Faculty of Engineering

RESEARCH BROCHURE

Contents

Introduction

We take pride in showcasing the research of the Faculty of Engineering and pay tribute to the immense dedication and talent of our researchers, all deeply committed to a common vision.

The Faculty of Engineering at Stellenbosch University (SU) is at the forefront of basic and applied research, and enjoys international recognition for its work. The focus is on cutting-edge and interdisciplinary research. Our research activities are supported by highly competent staff and world-class laboratories, computational facilities and research infrastructure.

We attract students of the highest calibre. Our researchers are very successful in supplying high-level engineering expertise to industry and postgraduate students. The Faculty is experiencing strong growth in its research and postgraduate programmes.

Our Faculty is research intensive and is one of the largest contributors to Stellenbosch University's research income. Research and teaching in the five academic departments is augmented by four research centres and two institutes of international standing, with research groups in these units being funded by various industries and research councils.

The Faculty of Engineering is a national leader in the field of research and in obtaining a good deal of funding from organisations such as THRIP (Technology and Human Resources for Industry Programme) and the National Innovation Fund. In these programmes the South African government matches funding made available by business or industry, supporting their promise of investing in science and technology.

The Faculty of Engineering was established in 1944 and over the decades has built up an excellent reputation amongst its peers both nationally and internationally. Some of our achievements over the last few years include:

- the NRF (National Research Foundation) research rating of more than 35% of our academic staff, signifying that their international peers are of the opinion that the quality of their research outputs is of an exceptional standard and on par with international standards
- the establishment of the NRF Square Kilometre Array Research Chair in the Faculty of Engineering
- the doubling of our postgraduate student numbers over the last 5 years
- our success in knowledge and technology transfer which is reflected in the large number of commercial research contracts requested and the resulting establishment of spin-out companies, such as *Sunspace* & *Information Systems* and *NioCAD*
- world-wide acknowledgement of our expertise, our researchers are requested to do consultation work for both national and international industries on a regular basis
- numerous prestigious awards received by our researchers for their outstanding work
- financial soundness of the Faculty's centres and institutes

The total annual income of the centres and institutes is comparable to the total annual SU budget for the Faculty. A substantial amount (in the region of 50% of the income) is re-invested in the form of bursaries to students, research material, equipment, software, books, travel for research purposes, and membership of professional associations, as well as SU levies. From this it is clear that the centres and institutes are a great asset to the Faculty.

Collaboration with the Faculty of Engineering at Stellenbosch University means collaboration with a learning and research centre of international standing. Postgraduate students can expect to be supervised by top-notch researchers and academics who share their knowledge in a collegial environment. We look forward to welcoming you to this world-class Faculty as a research partner, collaborator, supporter or postgraduate student.

The HOPE Project

The HOPE Project of Stellenbosch University was launched on 21 July 2010 and is a long-term strategic plan spanning the next decade. Through this ambitious, comprehensive and integrated initiative the University wants to apply its proven expertise in a purposeful manner and on a large scale to the benefit of society. SU has selected five themes from the International Millennium Development Goals on which to focus its mission and vision, and to create synergy between higher education and development and economic growth in a more comprehensive way.

Stellenbosch University has positioned its expertise to assist in:

- eradicating poverty and related conditions
- promoting human dignity and health
- promoting democracy and human rights
- promoting peace and security
- promoting a sustainable environment and competitive industry

Faculties were invited to develop research proposals that would direct their expertise into achieving these goals. The Faculty of Engineering could respond positively to this invitation, since engineers, by the very nature of their work, are creators of hope par excellence. The Faculty submitted a comprehensive proposal and divided its research projects into three initiatives, namely *Energy and the Environment, Communication and Information Systems,* and *Food Security*. Within these three initiatives there are 17 projects comprising close on 40 subprojects covering all five Millennium Development Goals.

The Faculty received the lion's share of the funding for the HOPE projects at Stellenbosch University as a result of the solid proposal it submitted. Of the R300 million made available by the University Council for projects, Engineering received R56 million over 3 years as seed money. In addition to this, the Faculty has also managed to inspire industry to contribute an additional R77 million by means of third-stream income for these projects in the first 30 months of the HOPE Project.

The Faculty also committed itself to deliver substantial numbers of postgraduate students and publication outputs. To date the projected income from postgraduate student enrolments and graduation, as well as third-stream income, exceeds the HOPE funding by a factor of more than 3, guaranteeing the sustainability of the initiatives.

All five of the Faculty's departments are actively involved in three large HOPE Project research initiatives on the terrains of *Energy and the Environment, Communication and Information Systems,* and *Food Security.* Many of the projects are multidisciplinary in approach and the scientific work being done contributes to more than one of the development themes.

Not all research projects carried out in the Faculty of Engineering fall under the HOPE Project. However, the largest proportion of them does. This publication reflects a good selection of the research projects being carried out, whether they fall under the auspices of the HOPE Project or not.

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HOPE PROJECT

SU Millennium Development goals addressed by HOPE Projects of the Faculty

Project	T1 Poverty	T2 Dignity & Health	T3 Democracy & human rights	T4 Peace & security	T5 Environment & competitive industry
ENERGY & ENVIRONMENT					
Energy efficiency					●
Electrification of remote & rural areas	●	●	●		●
Renewable energy				●	●
Removal of harmful waste byproducts					●
Water quantity and quality management				●	●
Efficient use of resources of businesses in SMME sector	●				●

Project	T1 Poverty	T2 Dignity & Health	T3 Democracy & human rights	T4 Peace & security	T5 Environment & competitive industry
COMMUNICATION & INFORMATION SYSTEMS					
Human interaction with computers		●	●		●
Novel communication systems	●				●
Intelligent decision support systems for process industries					●
Design and construction communication methods in civil engineering					●
Information systems in traffic and road safety				●	●

Project	T1 Poverty	T2 Dignity & Health	T3 Democracy & human rights	T4 Peace & security	T5 Environment & competitive industry
FOOD SECURITY					
Automated unmanned aircraft	●				●
Second generation bio-fuels	●				●
Modelling of alien invasion species and seed distribution of plants	●			●	●
Efficient use of water resources to maximise water availability	●	●		●	●
Bio-based materials for improved crop production	●			●	
Process improvement and technology transfer to upcoming farming, fishing and small entrepreneur sectors (resource-poor)	●			●	●

CIVIL ENGINEERING

- Advanced cement-based construction materials
- Coastal Engineering
- Engineering Geology
- River Hydraulics
- Transport Engineering

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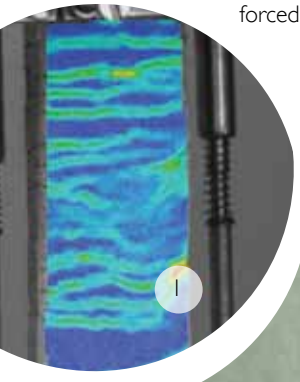
Advanced cement-based construction materials

A research group was established in 2001 as the Centre for Development of Sustainable Infrastructure (CDSI), combining expertise in construction materials, structural mechanics and performance, as well as structural reliability. Several hi-tech building materials are being developed, characterised and described in terms of mathematical and computational models to enable structural design. Such materials include ultra-high strength concrete, energy-efficient construction materials, and strain-hardening fibre-reinforced composites (SHCC). This material is able to deform similarly to steel, while allowing multiple, but fine, cracks to arise.



