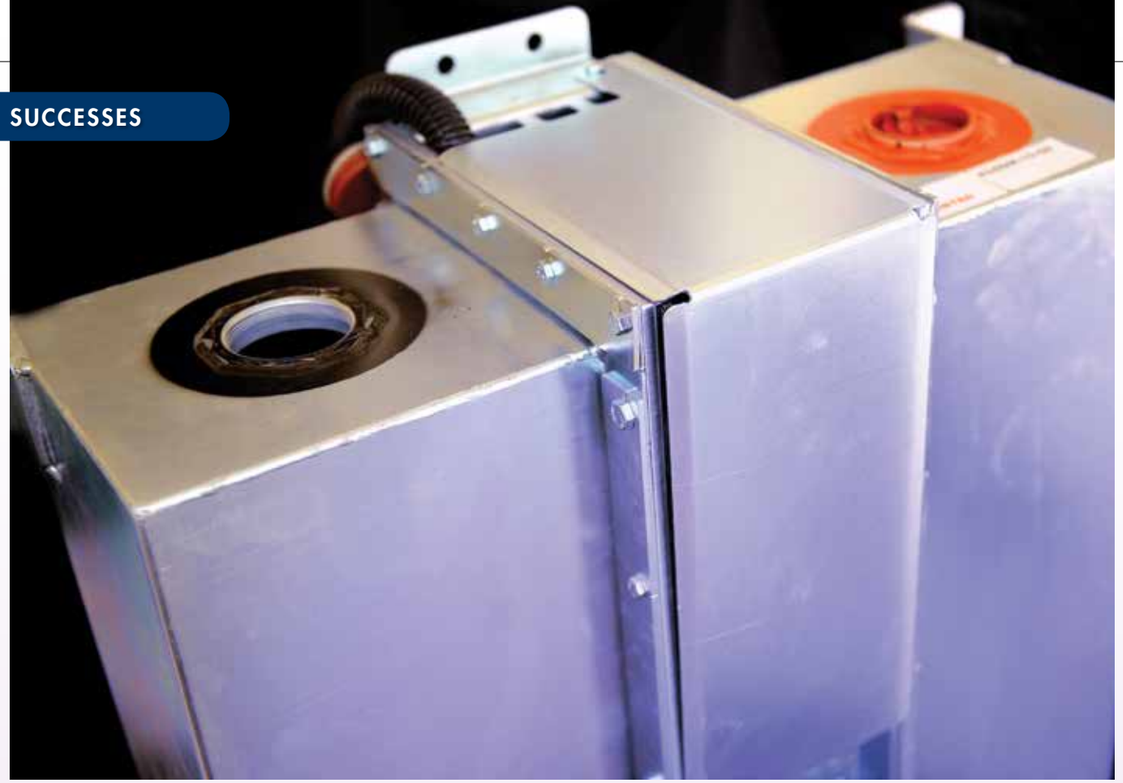
One of the Heavy Vehicle Simulator (HVS) machines in India, suitably garlanded for the launch occasion, with Louw du Plessis of the CSIR in the foreground.

HVS technology licensing

The HVS technology platform was licensed to Dynatest, a private company in the USA. Dynatest markets and manufactures the machines and also maintains the 11 machines already in operation. The CSIR receives a royalty for HVS sales from Dynatest.



Foiling cash-in-transit heists

Components of the sense-and-deploy device.

Cash-in-transit heists are well-planned criminal operations, executed with military-style planning and precision. In this form of robbery, criminals attack cash at its most vulnerable: away from the safekeeping of the bank and under the protection of only two or three armed guards.

THANKS TO TECHNOLOGY developed by the CSIR, security companies are now able to reduce attacks on their cash-in-transit vehicles. This innovation involves the installation of a polyurethane dispensing unit (the PUDU), which is essentially a sense-and-deploy device that dispenses quick-drying and solidifying polyurethane foam into the vault area of cash-in-transit vehicles when they are attacked. The polyurethane covers the cash in the vehicle's vault and makes it impossible for attackers to retrieve the transported assets from the vehicle.

The PUDU has been designed and developed for use in modular armoured vehicles, as well as the multipurpose vehicles that are used in the cash-in-transit industry. Its primary purpose is to protect the assets in the vault area of the vehicle in the case of a heist. It can be activated by different methods, depending on the client's needs and risk exposure. It has been tested in the field and has a proven track record in safeguarding assets during cash-in-transit heists, leading to asset recovery and a significant reduction in actual attacks.

The PUDU was originally developed for SBV Services, a local cash risk management company that has been rated by Lloyds of London as "the best risk managed cash-in-transit company in the world". The development of this technology was initiated in the 1990s when the company approached the CSIR with its need to develop technology to protect the so-called 'soft skin vehicles' transporting high volumes of cash. Although the protection of the vehicle itself had been achieved by bullet-proofing and armour-plating the vehicle, what was needed was a way to protect the assets inside the vehicle from attack.

Since the CSIR developed the first prototype and patented the innovation, it has been used by its client, SBV Services. In a statement, the company proclaimed that "we trust the PUDU to provide the last line of defence against attacks". It follows a two-pronged approach to safety and security: firstly the armour on the vehicles ensures the safety of its staff, and secondly, the PUDU ensures that the assets that are being transported are protected.

The CSIR has gone on to develop four generations of the product. It has now been licensed to the QD Group, a local company that designs, manufactures and distributes cash protection systems. According to Delon Mudaly, a CSIR manager of intellectual property and technology transfer for materials science and manufacturing, "This technology will now be available to the entire market, and other security companies can access this benefit too."

Production units of the PUDU system.

An example of a solidified foam block.

The licensing agreement allows the QD Group to manufacture the PUDU in South Africa, and to market and sell it locally and internationally. It has already been exported to security companies in South America, continental Europe and the United Kingdom, and the market potential looks encouraging.

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The polyurethane component.

The solidified foam that significantly delays access to assets.

Mobile Internet TV broadcasting

The CSIR is involved in the licensing of a broadcast platform that is set to have a major impact on the broadcast sector.

From its roots at the CSIR, a South African consortium has successfully licensed a broadcast platform that is set to change broadcasting as we know it. The platform allows viewers to watch live content on their mobile devices and computers from anywhere in the world without interruption to their video stream, even at very low connection speeds.

The trouble with streaming and viewing content on any device or computer is buffering, a particular type of disruption to the data stream. The simplest explanation as to why buffering exists when viewing content on a device, is that the connection to the Internet is slow or the network is congested, meaning there is insufficient bandwidth at a given instant in time to meet the demand.

Until recently, the best solution to this particular type of stream disruption has been to invest in a faster Internet connection, which is expensive for broadcasters and users in South Africa and other emerging economies. But now, buffering or any other type of speed-related network disruptions might be a thing of the past.

Science and technology unlocks new opportunities

A solution to this problem has been found in the development of a novel content delivery method that is a core feature of the Adaptive Real-Time Internet Streaming Technology (ARTIST) platform. This novel video content delivery technique has extended the concept of adaptive streaming to operate fast and at very low rates, thus widening the access not only to urban areas, but also to the rural African context. As the name adaptive streaming suggests, the technique involves adapting one or more data streams received from multiple sources to the real-time changes in the speed of the user's network. The broadcaster reproduces the content in multiple bit rates. Instead of the viewer selecting the bit rate, the selection is done automatically in the background; and is continuously adjusted for uninterrupted streaming and viewing.

The consortium behind the development of ARTIST comprises the CSIR, the University of Cape Town and Durban-based Internet service provider, East Coast Access (Pty) Ltd (ECA).

