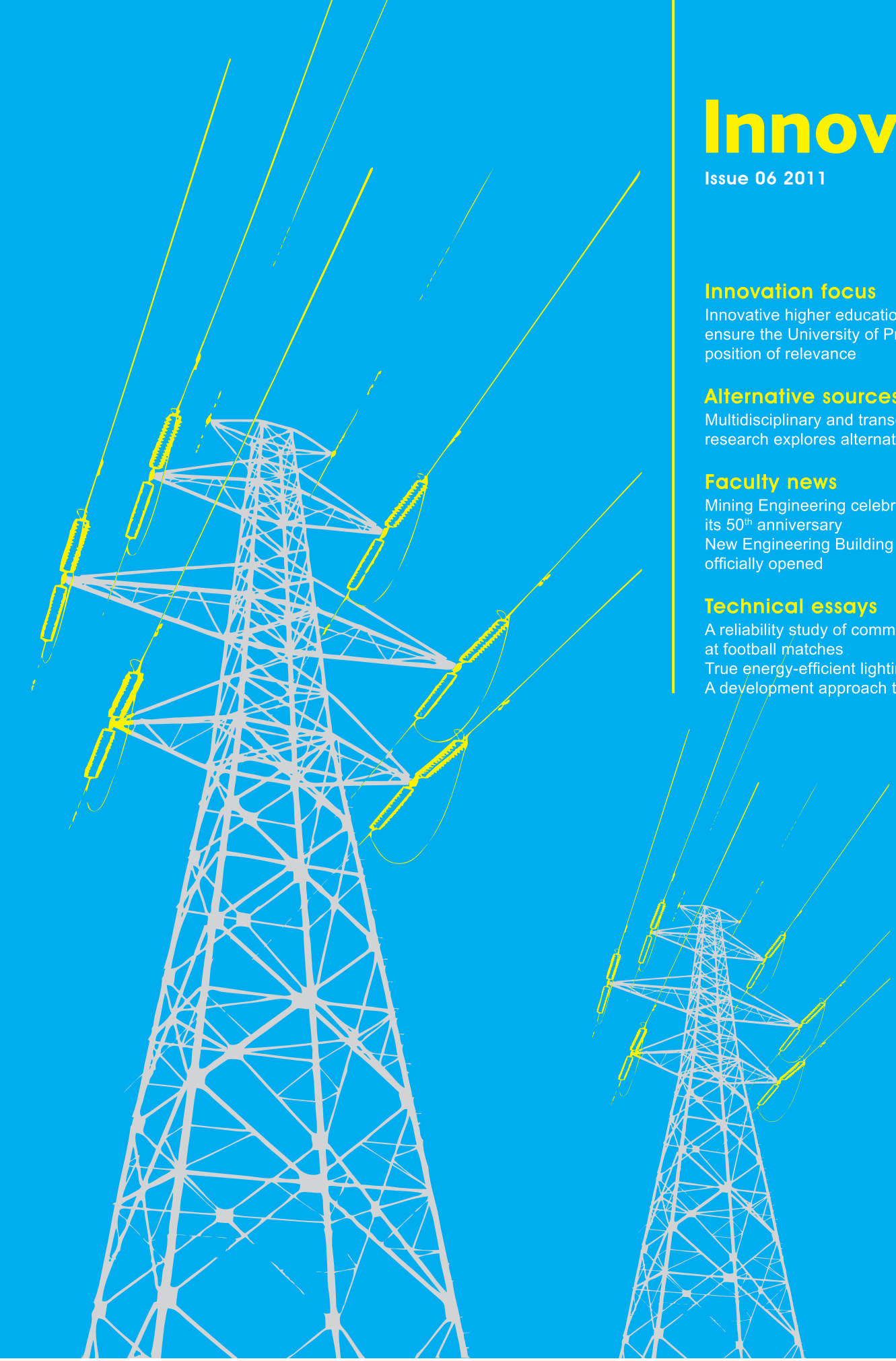

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UNIVERSITY OF PRETORIA
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Denkleiers • Leading Minds • Dikgopolo tša Dihlalefi

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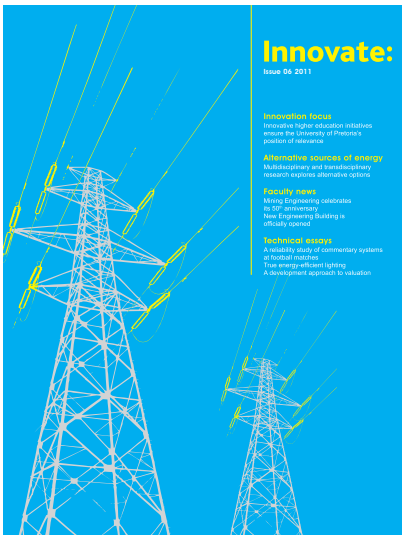

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The only graduate school of its kind in South Africa, GSTM provides skills solutions in **Engineering** Management, **Technology** Management, **Innovation** Management and **Project** Management to practising engineers and scientists!

Leading minds beyond engineering

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Applying knowledge to real-world problems

The Massachusetts Institute of Technology, or MIT, as it is known, has proven to be one of the leading universities in its field in the world. This year marks MIT's 150th anniversary. Through the years, MIT lived by its motto 'Mens et Manus', meaning 'Mind and hand', and it is recognised as a main contributor to its excellence.

The ability to apply new knowledge to real-world problems is a challenge facing most universities, also those in South Africa. Academic institutions that succeed in reaching this objective are the ones who attract funding, not only from first- and second-stream sources of funding (mainly from government), but also from the very important third stream (mainly industry). It is therefore of the utmost importance that close ties are developed between universities and industry. The University of Pretoria (UP) has Africa on its doorstep to realise these objectives. However, with South Africa recently having become a member of the Brazil, Russia, India and China (BRICS) group of countries, new opportunities were created for South African universities to develop these important global networks.

The University of Pretoria took a major step in this direction by initiating a number of research themes as a focus for its future research strategy. One of these themes is energy. Research has revealed that UP is outperforming all other research institutions in the country with its outputs in energy research. The Faculty of Engineering, Built Environment and Information Technology (EBIT), in close collaboration with the University's Faculty of Natural and Agricultural Sciences (NAS), takes the lead in this research area. The objective is not only to strengthen its core research capacity in this regard, but also to develop strong university-industry collaborative networks. There is no doubt that the economy of the country will benefit from the outputs of this initiative, especially in times when billions of rands are being invested in our country to ensure a sustainable future supply of energy. This edition of Innovate features several contributions focusing on activities related to energy research.

The lead article features an interview with the Vice-Chancellor and Principal of the University of Pretoria on how the institution plans to ensure its future position of relevance through innovative initiatives. The articles on energy cover topics such as UP's new energy research initiative and the Fukushima incident. Other interesting articles include an interview with Jack van der Merwe on the impact of the Gautrain on the economic performance of Gauteng, the University's new Engineering Building its Department of Mining Engineering, which celebrates its 50th anniversary this year. Of course, there is also the regular portfolio of articles on the innovative research conducted by EBIT's staff and students.

I trust that you will again enjoy this edition of Innovate!

Editor
Tinus Pretorius

Innovative higher education initiatives ensure the University of Pretoria's position of relevance

The long-term sustainability of universities depends on the way in which they respond to the challenges of their contexts in an increasingly knowledge-driven economy.

→ Prof Cheryl de la Rey singles out a number of educational innovations that have contributed to positioning the University as a leader in the field.

In advancing its position as a leading institution that is embedded in the realities of the continent, the University of Pretoria is not only committed to engaging with local developmental needs, but also to sustaining and further developing global knowledge production and technological innovation. In an interview with Prof Cheryl de la Rey, Vice-Chancellor and Principal of the University of Pretoria, *Innovate* discovers what it is that makes this an innovative institution.

"Innovation" – from a technology management point of view – can be defined as the development of a new product, process or service, or the improvement of existing practices to achieve improved results. The success of an innovation – be it a process, product or even a new idea – depends on its subsequent research and development, followed ultimately by the commercialisation of the intellectual property.

While innovations in the higher education sector might not necessarily lead to the commercialisation of new products, innovative processes and services in education are no less

groundbreaking. “In comparison to other institutions of higher learning,” says Prof De la Rey, “the University of Pretoria’s efficiency ratios are exceptionally good, and it is able to do better than others with the same resources."

“The University of Pretoria is consistently commended by quality assurance panels on the innovative ways it manages to expand its facilities and services without compromising quality,” she says. This ensures that the University can continue to deliver world-class teaching and produce cutting-edge research results – some of which have even been developed into economically viable products and services. The University’s commitment to innovation has enabled it to develop and apply appropriate technology to complement its operations, including its teaching and research programmes.

Prof De la Rey singles out a number of educational innovations that have contributed to positioning the University of Pretoria as a leader in the field.

Commercial entities

The establishment of a system of campus enterprises at the University of Pretoria in 2000 enabled the University to grow its resource base in a sustainable manner to create synergy between teaching, research and community engagement. It has also enabled the University to utilise its intellectual property for the benefit of society.

Over the past decade, these enterprises have succeeded in optimising the University’s assets and expertise, while at the same time generating an income for the University. The opportunities that exist in the expanding campus enterprise structure present themselves in three distinct categories: the provision of services (specialised services, skills development through the delivery of short courses, and commercial research and consulting services), the utilisation of existing resources, and the commercialisation of intellectual capital and intellectual property.

The establishment of the Gordon Institute of Business Science (GIBS) as a business entity in Johannesburg was another innovative endeavour. In order to be competitive, the MBA offered at GIBS had to be different from and more responsive than those offered by other institutions, both locally and internationally. Its success can, to a large extent, be attributed to the unique management model that is followed. It includes a compulsory global module that allows students to focus on the unique opportunities and challenges offered by various countries. Potential destinations include India, West and East Africa, Latin America, China, Japan, and the east and west coasts of the USA.

Opportunities that emanate from research activities at the University of Pretoria are optimised through the commercialisation of intellectual property and the transfer of technologies, products and services into start-up companies.

Opportunities that emanate from research activities at the University of Pretoria are optimised through the commercialisation of intellectual property and the transfer of technologies, products and services into start-up companies.

Intellectual property

A recent research initiative is that of INSiAVA (Pty) Ltd, which was founded by the University of Pretoria. This company owns and commercialises the intellectual property emanating from ongoing silicon photonics research (see article in *Innovate* 05: 2010).

Any attempt to assess the University’s position nationally in terms of research innovation will rely on indicators such as the number of patents, projects for which funding is received from the Technology and Human Resources for Industry Programme (THRIP) and projects that receive added value through the contribution of industry partners.

Innovations in education

Education innovations at the University of Pretoria make an impact on society in ways that sometimes extend further than the influence they have on teaching and learning.

In this regard, Prof De la Rey cites the practical experience gained by students involved in the clinics operated by various faculties at the University. This not only provides students with the opportunity to apply their academic knowledge and research skills to practical situations, but also develops the community by providing services to which members of society might not otherwise have access. The University of Pretoria’s Law Clinic is an example of such a social innovation. The Law Clinic, which celebrated its 30th year of existence in 2011, has been acknowledged for the positive impact it has on the community. Final-year law students are mentored and advised by candidate attorneys and experienced legal practitioners. They work in the clinic in “firms”, consisting of five or six students each, which mostly deal with civil litigation, including family law matters and labour disputes. The clinic

The University's engineering programmes play an important role in meeting the critical national need for engineering graduates.

operates on the University's Hatfield Campus, as well as the Mamelodi Campus.

Similar initiatives include the Itsoseng Psychological Clinic, the Educational Psychology Family Clinic, the Small Business and Entrepreneurship Clinic, the Animal Health Clinic and the Occupational Therapy Clinic. These clinics all provide services on the University's Mamelodi Campus, and are an excellent example of the impact of innovation at grass-roots level.

Future plans

Innovations that are planned for the future include the development of a virtual science park. However, a model needs to be developed that works for the University's dynamic situation, and in this regard, will differ from the traditional model. This is the essence of innovation from the perspective of the University of Pretoria.
Prof De la Rey emphasises the need to encourage companies to utilise the University's facilities as research and development laboratories.

In order to increase the University's innovation footprint, it is essential to develop innovation networks. "It is absolutely crucial to have networks on every continent," says Prof De la Rey. In this regard, the University needs to expand existing networks and identify new ones. Its alumni overseas

Innovations that are planned for the future include the development of a virtual science park.

can play a vital role in this, and the University needs to embrace this talent and expertise. "The 21st century is characterised by the mobility of people, many of whom have established networks, and we need to tap into this," she concludes.

The Principal recognises the fact that the University has had to be innovative in its teaching, and a number of innovative projects are already in place, particularly in terms of electronic and mobile learning. She also acknowledges that South African academics have had to be entrepreneurial to obtain funds for research, and in order to achieve this, a paradigm shift had to be made.

Coupled with this paradigm shift is the need to engage in more multidisciplinary research. Although the University is still organised according to clearly defined disciplines, the trend worldwide is to follow a multidisciplinary approach to develop new products and services. The current focus at the University is to form interdisciplinary research teams with specialists from various disciplines to enhance the value of individual contributions.

The University recently initiated a process of identifying unique research strengths that would support the development of strong multidisciplinary research groups clustered around these strengths. This resulted in the identification of institutional research themes, with accompanying faculty research themes. Institutional research

Theory and practice are combined to deliver students who are committed to solving global problems.

themes are designed to recognise and foster excellence in research. The research is led by recognised international leaders in their disciplines. The development of these themes will provide an environment for the growth of scholarship among academic staff and postdoctoral fellows, while also allowing for the increased production of doctoral graduates. In this respect, the Faculty of Engineering, Built Environment and Information Technology is focusing on energy as a research theme.

Prof De la Rey emphasises the role of postgraduate students in the development of interdisciplinary research. "Industry is changing in terms of the recognition of postgraduate qualifications and the University needs to create social and intellectual spaces that are conducive to interaction in order to utilise the capacity of these students," she says.

In order to enhance its position as a leader in the field of teaching and research, the University is constantly considering more multilateral opportunities in which it can exert an influence globally, while also increasing its students' exposure to challenges that are both locally relevant and internationally significant. The University is well positioned to achieve this because of its close proximity to government department offices and embassies.

Future markets

Prof De la Rey is confident that the University of Pretoria has several strengths that can make a significant contribution to the world at large. This includes a number of resources that can be developed for future markets, particularly in the field of wireless technology and the automotive industry, as well as energy production, distribution and optimisation. In this respect, the Faculty of Engineering, Built Environment and Information Technology is a major role-player.

In response to a question about her vision for the University of Pretoria as an innovative university for the future, she says: "I want to see us as leaders in innovation: leaders who make a difference." Given the University's location in the country's developing democracy, this is certainly an attainable goal. Prof De la Rey concludes by saying that innovation is an action that has a ripple effect. It is not just the acquisition of new knowledge, but also the application of existing knowledge in a way that will make a difference in people's lives.

If one examines its history, it is evident that the University of Pretoria has always managed to do things differently. "We have always had to be flexible, creative, innovative and responsive. It is part of our heritage," says Prof De la Rey. "It is important that as we grow, we do not lose what is valuable from our past: our responsiveness, our work ethic and the high value we place on public service."

By continuing to focus on the development of innovations that not only enhance its teaching, research and strategic networks, but also benefit society as a whole, the University will be able to ensure that it remains responsive to the developmental goals of the country and that its teaching and research is relevant in the global knowledge-driven community.

Exploring alternative sources of energy

South Africa has an energy-intensive economy, mainly due to the exploitation of the country's mineral resources. To date, mining and manufacturing processes have relied to a large extent on the cheap energy that is provided by the country's coal-fired power stations. However, this source of energy is non-renewable and needs to be replaced by the clean energy that can be provided by renewable resources such as wind, water and sun.

According to the Department of Energy, coal accounts for over 90% of the country's total electricity-generating capacity. In addition, about 95% of South Africa's population depends on coal to meet its energy needs. This has major environmental and economic implications.

The need for alternative sources of energy is compounded by the fact that there are no coal deposits in the country's western and eastern provinces, while such deposits have always been abundant in the north-eastern part of the country. The transmission of power from a single region leads to instabilities in the power grid, which is also a factor that needs to be urgently addressed.

Concerns about increases in the price of coal, the exhaustion of the country's reserves and global warming – partly as a result of greenhouse gas emissions and other atmospheric pollutants – necessitate a departure from the overreliance on electricity generated from coal. The global use of fossil fuel has been identified as one of the major causes of climate change. While the full consequences of climate change are unknown, what is certain is that neither the planet nor humanity will be able to adapt in time unless the process can be halted by developing and making use of new technologies to generate alternative and renewable sources of energy, such as nuclear, hydro-, wind and solar power.

This resulted in South Africa building its first nuclear power station in the Western Cape in the 1980s. Although nuclear power presently accounts for only about 6% of the electricity generated in the country, it is very important in an area where there are no coal reserves. South Africa also possesses sizeable uranium reserves and has an extensive uranium mining industry, making it one of the important producers of uranium in the world. The presence of this primary source of energy in South Africa is a key element of the security of energy supply nationally.

Dr Rob Adam, CEO of the Nuclear Energy Corporation of South Africa (NECSA), was the invited speaker at the annual Hendrik van der Bijl memorial lecture of the South African Academy of Engineering (SAAE) that was presented at the University of Pretoria on 1 June 2011. The theme of his address was the future role of nuclear technology in South Africa. He emphasised the fact that investment in nuclear power would go a long way in easing South Africa's energy crisis.

The Integrated Resource Plan (IRP) of 2010 of the Department of Energy, promulgated on 6 May 2011, forms the basis for South Africa's electricity generation mix going forward for an overall period of another 20 years. This plan is informed by the need to diversify the energy mix, with specific emphasis on broadening electricity supply technologies to include gas, imports, nuclear, biomass, and renewables (wind, solar and hydropower) in response to both the country's future electricity needs and to fulfil its commitment to reducing CO_2 emissions.

In terms of the IRP of 2010, demand for electricity in the country is expected to increase to about 454 TWh in 2030, compared to 260 TWh in 2010. It anticipates that 22.6% or 9.6 GW of the country's electricity generation capacity will be derived from nuclear power. Government has therefore given its support and commitment to nuclear power as a viable option for low-carbon, base-load electricity generation. The South African nuclear programme will be one of the largest programmes ever undertaken in this country, and the government has clearly indicated the importance of industrialisation and localisation of certain nuclear capabilities.


“While the full consequences of climate change are unknown, what is certain is that neither the planet nor humanity will be able to adapt in time unless the process can be halted by developing new technologies to generate alternative and renewable sources of energy.”
Fusion

Lessons learnt from the Fukushima incident

by Prof Johan Slabber

The recent events at the Fukushima Nuclear Plant in Japan, which followed the massive earthquake and tsunami, have been the source of major concern regarding the risks associated with nuclear power plants. A number of the reports in the media have conveyed rather conflicting opinions that have served to confuse rather than clarify the situation.

Nuclear fission power is produced when the nucleus of an element – usually uranium – splits into parts and in the process releases a relatively large amount of energy. In a nuclear reactor, this phenomenon takes place in the part called the reactor core.

The splitting process in reality forms new combinations of particles that make up the nuclei of the resulting products, and elements are created that are radically different from the original uranium. These elements are called fission products and are normally very radioactive.

Radioactivity can be seen as the release of excess energy from a very excited nucleus. As the energy is released, the degree of excitation decreases. This phenomenon is generally known as radioactive decay. The release of energy in a fission reaction comes at a price. This price is the creation of very radioactive fission products. It is a design objective for any reactor to provide successive barriers around the fuel material to inhibit the release of these highly radioactive fission products into the environment. The energy released by the radioactive decay of the fission products is deposited by reabsorption in the core and surrounding structures.

When the reactor is operating, this heating is less than 10% of the reactor power. However, when the reactor shuts down and the fission energy is reduced to practically zero, the heating from the absorption of fission product radiation energy becomes the main source of heating in the core, as well as in used fuel elements that might have been discharged from the reactor core.

During accident conditions (where cooling of the fuel is abnormal), there are two sources of heating in the reactor core and used fuel elements that need to be considered. The first is the fission product radiation heating, while the second is the heating due to an exothermic chemical reaction between the zirconium in the fuel-cladding material and its surrounding environment. In addition to the heat generated by this reaction, in the order of 500 m^3 of hydrogen per ton of zirconium oxidised is produced. It is therefore clear that if the fuel heats up to beyond a certain value, the integrity of the fission product barrier

> In the design requirements of power reactors, external events that may have an impact on the safety of the reactor are always stipulated for a specific site.

Prof Johan Slabber, former Chief Technology Officer at the Pebble Bed Modular Reactor (PBMR) Company (Pty) Ltd and currently associated with the University of Pretoria's Department of Mechanical and Aeronautical Engineering, recently presented a lecture on campus to explain what happened at Fukushima, starting from the generic basic principles on which reactor technology is based. He also illustrated that what happened at Fukushima was rather predictable, given the current boundary conditions surrounding the plant. He explained some of the features of the Koeberg nuclear power plant and highlighted the capability of this plant to handle external events of this nature.

The Fukushima nuclear power plant.

is challenged by two synergetic heating processes, accompanied by the production of an amount of hydrogen, depending on the mass of zirconium consumed in the process.

It is therefore clear that sufficient cooling must be available to keep the fuel elements cold enough to safeguard against degradation of the primary fission product release barrier (in other words, the zirconium cladding) during all modes of operation, as well as when the reactor is in a shutdown state.

The Fukushima incident

In the design requirements of power reactors, external events that may have an impact on the safety of the reactor are always stipulated for a specific site.

It is accepted practice to design for an earthquake of a certain magnitude and the possibility of flooding. For sites along the coast, this requirement normally includes tsunamis of certain intensity and flooding elevations.

From the sketchy information released by the Japanese authorities, it appears as if the tsunami flooded and damaged the cooling water intake equipment and structures of all four reactor units. This could have resulted in a total loss of main heat sink for the heat generated in the cores of three units and the unloaded fuel from the fourth unit, as well as older fuel stored in the fuel storage pond of all four units.

The heat generated by only the fission products one week after shutdown by one unit is roughly estimated at 6.5 MW. The plant seem to have survived the earthquake and the diesel engines that need to supply power in the event of a loss of off-site power to the cooling systems started. Forty minutes later, the tsunami knocked out all off-site power connections, as well as the diesels. Batteries took over, but died after some hours. With no power, water couldn't get anywhere.

It is clear from the reports that the power supply was eventually restored to some extent, but since a sufficient source of reactor-grade cooling water was unavailable, sea water was used directly on the heated fuel elements and structures. The time taken to get this operation going seems to have caused the fuel elements to overheat and an explosive quantity of hydrogen was produced due to the chemical reaction. From the television footage that was shown, it is clear that explosions occurred at the facilities, which blew off some of the cladding material that was used at the top of these reactors. This does not necessarily imply that the reinforced concrete buildings that acted as the last physical barrier against release were damaged.

The question now is what can be expected in the days to come? An answer to this question is based mainly on speculation, but some clear indicators already exist. The hydrogen explosions suggest that the cladding tubes that were supposed to contain the fission products were degraded. Degradation would most probably have resulted in an increase in the release of radioactivity into the building environment. If the ventilation system had been operational, then one could have

→ *The Koeberg nuclear power plant.*

expected some degree of filtration and dilution of the concentration of the radioactivity. However, some of these radioactive fission products were of a gaseous nature and some were even noble gases. If the plant manages to maintain cooling for the next months or even years and restore the containment with efficient ventilation around the damaged fuel elements, the radioactive releases will diminish. If not …?

The Koeberg design

All the nuclear reactor facilities in Japan are built close to the notorious "ring of fire". In the case of Koeberg, the situation is very different. Although the Cape is seismically very stable, Koeberg was designed with substantial conservatism using the Ceres-type seismic event on the Milnerton fault as basis. This fault is nine kilometres offshore. In addition, the nuclear island, which consists of the Nuclear Steam Supply System (NSSS) and fuel building, is supported by a large number of aseismic bearings that are specifically designed to reduce the peaks of horizontal building acceleration during a specified earthquake.

Although no tsunamis have ever been recorded on the West Coast, the design of Koeberg includes allowance for a three-metre tsunami under the assumption that the tsunami will coincide with maximum spring tide, a major storm surge and maximum wave height. This resulted in a total height of seven metres above mean sea level. The Koeberg terrace height is eight metres above mean sea level. As a modification to the plant subsequent to the Three Mile Island accident, platinum-based hydrogen recombiners were installed in the containment buildings of the two reactors to eliminate possible hydrogen explosions.

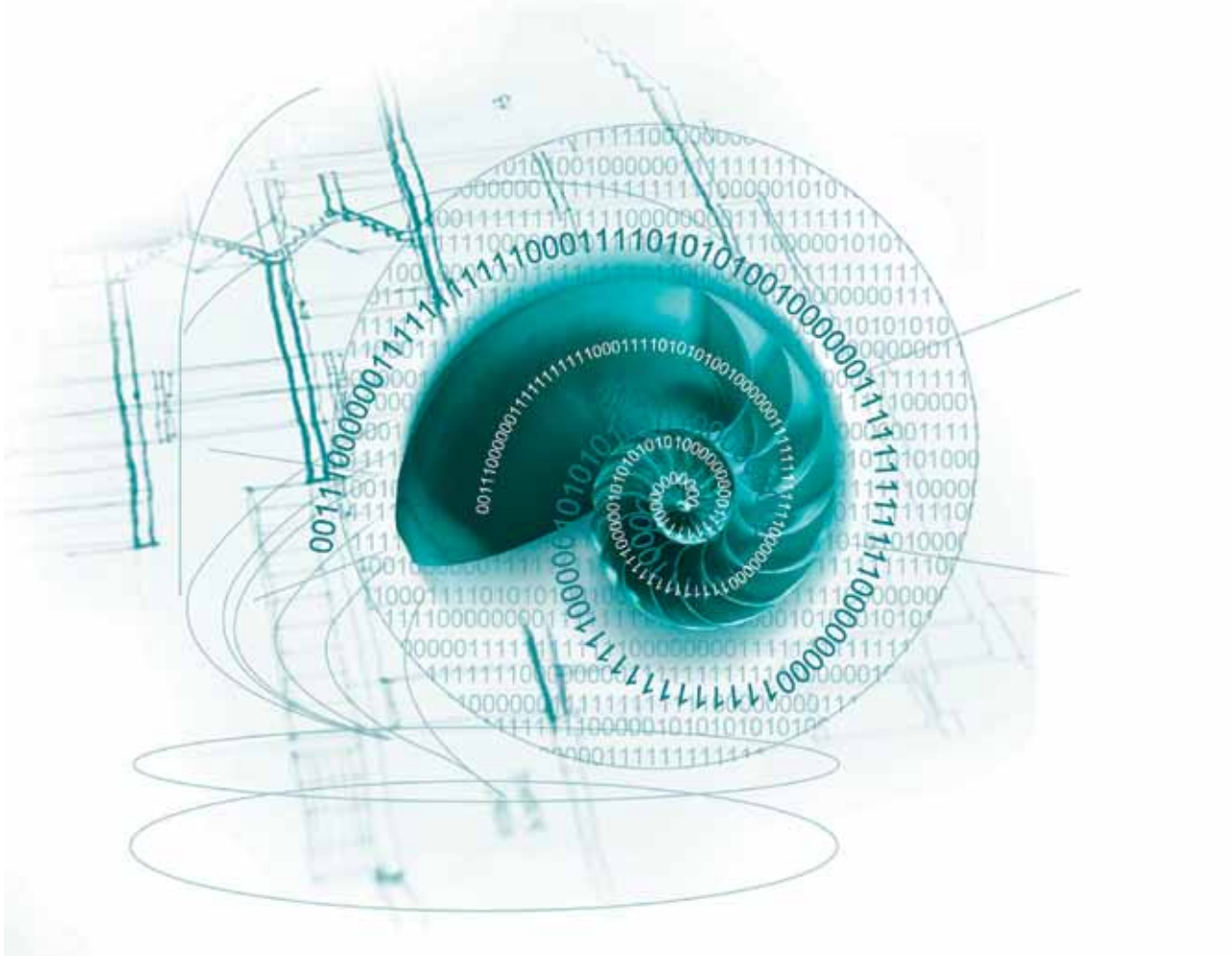
What is radiation?

Radiation is energy carried away from an excited nucleus of radioactive elements. This energy can be carried by energetic, charged particles or by electromagnetic radiation. Where this radiation interacts with a medium, energy is deposited. If the medium is a human being, then – depending on the nature and quantity of the energy bearing radiation – the energy deposited can damage or kill cells.

The importance of safety in the nuclear industry is generally recognised and – except for the use of radiation in medicine – strict standards for radiation exposure have been developed. This is fortunate, because so many of the devices of modern technology, such as accelerators, nuclear reactors, television sets and high-flying aircraft, represent potential sources of radiation exposure.

Notwithstanding the accidents that have occurred in nuclear facilities so far, the nuclear industry has contributed very little by way of radiation injury either to its own personnel or to the general public.

Leading minds to the future



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At the University of Pretoria, we strive to find innovative solutions in a rapidly evolving and developing world.

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Mr Nuclear joins the University of Pretoria

Undergraduate and postgraduate students in the University of Pretoria's School of Engineering who are interested in giving their qualification a nuclear flavour, now have the benefit of learning from the experience of Prof Johan Slabber, who joined the Department of Mechanical and Aeronautical Engineering in October 2010.

Before joining the University, Prof Slabber was Chief Technology Officer at the Pebble Bed Modular Reactor (PBMR) Company (Pty) Ltd. Prior to that, he held the positions of General Manager: Reactor Technology at the Atomic Energy Corporation of South Africa (now NECSA) and Chief Systems Engineer at Integrators of Systems Technology (IST), where he led a team that completed the first conceptual systems design of a small demonstration high-temperature reactor. In 1994, he joined the Safeguards Department of the International Atomic Energy Agency (IAEA) in Vienna, where he completed a contractual period of five years before joining the PBMR in 1999. He holds a doctorate in mechanical engineering from the University of Pretoria and also studied at the Oak Ridge School of Reactor Technology in the USA.

Following his years in industry, it is a pleasure for Prof Slabber to return to his Alma Mater and plough the extensive knowledge and experience he has acquired over the years into the training of the next generation of nuclear engineers. His particular focus is to add a nuclear engineering thrust to the Mechanical Engineering postgraduate academic and research programme, as well as the presentation of an elective in Nuclear Engineering in the undergraduate programme in Mechanical Engineering. This also gives the University of Pretoria a leading edge in terms of its product offering.

The application of nuclear technology in mechanical engineering provides graduates with a solid theoretical foundation from which to develop new innovations that will provide solutions to pressing global challenges.

The first master's project with nuclear engineering theme has just been registered. It examines the viability of using silicon carbide tubes for water-cooled reactor fuel elements and suggests replacing zircalloy nuclear cladding with silicon carbide. If this technology had been in use at Fukushima, the disaster that accompanied this event might have been averted. This project is being undertaken in collaboration with Westinghouse, a major international partner in the nuclear energy field, with the support of Eskom. A presentation has been made to the National Research Foundation (NRF) for funding from the Technology and Human Resources for Industry Programme (THRIP).

Prof Slabber is also involved in setting up the Nuclear Research Institute (NuRI) at the University of Pretoria, where he will provide technical guidance in the management of nuclear technology development projects.

Research initiatives in the Department of Mechanical and Aeronautical Engineering are linked to the newly established institutional research theme that focuses on energy. These initiatives are aimed at multidisciplinary and transdisciplinary research and will expand the network of expertise that was developed to conduct research and development work on the pebble bed modular reactor technology for the PBMR before the project was terminated by government.

Research themes include materials science and nuclear waste. Such initiatives present the University with the opportunity to expand its participation in nuclear energy research to include a wider range of themes related to energy production.

← *Prof Johan Slabber presented a lecture on the Fukushima tragedy as part of the Graduate School of Technology Management (GSTM) Lecture Series.*

University launches new energy research initiative

by Dr Jörg Lalk

The University of Pretoria recently established a number of institutional research themes (IRTs) that are aimed at multidisciplinary and transdisciplinary research. These research themes cut across faculty boundaries and will further strengthen the University's reputation as one of South Africa's leading research universities.

The idea behind the IRTs is to focus the University's research efforts on a number of carefully selected themes that are relevant to South Africa's economic and social growth and development.

With the closing of the pebble bed modular reactor (PBMR) project by government, an opportunity presented itself to expand the University's participation in nuclear energy research to include the wider energy field. Since the dark load-shedding days of 2008, the South African government has also been hard at work to ensure South Africa's energy security. This has resulted in a number of relevant national strategies and policies, most notably the Integrated Resource Plan (IRP) of 2010. This plan represents a road map to electricity security for the next 20 years.

A recent study by Prof Anastassios Pouris, Director of the University's Institute for Technological Innovation, found that the University of Pretoria was the most prolific publisher of core energy research in South Africa between 1997 and 2007, sharing the top position with the University of Cape Town. In this respect, the University outperformed even Sasol.

National energy security

Until about 2006, South Africa was seen as a country with abundant and cheap energy resources. Coal was seen as an infinite resource for the generation of electricity and, although the country had a few hydroelectrical power stations and the only nuclear power station on the African continent, there was little motivation to move away from coal as the dominant source of electricity.

This changed in late 2007, when Eskom suffered a number of unplanned plant outages. Together with a higher than expected economic growth rate, this created what one could argue was the "perfect energy storm". During 2008, the country suffered rolling blackouts (somewhat diplomatically referred to as "load-shedding") that saw even the key mining industry being cut off from electricity supply for a while. The effect on the economy was huge, and in some cases industries have still not fully recovered from the subsequent economic fallout. These events, together with increased pressure to substantially reduce greenhouse gas emissions, led to a fresh look at South Africa's energy future.

During and after the blackouts of 2007 and 2008, a number of government policy and strategy documents were released that were aimed at taking the country towards a more secure energy future. The most notable of these were the Nuclear Energy Policy (approved by Cabinet in 2008) and the Integrated Resource Plan of 2010. Others included the Industrial Policy Action Plan, which has been in force since April 2008, the Energy Efficiency and Demand Side Management (EEDSM) Policy, published in May 2010, and the draft Nuclear Research, Development and Innovation Strategy

International nuclear energy trends

Currently operating reactors	440
New reactors proposed	344
New reactors planned (order placement imminent) or on order	149
New reactors under construction	59

(Source: www.world-nuclear.org, 1 August 2010)

→ *Table 1: International nuclear energy trends.*

Energy distribution forms part of the University's institutional research theme.

(NERDIS), which is being reviewed by the Department of Science and Technology. These policy documents all have in common the issue of energy security and its contribution to job creation, economic growth, research and human capacity/skills growth. These are underpinned by the Department of Economic Development's draft New Growth Plan, released in November 2010.