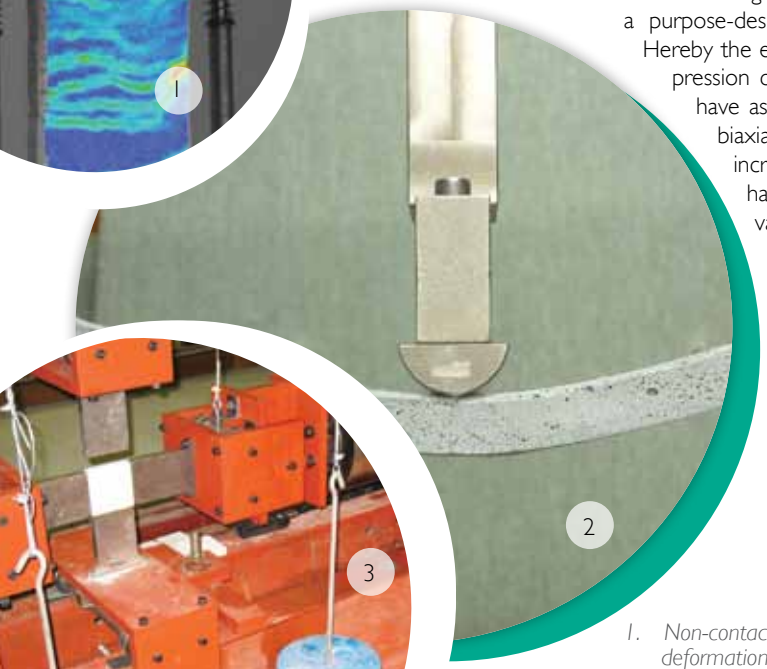


Figure 1 shows the multiple fine cracks and non-contact optical measurement of the deformation and cracks, which enables effective presentation and characterisation of the cracks. By a clear description of the cracks in terms of width frequency distribution, the durability afforded to structures by SHCC can be studied. By limiting the crack widths, the ingress of gas, water and salts, which may cause deterioration of the concrete matrix or embedded steel reinforcement, can be delayed or prevented, which is a theme of continued research in the CDSI. An example of SHCC bendability is shown in Figure 2.

The research is performed in collaboration with several groups internationally, in order to fast track the development of design guidelines for durability design with SHCC. The CDSI took the leading role in determining the time-dependent behaviour of cracking in SHCC, to understand how in time crack widths may widen under sustained loads and eventually allow increased ingress and deterioration rates.

Characterisation of mechanical response under biaxial loading is also studied by the CDSI, in a purpose-designed biaxial loading test facility. Hereby the enhanced resistance in biaxial compression could be quantified. Ongoing tests have as a final goal the confirmation that biaxial tension-compression also leads to increased response due to the strain-hardening nature of this class of advanced construction materials.

1. *Non-contact optical measurement of the deformation and cracks enables effective presentation and characterisation of the multiple fine cracks.*

2. *Bendability of strain-hardening fibre-reinforced composites.*

3. *Characterisation of mechanical response under biaxial loading studied in a purpose-designed biaxial loading test facility.*

Coastal Engineering:
COASTAL PROTECTION - A SOFTER APPROACH

Confronted by global warming impacts such as a rise in sea level and changes in storm patterns, our coastal areas have become very vulnerable. One of the research themes within our Port and Coastal Engineering Programme is investigation of a range of softer intervention measures for coastal protection. One such measure presently being studied in our thesis work is the use of "setback" lines for new developments. Difficulties are faced in many places along our coast where the present development is seaward of these lines and sometimes protective structures are necessary. Sandbag and sand tubes (geo-tubes) are becoming a popular "softer" coastal protection measure, but design guidelines are either scarcely available or conflicting with codes and guidelines which have not absorbed this technology. Research is being conducted into temporary or emergency coastal protection measures using geotextiles in the form of bags or tubes. For this project the research group collaborates with the National Research Foundation, the Council for Scientific and Industrial Research, the University of Luneberg in Germany, as well as knowledge bases in this field in The Netherlands and Germany. Local conditions are considered and physical model tests are performed in our flumes to optimise packing arrangements and towards development of local design guidelines.

Our laboratory wave flumes, which can generate wave energy spectra and minimise interference by reflections, were installed in 2010 and are now supporting theses and project works. One example is the optimisation of the seawall design for The Strand and other shoreline elements along the False Bay coast from Gordon's Bay to Zeekoevlei. A study is being conducted with consultants for the City of Cape Town (CoCT) and research within this project is focusing on establishing a good statistical and process-based understanding of the marine conditions in False Bay, Strand Beach and at the estuary mouths (Lourens and Eerste Rivers and Zeekoevlei) and then using these to advise CoCT on infrastructure management options.

1. *Wave flume laboratory.*
2. *Temporary or emergency coastal protection measures using geotextiles in the form of bags or tubes.*

Engineering Geology:
A GEODESIC OBSERVATORY IN MATJIESFONTEIN

The Engineering Geology research group participates in the development of the first Space Geodesy and Earth Observation Observatory in the southern hemisphere, which will be erected at Matjiesfontein in the Western Cape, South Africa, in a collaborative project between Stellenbosch University, the National Research Foundation, which provides financial support, the Hartebeesthoek Radio Astronomy Observatory and the Tshwane University of Technology.

A 7 ton telescope will be installed once the process of finalising the Matjiesfontein site is completed. The telescope will be developed into the first Lunar Laser Ranger (LLR) in the southern hemisphere. LLR is a process by which the orbit parameters of the moon are measured very accurately with a laser. This supplies data to the international scientific community which currently is biased because of data supply from the northern hemisphere only, which produces uncertainties in the Earth-Moon relationship models. The observatory will also combine with the telescope permanent instrumentation, which includes a GPS, a DORIS system that calculates satellite orbits extremely accurately, a gravity meter, a seismograph and an accelerometer.

