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CSIR

our future through science

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FOREWORD

A GLASS HALF FULL: STORIES ABOUT TALENT, SUCCESSES AND OPPORTUNITIES

As global citizens, we are surrounded by talented and dedicated individuals, and a myriad of possibilities for innovation and advancement. Although the challenges we face as a society are real, they are not insurmountable and we are hopeful about the future and the opportunity to make a lasting impact.

In recent months, the CSIR has been looking at how to optimise its contribution to industrial development in South Africa. In analysing the challenges, we had to acknowledge some stark realities, such as the declining growth in some of our country's traditionally strong industries. However, we are enthusiastic about the opportunity to have our multidisciplinary skills and capabilities applied – in a focused and meticulously planned manner – for industrial development. This does not mean that we now abandon the excellent work we have done to support the public. In fact, we intend to continue to grow our contribution to the creation of a capable state in future.

In this edition, we share positive developments and news on aspects of our strategic objectives. In the first section, we share some stories about the achievements and resilience of some of our emerging researchers. Few things provide me as much inspiration as experiencing the talent, drive and commitment of our emerging researchers, leaving me optimistic about our investment in human capital development. On the other end of the spectrum, we introduce you to two researchers who have reached chief researcher status, the pinnacle of the research career ladder at the CSIR.

We also share some of the exciting outcomes of our research and technological innovation programmes.

The CSIR's mandate calls for directed research and technological innovation. Ultimately, we want all of our work to be taken up for the benefit of the country and its people. To see our work go all the way from research to inclusion in a commercial product makes us proud. Read about how we found a solution for better probiotics with a longer shelf-life (p 32) and how CSIR expertise in nanotechnology has resulted in new products for a South African-owned cosmetics company (p 48). We also share the discovery of a solution that could help limit food waste associated with a post-harvest disease in avocados. This was achieved by combining our skills in polymer science, with the crop science expertise of the Tshwane University of Technology – a great collaboration.

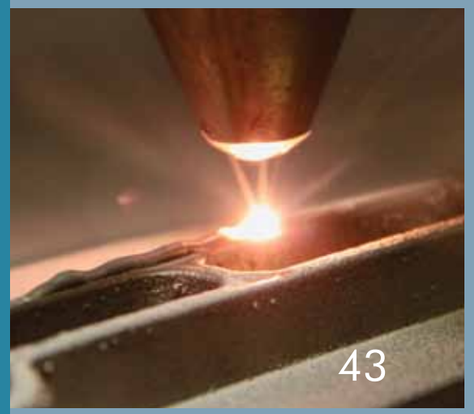
Two opinion pieces, one on the fourth industrial revolution and the second on the growing importance of statistical analysis in the context of the big data phenomenon, provide useful insights into two fields that will shape and influence our future.

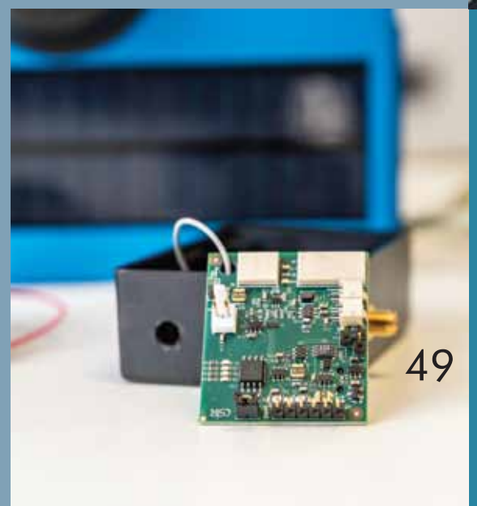
We remain committed to sharing with you – through this publication, as well as our website at www.csir.co.za – developments in terms of our strategic intent, our capabilities and how we apply these to make a difference.

I trust that you will find it a worthwhile read.

Dr Thulani Dlamini
CSIR Chief Executive Officer

IN THIS ISSUE





ON THE COVER

A scaled physical model of a breakwater at the CSIR's coastal and hydraulics laboratory.

The CSIR has now been assisting the Transnet National Ports Authority with monitoring the main breakwaters of South African ports for 23 years. The monitoring of the ports – Cape Town, Durban, East London, Ngqura, Mossel Bay, Port Elizabeth, Richards Bay and Saldanha – includes visually analysing year-on-year damage to the breakwater to help plan maintenance and optimise performance. It is also necessary in the context of predicted sea level rise and extreme sea conditions caused by global warming. Typically, armour units are packed on a slope of rubble that lies between the infrastructure being protected and the open water. These armour units break the power of the waves and without them, the entire port infrastructure would be compromised.

WALKING IN THE FOOTSTEPS OF **HISTORY'S GREATS**

When the name of the opportunity is Cambridge

Cambridge University, United Kingdom

The CSIR, in partnership with Cambridge University, had offered a joint scholarship programme to provide researchers with an opportunity to pursue their PhD studies at the University of Cambridge. The aim of the scholarship was to give emerging researchers international training in science, engineering and technology. Two CSIR researchers who have benefitted from the scholarship tell their stories.

DESTINED FOR SCIENCE: CHARLOTTE MASERUMULE

Since the age of six, Matsopiane Charlotte Maserumule has felt a pull towards science and medicine. Her desire to contribute in these fields was a combination of natural curiosity about the science of human diseases and health, as well as a disdain for ill-health and the devastation it brings – both of which were further stirred by the environment in which she grew up. Over time, she became more aware of her inclination to understand systems and problems, and find new solutions and better ways of doing things.

Charlotte Maserumule characterising synthetic tuberculosis detection molecules in a laboratory at the CSIR.

"I appreciate science both for its own sake (for its nature, complexity, beauty and symphony) and as a means to solve real life problems. Also, the field allows one to be a scholar, innovator and problem-solver with very little chance of stagnation and boredom," she says.

Maserumule obtained her BSc in medical sciences from the University of Pretoria. Thereafter, she pursued a BSc Honours in medical cell biology at the University of the Witwatersrand. She completed her MSc (Med) at the University of Cape Town on a CSIR Master's studentship. Her next goal was to obtain her PhD overseas and, in a moment of opportunity meeting preparation, Maserumule was giving a talk about her research at the CSIR, when she was approached by the CSIR Human Capital Development team about the CSIR South Africa-Cambridge Scholarship.

From there, Maserumule received funding and support from the CSIR to join the University of Cambridge as a PhD candidate. Her research focuses on understanding host genetic susceptibility to tuberculosis (TB), using forward and reverse genetic screens to probe critical host immune factors that control the outcome of early TB infection at cellular and molecular level, with the view of generating new insight into more effective, host-directed TB therapy approaches, which may bypass conventional antibiotic resistance.

Life at Cambridge

Maserumule says the move to the University of Cambridge was an easy decision. "I wanted to grow into a more seasoned, well-rounded scientist by international standards. I figured coming to Cambridge would not only sharpen my sword and propel me into an exciting world of intellectual advancement and skill in my field, but it would also afford me access into incredible professional networks and would-be future collaborators, mentors and enterprising partners, some of which would otherwise be difficult to establish."

Being in a foreign country has its highs and lows, as expected. Her highlights include receiving very good feedback on her first-year PhD report and being selected to represent the Department of Medicine at the annual Newcastle, Edinburgh, Cambridge and Sheffield Respiratory Medicine meeting in 2017, where she presented

(continued overleaf)

▲ Above: Charlotte Maserumule addresses the Cambridge-Africa Together Conference during a panel discussion on African women in leadership.

her PhD work, for which she received great appraisals from some of the brightest and most prolific scientists in the field.

"Through my PhD research, I have had the privilege of contributing significantly to an international collaborative research project between the University of Cambridge, the National University of Singapore and Colorado State University, among others, for which I was awarded the 2018 Biotech Fundi Young Researcher Award by The Innovation Hub," she says.

Maserumule has had to develop a thick skin during her studies. Apart from the cold weather and shorter days, she has had to deal with setbacks in her research project, due to technical issues, proving to others – sometimes renowned experts – that her research is sound. Dealing with the personal loss of loved ones has made the distance from family a real challenge. However, she has built a strong support structure from back home and her new home to get her through the rough patches.

Lessons learned

"I have learned a great deal and continue to be refined by this pilgrimage. I would like to contribute to the evolution of translational medicine and science in Africa and hopefully ease the burden of disease and improve patient care."

Maserumule understands the opportunity that she has been given and uses it to inspire others by giving back to her community in Limpopo, where she affords learners open access to higher education, wider career opportunities, resources and mentors. Her motto is inspired by Emerson's utterances: "Do not go where the path may lead; go instead where there is no path and leave a trail."

IN HIS DNA: CHRISTOPHER DE SAXE

As a child, Christopher de Saxe enjoyed things like Lego, Meccano and computers. His father's hobbies included electronics and motorbikes and his grandfather was a civil engineer – all of which made a career in engineering the natural choice for him. De Saxe obtained his BSc in mechanical engineering from the University of the Witwatersrand.

De Saxe joined the CSIR in 2011, pursuing his Master's through a studentship (also at the University of the Witwatersrand) and was exposed to heavy vehicle dynamics research. He enjoyed working in this field and his Master's research sparked an interest in furthering his qualifications abroad.

After investigating various funding options and universities, he learned about the CSIR South Africa-Cambridge Scholarship programme. "The university was a perfect match for me and I already had a supervisor in mind. I applied, and the rest is history. I graduated in April 2018, on my 30th birthday," he says.

◀ Left: Christopher de Saxe receives his PhD from Cambridge University.

The Cambridge connection

"I knew from the onset that this would be the experience of a lifetime; living and learning in a new country, surrounded by highly motivated people, in an environment steeped in culture and tradition. On a personal note, my preference for Cambridge was in no small way due to my love for British comedy. Many of my comedy idols studied there, including Hugh Laurie, Stephen Fry, John Cleese, David Mitchell, Eric Idle, Graham Chapman and Douglas Adams."

Even though he was leaving behind his soon-to-be wife, family and everything that was familiar, De Saxe knew that this was an opportunity of a lifetime.

On an academic level, having access to some of the world's finest minds and the university's extensive resources proved to be incredible. "There were also growth opportunities abound and I got valuable experience organising conferences, teaching and supervising students, being part of a multinational research programme, and working with Volvo in Sweden, spending quite a bit of time there as part of my research," De Saxe says.

Personal highlights, such as cycling to the office along old cobbled streets, attending formal dinners in ancient dining halls (often in academic gowns or black tie), all added to his personal experience. Meeting a number of diverse and inspiring people from across the world, many of whom became friends, and travelling within the UK and Europe with his wife, made Cambridge a wonderful place to live.

Next chapter

After Cambridge, De Saxe returned to the CSIR where he started incorporating new ideas and initiatives stemming from his time in Cambridge. His work focuses on heavy vehicle dynamics and safety, as well as sensing challenges for articulated trucks. There are two innovations in which De Saxe was key, namely a camera-based articulation angle sensor, which measures the articulation angle between a truck and trailer, and a stereo camera-based sensor for measuring trailer off-tracking in articulated trucks. Off-tracking refers to the amount of corner-cutting a truck or trailer exhibits during turning.

He hopes to take on bigger projects and start gaining experience in leading research. "I'm trying to get a feel for whether I prefer the academic or industrial side of engineering. The CSIR provides a bit of both, so that works quite well for me now."

De Saxe encourages researchers not to let opportunities pass them by. "Take on the daunting challenges that come your way, or define some for yourself, and then figure it out along the way. When you come out at the other end, you will be amazed at what you managed to achieve and what you learned along the way."

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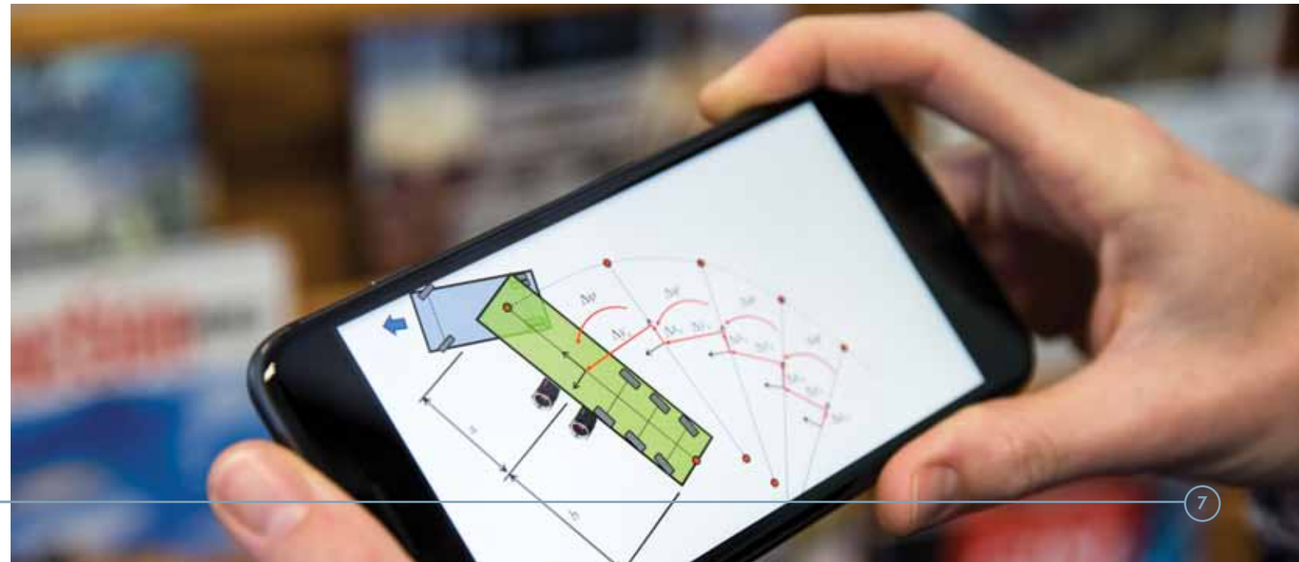
▼ Below: One of the data processing steps in converting visual odometry data from trailer-mounted cameras into trailer off-tracking measurements – as part of addressing sensing challenges for articulated trucks.