Against this background, an opportunity exists for focused research, as well as the training of scientists and engineers in the field. Over the last few years, the University has been involved in a number of energy-related activities, notably research relating to energy efficiency, demand-side management, fluoro-materials, carbon materials, nuclear energy, advanced materials, thermoflow, and engineering and technology management.

This, coupled with the fact that the University houses the largest school of engineering in South Africa and the only graduate school of technology management in South Africa, places it in a unique position to leverage its well-developed and highly rated scientific, engineering and management capabilities in support of government's energy objectives.

Research focus of the new energy theme

A careful analysis of existing research activities at the University revealed a correlation with known areas of interest in the wider energy sector, as well as a number of recent government policy papers, strategies and plans. Of importance are the typical national priorities that the Department of Energy evaluated while developing the new Integrated Resource Plan of 2010, namely future energy demand, required energy supply, the national economy, climate change and regional development. It stands to reason that the new initiative's research focus areas should be selected to support these national priorities. The University's new energy institutional research theme will initially focus on electrical energy, but will, over time, evolve towards the inclusion of other energy technologies such as biofuels.

The core focus areas are as follows:

Energy production

Nuclear energy

It is evident that South Africa cannot achieve its declared reduction in greenhouse gases and base-load requirements without expanding the contribution of nuclear power to the national power mix. The draft IRP made provision for at least six new nuclear power stations. At the same time, the Koeberg facility was to initiate a major project to extend the lifetime of the nuclear power plant. Despite ongoing problems in Japan, a number of countries – including China, Finland, the United Kingdom and the United Arab Emirates – are also engaged in major nuclear projects, which provide for research collaboration opportunities.

Nuclear energy is of particular importance to the University due to

→ **(Right)** *Coal-fired power stations provide for nearly 90% of the country's energy needs.*

the institution's participation in some research projects for the PBMR project. These projects benefited the University in a number of areas, including laboratory upgrades, new state-of-the-art equipment, new research skills and know-how in the nuclear field.

Coal
South Africa currently sources nearly 90% of its energy needs from coal, which in turn is responsible for the bulk of the country's greenhouse gas emissions. The University, through its South African Research Chair Initiative (SARChI) Chair in Carbon Technology and Materials in the Institute of Applied Materials, is already addressing this problem, notably with a focus on research into so-called "clean coal". In addition, the two new coal-fired power stations (Medupi and Kusile) that are currently being constructed by Eskom provide exciting research opportunities during their planned 40-year life cycles. Important areas of research would be the underground gasification of coal, CO_2 capturing and storage, as well as clean coal.

Renewable energy
It is the declared intent of government to drastically increase the contribution of wind and solar resources, in particular, to the national energy mix, with the anticipated contribution of these energy sources to approach 50% within the next 20 years. As these technologies are relatively new and in some cases rather novel, much scope for research exists. Examples include the planned new 5 000 MW solar park at Upington and the soon-to-commence 100 MW concentrated solar plant and 100 MW wind farm projects of Eskom.

Energy distribution

Smart grids
With the inclusion of non-traditional energy resources, such as renewables, with their inherently random availability, it becomes substantially more important to move towards so-called intelligent (or smart) distribution networks. As South Africa has barely touched this exciting field, opportunities for advanced research abound. In fact, once many of the anticipated new solar and wind plants are online, the country will have little choice but to invest in the upgrade of its current distribution network and move to a smart grid in the long term. This field includes research opportunities in areas as diverse as software engineering, control engineering, systems modelling and simulation, advanced sensing and measurement, secure communications and protection systems, all of which the University is well positioned to address. An interesting impact on the existing network would be a growing fleet of electric motor vehicles, especially with the pending release of such vehicles on the South African market by manufacturers such as Nissan, Toyota and General Motors, and possibly the locally developed Joule vehicle.

Energy storage
Renewable energy sources are generally viewed as not exhibiting base-load capabilities. They rely on the sun and the wind to generate energy. When the sun shines or there is a strong wind, it is quite plausible that there is no consumer need for the energy generated by these plants. A solution to this would be the ability to efficiently store energy when it is not needed and to release it later when it is needed, regardless of whether the sun shines or the wind blows. Further collaborative opportunities exist in this field, with both Eskom and the Council for Scientific and Industrial Research (CSIR), who already collaborate on finding a solution.

Energy optimisation

Energy efficiency and demand-side management
The University currently hosts the National Hub for Energy Efficiency and Demand Side Management (EEDSM) in the Centre of New Energy Systems. It continues to attract many postgraduates from across the country, as well as an increasingly strong contingent of international students to its programmes in energy efficiency. With its strong research track record, the hub has been recognised as a leader in EEDSM research, contributing to the alleviation of South Africa's energy problems.

Plant lifetime extension
Most power stations are designed to have a specific lifetime, typically 40 years, after which they are decommissioned and dismantled. Due to financial pressure and other reasons, many older plants are being upgraded to extend their lifetime expectancy, sometimes by 20 years or more. This poses particular problems with regard to engineering management, safety issues, materials longevity and maintenance. Examples include the pending Koeberg life extension programme. The University has excellent capabilities in these fields.

Thermal optimisation
Thermal efficiency is the key to optimised power plants. This is relevant to all coal, nuclear and solar power plants (wind being the exception). The University is already well positioned in this field and is known for its expert thermoflow know-how.

Advanced materials

Carbon and graphite
The SARChI Chair in Carbon Technology and Materials in the Institute of Applied Materials

→ *Solar energy is a renewable resource.*

(a joint effort between the Department of Chemistry in the Faculty of Natural and Agricultural Sciences and the departments of Chemical Engineering, and Materials Science and Metallurgical Engineering in the Faculty of Engineering, Built Environment and Information Technology) and the SARChI Chair in Fluoro-materials Science and Process Integration in the Department of Chemical Engineering are at the leading edge of specialist materials research in South Africa. Further research is also being done by the departments of Chemistry and Physics, including cutting-edge materials and computational modelling using the University's state-of-the-art cluster computing facility.

Ceramics
Silicon carbide (SiC) plays a critical role in high temperature nuclear reactors. This particular material is also being viewed with increasing interest by more traditional nuclear reactor designers, particularly as a cladding material in fuel elements is to replace existing zircalloy (this material reacted with steam in the Fukushima event, creating hydrogen, which then exploded). Other applications, such as high temperature heat exchangers, are also possible. The University is already regarded as an expert in the use and characteristics of SiC.

Composites
Although composite materials are traditionally viewed as important in automotive and aerospace applications, recent developments also demonstrated their applicability in the energy field. One example would be the use of such materials for nuclear reactor control rods. Other possibilities that exist include turbine blades for wind energy systems.

Heat-resistant materials
The issue of materials that are resistant to high temperatures enjoys substantial research interest. Applications of these materials range from nuclear applications to solar energy systems.

Material characterisation
The University has a world-class capability to do advanced and novel characterisation of materials. No research in advanced materials would be possible without the ability to determine the composition, structure, defects and behaviour of materials under specific conditions. Opportunities exist to collaborate with other such capabilities at both the Nuclear Energy Corporation of South Africa (NECSA) and the CSIR.

Materials modelling
Modelling of the properties of materials has reached such an advanced stage that it is more productive to first calculate the desired properties of advanced and exotic materials rather than to embark on expensive and time-consuming experimental investigations. The University of Pretoria is already recognised as a leader in this field, with excellent computational hardware and the most modern software in the field.

Policy, economics and society

Manufacturing localisation
It is quite clear that the rollout of new energy capacity will be hugely challenging for the South African manufacturing industry. The doubling of current generation capacity from about 40 GW to 80 GW will require the large upscaling of the local manufacturing industry, not only from a skills perspective, but also from a design, engineering management, manufacturing process and capacity perspective.

Legal and regulatory matters
Past experience illustrated the catastrophic effects on projects in the energy domain when specific legal and regulatory aspects are not properly addressed. What makes this so challenging is the fact that many energy technologies have surged ahead of the existing legal and regulatory frameworks. Areas of particular importance include carbon trading, compliance to environmental undertakings, such as the Copenhagen Accord, legal frameworks for energy regulators, etc.

Health and safety
It is generally understood that health and safety are important in nuclear energy plants. Clean energy sources, such as solar and wind, also have health and safety challenges, notably with regard to heavy and other exotic materials that are used extensively in these plants.

Dynamic system modelling
The scope of the modelling of energy systems and their building blocks can range from the development of detailed mathematical models that can be used to predict particular physical phenomena, to high-fidelity complete dynamic system models (for example, a complete power station) used for the study of accident and operational behaviour, as well as operator training, to atomic-level computational models. Also included would be economic models that are typically used by governmental and utility organisations to do financial predictions and help determine policy. This field is vast and complex and truly multidisciplinary, requiring expertise from the mathematical, physical and materials sciences, as well as engineering and business management.

Design life cycle
It is widely accepted that all successful solutions exhibit some, if not all, of the characteristics of a total life cycle approach. Not only are the basic design processes part of the system's creation, but so are all the elements required to support, maintain, expand and eventually discard the equipment in a safe and environmentally friendly manner. The University is fortunate in that the Graduate School of Technology Management's senior academic and research personnel all have vast practical and industrial experience in this field. In addition, the school hosts the Chair in Life Cycle Engineering, putting it in a unique position in South Africa.

Risk management and mitigation
As South Africa embarks on the difficult path towards energy security, it has come to realise that this path is not only fraught with engineering, scientific and economic problems, but also many risks. Many large capital-intensive undertakings fail in some way or other because of a poor understanding of the inherent risks. The very fact that South Africa has serious problems with reliable and sufficient energy sources can be attributed to poor risk management. There is a clear need for practical risk management models that can be used to mitigate the energy supply risks South Africa currently faces, especially as this must be seen within the contradictory requirements of both an increased energy supply capacity and reduced greenhouse gas emissions.

Techno-economic analysis
With the focus on sustainable energy solutions also comes a question on future trends. As technologies tend to cross traditional borders and energy plants become a complex multidisciplinary "consortium" of technologies, it also becomes important to analyse technology trends and their economic impact. This would be a critical enabler for national energy policy-makers.

Sustainability
Of primary concern is the sustainability of energy sources (and by default the resulting systems), not only from a social and economic perspective, but also from a scientific and engineering viewpoint. The long-term limited coal reserves are well known, as is the case with uranium (although thorium – as a future nuclear fuel resource – is relatively abundant in South Africa). On the other hand, the belief that renewable sources, such as wind and solar energy, are unlimited is a fallacy, as the wind and solar electricity-generating plants also use other limited sources (for example, rare earth materials). The subject of energy system sustainability seems to be mainly focused on renewable resources. This is a severely limited outlook of a much richer and larger research field.

Environment

Waste management
The University is currently engaged in a novel nuclear waste research project that makes use of bacteria to remove certain radio isotopes from high-level radioactive graphite waste. The results of this research project form part of a European Commission Framework 7 Project, Carbowaste. One of the most contentious issues in nuclear energy remains the long-term storage of radioactive waste. At the University of Pretoria, glassy carbon is being investigated as an alternative for glass.

Pollution
It is clear that despite the South African government's ambitious promises to reduce the country's greenhouse gas emissions by 42% within the next 15 years, this goal will in all likelihood not be achieved. Almost all the current energy sources pollute the environment in some way or other, which provides vast scope for research. This is underlined by the fact that South Africa only ranked 115th out of 163 countries in the 2010 Environmental Sustainability Index published by the Yale University Centre for Environmental Law and Policy.

The way forward

Initially, the Energy IRT will establish a number of kick-off projects that will allow multidisciplinary research that cuts across the faculties of Engineering, Built Environment and Information Technology, and Natural and Agricultural Sciences. These projects were carefully selected to fit in well with the institutional research focus areas. They also comply with national energy priorities in that they address

aspects of advanced materials, nuclear fuel, environment and renewable energy, while simultaneously leveraging existing skills of the University. It is anticipated that these initial projects will act as a catalyst for the establishment of further energy research at the University with the eventual aim of ending the initial three-year period of the IRT's University funding with at least 24 active projects, all of which are expected to attract substantial industry support and funding. Towards the end of 2011, a formal request for research proposals will be issued to ensure continued growth in new research projects.

The initial kick-off projects include the following:

Technology assessments and scenarios for energy systems
This aims to develop a detailed relational database and model to help energy decision-makers derive at realistic energy policies. In addition, the project aims to conduct a large and complete energy technology trend analysis, accompanied by a related gap analysis, focused on the South African industry. Discussions are already underway with a number of international and local organisations and universities as possible collaboration partners.

Contact Dr Jörg Lalk of the Graduate School of Technology Management (jorg.lalk@up.ac.za).

Energy optimisation
This project will be a continuation of the work being done in the National Hub for EEDSM, thermal optimisation and process optimisation fields.

Contact Prof Xiahua Xia of the Department of Electrical, Electronic and Computer Engineering (xxia@postino.up.ac.za), Prof Josua Meyer of the Department of Mechanical and Aeronautical Engineering (josua.meyer@up.ac.za) or Prof Thokozani Majozi of the Department of Chemical Engineering (thoko.majozi@up.ac.za).

Nuclear waste minimisation
This project will continue the work that has already been done by the departments of Chemical Engineering and Physics, where promising results were obtained. The project will – in all likelihood – continue its collaboration with the European Commission Framework 7 Programme.

Contact Prof Walter Focke of the Department of Chemical Engineering (walter.focke@up.ac.za) or Prof Johan Malherbe of the Department of Physics (johan.malherbe@up.ac.za).

Silicon carbide tubes for water-cooled reactor fuel elements
Ironically, this project was proposed about a month before the Fukushima event and aims to replace zircalloy nuclear cladding with silicon carbide. The project is undertaken in collaboration with a major international partner in the nuclear energy field.

Contact Prof Johan Malherbe of the Department of Physics (johan.malherbe@up.ac.za) or Prof Johan Slabber of the Department of Mechanical and Aeronautical Engineering (johan.slabber@up.ac.za).

Multi-product low carbon footprint power generation
This is a novel project that will make use of a variety of biofuels and bagasse to generate electricity in collaboration with a number of international partners.

Contact Dr Jannie Pretorius of the Department of Chemistry (jannie.pretorius@up.ac.za).

Smart grids for renewable energy integration
This project will attempt to understand the systems level impacts of renewable energy sources on the stability and sustainability of large distribution grids, with the eventual aim to develop decision models towards smart grids.

Contact Dr Louwrence Erasmus of the Graduate School of Technology Management (louwrence.erasmus@up.ac.za).

Of course, none of these projects, or those that will follow, will be possible without excellent postgraduate research.

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***Dr Jörg Lalk** is associated with the Graduate School of Technology Management at the University of Pretoria.*

→ *A wind turbine.*

Alternative sources of energy for South Africa in various shades of green

by Danie Smit

While it is essential to ensure that the country has a reliable source of base-load energy to fuel economic developments, such as mining, as well as for residential and commercial purposes, this should not be at the expense of the country's natural resources and biodiversity. Over the years, cheap energy from coal-fired power generation facilities has taken its toll on the quality and quantity of the country's water resources, as well as on the biodiversity that has made South Africa such a sought-after tourist destination.

Coal is not only a non-renewable resource, but also plays a major role in climate change. Due to the huge amounts of CO_2 and other gases that are emitted during combustion, the generation of electricity through coal has a large carbon footprint and impacts negatively on the country's water resources, air quality and biodiversity.

Over many decades, substantial areas of Highveld grassland and bushveld have been scarred by open-cast coal mining, accompanied by large ash and waste dumps. There has also been limited success at rehabilitation to restore the ecological potential of the area. The country's rivers and water resources have become acidic waste streams, which have had devastating consequences for the ecosystem and the country's biodiversity.

The country's rivers and water resources have become acidic waste streams, which have had devastating consequences for the ecosystem and the country's biodiversity.

Alternative sources of energy

As a result of the negative impact of coal-based power generation, alternative (renewable) sources of energy, such as the sun, wind and water, need to be considered. Such alternatives are also more sustainable and have come to be regarded as green energy sources. However, they do not come without a cost to the environment.

With its long, cloudless sunny days (especially in the Karoo and the Northern Cape), South Africa has one of the highest solar irradiation levels in the world. This makes solar power an attractive source of alternative energy. Solar energy is generated when the sun shines on special photovoltaic cells that use the sun's radiation energy to generate an electric current. The main benefit of solar power is that

→ *Open-cast coal mining has scarred large areas of natural vegetation.*

→ *A wind farm has a significant visual impact on the surrounding area, which can affect tourism.*

it can supply remote areas with reasonably inexpensive power. It is a clean source of energy with no direct emissions. In order for solar energy to make a meaningful contribution, however, a large battery bank is required that is capable of storing energy during the day and feeding it into the national grid. The solar plant itself will cover large areas of agricultural land or natural vegetation. These areas would have to be cleared of all large trees and buildings to ensure maximum radiation. Such a solar park would be visible over long distances and would impact negatively on several other economic sectors, such as tourism, agriculture and conservation.

The use of wind turbines to generate electricity is another source of alternative energy that is under investigation. Electricity is generated when the wind turns a set of blades attached to a generator that is situated on a mast about 80 metres above the ground. South Africa has a very long coastline with strong winds. Unfortunately, the areas that are most suitable for the development of wind energy overlap with prime tourism areas, like the West Coast. In order for wind energy facilities to be economically viable, several units need to be placed together in a wind farm development. These farms have a significant visual impact on the surrounding area. Although wind energy is regarded as a form of green energy, the footprint of a wind farm, which entails the construction of terraces for the wind turbines, is a matter of concern to the agricultural sector, as it represents a substantial loss of agricultural land.

Another alternative source of clean energy is that of hydropower. Hydro-energy is generated when gravity feeds water from a large dam or river through a tunnel into the propellers of a generator, which turns and creates an electrical current. For South Africa, this source of energy is not as desirable an alternative as one might imagine, due to the fact that South Africa does not have that many large rivers. The construction of a hydropower facility, with dams and water transfer schemes, will therefore have a significant impact on the receiving environment. The cost associated with constructing such a facility also has an impact on its feasibility, especially in a country with limited resources and sites to develop hydropower facilities.

Green alternatives

The research that is being conducted on alternative means of energy production, including nuclear energy and renewable sources of energy (the sun and wind), will also need to ensure that the impact of these sources of energy on the environment is minimised and that they do not have a negative effect on other sustainable economic sectors.

Danie Smit *is an alumnus of the University of Pretoria and is a specialist on environmental impact management.*

Gautrain enhances economic growth in the province

With the official opening of the Gautrain's north-south line at the beginning of August, visitors to the University of Pretoria can now make use of this state-of-the-art rapid rail route that runs right past the Hatfield Campus.

The opening of this phase of the Gautrain for commercial service on 2 August 2011 followed a rigorous evaluation of all the contractual and technical requirements for this phase. The complete route runs from Park Station in Johannesburg, past Rosebank, Sandton, Marlboro, Midrand, Centurion and the Pretoria CBD, terminating in Hatfield. The entire 60-km trip takes less than 45 minutes, travelling at maximum speeds of 160 kilometres per hour. Gautrain bus services are fully functional along the entire route.

Although the link between the OR Tambo International Airport and Sandton has been operational for some time now, the final, southward leg of the route, from Rosebank Station to Park Station in the Johannesburg CBD, will be opened at a later date. This is to accommodate additional engineering works in that section of the route and is a precautionary measure to ensure that the highest passenger safety standards are adhered to while engineering works are in progress.

According to Mr Jack van der Merwe, CEO of the Gautrain Management Agency, the biggest advantage of this long-awaited high-speed train is its predictable travelling time. This modern train offers international standards of public transport with high levels of safety, reliability and comfort.

Relieving traffic congestion

Passengers can expect a train every 12 minutes during peak periods (from 05:30 to 08:30 and from 16:00 to 19:00) and every 20 minutes in off-peak periods (from 08:30 to 16:00 and from 19:00 to 20:30) during the week, and every 30 minutes over weekends and public holidays. There are 125 buses to transport passengers within a radius of five to six kilometres of the various stations (with the exception of weekends and public holidays). Subject to road traffic conditions, the bus timetable is integrated with the train timetable.

The Gautrain offers a cost-effective, efficient, environmentally friendly and safe solution to some of the worst transport problems in the most densely developed area in the province, which is also the country's economic hub. It also brings Pretoria and Johannesburg in line with many major cities in the world where it is common practice to link cities by rail to international airports. The Gautrain will therefore form the backbone of many other modes of public transport in Johannesburg, Midrand and Pretoria.

Mobility is the key to future economic growth in Gauteng, and the need for an alternative mode of public transport to help alleviate congestion on the roads between Johannesburg and Pretoria has been evident for some time. Traffic congestion on the N1 freeway is currently estimated to cost more than R300 million a year, including production time lost during travelling time, higher transport costs and above-average accident rates.

Traffic congestion impacts negatively on quality of life. The N1 carries some of the highest traffic volumes in South Africa. More than 157 000 vehicles travel on it daily and it has a traffic growth rate of 7% per annum. It is estimated that approximately one-fifth of Pretoria-Johannesburg commuters will make the switch from travelling by road to travelling by rail. The Gautrain could transport more than 100 000 passengers a day.

The determined fares are based on the principle of affordability and are highly competitive compared to other modes of public transport. They are sufficiently price-attractive to create a substantial shift from private car use to public transport. The safety and security of passengers are of the utmost importance, and safety and security features have been extended to include

→ *The Gautrain on the test track at the depot.*

The Gautrain set on the test track at Bombardier's Testing Facility, Derby, in the United Kingdom.

other facilities, such as station precincts and vehicle parking areas.

Enhancing economic growth

The Gautrain project is primarily aimed at enhancing and supporting economic growth in Gauteng and generating employment. It is part of a longer-term vision, which will include a commitment to creating and sustaining a new culture of public transport usage in South Africa.

The project was initiated as one of eleven Blue IQ projects of the Gauteng Provincial Government (GPG). Blue IQ is a multi-billion rand initiative of the GPG to develop economic infrastructure for specific major projects in smart industries, high value-added manufacturing and tourism. It works in partnership with business and government departments as a catalyst to promote strategic private sector investment in key growth sectors of the Gauteng economy.

The Gautrain project is the largest public-private partnership (PPP) to be launched in South Africa. It links private enterprise and government in a project that will become the central hub of a future integrated transport project for South Africa's commercial heart. With a value of about R25.2 billion, the project was structured to ensure that the government and the concessionaire, Bombela Concession Company, operated within a strict set of financial and time parameters.

One of the main elements in the agreement was the sharing of commercial risk. This meant that Bombela took "transfer" from the government of the responsibility for delivering the Gautrain project at a fixed base price within a certain period.

It made Bombela accountable for the "turnkey contractor" appointed to construct the Gautrain system, as well as the contractor appointed to operate and maintain the Gautrain service.

The two parties had to make complex projections and calculations on the construction programme, spending, the sourcing of material, equipment, labour and skills – some of it sourced internationally due to the unavailability of certain skills in the country – over the life of the contract. All these issues had to be agreed on between the province and the Bombela Concession Company before laying a metre of track. Private-sector funding for the project was provided through equity in the form of shareholders' funds. The equity made available by shareholders in the Bombela Concession Company covered approximately 20% of the funding necessary for the project. Of the 80% balance, 71% was provided by bank syndication and 9% through a floating rate mezzanine funding facility.

Environmental impact

There can be little dispute over the fact that rail transport is more environmentally friendly than road

transport. It requires a relatively small amount of land and the pollution emanating from it in terms of emissions is insignificant when compared to most other means of transport.

International experience shows that cities that have effective, efficient public transport systems have significant improvements in air quality. Levels of nitrous oxide, carbon monoxide, diesel particles, carbon dioxide and airborne lead have negative impacts on society, particularly on developing children. The Gautrain will have a significant, positive impact on air quality by reducing the use of fossil fuels.

"The environmental impact of fossil fuels is going to result in a number of changes in the transportation industry," says Mr Van der Merwe, "and over the next 20 to 30 years, the country is going to be obliged to move the transportation of many goods and other products off the roads and onto its railway network." The technology developed for the Gautrain will therefore not just be utilised to address the problems experienced by commuters in densely populated areas, but also for transporting freight across the country. Routes that will benefit tremendously from this linkage are those leading from the country's harbours, such as Durban, to the economic hub of the country, Gauteng.

The future of rail transportation

In terms of commuter transportation, the Gautrain is the first of several that are being planned for South Africa. One of the problems that has been inherited from the previous political dispensation is the large numbers of workers that live in rural areas, such as KwaNdebele in Mpumalanga, who have to commute daily by bus to their places of work in Pretoria and Johannesburg. Investigations are already underway to utilise the existing ring route of 250 km that incorporates Koedoespoort in Pretoria in order to change the lives of hundreds of people who currently spend three hours twice a day just to get to their places of employment.

According to Mr Van der Merwe, there is also great interest in the exportability of the technology developed for the Gautrain to the rest of Africa. As a public-private partnership, the Gautrain has been commended internationally, and much interest has been shown in the lessons learnt from this contractual form and its application to other projects throughout the world. In 2008, it received a Partnerships Bulletin Award in the United Kingdom for the best private finance initiative (public-private partnership) deal in the world.

The Gautrain also received the annual Glenrand MIB Excellence Award of the South African Association of Consulting Engineers (SAACE) in 2007 in the category Visionary Client. In 2008, the project received an international Bentley Empowered Award for Excellence in Project Management in Baltimore, USA, specifically for innovation in rail and transit.

Its most recent achievements are the presentation of two awards by the International Association of Business Communicators (IABC) in March 2011. The African Gold Quill awards were received for the Gautrain's social media, as well as for its media relations. These awards recognise individuals and organisations for leadership, strategic management, creativity, resourcefulness and successful solutions in the communication sector.

Mr Van der Merwe says that the success of the project can, to a large extent, be attributed to the multidisciplinary approach that was followed. It is important to adopt a broader perspective. In this regard, it is important not only to focus on the engineering works that are involved in the project, but also the environmental impact, the economic modelling, factors related to socioeconomic development, the financial and legal-technical matters, as well as marketing and stakeholder engagement.

This project has certainly made the world sit up and take note of South Africa's innovative project management expertise and its vision to provide solutions that will improve the lives of its people and enhance economic growth.

***Mr Jack van der Merwe** is an alumnus of the University of Pretoria. He obtained his BSc(Engineering) and BSc(Hons)(Engineering) degrees in Civil Engineering from the University of Pretoria. He is also a graduate of the Harvard Business School's Senior Executive Development programme. As CEO of the Gautrain Management Agency, he has overseen the building and operation of the Gautrain Rapid Rail Link since its inception in 2000. In 2003, he was elected vice-president for Africa of the International Association of Public Transport (UITP). This organisation is a worldwide association for urban and regional passenger transport operators, authorities and suppliers. Under his leadership, the Gautrain project has developed into the largest public-private partnership in the history of South Africa. It has won numerous international awards.*

Training the next generation of engineers

The new Engineering 3 Building and Parkade on the University's Hatfield Campus has been under construction for the past two years. It was officially opened on 25 August 2011 by Dr Blade Nzimande, Minister of Higher Education and Training, and Prof Cheryl de la Rey, the University's Vice-Chancellor and Principal. It will significantly enhance the University's ability to train an increasing number of engineers to meet the critical national shortage of these important skills.

The University invested more than R400 million in the construction of this innovative, environmentally friendly, multifunctional building. Additional funding for the expansion of its engineering facilities was received through a government grant.

The new building has six lecture halls with a total of 1 800 seats, a drawing hall with 450 seats, and two levels of laboratories and offices totalling 10 800 m^2. The entire floor area of the building is approximately 40 000 m^2. A seven-lane entrance eases traffic flow into the parkade, as well as onto the campus.

The parkade comprises four-and-a-half levels of parking (two-and-a-half of which are underground) and makes provision for 996 parking bays. This consists of reserved parking for lecturers and university staff, as well as open parking for students and visitors. The parkade makes use of a pay-on-foot system and will also be used over weekends to provide parking for spectators attending events at the neighbouring Loftus Versfeld rugby stadium.

At the official opening, Dr Nzimande commended the University for "putting taxpayers' money to good use". He said the new facilities would contribute significantly to the role that the University can play in helping the higher education system produce young engineering graduates for the country and the region. He also expressed his delight in the fact that new life is being breathed into South African universities through infrastructure development initiatives, and lauded the University for its strong ties with industry.

Prof De la Rey said that the additional engineering facilities would enable the University to accommodate the annual growth in student numbers, which was in accordance with the University's growth strategy.

"Over the past five years, our student growth rate has been close to 5% per annum. We currently have just over 45 500 registered contact students and another 20 000 students in our distance education programmes. This makes us one of the largest universities in the country and the largest of the research-intensive universities," she said.

As a public university in a developing society, the University of Pretoria needs to be responsive to the human capital development needs of the country. According to the Vice-Chancellor and Principal, growth will be pursued in areas where the University already has expertise, capacity and infrastructural resources. This will enable the University to simultaneously meet its aspirations for academic excellence and sustainability.

Prof De la Rey regards the completion of the new Engineering 3 Building as a significant milestone in enabling the University's institutional strategy. She describes engineering as one of the University's flagship professional programmes, which will be grown further to meet national needs.

According to Prof Roelf Sandenbergh, Dean of the Faculty of Engineering, Built Environment and Information Technology, the University of Pretoria currently delivers 26% of all engineering graduates in the country. It is committed to making a significant contribution to the training of the next generation of engineers.

The new facilities include lecture halls, tutorial facilities, teaching and research laboratories and a CDIO centre, which forms part of an innovative, team-based educational framework where students go through the cycle of conceiving, designing, implementing and operating (CDIO). The offices

The new Engineering 3 Building on the Hatfield Campus.

and research facilities were designed to facilitate the building of research groups around specialised laboratories with close interaction between research leaders and students, and between research groups through the provision of communal spaces. Further expansion in the form of a study centre to support student learning and group work is planned for the near future, while more facilities are proposed as part of long-term growth plans.

Environmentally friendly design

The design of the building is primarily determined by pedestrian flow. A ten-metre wide concourse forms the central axis to the building and becomes the main feeder to secondary walkways leading to lecture halls, offices and laboratories. External balconies to the east and west with high-level planters, green screens and benches provide relief pockets. The concourse connects with the extension to the Music Library to the east and a new ramp to the north connects Engineering 3 to the western podium of the Aula, where a pedestrian bridge across the Ring Road links up with Engineering 2. On ground level, a cultural route runs to the east of the building, connecting the Musaion, Amphitheatre, Rautenbach Hall and Aula. The orientation of the building, governed by the parkade below, resulted in deep-set windows with high-performance glass and intense screening to the west façade. Strong façade lines and concrete frames were used to reflect the architecture of the adjacent buildings.

In its design brief, the University challenged the architects to come up with a design that is in line with the current international trend to make buildings as environmentally friendly as possible. The University made it clear that the building needed to be designed in terms of the principles of the Green Building Council of South Africa's Green Star Rating System. Although a Green Star Rating System has not yet been formalised for a mixed-use educational building, the design team employed best practice in all regards to register the development in future.

Such a rating recognises and rewards environmental leadership. It is based on the innovative use of design, construction and operational practices that significantly reduce or eliminate the institution's impact on the environment. In addition, the design, material and technology used should lead to a reduction in energy and resource consumption and create improved human and natural environments.

The conceptual design focused on assimilating the entire brief in the most cost-effective, yet sustainably responsible way. Additional capital expenditure was only sacrificed if it could be retrieved on lifecycle costing or proven as environmental investment.

Environmentally friendly elements were also incorporated to regulate temperature. Chimneys visible on the western façade are used to naturally extract relief air from ceiling voids above the labs and offices. Chimneys are allocated above the main and secondary concourses. These, together with mechanically operated

windows and louvres, assist in naturally ventilating the public spaces in the building. A central building monitoring system controls all levels of air volume and temperature in the building. Technologies such as insulation to the walls and to the slab below offices and laboratories, the use of variable air volume mechanical systems and motion sensors for lighting, as well as rainwater harvesting, were implemented to reduce the energy consumption of the building.

Some of the innovative design elements that were incorporated to shade the building and reduce heat induction include the following:

- Performance glass reduces solar radiation by up to 48% in summer and stops heat from escaping in winter.
- Solar screens eliminate direct solar radiation by approximately 50%. The screens are made up of louvres and mesh screens that have been designed in accordance with year-round sun angles for summer and winter conditions, as well as the daily angle of the sun.
- Isolation material was applied to the underside of the slab between the underground parking garage and the first floor of the building. This minimises heat loss in offices and lecture halls during winter months.
- Extensive use was made of plants to shade the building against the sun. Special frames were designed that house plant-holders that can easily be removed and replaced.
- Use was also made of environmentally friendly construction material such as concrete, clay bricks, glass, ceramics, organic wool isolation, gypsum boarding and Envirodeck, a composite decking system made from recycled plastic and timber.

Energy efficiency

A number of energy-efficient measures were incorporated in the design of the building. This includes a naturally ventilated atrium, filled with plants that help reduce CO_2 emissions. As a result, less air conditioning is required to cool the building. This means that the building's energy efficiency is measured at 25% below the requirements in terms of SANS 204 (South African National Standard: Energy Efficiency in Buildings).

Spill-over air from mechanically ventilated lecture halls is used to cool down public areas in summer and heat these areas in winter. A chimney convection system, which draws warm air out from ceiling voids and relieves it at roof level, was also incorporated in the design. Apart from the energy saving, the system also allows for the inflow of fresh air, which averts "sick building syndrome".

A rainwater harvesting system has also been included in the design of the building. A 50 000-litre tank allows for water to be redistributed throughout the building for irrigation, as well as being available for fire control purposes. Should the water drop below a certain level, the tank will be filled with municipal water, which will cool the building down even further.

Air conditioning is provided in the form of a chilled water variable air volume system, which greatly reduces energy consumption. The system makes use of a chiller to cool water down. The water is then distributed throughout the building. The system automatically measures the temperature on the inside and outside of the building, and then automatically adapts the inside temperature to a comfortable level. A building monitoring system automatically controls and monitors all systems in the building, including the use of electricity, and the monitoring of water and CO_2 emission levels.

All sanitary fittings are provided with economy cycle water closets, and taps are fitted with control valves to minimise water flow periods. In addition, chilled slab mechanical systems were used, whereby water pipes were cast in the slabs to heat or cool the slab. The system is quite complex and new in South Africa and results in a massive saving on the life cycle costing of the system.

Power-saving techniques include the use of occupancy sensors that detect the movement of nearby people or objects such as cars. The system eliminates the need to burn lamps in areas that have not been occupied for at least 30 minutes. Depending on the location and application of the area, power saving is achieved. These sensors are mostly employed in the parking areas, lecture halls and engineering laboratories of the new building.