Put through its paces

The consortium was formed in 2007 to develop the ARTIST concept into a commercial broadcast platform suitable for low network infrastructure networks. With a first round three-year investment from the Innovation Fund – now the Technology Innovation Agency (TIA) – in 2008, the ARTIST consortium completed the research and development (R&D) phase of the product in August 2011.

The technology was successfully piloted by several broadcast stations, among them Johannesburg-based radio stations namely, YFM and the Voice of Wits campus radio. In August 2012, the ARTIST consortium entered into a licensing agreement with a new start-up company, Tuluntulu (Pty) Ltd. The licence allows the commercialisation partner to actively explore various business models and pursue commercialisation. While Tuluntulu builds its own technical capability, the ARTIST consortium members will provide technical support and contract R&D services in the development of applications and solutions as dictated by market need.

Now taking it to the people

Africa has one of the highest mobile user populations in the world. However, the biggest challenge for users, content creators and advertisers has been the delivery of content caused by either undeveloped telecommunication infrastructure or exorbitant prices for broadband access. Low-rate, fast, adaptive real-time streaming technology is an answer to this problem because it not only allows viewers to have an uninterrupted broadcast stream on their mobile devices, but it also opens up new opportunities for content creators and advertisers. Content creators now have a new platform to distribute their content, while advertisers could potentially unlock an untapped market for their goods and services.

– Bandile Sikwane

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In the Voice of Wits pilot project, a camera captures dj@large during his show and broadcasts it via Internet streaming to mobile phones, as seen on the photograph third from left. The team comprises (below and from left) the CSIR's Dr Keith Ferguson, Pierre van Houten of Tuluntulu Pty Ltd, the CSIR's Simeon Miteff, Prof Tawana Kupe of Wits, and the VoW station manager, Mike Smurthwaite, with VoW DJ, dj@large (Tshepo Kgapane). The key adaptation of ARTIST has been patented.

Seeing what is invisible **to the naked eye**

The CoroCAM, here held by UViRCO marketing manager, Riaan Rossouw, is designed to visually display the corona discharges from defects on high-voltage electrical installations.

Visually displaying the corona discharge around a defective, high-voltage electrical installation is a problem that researchers at the CSIR have long since overcome – of that the worldwide success of its CoroCAM designs are proof. The CoroCAM range of products was licensed to UViRCO Technologies, a CSIR spin-off, staffed by ex-CSIR personnel, in 2008.

POWER UTILITIES WORLDWIDE are experiencing pressure to manage their available power efficiently. Preventative maintenance can reduce blackouts and power loss on high-voltage equipment, which results in minimising power losses. Under high load on transmission and distribution infrastructure, localised hot spots limit capacity and can cause black-outs due to failure. Power-loss causes can be minimised through inspection to verify that lines are installed as designed. It is for these inspections that the CSIR-developed CoroCAM has become irreplaceable.

The first CoroCAM was an ultraviolet (UV) imaging camera that could detect and display the UV discharges that indicate high-voltage equipment problems – discharges that are not normally possible to spot with the naked eye as they fall below the range of visible light that humans can detect. This camera could only spot the resulting corona at night and the request soon came for a device that could do exactly the same thing, but during the day.

Four models followed, with the CoroCAM 504 being the current and very popular version with the ability to detect faults during night and day. According to Riaan Rossouw, UViRCO's marketing manager, more than 150 units of the CoroCAM 504 have been sold internationally, the majority of which have gone to China, Russia and the USA.

"However, while the CoroCAM can visually show power utilities and large industrial users of electricity where corona discharge creating equipment faults are located, it cannot show them the severity of the problem. This still requires a human operator," says Rossouw.

UViRCO is about to release the CoroCAM 6D, the latest addition to the CoroCAM family.

The CoroCAM 6D was developed in-house by UViRCO and introduces a number of new features which the market demanded, that is, on-board recording and a simplified user interface.

The CoroCAM 6D leveraged optimised electronics and mechanical design to effect a reduction in production cost.

The technology behind CoroCAM

When looking at an object such as a high-voltage electrical wire through the UV detecting camera, the incoming light is split into two pathways. One path passes the visible light through to a standard video camera which records the images of the object being inspected in order to create a background image. The second path takes its light through a 240-280 nm wavelength solar-blind filter to a camera which is sensitive to UV light.

The UV image is overlaid on the background image to provide a final picture which shows the location of UV corona discharges on the object being inspected.

Other developments

Apart from the CoroCAM, the CSIR, which now acts as research and development (R&D) partner for UViRCO, also developed a product called MultiCAM. This camera can detect both UV and infrared (IR) wavelengths and visually display these images for the easy identification of high-voltage equipment problems.

Jeremy Wallis, competence area manager for the sensor science and technology group at the CSIR, says that by adding the IR ability to the UV function, the MultiCAM can show differences in temperature as well as faults that radiate a corona. "Having both the thermal and corona image allows the operator to eliminate possible causes of a problem and get to the real problem (and solution) faster."

With the MultiCAM, an IR dimension as well as the normal visible spectrum can be recorded at the same time as the UV spectrum. The UV image can be overlaid on top of either the IR or background image, showing a final image with temperature differences as well as coronas on the object being inspected.

This camera too has been transferred to UViRCO and the CSIR is currently applying for funding to develop a fully radiometric MultiCAM.

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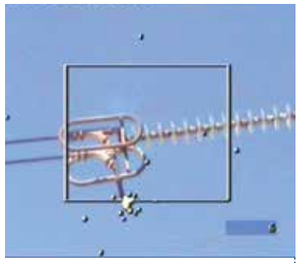
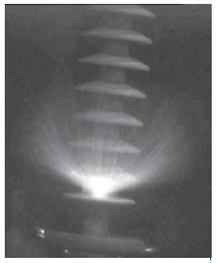
The CoroCAM being used at a substation in Russia.



This image, produced by the CoroCAM, shows a typical UV discharge overlaid on a background image.



An image taken with the CoroCAM 111, the best night vision camera. It shows the corona where a cable has been damaged.

The CoroCAM along with an FLIR product mounted inside a gimbal that is attached to a helicopter. Some power utilities find such a gimbal mounting handy especially when inspecting remote cable lines. This allows them to inspect thousands of km of cable in a much shorter time than would have been possible if done manually.

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about...

Corona – Corona discharge is an unwanted side-effect of high-voltage electrical installations. It is a phenomenon that results from the ionising of air due to a high electric field. The high electric field gradients form around geometric sharp points such as loose cables, cracks or badly designed equipment.

From polymer technology
to cosmetic products

A polymer gel that originated in the CSIR's polymers and composites research laboratories was reinvented to become a highly successful international cosmetic product. The product, called Eyeslices, is commercially available internationally.

EYESLICES is an innovative, cryogel eye pad, which slowly releases active ingredients to the skin to combat a wide range of eye irritations. It reduces the appearance of red eyes, dark circles under eyes, tired eyes, wrinkles and puffy eyes within minutes of use.

It started when CSIR researchers with expertise in polymers invented a water-soluble polymer gel that functioned as a dermal delivery system – in other words, a gel-like substance that could be liquefied and solidified to absorb and emit ingredients to the skin.

In 2000, entrepreneur Kerryne Neufeldt, licensed this technology from the CSIR and built up a company (i-Slices Innovations (Pty) Ltd) around it. By the end of 2006, the company had stocked the product in over 100 salons and spas in South Africa. The product is now exported to several countries, including Mexico, Australia, the United Arab Emirates and the USA.