FROM MAKING BETTER **RABIES VACCINES** TO BUILDING BETTER **ROBOTS**

Emerging researchers put their contributions to a better society on the table

CSIR engineer Mayur Tikam, postdoctoral fellow Sindisiwe Buthelezi and PhD student Thabang Matladi.

Three emerging CSIR researchers illustrated how they are applying their minds to innovate and walked away with top honours at the CSIR Emerging Researchers Symposium, receiving praise for their work and their ability to communicate it successfully.

South Africa's history is one in which young people helped to shape the country into what it is today. While today's struggles are different, CSIR Chief Executive Officer, Dr Thulani Dlamini, believes that, once more, the youth has a role to play in helping the country overcome its challenges – this time, the ills of poverty, inequality and unemployment. Speaking at the 6th CSIR Emerging Researchers Symposium in Pretoria earlier this year, he said, "You have all distinguished yourselves in various fields of education. Draw on this education and determine how you can drive innovation that will create a better society, a better South Africa and a better world."

Studying the stability of anti-rabies antibodies

Dr Sindisiwe Buthelezi worked on anti-rabies monoclonal antibodies that were proposed as alternative post-exposure treatment for rabies in humans. The study focused on the evaluation of their stability and proposed ways to improve them by pinpointing aspects that would cause the vaccine to expire if exposed to oxygen or varying temperatures. The World Health Organization (WHO) proposed the use of a combination of antibodies as the best way to prevent viral escape, which occurs when the virus changes certain aspects in its sequence to avoid being detected by the immune system or the drug.

Rabies is spread through the infected saliva of a rabid animal. This means that any encounter that allows the contaminated saliva to enter the body – through a scratch, wound or contact with mucous membranes – could lead to infection. According to the WHO, rabies is present on all continents, except Antarctica, with over 95% of deaths occurring in the Asia and Africa regions.

Rabies often affects people living in rural areas where there is a challenge of poor delivery and inadequate storage facilities for vaccines on their way to health centres. These challenges have been reported to result in vaccines being thrown away, thus increasing the financial burden already faced by the health-care sector.

Buthelezi holds a PhD in biochemistry; she began her career as a CSIR intern, having completed an honours degree in biochemistry and cell biology. She attributes her success to a great support system at work and at home. "A team of supervisors with different skills helped me to navigate my research field and I was exposed to different views, which opened doors to new opportunities."

▼ Below: Dr Sindisiwe Buthelezi infiltrating *Agrobacterium* containing light and heavy chain vectors of the anti-rabies antibodies into tobacco plants.

Posture control for a low-cost hexapod robot

Mayur Tikam is passionate about robotics and believes that South Africa can be a frontrunner in using this technology, especially low-cost robotics, as the country moves towards industrial development.

“My presentation at the event focused on my recently received Master’s (with distinction) in mechanical engineering. My research was aimed at improving the uneven terrain mobility of a six-legged walking robot (hexapod). The ability to automate such platforms to operate in environments that are either impossible or too dangerous for humans to access will have a great impact on industries such as mining, space exploration and deep sea research,” says Tikam.

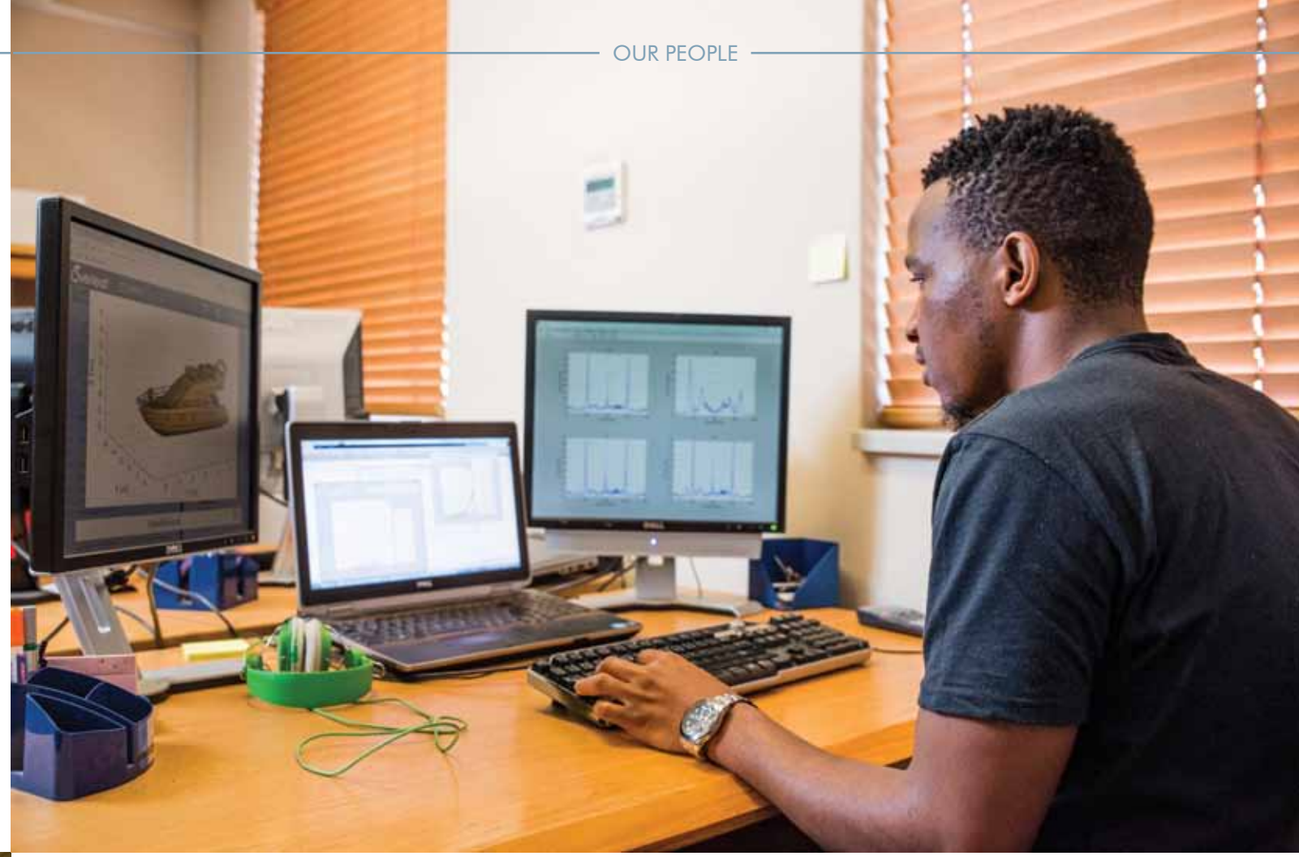
As a robotics and mechanical engineer, Tikam focuses on integrating and combining various emerging technologies, such as robotics and additive manufacturing, to advance the future capabilities of the technology and drive the evolution of Industry 4.0.

Going forward, he also aims to incorporate artificial intelligence and machine learning into these systems to push the boundaries of what can be achieved with the technology.

“The CSIR is a great environment for young researchers to gain exposure to a wide variety of fields and technologies, as well as collaborate with fellow researchers from a range of disciplines,” says Tikam.

> “My research was aimed at improving the uneven terrain mobility of a six-legged walking robot.”

▼ Below: CSIR engineer Mayur Tikam working on the hexapod in the CSIR additive manufacturing centre. The hexapod is designed to assist industries in the fields of mining, space exploration and deep sea research.



▲ Above: The research of Thabang Matladi, who has been awarded a PhD studentship at the CSIR, is aimed at improving the target detection of radar. This work can have a meaningful impact, as research on the topic has been limited.

Improving the detection of surveillance data

The need to monitor and protect humans, cargo, assets and wildlife has increased the use of surveillance radars. These radars use singular polarisation to search for and detect targets that move at relatively low speeds. This poses a challenge when looking for targets that are fast and change direction randomly.

Thabang Matladi investigated the use of polarisation diversity in radar systems to improve the detection performance of surveillance radar. With the use of a fully polarimetric radar system – a radar system that transmits two orthogonal polarisations and receives simultaneously in two polarisations – detection of targets can be improved significantly.

Fully polarimetric radars can aid in border patrols, maritime surveillance, as well as in the fight against animal poaching.

“Research on this topic has been limited and it thus provides a great opportunity for one to make a meaningful impact on the matter,” he says.

Matladi studied physics and electronics at North-West University, after which he completed an honours degree in astrophysics and space science at the University of Cape Town, followed by a Master’s in electrical engineering from Stellenbosch University.

Matladi wants to support disadvantaged people by showing them how they can also reach their potential and live out their dreams through science.

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FROM VENDA TO TOKYO IN PURSUIT OF **ROBOTICS EXCELLENCE**

CSIR researcher Dr Ndivhuwo Makondo.

Earlier this year, CSIR researcher Dr Ndivhuwo Makondo completed his PhD at the Tokyo Institute of Technology in Japan. His love for robotics was ignited when he was exposed to the world of electrical engineering during his tertiary studies. His vision is firmly set on creating a complete robotic machine, from research paper to marketplace.

Dr Ndivhuwo Makondo is a robotics researcher at the CSIR. He graduated with a Doctor of Philosophy in computational intelligence and systems science from the Tokyo Institute of Technology in Japan in March 2018 – worlds apart from the rural landscape of Venda in Limpopo. Yet, Makondo is not that surprised about where life has taken him; he dreamed big and set his goals high, early on.

"Before I went to high school, I wanted to be a medical doctor. At that stage, having only ever been exposed to life in a village, I saw it as the most prosperous career around. I did not necessarily have the passion for it, but I knew that I wanted to excel and come out at the top," he says.

His parents enrolled him at the Thohoyandou Technical High School where he was exposed to careers in engineering and he discovered his love for robots. Makondo realised that to build a machine with artificial intelligence you needed to start somewhere, and electrical engineering would lead him to his ultimate goal.

"I cannot say that I understood what electrical engineering would entail when I first heard about it in grade 10, but I was fascinated with the concept of building an artificial machine that manipulates our natural environment," he recalls.

He went on to study a BSc (Electrical Engineering) and a Master's, specialising in robotics, at the University of Cape Town. During his undergraduate studies, he participated in a vacation programme at the CSIR where he was involved in a project that focused on computer vision. The vacation work ended up taking him a step closer to ultimately working in the field of robotics.

When opportunity comes knocking

"A CSIR advert for a Master's studentship in robotics presented me with the chance to get into robotics. My vision had always been to program a complete system; complete in the sense that it has sensors to perceive the environment around it and makes decisions based on the collected data from the environment. I learned that in a research project you do not get to focus on the whole system; you focus on a small component that forms part of the bigger system. It is only now, by leading a project, that I get to control the bigger picture. I have not given up on that vision."

His parents laid a great foundation for him to flourish in his career because they made sacrifices for him to get the best things in life. "I did not have all the things I wanted, but what I had, provided me with a platform to pursue my degree," Makondo says.

Makondo draws inspiration from a number of scientists and philosophers around the world. He cites Sam Harris, "I like how he describes the world around us and the way he talks about complex topics as if they are simple. Another one is Michio Kaku, who excels in explaining science in layman's terms."

Closer to home, he is inspired by people who are doing great things, such as fellow scientists Prof. Fulufhelo Nelwamondo, Prof. Tshilidzi Marwala and Dr Rudzani Nemutudi, who come from similar backgrounds. "My former CSIR colleagues, Dr Ntsika Msimang and Dr Simukai Utete, also encouraged me and played a major role in me going to Japan," he says.

Off to the land of rising robots

It was through the encouragement of Nelwamondo, who heads the CSIR's modelling and digital sciences and Nkgatho Tlale, his Master's co-supervisor at the CSIR, that Makondo applied for a scholarship offered by the Japanese government, the MEXT scholarship of the Ministry of Education, Culture, Sports, Science, and Technology. MEXT scholarships make it possible for foreign students to study at Japanese universities.

Studying in Japan was not without challenges, but Makondo says, "I don't give up easily; once I start something I want to see it through." He realised that the Japanese tend to create friendships with their peers at an early stage in life, so he forged friendships with his fellow international students. To help overcome the language barrier, the MEXT scholarship provided a compulsory language course for the first six month of his studies. His pollen allergy worsened in Japan, causing him to struggle to sleep at night, which, in turned, affected his concentration. But Makondo was rewarded for his perseverance, obtaining a PhD and mastering robotics before returning to South Africa earlier this year to plough back his knowledge.

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SOUTH AFRICA SHINES AT **INTERNATIONAL SUPERCOMPUTER** COMPETITION

South African undergraduate students have placed in the top three positions of the international Student Cluster Competition every year since they first competed in 2012, claiming first prize a whopping four times.

David Macleod, CSIR principal engineer at the Centre for High Performance Computing (CHPC), who is responsible for South Africa's team each year, says that it all comes down to preparation.

"I think the students do well because we have a year-long relationship and engagement with the team. We've trained them, prepared them and they experience the competition we host at the national level," he says.

The Student Cluster Competition of the International Supercomputing Conference is the last stage of a year-long CSIR programme designed to introduce students to high-performance computing (HPC) at an early stage of their careers. Dr Happy Sithole, Director of the CHPC in Rosebank, Cape Town, believes that the CSIR is meeting an important need for HPC skills in this country.

"HPC is not taught at universities in South Africa," says Sithole. "We started this programme because we saw the need for HPC skills in the country. This initiative will enhance our research communities and improve how research is done, but also filter into industry."

HPC is a relatively new field in South Africa and the CSIR-managed national facility in Cape Town boasts the largest processing cluster on the continent – a collection of networked processors that provide the computing power needed to solve complex computing problems. The CHPC assists South African researchers to study complex climate models or sift through genomics data. The centre also assists industry, such as 3D animation companies like Triggerfish Studios.