- Total floor area of the building: 40 000 m^2 = 8 rugby fields
- Total excavation: 57 600 m^3 = 1 280 average swimming pools
- Total concrete volume: 16 800 m^3 = 373 average swimming pools
- Formwork: 65 000 m^2 = 13 rugby fields
- Reinforcement: 1 570 000 kg = 994 km of 16 mm rebar (from Pretoria to Beaufort West)
- Number of bricks: 1 180 000 = row of 270 km end to end
- Painted surfaces: 67 000 m^2 = 8 375 litres @ 8 m^2 per litre coverage (1 675 five-litre tins)
- Glazed area: 2 242 m^2 = half a rugby field
- Average of 6 m^3 trucks left the site every three-and-a-half minutes over the 64-working-day contract period

→ *The new Engineering 3 Building on the University's Hatfield Campus.*

Standing tall after 50 years

The University of Pretoria's Department of Mining Engineering – one of only three in the country (the others being at the University of the Witwatersrand and the University of Johannesburg) – may be one of the smaller departments in the School of Engineering, but can wield a lot of power when it needs to. The character of the people involved in this department over the years has proven to be its greatest strength. On its 50th anniversary, the department celebrates its provision to the mining industry of world-class leaders, steadily increasing white and black student numbers, innovative teaching and learning strategies, and half a century of existence.

The Department of Mining Engineering is in a healthy state at present. It has the most students (undergraduate and postgraduate) ever, and also prides itself on the high quality of its teaching output. The department's key priority is to develop its students as future managers and technical specialists, while it also encourages them to develop life skills and responsible leadership by participating in student activities. The aim for its lecturers is to develop into internationally recognised engineers and scholars.

In a bid to improve and promote its postgraduate programme, three research focus areas were identified in collaboration with industry experts. Dr Francois Malan and Dr John Napier (rock mechanics), Dr William Spiteri (explosive engineering) and Dr Jan du Plessis (energy and environmental engineering) were recently appointed as extraordinary professors in the department to drive the respective research initiatives.

> The Department of Mining Engineering not only focuses on delivering technical specialists, but facilitates students' development of soft skills to enable them to function optimally in their careers.

In the department they form part of the mining lecturing team of Prof Ronny Webber-Youngman (environmental engineering), Mr Wolter de Graaf (explosive engineering) and Mr Jannie Maritz (rock engineering), Mr Clive Knobbs (mining specialist) and Ms Refilwe Raphukula (junior lecturer). Contracted lecturers into the department are Mr Gerhard Keyter (geotechnics), Mr Gawie van Heerden (financial mine evaluation) and Mr Albert van der Vyver (risk management).

Apart from the full-time courses that prepare young students for the world of mining, the department also offers short courses in cooperation with industry and professional societies.

Its greatest contribution over the last few years was the Safety Risk Management Programme for Anglo American and the Global Industry Risk Management Programme for Sasol Mining. Prof Webber-Youngman, current head of the department, believes that many more mining companies will make use of these courses, as there is huge potential for the further development of such courses.

Brief history

In August 1956, UP's Senate approved a motion to establish a mining department in the Faculty of Engineering with effect from 1959. The Department of Mining Engineering started operating in 1961 under the leadership of Prof De Villiers Lambrechts. Six students enrolled for the first year of study. Prof Lambrechts headed the department from 1961 to 1974, after which Prof Frik Leiding took over the reigns until 1981, followed by Prof Alf Brown, until 1996. Prof André Fourie then took up this position until 2001, after which Prof Nielen van der Merwe led the department. The current head of department, Prof Webber-Youngman, has been at the helm since 2007.

Not all plain sailing

The years 1996 to 2007 were turbulent. There were two attempts to merge the department with the mining school of the University of the Witwatersrand (Wits), but the University of Pretoria opposed this proposal. During this time, Prof Fourie and, after him, Prof Van der Merwe headed the department. When Prof Fourie saw the department's budget and realised that student numbers were the only thing that could secure financial support,

→ Growth of white and black (historically disadvantaged) students has steadily increased in the Department of Mining Engineering.

he immediately prepared himself for some hard work. Together with a reliable team of lecturers, he started recruiting students in earnest and the numbers started to climb. However, at that stage, the question was raised by the Chamber of Mines whether it was really necessary to have more than one mining school. It was also proposed that the University of Pretoria and the CSIR should work together more closely and that the mining schools of UP and the University of the Witwatersrand should fall under the CSIR. Fortunately, senior UP alumni in the mining industry applied sufficient pressure on the chamber to continue with its support to UP, and the proposal on collaboration with the CSIR did not prove to be viable.

In 2000, an attempt was once again made to integrate the mining schools of the universities of Pretoria and the Witwatersrand. There were claims that there were fears in industry regarding the sustainability of separate mining schools and the preferred solution was to create a single school for training mining engineers in South Africa.

The Tertiary Mining Education Committee (TMEC) was created to investigate and solve the problem. If the schools were combined, it was logical that such a school should be situated at Wits, due to that institution's superior numbers and excellent laboratory facilities. The department of the University of Pretoria would then effectively be shut down.

When Prof Kader Asmal, Minister of Education at the time, announced exactly this decision by government in June 2002, the University of Pretoria decided to fight it. It formulated a plan and involved all the friends and alumni of UP in an attempt to block the plan. The Mining Alumni Society of the University of Pretoria played an instrumental role in this campaign. Several high-ranking University officials also put their weight behind the move, which was slowly gaining momentum. After countless meetings and letters, and a period of five years, a high-ranking executive of Anglo American stated in a Chamber of Mines Executive Meeting that the merger was not a good idea and that the matter would not be discussed any further. Prof Van der Merwe describes the moring of that meeting as one of his best moments at the department. From then on, the department only went from strength to strength.

Staff

The core resource of the department is its staff. It currently has a complement of six full-time staff members (with one vacancy), who are encouraged to improve their teaching and research skills, and be active in teaching and in industry in order to ensure that their knowledge remains current and that they are able to contribute to departmental administration and community service. Their work is complemented by the active participation of contracted industry experts as part-time lecturers.

This forms a very important part of the department's education strategy. The involvement of guest lecturers on an ongoing basis keeps the department in touch with industry needs.

The remuneration of academic staff, compared to what their counterparts earn in industry, is usually a problem for tertiary institutions. In the case of the University of Pretoria's Department of Mining Engineering and other mining schools in the country, however, the Minerals Education Trust Fund (METF) subvened lecturers' salaries to 80% of the industry equivalent in 2008. This enabled the department to attract teaching staff similar to the high quality that are currently employed.

Mining alumni

The department has a special relationship with its alumni. It is also one of only a few departments that has its own active alumni society. The Mining Alumni Society of the University of Pretoria (MASUP) serves as a great support structure for the department. This was evidenced by the indispensable role that it played in the department's survival when it was threatened with being shut down.

Students gain practical experience on site.

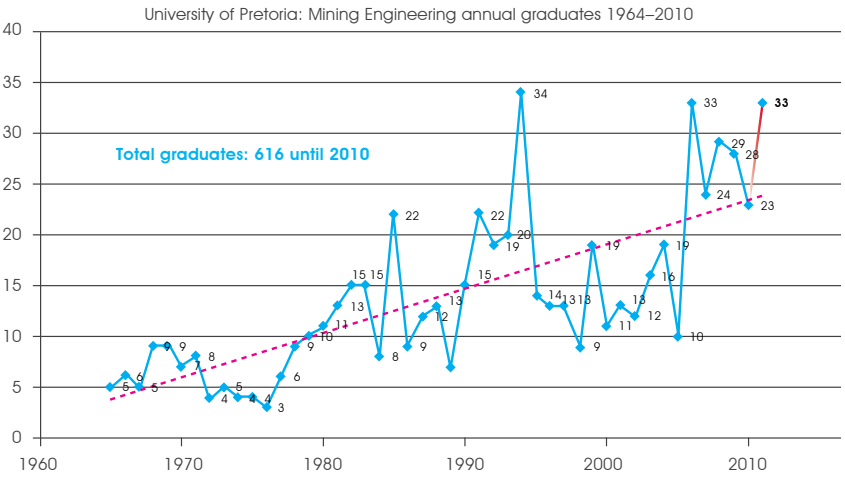


Figure 1. Annual graduates from the Department of Mining Engineering since its inception.

The society was established in 1977 by the first group of graduates in the Department of Mining Engineering. Membership is limited to people who have obtained undergraduate mining engineering or postgraduate qualifications from the University of Pretoria or have been lecturers in the department for at least one year.

Over the past few years, MASUP has actively promoted mining engineering as a career opportunity among learners, and organises and presents seminars at the University. It sponsors lecturers to attend local and international conferences, provides financial assistance to the department, organises international symposiums in South Africa – in collaboration with the Chamber of Mines and the Southern African Institute of Mining and Metallurgy (SAIMM) – and organises informal functions for MASUP members.

Student numbers

Student numbers have grown steadily through the years. A total of 616 students have graduated from the department since 1964.

At the turn of the millennium, a decision was made to change the language medium for third-year and fourth-year Mining Engineering students from Afrikaans to English. Prof Webber-Youngman describes this as one of the best strategic decisions the department has ever taken as it enabled the department to transform. In 2000, the first five black students, including one female student, enrolled at the University of Pretoria, and black student numbers have shown significant growth ever since. In 2011, the intake was 68% black students, compared to 7% in 2001. A remarkable fact is that white student numbers have not dwindled, but have remained fairly constant.

The growth in student numbers escalated to an increase of

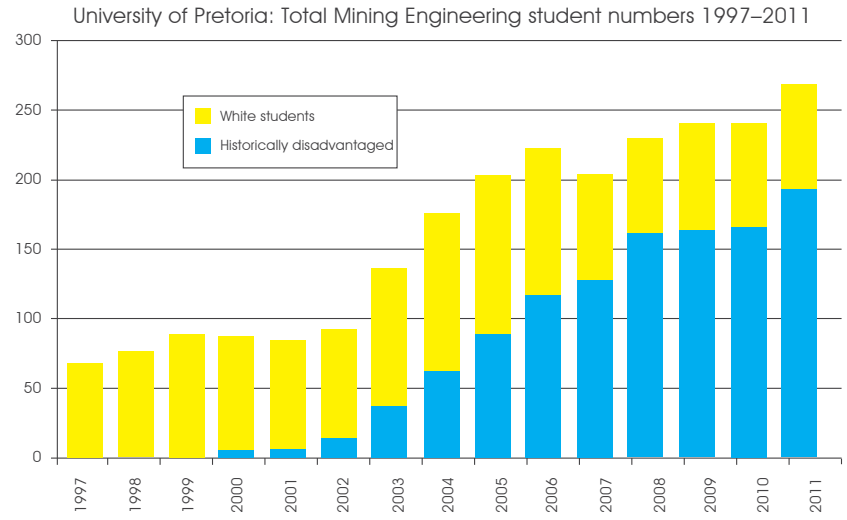
approximately 300% in 11 years, and included a similar growth in postgraduate numbers over the last five years. The department currently has approximately 250 undergraduate and 40 postgraduate students.

Furthermore, not only South African students choose the University of Pretoria's Department of Mining Engineering. Approximately 13% of its students are from other African countries: Botswana, Lesotho, Zimbabwe, Namibia, Swaziland, Tanzania and the Democratic Republic of Congo. With 11 national languages and several international students in the classroom, opportunities were created to revisit the learning styles and learning material used. It was necessary to change the teaching and learning methods used by the department. The department is very proud of the fact that its students reflect the demographic profile of the country.

This is shown in Figure 3, which represents the language mix of the first-year student intake. Another very promising aspect is that the female student numbers have also increased since 2000.

Learning and teaching

The Department of Mining Engineering focuses intensively on structuring its curriculum in such a way as to optimise learning and aims to have all its modules instructionally designed. Its undergraduate programme is accredited by the Engineering Council of South Africa (ECSA) and is internationally recognised through the Washington Accord. The department recently embarked on a new learning and teaching strategy for its third- and fourth-year students. This entailed the incorporation of non-technical and so-called soft skills in the curriculum for mining subjects. Skills such as emotional intelligence, intrapersonal and interpersonal skills, adaptability and stress management are included



→ *Figure 2. Growth of white and black (historically disadvantaged) students in the Department of Mining Engineering.*

→ *Students and lecturers at a gigantic Komatsu haul truck that is used for ore transport on surface mines.*

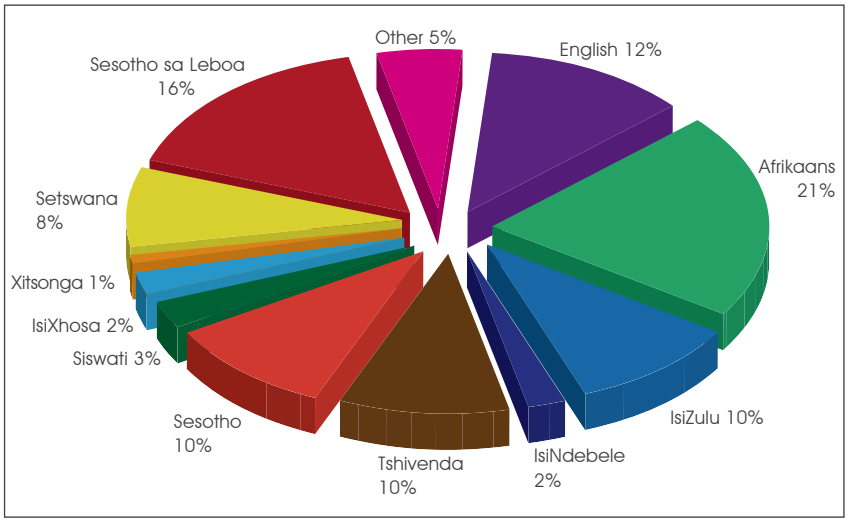


Figure 3. Mother tongue language distribution in the Department of Mining Engineering.

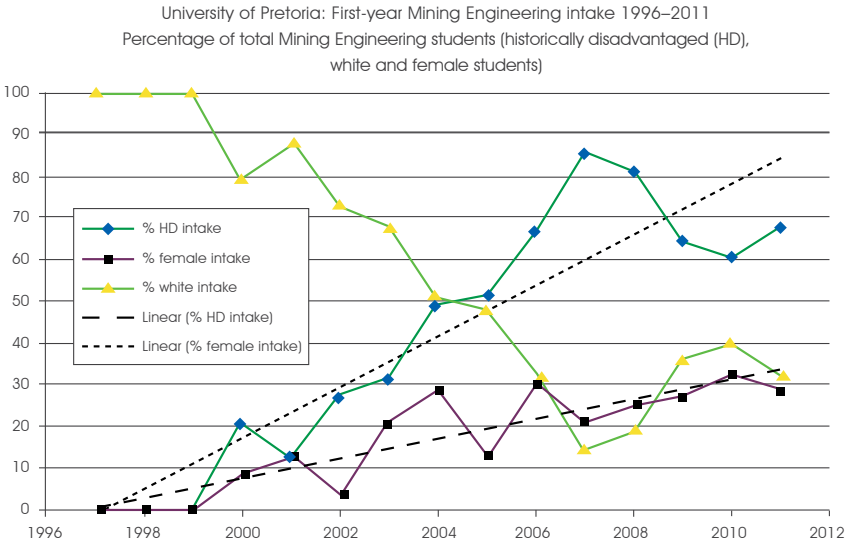


Figure 4. Demographic history of Mining Engineering students since 1997.

to simulate situations graduates will have to deal with in their careers later on. This assists students in understanding the complexities of mining and improves their chances of success in the industry.

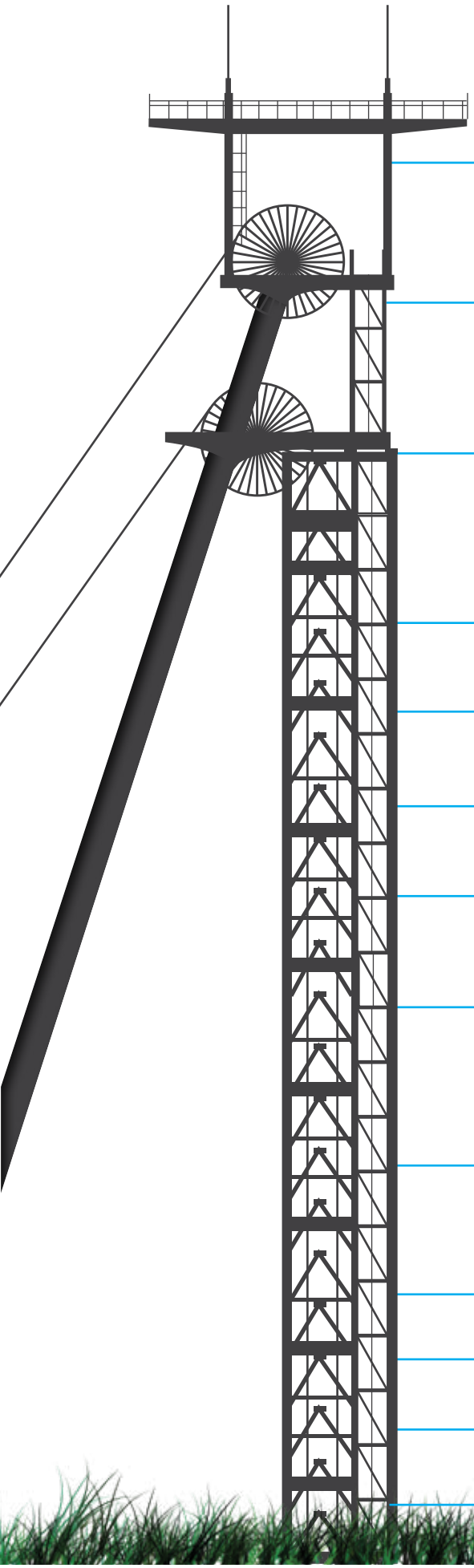
Assessment and psychometric tools are used for final-year students to determine thinking preferences and dominant habits. This enables lecturing staff to adapt teaching strategies and can be used to assist in students' professional development. The Hermann Brain Dominance Instrument (HBDI), Shadowmatch, the Myers-Briggs Type Indicator and DISC are used to assess the diverse mindsets in each class. Earlier in 2011, yet another psychometric test was introduced to establish the level of emotional intelligence of all final-year students. The department plans to develop an improvement plan for each of the students in terms of their shortcomings identified in the different psychometric tests.

This process makes a major contribution to the final-year students' lives. Mentorship and coaching also form a large part of the fourth-year academic curriculum. The introduction of clickers – a radio-based personal response system that allows student and lecturer interaction – added a new dimension to the teaching and learning process. Students answer questions on a PowerPoint presentation during a lecture, and the lecturer receives immediate feedback on how well the students know and understand the subject matter.

The importance of group work is emphasised, and as part of the strategy to make group discussions more feasible, the mining engineering laboratory area was converted into discussion rooms for group work. Other facilities include an IT laboratory exclusively for mining engineering students and three-dimensional animations and simulations. Furthermore, the department is one of only a few engineering departments that has an active bulk SMS system for communication with its students.

Another challenge that was addressed by the department is the inability of students to visualise mining activities and mining-related terminology. This was dealt with through an instructional design plan. It is the only engineering department with an employee who instructionally designs its modules on a full-time basis. The plan is to have all the mining engineering modules instructionally designed by mid-2012. At this stage, approximately 50% of the modules have been completed.

Prof Webber-Youngman says that as far as he knows, the department will be the only mining engineering department in the world that will offer instructionally designed material for all its mining-related subjects. The course material, which is duplicated on CD for all the students, includes the theoretical material, video clips of certain aspects of the study material being taught and up-to-date industry case studies with the emphasis on safety, health and environmental issues.



Mining highlights since 1996

2011: Department of Mining Engineering celebrates its 50th anniversary
Total number of mining engineering students stands at 287 – 248 undergraduate and 39 postgraduate students
A total of 13% of students hail from outside South Africa

2008: METF Board approves increased salary adjustments to attract new lecturers to the department

2007: The total number of black students exceeds the total number of white students for the first time
Prof Nielen van der Merwe resigns as head of department
Prof Ronny Webber-Youngman is appointed as head of department

2006: Number of undergraduate mining engineering students stands at 206
Final decision that the University of Pretoria's Department of Mining Engineering will not become part of one mining school for South Africa

2005: First black female student graduates

2004: Number of undergraduate mining engineering students stands at 162
First black students in mining engineering graduate from UP

2003: Number of undergraduate mining engineering students stands at 125

2002: Number of undergraduate mining engineering students stands at 88
First female mining engineering graduates from the University's Department of Mining Engineering under threat of being shut down

2001: Prof André Fourie resigns as head of department
Prof Nielen van der Merwe appointed as head of department
Language policy to change teaching language of third- and fourth-year students to English only, submitted and approved

2000: First black students enrol for mining engineering at UP

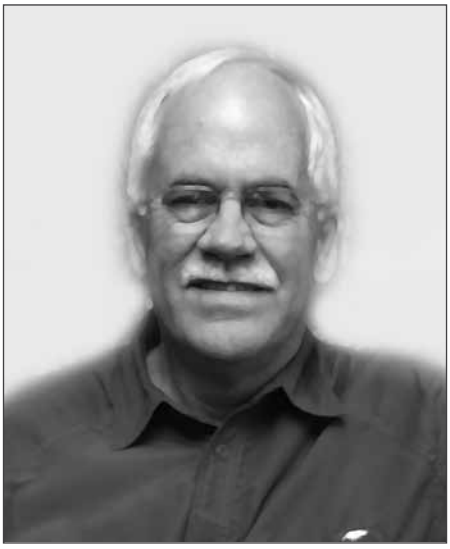
1998: First female student enrols for mining engineering

1997: Number of undergraduate mining engineering students stands at 63

1996: Prof Alf Brown retires as head of department
Prof André Fourie becomes head of department

Prominent mining engineering alumni

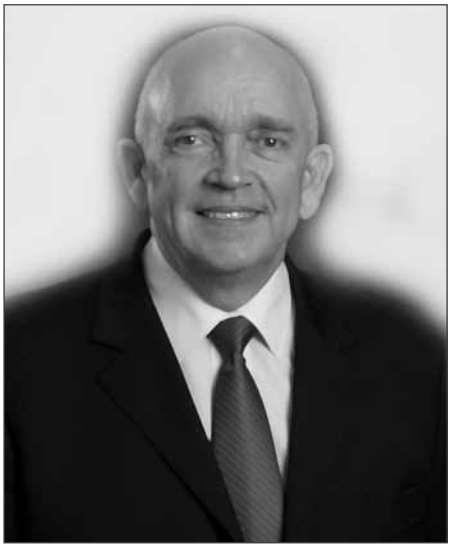
Wilco Uys graduated as a mining engineering student from UP in 1980. In 1988, he completed an honours degree in Mining Engineering *cum laude*. He is involved with MASUP, and served as chairperson of the society in the mid-1990s. Uys has also served as a member of the Mining Engineering Advisory Committee for the past eight years and as an external examiner for final-year subjects. He started his career as a learner miner at Sasol Mining in Secunda and progressed through the ranks. In 1995, he was appointed as mine manager and later as a member of the Sasol Executive Team and of Sasol Mining's Renewal Team. He joined BHP Billiton Energy Coal South Africa (BECSA) as Vice-President, Operations late in 2007. He is particularly proud to have been part of the Sasol Mining Renewal Team, and later leading the team that turned Sasol Mining into a billion-rand-plus-per-annum organisation. Sasol Mining was awarded the prestigious Platts/BusinessWeek Global Energy Award as Coal Company of the Year in 2002. He is the group leader of the formidable BECSA Production Team, and serves the country's mining industry as Chairperson of the Minerals Education Trust Fund and the Collieries Committee of the Chamber of Mines of South Africa.



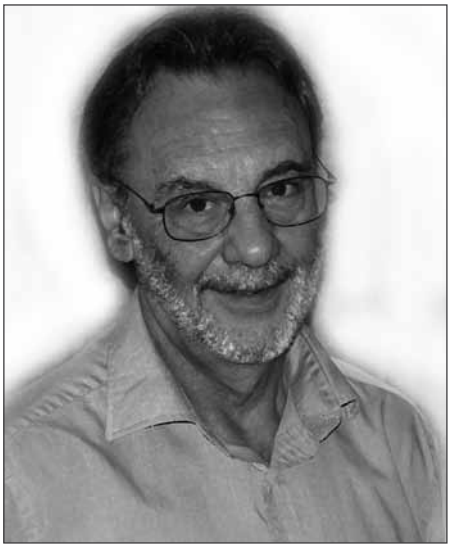
Jannie van der Westhuizen graduated with an industrial engineering degree from UP in 1972. In 1975, he completed an MBA and in 1979 a postgraduate diploma in Mining Engineering *cum laude* – both from UP. He also completed executive management programmes at Penn State University and Stanford University. After his studies at the University of Pretoria, he remained involved with his Alma Mater. He served as member of the advisory committees for mining and industrial engineering from 1997 to 2007, and as an external examiner. During the course of his career, he spent time at Iscor, Sasol and Eskom. In April 1997, he was appointed as Managing Director of Sasol Mining. In August 2002, he was appointed General Manager, Group Human Resources of Sasol Limited and Sasol Mining, and in 2003 Group General Manager with the portfolio Group Human Resources, Group IT, Sasol Mining and certain Sasol Group interventions. He is a past board member of a number of subsidiary boards in the Sasol Group and of the Sasol Group Executive Committee. Van der Westhuizen is a fellow of the South African Academy of Engineering, and he received a Laureate Award from the TuksAlumni Association in recognition of exceptional achievement in 2000.

Ben Alberts enrolled for mining engineering in 1964 and graduated in 1965, after he had already obtained a degree as agricultural engineer in 1963. He was the chairperson of the Engineering House, served on the Student Council and is a founding member of MASUP. He was also involved in the establishment of an advisory board that still exists and assists graduates in liaising with the Department of Mining Engineering and the Faculty of Engineering, Built Environment and Information Technology. Alberts is still involved in the board. He had also been a member of the UP Council for many years and served as chairperson from 2000 to 2003. He was the chairperson of the Alumni Association, now the TuksAlumni Association. Alberts had worked at coal, chrome and iron ore mines before he was appointed as the responsible official for all the Iscor mines. He managed the privatisation of Iscor and obtained the mining rights for the unbundling into Kumba Resources, and later Kumba Iron Ore and Exxaro. He has been an active member of the South African Institute of Mining and Metallurgy for many years, and served as President from 1985 to 1986. In 2011, he was honoured with the institute's highest accolade: the Brigadier Stokes Medal.

Con Fauconnier has four mining engineering degrees, including a doctorate in 1981, from the University of Pretoria. He is a member of the advisory committees for the Department of Mining Engineering and the Faculty of Engineering, Built Environment and Information Technology. He is also an honorary professor at the Department of Mining Engineering. In 1999, he received the prestigious TuksAlumni Laureate Award. He worked for the Anglo American Corporation, Gencor and JCI Limited before joining Iscor in 1995 and becoming Managing Director of Iscor Mining in 1999. As MD, Fauconnier was part of the team that engineered the unbundling of Iscor into a steel and mining company in 2001, and was appointed Chief Executive Officer of Kumba Resources, the mining company. In 2006, when Exxaro Resources was formed, he became CEO of this company, and retired in 2007. Currently he serves as an independent Non-executive Director on the board of Xstrata plc. He regards his assistance and advice to the Wilberg Coal Mine in Utah, USA, in the control of its disastrous underground fire as one of his achievements. In 2004, he was voted South Africa's Boss of the Year, largely on the back of the success of the launching of Kumba Resources and its phenomenal growth in its first years.



Nielen van der Merwe enrolled for a BSc Mining Engineering degree at the University of Pretoria. After making his mark at several mining companies, Van der Merwe joined the University of Pretoria as Head of the Mining Engineering Department in 2001. His first retirement was from that position, after which he became involved with the CIC Energy Group to plan coal mines in Botswana. Following his second brief retirement, he is now back in academia in the position of Centennial Chair for Rock Engineering at the University of the Witwatersrand. He also operates an independent rock engineering consultancy. He was President of the South African National Institute for Rock Engineering for a number of terms, and moved on to become the first African to be President of the International Society for Rock Mechanics. After his term expired in 2007, he is now President of the Federation of International Geo-Engineering Societies, representing around 35 000 geo-engineering specialists globally from three international societies. He is also chairperson of the Advisory Committee for the United Nation's International Atomic Energy Association Network for Uranium Production Education and Training, and is the current President of the Southern African Institute of Mining and Metallurgy.



UP presents SOMP 2011

The Department of Mining Engineering holds its own among international schools of mining. This again became obvious when the University of Pretoria won the bid to present the annual conference of the Society of Mining Professors (SOMP) in 2014. At the same time, Prof Ronny Webber-Youngman, head of the department, has been appointed president elect of the society from 2013 to 2014. This authoritative body originated in Europe, and 2014 will be the first occasion on which a mining school in Africa will host the society's annual conference. The fact that SOMP 2014 will be hosted by the University's Department of Mining Engineering is particularly significant, as the society will also be celebrating its 25th anniversary then. SOMP has 171 members from 71 universities in 40 countries. All six the continents are represented on the society.

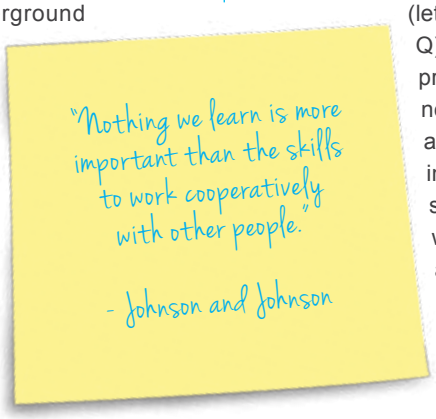
Employing small groups to promote independent learning and to develop social skills

Clive Knobbs

The United States Army at Westpoint, where they train and develop officers for combat duty, follows a model that has been adopted by sections of the Harvard Business School in its MBA programme. The model deals with "being", "knowing" and "doing".

This can, interestingly enough, be nicely superimposed on the Massachusetts Institute of Technology (MIT) model of conceive, design, implement, operate (CDIO) in engineering education and the "thinking" psychometric model of the Herrmann Brain Dominance Instrument (HBDI). It has been referred to as attitude, knowledge and skills in certain quarters, so it's not entirely new, like many models.

The first semester of the University of Pretoria's Underground Mining course, PMY 410, started with the psychometric testing of 31 students. The results were not only used for selecting groups, but also for addressing the "being" component of the Westpoint Model ("know thyself", as the ancient Greek aphorism on the Temple of Apollo at Delphi exhorts us to do) – the intrapersonal skills, such as self-awareness and assertiveness.



However, knowing others is also important, and students were encouraged to discuss their profiles with other members in the group and to familiarise themselves with similarities and differences, and the implications of this for performance in the group. "Knowing" refers to hard technical knowledge, the core of what engineers need to learn about their profession. "Doing" is getting the job done, and here social or interpersonal skills, such as empathy, communications, conflict handling and relationships are a *sine qua non*. Initially, not everyone saw it this way.

> *"This subject is supose [supposed] to be mining methods with [which] is a purely academic subject. Writing this what I'm doing right now is like sitting in a phycology [psychology] class. I don't like it...feelings is for the phycologist [sic]."*

This was a comment made by one of the students a few weeks into the course. It's a fair question and statement from a student in his final year of mining engineering! His retort (let's call him Student Q) was one of many pronouncements, not all so strident and trenchant, but inquisitive and seeking explanation without baulking at the programme completely. The students were commenting in a reflection paper on the "prolific" use of small groups for teaching and learning both content and skills. Constant feedback was vital for me in gauging the climate in the groups.

> *"This has a place, but not at the expense of technical matters."*

This was the response of Student A when asked to submit an opinion paper based on the findings of three published papers dealing with the whole question of soft skills for engineers. In addition to summarising and discussing the papers in groups and in the class, students were asked for a personal opinion on the findings in the papers. Another opinion was the following:

> *"This is an essential component of learning to communicate our ideas and projects as engineers."*

→ *Students in Mining Engineering practise their soft skills.*

The pronouncements ranged between the extremes displayed by Student Q and Student A, but generally there was acceptance of the importance of social skills. Are they important? Should we start at university? How can we maintain a balance, or better still, integrate the two forms of education?

As expected, most controversy emanated from working in groups, working independently at home and a paucity of input from the lecturer.

The groups were selected on the basis of results from a number of psychometric tests. Race and gender were also determining factors. The size started at five to six, but was later reduced to three to four members per group to minimise the "free-loader" situation. The groups changed every four to six weeks to give greater exposure to working with different personalities and characters. Technical topics were first discussed in the small groups, prompted by questions, which were different for each group. After 20 to 30 minutes of group deliberations, answers or viewpoints were presented to the full class by each group. I decided who in the group would make the presentation. The debate on the subject would continue in the full class.

Independent learning was inculcated by distributing (ClickUp) papers, articles, references to chapters in books and the like in the week prior to discussion and debate. Between 15 and 20 pages had to be read in preparation for the following week, which consisted of five lecture periods. The following was a frequent refrain:

> *"I feel overwhelmed by the amount of work and become scared that I might not complete reading all documents by test week."*

My involvement was peripheral in a way and muted by design. To give pat answers, particularly in mining engineering where there is always more than one way of doing things, seemed short-sighted and counterproductive. I was looking for an understanding of the principles and applications under different circumstances. The generation of alternative solutions was my aim, and an appraisal of the merits or otherwise of each alternative. My reticence to giving firm solutions was met with unease and confusion by half the class. They wanted more direction, clarity and guidance, as they had received in the past in their secondary education and in the early years of their university education. My involvement was inadequate according to many. The lecturer as "coach" or "mentor" was indeed a foreign, unnerving experience, which they were railing against.

Finally, in May, the students completed a comprehensive questionnaire. It was intended to gauge the efficacy of the programme in meeting the objectives of "knowing", "being" and "doing". Without going into a full analysis of their responses, which was a bit like the curate's egg, I leave you with some refreshing words of approbation:

> *"I enjoyed attending a class in which my ideas were not deemed dull, even when I was wrong, but corrected. It built the willingness to share knowledge with others and to learn from others."*

***Clive Knobbs** is a senior lecturer in the Department of Mining Engineering. He graduated from the University of the Witwatersrand in Johannesburg with a BSc(Eng) degree in mining engineering. He also holds an MBL and a BCom degree from the University of South Africa. He attended the Executive Development Programme at Harvard University and was recently awarded a diploma in Clinical Organisational Psychology by INSEAD. He has been chairperson and CEO of a number of listed mining companies and served two terms as President of the Chamber of Mines of South Africa. He is a professional engineer, a member of the Association of Mine Managers South Africa (AMMSA) and a fellow of the Southern African Institute of Mining and Metallurgy (SAIMM).*

Community projects go virtual

All undergraduate students of the Faculty of Engineering, Built Environment and Information Technology at the University of Pretoria have to complete a compulsory undergraduate course, Community-based Project (JCP). This module, which was launched in 2005, requires students to work for at least 40 hours in the community and then to reflect on their experiences. In 2011, 1 590 students were enrolled for the module.

One of the projects in which students can become involved is Dr Maths on MXit. This is a tutoring programme that uses South Africa's popular cellphone-based instant messaging software, MXit. The Dr Maths on MXit programme was developed by Dr Laurie Butgereit, a programmer at the CSIR's Meraka Institute in Pretoria.