The company has received numerous awards for this innovative product, including a Technology Top 100 award in 2007 and a SABS Design Institute Award in 2004. In 2011, the company won the Technology Top 100 award for sustainability.

The product continues to capture market share, with direct response television campaigns marketing the product (under different brands) set to start in the USA in the near future.

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Lobsight technology
gets it 'right on target'

CSIR PRINCIPAL ENGINEER Danie de Villiers is the mastermind behind a technology innovation that is – literally – aiming for a high hit rate. His brainchild, Lobsight, is a novel Indirect Aiming System (IAS) to improve the hit probability of mortars and other light artillery weapons used in indirect firing mode, in other words, in situations where a projectile is aimed and fired without the gun and target being in line of site.

Indirect fire most commonly occurs in field artillery, although it sometimes is used in naval combat, anti-tank operations or anti-aircraft guns. It is mostly used when the target is at longer range and invisible to the firer due to the terrain. Many factors can influence the projectile trajectory – atmospheric conditions, the velocity of the projectile, differences in altitude between the firer and the target, to name a few. Determining the trajectory to ensure that the elevation and range are effective, is therefore a challenge.

Lobsight consists of a ballistic computer with an integrated tilt sensor and a shaft encoder interface. The tilt sensor determines the elevation of the weapon and the shaft encoder keeps track of the compass bearing – measuring the angle at which to fire. The system is battery-powered.

In a deployment of forces, an observation post identifies the target's location and issues the coordinates to the artillery operators. The data are then entered into the computer to aim the weapon in terms of the angle and elevation to ensure that it is on target. The firing table data on the system can be rapidly updated with corrective data to re-aim – should that be required.

By improving the accuracy of indirect fire, the Lobsight technology has delivered many benefits in terms of tactical and logistical advantages in the principles and doctrines required by modern warfare – particularly in the realm of a 'system-of-systems' approach of network centric warfare where various components work together to achieve optimal firepower or situation awareness.

Also, more accurate firing means less waste due to missing targets – and less ammunition needed to be carried or otherwise brought to the combat space.

Not only a logistical improvement, but more importantly, the risk of secondary impact – for example accidentally striking a non-threatening target – is also reduced.

The man behind the invention

Inventor Danie de Villiers has a background in electronic engineering and a track record of coming up with solutions that improve soldier systems.

De Villiers had started work on the indirect aiming system in the mid '90s when employed by the company Mechem.

"I was the lead engineer at that stage and my team and I demonstrated an indirect firing system for mortars," he says. The demonstration soon piqued the interest of players in the industry. In 2000, Denel requested an indirect aiming system for grenade launchers similar to that demonstrated earlier by De Villiers.

"This is the critical point in the process of developing a new product: One needs the specific requirements from a client and work towards solving a specific problem," De Villiers explains.

Increasingly, the defence industry opts to further develop or enhance existing capabilities instead of investing in new and novel tools. This requires higher-systems level integration and technology adaption.

The Lobsight technology was licensed to a manufacturing partner and it was phased into use by the SA Army over a number of years. It has become a tried and tested – and well-used – technological aid in the field. It is used most often to improve the speed and effectiveness of the 40mm automatic grenade launcher. Several hundreds of the systems were deployed.

De Villiers is always onto new challenges. Aside from his work in indirect fire solutions, he has also contributed to the development of battery power (specifically for dismounted troops and soldiers in the field).

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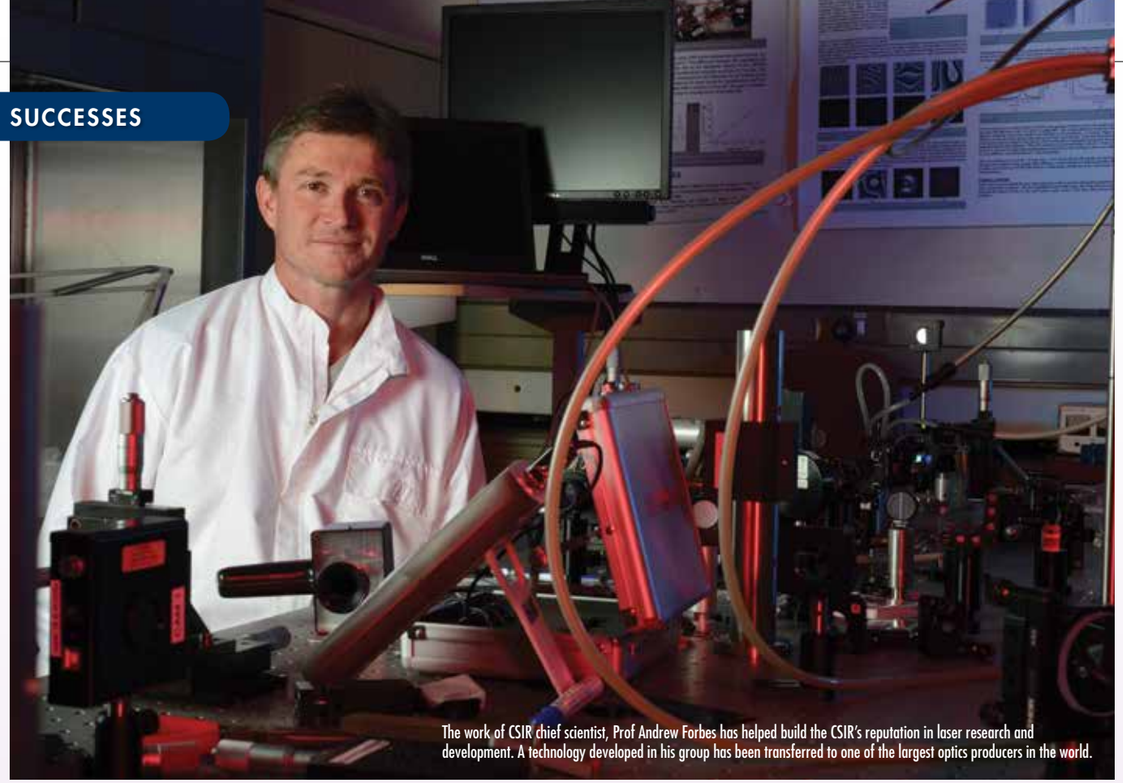

The work of CSIR chief scientist, Prof Andrew Forbes has helped build the CSIR's reputation in laser research and development. A technology developed in his group has been transferred to one of the largest optics producers in the world.

An invention resonates with a local laser manufacturer

A breakthrough by CSIR chief scientist, Prof Andrew Forbes, led to the design and development of a new laser system with special optics inside, characterised by features on the micro-scale. The technology was licensed to a South African company in 2011.

"QUITE SOMETHING to see one's idea and design go all the way to inclusion in a commercial product," says Forbes. "Not all research and development results in uptake, and because the time lapse from the initial work to uptake by industry or society is often significant, inventors are not always present to experience this thrill. I feel privileged to have experienced this."

He says that the work that led to this technology started as early-stage research on laser resonators. Lasers are made up of three parts, namely an energy source, a gain medium, and mirrors that form an optical 'box' resonator.

"The technology worked well, with obvious commercial benefit, which led to us opting to license it to an industry player," he remarks.

Forbes explains what happened at the lab on the day of the breakthrough, "The beam jumped the single mode energy, up by a factor of 25. It turned a commercially nonviable process into a viable process for a local laser exporter. It surprised me how well it worked and that it did so, on the very first attempt."

"With lasers, one generally has to choose between having lots of energy, and having a 'nice' laser beam. A quality that incorporates both these parameters is the so-called 'brightness' of a laser: high brightness means good laser beam quality and high energy. This is difficult to achieve because good beams tend to come at the expense of energy, while high-energy beams are highly distorted and difficult to use in practical applications," Forbes explains.