The 7 ton, 1 m telescope was donated by the Obervatoire Cote d'Azur in France. This telescope will be transferred to Matjiesfontein and be developed to perform LLR and to participate in certain NASA missions to track space vehicles going to the moon and Mars.

In the initial phases of the Matjiesfontein development the Stellenbosch Engineering Geology group is involved in establishing the infrastructure, including access roads, bridges and the final installation site. A first phase involved adapting an international test standard, to test the fitness of the soil and rock as stable and durable road building material for the observatory access roads and foundations, for local conditions and materials.

1. *Erection of the Space Geodesy and Earth Observation Observatory at Matjiesfontein.*

2. *Slake durability test.*

Although the local material appears robust and durable, the first accelerated degradation test results on slake durability in the locally developed equipment indicates that the material may degrade within 2-4 years of cyclic drying and wetting when exposed in the envisaged applications. While the local shale material is unusable, some of the tillite has been shown to have the desired resistance to degradation in the envisaged construction.

River hydraulics: SEDIMENTATION AND THE INFLUENCE OF DAMS

The Institute for Water and Environmental Engineering (IWEESU) of the Department of Civil Engineering researches the design of hydraulic structures, river hydraulics and fluvial morphology, all of increasing concern in South Africa and the rest of Africa.

Ever more dams are being planned and constructed on major rivers throughout the continent. This construction significantly alters the river morphology upstream and downstream of the dam, as well as the flow downstream of the dam, which can have significant environmental effects, particularly on sensitive ecological systems which rely on seasonal droughts and floods for natural processes. Rural communities along rivers employ traditional farming and fishing methods, dependent on natural seasonal river flow patterns.

To ensure the protection of our water resources and general environment for future generations, it is important to protect natural ecosystems. South Africa has incorporated conservation measures into the National Water Act. The Berg River Dam, completed in 2008, hydraulic model studies of which were done by this research group, is the first dam in South Africa designed to reasonably reproduce natural flood releases at the correct temperature to protect the downstream environment (Figure 1). In future, dams will be designed with this capacity and investigations into the effects of any proposed dam on the downstream hydraulics and sediment behaviour should be conducted during the design phase.

A current project involves the Lower Zambezi River, downstream of the Cahora Bassa Dam, entailing development of mathematical modelling tools to assess the long-term effects of dam spillage and releases on the downstream river hydraulics and sediment dynamics, applicable to any future large dam projects. Large dams are often constructed to generate hydropower, considered a renewable source of energy. However, such dams can result in systems that are not truly sustainable in light of the detrimental effects they may have downstream. This project may, therefore, assist in providing sustainably for Southern Africa's increasing energy demands.

1. *The Berg River Dam.*
2. *Field work on the Zambezi River.*

Transport Engineering: ROAD SAFETY

The level of injuries and deaths from motor vehicle accidents in South Africa is one of the highest in the world, higher than many other African countries. This not only results in huge financial costs (estimated at around R100 billion per annum) but also creates significant problems for communities, health professionals and traffic officials. Highly motorised countries of the world have dramatically cut road deaths by applying intelligence-led responses to key risk areas. The road environment, human error and vehicle condition are common contributing factors to accidents, and most advances in road safety internationally have occurred when interdisciplinary work has been undertaken to understand the relationships between these factors. Since 2009 the division of Transportation Engineering of the Department of Civil Engineering has undertaken research in two of these three fields, namely the road and human behaviour, and is involved in facilitating interdisciplinary research and teaching on road safety issues across the wider University.

Current road design projects include the evaluation of differential speed limits on highways, and the determination of road safety problems at specific locations on the road network (e.g. level crossings). Human factors projects include the use of Naturalistic Driving studies to evaluate the driving decisions and errors of novice drivers; the use of real-time data recording devices to monitor the behaviour and safety of a fleet of taxi drivers in KwaZulu-Natal and the Western Cape, and research into the factors that influence driving behaviour at a communal level. The Department is also involved in a number of community-based research projects which are intended to improve safety in specific neighbourhoods or populations; child safety in the low income area of Du Noon; alcohol awareness among the youth in the Western Cape and Mpumalanga, and work with the Western Cape Traffic Police to increase seatbelt use by drivers and passengers.

For South Africa to make serious and sustainable inroads into an unacceptably high death rate requires a better understanding of the local causes of the crisis. The scope and scale of the research topics around this is very wide. This is an exciting and highly relevant field of research and one which can make a direct impact on the lives of all South Africans.

1. *Approximately 42 people are killed in traffic accidents on South African roads each day.*

2. *Performances on road safety held in schools in the Western Cape.*

ELECTRICAL & ELECTRONIC ENGINEERING

- Airbus-NAC Research Partnership Programme
- The MIH Media Lab
- Research on MeerKAT and SKA
- The Solid-State Transformer Project
- Telecommunications Research: Networks & Systems

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Airbus-NAC Research Partnership Programme

In 2008, the Department of Electrical and Electronic Engineering at Stellenbosch University kicked off a 7-year research partnership programme in conjunction with Airbus and the National Aerospace Centre (NAC). Under this programme, Airbus and the South African Department of Trade and Industry co-fund strategic graduate student research projects concerned with the control and automation of large commercial transport aircraft. The aim is to develop a national research relationship with Airbus, while training graduate students in relevant areas of expertise and accessing and solving cutting-edge research challenges facing the modern aircraft industry.

From the beginning of the programme students and staff have been involved in research projects with Airbus Centres of Competence (CoCs) in the United Kingdom and France and will expand activities to a facility in Germany. Flagship projects include autonomous flight control for refuelling an Airbus A330 aircraft, novel actuation of control surfaces in confined spaces, and autonomous flight envelope upset recovery. On these topics, the research teams elected to collaborate with other universities, including the University of Cape Town and the Cape Peninsula University of Technology.

Stellenbosch students gain tremendous exposure to the activities and challenges of one of the largest aircraft manufacturers in the world through regular interaction with Airbus CoCs. For example, a PhD candidate within the Department completed a three month internship with Airbus in Toulouse, France, where he implemented and successfully demonstrated his research results.

Building on the successes attained, Airbus and the NAC have agreed to expand the research programme at Stellenbosch University and to include other local universities.