This programme is aimed at assisting learners of all grades with their maths problems, thus offering an affordable tutor.

Dr Maths on MXit gives learners the opportunity to ask for help with their mathematics homework questions. By using MXit on their cellphones, learners can contact Dr Maths in the afternoons after school and Dr Maths can guide them through the problematic areas of their homework. It does not do their maths homework for them. Instead, it helps the learners to solve their problems on their own using a medium that the learners find fun and exciting.

→ *Dr Maths on MXit from the view of the learner recipient.*

Students in the Community-based Project module have been involved in the Dr Maths programme since 2006. They tutor learners by logging on to Dr Maths as tutors from their own computers or from computers at the University. The community members they serve are therefore part of a virtual community.

This project has been so successful that the number of learners registered on the server increased from 800 in 2005 to 19 000 in 2010.

Maths in a minute

The idea behind the Dr Maths project can be extended to the rest of the world via YouTube and Facebook. This concept is derived from the following scenario: You have to sell an idea to someone like Bill Gates and the only time he has is the minute it takes you to ride in the lift with him.

A cellphone video project was developed in 2010 by two civil engineers, Ansia Labuschagne and Chris Berrangé. This project was aimed at selling a mathematical principle in one minute. The students designed and uploaded four cellphone videos, which depicted mathematical principles. Through this innovation, learners are also able to send each other interesting footage via their cellphones, such as the dissection of a frog. The only restriction – as the video needs to be distributed by secondary school learners via cellphone – is that the video should be short (no longer than 60 seconds) and it should be interesting. Along with these two requirements, it should be kept in mind that the full mathematical meaning of the specific principle must be clear and concise.

The following video clips can be viewed on YouTube:

- Straight lines: http://www.youtube.com/watch?v=eAZVNRhpWFs
- Cutting corners: http://www.youtube.com/watch?v=bm9a6b5ap34
- Signs: http://www.youtube.com/watch?v=10vAKFNnva0
- The gods must be crazy: http://www.youtube.com/watch?v=VsuKKVIp2O8

Dances with wolves

Students of the Faculty of Engineering, Built Environment and Information Technology are getting more and more creative in the projects that they take on to complete the compulsory undergraduate Community-based Project (JCP) module.

This module encourages students to think for themselves and to apply their practical, theoretical and communication skills to make an impact in a community.

A student's mark is awarded specifically for the quality of learning exhibited and not for the quality or quantity of service provided.

Donovan Risk, Johannes Mentz, Stoffel Fourie and Arne Smit decided to use this opportunity to design and build shadow structures for the huskies and wolves that live at the HuskyRomi rescue and rehabilitation centre in Reitz in the Free State.

HuskyRomi is supported by the farmers in the area, but needs every bit of extra help it can get to stay afloat.

The students spent their weekend mixing cement, putting poles in the ground and attaching shadow nets to create some shelter for the animals. They managed to put all 28 poles in the ground during the first day. They also got involved in the day-to-day operations on the farm over the weekend and had to help move three adults and two pups to new enclosures.

On their blog report, the students write how grateful they are to have been involved in such a project. "We realise that without JCP we would not necessarily have got involved in community service. After an experience like this we are thankful and glad to have participated... We would suggest a weekend like this to all animal lovers and for future community projects," they wrote.

→ The students with the huskies at the rehabilitation centre in Reitz, which benefited from the community project.

A reliability study of commentary systems used at football matches

by Tawanda Victor Mutshiya and Kristian Adendorff

The success or failure of operations involved in broadcast commentaries can be attributed to the reliability of constituent broadcast commentary subsystems and components. Reliability, simply put, is a facet of quality assurance that considers a collection of components that are arranged in a structure that allows the system state to be determined as a function of its component states.

Reliability is essentially a probability, and in the context of broadcast commentaries, can be defined as follows: The probability that the commentary system will adequately perform its specified purpose of enabling video and sound output for the specified duration of a football match under prevaling environmental conditions.

Environmental conditions are assumed to be constant since the commentary system is often used in environments at room temperature that employ air conditioning systems to ensure a constant temperature and humidity.

The commentary control room is the main operations centre for commentary services, where all commentary facilities are handled in a complex arrangement. Ideally, broadcasters demand 100% reliability of consistent live broadcasts, which are ensured through built-in redundancies by way of satellite feeds and backup equipment, but still, no one system is 100% reliable.

During the FIFA 2010 Soccer World Cup, a complex commentary system was used, and even with the built-in redundancies, minor problems, such as lip-sync and excessive variable loudness errors, were noted, which influenced the overall reliability of the system.

John Moulding, on the official blog of the International Broadcasting Convention (IBC) of 2010, states: “There is still work to be done to ensure ‘the five-nines’ reliability needed to achieve consistency.” He refers to a failure rate of one in 100 000 runs of broadcast equipment, and infers that a reliability of approximately 0.99999 is sufficient to achieve consistency in broadcast system operations.

The reliability model for the commentary system configuration used at football matches can be modelled as the series reliability of the subsystems shown in Figure 1.

The stadium system involves the location from which audio and video signals originate. The signals are propagated through a variety of subsystems in the stadium system, which include commentary positions, the commentary control room, the technical operations centre (the main distribution point and interface between facilities used to transfer signals) and the commentary interface room.

From the stadiums, the signals are sent via fibre optic cables, which are made redundant by satellite feeds, to the International Broadcast Centre (IBC) system. In the IBC, signals are propagated through the master control room, which acts as the central distribution point at the IBC for all incoming and outgoing video and audio feeds from the stadium venues, and the commentary switching centre, which controls and patches all the commentary circuits coming from stadiums to the IBC and beyond.

In the IBC, the feed is combined and sent to various television broadcast

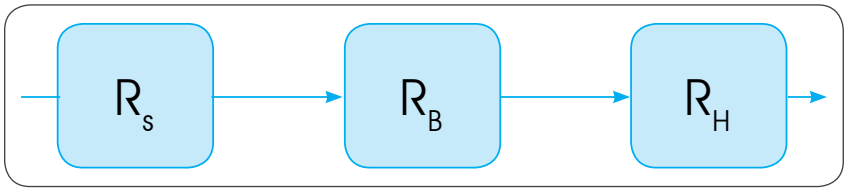


Figure 1. Constituent subsystems of the commentary system.

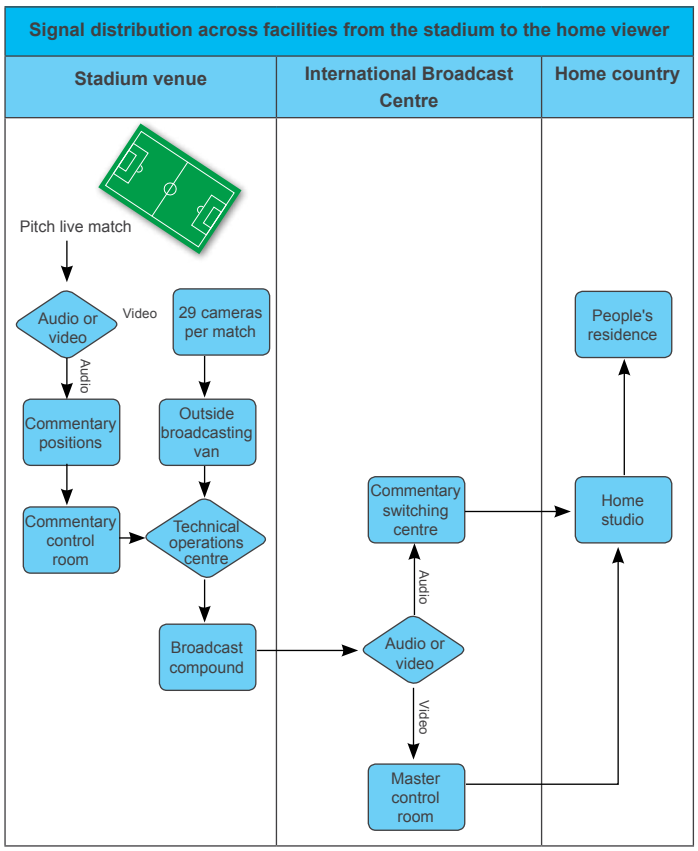


Figure 2. Reliability block diagram.

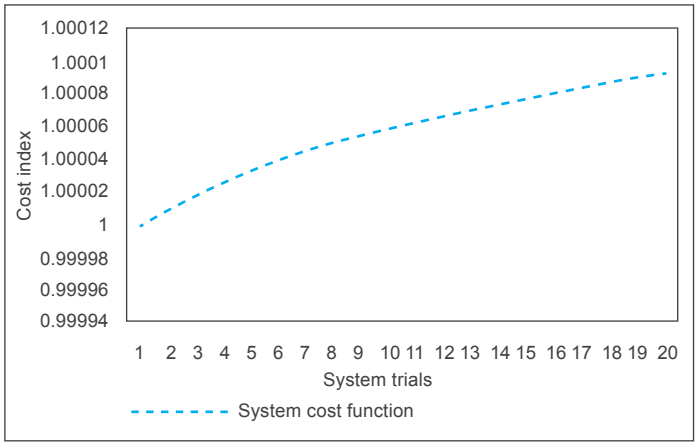


Figure 3. System cost function obtained from the commentary system reliability values.

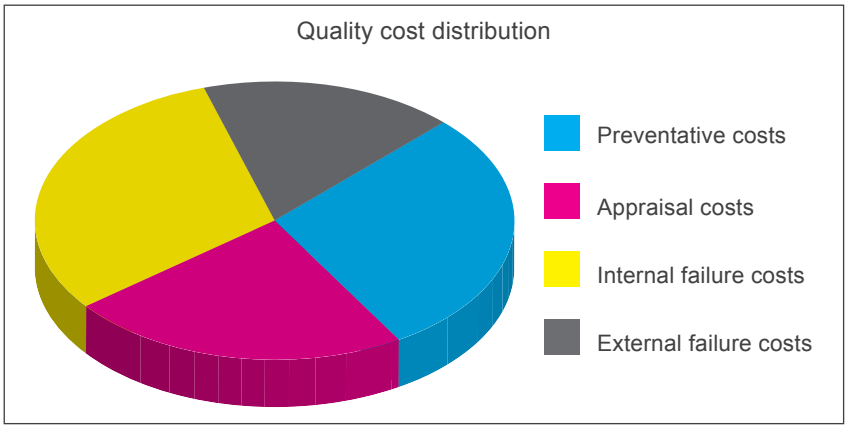


Figure 4. Quality cost distribution.

studios around the world. The reliability of these is denoted by R_H in Figure 1. Signal distribution across facilities is shown in the reliability block diagram in Figure 2.

Commentary system reliability is significantly influenced by the impact of human reliability, since man-machine interfaces are ubiquitous throughout the entire system. It is important to note that man-machine interactions in the commentary system are tightly coupled with some that are composed of complex interactions. Consequently, this has led to the viewpoint that technicians and commentary components are seen as interacting parts of the overall system, and are thus not considered separately as components. In addition, technicians and various users of the commentary system rarely work alone and form part of a team. In a reliability context, this means that the technicians' actions are a result of beliefs and cognition, rather than simple responses to events influenced by environmental factors, and that these beliefs may be shaped and shared to various degrees by the group.

Reliability varies naturally across environments to which the commentary system is exposed, including penalties. This reduces the ability of broadcast investors to forecast cash flows. A reliability cost function is therefore used to gauge cost as a function of the system reliability. An exponential behaviour of the cost is assumed and the function has the following form:

$$C = e^{\wedge(1-f)*(R(i) - Rmin)/(Rmax)}$$

Where:
C is the cost index as a function of the system reliability
f is the probability of improving the reliability
Rmin is the minimum achievable reliability that may be allowed
Rmax is the maximum achievable reliability of the system

From the reliability data obtained, the system cost function is shown in Figure 3. The system cost function draws towards a constant maximum, reflecting all the efforts involved in maximising the reliability of the system. This is due to the maximum attainable probability value of reliability

→ *A commentary control room identical to the ones used during the FIFA 2010 Soccer World Cup.*

being 1, and therefore all efforts to ensure that reliability is as great as possible will always reach a maximum when the highest desired reliability is reached. These efforts to ensure a high reliability value form part of what is referred to as the Cost of Quality Model. This model breaks costs down into four groups: prevention costs, appraisal costs, internal failure costs and external failure costs.

Prevention and appraisal costs occur as a result of having backup equipment, redundancies and using improved technology to prevent defects in propagating the audio and video signal feeds to viewers.

Internal and external failure costs come about as a result or consequence of the fact that no single system built is 100% reliable, despite the best efforts to prevent service defaults.

A summary of the costs obtained from the quality cost report, detailing the financial consequences to attain improved reliability, is shown in Figure 4.

The pie chart in Figure 4 illustrates a distribution of the cost facets of the quality model. Prevention and appraisal costs make up 52% of the total, indicating that the broadcaster spends more on mitigating failures and detecting defects in the system through appraisal and prevention activities. An increase in the appraisal activity of a broadcaster will lead to more defects being identified before live broadcasts, resulting in higher internal costs by way of the cost of scrap, reworking and downtime of the defective equipment observed. This positively influences external costs, which become less as savings are made in warranty repairs, warranty replacements, as well as costs incurred in field servicing. The pie chart indicates that external failure costs are the lowest, owing to the influence of appraisal activities.

Further emphasis on prevention and appraisal may have the effect of reducing total quality cost as prevention and appraisal costs should be more than offset by a decrease in internal and external failure costs.

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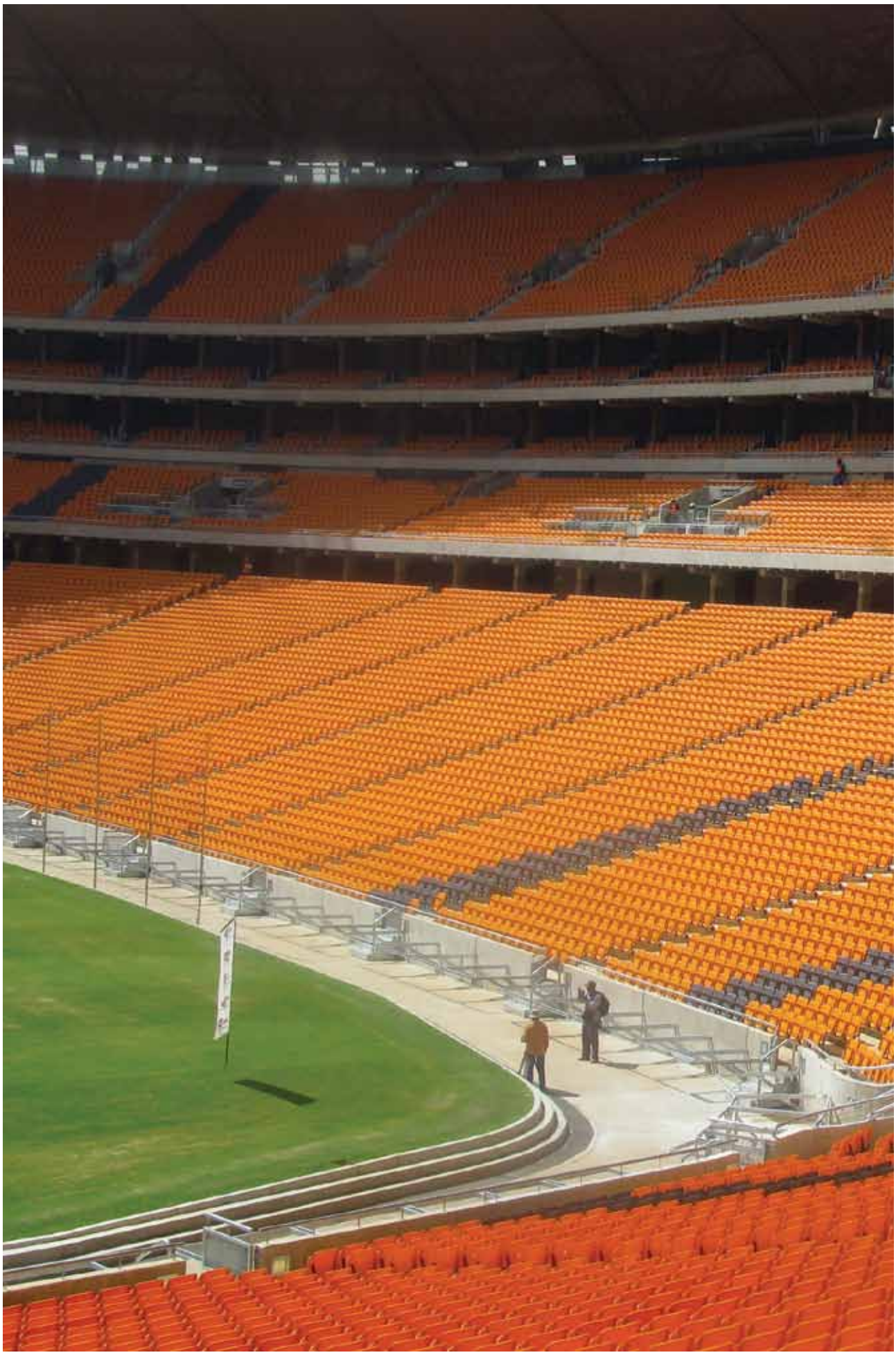


True energy-efficient lighting: the fundamentals of lighting, lamps and energy-efficient lighting

by Prof Wilhelm Leuschner and Lynette van der Westhuizen

Energy efficiency and saving electrical energy are concepts that are quite generally known. Whether these savings are sustainable or cost-effective for the consumer is another question. After almost 150 years of gas discharge and incandescent light sources for general lighting, we have recently entered the field of semiconductor lighting, generally called solid state lighting (SSL) in the form of light-emitting diodes (LED) and organic LEDs (OLEDs), to use for energy-efficient lighting.

Energy-efficient light can be defined as improved lighting at reduced life cycle cost or pay-back period. To determine the quality of light, one has to cover all the metrics involved: not only the quantity of light, but also the colour appearance and the colour rendering of the lamp. To determine energy saving and energy efficiency, one has to take more than just the electrical input power (Watts), the cost of electricity and the life expectancy of the lamp into account. There are several fundamental metrics involved in evaluating cost-effective, energy-efficient lighting that improves the quality of the light at the same time.

Light and vision

Figure 1 shows six different lamps of more or less the same light output in the on and off conditions. However, a photograph does not accurately portray the colour appearance or actual luminous flux. The eye is a much better instrument for instantaneous comparisons of light and colour.

Vision and visibility relies on luminance ("brightness") contrast and colour contrast only. This applies to light radiated (lamps) and/or reflected (tasks) from surfaces of various shapes and formats. The light or light power radiated from a light source is defined as the luminous flux Φ specified in lumens. This luminous flux can be rated as a density unit of solid angle (steradian) or a surface area (square metres). The first quantity is called the luminous intensity I, where 1 lumen radiated in 1 steradian is called 1 candela. Luminous intensity is measured as a function of direction and these results are usually presented as polar diagrams of luminous intensity, from which the beam angle (full width half maximum value of luminous intensity) can be determined.

Illuminance E is defined as the luminous flux falling on a surface area, where 1 lumen falling on 1 m^2 is called 1 lux. Neither luminous flux nor luminous intensity can actually give an indication of the "brightness" of the source of light. The quantity used for evaluating the visibility of a surface (light source or reflecting surface) is the luminance of the

a. b. c. d. e. f.

→ *Figure 1. Six lamps (off and on) (from left): a. 100 W incandescent b. 15 W warm white CFL c. 15 W cool white CFL d. 8 W 2700 LED e. 8 W 4000K f. 7 W 6000 LED*

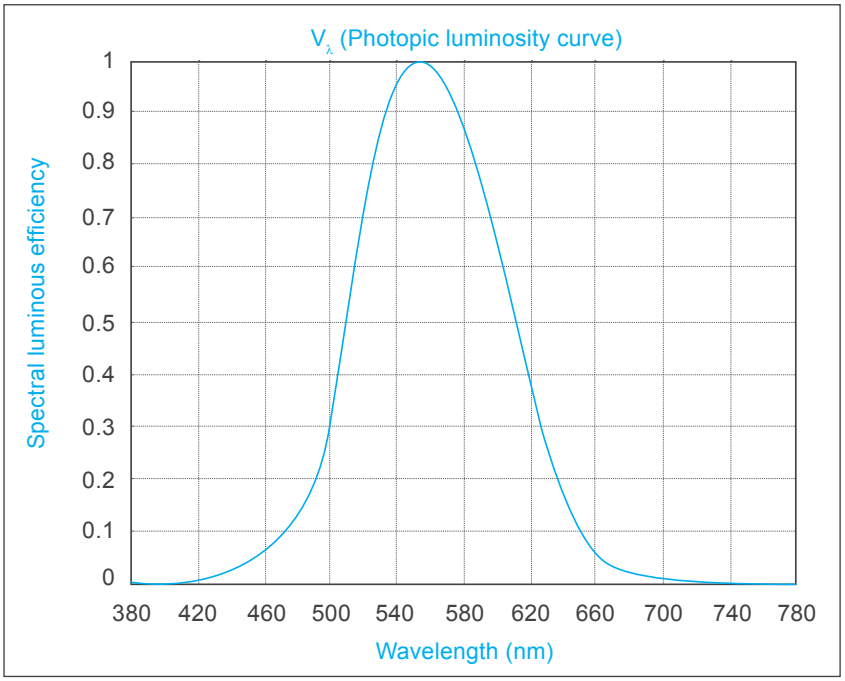
specific "radiator". This is determined by dividing the luminous intensity of the surface (facing the observer or luminance meter) by the specific projected area of the surface. This is determined by the viewing angle of the observer or luminance meter. The unit used is candela per square metre. For example, for a lamp with a luminous intensity of 1 candela in a specific direction and a projected surface area of the lamp (or reflector surface) on 1 m^2, the luminance L of the surface L = 1 cd/1 m^2.

Once these three quantities (Φ, I and L) are matched for two light sources, they produce the same quantity of light, with the same distribution and the same luminance. One will not be able to see the difference. Matches are seldom complete and one has to evaluate the importance of variations that are present.

Colour

Visual colour appreciation of light sources relies on two fundamental metrics, i.e. the colour appearance of the light source and the colour rendering of different colour objects illuminated by the same light source. Over many years, many different scientists have recommended different ways of producing these two metrics for a lamp of a known spectral power distribution (SPD), i.e. radiant or luminous flux as a function of the wavelength in the visible region of approximately 380 to 780 nm. This range of electromagnetic radiation, which is called visible light, peaks at 555 nm for standard photopic vision (luminance levels of above approximately 3 cd/m^2) – see the V_λ curve in Figure 2.

In general, colour appearance is a personal preference and there is no optimal colour. Colour rendering is a metric where (irrespective of which system of evaluation is used) the higher the number, the better; with no personal preference involved. One should not confuse these two metrics, as one can get excellent colour rendering from various lamps of dramatically different colour appearances (for example, warm white, natural white, cool white to daylight).



→ *Figure 2. V_λ curve.*

Colour appearance describes the dominant hue of the light, i.e. red, green, blue, yellow, white, etc. For general lighting, white light has been the dominant colour in use. The colour appearance can be defined uniquely through two numbers or coordinates on the International Commission on Illumination (CIE) chromaticity diagram; known as the x and y or u and v colour coordinates.

In the case of "white light" sources, the use of adjectives such as cool white, warm white, daylight and natural white have been used for many years in linear fluorescent and compact fluorescent lamp (CFL) products.

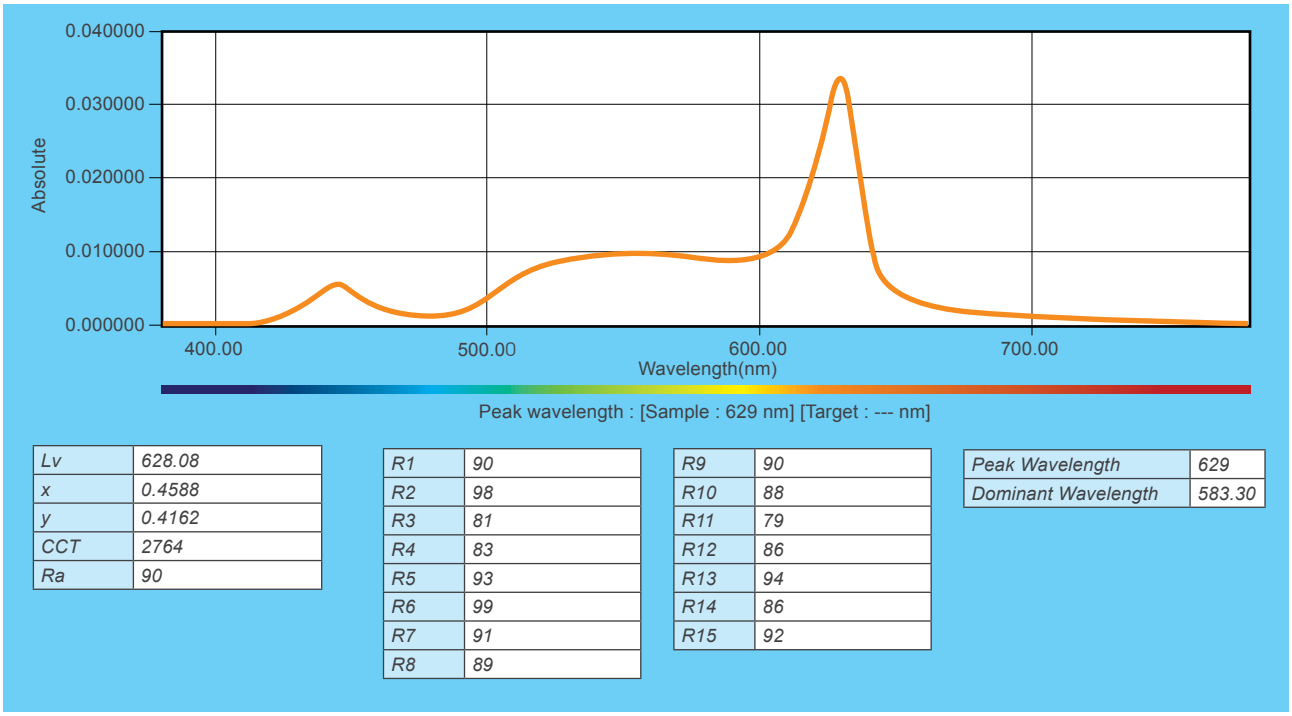
To make these shades of white more quantifiable, measurable and universally acceptable, the metric of colour temperature and correlated colour temperature (CCT) with units of Kelvin (K) was introduced.

These CCT numbers can be summarised as follows:

- Warm white : CCT = 2700 to 3000K
- White : CCT = 3500K
- Cool white : CCT = 4000K
- Daylight : CCT = 6500K

These numbers can, however, be misleading as they represent numerous chromaticity coordinates.

This is due to different SPDs, which have different chromaticity coordinates, having the same best match to a blackbody radiator of that CCT.



Lv	628.08
x	0.4588
y	0.4162
CCT	2764
Ra	90

R1	90
R2	98
R3	81
R4	83
R5	93
R6	99
R7	91
R8	89

R9	90
R10	88
R11	79
R12	86
R13	94
R14	86
R15	92

Peak Wavelength	629
Dominant Wavelength	583.30

→ *Figure 3. SPD and colour metrics of a typical warm white LED lamp. (Note: L_v is the relative luminance of the measuring point in the measuring sphere.) LED supplied by Kwalico.*

Radiant flux as a function of spectral radiant flux

$$\Phi_e = \int_{\lambda=0}^{\infty} \phi_{e\lambda}(\lambda)\, d\lambda$$

Where: Φ_e = total radiant flux in Watt
$\phi_{e\lambda}(\lambda)$ = spectral radiant flux in Watt/nanometre

Luminous flux as a function of special radiant flux

$$\Phi_v = 683 \int_{\lambda=380}^{760} \phi_{e\lambda}(\lambda)\, V_\lambda(\lambda)\, d\lambda$$

Where: Φ_v = total luminous flux in Lumen
$\phi_{e\lambda}(\lambda)$ = spectral radiant flux in Watt/nanometre
$V_\lambda(\lambda)$ = photopic eye responsivity curve in p.u. with the peak value of 1 at 555 nm

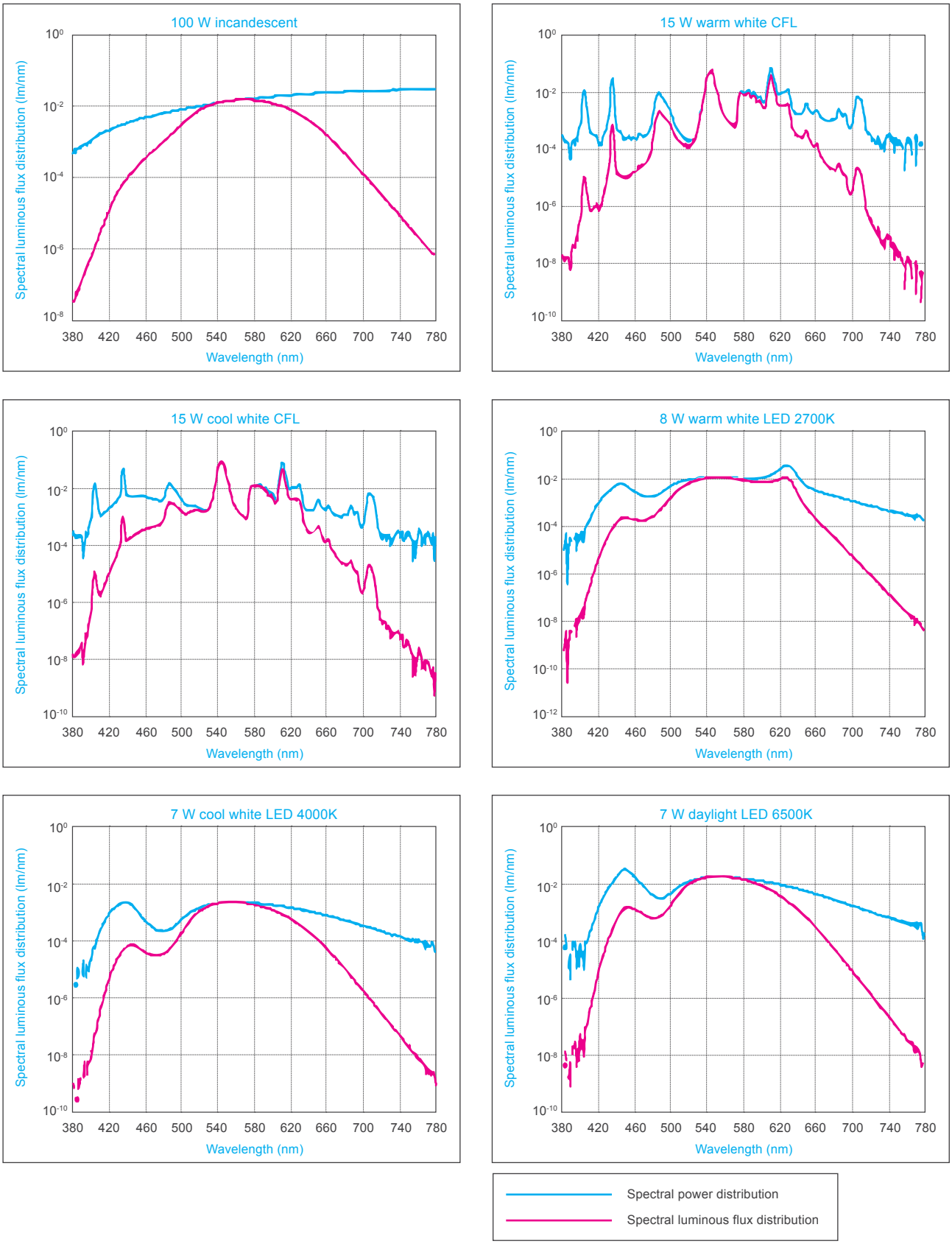
The value 683 is the maximum luminous efficacy of radiant flux in $lm \cdot W^{-1}$.

The second metric in evaluating the quality of the colour of a lamp is the colour rendering characteristic, which can also be described as the colour fidelity of the light source. Currently, a most unsatisfactory way of calculating the colour rendering index (CRI) from the SPD of a lamp's radiation is used. The general CRI (R_a) of a light source has been prescribed by the CIE. The procedure, in essence, entails the use of eight printed colour samples to be illuminated in turn by a reference light source and the lamp under test. The shift in colour appearance is calculated for all eight samples and the average of the eight indices represents the R_a value. One of the main complaints against the use of the CRI is the use of a reference light source, which in most cases is a black body radiator of the same CCT as the lamp under test. There are many other colour rendering evaluation systems under consideration for improving accuracy without using an incandescent lamp as a reference light source.

In the assessment of colour appearance and colour rendering, it is important to evaluate the SPD curves of different light sources and weigh that with the eye responsivity curve (also known as the V_λ curve) in Figure 2.

For evaluating the six different lamps with respect to actual visibility, we present the SPD in $W \cdot nm$, as well as the spectral luminous flux distribution in $lm \cdot nm^{-1}$. Note that the SPD values have been multiplied by 683 to match the peak value of the V_λ curve at 555 nm.

A spectroradiometer (Konica Minolta) is used to measure the SPD of any light source (lamp or reflector). The lamp under test is placed in an integrating sphere to eliminate special variations in the



→ *Figure 4. The spectral luminous flux distribution as compared to the normalised SPD.*

light distribution of the lamp. The spectroradiometer (through a close-up lens) is focused on the reflected surface in the small measuring sphere attached to the integrating sphere. From the SPD for a specific lamp, the spectroradiometer software is used to calculate all the different colour metrics of the lamp as shown in Figure 3 for a typical warm white LED lamp.

Figure 4 shows the SPDs (blue curve) of the six different light sources as shown in Figure 1. Once the individual SPDs are multiplied with the V_λ curve, the spectral luminous flux distribution (red curve) is obtained as a function of wavelength (in lumen per nanometre), as normalised to 1 000 lumen output for all six light sources. The integral under the curve will produce the normalised luminous flux for all six lamps (normalised to 1 000 lumen).

It is important to note that the actual spectral luminous flux from the individual lamps (the light we see) drops off very quickly below about 450 nm and above 660 nm. The incandescent lamp is slightly higher at the long wavelengths around 700 nm. It is clear that using the incandescent lamp as the reference light source for obtaining colour rendering characteristics may not be the optimal reference source.

Rated life

Historically, the life expectancy of lamps is determined from cyclic batches of each type of lamp through a switching procedure and then ensuring that at least 50% of the batch of lamps are still burning at the time when rated life is reached. Life expectancy can range from 1 000 hours for general lighting service (GLS) incandescent lamps to over 50 000 hours for LED lamps.