The new CSIR laser technology makes almost any laser operate in a 'high brightness' mode, which results in more efficient lasers for long-range communication systems, and in the military for target designation. The technology has the potential to make lasers smaller and less expensive, by exploiting the extra efficiency to make the support systems work a little less.

The CSIR has for several years invested in developing core expertise in shaping light with diffractive optical elements; optics that have feature sizes down to the micrometre scale, and sometimes to the nanometre scale.

The idea is that given a laser beam of a particular intensity profile (i.e. how the energy carried by the laser is distributed in space), it is possible to reshape the profile of this laser beam by redistributing the energy.

If this is done correctly, then in principle any laser beam shape can be achieved. The group worked on achieving this same result, but inside a laser, so that the diffractive optical elements are the mirrors of the laser. The idea was that if the mirrors were correctly calculated, and then fabricated, the laser itself would select the best beam for maximum brightness. The shape of the laser beam bouncing around inside the laser was chosen to extract as much energy as possible from the laser, but in a 'good' shape.

The licence agreement sees CSIR technology helping to make local industry more competitive. In this case, the aim was a more efficient industrial laser, but similar technology can be used to make almost any laser operate in a 'high brightness' mode.

– Mzimasi Gcukumana

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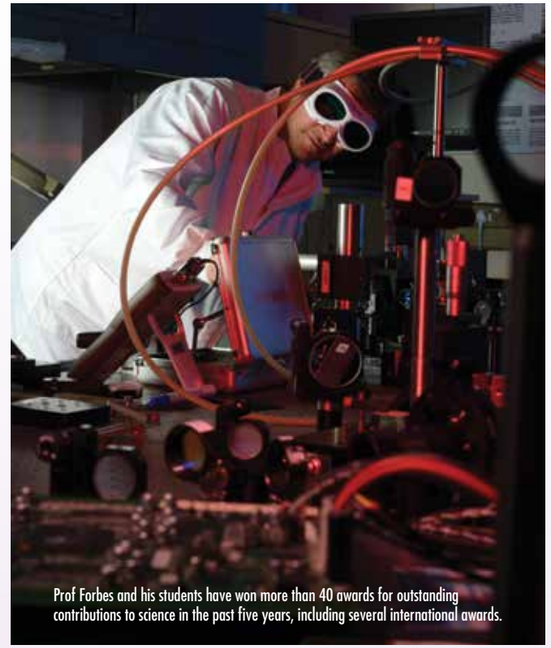
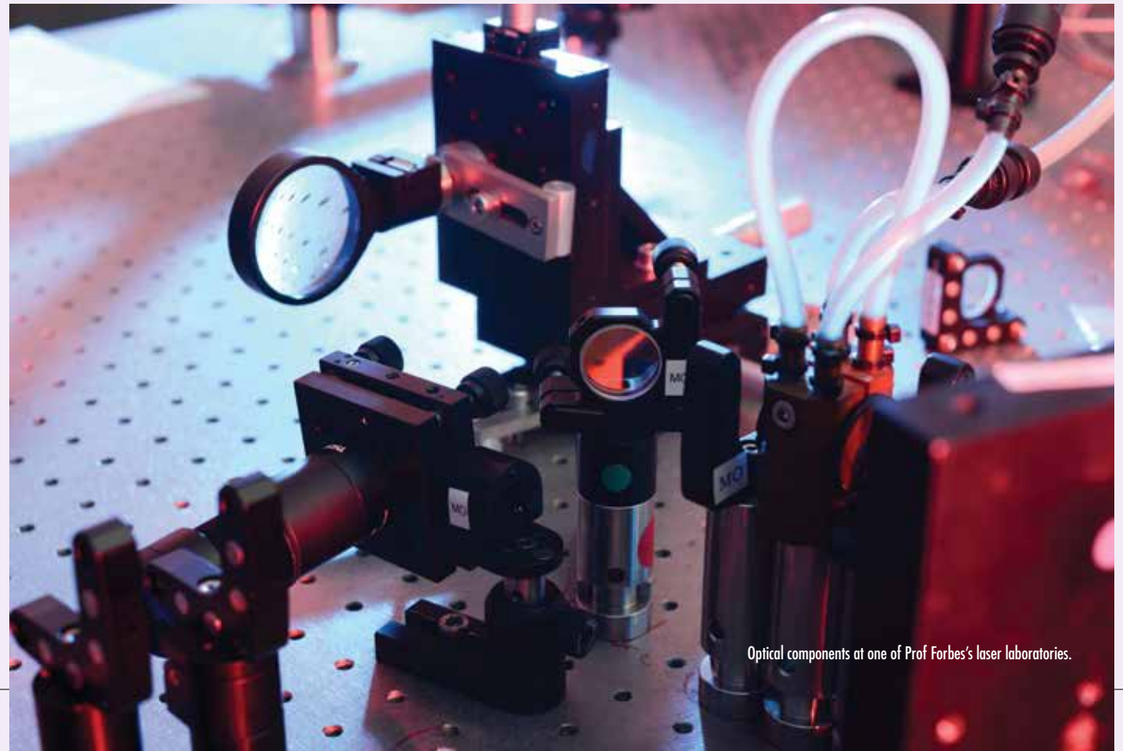


Prof Forbes and his students have won more than 40 awards for outstanding contributions to science in the past five years, including several international awards.



Optical components at one of Prof Forbes's laser laboratories.

The team behind Schreiber are, from left, senior technicians Richard Rapoo and Johan Sachse, technical specialist Michael Sehlabana and senior technician Jonathan Manganye.

CSIR and Afrox in licensing deal

The CSIR licensed the manufacturing of rubber mouthpieces used in self-contained self-rescuers in underground mines to Afrox.

THE CSIR HAS LICENSED TO AFROX its patented rubber mouthpiece used in self-contained, self-rescue (SCSR) breathing apparatus. The breathing apparatus produces oxygen for underground workers during an emergency escape from irrespirable atmospheric conditions.

Underground workers breathe into the apparatus via a mouthpiece connected to a breathing tube. The exhaled carbon dioxide is then converted into oxygen through a chemical reaction. The system can provide life-giving oxygen for up to 40 minutes during an escape or up to two hours when waiting to be rescued (depending on breathing rate).

How it works

The system comprises a protective casing that is belt-worn. Inside the protective casing is the breathing apparatus which contains a chemical with potassium super oxide (KO_2). This chemical is activated when breathing into the unit and then produces oxygen to the wearer (this same chemical is used in emergency oxygen supply systems for space missions and submarines). This unit includes a CSIR-designed mouthpiece, which is connected to the breathing apparatus via a breathing tube; and a nose clip (also CSIR-designed) to prevent the inhalation of harmful gases.

Why the redesign?

"Many of the mouthpieces that are currently in use cause irritation and stimulation to the saliva glands inside the mouth, leading to an over-production of saliva in some cases, which in turn could block the flow of breathing air to the wearer," says the CSIR's Wilfried Schreiber, the co-inventor of the new mouthpiece design.

"In addition, mouthpieces available to date were very uncomfortable and restricted the movement of the tongue, thereby making verbal communication impossible," he adds.

The CSIR is the only accredited testing authority for these self-rescuers in South Africa. Schreiber, who has extensive experience in self-rescuer research, and his team – who has over 100 years of combined experience working with SCSR apparatus – have garnered worldwide recognition for their work.