1. *Stellenbosch University performs research for Airbus on the flight control systems of large transport aircraft such as the Airbus A330.*

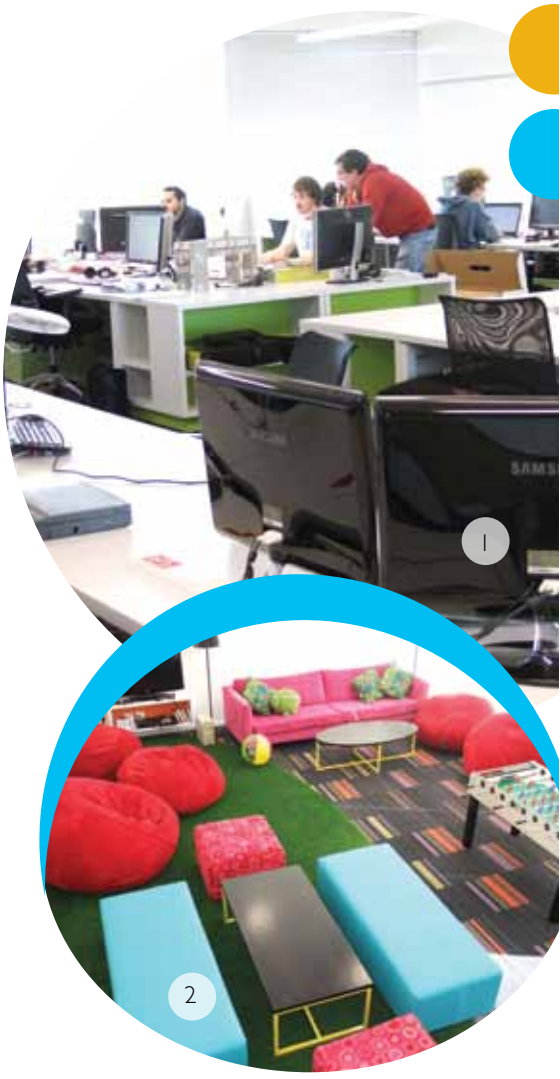
2. *The flight control systems for automated air-to-air refuelling of large transport aircraft are verified using simulations.*

The MIH Media Lab

The last decade of the 20th century saw the birth of the public Internet; the first decade of this century saw it changing the fabric of our society. Commerce, information access, entertainment and social interaction have been completely transformed by new media of communication. The MIH Media Lab at Stellenbosch University was founded in 2008 to research these new applications of Internet and mobile technology. Applied research in a field that cuts so broadly across human experience and endeavour, requires a research team that combines a wide variety of specialisations. Consequently, if you were to spend some time with the postgraduate students in this off-beat technology lab, you would meet computer scientists, electronic engineers, commerce researchers, applied mathematicians, marketing researchers, and socio-informaticians. Although the balance tips strongly towards engineering and computer science, it is the broad perspective on the applications of new technology that gives the MIH Media Lab its unique character.

The Media Lab works closely with industry partner MIH (a subsidiary of Naspers) to study emerging topics in new media technology. A strong emphasis is placed on cross-disciplinary innovation and technology entrepreneurship. Current focus areas include peer-to-peer media distribution, conditional access to media, next-generation Internet technologies, augmented reality and gaming. A primary objective of the project is to develop leading-edge local industrial expertise in these areas.

The Media Lab's activities tie in closely with Stellenbosch University's Overarching Strategic Plan (OSP), which has identified Information and Communication Technology (ICT) as key to bridging the country's digital divide. The South African Government Department of Science and Technology has also identified ICT research as a primary technology mission.



1. *The MIH Media Lab's spacious, modern facilities on two levels can accommodate up to 40 postgraduate students.*

2. *The funky chill area stimulates creative minds.*

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Research on MeerKAT and SKA

The South African Research Chair Initiative (SARChI) of the Department of Science and Technology (DST) and the National Research Foundation (NRF) established the research chair in Electromagnetic Systems and EMI Mitigation for the Square Kilometre Array (SKA) as of January 2011. The chair is embedded in the Department of Electrical and Electronic Engineering and Prof David Davidson is the first incumbent.

SKA-SA also supports a lecturer in the Department and a second professor is spending half his time on the project, for which the research chair is compensating the Department. A further three staff members are supervising research students in this field.

The KAT-7 array erected near Carnarvon in the Northern Cape.

Progress on the South African SKA pathfinder/technology demonstrator projects (KAT-7 and MeerKAT) has been rapid. Construction of the KAT-7 array in the Karoo has been completed and that system is currently in the commissioning phase. The provisional design of the 64-dish MeerKAT system was reviewed and the final design decisions are under consideration.

Work on radio frequency electromagnetic interference (EMI) mitigation for KAT has continued in 2011 and detailed design has been done for the new Gregorian offset-feed dish antennas. Close collaboration has been established nationally with key role-players. These include: EMSS-Antennas (antenna designers); the Cape Town KAT office with overall responsibility for the KAT-7 and MeerKAT projects; the Centre for High Performance Computing, which has awarded a three-year grant in the new MeerKAT High Performance Computing for Radio Astronomy Programme; and the main SKA office in Rosebank, Johannesburg and the other SKA research chairs.

Internationally, collaborative projects are underway on focal plane arrays for SKA with Chalmers University (Sweden) and on the SKA aperture array verification programme with Cambridge University (UK).

On 25 May, 2012 the SKA Organisation announced that a dual site solution had been agreed upon for the SKA, and that the array would be sited in both Southern Africa and Australia/New Zealand. MeerKAT will now become an integral part of SKA Phase 1. The majority of SKA mid-frequency dishes in SKA Phase 1 are to be deployed in South Africa, and combined with MeerKAT; 190 additional dishes are planned. SKA Phase 2 will see around 3 000 more dishes in Southern Africa, as well as a large number of mid-frequency dense arrays. This announcement has added further impetus to this research.

The Solid-State Transformer Project

The solid-state transformer (SST) is a power electronic based transformer performing the same functions as the steel-core line-frequency transformer. However, due to its power electronic nature, the SST can perform many other functions important to the grid of the future. The SST will operate as an intelligent power-flow node integrating many functions of other network equipment. Because the SST is a software-controlled device, it has the features required for a modern smart-grid device. Some of the benefits that the SST could bring to a future grid are that:

- the output voltage of the SST is carefully controlled
- the SST acts as a power-flow node, providing a platform for the integration of resources such as renewable energy sources and energy storage devices
- the SST can deliver power using power levels other than 400 V 3 phase (AC)
- the SST has full control over the output(s) and can limit fault currents when necessary.

The problem that must be overcome in developing a medium-voltage SST is the blocking-voltage capability of existing semiconductor switches. Although semiconductor technology has greatly improved recently, the voltage blocking capability is much lower than the required 22 kV for the high-voltage side. This limitation was overcome by developing a multi-level converter topology comprising 12 modular converter cells per phase. Each cell is equipped with a digital controller and communicates with a main controller through fibre optic connections. Digital control algorithms were developed for the cell and main controllers. Each cell contains a high-frequency transformer developed specifically for this project.