To test LED lamps for such long periods of time (five years or more) is impractical and cannot be done for such a dynamic and rapidly improving new technology. New life-testing procedures for LED lamps take place over a test period of a maximum of 6 000 hours. An extrapolation procedure is then followed to determine rated life at a specific lamp lumen depreciation level (for example, when 70% of the initial luminous flux output is reached), called the L_{70} point. Values such as L_{80} or L_{90} can also be used. This number is accompanied by the failure rating (for example, F_{50} will indicate a failure rate of less than 50%).

It is important to realise that with life expectancy or rated life, irrespective of whether it is 1 000, 15 000 or 50 000 hours, there is a large chance of many of the lamps failing anywhere during that time; some even within hours of installing them. To allow for such early and normal early failures of lamps, some lamp manufacturers now include guarantee inserts in the packaging to replace such lamps within one to three years of purchase.

Electrical characteristics

By moving from simple incandescent lamps (non-linear resistance filament) to electronic-driven fluorescent lamps (including CFLs) and semiconductor (including LED and OLED) lamps, the resulting electrical current and power characteristics have changed dramatically. The electronic components in the lamp power supply for these lamps create current harmonics, which can be measured as current harmonic distortion (total harmonic distortion or THD), which also results in a distortion power factor, which means that the apparent power (measured in volt ampere or VA) and the active power (measured in Watt or W) can be dramatically different. Power factor, as defined by active power divided by apparent power, can be as low as 40% for some CFL and LED lamps. Most users of electricity (except for single residential) pay for electrical energy usage in kilowatt-hours (kW·h), as well as electrical apparent power measured as half hourly maximum demand in kVA. So, a high power factor is essential in searching for cost-effective energy-efficient lighting.

Energy-efficient lighting

By selecting a replacement lamp for a failed or inefficient light source appears to be simple: pick an "energy saver" with the same luminous flux output (in lumens) as that of the lamp to be replaced, but use one with lower rated active power in Watts. Reducing the electrical power consumed to produce the same light reduces the CO_2 and other toxic gas emissions from coal-fired power stations, as well as water consumption and other ecological benefits. This approach does not, however, automatically result in cost-effective energy-efficient lighting of the same quality of light or better.

In the competition between CFL and LED as the only general light source for the future, the outstanding good and bad characteristics of each can be listed and weighted fairly easily, as shown in Table 1.

Cost of energy efficiency (pay-back period)

Some of the most important factors that influence the pay-back period when replacing legacy lamps with energy-efficient lighting of the same or better light output (quantity and quality) include the cost of the lamp, the cost of electricity (kWh and kVA), lamp replacement costs and the number of operating hours a day.

Lamp type/criteria	CFL	LED
Cost	Low	High but dropping
Life	Fair	Very long
Lumen/W	Fair	Better and improving fast
Supply	Limited voltage range	Wide voltage range
Robustness	Bad	Good
Colour characteristics	Average	Good to excellent
Disposal	Restricted	No restriction
Light source	Area (linear or spiral, etc.)	Point or area
Controllability	Limited to some dimming	Excellent: smart lighting
Environmental effect	Mercury content	Sapphire chips: no danger

→ *Table 1. Comparison between CFL and LED lamps.*

Future predictions

Historically, with the GLS incandescent lamp, the wattage rating was the most important factor to consider, as it defined luminous flux output, luminous intensity distribution, luminance, colour appearance and colour rendering, power factor, current distortion, life expectancy, etc. With the CFL and LED electronic-driven lamps from many suppliers all over the world, minimum quality specifications have to be set and certified by individual manufacturers.

The lamp packaging should clearly specify and guarantee the most important metrics, such as the following:

- Power supply details (voltage and frequency)
- Luminous flux output in lumens
- Luminous intensity distribution (polar diagram and/or beam angle)
- Luminous efficacy in lumen/Watt
- Colour appearance (chromaticity coordinates or CCT)
- Colour rendering (CRI or better index)
- Rated life (L_{70} F_{50} or better)
- Approximate pay-back period (not more than three years)

Conclusion

It is the opinion of the authors that the introduction of semiconductor lighting is opening up a new era of quality aesthetic and functional lighting of outstanding quality, with reduced concerns relating to lighting maintenance and lamp replacement. This can be achieved with excellent energy efficiency and high affordability.

Source

Commission International de l'Eclairage, Division 1. 1995. *Vision and colour: Method of measuring and specifying colour rendering properties of light sources. Technical Report CIE 13.3-1995.* Kegelgasse, Vienna: CIE.

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→ *Lynette van der Westhuizen*

A novel method to mitigate the peak-to-average power ratio in OFDM

by Kahesh Dhuness and Prof Sunil Maharaj

Orthogonal frequency division multiplexing (OFDM) has become a very popular method for high data rate broadband communication, primarily because it allows for more data to be transmitted in less bandwidth, hence increasing spectral efficiency. It also allows channel effects to be easily mitigated. This has led to it being deployed in various standards, such as digital subscriber lines (DSL), digital video broadcasting (DVB), worldwide interoperability for microwave access (WiMAX) and recently in 4G technology, such as long-term evolution (LTE).

Very soon a large number of devices will be encountered that employ OFDM. For instance, the South African government has announced that it will begin digital television broadcasting (which employs OFDM) and eventually shut off the traditional analogue television transmission by December 2013. This implies that a large percentage of South African households will eventually have to buy a set-top-box (STB) to receive a digital (OFDM) television transmission. Not only is OFDM confined to television transmission, but it has also been established as a basis for fourth- and fifth-generation cellular technology. So, in addition to STBs, it will also be used in cellular phones, 4G and 5G cards, digital radio and local area networks (LAN), which constitute a large percentage of the wireless market.

However, it is known that OFDM is plagued by a large peak-to-average power ratio (PAPR). It is this high PAPR that results in energy-inefficient devices. Inefficient devices are especially unattractive in mobile devices like cellular phones, since this would result in regular recharging of the mobile device, which is not desirable. The current demand for energy-efficient devices has resulted in various methods being proposed to reduce the PAPR of an OFDM transmission. However, all these methods have a number of drawbacks.

The current demand for energy-efficient devices has resulted in various methods being proposed to reduce the peak-to-average power ratio of an OFDM transmission.

In research conducted in the Sentech Chair in Broadband Wireless Multimedia Communications (BWMC) at the University of Pretoria, a method called offset modulation (OM-OFDM) has been developed that does not suffer from the drawbacks experienced by current methods in the field. A simple block diagram, depicted in Figure 1, shows the processes involved during an OM-OFDM transmission.

The OM-OFDM method involves phase modulation of an OFDM transmission. Thereafter, by controlling the dominant component of this OM-OFDM transmission, it allows for the PAPR of a transmission to be controlled.

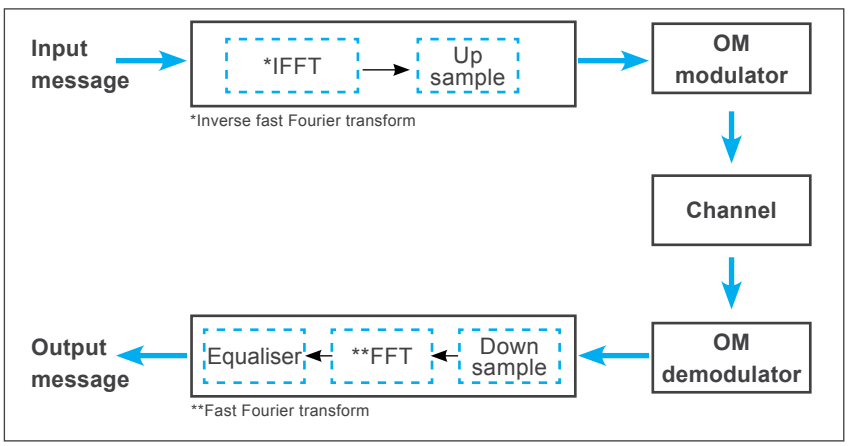

Figure 1. An OM-OFDM transmitter receiver.

A power performance decision metric *(D)* has also been introduced, which allows for various methods in the PAPR field to be compared. The decision metric is given by $D = (E_t / N_0) \cdot (W / R_b)$ where N_0 is the noise power, W refers to the bandwidth occupancy and R_b is the data rate. Furthermore, E_t is the total energy per bit and can be written as $E_t = E_b + E_w$ where E_b is the received energy per bit and E_w is the wasted energy per bit due to inefficient power amplifier utilisation.

The proposed OM-OFDM method has been compared to two well-established PAPR reduction methods, which are tone reservation (TR) and active constellation extension (ACE) (both methods are used during digital television broadcasting), as well as the clipping PAPR reduction method. By using a decision metric (D), Figure 2 demonstrates the benefits of OM-OFDM in terms of energy efficiency when compared to the aforementioned methods. The simulations are done using a 64-QAM DVB-T2 transmission (a typical television transmission) through a real-world (5-tap typical urban frequency selective fading conditions) channel, in conjunction with two different off-the-shelf amplifiers, an AN10858 and FPD2000AS amplifier. The OM-OFDM method in Figure 2 is shown to offer between 23.6% and 60.8% at a bit error rate of net power performance improvement when compared to a traditional OFDM, clipped OFDM, TR and ACE methods.

In conclusion, the proposed offset method is shown to offer a performance improvement when compared to both simple (clipping), as well as more complex, well-established (ACE and TR) PAPR reduction methods. The 23.6% to 60.8% net power performance improvement obtained when using OM-OFDM would significantly improve the energy efficiency of devices that employ OFDM technology, hence showing promise of a potential innovation.

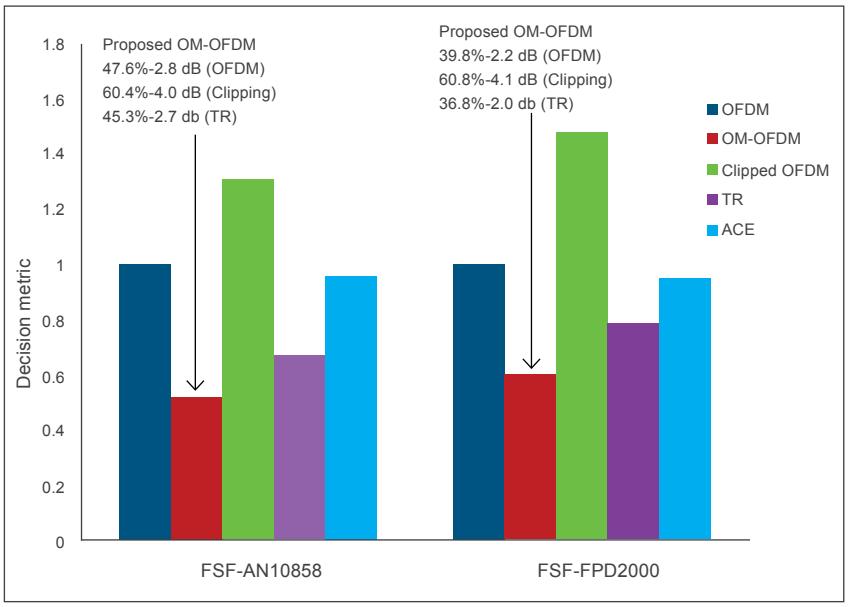

Figure 2. Normalised decision metric (D) results for a 5-tap typical urban channel.

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Kahesh Dhuness

Prof Sunil Maharaj

Introducing micro-pelletised zinc concentrates into fluidised solid roasters

by Sean Heukelman and Dr Dick Groot

Research conducted in the Department of Materials Science and Metallurgical Engineering at the University of Pretoria focused on the introduction of micro-pelletised zinc concentrates into the fluidised solid roasters at Zincor, a refinery in South Africa.

Zincor uses the conventional roast-leach-electrowinning process to produce zinc metal. The roasting process of ZnS concentrate makes use of four Lurgi fluidised bed roasters to produce calcine (which contains ZnO and $ZnFe_2O_4$ as zinc products) and SO_2 gas. The roasting plant consists of two 18 m^2 and two 35 m^2 cross-sectional area roasters.

Prior to 1996, Zincor utilised air as the only oxidant and fluidising medium in its roasters. The maximum dry feed rates that the roasters could process were 6.5 t/d.m^2. In an attempt to increase production, oxygen enrichment was first trialed. The ability of oxygen enrichment to increase the rate of the ZnS oxidation reaction allowed higher feed rates to the roasters. This was successful and oxygen enrichment of the fluidising air up to 26% of total oxygen was permanently implemented. That enabled dry feed rates to be maintained at 7.0 t/d.m^2 and 7.3 t/d.m^2 for the small and big roasters respectively. Due to the highly competitive nature of the zinc industry, innovative processing techniques are necessary.

The aim of this study was to determine whether oxygen enrichment could be reduced by introducing micro-pelletised concentrate into the roaster feed blend, while maintaining current roaster feed rates and calcine quality. This study was executed in four parts. Firstly, the role entrainment plays in influencing average particle residence time was considered. Secondly, a study was made of production methods for stable micro-pellets. Thirdly, the influence of oxygen enrichment and particle size on the roasting rate of micro-pellets was studied. The fourth part of the study was a pilot trial for the introduction of micro-pellets into the Zincor roasters.

The particle size distribution of a typical blend of feed concentrate to the roasters has been decreasing with time, and 50% is now passing approximately 48 µm. This leads to entrainment values between 87% and 91%. The micro-pelletisation process reduces the –500 µm fraction from 87% to 10%, which degrades to 30% during roasting. This requires that approximately 48% of the concentrate needs to be micro-pelletised to restore the 70% designed entrainment target.

It was determined that entrained particles spend 0.46 to 2.44 hours on average in the roaster bed, compared to particles in the bed overflow that have residence times between 3.93 and 4.00 hours. The experimentally determined reaction time for micro-pellets was found to be far below their actual residence time in a Zincor roaster. Thus complete conversion of micro-pellets can take place.

With a load of 20% micro-pellets introduced into the feed concentrate, it was found that the oxygen enrichment could be reduced by 60% to 23% of total oxygen. The quality of the calcine produced was maintained above the target of 98.8% ZnS to ZnO conversion. The results of this study have shown that the use of the micro-pelletisation of concentrate at Zincor successfully reduces the entrainment of particles. The manipulation of entrainment through micro-pelletisation can be used successfully to reduce oxygen enrichment, while improving production and maintaining quality at Zincor.

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Mobile tolerant hybrid network routing protocol for wireless sensor networks

by Jacques Nicolaas Pretorius and Prof Gerhard Hancke

Wireless sensor networks (WSN) may consist of hundreds or even thousands of nodes and could be used for a multitude of applications, such as warfare intelligence or to monitor the environment. A typical WSN node has a limited and usually irreplaceable power source and the efficient use of the available power is of utmost importance to ensure the maximum lifetime of each WSN application.

Each of the nodes needs to transmit and communicate sensed data to an aggregation point for use by higher layer systems. Data and message transmission among nodes collectively consume the largest amount of the energy available in a WSN. The network routing protocols ensure that every message reaches the destination and has a direct impact on the amount of transmissions to deliver messages successfully.

To this end, the transmission protocol in the WSN should be scalable, adaptable and optimised to consume the least possible amount of energy to suit different network architectures and application domains.

Research conducted in the Department of Electrical, Electronic and Computer Engineering proposed a mobile tolerant hybrid energy-efficient routing protocol (MT-HEER), where hybrid refers to the inclusion of both flat and hierarchical routing architectures as proposed in the hybrid energy-efficient routing protocol (HEER). HEER was previously developed at the University of Pretoria and formed the starting point of the current research project.

The inclusion of mobile nodes in the WSN deployment proved to be detrimental to protocol performance in terms of energy efficiency and message delivery. This negative impact could be attributed to assuming that all nodes in the network are statically located. In an attempt to adapt to topological changes caused by mobile nodes, too much energy could be consumed by following traditional network failure algorithms.

MT-HEER introduces a mechanism to proactively track and utilise mobile nodes as part of the routing strategy. The protocol is designed with the following in mind: computational simplicity, reliability of message delivery, energy efficiency and – most importantly – mobility awareness. Messages are propagated through the network along a single path, while performing data aggregation along the same route. MT-HEER relies on at least 40% of the nodes in the network being static to perform dynamic route maintenance in an effort to mitigate the risks of topological changes due to mobile nodes. Empirical tests and results have shown that MT-HEER performs as expected by preserving energy within acceptable limits, while considering the additional energy overhead introduced by dynamic route maintenance.

Mobile node tolerance is evident in the protocol's ability to provide a constant successful message delivery ratio at the sink node with the introduction and increase in the number of mobile nodes. MT-HEER succeeds in providing tolerance to mobile nodes within a WSN, while operating within acceptable energy conservation limits.

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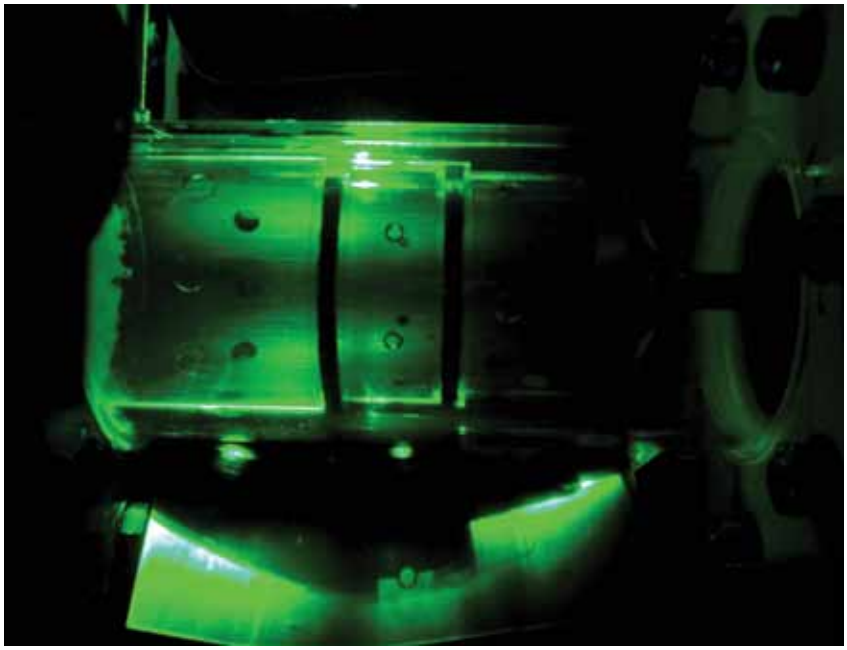
The experimental flow field and thermal measurements in an experimental can-type gas turbine combustor

by Bronwyn Meyers and Prof Josua Meyer

In a study conducted in the Department of Mechanical and Aeronautical Engineering, experimental data was collected in order to create a test case that can be used to validate computational fluid dynamics (CFD) simulations and the individual models used in them for gas turbine combustor applications.



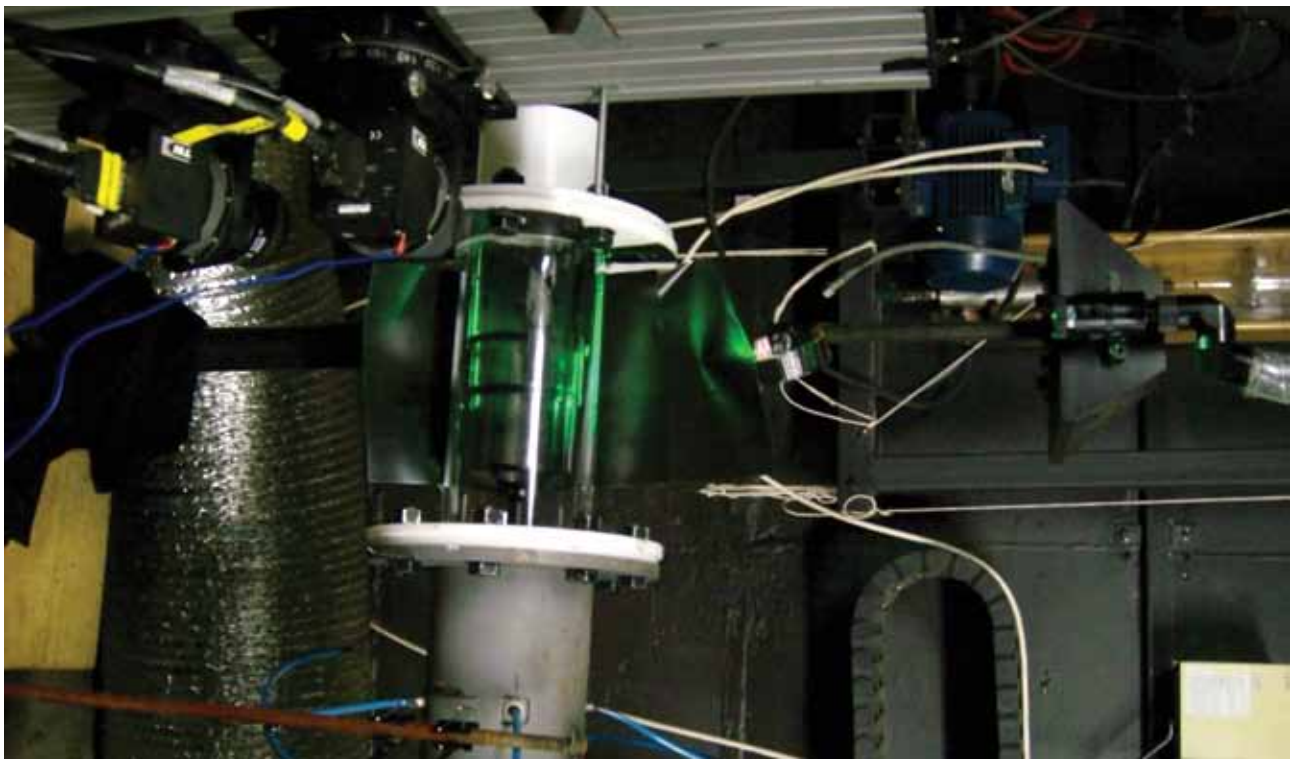
→ *The transparent test section was illuminated using a laser for PIV measurements.*

In many cases, the CFD results of gas turbine combustors do not correlate well with experimental results. For this reason, the simulation method used needs to be tested before CFD can successfully be used for combustor design. This test case encompasses all the features of a gas turbine combustor such as a swirler, primary, secondary and dilution holes, as well as cooling rings.

Experiments were performed on the same combustor geometry for both non-reacting and reacting flows. The non-reacting flow experiments consisted of stereoscopic particle image velocimetry (PIV) measurements performed at various planes in the three zones of the combustor. Data was collected on planes, both in line with the holes and in-between the holes of each zone.

For the reacting experiments, the temperatures on the outlet plane were measured using a thermocouple rake, thus a temperature contour plot on the outlet plane was produced. Furthermore, the combustor can was modified with passive inserts, which were tested to determine their influence on the outlet temperature distribution during reacting runs. In this set-up, the outlet velocity profiles were also measured using a pitot tube during both non-reacting and reacting flows. In addition to the outlet temperature distribution and velocity profiles, images of the flame patterns were captured, which showed the positions of flame tongues, fluctuating flames and steady flames. Carbon burn patterns on the walls of the combustor liner were also captured. From the data collected during the reacting runs, the pattern factor, profile factor, overall pressure loss and pressure loss factor were calculated.

The non-reacting experiments were performed using the PIV-produced three-dimensional velocity vector fields throughout the combustor. These experiments were performed at various flow rates, which gave an indication of which features of the combustor flow were affected by the flow rate. When comparing the



The transparent test section was illuminated using a laser for PIV measurements.

individual PIV images alongside one another, the temporal nature of the combustor flow was also evident.

The reacting experiments revealed a hot region of exhaust gas around the outer edge of the exhaust, while there was a cooler region in the centre of the outlet flow. The PIV flowfield results revealed that the reason for the hot outer ring-like region was due to the path the hot gases would take. The hot combustor gas from the primary zone diverges outwards in the secondary zone. It is then further forced to the outside by the dilution recirculation zone. The hot flow leaves the combustor along the wall, while the cooler air from the jets leaves the combustor in the centre.

The experiments performed produced a large variety of data that can be used to validate a number of aspects of combustor simulation using CFD. The non-reacting experimental data can be used to validate the turbulence models used and to evaluate how well the flow features were modelled or captured during the non-reacting stage of the combustor simulation process.

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Concentration and desalination of industrial effluents with membrane distillation

by S Muhammad Suhail Osman and Prof Japie Schoeman

Industry generates large quantities of saline aqueous effluent and brine that need to be disposed of in such a way as to prevent the pollution of the environment. For landlocked plants, a serious challenge is posed, as ocean disposal of brine is not readily available.

Effluent disposal options for inland industries include brine disposal into lined and unlined evaporation ponds, the treatment of effluent with membrane technologies, such as reverse osmosis (RO) and electrodialysis reversal (EDR), the treatment of brine with mechanical evaporation technologies and deep-well injection.

Brine disposal to evaporation ponds holds the danger of ground and surface water pollution. Treatment of effluent with RO and EDR generates large quantities of brine. This brine is a potential water and chemical source. Mechanical evaporation technologies for brine treatment are very expensive and scaling is a big problem. Deep-well injection is an attractive technology for brine disposal, but is not practised in South Africa.

Membrane distillation (MD) is an alternative technology that has potential for brine treatment for water and chemical recovery. This technology makes use of hydrophobic microporous membranes, which are claimed to be fairly well resistant to membrane fouling or scaling. Water and chemicals can be extracted from brine with high water recoveries without serious fouling or scaling of the membranes. The driving force for this process is a temperature difference across the membrane for the concentration and desalination of brine. This process uses lower pressures than RO, lower temperatures than distillation processes and membranes with less demanding properties as required by RO. Salt rejections of more than 99% are possible. A further advantage of this process is that it should be possible to apply waste heat from industry to drive this process. This will have economic advantages.

However, very little information is available in South Africa regarding the use of MD for brine treatment, and research concluded in the University of Pretoria's Department of Chemical Engineering was aimed at evaluating this technology for brine treatment for effluent volume reduction and water recovery.

The main objectives of this study were to evaluate MD for the concentration and desalination of salt solutions and industrial brines for effluent volume reduction and water recovery for reuse. The industrial effluents selected for the study included petrochemical effluent, EDR brine, RO brine and ion exchange (IX) spent regenerant. The specific objectives of the study were to determine the effect of temperature, concentration and flow rate on process performance for the concentration and desalination of salt and industrial brines, to develop a theoretical model that could be used to predict permeate flux, and to determine the fouling or scaling potential of the effluents for the membranes and investigate membrane cleaning methods.

It was found that sodium chloride feed solutions could be successfully concentrated by reducing their volumes. Salt rejections of greater than 99% and water recoveries up to 79% could be obtained. Little or no decline in permeate flux was experienced, showing that membrane fouling or scaling should not be a serious problem. An increase in feed water temperature increases the permeate flux, while an increase in the sodium chloride feed solution concentration results in a decrease in the permeate flux, as well as a decrease in temperature polarisation effects. An increase to the feed flow rates increases the permeate flux, but to a lesser degree than the increase in feed temperature. An increase in the permeate flow rates also increases the permeate flux, but to a lesser degree than the increase in feed temperature. The fouling or scaling potential of the salt solutions for the membranes appears to be negligible. An excellent

quality permeate could be produced, which would be suitable for boiler feed make-up.

The model that was developed agreed relatively well with the experimental data. The transition flow model was found to be the most suitable predictive model, as it best described the permeate flux of the system. The model shows that an increase in feed flow rate, permeate flow rate and feed inlet concentration leads to an improvement in the temperature polarisation coefficient (TPC). It is also evident from the model that the TPC becomes more significant as the feed inlet temperature increases. The model further confirms that as the feed inlet temperature, feed inlet flow rate and permeate inlet flow rate increase, so the heat flux also increases. However, as the concentration increases, the heat flux decreases. This decrease is fairly negligible and can be considered constant. The effect that the tortuosity factor (τ) plays on the permeate flux is very important, as it determines the mass transport mechanism. The larger the value of the tortuosity factor, the lower the permeate flux.

An increase in the feed temperature to the membrane increases the permeate flux in the case of the petrochemical effluent. The permeate quality produced from the brines should be suitable for boiler feed make-up. The fouling or scaling potential of all four industrial brines for the membranes, except the IX brine, was not found to be very serious. The permeate flux remained almost the same for three consecutive runs for the petrochemical effluent. Permeate flux, however, declined with time, but the permeate flux could be restored with a water rinse. The clean water flux (CWF) at the end of the runs was slightly less than the CWF on the clean membrane surface.

In the case of the EDR brine, the permeate flux decrease was more or less the same for three consecutive runs, but declined somewhat with time. The CWF was approximately 17% lower after the runs. However, cleaning of the membranes with acid solution almost restored the flux.

The permeate flux also remained more or less constant for three consecutive runs in the case of the tubular reverse osmosis (TRO) brine, but also decreased with time. The CWF was approximately 14% lower after the runs. Acid cleaning could not restore flux. However, cleaning of the membranes with a salt or caustic solution almost restored the flux. The permeate flux of the spent IX regenerant also remained more or less the same for three consecutive runs. Permeate flux, however, declined with time. Water rinsings between the runs apparently restored the flux. However, the CWF flux was approximately 21% lower after the runs and it was not possible to restore the CWF after cleaning the membranes with hydrochloric acid, sodium chloride or caustic, citric acid or EDTA cleaning solutions. The average CWF had decreased by about 15%. Therefore, fouling or scaling of the membranes took place.

Crystals were detected in the MD brine when the EDR and TRO brines were used as feed. Calcium sulphate hydrate crystals formed in the case of the EDR brine. A mixture of sodium sulphate, calcium carbonate and glauberite formed when the TRO brine was treated. No solids were observed in the feed tank when the petrochemical effluent and IX brine were used as feed.

The experimental studies showed that membrane distillation has the potential to concentrate and desalinate industrial brines effectively. It appears that membrane fouling or scaling should not be a problem with the limited amount of runs conducted on the TRO and EDR brines. However, more serious membrane fouling or scaling was observed in the case of the spent IX regenerant brine. Therefore, longer runs should be conducted to work out a membrane cleaning strategy for fouled or scaled membranes.

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The industrial effluents (petrochemical, EDR, TRO and IX brines) could be successfully concentrated and desalinated with MD. The salt rejections, water recoveries and permeate conductivities were as follows:

Effluent	Water recovery (%)	Salt rejection (%)	Permeate quality (µS/cm)
Petrochemical effluent	84	99.77	127.2
EDR	75	99.70	119.2
TRO	78	99.66	120.3
IX	68	N/A	131.4

A secure client/server interface protocol for the electricity prepayment vending industry

by Kennedy Pregarsen Subramoney and Prof Gerhard Hancke

Electricity prepayment systems have been successfully implemented by South Africa's national electricity utility (Eskom) and local municipalities for more than 17 years. The prepayment vending subsystem is a critical component of prepayment systems, as it provides convenient locations for customers to purchase electricity. It predominantly operates in an "offline" mode. However, electricity utilities are now opting for systems that operate in an "online" mode.

→ Customers purchasing prepaid electricity from the first XMLVend 2.1-enabled point of sale in Vereeniging (Sharpville).

The online mode of operation or online vending is when a prepayment token is requested from a centralised server that is remote from the client at the actual point of sale (POS). The token is only generated by the server and transferred to the POS client once the transaction, the POS client and the payment mechanism have been authenticated and authorised. The connection between the POS client and the server is a standard computer network channel (like Internet, direct dial-up link, X.25 or general packet radio service (GPRS).

Research concluded in the Department of Electrical, Electronic and Computer Engineering identified the lack of online vending system standardisation as a matter of concern, as it posed a significant risk for utilities, which faced the problem of being locked into proprietary online vending systems. Thus, the South African prepayment industry (led by Eskom) initiated a project to develop industry specifications for online vending systems.

The first critical task in this project was to conduct a current state analysis of the South African prepayment industry, technology and specifications. The prepayment industry is built around the standard transfer specification (STS). This has become the de facto industry standard to securely transfer electricity credit from a POS to the prepaid meter. STS is supported by several offline vending system specifications.

The current state analysis was followed by a requirements analysis phase. The requirements analysis confirmed the need for a standard interface protocol specification, rather than a full systems specification. The interface specification focused on the protocol between a vending client and vending server, and did not specify the client and server application layer functionality and performance requirements. This approach encouraged innovation and competitiveness among client and server suppliers, while ensuring

interoperability between these systems.

The online vending protocol design was implemented using the web services framework, and was therefore appropriately named XMLVend. The protocol development phase was an iterative process with two major releases, XMLVend 1.22 and XMLVend 2.1. XMLVend 2.1 is the current version of the protocol. XMLVend 2.1 addressed the shortcomings identified in XMLVend 1.22, updated the existing use cases and added several new use cases. It was also modelled as a unified modelling language (UML) interface or contract for prepayment vending services. Therefore, clients using the XMLVend interface are able to request services from any service provider (server) that implements the XMLVend interface. The UML-modelled interface and use case message pairs were mapped to Web Service Definition Language (WSDL) and schema (XSD) definitions respectively.

XMLVend 2.1 is a secure and open web service-based protocol that facilitates prepayment vending functionality between a single logical vending server and n number of clients. It has become a key enabler for utilities to implement standardised, secure, interoperable and flexible online vending systems.

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→ *Successful commissioning of the first XMLVend 2.1-enabled point of sale.*

Phase noise analysis of a tail-current shaping technique employed on a BiCMOS voltage-controlled oscillator

by Wynand Lambrechts and Prof Saurabh Sinha

Several techniques exist to improve phase noise performance in voltage-controlled oscillators (VCOs). These techniques range from VCO topology considerations, inductor dimensioning and placement for improved quality factor (Q-factor), semiconductor process parameter considerations, and reducing low-frequency tail-current noise sources. The latter option is employed to study the overall effect on VCO phase noise performance, as it has been recognised that the tail transistor may have a large impact on the generation of phase noise, often being the largest contributor.

Tail-current noise suppression in radio frequency (RF) BiCMOS VCOs prevents the low-frequency tail-current noise from being converted into phase noise during normal operation of the oscillator. The tail current is made large when the oscillator output voltage reaches its maximum or minimum value and when the sensitivity of the output phase to injected noise is the smallest. The tail current is made small during the zero crossings of the output voltage when the noise sensitivity is large. No additional power is added to the system, ensuring low power operation at low noise levels. Tail-current shaping techniques reduce phase noise with three separate, but simultaneous mechanisms. The increased oscillation amplitude, narrower drain current pulses, and finally the shunt capacitor that acts as a noise filter for the tail current, all contribute to lowering the phase noise.

Silicon Germanium (SiGe) BiCMOS processes, implemented with heterojunction bipolar transistors (HBTs), offer remarkable high-frequency performance (with peak currently at 350 GHz) without large expense of noise (through trapping of hot carriers in the isolation between the emitter and extrinsic base) performance, with low-cost implementation possible and compatibility with very large-scale integration (VLSI) processes. Doping of the Silicon (Si) transistor base-layer with a Germanium-graded composition lowers the thermal conductivity of the transistor and increases electron mobility, which results in faster switching speeds compared to Si processes.