Tackling it as a team

The new mouthpiece has been redesigned and re-engineered by the CSIR and Hannover Engineering, a South African company. "Although the new mouthpiece has been co-developed, the ownership of the Intellectual Property vests in the CSIR," says CSIR commercialisation manager Brian Mphahlele. "Afrox has been granted a non-exclusive license to manufacture and distribute the mouthpieces," he says. The deal was concluded in July 2012.

The redesign of the mouthpiece follows the redesign of nose clips for SCSRs in 1997, of which Schreiber was the sole inventor. The redesigned nose clips are now distributed globally with over half a million units sold worldwide and have become the de facto standard in South African mines. It is envisaged that the newly designed mouthpiece will have a similar impact in the local and international market.

– Bandile Sikwane

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Wilfried Schreiber with his invention: a mouthpiece for self-contained self-rescuers.

Electronic sounding device for mines commercialised

A device invented by the CSIR and used in the detection of loose, overhead rocks in underground mines has been licensed to a commercial partner.

AN ELECTRONIC SOUNDING DEVICE is a sensor that mimics the performance of an experienced miner in determining whether loose rocks are present in the roof of the excavation during the entry inspection. With rock falls responsible for more than 30% of fatalities in South African gold and platinum mines, the entry inspection that occurs before workers enter a newly blasted workplace is one of the most important and dangerous tasks in underground mining operations.

The current process used in ensuring that there are no dangerously loose overhead rocks following blasting underground, includes tapping the roof of the excavation with a pry bar. A hollow sound is an indication of a loose rock. This sounding process is an acquired and somewhat subjective skill. The quality of sounding is related to the physical state of the miner undertaking the sounding. Fatigue, noise-induced hearing loss and illness often affect the competence of individuals, even within a single shift. The electronic sounding device improves the sounding process by eliminating common human errors that could lead to injuries or loss of life. The CSIR has finalised a licence agreement with Draxin Technology to commercialise the device.

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The electronic sounding device seen here fitted to a mining hard hat.

Converting waste to energy through fluidised bed processing

Fluidised bed technology is not only used to burn low-quality coal, but various forms of industrial waste.

Fluidised bed combustion has been used to burn coal for many years, but using the experience gained at the CSIR to convert industrial waste to energy gives an important new slant to existing technology. CSIR research and development (R&D) activities in this area, span the past three decades. The earliest developments were in low-grade coal combustion, but fluidised bed technology has since been applied to designs for a hot gas generator, a biomass sludge boiler, a high-sulphur pitch incinerator and an industrial deodoriser.

Initial research: low-grade coal combustion

In the mid 1970s, the CSIR commenced with investigations into fluidised bed coal combustion and gasification. For this purpose, an initial refractory-lined bubbling fluidised bed test rig was constructed. Research became more focused in the early 1980s when an investigation was initiated into the use of discard coal, duff coal and coal slurries by means of fluidised bed combustion technology.

This resulted in the development of the National Fluidised Bed Combustion (NFBC) boiler for the former Department of Minerals and Energy Affairs in 1984.

This facility was primarily used for thermal and combustion efficiency trials, where the effects of load, cyclone grit re-firing and bed temperature on the thermal and combustion efficiencies of the waste coals were investigated. Sulphur reduction trials were conducted to determine the ability of South African sorbents to reduce sulphur dioxide emissions in situ, as the high-ash discard coal generally also contained elevated levels of sulphur.

In 1990, the original small-scale fluidised bed combustor was replaced by a larger one that combined the functionality and freeboard (above-bed) height of the NFBC boiler with the flexibility of the initial test facility. This was dubbed the Multi-Purpose Fluidised Bed Combustor (MPFBC). The MPFBC was used extensively for process development in the fields of waste combustion, calcination and minerals treatment.

Commissioned plants

Experience gained through R&D conducted on the NFBC and the MPFBC has been successfully applied for the benefit of South African industries. The CSIR was commissioned to design fluidised bed combustors for a number of plants in South Africa, to deal with a variety of environmental and industrial challenges.

These included the design of a hot gas generator for Slagment in Vanderbijlpark, Gauteng; a biomass and coal co-fired boiler for a multinational food producer in Estcourt, KwaZulu-Natal; a high-sulphur pitch thermal oxidiser for Sasol; and a coal-fired fluidised bed deodorising and steam generation plant for African Products.

In each of these cases, the CSIR was commissioned to design a customised fluidised bed combustion unit to meet the client's specific and often multiple needs. The technology is licensed through South African engineering companies that manufacture the combustors according to the CSIR's design specifications.

Fluidised bed technology is robust with unique characteristics, rendering it suitable to a host of different applications. This includes the recovery of precious metals through the incineration of carbon and wood chips, as well as chemical vapour deposition onto valuable substrates. Utilising this technology not only has environmental benefits, but makes economic and business sense. It enables the manufacturer to generate his own hot gas, steam or electricity, while enabling him to dispose of waste matter easily and cost-effectively.

This innovative research in the field of clean energy certainly proves that there is no end to the application potential of FBC technology, which leads to new opportunities for commercialisation and technology transfer.

The CSIR's Brian North at the CSIR fluidised bed combustion stalwart which has been in use for many years and where pilot scale process development is undertaken prior to application at an industrial scale.

Converting waste to energy through fluidised bed processing continued

Hot gas generator earns the CSIR a projects and systems award from the South African Institution of Mechanical Engineers

The hot gas generator that was developed for Slagment in Vanderbijlpark was the first commercial fluidised bed combustor to be designed by the CSIR. The client had an existing coal-fired furnace, which was used to supply hot gas to a slag dryer. High maintenance costs and the need to use a high-quality graded coal product in this furnace prompted the organisation to look for an alternative. The fluidised bed combustor that was designed by the CSIR could utilise low-grade 'duff' coal, which was regarded as a waste product and was available at a low price.

Experience gained in the research carried out on the NFBC was applied to this design, and features, such as a deep bed, a conservative fluidising velocity and a large freeboard (above-bed) area, were adopted to ensure a high combustion efficiency, and therefore low carbon carry-over into the dry slag product. An air distribution system was designed to deliver fluidising/combustion air uniformly to the base of the bed, yet allow the drainage of solids over the entire bed area. This was necessary to avoid the build-up of inert 'tramp' material, which will inevitably be found in low-grade or waste fuels.

This highly successful 10 MW plant was awarded the South African Institution of Mechanical Engineers' Projects and Systems Award in 1990.

Biomass and coal co-fired boiler receives the Innovation Award of the South African Institution of Chemical Engineers

A unique biomass and coal co-fired boiler was designed for a multinational food producer based in Estcourt. The purpose of this boiler was to develop a reliable system of incineration to dispose of a stream of 12 tons of coffee grounds per hour (comprising 85% water), while raising 26 tons of process steam with the off-gases. A fluidised bed combustor that could burn the coffee grounds in their wet state, rather than drying and treating the press water, provided the best solution to the client's problem at the lowest capital cost.

Again, past experience was applied. In particular, a deep bed, which creates a 'thermal flywheel', allowed for swings in fuel quality and water content. Extensive process development was carried out in the MPFBC and the NFBC to prove the practical application of calculated design parameters. The boiler was designed in 1992, and is still operating successfully. This project earned the research team the Innovation Award of the South African Institution of Chemical Engineers in 1994.

An industrial boiler used to generate steam from hot gases leaving a fluidised bed combustor.

Brian North describes the upward blowing of air required for the fluidised bed combustion process.

About fluidised bed combustion

Fluidised beds suspend solid fuels in upward-blowing jets of air during the combustion process. The result is a turbulent mixing of gas and solids that provides more effective chemical reactions and heat transfer. It is ideal to burn fuels that are difficult to ignite, like low-quality fuel such as coal mine waste.