Each year, universities around the country are invited to send teams of four to the first stage of the CSIR programme, which involves a week of intensive practical learning and culminates in teams designing their own supercomputer. The CSIR ensures that teams are entered from as many universities as possible, so that students from all backgrounds are given a chance to learn and compete.

After the first week, half of the teams are selected for the national CHPC Student Cluster Competition. Teams design and build computing clusters within a budget and the winning team goes to the international event in Germany. Supercomputers are expensive and this programme would not be possible without the generous support it receives from the Department of Science and Technology, Dell and Mellanox. Dell and Mellanox sponsor much of the hardware required for the national and international events. The South African team goes on a week-long tour of the Dell research labs in the United States of America, where they learn about the latest technology and work with Dell engineers to design the perfect cluster for the international competition.

Katleho Mokoena recently attended the international competition in Frankfurt, and says that the experience changed his life.

"I didn't even know the HPC industry existed," says Mokoena with a laugh. "A year later, I got to pick the brains of the professionals who create these supercomputers and push the industry forward.

"The competition took place over a period of three gruelling and stressful days. We had to keep our cluster operating at its best to reach more and more difficult benchmarks. Our mentors really helped us to just keep going when things were falling apart," says Mokoena.

The CSIR's HPC programme is already paying dividends. The CHPC donates old clusters to universities around South Africa and these students have the skills required for universities to develop their own HPC capacity. Others have applied what they learned to their own postgraduate research and a few are now putting their skills to use in the private sector. Sithole says that the company that installed the CSIR's most recent cluster employed two of their former competition winners.

"These students are really brilliant. Armed with this training, when they get into their research teams, they really fly," he says. "We're building a strong base of HPC skills in the country in both the public and private sectors."

The sponsors of South Africa's participation in the competition are the Department of Science and Technology, Dell EMC, Mellanox, Eclipse Holdings, Altair, Bright Computing, Intel and Microsoft.

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SETTING ALIGHT A PASSION FOR **EARTH OBSERVATION** IN YOUNG SOUTH AFRICAN SCIENTISTS

Meet Dr Renaud Mathieu

Dr Renaud Mathieu, supported by CSIR researcher Nokuthula Wistebaar.

Once you have reached a certain point in your career as a scientist, it is very important to contribute to uplifting the scientific community and ensuring that young scientists are exposed to the same opportunities you have enjoyed in the past. That is your main legacy, says CSIR chief scientist Dr Renaud Mathieu.

In South Africa, earth observation is a very young field. Dr Renaud Mathieu is the first to admit that, for this reason, there is a large number of foreigners, like him, in the field. Mathieu is of French descent and endeavours to leave behind a legacy of contributing to the development of earth observation skills in South Africa. Under his and his team's mentorship, the CSIR produced the first PhD in remote sensing by a black South African in 2011, Dr Abel Ramoelo and, since then, more than 10 PhD-level South African remote sensing experts.

Mathieu joined the CSIR a decade ago when the organisation did not have any radar remote sensing skills. "I developed a research programme to use light detection and ranging (LiDAR) air-borne datasets and satellite-based synthetic aperture radar (SAR) to map forests," says Mathieu, who is also the CSIR research group leader for earth observation. Under his leadership, the CSIR produced South Africa's first map of woody cover and biomass that is used by the Department of Environmental Affairs and South African National Parks for the management of forestry, biodiversity and agricultural resources.

He attained the title of chief scientist in 2015. "Hard work and persistence are needed to attain the title of chief scientist, but it is an achievable goal for all dedicated scientists," he says. While he already works closely with the staff in his research group to exploit their potential, he says he would be overjoyed to mentor other young CSIR scientists and show them how to advance on the CSIR career ladder. His advice to aspiring chief scientists is to look at the criteria – not at other chief scientists – and work towards that.

For this chief scientist, it all comes down to passion. "It is important for scientists to have a passion for their science; the technical aspects can always be learned." Testament to his passion for remote sensing, he says that if funding was not an issue, he would further investigate bush encroachment in Africa. "It is a significant issue because it is linked to biodiversity and food security," he says. More trees mean less grass for cattle to graze on, resulting in food insecurity.

"I am not the most technological savvy person around," he quips, seemingly embarrassed by this admittance, "but it was the combination of technology and natural sciences that attracted me to earth observation."

"The core of what my team and I do at the CSIR is develop systems to document what is where and how it changes, in a wide range of environmental aspects and biomes, including forests, rangelands, wetlands or marine biomes," says Mathieu. "This then provides a foundation from which to make decisions." Although the team relies on satellite data, Mathieu emphasises that a lot of the time the team has to physically go to the field to validate and calibrate models.

Having applied his skills set to water, soil moisture, snow, glaciers and wildlife, Mathieu is particularly intrigued by the versatility in the application of remote sensing.

Meet Dr Renaud Mathieu

Mathieu has a PhD in geographic information sciences from the Université Paris-Est Marne-la-Vallée, France. He has 23 years of international research experience, gained in countries including Canada, Chile, France, New Zealand and the United Kingdom, in remote sensing and spatial analysis applied to soil and water conservation, natural resource and wildlife management, ecology, environment and agriculture. He has experience in a wide range of earth observation platforms from ground to airborne LiDAR and satellite sensors at high, medium and coarse resolution (SAR, optical).

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object. Remote sensors collect data by detecting the energy that is reflected from Earth. These sensors can be on satellites or mounted on aircraft.

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▲ Above: Dr Mathieu enjoys mentoring the young scientists in his research group. Pictured alongside him are (from left) Russel Main, Dr Laven Naidoo and Nokuthula Wistebaar.

EXTENDING THE LIFESPAN OF OUR **NATURAL RESOURCES**

Meet Dr Bruce Sithole

CSIR chief researcher Dr Bruce Sithole.

CSIR chief researcher Dr Bruce Sithole says at one point he did not realise how much science and engineering went into making paper. With the use of paper declining, he has been instrumental in interventions to use waste from wood to create more high-value products that can place the CSIR at the forefront of global research and improve various industries.

Planting the seed

Dr Bruce Sithole grew up in Zimbabwe and, as one of the most promising students in primary school, he was selected to spend a day at his potential high school. During this excursion, his visit to the science class – where an experiment using ice as a conductor of heat was being carried out – peaked his interest in chemistry. He began running his own experiments at home; teaching his siblings about all the new work he was now learning.

Sithole's resilience was forged when he pursued his Bachelor of Science in chemistry, in Sierra Leone. At the time, the University of Freetown was the only place he could pursue the science he wanted to learn. A new environment and culture also gave him exposure to new ways of thinking. He obtained his MSc in analytical chemistry from the University of Aberdeen, in Scotland, and his PhD in industrial chemistry from the Dalhousie University, in Canada. Here he began his work to develop methods to improve the quality of Canada's paper industry, which, at the time, contributed to 25 per cent of the country's GDP. As more people and industries moved away from using paper, the world started to look at what else could be done with wood waste. He was recruited by the CSIR to help revitalise the CSIR's forestry programme while at the Pulp and Paper Research Institute of Canada, where he was a principal scientist and a group leader.

Turning trash into treasure

Sithole is currently the research group leader and director of the CSIR's Biorefinery Industry Development Facility (BIDF), which he was instrumental in establishing. He is also a professor of chemical engineering at the University of KwaZulu-Natal (KZN). He leads and conducts research on biorefinery technologies that are helping to extract value from waste materials, such as saw dust waste. "Part of what I do is to explore the ways in which we can extract valuable materials from waste by creating new products and value chains. This comes at a time when landfills are overfilled and greenhouse gases are a cause for concern for governments," he says.

The BIDF helps local industries that can benefit from the high-value products extracted from waste. One example is the Eucalyptus tree, which is used to make paper or used in the timber industry, where only about 47% of the tree is used and the majority lost as waste. CSIR researchers

"Part of what I do is to explore the ways in which we can extract valuable materials from waste by creating new products and value chains."

extract hemicelluloses (xylose) from saw dust waste from the tree and use it to make products such as xylitol, an alternative for sugar, which is recommended in the lifestyle and wellness sectors. His research group focuses on revitalising and improving the resilience of the pulp and paper and forest industry, by diversifying the production into biorefinery activities that will generate high-value products. The technologies and infrastructure of the BIDF are capable of processing other biomass and thus, the facility is recognised by the Department of Science and Technology (DST) as a national facility for biorefinery technologies. For example, the researchers are working on beneficiation of waste chicken feathers to produce high-value materials, such as keratin and lightweight composites.

Growing the next generation of researchers

Sithole is a C-rated NRF scientist and, through his work, he has had extensive collaborations in South Africa, Europe, Japan and North America. He provides local and international consultation services to the pulp and paper industry. He is also a permanent international executive committee member of the International Symposium on Wood, Fibre and Pulping Chemistry.

During his tenure at the CSIR, Sithole has helped to secure funds and collaborated with stakeholders, such as the DST, which, through its Industrial Innovation Partnership Fund, contributed to the new world-class biorefinery facility in Durban. He has contributed to the graduation of 10 MSc and PhD students who have been absorbed by industry and academia. He is currently supervising 20 PhD and MSc students at the UKZN, and hosts a number of post-doctoral fellows. He has over 130 publications in peer-reviewed journals, with an h-index of 19.

He is now teaching new scientists about the benefits of reusing waste to create a sustainable future, much like he taught his siblings when he first fell in love with science.

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YOUNG, QUALIFIED AND GAINING EXPERIENCE

Working with SETAs to provide valuable practical experience

The CSIR runs an internship programme that provides new graduates and post graduates with the opportunity to gain practical experience, which augments their theoretical studies under the guidance of more experienced professionals. The programme is spread across various fields, with a strong focus on science, engineering and technology. The CSIR collaborates with various institutions, including sector education and training authorities (SETAs), as part of its strategy to address youth unemployment in the country.

As part of an agreement with the Media, Information and Communication Technologies Sector Education and Training Authority, the CSIR trained 45 unemployed youths in a year-long programme. The CSIR also hosted four interns as part of an agreement with the Energy and Water Sector Education and Training Authority.

In another collaborative undertaking, the CSIR and the Manufacturing, Engineering and Related Services Sector Education and Training Authority are jointly developing new apprenticeship skills in preparation for the current worldwide technological transformation known as the fourth industrial revolution.

New graduates in science, engineering and technology fields interested in gaining work experience are eligible for the CSIR's internship programme. The interns receive informal training through tailored short courses and financial support through a monthly stipend. They also get the opportunity to work on CSIR projects under a mentorship programme.

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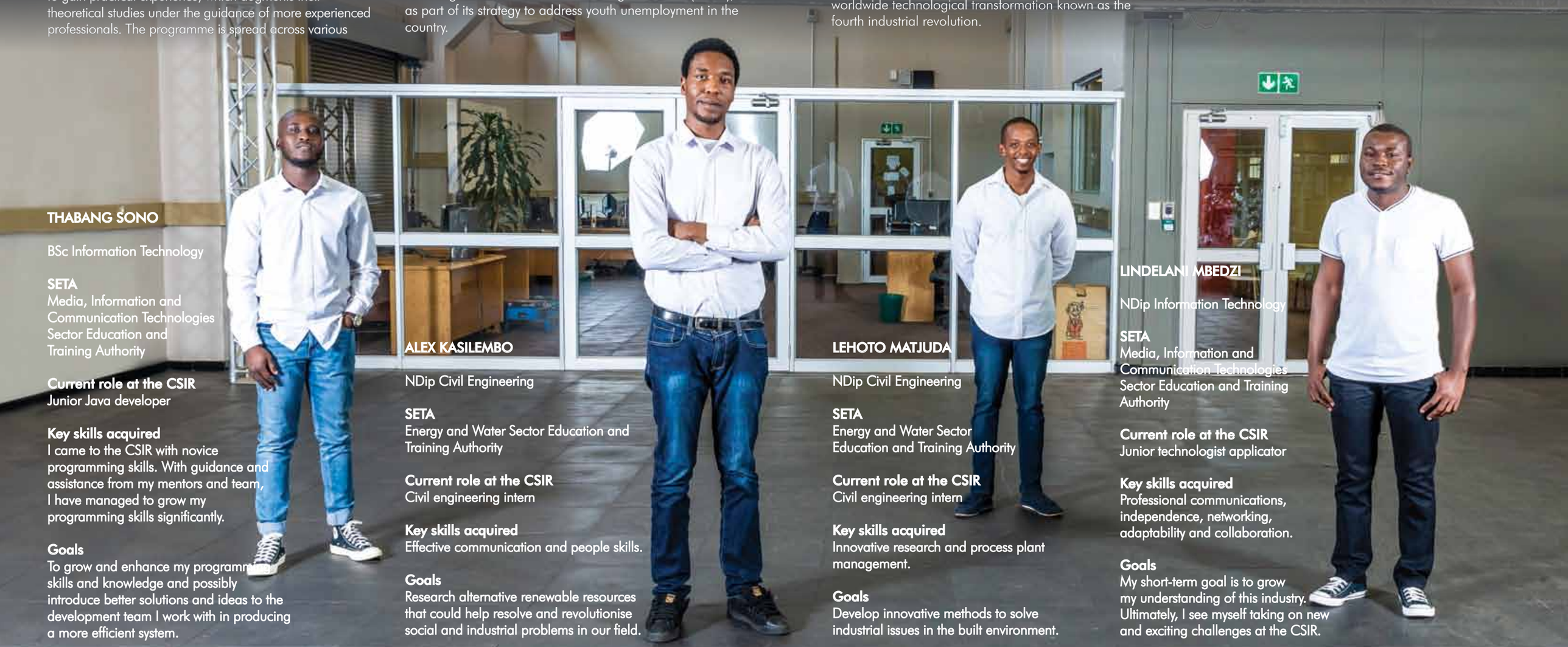


THABANG SONO

BSc Information Technology

SETA
Media, Information and Communication Technologies Sector Education and Training Authority

Current role at the CSIR
Junior Java developer

Key skills acquired
I came to the CSIR with novice programming skills. With guidance and assistance from my mentors and team, I have managed to grow my programming skills significantly.