The VCO was implemented using the 0.35 µm BiCMOS (thick metal) process provided by Austriamicrosystems (AMS).

To achieve a low phase noise VCO, several considerations influence the overall operation and phase noise characteristics of the VCO. The initial VCO should operate at respectable phase noise levels, and improvements to the phase noise should give the VCO an edge over existing works, bearing in mind the technology used for integration. Some of these considerations include the topology of the VCO, inductor geometry and quality, design process, current source topology, and finally the method used to improve phase noise performance.

For the design process, some comparable oscillator specifications have been achieved using CMOS, BiCMOS and InGaAs/GaAs technologies. It is important to weigh performance versus cost-effectiveness and ease of implementation as trade-offs when choosing the process technology. Therefore, SiGe BiCMOS was chosen as the preferred process for implementation. An advantage of this process, compared to GaAs, is its compatibility with silicon VLSI processes and scalability to higher current densities.

Considering the inductor geometry, when designing a low phase noise RF VCO, an inductor with a good quality factor with minimum additive noise is critical. Spiral inductors are commonly used for on-chip integration. For the tank circuit, a standard spiral inductor was implemented. For the tail-current filter, a spiral inductor with larger inductance but lower Q-factor was chosen. The Q-factor does not influence overall circuit performance and the increased inductance has an advantage of creating a higher impedance path between the tail-current and switching transistors to limit the up-conversion of low-frequency noise.

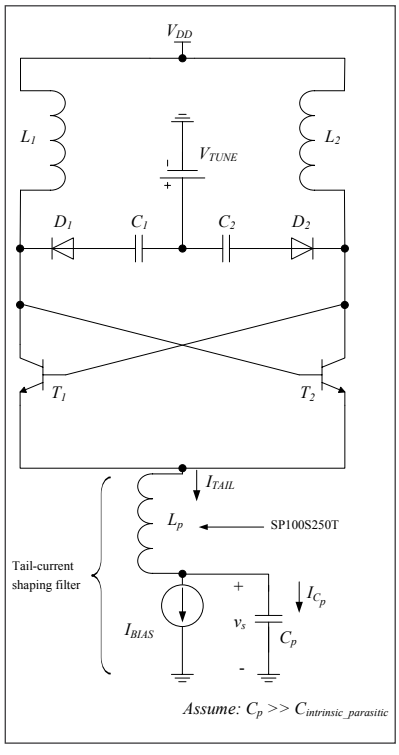
Topology considerations showed that LC oscillators display the most attractive characteristics for high-frequency, low phase noise designs. These oscillators consist of a tank circuit with a quality factor that can

be improved by improving the Q-factor of the inductor. Phase noise ratings of between -110 dBc/Hz and -130 dBc/Hz at an offset of 1 MHz from their respective 5 GHz carriers have been reported.

For the current source, a Widlar current mirror presents a stable current as any changes in output current are countered with a decrease in the gate-source voltage of the driver transistor.

Tail-current shaping

A tail-current shaping circuit presents a high impedance path that circulates odd harmonics in a differential path, while even harmonics flow in a common-mode path through the switching transistors towards the ground. This entails the employment of a filtering technique to suppress low noise modulation of the dominant even (second) harmonic where device noise is up-converted to noise. Subsequent harmonics are assumed to be minute and negligible. An important factor to consider is that the filter capacitor may be detrimental to the overall phase noise performance of the current-source driver as the transistor enters the triode region and therefore this transistor must ideally be kept in the active region. The tail-current filtering technique is shown in Figure 1.



→ *Figure 1. Tail-current shaping technique employed to LC VCO.*

A capacitor (C_p) in parallel with the current source, as seen in Figure 1, adds a path that the current may follow during operation, as shown below (assuming that it is much larger than the intrinsic gate-drain (C_{GD}) and base capacitance (C_π).

$$I_{TAIL} = I_{BIAS} - IC_p \quad (1)$$

The capacitor is sized so that most of the current generated at (2) is grounded. The voltage across the capacitor (v_s) is given by the following formula:

$$v_s = A_s \cos(4\pi f_0 t - \theta) \quad (2)$$

where A_s is the voltage amplitude at this point, and θ is the phase delay between the output signal and the signal measured at the common emitters of the switching transistors. The current through the capacitor is as follows:

$$i_c = C_p \frac{dv_s}{dt} = -4\pi A_s f_0 C_p \sin(4\pi f_0 t - \theta) \quad (3)$$

Therefore, the maximum current through the capacitor from (3) is $-4\pi A_s f_0 C_p$. If this value is set to I_{BIAS}, a minimum current I_{TAIL} is achieved at $2f_0$. Thus,

$$C_p = \frac{2I_{BIAS}}{4\pi A_s f_0} \quad (4)$$

where the $2I_{BIAS}$ current reflects the peak-to-peak value, the dominant part of the current at the distorted second harmonic will flow through the capacitor, towards ground during $2f_0$. To ensure that the current at the fundamental frequency component, where most of the power lies, does not pass through the capacitor freely, an inductor (L_p) is placed between the current source and the differential pair, as depicted in Figure 1. The inductor and capacitor creates a band-pass inductor-capacitor (LC) filter configuration. The inductor also increases the impedance path between the switching transistors and current source to avoid noise from the low frequency currents to be up-converted to phase noise in the oscillator.

Simulation results

Simulation results confirm that tail-current shaping has enhanced the phase noise performance of an LC BiCMOS VCO, as summarised in Table 1.

Offset frequency	10 kHz	100 kHz	1 MHz
Without tail-current shaping	-57.61	-83.7	-105.3
With tail-current shaping	-64.9	-88.1	-108.6
Improve-ment	7.3	4.4	3.3

→ *Table 1[1]. Phase noise simulation results.*

The simulated results for the VCO with the tail-current shaping filter employed is depicted in Figure 2, where the vertical axis represents the phase noise in dBc/Hz and the horizontal axis is the relative offset frequency from the 5 GHz carrier.

The VCO was implemented on-chip (see Figure 3) to relate the measured results (as seen in Figure 4) with the simulated results. Figure 3 indicates the prototyped circuit used for measurements, as well as the relative size that the inductor occupies on die.

[1] All tabulated values represent the phase noise rating in dBc/Hz at a 1 MHz offset from the 5 GHz carrier frequency.

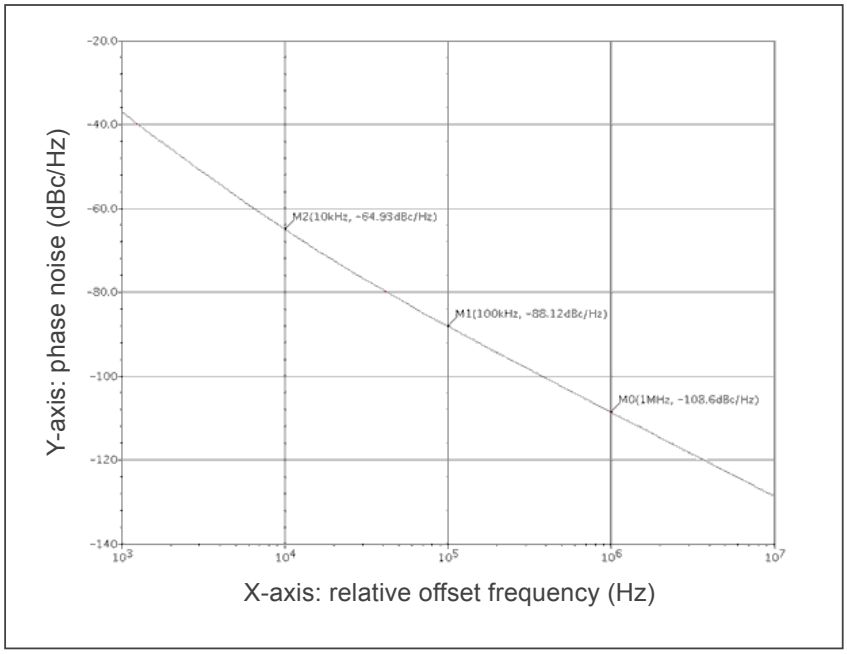


Figure 2. Simulation results of VCO with tail-current shaping.

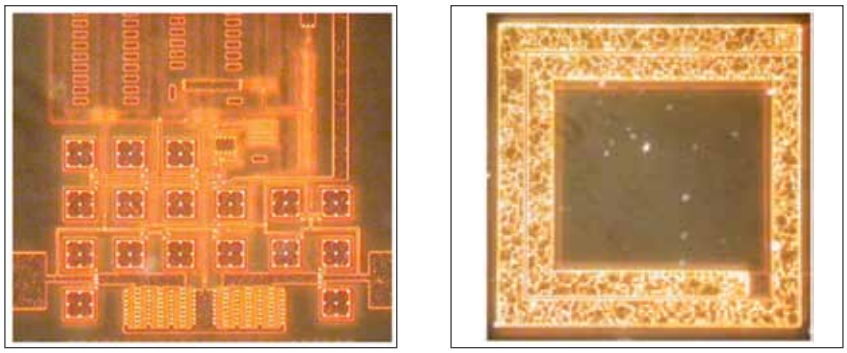


Figure 3. Prototyped circuit and inductor.

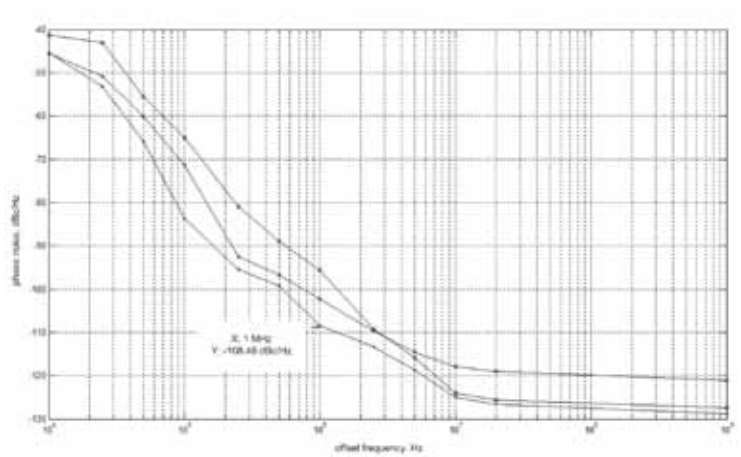


Figure 4. Measured phase noise of prototyped VCOs.

However, an error was encountered during the layout process of the VCO, and the relative phase noise improvement between separate VCOs could not be measured. The measured results can only serve as proof that the simulated phase noise correlates with the prototype phase noise of around -108.5 dBc/Hz at a 1 MHz offset from the 5 GHz carrier frequency.

Simulation results provided a 3.3 dBc/Hz improvement from -105.3 dBc/Hz to -108.6 dBc/Hz at a 1 MHz offset frequency from the 5 GHz carrier when employing tail-current shaping. The relatively small improvement in VCO phase noise performance translates in higher modulation accuracy when used in a transceiver. This increase can therefore be regarded as significant. The power consumption of the simulated VCO is around 6 mW and 4.1 mW for the measured prototype. The circuitry occupies 2.1 mm^2 of the die area.

The simulation results confirm a 3.3 dBc/Hz phase noise improvement at 1 MHz offset from the 5 GHz carrier when employing tail-current shaping. The LC VCO was designed in a technology that not only contains metal-oxide-semiconductor field effect transistors (MOSFETs), but is combined with the speed and low noise of SiGe heterojunction bipolar transistors (HBTs). Tail-current shaping can be expanded for other configurations (and ring oscillators), which could serve as a good basis for future work. If this application proves viable in a number of different scenarios apart from experimental results obtained here, it could be used as a standard implementation to provide a guaranteed improvement on phase noise without the use of any expensive, process-altering techniques.

Acknowledgements

The authors would like to thank Grintek Ewation (Pty) Ltd for funding the research project and providing access to measurement equipment. The authors would also like to extend their gratitude to the non-linear RF laboratory at Ohio State University for access to and support with measurement equipment.

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Wynand Lambrechts *and* ***Prof Saurabh Sinha*** *are associated with the Carl and Emily Fuchs Institute for Microelectronics in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria.*

Student research earns award at peer-reviewed international conference

The research paper of Wynand Lambrechts, a student in the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria, was awarded the Best Paper Award in the Student Paper category at the 33rd International Semiconductor Conference (CAS 2010), which was held in Sinaia, Romania, in October 2010.

This conference was technically co-sponsored by the Institute of Electrical and Electronics Engineers (IEEE). Wynand's travels were funded as part of a National Research Foundation (NRF) grant. His master's research, conducted under the supervision of Prof Saurabh Sinha, involved a phase noise analysis of a tail-current shaping technique employed on a BiCMOS voltage-controlled oscillator.

As part of his studies, Wynand also spent two months at the non-linear radio frequency (RF) laboratory at Ohio State University (OSU) in the USA, which is a top international laboratory in this field.

This visit provided him the opportunity to expand his knowledge of microelectronic engineering to the point where it was possible to improve his skills. It enabled him to focus future research on making a unique or novel contribution. The aim of this visit was specifically to spend time at the non-linear RF laboratory at OSU and to perform measurements on a prototype integrated circuit (IC) using equipment not available in South Africa, and to get an idea of the work being done outside South Africa in his specific field of research.

Single and multi-antenna MC-DS-CDMA with joint detection for broadband block-fading channels

by Daniel Jorge Basilio and Prof Sunil Maharaj

In the context of broadband wireless communications, using code division multiple access (CDMA), the main multiple access (MA) options include single-carrier direct sequence CDMA (SC-DS-CDMA) using time-domain direct sequence spreading, multicarrier CDMA (MC-CDMA) using frequency-domain spreading and multicarrier DS-CDMA (MC-DS-CDMA) using time-domain direct sequence spreading of the individual subcarrier signals.

Research conducted in the Department of Electrical, Electronic and Computer Engineering showed that MC-DS-CDMA has the highest degrees of freedom in the family of CDMA schemes that can be beneficially exploited during the system design and reconfiguration procedures. An amalgam of MC-CDMA and MC-DS-CDMA, known as time and frequency domain spreading (TF-domain spreading) MC-DS-CDMA, was proposed.

TF-domain spreading MC-DS-CDMA has several benefits over conventional MC-DS-CDMA with regard to both capacity and performance. However, in contrast to conventional MC-DS-CDMA, TF-domain spreading MC-DS-CDMA introduces multi-user interface (MUI), which necessitates the use of joint detection at the receiver. Recently, multiple input multiple output (MIMO) or multi-antenna TF-domain spreading MC-DS-CDMA schemes have been proposed that efficiently exploit both the spatial and frequency diversity available in MIMO frequency-selective channels.

Although an extensive amount of research has been done on single- and multi-antenna TF-domain spreading MC-DS-CDMA schemes that achieve both spatial and frequency diversity in frequency-selective slow fading channels, very little research considers the time selectivity of the wireless channels encountered. Thus, the abovementioned schemes may not be sufficiently efficient when communicating over wireless channels that exhibit both frequency-selective and time-selective fading. There are very few MC-DS-CDMA schemes that consider the time selectivity of the wireless channels encountered.

This study considered the design of single- and multi-antenna TF-domain spreading MC-DS-CDMA, for frequency-selective block-fading channels, which are capable of exploiting the full diversity available in the channel (i.e. spatial, frequency and temporal diversity), using various methods of joint detection at the receiver.

It was shown that the diversity gain in block-fading channels can be improved by coding across multiple fading blocks. Single-antenna TF-domain spreading MC-DS-CDMA was considered for the quasi-synchronous uplink channel, and multi-antenna TF-domain spreading MC-DS-CDMA was considered for the synchronous downlink channel. Numerous simulated bit error rate (BER) performance curves, obtained using a triply selective MIMO channel platform, were presented in this study using optimal and suboptimal joint detection algorithms at the receiver. In addition, this study investigated the impact of spatial correlation on the BER performance of the MC-DS-CDMA schemes considered.

From these simulated results, one would be able to conclude that TF-domain spreading MC-DS-CDMA that is designed for frequency-selective block-fading channels performs better than previously proposed schemes designed for frequency-selective slow-fading channels, owing to the additional temporal diversity exploited under the block-fading assumption.

Daniel Jorge Basilio *is a graduate of the Department of Electrical, Electronic and Computer Engineering at the University of Pretoria.*

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The Laves phase embrittlement of ferritic stainless steel AISI 441 used in shells of vehicle catalytic converters

by Maitse Sello and Prof Waldo Stumpf

Columbus Stainless of Middelburg is the primary manufacturer of flat wrought stainless steel products in southern Africa. One of the growth sectors in the use of stainless steel is in the automotive components industry and – more particularly – in catalytic converters for use in vehicles.

The manufacture of automobile emission control systems in South Africa is one of the fastest growing industry sectors in the world. Founded on the growth and development of catalytic converters, South Africa produces in excess of 10% of the world's market, which mainly stems from its dominance in Platinum Group Metals (PGM) production. Catalytic converters are the largest of the auto component groupings exported from South Africa and its value now amounts to $500 million a year. The growth of the local catalytic converter industry has been spectacular, as indicated in Figure 1.

The operating temperatures for catalytic converters are in the region of 900°C, but are associated with frequent temperature variations as automobiles are used intermittently. Thus, the material for this application requires excellent thermal fatigue resistance and high temperature strength. The primary steel used in this application is type AISI 441 stainless steel, which is equivalent to DIN 1.4509. This steel is fully ferritic over a wide range of temperatures.
Type AISI 441 is a dual-stabilised (titanium and niobium) ferritic stainless steel with 18 weight percentage chromium. Titanium and niobium carbides are more stable than chromium carbides and prevent the formation of chromium carbides on grain boundaries, which is the cause of sensitisation of the alloy in near-grain boundary regions. The dual stabilisation imparts beneficial corrosion resistance, oxidation resistance, high temperature strength and formability to the steel.

The effect of Laves Phase (Fe_2Nb) formation on the Charpy impact toughness of the ferritic stainless steel type AISI 441 was investigated. The steel exhibits good toughness after solution treatment at 850°C, but above and below this treatment temperature, the impact toughness decreases sharply. With heat treatment below 850 °C, the presence of the Laves phase on grain boundaries and dislocations plays a significant role in the embrittlement of the steel, whereas above that temperature, an increase in the grain size from grain growth plays an equal role in the impact embrittlement of this alloy.

The toughness results agree with the phase equilibrium calculations made using Thermo-Calc®, whereby it

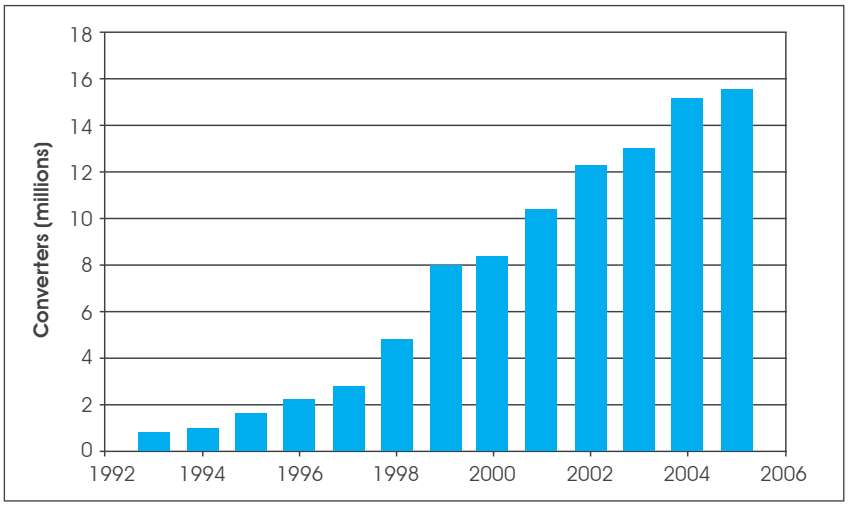

Figure 1. Local catalytic converters growth industry.

was observed that a decrease in the Laves phase volume fraction with increasing temperature corresponds to an increase in the impact toughness of the steel. Annealing above 900 °C, where no Laves phase exists, grain growth is found, which similarly has a very negative influence on the steel's impact properties. Where both a large grain size as well as Laves phase are present, it appears that the grain size may be the dominant embrittlement mechanism. Both the Laves phase and grain growth therefore have a significant influence on the impact properties of the steel, while the precipitation behaviour of the Laves phase has also been investigated with reference to the plant's manufacturing process, particularly the cooling rate after hot rolling or after a solution treatment.

During isothermal annealing within the temperature range of 600 to 850°C, the time-temperature-precipitation (TTP) diagram for the Laves phase, as determined from the transformation kinetic curves, shows two classical C-type noses on the transformation curves.

The first one occurs at the higher temperatures of about 750 to 825°C and the second one at much lower temperatures, estimated to possibly be in the range of about 650 to 675°C. The transmission electron microscopy (TEM) analyses show that there are two independent nucleation mechanisms that occur within these two temperature ranges. At lower temperatures of about 600°C, the pertaining nucleation mechanism is on dislocations. As the temperature is increased to above 750°C, grain boundary nucleation becomes more dominant. The morphology of the particles and the misorientation with the matrix also changes with temperature. At lower temperatures, the particles are more needle-like in shape, but as the temperature is increased, the shape becomes more spheroidal.

The effect of the steel's composition on the Laves phase transformation kinetics shows that lowering the Nb content in these type 441 stainless steels had no significant effect on the kinetics on the precipitation of the Laves phase. However, an Mo addition and a larger grain size of the steel retard the formation of the Laves phase, although the optimum values of both parameters still need further quantification.

The calculational model made for the transformation kinetics of the Laves phase, using the number density of nucleation sites N_o and the interfacial energy g as the fitting parameters in this work demonstrated a reasonable agreement with the experimental results.

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Having a good look at vibrations

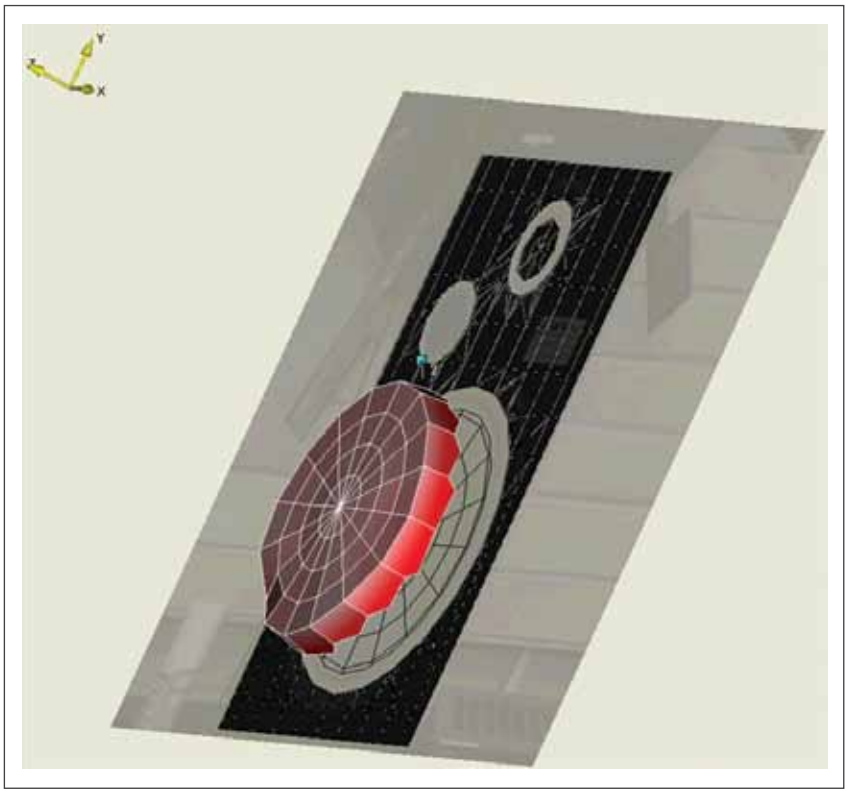
by Prof Stephan Heyns

The growing demand for reliable engineering products that can withstand very severe dynamic environments, as well as the human desire for more pleasant and healthy working conditions, is leading to rapid growth in the sophistication of vibration test techniques and instrumentation. Optical techniques to conduct such measurements are becoming increasingly important and offer some very significant advantages compared to traditional vibration measurement techniques.

These measurements are non-contact and do not influence the dynamics of the structure under consideration. This allows for detailed vibration measurements on structures ranging from very light, such as the vibration of loudspeaker diaphragms, to large engineering structures where physical access is difficult and measurements from large standoff distances might be required, and red-hot vibrating metal sheets and rotating machinery. Vibration measurements on bio-medical structures, such as *in vivo* tests on human skin during the interaction of operators with vibratory machines, are also very feasible.

The Department of Mechanical and Aeronautical Engineering at the University of Pretoria is now uniquely positioned to conduct specialist vibration measurements using very advanced optical equipment. Recent acquisitions include a PSV400 Polytec scanning laser vibrometer and a GOM Aramis and Pontos system for using stereophotogrammetry with digital image correlation to track the motion history of optical markers on structures dynamically in three-dimensional space, and to further process this information to get full-field dynamic images of strain in structures by looking at the structures. These instruments were purchased through a grant from the Department of Education, and allow undergraduate students to develop an excellent physical understanding of the way in which structures deform and vibrate under different dynamic loading conditions.

Of course the equipment also allows very exciting research to be conducted. The reliability of computational models of structural behaviour is becoming increasingly important in the design and optimisation process. However,



→ *Figure 1. Measured rigid body mode of a loudspeaker membrane.*

→ *Figure 2. Scanning laser vibrometer measurements on a composite model aircraft wing.*

very little is often known about the properties of advanced new materials, such as specialised composites or even human tissue and bone.

By updating the computational models with very accurate high-resolution experiments, much can be learnt about the effective dynamic characteristics of these materials and reliable modelling strategies.

Laser Doppler vibrometry is an optical technique based on the Doppler effect when laser light is scattered from a vibrating surface and on the interference between the measuring and reference beams. This allows for determining the instantaneous velocity component of the moving surface, along the direction of the incident laser beam. Scanning from point to point on the structure allows a very fine resolution of the system dynamics, without disturbing the system dynamics by mass-loading, as is the case with conventional accelerometers. When the system is excited by real operational excitation, so-called operational vibration modes can be measured. Using artificial excitation, which is accurately measured (such as with a shaker or impact hammer with a load cell), one can also capture the inherent modal properties of the system, such as natural frequencies, mode shapes and damping.

One example of measurements on a light structure at the University is depicted in Figure 1. Here a scanning laser vibrometer was used to study the dynamic behaviour of a loudspeaker membrane, without mass-loading the membrane. It thus allows reliable understanding of the membrane motion in a way that can easily be visualised and understood.

Current research in the department includes the modelling of very light composite materials typically used in aerostructures. The aim is to extract accurate structural dynamic models, which can be used to improve finite element models for detailed design and damage detection purposes. Since the laser scans the structure point by point, this requires steady excitation conditions if one wants to obtain a high-resolution image of the vibration modes of the system. Figure 2 depicts the laser vibrometer at the University while it is conducting experiments on a composite wing for a model aircraft. Because of the black light-absorbing composite material and the desire to do very accurate measurements in this case, small reflective stickers were attached to the wing to improve the quality of the reflected light and the signal-to-noise ratio. By exciting the wing with an electrodynamic shaker (not seen in the figure) and measuring the input force, one can construct frequency response functions, which capture the inherent dynamics of the structure, and allow one to extract the natural modes of the structure. A typical natural mode is shown in Figure 3, which clearly illustrates the effect of the spar on the wing response. Detailed information like this allows updates or improvements of the finite element models through optimisation studies, in which the material or modelling parameters that are considered to be most uncertain are systematically changed to best fit the model to the measured results.

Measurements like these have also been used at the University of Pretoria to study the effects of damping materials on the noise, vibration and harshness behaviour of automotive structures. Figure 4 shows the measured vibration of a roof panel on a pickup to explore the effects of different damping configurations. While vibrations can often be reduced by adding more damping material to the inside of the vehicle panels, this should be done very carefully because of the detrimental effect of the additional mass on the responsiveness of the vehicle and the effect on fuel consumption.

An alternative approach to looking at vibrational phenomena is through the use of full-field stereophotogrammetry. In this approach, two high-resolution cameras are used to take sequential photographs. By employing digital image correlation techniques that follow the relative deformation of a speckled surface (prepared by using

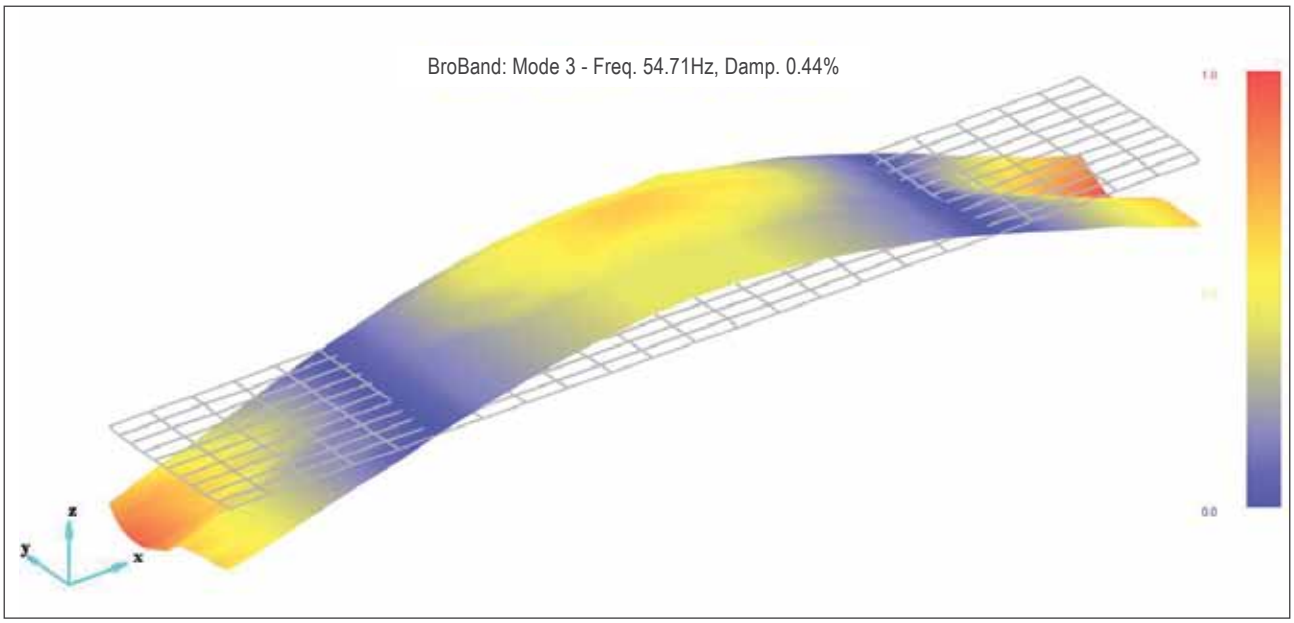


Figure 3. Typical elastic mode of the composite wing.

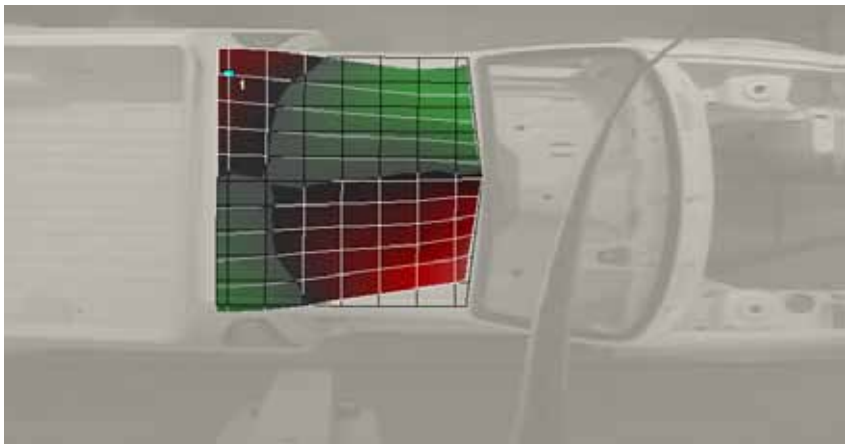


Figure 4. Vehicle roof vibration mode.

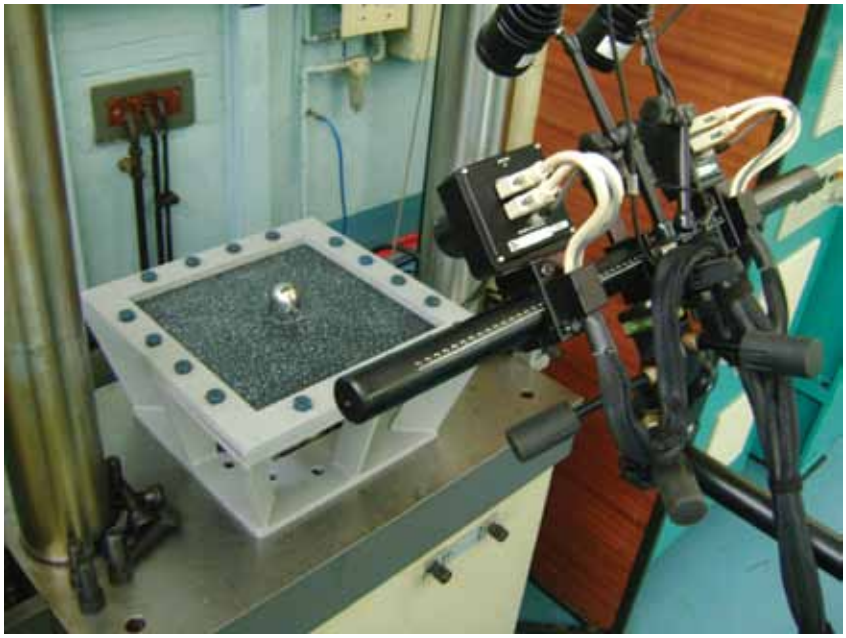


Figure 5. Experimental setup for measuring full-field dynamic strain in a plate being perforated by a steel ball.

ordinary black and white spray paint), it becomes possible to produce very detailed 3D images of the dynamic deformation. Deformations of between 0.01% and several at 100% can be measured. These measurements could be used to study transient phenomena, such as buckling, door slamming or crash analysis, or even the deformation of human skin during exercise, by looking at full-field dynamic views of the deforming structure under transient conditions.

Figure 5 shows the two cameras with lights in a study of the plastic deformation of a suitably painted plate for the experimental verification of finite element models of rocks falling through the protective roofs on mining conveyances in mining shafts. Understanding such phenomena is important to reduce the risk of serious accidents.