Disposing of high-sulphur pitch while reducing sulphur emissions

Sasol produces approximately two tons of high-sulphur pitch per hour in its coal-to-liquids process. This waste stream has a high calorific value (similar to heavy fuel oil), but contains a number of contaminants and sulphur that renders it unsuitable for disposal in a landfill site. The best disposal option is to thermally oxidise the pitch, while reducing the sulphur emissions in the flue gases. The high sulphur pitch (HSP) thermal oxidiser, which was designed by the CSIR, is a fluidised bed combustor that achieves exactly this.

The design team drew on past experience in the combustion of liquid fuels (coal slurries and biomass sludge) to develop an HSP injection system that would ensure that the pitch was delivered into and burnt in the fluidised bed rather than burning it above the bed. This ensured uniform, controlled temperatures in the bed and freeboard to enable sulphur to be captured in situ using a limestone addition to the bed.

The design of the air distribution system for the Slagment hot gas generator was employed to allow the sulphur to be continuously removed as solid calcium sulphate. The gases leaving the fluidised bed combustor were used to generate 20 tons of process steam per hour in a waste heat boiler.

Environmental claims that can be made for this fluidised bed combustor include a reduction in sulphur oxides through in situ sulphur capture, a reduction in nitrogen oxides due to a relatively low combustion temperature, and a reduction in carbon dioxide since the steam produced displaces steam previously generated by burning coal in a boiler.

Deodorising of air using FBC technology

The 12 MW coal-fired fluidised bed deodorising and steam-generation plant that was commissioned by African Products, one of the largest maize-processing plants in the southern hemisphere, is another one of the CSIR's customised designs. The process air from the plant's maize-drying circuits contained odorous organics, and the client wished to render this air odourless in order to conform to current world standards in the minimisation of environmental impact.

The CSIR's fluidised bed thermal treatment was selected as the most appropriate technology for this purpose. The odorous air was used as the fluidising air for the fluidised bed combustor. Coal was burnt in the fluidised bed to maintain it at 900°C, and the odours in the air were thereby destroyed. Process steam was generated using the off-gases to minimise the total CO_2 emissions from the plant.

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From a research tool for the few to an everyday commodity

The CSIR and the early days of Internet services in SA

The Worldnet Africa web page as it appeared in 1996.

Today Merryl Ford is still active in information and communications technology (ICT). She currently works on a range of technology-intensive interventions in the rural education context. The CSIR has been enlisted by the Department of Science and Technology to assist in directed ICT for improved educational outcomes. These activities are taking place in the Nciba school circuit, part of the Comfimvaba School District in the Eastern Cape.

Almost nine million South Africans have made the Internet an integral part of their daily lives. Very few of these Internet users know that the CSIR laid the foundation for the World Wide Web's evolution on the southern tip of Africa.

IT ALL STARTED IN THE EARLY 1990S in a little office in Building 9 of the CSIR's Pretoria site. There, a small team headed by Merryl Ford, currently manager: ICT for education and mobile learning at the CSIR Meraka Institute, delved into the bits and bytes of the cyberworld in what she describes as 'exciting times'. They played with obtuse-sounding services like Archie, Veronica, Cello, Mosaic and UseNet. The exploration into this new frontier kept the information technology-wired brains of Building 9 occupied for a good few years, before the need for commercialisation became clear, resulting in M-Net buying the CSIR's platform lock, stock and multi-gigabyte barrel in 1997.

"Initially," says Ford, "we saw the potential for localising CompuServe, America's first commercial online service, and launched CompuServe Africa, a fee-based, dial-up service. At the time, the Internet was in its infancy. No-one had a real grasp of it." The initial plan was the development of a bulletin board system to enable the CSIR to provide online access to subscribers to its various scientific information services.

In a paper published in 1993, Rosemary McGillivray of CSIR Information Services, noted the CSIR's move from a research organisation to a technology transfer enterprise described by the then CSIR president as fulfilling the functions of a 'funnel and a bridge' – funnelling into the country, appropriate technology, modifying it as required and bridging it into companies and communities in South Africa.

Ford and her colleagues started to investigate global information technology trends with a view to using the Internet and the World Wide Web as the platform for online services from the CSIR, rather than the bulletin board system initially envisaged. They created one of the first websites in the country for the CSIR and showcased it to Robert Caillliau when he visited the organisation in 1993. Robert Caillliau, together with Sir Tim Berners-Lee, invented the World Wide Web. Ford also remembers her husband (also one of the intrepid bands of Internet explorers) and herself attending one of the first Internet world conferences in London and realising that the trends being debated were old hat for the boffins at the CSIR. They were both interviewed on British television talking about the pioneering work that the CSIR was doing. "We were definitely ahead of our time," she says.

When the manager of CSIR Information Services' Compuserve Africa, Richard Webb, recognised the significance of the work being done, he took the team under his wing and oversaw the development of South Africa's first Internet service provider, initially called Commercial Internet Services and subsequently, CSIR Internet Services. The service provided dial-up connectivity and email functionality.

In 1994, the name was changed to Worldnet Africa, which was billed as a portal to the services offered by the CSIR and as a structured and indexed information platform that focused on providing South African-centric information to the Internet community. "There was a big drive to contract experts in their fields to provide content and services for the public for a fee and we established a content acquisition team," says Ford. "One of our early suppliers was Sister Lillian, a radio personality well respected for her advice on pregnancy and parenthood."

In 1996, a legal hub was introduced to provide relevant information to the legal fraternity and other interested parties. By this time, 200 000 South Africans were using the Internet daily.

Being the CSIR, the focus remained academic, although the platform itself enabled many innovative approaches to create new solutions for a new world that was just starting to emerge. Ford remembers team member Abu Abrahams digitising South Africa's labour law books. "Abu took every page of every book, scanned it and converted it to HTML text. Scanned versions were then legal for use in court as references during arguments and HTML versions could be easily and quickly searched for appropriate cases. The problem was that laptops were not the norm they are today – his solution was at least 10 years before its time.

Ford acknowledges that the fee-based model was flawed, as people, naturally, were not keen to pay for information that they assumed could be obtained freely elsewhere on the web. In addition, small payments were not easy to make as services such as Paypal had not yet been invented. But again, the CSIR was advanced in its thinking. A decade later, Internet users are becoming used to paying for specialised digital content, and e-commerce is big business, with the advent of e-books, Kindles and the like.

By the mid 1990s, the CSIR acknowledged the need for commercialisation of the service. Says Ford: "We had laid the foundation, but a commercial service would never have sat comfortably in the CSIR stable, which was not set up – nor was ever intended – to run such a venture."

Thus, the academic brains of the CSIR met the hard-nosed business types of the corporate world across the boardroom table, in what Ford remembers as a culture shock for all parties. Discussions were conducted with both IBM and M-Net, and the result was arguably one of the biggest business coups of recent decades. M-Net acquired a platform that would have taken it years and vast expertise to establish, packaged for immediate expansion and commercialisation at a very affordable price. The new owner immediately injected R30 million in the business and rebranded it M-WEB. The service was later incorporated into Multichoice.


MIH HOLDINGS

Saturday night fever on World Wide Web

M-Net's sister plans Internet viewing through pay-TV channels, which could deliver a death blow to competition

MIH Holdings, the sister company of M-Net, is poised to become a powerful force in the Internet industry following M-Net's acquisition last year of CompuServe Africa and WorldNet Africa from the CSIR for about R8m.

All possible ways of delivering Internet access to subscribers are being investigated, says Antonie Roux, new head of the company (still unnamed) which will manage integration of MultiChoice's Internet and broadcasting products.