A three-phase laboratory prototype, comprising 36 modular cells, was developed and tested. While this project confirmed the technical feasibility of the STT (in the laboratory) a number of challenges remain. The high cost compared to conventional iron and copper transformers remains the biggest.

Research is continuing on the predictive control of the active rectifier input stage of the device. Using current semiconductor devices to reduce the number of cells is being investigated. However, with a new generation of semiconductor devices using silicon carbide, the voltage blocking capability of the semiconductors should increase several times. With these devices available, the SST will be more reliable and cheaper to manufacture, since fewer switching devices and cells can be used.

1. *The solid-state transformer cell.*
2. *The completed single-phase stack consisting of 12 cells.*

Telecommunications Research: NETWORKS & SYSTEMS

The Telecommunications research group's activities involve: Wireless communications, protocols, teletraffic modelling, communications link design and optimisation, integration and development of network types for specific applications. Some of the projects are:

Satellite payload and communications link development: A short message and data service for the Sumbandila satellite is adapted to commercial satellite networks for environmental monitoring. Under a joint project with the Katholieke Universiteit Leuven an electronically beam-steerable antenna and its host platform is being developed. This has wide applications and a second phase for mobile and personal communications is underway, based on previous research (protocols, link quality improvement, and software-defined radio).

Wireless mesh network (WMN)/Ad hoc network advanced routing strategies and applications: Energy usage is very important and various harvesting techniques are being investigated.

Ad hoc network development: A flexible and easily deployable network, suitable for industrial applications and field data acquisition, is being developed for animal tracking and behavioural monitoring, for conservation and food security purposes. Innovative routing strategies will result. Ties with the INRIA research lab in France enable use of their simulation platform for tests, and joint research.

Development of robust communications links using advanced coding techniques: Implementation of advanced Forward Error Correction techniques in communications links enables reliable communication over noisy channels such as satellite communication, terrestrial mobile and static networks, such as our own Wimax network.

Communications technology development for animal behavioural research: We are working with the Cape Leopard Trust in the Cederberg, Western Cape. Many problems face conservationists and biologists in obtaining reliable animal behavioural field information. Conservation of rare and threatened species, but also the impact of predators such as the black-backed jackal on small-stock farming, is important and financially serious. The complex interactions between animals and the environment are not well understood and there is need for a diversified data gathering technological platform for acquiring reliable field data, for management decisions. Innovative and very interesting research activities resulted in:

- the design of a new generation tracking collar, a very difficult engineering problem
- a satellite-linked animal trap monitor; whenever an animal is trapped, a photo is transmitted to the office of the researcher
- application of pattern recognition techniques to identify animal species and their movements
- to capture and present data from the devices and systems above, a flexible and mobile field network of data acquisition nodes is required, based on our knowledge of ad hoc network topologies. A new generation wireless-enabled camera trap is also in development

1. *A joint project with the Katholieke Universiteit Leuven developed an electronically beam-steerable antenna and its host platform.*

2. *The impact of predators such as the black-backed jackal on small-stock farming is investigated.*

INDUSTRIAL ENGINEERING

- Advanced Manufacturing
- Enterprise Engineering
- Health Systems Engineering
- PRASA Chair in Maintenance Management
- Systems Optimisation

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Advanced Manufacturing

For four years the Joint Laboratory of the Global Competitiveness Centre (GCC) in the Department of Industrial Engineering, the Fraunhofer Institute for Machine Tools and Forming Technologies (Fh IWU) and the Institute for Advanced Tooling (IAT) have been involved in a large collaborative AMTS project. This project, *High performance machining of light metals with an emphasis on titanium and selected alloys* is also done in collaboration with research groups from the Universities of Cape Town and Johannesburg, Chemnitz University (Germany), and Stellenbosch University's Department of Mechanical and Mechatronic Engineering.

The objective was to open new potential for South African aerospace and automotive companies of the first supply chain tiers, reduce lead times and decrease development and production costs, with focus on high value added aerospace components manufactured by multi-axis high performance machining (Figure 1).

Besides overall coordination of the project, the Department has focused its research on two of the four main areas:

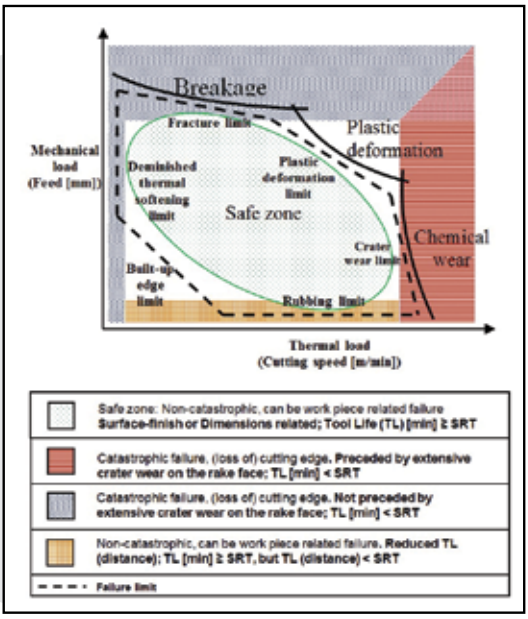
- consolidation of a high performance machining (HPM) knowledge base
- investigation of new high performance technologies for machinability of titanium alloys in raw or near net shape condition

The goal of the first subproject was to avoid unnecessary work at a fundamental level on aspects already sufficiently researched and transferred to industry supply chains as product support information. Based on extensive cutting trials for three selected benchmark parts, guidelines have been developed in generic terms for the machining of aluminum and titanium components.

The objective of the second subproject was to study the influence of technological developments on the efficiency of HPM. Cooling techniques such as high pressure through spindle cooling, gaseous cooling and localised insert cooling, as opposed to the general practice of side-mounted flood cooling, were investigated. Another task focused on innovative cutting tool coatings and materials. There are challenging demands for a tool material to machine titanium alloys, considering tribo-chemical and impact-related wear mechanisms. A generic wear characterisation map was developed specifically for the milling of Ti6Al4V alloy (Figure 2).

Further studies of the analysis of the geometric and technological characteristics of the machined components, selection of the best cutting strategy, and efficient determination of an acceptable tooling cost, leading to a cost minimal machining operation, are in progress.