Using the same approach to study the failure of composite material coupons to determine the characteristics of these materials (Figure 6), one can see what the strain field looks like the instant before the coupon breaks, while being tensioned on a universal testing machine. With the facilities available at the University, tests of this nature can be done with sampling frequencies of up to 460 Hz. Combining the system with ultra high-speed cameras that are available at the CSIR, however, 3D strain

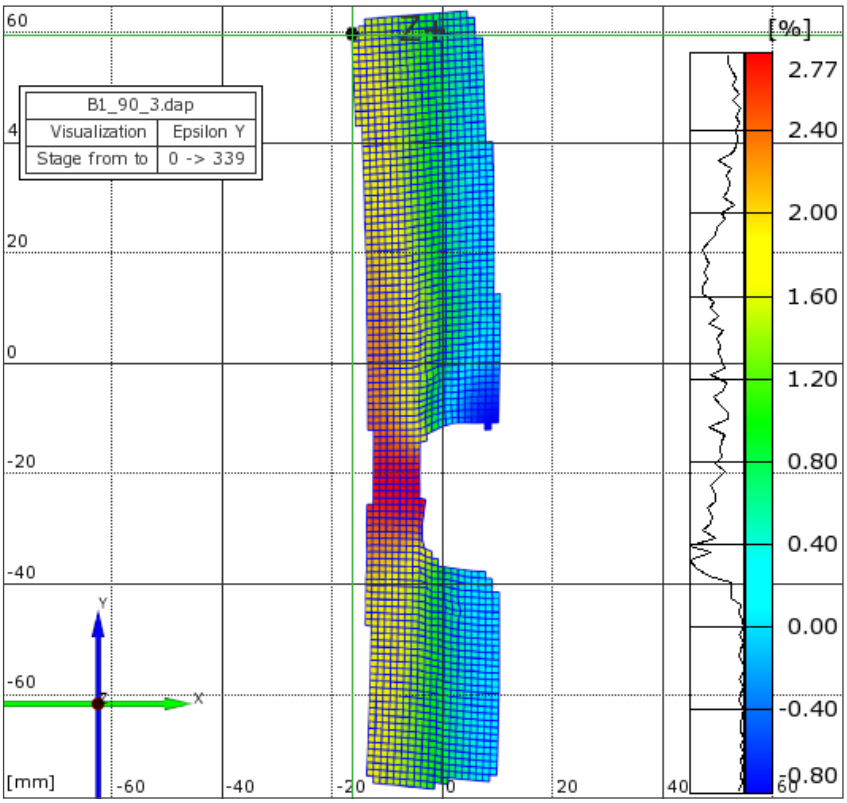


Figure 6. Three-dimensional strain field in composite coupon.

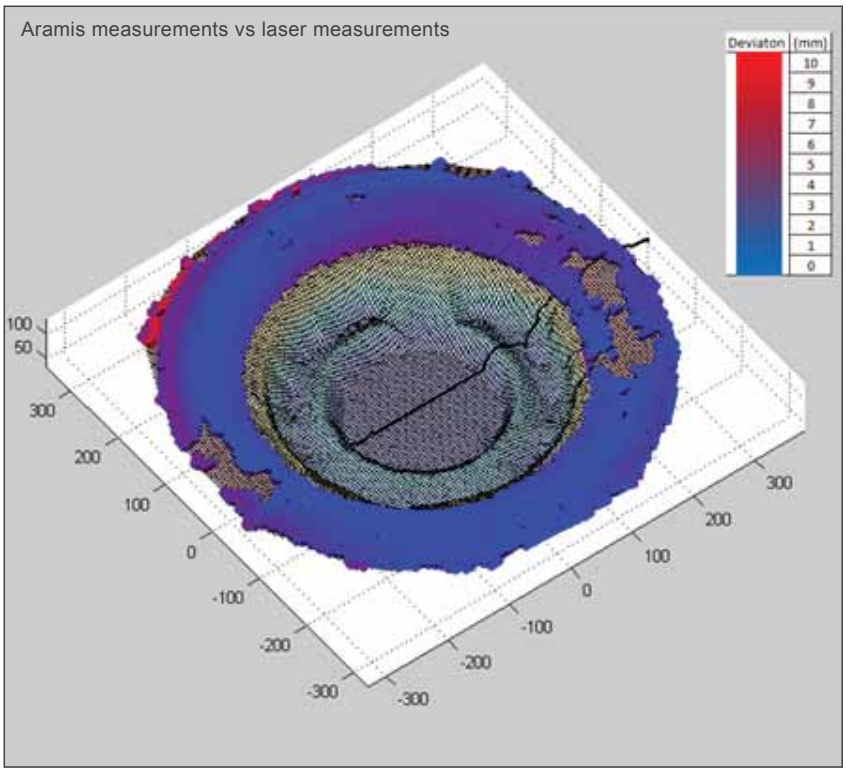


Figure 7. Using photogrammetry to determine tyre coordinates.

images can be generated at very high frequencies that would even allow for measurement of strain fields under explosion conditions.

The department has a very active programme on the modelling and verification of off-road tyre behaviour. This is an important issue because of the pronounced influence that tyre behaviour has on vehicle response. It is also a complex problem because of the anisotropic properties of the materials and the very large non-linear deformations that tyres experience during off-road operation. The department has successfully studied the behaviour of large off-road tyres excited by large servo-hydraulic actuators, simulating impacts on tyres while driving off-road. A useful added advantage of the photogrammetry is that it can also be used to measure the three-dimensional coordinates of the tyre as an input to the finite element model. Results from such a three-dimensional model are shown in Figure 7, compared to other geometrical measurements.

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Subject-specific modelling of neural responses to electrical stimulation of the auditory system

by Ramana Govindasamy, Tiaan K Malherbe, Prof Tania Hanekom and Prof Johan J Hanekom

The cochlear implant has restored partial hearing to over 200 000 profoundly deaf people, making it the most widely distributed and successful neural prosthetic by several orders of magnitude. It has also proven useful as a research tool in expanding the understanding of neural plasticity in children and the mechanisms involved in auditory pattern recognition. Speech perception in certain users is incredible, considering that the low-resolution signal, presented through a limited number of channels, still provides enough information for speech recognition.

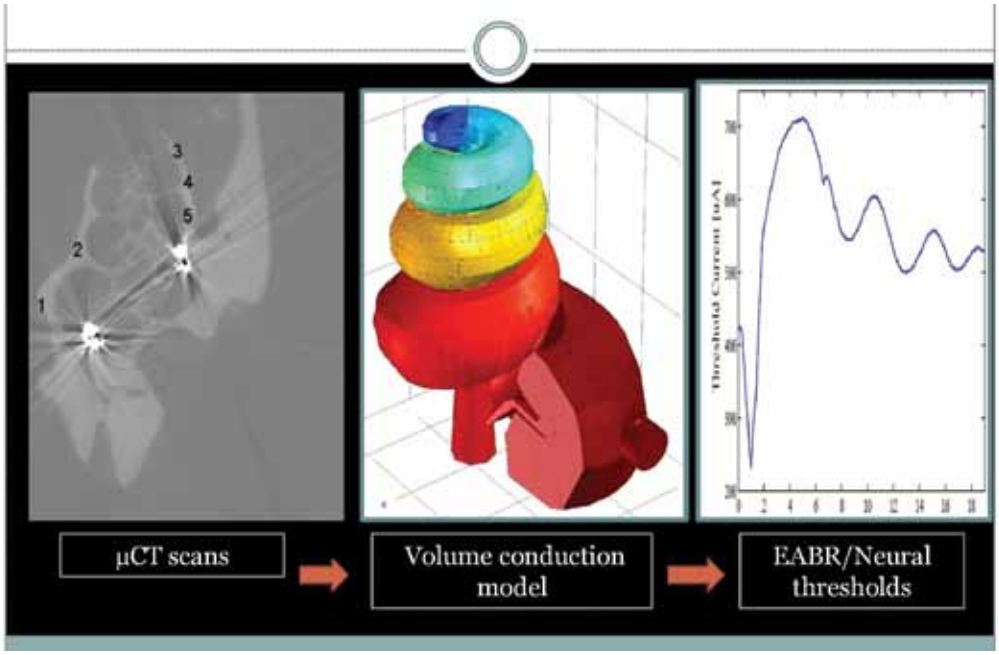
In the vicinity of the inner ear lies the cochlea (Latin for "snail"), which is responsible for the conversion of sound waves into neural impulses. This transduction is inclusive of displacements in the nanometre range and can occur at a rate that humbles other peripheral systems. Engineers are familiar with the Fourier transform, which enables the decomposition of complex signals into fundamental sinusoids.

This spectral discretisation is explanatory of the cochlea's ability to represent audible frequencies as a function of length along the cochlea (tonotopy). This organisational structure is preserved through to the inferior colliculus, a metabolically vibrant region in the midbrain involved in acoustic integration and linked to the cochlea via the auditory nerve.

Sensorineural hearing loss occurs when the hair cells required for transduction are damaged. The cochlear implant is an engineering feat enabling thousands of people to regain some perception of hearing by the controlled electrical stimulation of the auditory nerve fibres. Existing implants provide varying degrees of speech perception, enabling some users to engage in telephonic communication without associative lip reading. In addition, they have been clinically proven to enhance the implantees' quality of life.

Despite its widespread success, the level of hearing restoration, speech intelligibility and music perception provided by the cochlear implant varies greatly among subjects. Speech intelligibility is particularly difficult in noise, while music perception is generally poor, although quiet environments also lead to variance in speech perception, suggesting that there may be inherent subject-specific variables that influence this.

Members of the University of Pretoria's Bioengineering Group have been working in the field of cochlear implants for more than two decades. The research group specialises in computational modelling of the electrically stimulated hearing system. The models are used to probe and understand the underlying



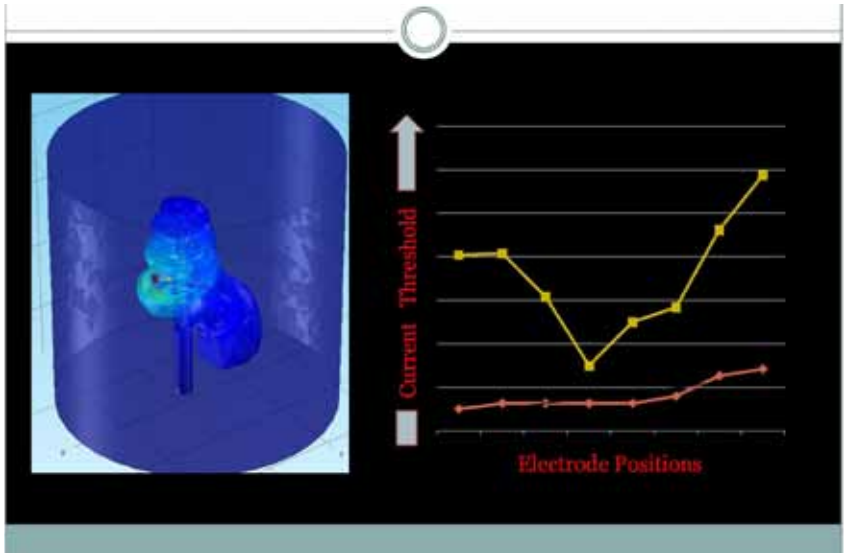
→ *Figure 1. Modelling of a specific subject's auditory neural response.*

processes that translate an electrical stimulus into the impaired auditory system to the hearing sensation perceived by the subject.

One of the group's key research areas is the development of models to study the influence of subject-specific variables on hearing performance. The first steps towards the development of a subject-specific model are the identification of the important parameters that govern the behaviour of the stimulated auditory neurons and the development of a technique to represent the anatomy of a subject's cochlea with a computational model using standard non-invasive measurements. Computer tomography (CT) images are used to extract anatomical parameters.

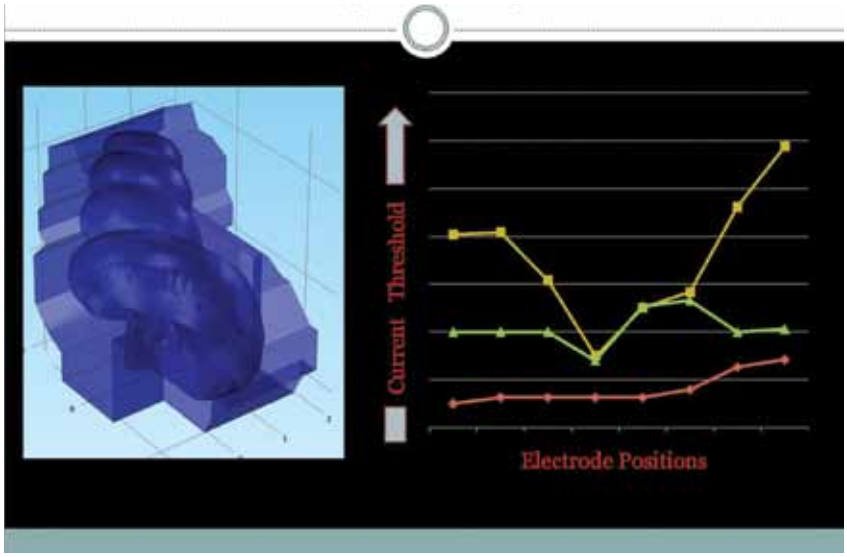
An animal model is a good starting point for the development of subject-specific models, since histological sections can be obtained and used to steer the development of the technique that is used to extract geometrical parameters from the CT scans. Another advantage of an animal model is that invasive measurements of neural responses can be made directly from single-nerve fibres to evaluate the model's accuracy on a neural level. For these reasons, a three-dimensional subject-specific computational model of a specific guinea pig cochlea was developed by the Bioengineering Group using micro-CT data and electro-physiological measurements provided by a partner research group in San Francisco, USA. The complete model incorporates a realistic volume conduction description of the subject's cochlea, constructed from the micro-CT scans, coupled with a neural model that describes the consequential neural excitation behaviour (see Figure 1).

The neural excitation behaviour predicted by the model was compared to measured electrically evoked auditory brainstem response (EABR) data captured from the guinea pig. In Figure 2, the yellow line shows the threshold currents (currents required to elicit a neural response) that were predicted by the model for different electrodes inside the cochlea. The orange line represents the threshold currents that were measured in the guinea pig subject for the same electrodes. The ideal result would be if the predicted threshold currents approach the measured values.

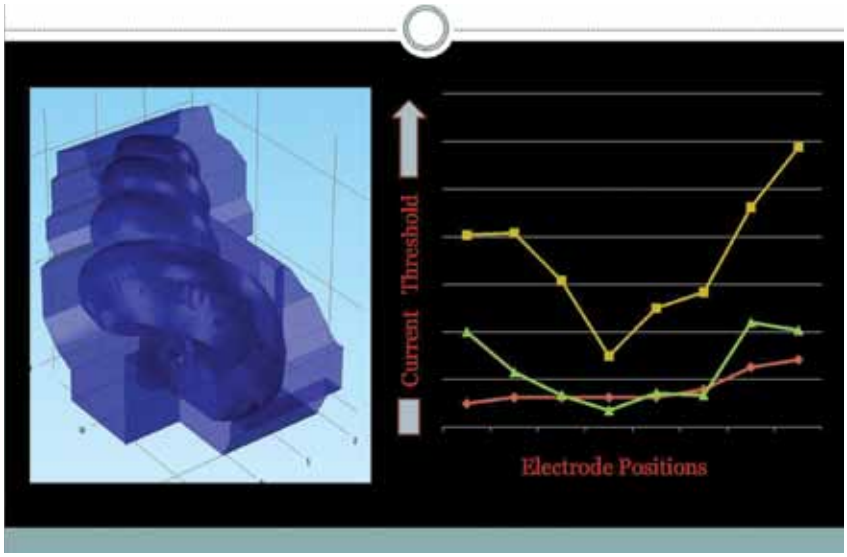


→ *Figure 2. Original subject-specific guinea pig model (left) and threshold current predictions (right).*

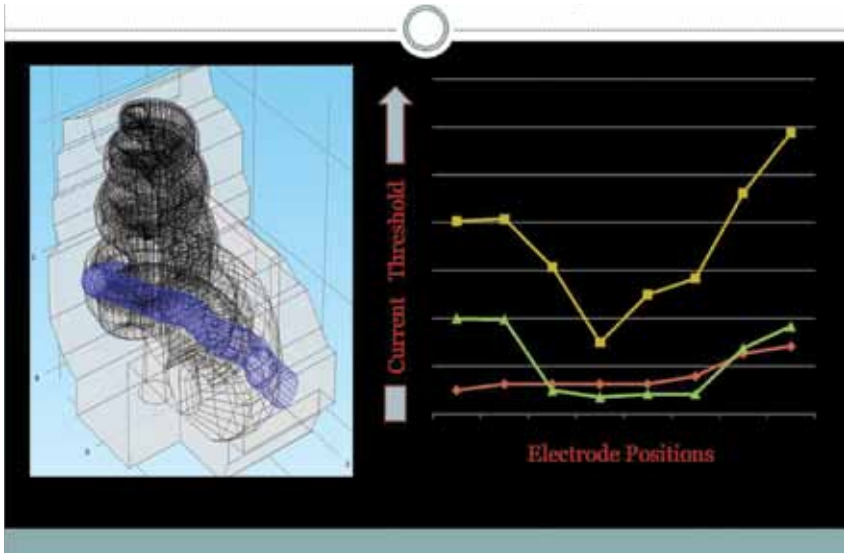
Although the model did not predict the EABR responses with a high degree of accuracy, it was validated as a scientific research tool with significant potential. Initial results also suggested that the model had the potential to perform better than a generic model when predicting EABR data. In retrospect, it was revealed that increasing the



→ *Figure 3. Thin bone enveloping the cochlea (left) and threshold current prediction (right).*



→ *Figure 4. Thin bone enveloping the cochlea in combination with increased model resistivities (left) and threshold current predictions (right).*



→ *Figure 5. Location of electrode carrier in model mesh (left) and threshold current predictions (right).*

complexity of the subject-specific representation may improve the model's predictions.

A follow-up study was thus targeted at the improvement of the model's accuracy, with encouraging results. This research showed that significant improvements to the model's predictions could be achieved with specific alterations to the original model.

Figure 3 illustrates an improvement of the model's prediction when the bone enveloping the guinea pig cochlea is described with greater accuracy. In the original model, the cochlea was embedded in a bone volume extending to infinity in all three dimensions (see Figure 2), but the guinea pig cochlea actually protrudes into an air-filled space with only a thin bone layer surrounding the cochlear structure.

The green line shows the threshold currents predicted by the model with the improved representation of the bone envelope relative to the predictions from the original model (yellow) and the measured data (orange).

Another important factor that influences the threshold current predictions of the model is the impedance values that are used to represent the different tissues. A recent study showed significant intersubject variation in impedances of the same cochlear structure. Figure 4 shows that an even greater improvement can be obtained in the model's predictions through the use of refined impedance values. Increased impedances of the fluids in the cochlear ducts lower the threshold currents by increasing the current density at the target nerve fibres.

Finally, the silicon electrode carrier onto which the electrode contacts are mounted and which fills a significant portion of the cochlear duct into which the electrode array is implanted was also included in the model. The original model excluded the carrier to simplify generation of the model geometry. The most accurate prediction is provided when the thin bone envelope, insulative electrode carrier and refined impedances are integrated, as shown in Figure 5.

These findings provide insight into the various parameters that affect neural excitation behaviour in the electrically stimulated auditory system and also lay the foundation for the development of subject-specific human models. Development of the first human models commenced following the encouraging results from the initial animal model and is well advanced. It is expected that these models could potentially provide a tool to

individualise implant parameters, so that a subject can benefit optimally from his or her implant.

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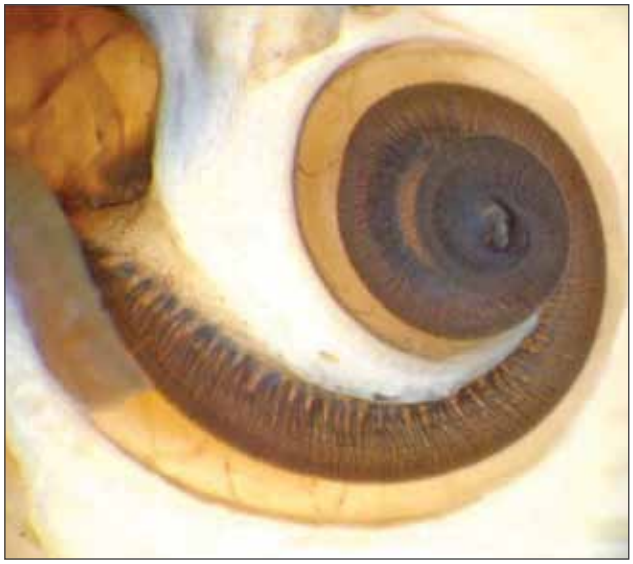


→ *Osseous lamina with its nerve fibres in a specimen oriented in a nearly horizontal plane.*

→ *A preparation in which the modiolus and osseous lamina are seen in profile after removal of the otic capsule bone covering the human cochlea.*

The development approach to valuation

by Douw Boshoff

Professional valuers often struggle to perform accurate valuations due to a lack of comparable information. They have to rely on alternative methods to quantify the value of a property. One such approach is the development approach. There has, however, been much criticism and resistance to using this approach. This could be due to valuers not understanding the method or the variables involved, as well as the sensitivity of the approach.

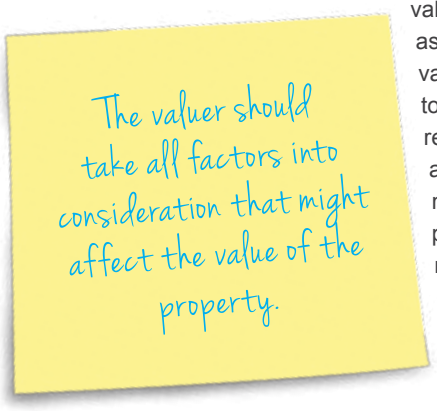
A study conducted in the Department of Construction Economics at the University of Pretoria considered the theory, as well as some legal cases, pertaining to the use of the method. The study explained the problem by way of a practical case study to illustrate the basic method, where it is used, as well as its main shortcomings.

Property owners often require an indication of the amount for which the property could be sold. A professional property valuer would be able to provide a formal and accurate figure. According to the Valuers Manual of the South African Institute of Valuers, "A valuer cannot expect to arrive at a logical deduction from the factual data and form a responsible estimate of value unless he exercises diligent care and employs his skills to the best of his ability in making his valuation and compiling his report."

The estimated selling price is referred to as the open market value of the property. According to the International Valuation Standards Council (IVSC), an independent body that sets global standards for valuation, "this is the estimated amount for which a property should exchange on the date of valuation between a willing buyer and a willing seller in an arms-length transaction after proper marketing wherein the parties each acted knowledgeably, prudently and without compulsion."

This definition implies that the valuer should estimate the amount for which the property could be sold. If it is considered that the willing seller would want to maximise his returns, the valuer would need to consider all aspects of the property that might influence the possible selling price. This does not mean that the valuer acts in the interest of the owner, but that he or she needs to provide an independent assessment of the value that would satisfy the owner and make him or her willing to sell.

This means that the valuer determines the highest and best use of the property, and the associated value of such a use. The problem many valuers face is that the current use is not necessarily the highest and best use. The more reliable methods of valuation, such as the comparable sales method or the income capitalised method, do not necessarily provide accurate comparable variables to determine the highest and best use value of the property.



The development approach to valuation (also known as the residual land value method) is to varying degrees recognised as an acceptable method for valuing properties. The main purpose of this method is to value the potential of land, in the absence of comparable sales. In other words, to consider the development that could be effected on a property, and thereby consider the eventual value after the development has been completed. By deducting the cost of such a development, the remaining amount (or residual amount) is the amount that a developer would be prepared to pay for such a property in order to obtain the development potential. The Valuers Manual describes it as "a complicated exercise involving specialised skills in several spheres".

In the case between Estate Marks v Pretoria City Council, the judge said:

"The validity of a residual land value projection vitally depends on three basic factors: the development cost of the projected building, the anticipated net income from the project and the net yield required by the prospective purchaser".

This approach also suffers from credibility internationally, as pointed out in an article in the professional journal of the Appraisal Institute, "Courts that have expressed concern regarding the development approach have focused their reliance on multiple assumptions about the occurence of uncertain future events. To these courts, the necessity of predicting governmental approval of plans and permit applications, as well as the timing of income and expenses for a project in its embryonic stages, renders the development approach more akin to educated guesswork than reliable forecasting."

Two conflicting situations arise from the abovementioned statement: The valuer should take all factors into consideration that might affect the value of the property, and should therefore consider the potential of a property in the same way as a prospective developer would in order to determine the potential of the property as opposed to the lack of information that might render the method inaccurate. These two situations have given rise to a general viewpoint that the development approach is only used when full details of a particular development are available.

This means that a valuer would only consider the potential of a property if full information is available on the costs, plans and timing of a development. This would give an accurate result, but does not take into account the fact that a developer would not spend money on the planning aspects of a development before he knows if he will actually be able to buy it. Therefore, before purchasing a development property, the developer would only do a superficial investigation as to the possibilities of development and base his decision to buy, as well as his negotiation approach, on this deficient information. In a similar way, the valuer should not be too wary to use information that could result in a value that would be the same as that determined by the real willing buyer.

→ *The Constitutional Court forms part of the Constitutional Hill Campus in Braamfontein.*

This method was tested on a specific case and a valuation was performed for Blue IQ (Pty) Ltd on the Constitutional Hill Campus (Conhill) in Braamfontein, Johannesburg. Conhill comprises the Constitutional Court, accommodation for the constitutional commissions, 1 724 super-basement parking bays, bus and taxi holding and drop-off facilities, upgraded peripheral roads and internal streets, a visitors' information and exhibition centre, new museums, and related heritage and tourism activities, a restaurant and public open spaces.

The western portion of the site comprises four development blocks situated above the parking super-basement and, in turn, subdivisible into smaller development land parcels. These are paramount in creating a critical mass that will sustain the development of Constitution Hill.

Each development block is subject to architectural coding and earmarked for a range of uses. Development Block A would accommodate a publicly accessible information centre and shared facilities complex that would include conference facilities, an auditorium, training facilities, a library, meeting rooms and an information desk for key tenants. The total bulk of the rentable floor space is approximately 5 000 m^2. Development Block B would accommodate a 75-room hotel, 5 600 m^2 of office space and approximately 1 300 m^2 for retail

There is an increased demand for property in the area surrounding Constitutional Hill.

purposes. Development Block C would allow for 11 800 m^2 of office space and approximately 100 m^2 of retail facilities. Development Block D would accommodate 12 500 m^2 of office space. About 145 residential units would be created on the site by means of conversions of the existing Queen Victoria Hospital and Nurses' Home, as well as new unit construction on the upper levels of each of the development blocks.

The different components were valued seperately and then combined into a single valuation report. In order to explain the principles of the development approach, only the super-basement will be considered and therefore reference to the property will only mean the basement. The actual figures have been changed to fictitious numbers due to the sensitivity of the actual events, but will still explain that under certain circumstances it is inevitable to use the development approach, even though there is a lack of information on the different variables of the method.

The valuer was requested to provide a value for the property as if it was vacant land, as well as a value for the improvements in their current condition. The area was previously known for its high crime rates, with a very low demand for property investment. Local government investment and intervention have brought about a change in the area, with a substantial increase in demand for property, rental rates and development.

The current improvements to the property include a basement parking structure, complete with all the required services, such as fire sprinklers, basement to ground floor lifts, fire escape stairs, access control and signage in order to make the basement fully functional as a parking structure. For some reason, no further construction or development plans were done for the top structure, but the demand for parking in the area due to other development in the area is very good, indicating that a good income stream is possible from the property.

Following the above, the immediate consideration is to perform the vacant land valuation on a comparable sales method, as there is evidence of land with development potential that was recently sold, and to do an income capitalisation on the basement parking. Although the evidence for a capitalisation rate would be difficult, it could be derived from other properties that were sold, with adjustment due to different usage.

The variables of the property are as follows:
Property size: 50 000 m^2
Coverage: 80%
Floor space ratio: 3.0
Permitted use: Commercial (offices)
Height restriction: 5 storeys
Parking: 4 bays per 100 m^2 offices
Basement size: 65 000 m^2 (3 500 bays)

According to *Rode's Report on the South African Property Market* (issued in 2009 by Rode & Associates), office space is let as follows:
A-grade: R71.63/m^2 with standard deviation (SD) of R7.56
B-grade: R50,33/m^2 with SD of R5.03
C-grade: R33.00/m^2 with SD of R7.55

Brokers active in the area have office space available between R50.00 and R85.00/m^2, depending on the size and quality of the improvements. Smaller office areas that range from approximately 60 to 500 m^2 are let at rates ranging from R95.00 to approximately R165/m^2. A property nearby is rented by a semi-government organisation at R140.00/m^2. From the above information, it is believed that an average of R120.00/m^2 can be achieved on the subject premises for newly constructed offices.

Vacancies in the area are reported to be below 10%, with A-grade offices having a vacancy rate of approximately 5% (the average is elevated by lower grade buildings). A perpetual vacancy rate of 3% is deemed sustainable for A+ grade office space to be developed.

Capitalisation rates are indicated by various brokers and other market players to be between 10.2 and 14%. Although the subject property would be developed to a high standard, it is still considered to be a higher risk than other prime nodes. The mixed use of the property would reduce risk and result in lower than average capitalisation rates. A rate of approximately 10.5% is attainable for a mix of office and some retail space.

Office outgoings are reported by the Rode report to be approximately R19.50/m^2. Brokers indicate this to be between R15.00 and R18.00/m^2, while a new development close to the case study has outgoings of approximately R16.00/m^2. This figure includes all operating costs, such as electricity and water that is not reimbursed by the tenant, insurance, maintenance, rates and taxes, and management fees.

Parking rentals are indicated to be between R465.00 and R550.00 per bay. Other buildings in the area revealed R550.00 and R520.00 per bay for two comparable buildings close to the case study. The bays in the basement in the case study are let at R530.00 per bay, which is considered to be market-related and a good estimate to calculate the open market value.

Land values for development purposes in the area indicated an amount of approximately R1 650.00/m^2 for erven that were sold close to the case study, and which are subsequently being developed with an office block.

In order to calculate the replacement cost of the various buildings on the subject property for the purposes of a depreciated replacement cost calculation, estimates are based on the *Davis Langdon Construction Handbook*. Once the above market information has been obtained, it is possible to perform calculations to interpret the values of the case study.

Vacant land value

As mentioned earlier, a comparable property was sold at a rate of R1 650.00/m^2. Normally, an analysis would be performed to establish the different variables that might indicate a difference in value for the comparable sale and the subject property, but for the purposes of the study, the two properties were accepted to be directly comparable. This indicates the value for the case study as vacant land to be only R1 650.00/m^2. The property size is 50 000 m^2, indicating a total value of R82 000 000.

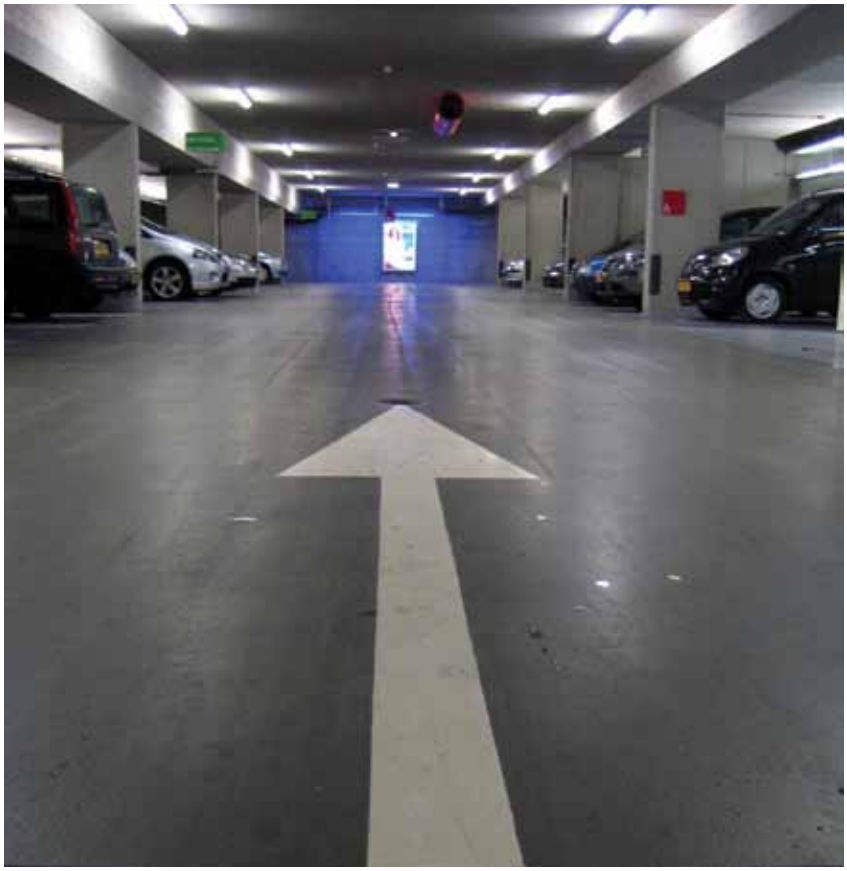
Value of basement – income capitalisation method

The income capitalisation method of valuation considers the first year's net income, which is then capitalised at a market-related capitalisation rate. This is done as follows:

Income per bay	R530
x 3 500 bays	R1 855 000 per month
x 12 months	R22 260 000 per annum
Less: Vacancies at 10%	R2 226 000
Less: Outgoings at 20%	R4 452 000
Net income:	R15 582 000
***Capitalised at 12%**	**R129 850 000**

**10.5% capitalisation rate for offices plus 1.5% risk premium for basement.*

The value of the basement structure is clearly substantially higher than the land value, but in order to evaluate the appropriateness of this value, the cost of construction should also be taken into account. According to the *Davis Langdon Construction Handbook*, the cost of basement parking structures is approximately R3 000.00/m^2. This indicates a total cost of R195 million for construction only. If the total development cost is taken into account (land value, professional fees, etc.), it is clear that the value of the basement does not make sense. This means that the seller is not recouping his costs if he were to sell, and the purchaser is purchasing an asset at a cost substantially lower than the cost to build it.



The value of basement parking contributes to the value of commercial property.

Value of basement – development approach

From the preceeding information, it is evident that an alternative approach should be adopted. If it is considered that parking is a requirement from a town planning perspective, the basement should be seen as a cost for the development, not an asset. The income that could be derived from the parking is merely additional income to the end product, and not the total income that is capitalised.

For the sake of simplicity, only a static example of the development approach is performed. In practice one would rather adopt a discounted cash flow approach. The static method is normally used in initial calculations.