He does not want to detail plans but indicates this could include an Internet channel on the DStv satellite system. DStv already has more than 100 000 subscribers.

He confirms the company is looking into options that include installing TV cards in PCs and integrating network computers into TV sets. Millions of rand have been spent upgrading WorldNet and CompuServe.

MIH, formerly MultiChoice, acquired the Internet companies from M-Net earlier this month. M-Net will continue to focus on content creation and marketing advertising space on the Internet, says CEO Gerrie de Villiers. MIH will manage connectivity and subscribers.

MultiChoice is also examining ways to raise market awareness of the CompuServe brand and is investigating ways of repackaging the product.

MIH CEO Hans Hawinkels says MIH is considering a firmware upgrade to digital decoders to make them Internet-ready. This would include installing modems to promote two-way communication between subscribers and MIH's Internet service provider.

MIH says it cannot comment on the feasibility of upgrading ordinary analogue M-Net decoders. But such a move would put MIH in a dominant position in the Internet market virtually overnight — the pay-TV channel has more than 1m subscribers.

More details of MIH's Internet plans are expected to emerge next week. It has not yet revealed if it hopes to offer interactive shopping services and other value-added products.

Duncan McLeod

Financial Mail, 13 June 1997

Although much of what the CSIR team worked on has now disappeared or morphed into other services under the M-WEB banner, South Africa's online connectivity almost certainly would not have advanced as rapidly without the pioneering work of Ford and her colleagues.

"I still consider this as my baby and am very proud to have been part of a team that provided the early technical platform on which Multichoice could catapult M-WEB into the global Internet family," she says.

Today, Ford's 'baby' has more than 320 000 subscribers and is well placed with innovative products and competitively priced packages to take advantage of the projected growth in local Internet coverage to 10 million users by 2015.

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Fever-Tree candles are available at more than 200 South African stores.

Winning recipe for a 'home-grown' mosquito repellent candle

Studies by CSIR researchers and traditional healers on indigenous plants with mosquito repellent properties in the mid-1990s led to the discovery of a novel mosquito repellent. The essential oil of the indigenous plant, *Lippia javanica*, has more effective repellent properties than similar or comparable commercial products on the market.

A LICENSING AGREEMENT with Zollhaus International (Pty) Ltd has paved the way for marketing of mosquito repellent products, thereby realising the commercial benefit of this local essential oil.

Mosquito control

As the most widespread and devastating of tropical diseases, malaria kills one African child every 30 seconds. Sufferers from chronic forms of malaria have diminished quality of life. Together with HIV and tuberculosis, malaria is the major public health challenge undermining development in the poorest countries of the world.

In South Africa, malaria is present in the three northern provinces bordering Mozambique and Swaziland, with seasonal transmission during October to April. Because of their nocturnal feeding habits, malaria transmission by the Anopheles mosquito occurs primarily between dusk and dawn.

Local populations have traditionally utilised *Lippia javanica* as a mosquito repellent. Cut branches are wiped on the skin and at the entrances to dwellings, or burnt on an open fire at night.

Facts about malaria

- Malaria transmission is caused by the bite of a female Anopheles mosquito carrying the *Plasmodium falciparum* parasite.
- Worldwide, mosquitoes transmit disease to more than 700 million people. Annually, it leads to more than 300 million acute illnesses and claims the lives of at least one million people.
- Ninety percent of deaths due to malaria occur in Africa, with the majority of its victims children under the age of five.

Traditional health practitioners whose knowledge led to the discovery and commercialisation of the mosquito and repellent candle celebrate the first royalty payment.

From left, the CSIR's Brian Maphalele, Drs Marthinus Horak and Vinesh Maharaj with Gordon Muller, Zollhaus International (Pty) Ltd.

CSIR researchers worked with traditional healers to identify the chemo type of the plant species with superior mosquito repellency properties. Dr Vinesh Maharaj, CSIR natural product chemist, confirms the outcome of this collaboration, "A benefit-sharing agreement between the CSIR and the owners of the traditional knowledge resulted in the first benefit payment to traditional healers during July 2012."

Coming up tops in efficacy

The efficacy (or effectiveness at producing a result) of the essential oil was evaluated at the South African Bureau of Standards (SABS) using olfactometer tests. An olfactometer is a device used to study insect behaviour in the presence of an olfactory stimulus.

Using a standard protocol with the yellow fever mosquito (yellow fever is an acute viral haemorrhagic disease), it was demonstrated that the CSIR-developed products are significantly more efficient at repelling and expelling mosquitoes when compared to the current products on the market.

Both repellency and expellency are important qualities. Repellency is the ability to prevent mosquitoes from entering an area; expellency is the ability to drive or force mosquitoes from an area.

Producing mosquito repellent candles

According to Dr Marthinus Horak, a key contributor to the CSIR's enterprise creation for development activities, the essential step to realising the economic benefit of this discovery was the establishment of a community-based production process in Limpopo with funding from the Department of Science and Technology. This followed the success of the trial plantation of the indigenous plant and the efficacy testing.

The production process starts with cultivation of the plant species on a 20 hectare cultivation site where the mosquito repellent crop is grown. The crop is harvested and distilled in an essential oil distillation factory on the site.

Workers at the factory of 650 m^2 in Giyani (Limpopo) have acquired the production technology and skills required to manufacture the mosquito repellent candles on-site. The factory contains equipment to formulate the active ingredients of the candles, and manufacture and package up to 400 000 candles per year.

The project provides employment for more than 20 people in rural communities.

To market

As its first step, the CSIR filed a South African patent on the use of extracts and chemical substances derived from the plant as mosquito repellents. Brian Mphahlele, CSIR commercialisation manager, confirms that this gives the CSIR the right to stop anyone from making unauthorised use of the intellectual property.

He took the lead in negotiating commercial terms for a licence agreement with Zollhaus to formulate the patented extract into mosquito repellent/expellent products for distribution and sale to local and export markets. All royalties negotiated under the licence will be paid in full to the owners of traditional knowledge. Through this licence, the CSIR secured demand for the oil produced by the local community and in the process helped generate economic activity for the local community. This falls squarely within the CSIR's mandate – bettering the lives of ordinary South Africans through research and development. Mphahlele explains, "Zollhaus's expertise lies in developing and positioning products in key market segments."

Based on its market findings, Zollhaus developed a range of fragranced candles that effectively repel mosquitoes. Additional SABS tests indicate that the improved product has fly-repellent properties.

Zollhaus has taken some additional steps to firm up marketing prospects. The registration of the mosquito-repellent candle in terms of Act 36 of 1947 allows the sales of candles to the public. Zollhaus also successfully negotiated sales with South African chains stores and the product is currently available under the brand name 'Fever-Tree' in more than 200 South African stores.

What lies at the heart of the success of South Africa's 'home-grown' mosquito repellent is a winning technology recipe in which several players at the CSIR fulfilled key roles: natural product chemists working with owners of traditional knowledge; enterprise creation experts giving guidance; and technology transfer experts who recognise the market potential of this product.

– Biffy van Rooyen

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C-Mussels shareholder Cratton van Niekerk lifts a growing rope, covered in mussels. C-Mussels has a monthly harvest of 13 000 kg.

Local mussels are 'lekker'

Supporting production of South African seafood

Black mussels (*Mytilus galloprovincialis*) from Saldanha Bay on the South African west coast are arguably some of the best in the world; larger than their overseas counterparts and of excellent quality due to the high level of nutrients in the Atlantic.