1. *Typical integral parts in aerospace applications.*
2. *Tool wear map for milling of Ti6Al4V as a function of thermal and mechanical loads.*

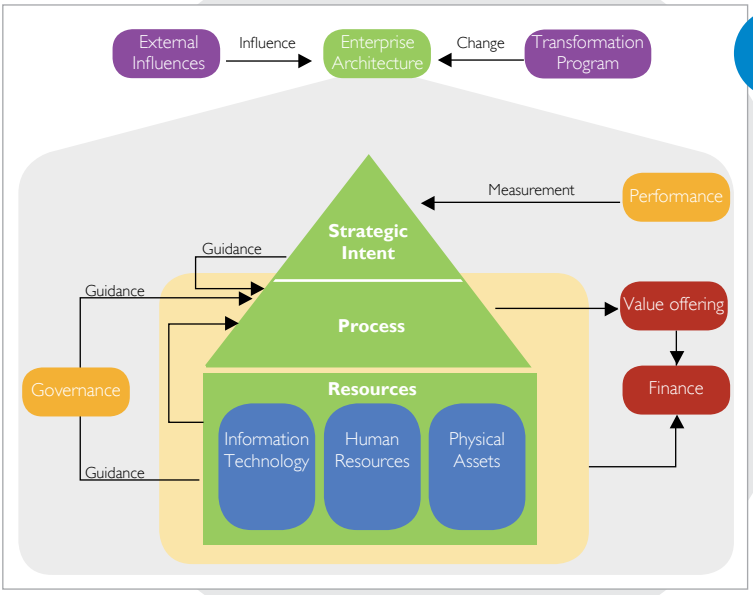


Enterprise Engineering

Enterprises are dictated by internal and external drivers to change continuously in order to maintain their competitive advantage. Enterprise engineering is the discipline concerned with the design and the re-design of enterprises, regarding both their business and organisation.

The Enterprise Engineering research group focuses on:

- the application of enterprise engineering processes and architectures in renewing or designing enterprises
- the innovation management process and the knowledge supply chain to support it
- determining an enterprise's innovation capability and deciding on what its innovation strategy should be



Enterprise Architecture Reference Model (Adapted from the AER model).

Change cycles can be viewed from an engineering life cycle perspective in the sense that the "change" is created, designed, maintained or developed. In this regard, "engineering" these changes is equivalent to managing the changes imposed on the enterprise. One is thus literally busy "engineering the enterprise".

Several reference models are available to model an enterprise. A simplified version is shown in the above Figure. This model ensures that one considers all aspects that need to be engineered in the Enterprise Engineering Process.

Innovation is often the driver for changing an enterprise and it is important to focus on the management of innovation so as to optimise the benefits and to make sure that the attempted innovation projects fit the strategy for the enterprise.

The availability of suitable knowledge necessarily supports the Innovation Process – it is therefore also necessary to understand the knowledge supply chain – that is the creation and mining of knowledge necessary to support the innovation and enterprise engineering processes.

To what extent an enterprise is capable of innovating is important in the competitive environment today. Determining a company's Innovation Capability Maturity is a way of quantifying this capability and providing enterprise engineers with a toolset to identify strengths and weaknesses in an enterprise's innovation capability, therefore helping to create a plan for improvement.

Health Systems Engineering

Health Systems Engineering (HSE) is concerned with the optimisation of health systems and processes. In recent years, many international HSE groups and institutes have been established in association with Industrial Engineering departments at various universities. Stellenbosch University is following this trend. The health systems considered at Stellenbosch University range from those as extensive as the National Health Insurance System to simple mobile phone applications. Research outputs include state-of-the-art technology, for example a telesurgery robot, or may entail technology independent enterprise engineering solutions, such as a maturity business model for telemedicine implementation. Our research projects relate to the private as well as the public health sector of South Africa and often involve integration of, or comparison between, these sectors.

The entire mind and skill sets of Industrial Engineering are used in the optimisation of these systems. Current research projects are directed towards nurse scheduling systems; pharmacy inventory control and supply chain management; patient flow queuing models; innovation management and feasibility studies of medical devices and technology; telemedicine business process redesign; decision support systems as well as information system design.

Training in the use of a nurse scheduling decision support system, developed by the HSE research group.

Due to the multidisciplinary nature of HSE, collaboration with other research entities, such as the Telemedicine and mHealth division of the Medical Research Council of South Africa (MRC), the Biomedical Engineering research group (BERG) and Stellenbosch University Faculty of Medicine and Health Sciences, is imperative. The dissemination of knowledge, amongst other things, is facilitated through formal continuous professional development (CPD) courses, targeted at health care practitioners and information technology managers in the health sector, as well as through interaction with the Student in Free Enterprise (SIFE) organisation and the annual ICT4HEALTH conference held in collaboration with the MRC. Industry partnerships with businesses, such as Mediclinic Southern Africa, Broadreach Healthcare and Geomed, as well as local public hospitals and clinics, such as Stellenbosch Hospital, are crucial to foster the symbioses between research and community interaction and to contribute to the significance and relevance of these Health Systems Engineering research outputs.

PRASA Chair in Maintenance Management:

PRASA SPONSORED ACADEMIC CHAIR

As the brainchild of Dr Daniel Mtimkulu of PRASA/Metrorail and Prof Neels Fourie, the PRASA Chair in Maintenance Management was established in the Department of Industrial Engineering in 2011.

The primary goal of the Chair is to initiate and execute research into aspects of maintenance management and applicable engineering management principles best suited to the needs of PRASA/Metrorail. A formal postgraduate programme has also been established under the umbrella of the existing Engineering Management Programme.

Prof Fourie is the first incumbent of the Chair and a senior as well as a junior Research Engineer have been appointed to assist in carrying out the projects.

Initiating an undertaking of this magnitude necessitated a clear understanding of the existing environment. Therefore Prof Fourie undertook a national road show, visiting all the main Metrorail depots across South Africa with a view to improving existing maintenance strategies and the operation of these strategies. As a result of this and the analyses of various problems, it was decided to initiate an on-the-floor approach to training, involving the introduction of the Mission Directed Work Team© principles. When these work teams are fully operational, further modules such as the 5S Program (Visual Workplace) and Problem Solving for Engineers will be introduced. This will be followed by the training of middle management, which could include a selection of short courses from the 30 ECSA-registered courses which the Department has on offer.

In addition to these training initiatives, a number of projects have been successfully completed, the solutions of which will be expanded into one-day workshops, which will be presented throughout the country at the different Metrorail depots. In this way it is hoped that solutions to typical problems will be disseminated to the company as a whole.

To support the Chair activities, the go-ahead has been given to establish a laboratory/workshop in the Faculty of Engineering. The possibility of creating a "virtual" laboratory is being considered.