Goals
To grow and enhance my programming skills and knowledge and possibly introduce better solutions and ideas to the development team I work with in producing a more efficient system.

ALEX KASILEMBO

NDip Civil Engineering

SETA
Energy and Water Sector Education and Training Authority

Current role at the CSIR
Civil engineering intern

Key skills acquired
Effective communication and people skills.

Goals
Research alternative renewable resources that could help resolve and revolutionise social and industrial problems in our field.

LEHOTO MATJUDA

NDip Civil Engineering

SETA
Energy and Water Sector Education and Training Authority

Current role at the CSIR
Civil engineering intern

Key skills acquired
Innovative research and process plant management.

Goals
Develop innovative methods to solve industrial issues in the built environment.

LINDELANI MBEDZI

NDip Information Technology

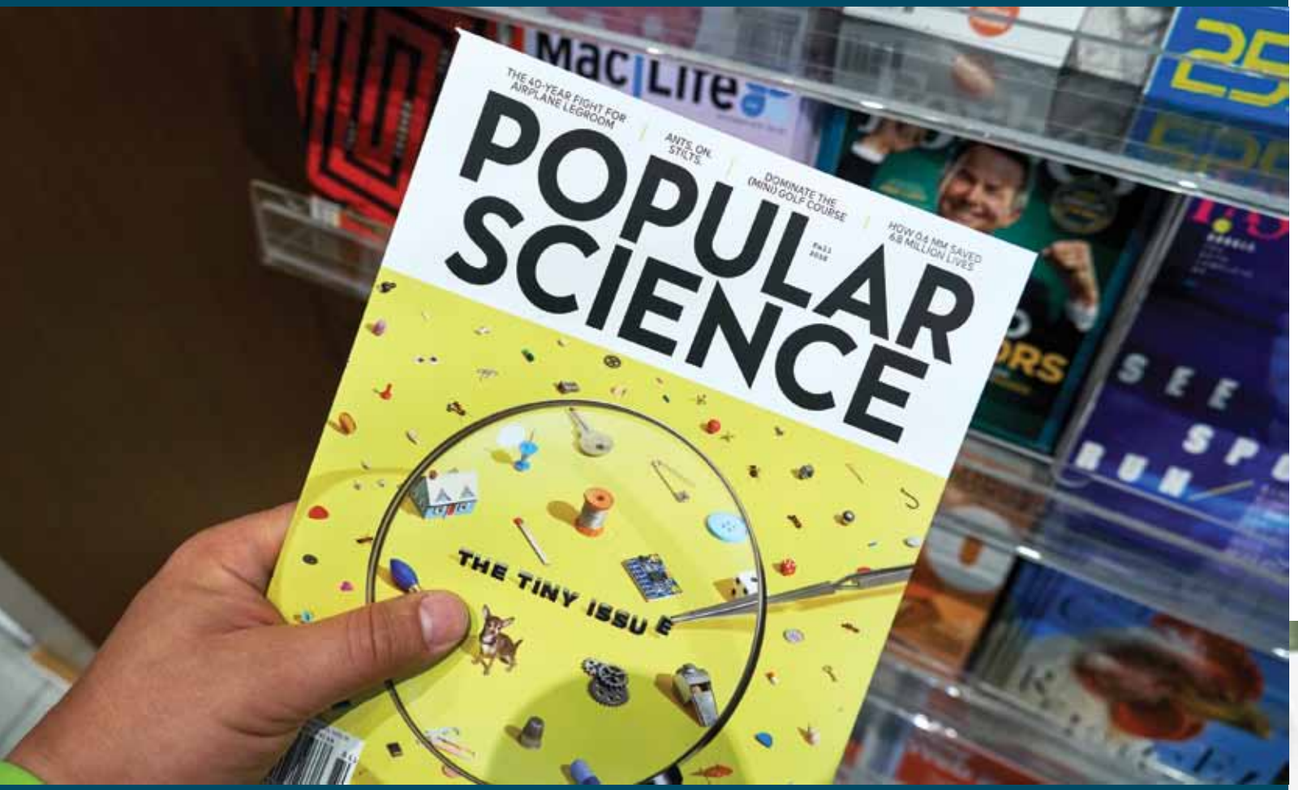
SETA
Media, Information and Communication Technologies Sector Education and Training Authority

Current role at the CSIR
Junior technologist applicator

Key skills acquired
Professional communications, independence, networking, adaptability and collaboration.

Goals
My short-term goal is to grow my understanding of this industry. Ultimately, I see myself taking on new and exciting challenges at the CSIR.

GETTING PUBLISHED: DISSEMINATING SCIENCE THROUGH PUBLISHING



Scientists strive to see their work appear in top science journals. Scientific publishing is commonly used as an indicator of research performance, typically because it has the built-in quality control mechanism of peer review – when two or three experts review the methods, data and reasoning. Inclusion in a top science journal is no easy feat, as high-impact journals typically have a low acceptance rate because the competition is fierce. Meet some of the CSIR researchers who have recently contributed to the organisation's research being included in reputable journals and books.

Top chemistry journal publishes CSIR research on metal organic frameworks

Dr Jianwei Ren, principal researcher at the CSIR's hydrogen research group, and his colleagues in the group, are working towards South Africa's national aims for hydrogen. At Hydrogen SA (HySA) Infrastructure, they work with a new generation of materials called metal-organic frameworks (MOFs), complex sponge-like materials that can be used to store gases, like hydrogen, very efficiently. In 2017, Ren and his colleagues published two articles in *Coordination Chemistry Reviews*, one of the best journals in chemistry, with an impact factor of 14.5. One of them was a review of pilot-scale production of MOFs, which the researchers are extremely proud of.

"Usually, only top researchers would be invited to publish a review in high-profile journals," says Dr Henrietta Langmi, key programme manager for HySA Infrastructure. "For us to have an uninvited submission be successful is a really big thing. It means the quality of the work is extremely good."

Ren believes that they were successful because they identified a gap in the literature and worked extremely hard to write a good review that will be beneficial to other researchers in the field. The HySA Infrastructure team has been working to reduce the cost of producing MOFs for about six years, and they are world leaders in some aspects of this process.

"We focus on applications of MOFs, rather than discovery," Ren says. "We are interested in stable and cost-effective MOFs that we can use for various applications, so we look for ways to bring down the production cost." One way that they are pursuing, is making MOFs from recycled PET (polyethylene terephthalate) plastic waste, which can potentially reduce the costs of production.

"We saw that the literature on pilot-scale MOFs production was scattered. It was the right time to bring it all together and convey that information to other people working in this area," says Ren.

"Because we saw a gap, we expected it would be well-received," Langmi adds. "So, we identified the highest impact factor journal we could find with the right scope for the work, and we went for it. If you know your work, you know the impact it will have."

The researchers point out that it is not easy to write a good review paper, and that they worked hard to make sure that it was well-written.

"If a paper is well-written, you actually enjoy reading it; that is a very important skill," explains Ren. "We are always practicing our writing skills to improve the quality of our papers."

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▼ Below: CSIR principal researcher Dr Jianwei Ren.

Fast fact

In 2017/18 the work of CSIR researchers was published in 546 journal articles, books and conference papers.

CSIR post-doctoral researcher Dr Sabelo Madonsela.

Improved estimate of tree species diversity in the African savannah included in top remote sensing journal

Sabelo Madonsela, a recent PhD graduate of the CSIR's earth observation research group, says that research is not complete until it has been shared with an international audience.

"If I do research, I must publish the results, but also go and present it at a conference; find an audience to hear it," says Madonsela. "I want that international perspective on my work."

Madonsela has been hungry for publication since his honours work, even before he joined the CSIR.

"I was ambitious in terms of getting published, I even wanted to publish my honours thesis. Looking back now, I know that would have been premature," he says with a laugh. "When you get published and cited, that says that other researchers are in agreement with the ideas that you have put forward. That is important to me."

Madonsela completed his MSc at the CSIR and has recently completed his PhD using satellite data to estimate tree species diversity in the African savannah. He has published six papers in the six years that he has been at the CSIR, a remarkable achievement. The first paper to come out of his PhD was included in a high-impact journal in this field.

"Journal rankings are released annually and, last year, the *ISPRS Journal of Photogrammetry and Remote Sensing* was number one in remote sensing. I knew that was where I wanted to send my work."

Madonsela knew that publishing in a high-impact factor journal meant that his work would be subjected to an unprecedented level of scrutiny. But, he was confident that it was good enough and welcomed the criticism.

His paper, titled *Remote sensing of species diversity using Landsat 8 spectral variables*, described a method to estimate biodiversity using satellite data, which he believed would be more robust than previous methods, because it uses spectral information across all wavelengths detected by Landsat 8.

"Previous studies estimating biodiversity have mostly relied on normalised difference vegetation index, which uses red and near-infrared light. Our approach moves beyond the visible and near-infrared regions and incorporates shortwave spectral bands, which contain additional information about plants. At the back of our minds, we thought it would give us a better diversity estimate, and that turned out to be the case."

His advice is to welcome reviewers' criticisms, as they help to make your work better.

"In good journals, the reviewers are attentive; they help you to see your mistakes more clearly. You have to take the comments seriously and be objective in your response or your paper will not be accepted."

He also believes in the value of writing well and thinking carefully about your audience.

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Reaching the green building sector in South Africa

Llewellyn van Wyk, a CSIR principal researcher and guest lecturer at the University of Pretoria, is currently working on the 12th annual Green Building Handbook. He has been its editor since the first edition in 2006 and believes that the handbook reaches people that other forms of academic publication cannot.

Aimed at architects, engineers, quantity surveyors, as well as municipalities, the free manual provides people who are interested in sustainable building practice with credible information, as well as economically and functionally viable green building options.

"We try to present scientifically sound information: You can use this; this is how you use it and this is the likely performance you can expect," says van Wyk. "We are sharing our research with a broader domain, in a format that has a life of its own. Most people I know have kept the handbook and the volumes build up to a compendium that should not date much."

Van Wyk spent 20 years working as an architect in the green building sector before helping to form the Green Building Council of South Africa and serving as a member of its first board. In 2002, he joined the CSIR to find ways to make the construction industry more sustainable.

"The construction industry is one of the most old-fashioned industries around. It is dirty, slow, and dangerous. We expect people to put together complex structures of a certain quality, out in the elements, within a certain time and budget. It just does not happen."

His work looks at ways to improve on this, for instance, by developing new materials to replace bricks and cement.

"The Green Building Handbook is something that people will use; it started with the theory of green building and we have seen a shift from theory to practice over the years. It has documented the growth of sustainable building in South Africa."

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CSIR principal researcher Llewellyn van Wyk.

CSIR senior researcher Dr Darryl Naidoo.

CSIR researcher cracks unconventional method to enhance the brightness of solid-state lasers

A journal paper, titled *Brightness Enhancement in a Solid State Laser by mode of Transformation*, by senior researcher Dr Darryl Naidoo, has been published in the Optical Society's high-impact journal, *Optica*. The paper formed part of his PhD studies. Prof. Andrew Forbes of the University of the Witwatersrand contributed in terms of the research idea and his CSIR colleague, Dr Igor Litvin helped develop the theory.

"We took an interest in this research work because, according to conventional standards, it is not possible for a solid-state laser to simultaneously maximise both the mode quality and mode energy and therefore, brightness cannot be optimised. We were determined to demonstrate that this is possible if an intra-cavity laser beam shaping method is used," says Naidoo.

The brightness of a laser is an important characteristic that defines the potential of a laser beam to transmit high energies over long distances. Usually, to achieve this, one is required to maximise energy from a laser, while maintaining a good quality laser mode. These two critical factors need to be taken into consideration for the desired output. Since the laser mode is the same everywhere in solid-state laser cavities, achieving both parameters is not trivial. In the pursuit of high power, the quality of the laser mode often declines and ultimately decreases the brightness. Similarly, by optimising a laser for a good quality mode, the output power decreases, which results in a degradation of the brightness.

The CSIR, in collaboration with the University of the Witwatersrand, did the unconventional by using laser beam shaping via two optical components internal to a laser to transform a good quality laser mode into a mode that is optimised for energy extraction and back again. As a result, the mode inside the laser was now not the same, thus enabling both parameters to be achieved. In this work, the team demonstrated an enhancement of the brightness of an off-the-shelf commercial laser by 350%.

Naidoo, who was responsible for the experimental realisation of the concept both external and internal to the laser and simulating the profiles of the optical components, explains: "External to a laser, the concept was tested on a spatial light modulator where the corresponding designs were used to manufacture optical components for use inside a laser cavity." His biggest challenge was handling the optical components inside the laser as each component had four degrees of freedom. As a result, this made the system difficult to construct and manipulate.

The envisaged impact of the research is to break away from the conventional design approach that indicates that a laser mode inside a solid-state laser cavity is one particular beam.

"This work explored a novel approach to mode selection in solid-state lasers that now gives allowance for geometrical adaptation. Additionally, this method serves as a general approach for optimising laser brightness, which will be especially useful for slab laser configurations," says Naidoo.

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CSIR TECHNOLOGIES CONNECT **SMART MEDICAL DEVICES** TO CLOUD

▲ Above: Product lifecycle management for point-of-care medical devices.

The CSIR has partnered with a leading health care provider in Africa to connect point-of-care medical devices to a cloud service.

The CSIR's Pieter Roux says researchers are developing a platform that will enable medical device manufacturer and distributor MSQ Health to improve device management and, hence, patient care.