THANKS TO A FINANCIAL INJECTION from the provincial government of the Western Cape through its Rural Economic Assistance Fund and with enterprise creation assistance from the CSIR, a small, wholly black-owned enterprise at Saldanha Bay has expanded its mussel farming operation to supply the South African seafood market.

How it all began

African Olive Trading 232 (Pty) Ltd, trading as C-Mussels, started with a single metal mussel raft from which harvesting was possible only twice a year. The goal of the owners was to expand the operation by harvesting mussels more often from more rafts.

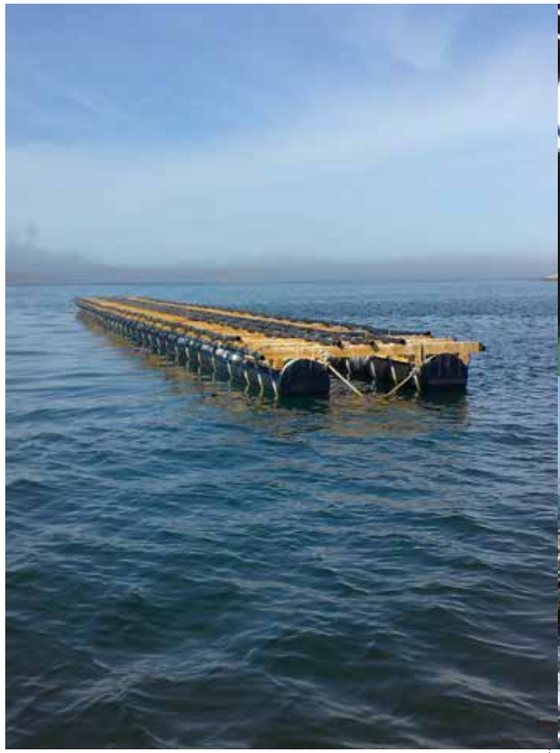
The CSIR's Wendy Long explains, "We assisted the company to purchase two robust rafts designed and built to withstand inclement weather and superior in every way to the old metal rafts."

C-Mussels has been operating successfully with the new rafts since 2010. Significantly, the CSIR helped the company to make a successful application to acquire valuable water rights.

The CSIR's role also extended to other necessary enterprise interventions to support the expansion of this small business. Long continues, "We arranged director/shareholder and corporate governance training as well as legal support to secure agreements that would protect the company's interests."

Necessary administrative procedures and templates were set up to facilitate business systems. This included the design of a fresh new logo that was incorporated into the company documentation.

C-Mussels



Clockwise from above: The mussel raft is 50 m long and 5 m wide, with 700 ropes. It is made of wood, with floats made of steel and plastic materials. The CSIR's Wendy Long with C-Mussels shareholders Elizabeth Cloete, left and Joslin Cloete, right. The mussel raft is accessed by boat.

A viable business

Long notes, "Since most of South Africa's consumption is imported mussels, this offers a great opportunity for growth and expansion. The demand for mussels is higher than the supply."

She explains the processes set in place to ensure that C-Mussels realises the market potential of its product, "To ensure food safety and quality, mussels are continually checked for biotoxins and heavy metals by the CSIR's consulting and analytical services to meet quality regulations."

C-Mussels has a secure contract with an industry partner, a wholesaler, who has also played its part in developing skills and mentorship.

Taking ownership

C-Mussels now seeds and harvests on a much larger scale and has moved to its own new, cleaner water space. The company employs four individuals currently.

Shareholder Cratton van Niekerk shows great initiative and determination to grow the business, "We are aiming to have enough rafts to harvest monthly with the intention of making a meaningful impact on unemployment in the Saldanha Bay area. We do not just have an eye on improving our own circumstances; we are looking at the bigger picture of the community around us."

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Cultivating *Mytilus galloprovincialis*

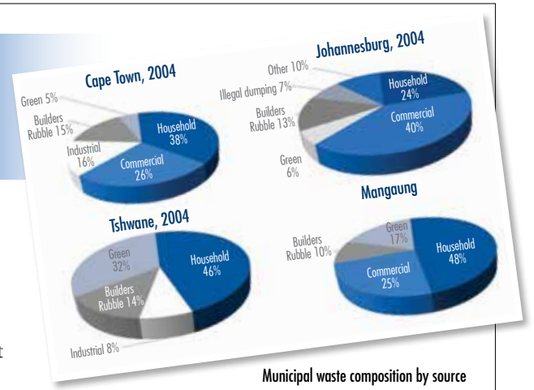
- Mussels have been eaten by humans for thousands of years. A popular seafood, they can be smoked, boiled, steamed, roasted, barbecued or fried in butter.
- *Mytilus galloprovincialis* is a marine mollusc that grows up to 140 mm in length. It is the dominant low intertidal mussel on the west coast of South Africa.
- Spanish cotton and baby mussels ('seed') are used on a growing rope for the aquaculture of these mussels. The cotton contains the seed until the mussels can attach to the rope. It disintegrates after a time.

snippets

All South African households in large centres to separate household waste by 2016

A recent CSIR study revealed that only 3.3% of the country's urban population regularly recycled household waste in 2010. This finding is underscored by another study, also conducted by the CSIR, which shows that, of the estimated 19 million tons of municipal waste generated in South Africa in 2011, about 25% were mainline recyclables such as glass, paper, tins and plastics.

Separating recyclables at household level is a requirement in terms of the Waste Act. The National Waste Management Strategy requires that in four years' time all metropolitan municipalities, secondary cities and large towns will have initiated programmes for waste separation at source.



Municipal waste composition by source

According to the 2010 survey more than 73% of South Africans living in urban areas reported no recycling at all and about 27% of urban South Africans reported some recycling behaviour.

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Digital Doorway installed Down Under

From left: Kim Gush, Ronel Smith, Grant Cambridge and Prof Marlien Herselman with the three Digital Doorway units destined for Australia.

A local innovation that is promoting computer literacy in South Africa and Africa by providing rural communities with Information and Communications Technology (ICT) access is set to impact on the lives of indigenous communities of Australia. The Digital Doorway™, a joint initiative of the Department of Science and Technology (DST) and the CSIR Meraka Institute, is expanding its influence beyond Africa's borders to promote formal and informal learning in high-needs communities in Australia.

The installation of Digital Doorway™ systems in three rural indigenous Australian communities was the result of collaboration between the CSIR and Monash University, and received funding from the Australian national government. It forms part of a research project to compare the results of the use of this system for social inclusion and community development in Australia to those in South Africa.

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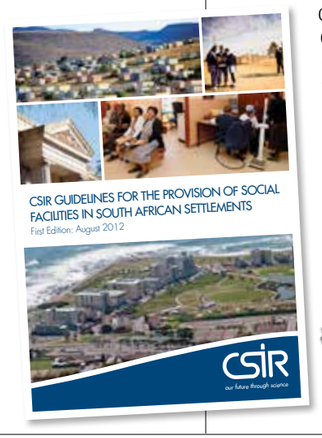
CSIR publishes guidelines for social facility planning

The CSIR has published guidelines for the provision of social facilities in South African settlements. These are for use in the planning and development of social facilities locally in towns, cities and provinces.

The guidelines apply to a wide range of facilities across many sectors, including health, education, sports, recreation and the public service. The guidelines can be used for more focussed and needs-based municipal infrastructure spending and the development of adequately provisioned towns and suburbs.



CSIR town planning specialist Chéri Green says that guidelines for basic services like water and electricity are well-established, but those for social facilities were either outdated, non-existent or where available, had not been sufficiently tested in the South African context.

Available at http://www.csir.co.za/Built_environment/Guidelines_Standards.html

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