1. *Prof Neels Fourie, the first incumbent of the PRASA Chair in Maintenance Management.*
2. *The Mini-business program.*
3. *The start of an undertaking of this magnitude necessitated a clear understanding of the existing environment.*

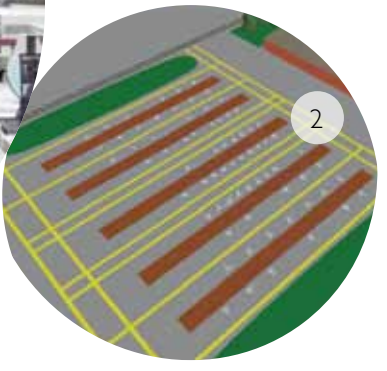
Systems optimisation

This Systems Optimisation research group uses Operations Research methods to improve and optimise systems. The methods applied include Markov chains, mixed-integer linear programming, computer simulation and metaheuristics, or combinations of these, for example a combination of metaheuristics and computer simulation. Systems studied include airport, mining, manufacturing, healthcare, traffic junction and retail bank operations. Specific cases are:

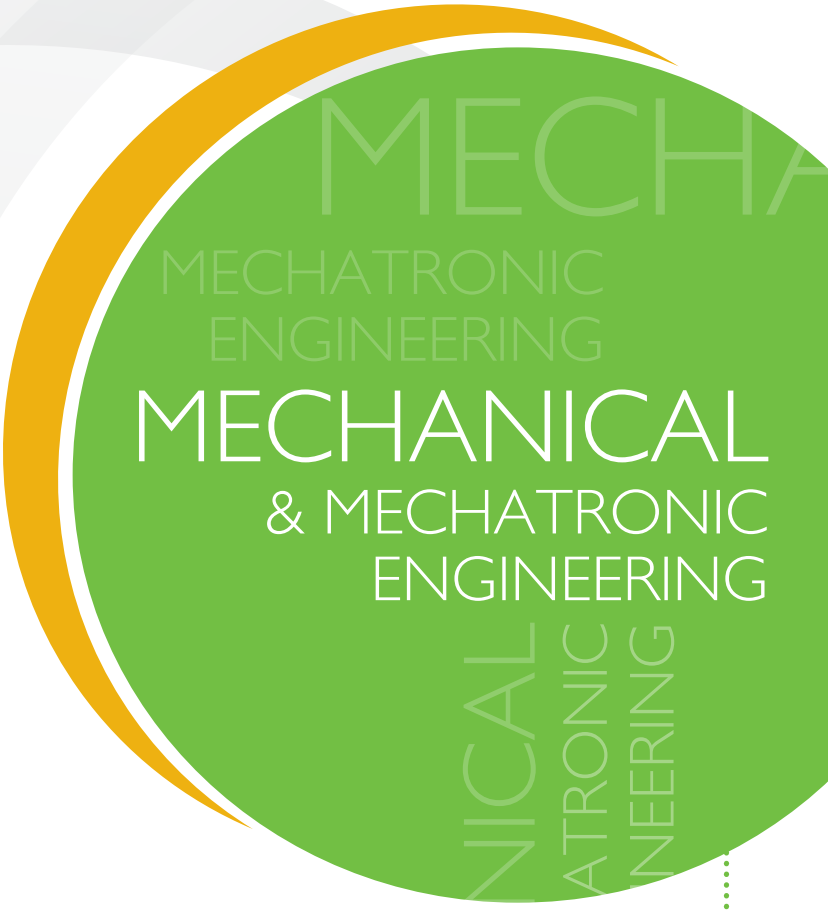
- design of an airport apron layout for a new South African airport
- conveyor maintenance plans for an opencast mine based on equipment reliability
- resource requirements and allocation in reconfigurable manufacturing systems
- scheduling of nursing staff in a government hospital
- simulation of process flow in a pathology laboratory
- planning of traffic light management at specific junctions in local towns
- cash management and route planning of distribution in retail banking

Research focuses on improvements that would optimise systems with dynamic, stochastic operations and multiple, conflicting objectives. Processes are modelled using computer simulation, while Operations Research methods dictate the optimisation process. The cross-entropy method, tabu search, simulated annealing and genetic algorithms are currently used as primary optimisers. One aspect of the research is to find more efficient and faster algorithms – by modifying them or developing new ones – to mitigate the computational burden imposed by simulation models of real-world systems.

Multi-objective optimisation is applied to real-world problems with two or more conflicting objectives. In manufacturing, for example, a balance must be found between the number of resources acquired (cost) and the production capability provided (profit). When distributing new vehicles from plants to dealers, a number of distribution trucks are assigned to service a specific demand. More trucks lead to faster distribution and thus customer satisfaction, but also to lower truck utilisation and higher cost. The optimisation process of such problems proposes a set of trade-off solutions. This group's research focuses on improving the quality of these trade-off sets and the application of these improvements to practical problems.



1. *Flow of specimens and resource utilisation in a pathology laboratory are improved.*
2. *Part of an animated simulation model of an airport apron.*



Mechatronics, Automation and Design

Biomedical Engineering Research Group

Industrial Cooling Systems

Numerical Design Optimisation Group

Solar Thermal Energy Research Group

www.mecheng.sun.ac.za

Mechatronics, Automation and Design

In this ever-changing world, factories must adapt to large product variations over short time periods while maintaining the cost-effectiveness and quality that automation brings. This means that manufacturing systems must be reconfigurable. With minimal effort, the system must be able to switch between product variants. This calls for a manufacturing strategy that is somewhere between a dedicated plant, such as the traditional automotive assembly plants and the highly adjustable workshop. Our research is thus focused on assembly systems that must be reconfigurable to many product variants. Robots are an obvious choice in these systems, but the hardware that supports the robotic operations, such as feeding systems and quality control systems, also require careful planning. On top of this, all the systems must be efficiently controlled.

Various control approaches, such as agent-based control and function block control are being studied. These strategies must ensure the most efficient flow of the parts through the assembly system. They must deal with defective parts as well as malfunctioning subsystems in the assembly plant. They must also be designed in such a way that they, too, can be efficiently reconfigured for new product variants. It should not be necessary to reprogram the entire control system; hence the focus on function blocks and agents.

In automated assembly systems, machine vision has the important functions of quality control and part identification. The vision system must robustly identify parts and determine their position and orientation. It must often inspect parts, from simple completeness checks to highly accurate dimensional inspections. This must be done on the fly. We are therefore studying high precision vision-based metrology systems and developing machines for that purpose.

1. *The assembly test system with its robot.*
2. *The structure for the high precision measurement system.*

Biomedical Engineering Research Group (BERG)

Biomedical engineering applies the concepts, knowledge and approaches of engineering disciplines to solve or improve healthcare-related problems. The biomedical engineer is ideally trained to work at the intersection of science, medicine and mathematics to solve biological and medical problems. The Biomedical Engineering research group (BERG) works in close association with the Departments of Industrial Engineering, and Electrical and Electronic Engineering, as well as the Faculty of Medicine and Health Sciences. The research focus areas are:

Biosignal processing involves extracting useful information from biological signals for diagnostic and therapeutic purposes, such as studying cardiac signals to determine a patient's susceptibility to sudden cardiac death, developing speech recognition systems that can cope with background noise, or detecting features of brain signals that can be used to control a computer.