"The technology that we are currently working on will allow MSQ Health to monitor a device in a clinical setting or location," says Roux. Instantaneous information, such as who is using the device and for how long, could help the company to proactively maintain and service its products, which would increase their lifecycle.

Roux envisions that once the cloud service has been established, there will be room for further innovation to turn the point-of-care devices into smart devices, which could then be monitored from the time they are manufactured in the factory until they are used in the field. They also hope to introduce machine learning to further improve business practices.

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ELECTRONIC WARFARE **LABORATORY** TAKES OFF

The engineering teams refer to the pod, here seen beneath an Impala aircraft, as Inundu – an isiZulu word for moth. The tiger moth uses click sounds to disrupt a bat's echolocation ability, making it nature's own cunning 'acoustic warfare expert' and a fitting moniker for a smart detection/deception capability.

The CSIR has developed an electronic warfare pod that can be hosted on a number of fast jet types to provide a dynamic, multi-angle and more agile means of testing the effectiveness of radar and electronic warfare applications than the traditional ground-based systems. In the most recent tests, the pod, which serves as a mobile test laboratory, has proven its compatibility with the Hawk aircraft.

RESEARCH AND TECHNOLOGICAL INNOVATION

▲ Above: The pod, or mobile test laboratory, fitted on a Hawk aircraft.

The pod is the result of a multiyear development programme between aeronautics experts and their counterparts in the fields of radar and electronic warfare at the CSIR, as well as a set of commercial partners from industry.

The pod is similar in look, size and mass to a commonly used external store on fast jet types, such as the BAE Hawk, Alpha Jet, Hawker Hunter, F-16, Tornado, F-4 Phantom and the Mirage III – which all have the ability to carry the system without costly reconfigurations or integration and clearance. It is a faster and less costly platform with which to test new airborne payloads. Its programmable capability means it can be used to test a range of radar or electronic warfare threats. It is also an effective and safe way to train operators.

The pod has proven its compatibility with and safe operation on the Hawker Hunter, the Cheetah and the Hawk aircraft – the latter being a platform operated by the South African Air Force.

In the test phases, the functionality of the pod's various systems, including its electronic warfare payload, was tested rigorously in various operational flight profiles, including simulating anti-ship missile engagements at high speeds and very low altitudes. Stringent environmental testing was also done. By 2015, the first flight trials were performed to evaluate the effect on aircraft handling, performance and robustness of the pod structure and reactions in its internal environment.

Independent power supply

The pod was designed and has been tested to operate using a CSIR-designed ram air turbine to avoid it drawing on the power supply of the host aircraft. The ram air turbine is a small, electrical device that generates power by utilising the airstream of the aircraft in flight. This is an alternative to a battery-based powerpod – similar in size – that would also need to be installed on the jet. The ram air turbine underwent rigorous testing at the CSIR's turbine test facility, as well as wind tunnel testing at different speeds and air pressure monitor points.

While the main use of the pod is to evaluate the effectiveness of electronic warfare and radar interventions, it also allows engineers to experiment with different approaches and is an ideal platform for the training of young electronic engineers, as well as radar and electronic warfare operators.

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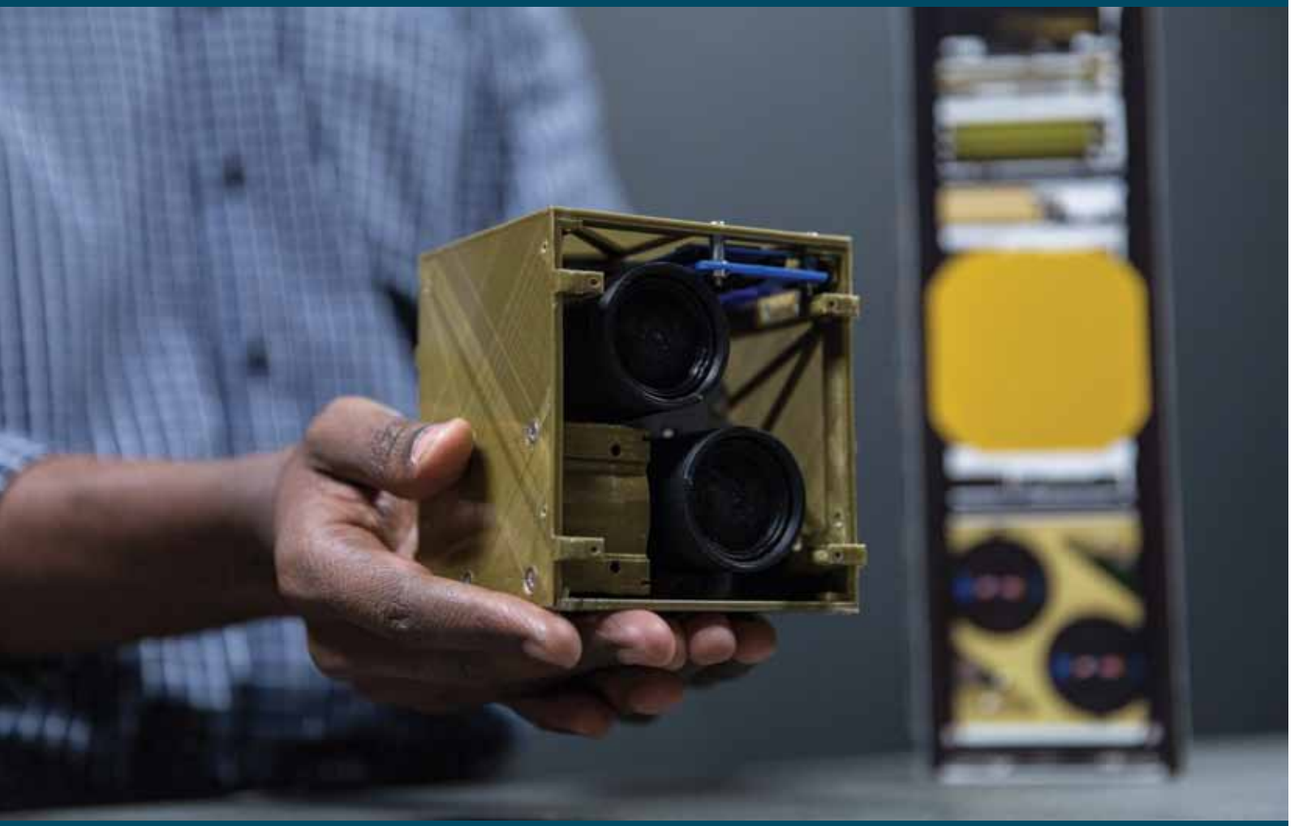
▼ Below: (left) The ram air turbine underwent tests in the CSIR's medium speed windtunnel to validate the levels of power it was able to generate over the full flight envelope of the pod. (Right): The pod was also tested on a Mirage F1 fighter plane.

HOME-GROWN TECHNOLOGIES TO HELP **DETECT WILD FIRES**

CSIR-developed camera set to be launched on South African nanosatellite



When South Africa's ZA-CUBE-2 nanosatellite is launched, a CSIR-developed optronic payload will be travelling into space with it. The CSIR has been working with the Cape Town University of Technology, the South African National Space Agency and the Department of Science and Technology on the Operation Phakisa ZA-CUBE-2 nanosatellite programme for a number of years to find a solution for improved monitoring and early warning of wild fires.

▲ Above: (left) A 3D printed plastic model of the K-line camera. (Right) A mock-up of the 30 x 10 x 10 cm ZA-CUBE-2 satellite with the K-line camera at the bottom of the cube stack.

Said to be a result of global warming, wild fires have been increasing – in frequency and due to longer fire seasons. According to Lloyd's insurance index, the economic impact of wild fires in South Africa has been estimated at £225 million (about R4 billion) over the past five to seven years. This, of course, aside from the tragic loss of lives.

The ZA-CUBE-2 was originally intended to host an automatic identification system for ships and software-defined radio payloads; the addition of the camera payload for fire detection was accommodated as a secondary mission objective.

The nanosatellite has compact dimensions that fit in a 10 x 10 cm footprint, with a height of 30 cm.

The CSIR's optronic sensor, dubbed the K-line camera, spots forest fires from space by detecting traces of potassium (the element K on the periodic table of elements) emitted and radiated from burning vegetation. It is one of the first known instances of using potassium line emissions technology for fire-sensing applications in space.

Once successfully in orbit, the K-line camera prototype is expected to demonstrate the power consumption, false alarm rate, spatial and temporal resolution advantages of this low-cost system over other near-infrared thermal imagers.

Captured forest fire data are to be transmitted to ground stations owned by project partners from where they will be made available to end-users via the CSIR's Advanced Fire Information System.

The CSIR has developed calibration and space-qualification procedures to support the expansion of the nanosatellite constellation in future, as well as further K-line camera applications. The increased constellation will reduce the ground revisiting times and support near-real time global coverage, which has a variety of benefits for commercial players.

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PROTECTING PROBIOTICS FOR **IMPROVED EFFICACY**

Researchers aim to extend the application of a CSIR-developed encapsulation technology for probiotics to other sensitive actives, such as vitamins, enzymes, vaccines and phytochemicals.

Researchers at the CSIR have found a novel way of encapsulating probiotics, which will prolong their shelf-life and improve their efficacy by ensuring that they are not destroyed by gastric fluids prior to being released in the small intestines, after being ingested.

▲ Above: (from left) Preparation of a polymer-probiotic premix; adding the premix to a high-pressure CO_2 vessel and the encapsulated probiotic.

Probiotics are healthy bacteria found naturally in the small intestines in the human body. These bacteria help with the absorption of nutrients and boosting the body's immune system, among others. However, factors such as illness, poor eating choices, stress and antibiotic use can affect the balance of the probiotics found in the body.

To replenish the body with healthy bacteria, probiotic-containing supplements are prescribed. However, due to the very sensitive nature of probiotics, many die during manufacturing, transportation or storage. In addition, large numbers of viable probiotics are degraded in the acidic gastric juices before they reach the intestines.

As a result, many probiotic-containing products do not meet the World Health Organization's minimum recommended concentration of probiotics to impart health benefits.

A novel technology to preserve probiotics

To ensure that the full count of probiotics originally included in a product reaches the small intestines, probiotics need to be encased in a shell material that protects them from external environmental factors, such as oxygen, moisture, high temperatures and gastric fluids. Using their expertise in polymers, CSIR researchers determined that an interpolymer complex was a feasible choice as shell material for probiotic encapsulation. An interpolymer complex is a system whereby two different types of polymers attract each other, usually via hydrogen bonds, to form a dense network. In acidic conditions, the attraction between the polymers is strong and the complex remains intact, while in basic conditions the molecules repel each other, leading to complex dissolution.

The shell material is pH-responsive, which protects the probiotic when passing through the acidic stomach and releases the probiotic in the small intestines. Furthermore, the dense network of the interpolymer complex acts as a barrier, limiting the amount of atmospheric oxygen and moisture reaching the probiotic.

Conventional methods of encapsulation include spray drying, freeze-drying, prilling and extrusion. These processes expose the active ingredients to one or more of the following: organic solvents, water, high temperatures and atmospheric oxygen. All of these have negative effects on the stability of probiotics. The CSIR employs an encapsulation process based purely on supercritical carbon dioxide. This process is oxygen-free and does not require the use of organic solvents, water or high temperatures. When carbon dioxide is heated slightly and compressed, it turns into a supercritical fluid that can dissolve or liquefy substances, such as drugs, lipids or polymers. The result is that an active, such as probiotics, can be blended with an encapsulating shell material in the complete absence of oxygen and organic solvents, while operating at very mild temperatures.

Upon evaluation of a wide range of potentially suitable interpolymer complex formulations, the CSIR researchers discovered a novel interpolymer complex that can be formed in supercritical CO_2 and used for probiotic encapsulation. The combination of this interpolymer complex and the supercritical CO_2 process ensures probiotic stability on the shelf and when passing through gastric fluids. The research was validated by the University of Pretoria, through several successful tests, to show that the count of viable probiotics in the interpolymer complex encasing was significantly improved after accelerated shelf-life trials and exposure to simulated gastric fluids. An independent study at Ghent University, in Belgium, using their Simulator of Human Intestinal Microbial Ecosystem, showed that probiotics encapsulated using the CSIR probiotic encapsulation technology delivered 10 000 times more probiotics in the small intestines than unencapsulated probiotics.

Snatched up by the market

A commercial licence of the CSIR probiotic encapsulation technology was sold to Cantobiz Lighthouse (Pty) Ltd, where the encapsulated probiotics will be incorporated into meal replacement preparations and dietary supplements for various target audiences.

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SHIMMERING GLASS-INFUSED ASPHALTS COULD BE THE FUTURE OF SOUTH AFRICA'S ROADS

CSIR researchers are exploring the potential use of crushed glass as a substitute for traditional aggregate in asphalt mixes by determining the performance characteristics of hot-mix asphalt produced with glass material.

RESEARCH AND TECHNOLOGICAL INNOVATION

For the first time in South Africa, researchers are studying the potential use of glass in road construction. Glass is considered a potentially promising modifier to asphalt. The research to date, led by the CSIR's Dr Joseph Anochie-Boateng, has found that asphalt containing crushed glass performed better compared to traditional asphalt in some performance categories.

"Based on the lab evaluation, a glass-asphalt mix fared better than traditional hot-mix asphalt on rutting performance. Put simply, rutting happens when the passage of a vehicle causes a furrow or track in the surface. In terms of durability, the glass-asphalt mix performed very well," says Anochie-Boateng.

The dynamic modulus (stiffness characteristic) of the glass asphalt was 25% higher than that of the conventional asphalt mix and the flow number (rutting parameter) of the glass asphalt was approximately 26% higher than that of the conventional asphalt mix. These indicate that the glass mix would exhibit better rutting performance in the road than the conventional mix.

In addition, the microscopic morphology test indicated higher angularity (containing sharp corners) of the crushed glass than that of the natural aggregates, which results in an increased interlock between the particles and high resistance to rutting.