The first step is to determine the extent of the development. Normally, with the development approach to valuation, the design of the proposed building has already been finalised, but in this case, one would have to consider the town planning conditions of the property:

Permitted development (land x floor space ratio)	150 000 m²
at 80% coverage	40 000 m² footprint
Therefore height is (150 000/40 000)	4 storeys
Parking requirement [(150 000 x 4)/100)]	6 000 bays

The existing basement that has been built only has 3 500 bays, therefore another 2 500 bays will have to be constructed to develop the property to its highest and best use. As these 2 500 bays will be constructed above ground, the cost is slightly less than the basement.

The total development cost could then be summarised as follows:

Parking (2 500 bays above ground)	R116 071 429
Offices (150 000 m² at R7 000/m²)	R1 050 000 000
Professional fees at 15%	R174 910 714
Other fees and costs at 3%	R40 229 464
***Loss of interest at 12%**	R82 872 696
Total development cost:	**R1 464 084 303**

**Assume 50% cash flow factor with a 12-month construction period.*

In order to determine the residual land value, the value of the development on completion should be determined using the income capitalisation method:

Income per m²	R120
x 150 000 m²	R18 000 000 per month
x 12 months	R216 000 000 per annum
Less: Vacancies at 3%	R6 480 000
Less: Outgoings at R16/m²	R2 400 000
Net income:	R207 120 000
Capitalised at 10.5%	**R1 972 571 429**

The residual land value is then calculated as follows, taking developers' profit into consideration:

Value on completion	R1 972 571 429
Less: Total development cost	R1 464 084 303
Less: Developers' profit at 15%	R219 612 646
Residual land value	R288 874 481
Rounded to	**R290 000 000**

The value of R290 000 000 is much more in line with the cost of the construction of the existing basement plus the vacant land value plus other costs. Although it would not necessarily be the same, the development approach takes the improvements that have already been

done into consideration and excludes that cost from the cost to complete the development, indicating a higher existing value. The method considers the fact that the basement is a supporting structure to develop the real investment (the office block).

Shortcomings of the method

The main criticism of the development approach is the sensitivity of the variables. If one were to consider the calculations above, but increase the construction cost of the main office component by R500.00 to R7 500.00/m^2, the results are as follows:

Development cost

Parking (2 500 bays above ground)	R116 071 429
Offices (150 000m^2 at R7 500/m^2)	R1 125 000 000
Professional fees at 15%	R186 160 714
Other fees and costs at 3%	R42 816 964
Loss of interest at 12%	R88 202 946
Total development cost:	**R1 558 252 054**

Residual land value

Value on completion	R1 972 571 429
Less: Total development cost	R1 558 252 054
Less: Developers' profit at 15%	R233 737 808
Residual land value	R180 581 567
Rounded to	**R180 000 000**

The above change of 7.14% in the construction of the offices, or 6.43% in the total development costs, brought about a change of 40% in the residual land value.

Although the courts are not keen to accept this method as valid, due to the specialist calculations that need to be performed and the sensitivity of the variables, which could result in large errors, it is a method that, if applied with skill, could provide accurate assessments of properties that would not otherwise have been possible.

When applying the approach, valuers should take care to ensure the accuracy of variables. Where assumptions are made, it should be determined by taking everything that could affect each variable into consideration to also ensure that the assumptions are made within well acceptable parameters, and "without indulging in feats of the imagination" (Sri Raja Vyricherla Narayana Gajapatiraju Bahadur Garu v Revenue Divisional Officer, Vizagapatam 1939 2 All ER 317).

This research only considered the basic format of the development approach to valuation, which could be explained in more detail considering more advanced techniques, such as the discounted cash flow method. This also opens the approach for consideration with other disciplines, such as performing feasibility studies in association within quantity surveyors that could provide more accurate information on the development cost of a property.

Further research on the possibilities of the approach, with a more accurate explanation of the value of the approach, would provide possibilities for bridging the gap between different built environment practitioners, and enhance the body of knowledge in the valuers' profession.

→ *Douw Boshoff conducted a study on the development approach to property valuation.*

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The Department of Construction Economics within the Faculty of Engineering, Built Environment and Information Technology, offers a three year BSc degree in Real Estate, followed by a two year BSc (Honours) degree, to prepare students for career opportunities in the real estate industry. On completion of the degrees, students will be equipped to enter the industry as entrepreneurs in the private sector or as employees in the private, government or semi-government sectors.

Career opportunities include:

- Property Investment
- Property Finance
- Property Development
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For more information on these degrees, contact:

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Industry applauds new degree in real estate

The new BSc Real Estate degree that was launched in the Department of Construction Economics at the University of Pretoria in 2010 is already in high demand. It is the only one of its kind in the country and prepares students for career opportunities in the real estate industry.

Although the University of Pretoria has been offering an MSc in Real Estate since 1990, there were no undergraduate options specialising in this field. Candidates who were interested in pursuing a career in real estate – either as an entrepreneur in the private sector, or as an employee in the private, government or semi-government sector – therefore had to enrol for a degree in commerce or in construction economics (construction management or quantity surveying).

This new programme opens the door to career options that include property investment, property finance, property development, facilities and property management, and professional property valuation. It will also contribute to the professionalisation of the career through accreditation by the Council for the Built Environment (CBE).

The first undergraduate class will graduate at the end of 2012, after which the honours programme will be launched. The Department of Higher Education and Training initially approved this degree as a five-year programme, but it was converted to a three-year BSc degree and a two-year honours programme in 2010 to align it with the other programmes in the department.

According to Mr Douw Boshoff, the programme coordinator, this programme is unique in its approach, as it is based on successes achieved in the existing undergraduate and postgraduate programmes that are offered in the Department of Construction Economics, as well as the MSc in Real Estate.

Students learn more about property investment, as well as the financing, marketing, valuation and management aspects related to property development. Topics that are dealt with in the undergraduate programme include town and regional planning, project management, financial mathematics, maintenance, risk management, energy management, management practice, financial statements, budgets, contract law and facilities management.

There is no other programme in the country that deals with this combination of topics, specifically aimed at producing well-rounded professionals who can manage and develop real estate assets and contribute to the economic growth of the country.

According to Boshoff, the degree focuses on real estate as both an asset and an investment. It therefore provides candidates with much more than merely training to become estate agents or property valuers, although this is not excluded. In the honours programme, students learn more about cost estimations and property development, while they also follow specialised real estate subjects.

In the honours programme, lectures only take up 15 hours a week. During the remainder of the time, candidates are encouraged to take up internships and to work in the industry and put their theoretical knowledge to practice.

“We get a lot of positive feedback from large companies in the industry,” says Boshoff. “They are not only impressed with the programme, but also with our students.”

This programme appears to be filling a large void in the industry, and it looks as though honours students will certainly be accepted as interns. Job opportunities are abundant for these students.

The University of Pretoria, through Continuing Education at University of Pretoria (CE at UP), also offers a variety of short courses related to the management of real estate, where the staff of organisations involved in property development can receive in-service training.

Marabastad bath house proposal wins prestigious international prize

Tuks Architecture graduate Ruann van der Westhuizen was ranked among the world's eight best graduates in architecture, urban design and landscape architecture at the prestigious Hunter Douglas Awards, proving once again that graduates from the University of Pretoria's Department of Architecture are among the best in the world.

The Hunter Douglas Awards is a competition organised by the Archiprix Foundation – a network of young, prominent architects. The foundation biannually invites 1 400 universities worldwide to submit their best graduation projects. A jury studies the entries and nominates 24 projects for the awards, from which eight winners are selected.

Ruann's project was one of more than 300 entries from approximately 70 countries. It was also nominated as one of the participants' favourites. The proposal formed part of Ruann's master's dissertation, which he completed in 2009. With the concept of a public bath house in Marabastad, Pretoria, he investigated the ritual of cleansing in an urban environment.

According to Ruann, the project was essentially an experiment to investigate the potential of introducing basic (ablution) services in an area where the density of people in need of such services would easily justify the infrastructure investment. Marabastad is such a place, as it is a large public transport interchange and is a prominent point of entry to the Pretoria CBD. "The strength of the project lies in the fact that it addresses a simple activity through a sensitive architectural intervention. It is based on the needs of users and presents opportunities through the reinterpretation of the loaded term "bath house" in a South African urban context," says Ruann, who now works at DVDWA Architects in Pretoria.

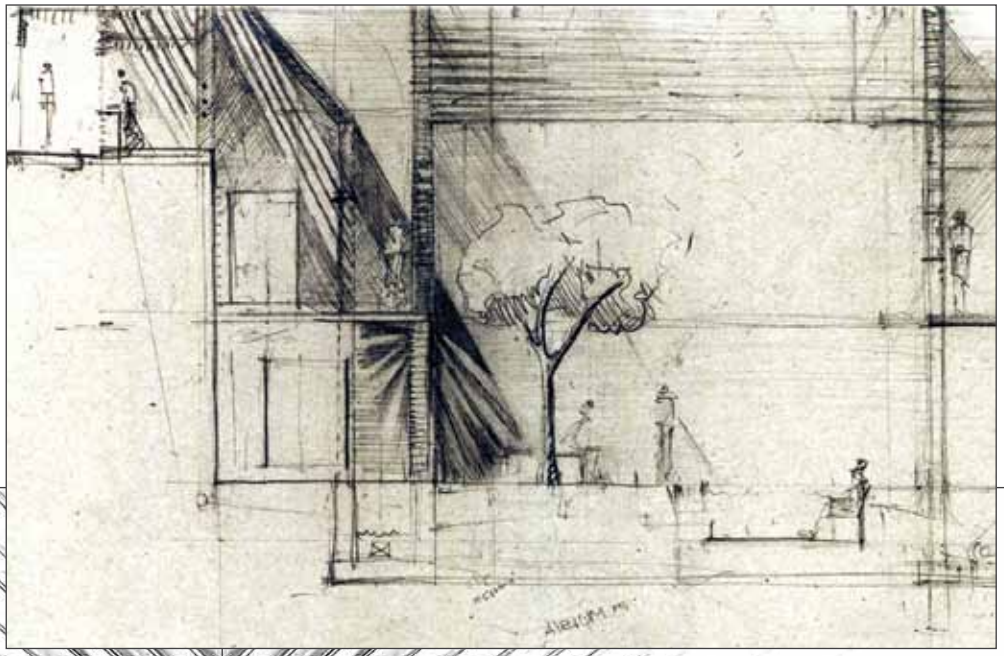
As one of the 24 finalists, Ruann participated in workshops and an exhibition hosted by the Massachusetts Institute of Technology (MIT) in the build-up to the awards ceremony, which took place at the Guggenheim Museum in New York on 9 June 2011.

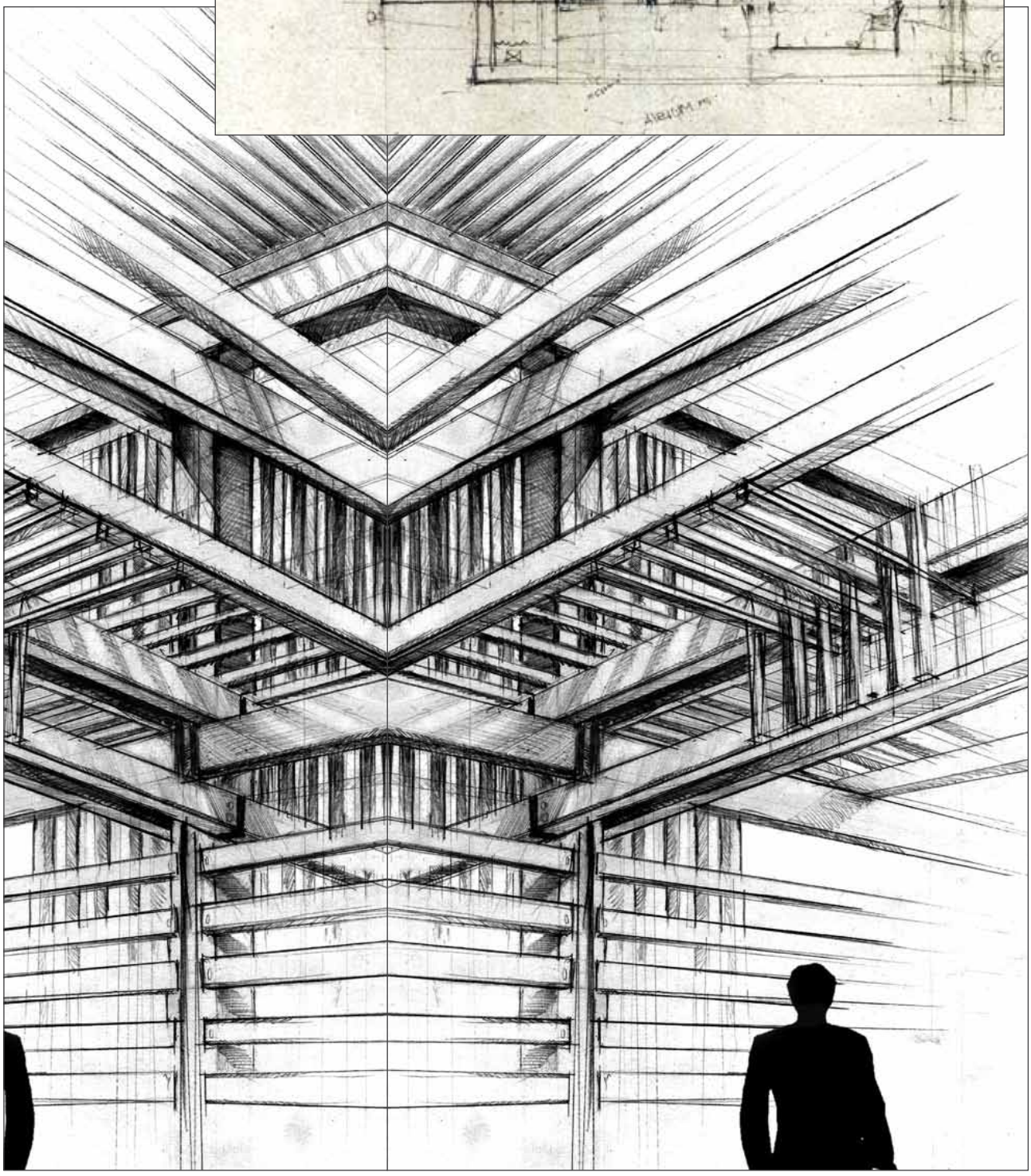
Ruann's dissertation, completed under study leader Jacques Laubscher and mentor Marianne de Klerk, achieved top honours in the department in 2009.

This is the fourth major accolade awarded to students or graduates of the Department of Architecture in the last 12 months. A year ago, Jacques Orton's electronic dissertation received an international award from the Networked Digital Library of Theses and Dissertations. In September 2010, Carla Taljaard, Stephen Steyn and Warwick Manley won the national Murray & Roberts Des Baker Competition.

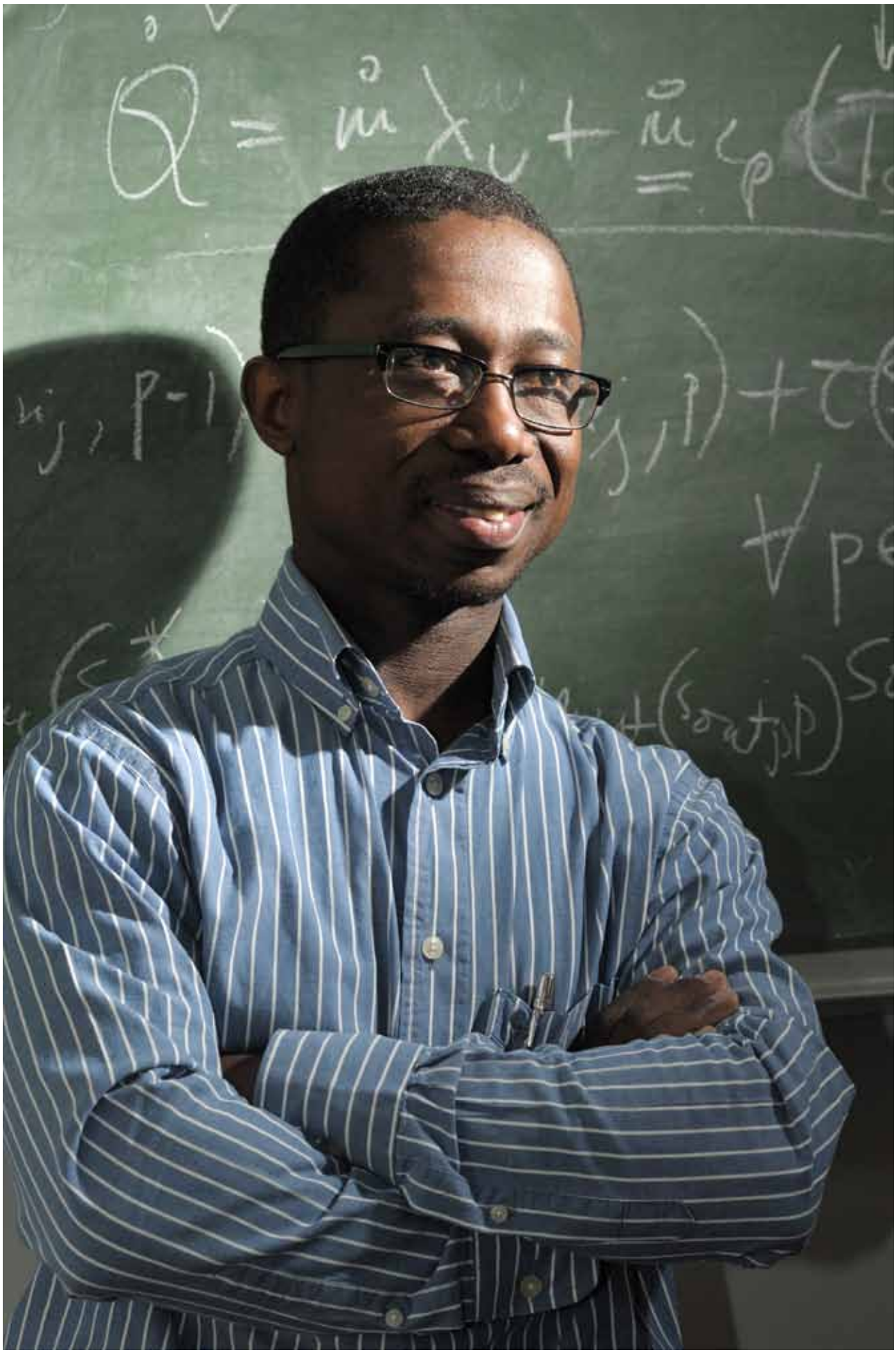
The most recent award was that received by Jankel Nieuwoudt, who won the DesignHub Respond-Renew-Revitalise Competition in February 2011, sponsored by Saint Gobain. The University's Department of Architecture was also named best university participant.

→ *The act of layering permeable concrete skins establishes a hierarchy of privacy. Movement through the structure aims to manifest this layered concept seamlessly, resulting in deep edges.*





→ *Prof Thokozani Majozi*



NSTF winner changes thinking of the chemical industry

Prof Thokozani Majozi, the Department of Chemical Engineering's most recent winner of a National Science and Technology Forum (NSTF) Award, is fundamentally changing aspects of the chemical engineering industry with his innovative techniques. He hopes to bridge the gap between academic achievement and industrial applications to truly improve the lives of the people he serves.

Prof Majozi was recognised at this year's NSTF Award ceremony for his individual contribution to chemical engineering through research and its outputs over the past five to ten years. He received the award for his research, which led to the development and application of new techniques in batch and continuous chemical process integration, relating to freshwater use and wastewater generation.

Prof Majozi has made significant contributions in the area of process integration. Among other things, he developed a mathematical technique for wastewater minimisation and heat integration in multipurpose batch chemical plants that are characterised by complex recipes. This includes the development of a framework for the synthesis of cooling water and steam system networks.

"In any chemical plant there are cooling and heating streams that serve as heat sink and heat source, respectively. Consequently, these are part of the chemical process. A steady supply of both streams is needed to keep the process going," he says.

In the past, the cooling and heating networks were considered separately. "No one had looked at the process as a whole. However, we have seen the benefits of a comprehensive integrated system."

While both the heating and cooling networks are complex in their own right, they are even more complex when integrated. Prof Majozi believes that this is the reason research on integrated systems was avoided in the past, even though the traditional discrete methodology is suboptimal. Developing methods and tools to analyse the systems in a more systematic fashion creates an optimised plant.

The technique developed for batch plants is based on a state-sequence-network recipe representation that yields structurally efficient mathematical models, while the synthesis methods rely on an insight-driven graphic platform. Typically, the techniques have been successfully applied in multinational industries with more than 20% savings in freshwater use and wastewater generation.

"It is an overriding ambition to see these methods accepted as a standard. The chemical industry is one of the biggest contributors of pollution due to poor process design. I recognise that we are fundamentally changing the thinking of industry and that it will take time to accept new techniques.

"At some point, every scientist must ask how they are improving the lives of the people they serve. We can only make an impact if new developments and information are accepted. Currently, academic work is too isolated and academics need to bridge the gap," says Prof Majozi.

This is not the first time that Prof Majozi has received an award from the NSTF. In 2006, he was recognised in the category distinguished young black researcher in the last five to ten years.

He also received the prestigious President's Award of the National Research Foundation (NRF) in 2007 and 2009. In 2008, the University of Pretoria recognised him by way of a Leading Minds Centenary Award, and in the same year he also received the S_2A_3 British Association Medal.

More recently, in 2010, he was awarded the Bill Neal-May Gold Medal for Outstanding Achievement and International Recognition. This award was made by the South African Institute of Chemical Engineers (SAIChE).

INSiAVA makes a major breakthrough

A team of researchers in the University of Pretoria's Department of Electrical, Electronic and Computer Engineering recently made significant progress in their quest to develop silicon light emitters with high optical data transfer rates that can eventually replace the copper wires currently used in the computing industry.

They have managed to design and manufacture light emitters that can attain an optical data transfer rate of 10 Mb/s – the fastest all-silicon all-CMOS (complementary metal-oxide-semiconductor) optical data links to be reported in the world to date.

This team of researchers, led by Prof Monuko du Plessis, is using silicon electroluminescent technology (generating light from an electrical current) to find a practical, usable solution to the chip-to-chip interconnect problem that faces the computer industry. They are hoping to be the first in the world to do so.

The so-called interconnect dilemma is a challenge that was predicted decades ago by Gordon Moore, co-founder if Intel. Essentially, it relates to the fact that the number of components that can be placed on an integrated circuit has doubled every two years. This trend is expected to continue.

Optical interconnects between microchips (see feature in *Innovate* 05: 2010) will potentially transfer data faster by overcoming the ever-increasing delay that results from the additional functionality incorporated onto a microchip.

The research is being done through INSiAVA (Pty) Ltd, a South African start-up company with executive offices in Pretoria and Atlanta in the USA. The company was established through start-up funding from the Carl and Emily Fuchs Institute for Microelectronics (CEFIM), based at the University.

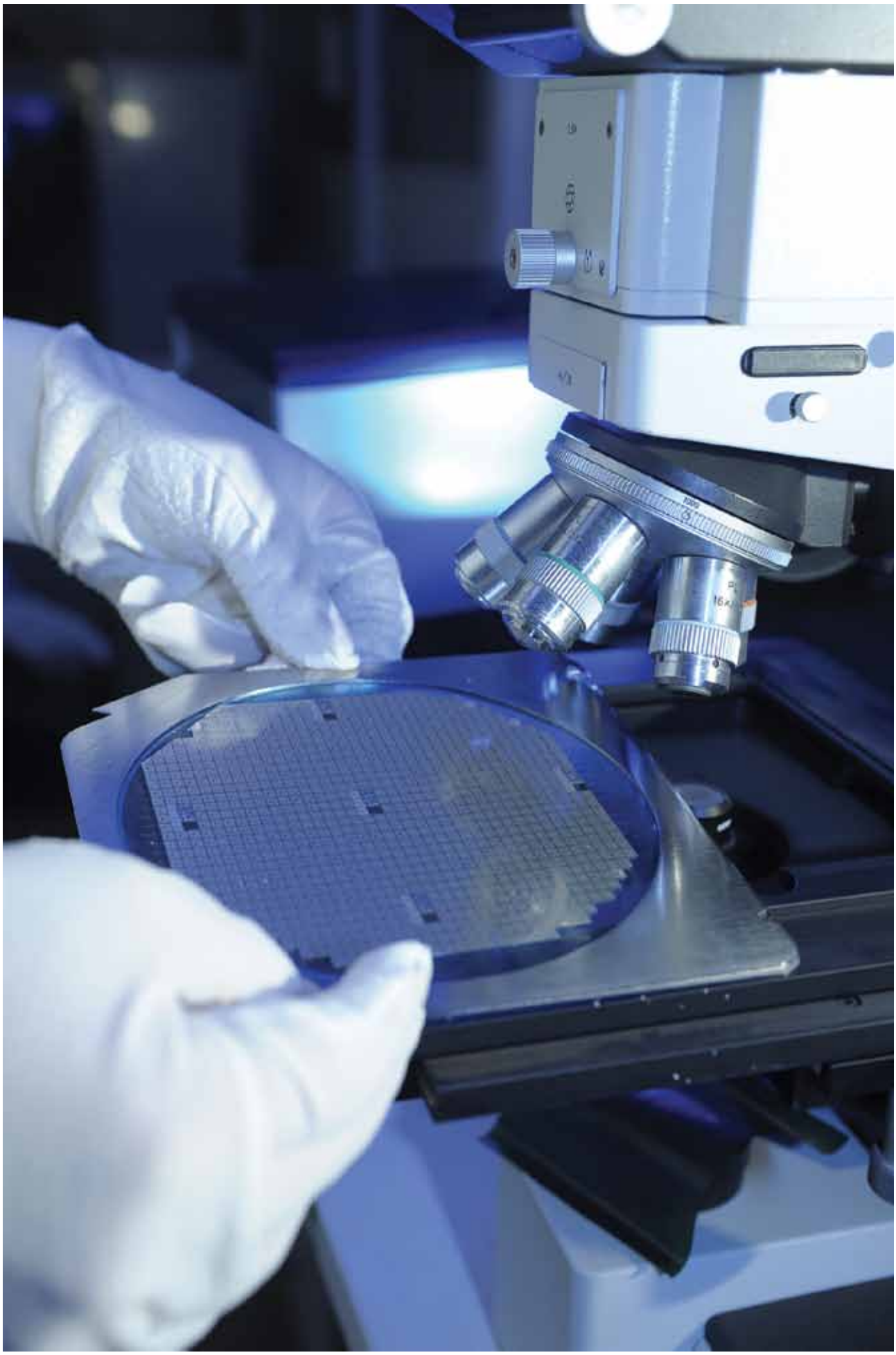
Prof Robin Crewe, Chairperson of INSiAVA (Pty) Ltd, announced the team's breakthrough in August 2011. "Advances in device efficiency, increased output power and improved light source design have increased the measured optical output power by a factor of three from our previous benchmark. In this latest demonstrator, the enhanced optical power increased the signal-to-noise ratio, which in turn resulted in a data transfer rate of 10 Mb/s."

He added that INSiAVA now boasts the fastest known all-silicon electroluminescent devices (switching at frequencies above 350 MHz), as well as the fastest all-silicon optical data links (data rates of 10 Mb/s) in the world. The company's aim is to attain a data transfer rate of 10 Gb/s for short-haul interchip optical communication links, all in CMOS-compatible technology. "INSiAVA has filed patents on various techniques that provide the necessary means and capability to reach this goal," he said.

Prof Du Plessis, an internationally recognised leader in the field of silicon photonics, added that the team achieved the data rate of 10 Mb/s at a statistical bit error rate of 10^{-12}, which represents a tenfold increase in data transfer over its previous achievement. "INSiAVA's light sources are completely VLSI (very large-scale integration) and CMOS-compatible with no post-processing required.

Being fully CMOS-compatible, this technology is bound to have a significant cost advantage over some of the competitive technologies being developed," he added.

→ *The research conducted at the University of Pretoria has led to the filing of patents on various techniques.*



UP students make the best beer, again

They might not have state-of-the-art brewing machinery and technology, but students in the University of Pretoria's Department of Chemical Engineering know how to make good beer.

For the second consecutive year and for the third time in the competition's four years of existence, UP's microbrewery team outperformed nine other universities in the South African Breweries (SAB) Intervarsity Brewing Challenge 2011 and walked away with the Ben Lamaletie Institute of Brewing and Distilling (IBD) Intervarsity Beer Challenge floating trophy.

It all started in 2003 when SAB sponsored the first microbrewery at the University of KwaZulu-Natal. Since then, SAB has sponsored a number of microbreweries at many other academic institutions across South Africa. This is how UP's microbrewery came to be established in 2005.

In 2008, the first Intervarsity Brewing Challenge was held to see which university team could make the best lager, ale and speciality beer. A floating trophy, named after Ben Lamaletie, the SAB brewer who conceptualised and launched the competition, is at stake in the competition and gets awarded to the overall winner. Other prizes include prize money for the winning team members, bursary money for the faculty of the winning team, and prize money for the further development of the winning university's microbrewery.

This year's Intervarsity Brewing Challenge took place on 26 and 27 August 2011 at the SAB Training Institute in Kyalami. The competition is held in partnership with SAB, the FoodBev SETA and the Institute of Brewing and Distilling. It was hosted by the University of the Witwatersrand.

Since 2008, UP's brewing team has outshone the other universities, winning the trophy for the overall best beer in 2008, 2010 and 2011. The UP team also won the categories for best ale and best lager this year.

Beer-brewing forms part of a laboratory practical for third-year Biotechnology students at UP, but the team that enters the SAB Intervarsity Brewing Challenge may comprise students from any academic year. Students vote internally to pick the final five-member brewing team.

According to Mr Carl Sandrock, the lecturer in charge of the University's brewing team, the microbrewery provides students with an opportunity to learn important basic aspects of the brewing process. "Our microbrewery is relatively simple in comparison to other breweries. We dedicate our time to developing our brewers' skills, rather than automating the brewing processes. The microbrewery offers valuable practical experience to students who are interested in careers in brewing or microbiology," he says.

Mr Sandrock added that the competition is about more than just the prize money and skills development. "The competition is an excellent opportunity for students who are potentially interested in this line of work to meet and network with researchers and potential employers. Importantly, it also serves as a great marketing tool and is excellent for team-building among the students."

→ *One of the adjudicators inspecting a glass of student-made beer.*

→ *The award-winning team with their* Imperial Troll Stout *lager. From left to right: Krappie Eloff, Ben Lamaletie, an unknown representative of the IBD, Edward Mills, Anré van der Merwe, Harald Golob, Lofté Grobler, Ryan Merckel, David Wilson, Carl Sandrock, Mike Heydenrych and Anton Erasmus. Photographs courtesy of SAB.*

The roots of industrial engineering: Leonhard Euler – the prolific man

by Paul Kruger

Leonhard Euler, a pioneering Swiss mathematician and physicist, was born in Basel on 15 April 1707 to Paul Euler, a pastor of the Reformed Church, and Marguerite Brucker, a pastor's daughter. Members of the Bernoulli dynasty, in particular Johann Bernoulli (who was at the time regarded as Europe's foremost mathematician), were close family friends.

Euler made important discoveries in fields as diverse as infinitesimal calculus and graph theory. He also introduced much of the modern mathematical terminology and notation. Among his contributions to the language of Mathematics are the basic symbols π, e and i, the summation notation Σ and the standard function notation $f(x)$. He is also renowned for his work in mechanics, fluid dynamics, optics and astronomy.

At the age of 13, Euler was already attending lectures at the University of Basel. He obtained his master's degree in 1723 with a dissertation comparing the natural philosophy systems of Newton and Descartes. In 1726, Euler completed his doctoral thesis on the propagation of sound, entitled *De Sono*. On his father's wishes, Euler furthered his education by enrolling in the theology faculty, but devoted all his spare time to studying Mathematics. He wrote two articles on reverse trajectory. These were highly valued by his teacher, Johann Bernoulli. Bernoulli convinced Euler's father to allow his son to pursue a career in Mathematics. In 1727, Euler applied for a position as professor in Physics at Basel University, but was turned down. During his life, he applied for various positions at the University of Basel several times. This was an appointment he very much coveted, but never successfully obtained.

Although he was born in Switzerland, he is most closely associated with the Berlin of Frederick the Great and the St Petersburg of Catherine the Great. Euler's sight in his right eye deteriorated during his stay in Germany, so much so that Frederick referred to him as 'Cyclops'. Frederick also expressed disappointment with Euler's practical engineering abilities: "I wanted to have a water jet in my garden: Euler calculated the force of the wheels necessary to raise the water to

→ *Leonhard Euler*

a reservoir. The plans for my mill were carried out geometrically and it could not raise a mouthful of water closer than 50 paces to the reservoir. Vanity of vanities! Vanity of geometry!" Tired of the chiding of Frederick and Voltaire, who was also a member of Frederick's court, Euler went to the Imperial Russian Academy of Sciences in St Petersburg on the recommendation of his friend, Daniel Bernoulli, after Daniel's brother, Nicolas, died and Daniel asked him to fill his brother's position in his place. Euler swiftly rose through the ranks in the academy and became professor of Physics in 1731. In 1733, when Daniel left for Basel, Euler succeeded him as professor in the Mathematics department.

He is considered to be the pre-eminent mathematician of the 18th century and arguably one of the greatest of all time. He is also one of the most prolific mathematicians ever, having published more than 800 mathematical papers. Until his death in 1783, the Academy of Sciences in St Petersburg was presented with over 500 of his works. The academy continued to publish them for another half century after his death. He and his wife had 13 children, of which only five survived childhood.

Euler's eyesight worsened further throughout his mathematical career.

→ *Leonhard Euler*

In 1735, he became nearly blind in his right eye and later suffered a cataract in his good left eye, rendering him almost totally blind in 1766. Even so, his condition appeared to have little effect on his productivity. With the aid of his scribes, Euler's productivity in many areas of study actually increased. He produced on average one mathematical paper every week in 1775!

Richard Feynman called the formula, known as Euler's identity ($e^{i\pi} + 1 = 0$), "the most remarkable formula in Mathematics" for its single use of the notions of addition, multiplication, exponentiation and equality, and the single use of the important constants 0, 1, e, i and π. Euler, a simple religious man and a hard worker, was very conventional in his beliefs and tastes and is commemorated by the Lutheran Church on their Calendar of Saints on 24 May.

"Liesez Euler, Liesez Euler, c'est notre maître à tous."
(Read Euler, read Euler, he is our master in everything.)
Pierre Simon Laplace

"He remains living in thought in terms of the splendid example he provided of a mind capable of movement without friction and so achievement without effort."
– David Berlinski

Adapted primarily from, http://www-history.mcs.st-andrews.ac.uk/Mathematicians/Euler.html, http://en.wikipedia.org, http://www.scienceworld.wolfram.com, *Chambers Biographical Dictionary*, edited by Magnus Magnusson, *The Oxford Concise Dictionary of Mathematics*, *Infinite Ascent: A short history of Mathematics* by David Berlinski and *Leonhard Euler – the greatest mathematician of all times*, by Simon Patterson.