The benefits of using crushed glass outstrip the use of conventional aggregates in asphalt hot-mix. "The use of glass in road construction will not only cut the costs of asphalt production, but will also address environmental issues associated with glass as waste," Anochie-Boateng says.

"The use of glass in road construction will not only cut the costs of asphalt production, but will also address environmental issues associated with glass as waste."

Even though most glass can be recycled, in recent years, only about 20% of glass containers produced in South Africa have been recycled. About 550 000 tons of waste glass is not recycled and ends up in landfills every year.

"Based on an extensive literature survey on the use of crushed glass in asphalt, we decided to undertake a thorough local research study on the use of glass materials in asphalt," says Anochie-Boateng.

The next step is to conduct field trials and invite industry as a way of demonstrating that crushed glass, as an alternative to traditional aggregate, works.

CSIR researcher Theresa George has completed her Master's (cum laude) at the Stellenbosch University. Anochie-Boateng and George published a paper in *Proceedings of the Institution of Civil Engineers – Construction Materials* in 2017 and have presented papers at two international conferences.

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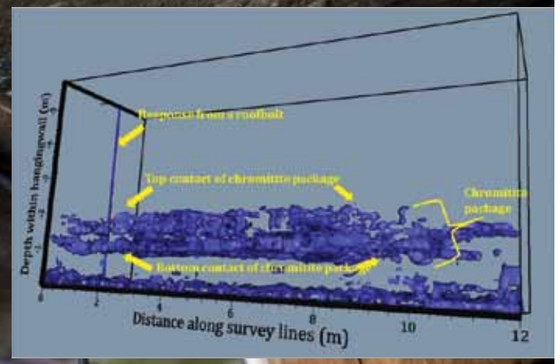
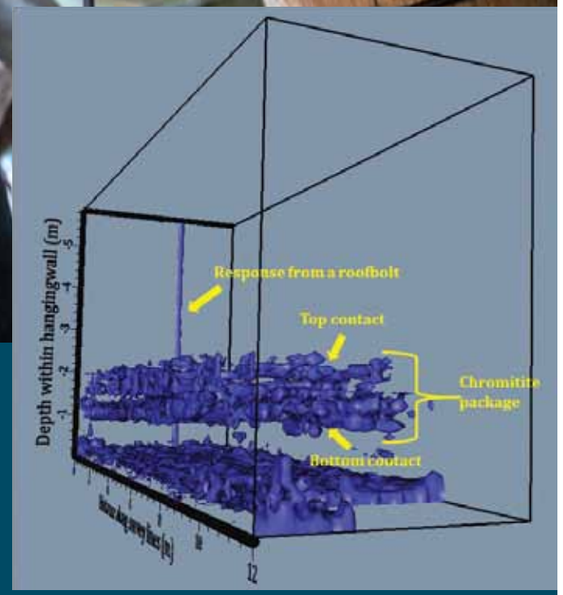
◀ Left: A sample of crushed glass. The use of crushed class is being studied as a substitute to natural aggregate in asphalt mixes.
▲ Above: Laboratory-compacted glass-asphalt test samples.

3D MODELS OF HANGING WALLS IN PLATINUM MINES TO IDENTIFY THE **RISK OF ROCK FALLS**





In the first study of its kind, CSIR geophysicists illustrated that generating three-dimensional models of the hanging wall in platinum mines is possible; and that these models could possibly aid in identifying and quantifying the risk posed by rock falls.

In recent years, the mining sector, which is a cornerstone of South Africa's economic development, has suffered decreased productivity, increased input costs and increased geotechnical complexities at current mining depths. And, despite a significant decrease in the number of mining related fatalities, CSIR geophysicist, Thabang Kgarume says that rock falls still remain a major concern to the industry.

South African underground gold and platinum mines extract tabular orebodies where intense fracturing around the excavation occurs due to the high stresses encountered at such depths. Kgarume explains that the hanging wall is often compromised by the combination of joints and fractures in tabular stopes. Joints are naturally occurring breaks in the rockmass, while fractures are usually caused by rockmass failure due to high-induced stresses.

"This causes blocks of rocks to fall and may result in injury to underground personnel and damage to infrastructure," explains Kgarume. "In order to mitigate these risks, it is imperative to better understand the hanging-wall conditions from a safety perspective."

CSIR geophysicists conducted a study to test whether or not it is possible for three-dimensional (3D) ground penetrating radar (GPR) surveys to be conducted underground. Kgarume explains that 3D GPR surveys are mostly carried out on the surface. They are often used to assess road integrity, locate underground pipes and detect ground subsidence, among others.

He says that, to date, only two-dimensional (2D) GPR surveys have been conducted underground. "But such surveys provide limited information about the hanging-wall conditions – rock engineers want to see and understand more. You want to understand the lateral extent of hazardous structures, such as low-angled joints and faults, or the spatial variation in fracture characteristics, as this information can be used to improve hanging-wall support design and to contribute to a safer working environment as part of the goal of causing zero harm." To do this, the researchers designed a 3D GPR survey.

The first 3D GPR survey in a South African platinum mine

A 3D GPR survey was conducted to assess the hanging-wall conditions in an underground platinum mine. The

To date, only two-dimensional ground penetrating radar surveys have been conducted underground.

depth of penetration was approximately six metres within the hanging wall, with the survey lines collected parallel to each other with 10 and 20 cm line spacings.

"The two line spacings were used to assess the effect of the line spacing on the quality of the model derived," says Kgarume. He adds that 20 cm was found to be the maximum line spacing for data acquisition. Anything more would compromise the accuracy of the 3D image rendered."

In traditional 2D surveys, a single survey line is acquired, only rendering information and imaging from one perspective, "but there is more to understand about the rockmass from a 3D perspective," says Kgarume, explaining that the team had to conduct a series of 2D GPR surveys to attain a 3D GPR volume image.

Once the surveys are completed, a 3D image of the hanging wall is rendered. These images can be used by rock engineers to understand the hanging-wall conditions and mitigate risks posed by any rockmass instabilities. A measure of mitigation may be the improvement of hanging-wall support design and criterion.

Kgarume admits that conducting several 2D GPR surveys to attain a 3D image was an extremely time-consuming task. CSIR geophysicists are already focusing their efforts on developing a prototype multi-sensor system that has the ability to acquire several survey lines simultaneously.

What is a hanging wall?

The hanging wall is the rockmass on the upper side of the orebody. In an underground excavation, the hanging wall is thus the roof of the excavation.

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◀ **Left: (top inset): A 3D isosurface model. One is able to view the depth within the hanging wall of the chromitite package – one of the prominent marker horizons found in the hanging walls of platinum mines. (Bottom inset): A 3D GPR survey allows rock engineers to rotate the same image, viewing it from different perspectives to analyse potential risks.**

EXPERTS PINPOINT **EIGHT UNIQUE LAKES** IN SOUTH AFRICA

Eight South African lakes with unique characteristics have been identified in the course of the National Biodiversity Assessment 2018. Experts emphasise the need to protect these wetlands from environmental and other pressures that threaten to degrade them.

Scientists have singled out eight South African lakes for their unique characteristics. "These are the only depressions or pans in South Africa – that we know of – that are more than two metres deep, making them unique," says CSIR senior researcher, Dr Heidi van Deventer. She adds that a 100% biodiversity target has been set on these lakes. The biodiversity target is the minimum proportion of an ecosystem type that needs to be kept in a natural or near-natural state, in the long term, to maintain viable representative samples of all ecosystem types and the majority of species associated with those ecosystems.

Wetlands, in general, are impacted in several ways, including water abstraction, deteriorating water quality, invasive species, land degradation and fragmentation, climate change and a collapsing capacity of expertise to monitor and minimise the impacts. "This tends to change the condition and threat status of the ecosystems," she says. "The 2018 National Biodiversity Assessment (NBA 2018), due to be released in 2019, will model the condition of wetlands on a national scale."

The eight unique lakes were distinguished from other water bodies from a literature review, conducted for the NBA 2018, during which the first South African Inventory of Inland Aquatic Ecosystems was established. The inventory offers a collection of data layers pertaining to the aquatic ecosystem types and pressures for both rivers and inland wetlands. According to the inventory, South Africa boasts a total of 158 407 wetlands of which 147 044 are inland wetlands and the rest rivers and estuaries.

The National Biodiversity Assessment

The NBA is a national collaborative effort led by the South African National Biodiversity Institute (SANBI). Van Deventer leads the inland aquatic component of the NBA 2018, which contains a rivers subcomponent led by CSIR senior researcher, Dr Lindie Smith-Adao. CSIR senior researcher, Dr Lara van Niekerk leads the estuarine component of the assessment. The assessment also contains a terrestrial and marine component, which is led by SANBI.

The assessment evaluates the state of South Africa's ecosystems based on best available evidence and is used to understand trends over time and inform policy and decision-making across a range of sectors, including mining, fisheries and agriculture. It informs South Africa's Outlook reports on the Sustainable Development Goals to the United Nations Environment Programme and the Convention on Biological Diversity.

The eight unique lakes cover just over 13 000 hectares. They are Barberspan, Chrissiesmeer, De Hoop, Groenvlei, Lake Banagher, Lake Fundzudzi, Lake Sibaya, featured on page 38, and Tevredenpan. Lake Sibaya is the largest freshwater lake, making up more than 8 000 hectares or 63% of all of the lakes. It provides freshwater to the communities surrounding it.

2018 NBA: Estuarine component

An estuary is a body of water containing freshwater from rivers and saltwater from the sea, forming a transitional zone between the river and maritime environments. The major pressures on estuaries include pollution, flow modification, overfishing, habitat modification and emerging pressures from alien species and desalination.

"These pressures are increasing and it is challenging to track the condition every five years because aquatic systems do not change that fast," says Van Niekerk. More than half of South Africa's estuaries are in good health, but over 60% of estuarine areas have been modified significantly, placing a strain on important ecological functions, such as nursery functions and fisheries production.

2018 NBA: Rivers subcomponent

South Africa boasts a total of 200 955 km of rivers, measured in length. A key finding of the NBA 2018 points to only 33% of South African rivers being in good condition. Smith-Adao warns that the country's rivers are impacted severely by flow alteration, resulting from damming or over-abstraction, habitat destruction, invasive alien plants and water pollution. Hence, free-flowing rivers are rare features in our landscape. A free-flowing river is a long stretch of a relatively large river that has not been dammed or does not experience major flow alteration. The NBA 2011 identified 19 flagship free-flowing rivers which are an important part of our natural heritage. Examples include the Doring, Elands and Mtentu Rivers. These rivers should be protected to maintain their free-flowing character.

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MEETING ETHIOPIA'S GROWING DEMAND FOR STARCH USING **MANGO SEEDS**

Tossing away the huge mango seed after enjoying its fruit is a habit Ethiopians may well have to unlearn. A team of South African and Ethiopian chemists and engineers have successfully extracted commercial-grade starch from mango seeds to meet the Ethiopian starch demands.

PARTNERING FOR AFRICAN RESEARCH AND DEVELOPMENT

▲ Above: (left): Arba Minch Town, Ethiopia, is a known source for various fruit, including mangoes. It is the chosen site for a proposed starch extraction plant because of the steady supply of the raw material in the town. Right: The weight of a mango seed constitutes up to 25% of the total weight of the fruit, meaning that a quarter of the fruit is thrown away. A team of chemists and engineers have successfully extracted starch from waste mango seeds.

Located in the Horn of Africa, Ethiopia currently imports 45% of its starch needs and, with the demand for starch expected to increase, this figure could become much higher.

"A local supply of starch that does not compete with the food market is needed," says Dr Tamrat Tesfaye, a researcher in the Department of Science and Technology–CSIR Biorefinery Industry Development Facility (BIDF).

Tesfaye is originally from Ethiopia, where he completed his undergraduate and MSc degrees before joining the CSIR to undertake a PhD programme in chemical engineering at the University of KwaZulu-Natal. He explains that of the most common types of mangoes grown and consumed in Ethiopia, thousands of kilograms of mango seeds are thrown away annually.

The BIDF collaborated with the University of KwaZulu-Natal and the Ethiopian Institute of Textile and Fashion Technology to extract starch from waste mango seeds. The team of chemists and engineers also conducted a techno-economic analysis for the establishment of a facility to extract starch from mango seeds in Ethiopia and estimated that the return on investment would be visible within two years.

Starch, commonly found in potatoes, rice, maize and wheat, is used in the beverage, food, textile, pharmaceuticals, paper and pulp and cosmetics industries.

Malnutrition in Ethiopia has been widely documented and the production of starch for non-edible uses from foods such as potatoes, maize and rice only exacerbates the country's food security challenges. The team believes that starch extraction from mango seeds will benefit the local agricultural sector and create employment opportunities.

Local starch production

A techno-economic analysis conducted by the team concluded that establishing a plant in Ethiopia to extract starch from mango seeds at an industrial scale could be viable. "The supply of raw material is a key factor in ensuring the success of the operation," says Tesfaye. He says that the team considered the major mango growing zones of the country and settled on Arba Minch Town as a site to establish the starch extraction plant because of its close proximity to market centres and labour, as well as the availability of utilities and transportation infrastructure.

Some of the industrial equipment required includes a washing machine, a desander, a grinder, and a packing machine. After a process of washing and destoning mango seeds, they are crushed to produce a slurry of starch granules. "The slurry is then sieved and washed, making this a water-intensive exercise," says Tesfaye.

After a series of processes of washing and dewatering, the dewatered starch cake is then dried in a flash dryer, yielding a commercial-grade starch product.

The team believes that starch extraction from mango seeds will benefit the local agricultural sector and create employment opportunities.

▲ Above: Mango harvesting in Ethiopia.

The project team tested extracted starch and found it to be comparable with a standard starch sample used in the local textile industry. The starch consumption of several textile, paper and pulp and starch manufacturing industries was considered in the plant design. The proposed plant is envisaged to produce 500 tons of starch per annum, operating for eight hours a day, 300 days per annum.

Environmental benefits

Seeds, peels and pulp from the fruit industry contribute significantly to the country's waste streams. Removing mango seeds from waste streams and beneficiating them for high-value materials is one way of reducing the environmental and health risks associated with incinerating, composting and landfilling waste from the fruit industry.

Additionally, Tesfaye states that using mango seeds – which are discarded as waste – instead of food-based materials, such as potatoes, rice and maize, has economic benefits and adds to the country's food security. "If these food materials are consumed for industrial applications, we need to plant additional starch sources for human consumption," he adds, citing the use of fertilisers and pesticides that impact the environment negatively. Thus, using mango seeds instead reduces the environmental burden on ecosystems and adds significant economic value.

"This is another way in which the recently launched biorefinery facility is facilitating the removal of organic waste products from waste streams and biorefining them into higher value products," says the facility director, Prof. Bruce Sithole.

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CSIR-TUT COLLABORATION IN WATER PURIFICATION, IMPROVED FRUIT SHELF-LIFE AND LASER TECHNOLOGY

Master's student Khule Dlamini and CSIR principal researcher Dr Sreejarani Pillai prepare sachets with essential oil-infused pellets. Read about this and other CSIR–TUT projects from pp 44 - 47.

The National Development Plan identifies the education, training and innovation sector as a key area that needs to be developed before 2030. Consistent with this, is the increasing need to accelerate the number of people embarking on a career in science and technology, graduates in science, technology, engineering and mathematics, and doctoral graduates. The CSIR's collaboration with the Tshwane University of Technology is contributing to these aims.

INVENTING A NEW NATURAL FUNGICIDE TO STOP THE AVO ROT

Researchers at the Tshwane University of Technology and the CSIR have pooled their respective skills in crop science and polymer science to find a green solution to a post-harvest disease in avocados.

South Africa is the second largest exporter of avocados to Europe and some 64% of locally produced avocados is exported yearly. However, the fruit is highly susceptible to postharvest diseases and losses, with the fungal disease, anthracnose, being one of the main culprits.

"To prevent decay during the often extended transport and storage periods of avocados, synthetic fungicides are used. However, consumers are increasingly demanding chemical free food and regulators around the world are becoming increasingly strict about what levels of chemical residue they will allow," says CSIR principal researcher and expert in material science, Dr Sreejarani Pillai.

The Tshwane University of Technology, under the leadership of crop scientist Prof. Dharini Sivakumar, already had half the answer. Her research team had established that a locally sourced essential oil is highly effective in protecting the Hass and Fuerte cultivars of avocados against the fungi that cause anthracnose. However, a natural fungicide solution ideally needs to release evenly and in controlled quantities to ensure that the fruit is protected for extended storage times, without it acquiring an overbearing smell or taste.

Sivakumar called on the CSIR to assist. CSIR materials scientists first looked into incorporating essential oil into packaging film, but the result was disappointing as the fumes from the film were too strong. They then looked into producing small polymer pellets that stored oil in its matrices and could be packaged as sachets and inserted into existing avocado packaging. This proved successful, with laboratory tests proving that the new active materials uniformly dispersed antimicrobial actives over an extended period, and substantially inhibited the fungus in retail shelf packaging.

Westfalia, a multinational supplier of fresh subtropical fruit that grows, sources, ripens, packs and processes avocados, reported favourable results when testing the materials in their pack house and storage facilities at semi-commercial level.

"Trials continue as we refine and analyse issues of commercial production scales and undertake detailed cost analysis.

We are optimistic that a solution with real benefits for the avocado grower industry has been found," says Pillai.

"Uptake of this technology would mean that the use of synthetic chemical fungicides can be avoided by drawing on affordable, locally sourced essential oils, in combination with locally produced polyolefins. It would also mean reducing food waste and having better fruit quality overall," she says.

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PREPARING **INDUSTRIAL PHYSICS STUDENTS** FOR INDUSTRY

The Photonics Initiative of South Africa (PISA), a programme fully funded by the Department of Science and Technology and the CSIR, established a six-month experiential learning programme for students in industrial physics at Tshwane University of Technology (TUT).

"Part of the discussions that took place during the formation of PISA was the urgent need for relevant skill sets that will take the South African photonics industry forward. As a result, an industrial physics curriculum through TUT was put in place and, to improve the academic scope of the programme, an experiential learning programme was designed to equip the students with practical experience. This is how the CSIR and TUT relationship started and continues to grow," says CSIR principal researcher, Prof. Sisa Pityana.

Nana Arthur, CSIR senior researcher and co-supervisor, says student trainees are assigned to experienced researchers who guide students, exposing them to the technical and research work done at the CSIR. Such projects are, for example, in the fields of additive manufacturing and laser surface engineering. "Through laser surface engineering projects, they usually get the opportunity to work on the entire value-chain and as a result, sharpen their skills in surface treatment, laser cladding and welding," says Arthur.

In the 2016/17 financial year, 11 students received training through the TUT-CSIR partnership agreement.

"Quality higher education needs excellence in science and technology, just as quality science and technology needs excellent higher education."

One of the students who has benefitted from the exposure, is Joshua Bila, a TUT industrial physics graduate who is now a photonics technician at the CSIR.

"I started off as an in-service trainee with the CSIR's laser-enabled manufacturing group where I worked closely with the maintenance team, learning how to maintain, operate and inspect high-power laser systems, laser cooling systems, optical equipment and electrical equipment. After my in-service training, I was appointed by the Photonics Prototyping Facility, first as an intern and thereafter permanently as a photonics technician," says Bila.

"As an organisation that thrives on creating ideas that work for industry, we hope to help shape innovative young people in science and technology who will be significant contributors in developing South Africa's photonics industry and will be role players in the drive toward industrialisation," concludes Arthur.

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▲ CSIR photonics technician, Joshua Bila working on the Kuka Robot in the Eskom laboratory of the CSIR National Laser Centre.

▲ CSIR senior researcher Nana Arthur (left) explains aspects of the functioning of the Kuka robot to photonics technician, Joshua Bila.

The CSIR's laser cladding capability is a laser refurbishment process for worn, damaged or faulty components. The process is used to repair turbine blades, press tools and shafts.

IMPROVING **WATER PURIFICATION** SYSTEMS

The CSIR and TUT are collaborating to test downstream applications of the CSIR's biocomposite technology. Researchers have developed nanomaterials found in wood pulp that can optimise TUT's water treatment projects.

Biorefinery experts at the CSIR's Biorefinery Industry Development Facility (BIDF) are extracting high-value chemicals from sawdust, such as nanocrystaline cellulose, which can be used to strengthen various types of materials. CSIR chief researcher Prof. Bruce Sithole, who heads up the BIDF, says researchers are optimistic that in two years South Africa will be among the top 10 producers of this nanomaterial and the only producer using waste as a resource.

The nanomaterial's application is being validated as part of the TUT's water purification process. The institution currently uses various nanotechnologies during filtration, where membranes made from biomaterials are used to remove contaminants from the water. These membranes collapse when high pressure is applied and CSIR researchers believe that binding their nanocrystaline cellulose to the membrane will make it stronger when the pressure is increased.

The research project is funded by the Department of Science and Technology and is part of the national vision of beneficiating various forms of waste to stop overfilling landfills and create new industries.

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CSIR-DEVELOPED **NANOCLAYS** IN COSMETICS AND PERSONAL CARE PRODUCTS

▲ **Skin-care products developed by using non-toxic, environmental friendly additives as part of the CSIR-AMKA collaboration include petroleum jelly with nanoclay, a controlled-release topical formulation and a mineral-based roll-on formulation.**

The CSIR has licensed five products to the fully South African-owned cosmetics company, AMKA (Pty) Ltd.

Under the leadership of Dr Sreejarani Pillai, these unique products were jointly developed with AMKA, after the CSIR approached the company in 2014 with ideas on advanced cosmetic formulations. The licensed products include a mild hair-relaxer formulation, an ammonia-free hair dye formulation, an anti-dandruff formulation, a petroleum jelly, as well as a new emulsion for men's facial grooming, based on controlled-release technology. The unique approach releases an active ingredient over a longer period than conventional applications, thus making it more effective.

CSIR expertise in nanotechnology, and specifically nanoclays, the comprehensive characterisation equipment available at the DST-CSIR National Centre for NanoStructured Materials, as well as the scale-up equipment at the DST-CSIR Nanomaterials Industrial Development Facility, were instrumental in making the collaboration and technology development possible. While both parties invested considerably in the development of these products, the company not only benefited from the technologies, but also from two AMKA employees completing their PhDs as part of the collaboration, with supervision by the CSIR.

The project proved to be a good example of how the CSIR and industry can benefit from collaboration. The CSIR is able to get first-hand information from the manufacturer and market, while industry gets access to the unique skills and facilities that the CSIR has to offer.

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CSIR EXTENDS INSTANT ACCESS LICENCES FOR TECHNOLOGY TO HELP **MONITOR WATER LOSS**

▲ Unit components of SmartSense, a CSIR technology that enables real-time monitoring and controlling of water or energy distribution network components.

Five small, medium and micro enterprises (SMMEs) have been granted instant access licences for SmartSense, a CSIR technology that enables real-time monitoring and controlling of water or energy distribution network components.

The novel technology aims to address water loss and non-revenue water, which costs the country more than R7 billion per annum. It is a low-cost and energy-efficient long-range communications sensor node. It can be easily fitted to ageing or new infrastructure, such as legacy pulse meters and water pressure sensors. Furthermore, it can be attached to more than one device simultaneously.

The real-time sensory data collected by SmartSense is fed into a back-end system where various techniques and tools are used to analyse data, enabling wise water management.

The CSIR has opted for an innovative instant access licensing approach with the aim of increasing uptake and dissemination of CSIR technologies. Instant access licensing involves a non-exclusive option agreement for a limited duration with nominal royalty to cover the organisation's transaction costs. The CSIR designates such licences where both the CSIR and the potential licensee are uncertain about commercial viability, the business model and scalability. The CSIR provides an option to negotiate a full licence during the term of the instant access licence agreement.

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THE **AIR** WE BREATHE

What do we know about the air we breathe? Through its air quality modelling expertise, the CSIR is attempting to enhance the understanding of South Africa's air quality and its impacts on human and ecological health. The CSIR's skills base in air quality modelling will help South Africa to better understand, manage and regulate emissions.

Air pollution is a worldwide problem, but wearing face masks and banning certain vehicles from cities may not be the best answers; at least not for South Africa. "Air quality monitoring stations are not plentiful in South Africa because they are very expensive," says Mogesh Naidoo, a CSIR air quality modelling expert.

"This is where air quality modelling becomes relevant," he says. Leveraging climate and air quality models, Naidoo is able to map the air quality of an area or city by simulating how air pollutants disperse and react in the atmosphere to affect ambient air quality. "We look at vehicle emissions and try to determine how far the emissions travel and what they transform into. Using this information, we can simulate air quality." The pollutants transform due to chemical reactions; many driven by sunlight.

Why do we need to understand our air quality?

"We need to know the concentration at which pollutants are present in the atmosphere to understand the likely impacts on human and ecological health," he says. Bad air quality has an impact on agricultural production. Maize crops are sensitive to ozone; oxides of nitrogen and sulphur dioxide may enter leaves during photosynthesis and have the potential to affect crop yields.

Continuously monitoring air quality is imperative for human health; it tells us if the quality of our air is detrimental to human health and warrants major changes in areas such as road traffic. Naidoo cites France as an example. In early 2018, the most visited tourist destination in the world experienced a heat wave that prompted several cities, including Lyon, Paris and Strasbourg, to ban certain vehicles from entering them. This was an attempt to limit the impacts of the heat wave on air quality and, consequently, human health.

Applications of air quality modelling data

Air quality modelling empowers a city or a municipality to make informed air quality decisions for the betterment of its citizens. The model allows one to build emissions scenarios, varying the data. "A municipality may decide to ban diesel vehicles above two litres in engine capacity from entering the city, but want to know upfront what difference it would make. Our model enables the city to view the likely impacts of this scenario," says Naidoo.

Municipalities are also able to use this information to declare air quality hotspots. These hotspots are areas

"We need to know the concentration at which pollutants are present in the atmosphere to understand the likely impacts on human and ecological health."

within which emissions from specific sources, such as factories and mines, are considered toxic and may expose citizens to health risks. "This is why air quality monitoring stations are generally placed in locations that people frequent, such as schools and urban areas," says Naidoo. He adds that these stations are not usually found near farms, but applying air quality modelling skills and expertise, one is able to estimate the impacts of air quality in areas lacking air quality monitoring stations.

Air quality modelling also allows for anticipated problems to be addressed proactively. For example, a power station may be proposed in a specific area. This will emit large amounts of pollutants. Using a model, the emissions can be quantified and their likely impacts on ambient air quality illustrated to enable informed decision-making.

South Africa has made it a legal requirement for municipalities and provinces to have air quality management plans that indicate the status of air quality in their areas of jurisdiction. If the quality of air is poor, the plans need to detail how this will be addressed.

Naidoo is currently completing a PhD looking at the impacts of climate change on ozone in South Africa.

Air quality monitoring stations monitor the quality of air in communities. The data collected are used to identify the main sources of pollution and determine what interventions are required to improved air quality.

CSIR expertise in air quality
- Environmental and human health
- Prioritisation of climate responses

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◀ Left: CSIR air quality modelling expert Mogesh Naidoo uses current climate and air quality models to monitor air quality in South Africa.

THE FACILITY BEHIND THE CSIR **DIABETES** BREATH ANALYSER

The micro nanochip manufacturing facility

The CSIR's micro nanochip manufacturing facility has its roots in a breath-analysing solution that enables the development of a wide range of gas-sensing micro nanochips that have the ability to detect diseases, such as diabetes, lung cancer and renal failure, at an early stage, simply by breathing into the device. The CSIR diabetes breath analyser could eventually replace current medical finger prick testers used for this purpose.

INFRASTRUCTURE AND SCIENTIFIC EQUIPMENT

The current global market for medical prick testers and other medical care devices is more than R132 billion and is dominated by international companies. Researchers at the CSIR hope to help change this.

Fast fact

Before the establishment of the facility, researchers conventionally developed the sensors by placing an acetone drop next to the sensor in an improvised box to determine the functionality of sensors and their responses to acetone vapours.

◀ Left: CSIR chief researcher Dr Bonex Mwakikunga and researcher Malose Mokwena setting up a gas sensor testing station.
▲ Above: The gas sensor testing station.

CSIR expertise in nanotechnology and nanoscale manufacturing enabled the organisation to develop a diabetes breath analyser – a painless alternative to the finger prick blood test for detecting high blood sugar levels. The diabetes breathalyser detects acetone, which is a by-product of high blood sugar levels, and a biomarker of diabetes in breath. It basically works the same way that a common alcohol breathalyser tests blood alcohol levels, but its key innovation is a micro-nanochip constructed to detect substances with fine-tuned precision.

The small device can be tuned to detect different substances in the same way a radio can be tuned to detect different stations. The micro-nanochip can also amplify the substance it detects, just like turning up the volume on the radio amplifies the sound it emits. It can be used to detect light, pressure and sound; and it can also sense other gases with high accuracy. The chip is being harnessed as a gas analyser to sniff environmental pollutants, such as nitrogen oxides, ammonia, methane and sulphur compounds.

Patents on the nanosensor, which also has other applications in mining as well as the environmental and health sectors, have been accepted in South Africa and numerous other countries.

Equipped for material synthesis

The facility has a synthesis lab for synthesising the materials needed to provide active nanosensors in the chips. The lab enables researchers to synthesise materials ranging from diactin oxide to stannic oxide. The facility also boasts an advanced gas station tester, which allows researchers to determine the sensitivity of materials relative to certain gases.

Researchers at the facility make use of related machinery, such as scanning electron microscopes, transmission electron microscopes, as well as the focused ion beam scanning electron microscope. The equipment is used by a team with advanced skills in nanotechnology, nanoscience, materials science and engineering.

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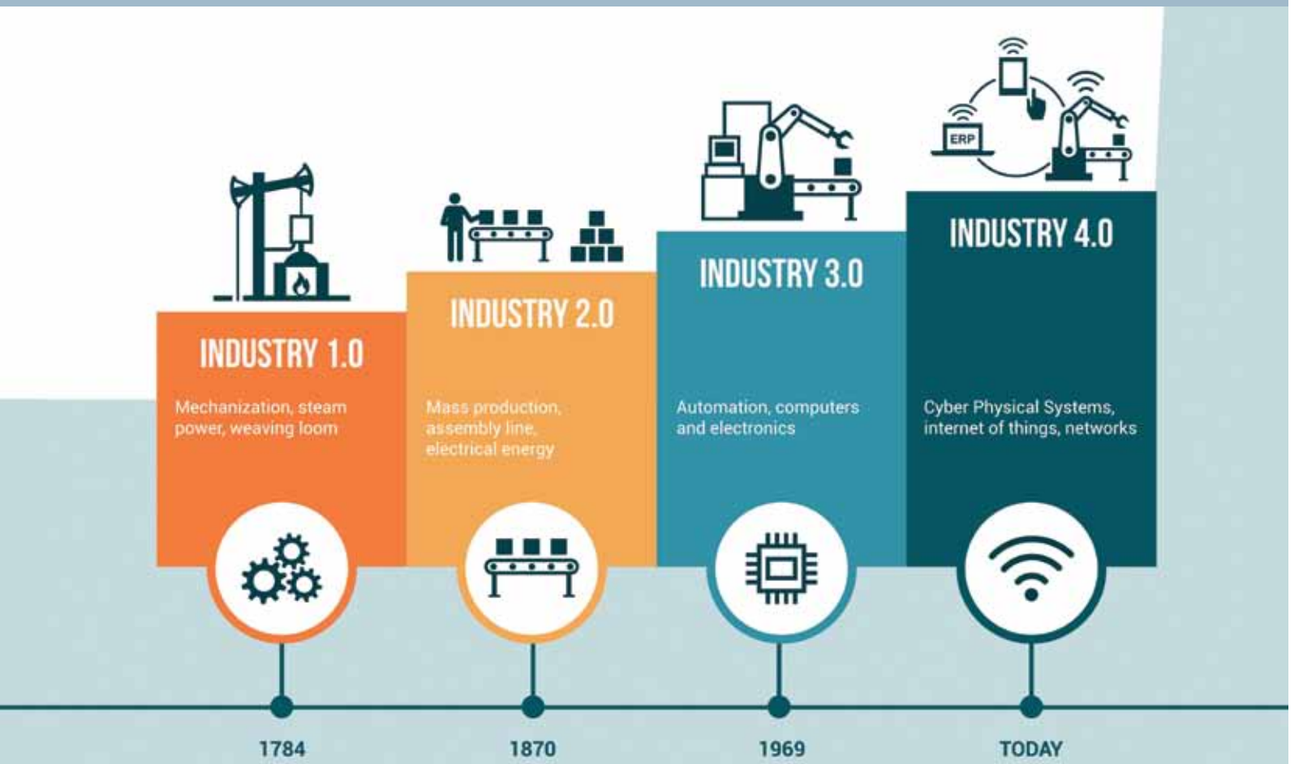
THE FOURTH INDUSTRIAL REVOLUTION – IT'S HAPPENING BUT WHAT DOES IT MEAN?

By Dr Daniel Visser



When I was 10, I got my first radio – it had two tape decks so you could make mix tapes and even record from the radio (with permission, of course!). At the time it was high tech. Nowadays I can play any music I want from my smart phone, wirelessly. My first CD, which I got around 1990, was U2 – amazingly they're still making music, but their last album was never on CD, only digital. Technology is moving at an unprecedented pace. We are moving into a new technological age – some call it the fourth industrial revolution. Regardless of what it's called, we are in an era where technology has advanced to a stage where it will have a significant impact on the nature of manufacturing as well as all aspects of our lives.

A fusion of the physical, digital and biological worlds

The fourth industrial revolution is described as a vision of the future where we see a fusion of physical, digital and biological worlds. The previous three industrial revolutions were characterised by major individual technological breakthroughs, such as steam power, electricity and information technologies; whereas now there are a number of evolving technologies, which can be combined to develop a new industrial era. In this future, we will see increased growth, connectedness and human productivity. The big difference is that the fourth industrial revolution will be characterised by increased productivity but will not be driven by it. Instead it will be driven more by the needs of the consumer – convenience, customisation and the user experience.

The key drivers

The key drivers of the fourth industrial revolution are advanced robotics, big data and analytics, simulation, augmented reality, digital integration, advanced manufacturing, cloud computing and the Internet of Things. These drivers will all influence this future, although none of them will influence the nature of the revolution more than the others. Advanced manufacturing, for instance, is based on new manufacturing technologies, such as additive manufacturing and biomanufacturing, and new smart materials, but incorporates digital integration, simulation, big data and the Internet of Things (among other evolving technologies). In future factories, we will see increasing data generation, interpretation and reaction on a realtime basis across the manufacturing environment and outside of it.

Far-reaching impact

The fourth industrial revolution will impact almost all economic sectors. It will extend, due to the integrative nature of the revolution, to business systems, technology development and society in general. Businesss systems will change to more decentralised and globalised manufacturing and distribution, accompanied by entirely new business models. Society will need to adapt. We are already more connected and this will increase exponentially. From a social point of view we will need to consider how this impacts communication, personal privacy and the methods of personal interaction with the world around us. Due to the new ways of doing business and changes in technologies, the associated skills base will also need to change, and the nature of education itself.

It has been predicted that people will live to the age of 140 within a few decades. More and more people are choosing to take care of themselves and technology will greatly assist with this. Already cancers are being detected months earlier than before, thanks to small, wearable health-monitoring devices. Computer vision is allowing the visually impaired to 'see' ; dyslexia sufferers are reading. Care will become increasingly personalised as the particular, often unique, issues of individuals are identified through advanced diagnostics.

The CSIR and the fourth industrial revolution

The CSIR is already involved in a number of the technology areas associated with the fourth industrial revolution. Our new organisational strategy, to leverage our science, engineering and technology capability to strengthen industrial development, is well aligned with the anticipated changes. Furthermore, we have initiated a programme to create a consolidated approach to CSIR activities in the fourth industrial revolution space. This will see coordination among our innovation programmes and a number of demonstration facilities that are being implemented. Within these demonstration facilities, we will integrate and test the technologies for a variety of scenarios and adapt them to specific sector requirements. This is very much in line with best practice in countries like Australia, Germany and Switzerland.

Remaining people-centered

Robots and machines have come a long way. Some may argue that they can think and process information better than we can. The human body is an incredible machine though. The mere act of walking without falling has taken technologists decades to figure out and their robots still cannot do it with the grace and poise of a ballet dancer. The human mind is still the most powerful computer capable of billions of computations every second. And while robots may be able to think faster, they still cannot be human – be intuitive, show emotion, sympathy or empathy. As we move into the fourth industrial revolution, it is the one thing we must not forget – to be human. To ensure that technology makes our lives better instead of replacing our value; that it makes our work easier and safer, but no less important. We must ensure that the fourth industrial revolution, for our context in South Africa, is centered on people.

Dr Daniel Visser is the CSIR research, development and innovation strategy manager.

STATISTICS KNOW-HOW KEY IN MAKING BETTER DECISIONS

In our technology-driven world of today, it is difficult to imagine a world without data. Imagine a large research organisation, such as the CSIR, without information or evidence. In the CSIR, data may be collected by a lone lab technician recording test measurements, or by a PhD student counting the answers from respondents to their questionnaire, or through a large number of fieldwork records regarding whether or not an intervention was successful in changing lives in a rural community, or even from the monitoring of atmospheric changes with advanced instruments at sub-continental level. It is unthinkable to have a research report or scientific paper that does *not* include some form of research data.

In any business organisation, data is collected in various ways during the course of manufacturing activities, the gathering and transportation of supplies, in conducting sales transactions or in planning future activities. Huge amounts of financial reports are generated for summarising business activities, determining taxes that are due, or managing debtors and creditors. In government departments, information may be recorded for service delivery purposes and planning is done on the basis of regular statutory data reporting.

But what are the best ways to work with collecting or collected data? When it comes to quantitative data (i.e. numerical measurements), CSIR researchers have found the methods contained within the field of statistics useful for changing data from a group of separate data points into usable information or scientific evidence. Statistics contains various discipline-free methods that can be applied within a scientific research organisation, such as the CSIR, or in any business, government department or agency, or even a non-governmental organisation. Statistical methods include approaches to assist with the collection of data, such as designing an experiment or determining the number of data points (the sample size) required for one to get the most informative data possible – even when money, time or equipment are in short supply. There are also methods that can compress large sets of data into usable indicators and summary measures, or analysis graph and chart types that can provide a concise picture of meaningful patterns in a large dataset, such as a large group of financial transactions. Finally, within statistics there are methods to extract relationships and significant patterns from the data so that conclusions can be drawn and decisions made.

In the CSIR, we have found that many scientists are introduced to the field of statistics during their studies and can therefore use statistical methods when they need to. However, it is also necessary to have a number of specialists in statistics within the organisation. Such experts can help the organisation to deal with its growing amount of research data and make sure that the data is analysed in an appropriate way.

However, it is not only at the CSIR that statistics and other quantitative analysis fields are growing in importance.

The demand for the generation and publication of figures and conclusions resulting from statistical (and other types of quantitative) analyses is increasing within the industrial, public, private and educational sectors of our nation. This was highlighted by former minister Trevor Manuel on various occasions. The sentiment was also echoed by former statistician-general, Dr Pali Lehohla. The analysis of 'big data' and the related quantitative fields of statistics, data management and data science are some of the fastest growing occupational areas nationally and internationally.

However, South Africa is currently faced with many challenges. Our skills and capabilities are being challenged to respond effectively to our troubled economy as the world embraces the fourth industrial revolution, as Prof Klaus Schwab refers to a revolution with the associated new technologies of advanced materials, digitisation, additive manufacturing, advanced robotics, the Internet of Things and sensor technologies. South Africa requires engineers, technologists and economists to respond to economic development. But will we have sufficient skilled people to deal with the data generated by the advanced technologies so that better decisions and plans can be made?

Such analytical skills must be cultivated and developed urgently. *The Global Information Technology Report of 2016* by the World Economic Forum shows that, over the past three years, the quality of South Africa's mathematics and science education has been ranked last out of 139 countries. Furthermore, South Africa was ranked 137 out of 139 countries when looking at the overall quality of its education system. Therefore, attention needs to be directed at educational programmes and the standard of science and mathematics education in schools and tertiary institutions in South Africa, if we are going to lay the foundation for the development of advanced analytical skills. The CSIR and other research organisations must team up with tertiary institutions to further enhance skills and research improved methods; and organisations in the public and private sectors need to become more aware of the way in which the analysis of their data could improve their operations and activities.

Prof Pravesh Debba is the CSIR manager for spatial planning and systems, and Renée Koen is a CSIR senior researcher and research group leader for decision support and systems analysis.

◀ **Left: Statisticians in the CSIR's decision support and systems analysis research group use statistical methods to understand how phenomena such as predicting election results, urban growth and electricity demand forecasting could influence policies and shape future interventions. The team members are (front, from left) senior researchers, Nontembeko Dudeni-Tlhone, Paul Mokilane, Jenny Holloway and (back, from left) Renee Koen, research group leader and Prof Pravesh Debba, competence area manager. Dr Sibusisiwe Makhanya, CSIR senior researcher (absent) is also a member of the team.**

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