Instrumentation, sensors and measurement involve the hardware and software design of devices and systems used to measure biological signals. This ranges from developing sensors to capture a biological signal of interest, applying methods of amplifying and filtering the signal, to dealing with sources of interference with a signal, or building an instrumentation system such as an X-ray machine or a heart monitoring system.

Biomechanics includes the study of motion, material deformation and fluid flow. For example, studies of the fluid dynamics involved in blood circulation have contributed to the development of artificial hearts, while an understanding of joint mechanics has contributed to the design of prosthetic limbs, as well as the design and testing of artificial knee and spinal implants.

Information technology in biomedicine covers a diverse range of applications and technologies, including the use of virtual reality in medical diagnostic procedures, the application of wireless and mobile technologies in healthcare settings, artificial intelligence to aid diagnostics, and security issues of making healthcare information available on the World Wide Web.

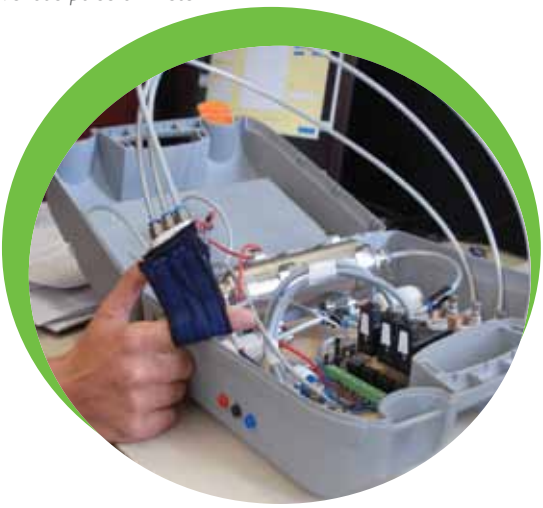
Robotics in surgery includes the use of robotic and image processing systems to interactively assist a medical team in both planning and executing a surgery. These new techniques can minimise the side-effects of surgery by providing smaller incisions, less trauma, and more precision, while also decreasing costs.

Telemedicine involves the transfer of electronic medical data for the evaluation, diagnosis, and treatment of remote patients. This involves the use of connected medical devices, advanced telecommunications technology, video-conferencing systems, and networked computing, as well as the use of these technologies in health-related distance learning.

Sport technology: The world of sport is continuously changing and the development and use of technology has provided a catalyst for this change. Sport technologies range from high-tech aids for referees and coaches to equipment and technique analysis. Examples include games analysis, measurement technology, sports specific product development and biomechanical analysis of equipment and sportsmen.

BERG
Biomedical Engineering Research Group

Development and testing of a non-invasive artificial venous pulse oximeter.



Industrial Cooling Systems

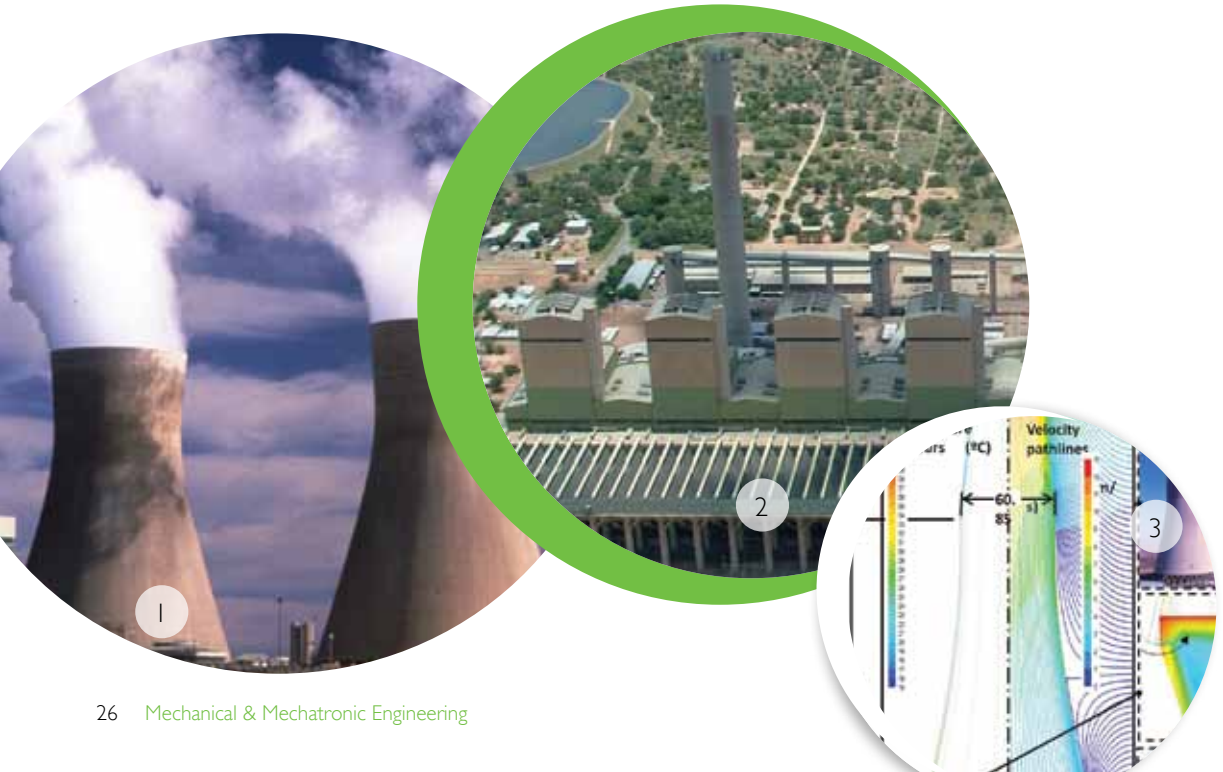
Cooling systems find application in the electronic, automotive, refrigeration and air-conditioning, mining, process, petrochemical, power and other industries. This Department has been involved in research, development and the design of such systems for more than 40 years and is presently recognised as the undisputed world leader in the field of air-cooled heat exchangers and cooling towers. Local and international consulting projects include the design or performance evaluation of a wide spectrum of cooling systems for application in gas, coal and nuclear power plants, automotive cooling systems, uranium enrichment plants, and liquefied natural gas (LNG) cooling plants.

The primary research and development activities relate to performance enhancement of dry, wet and dry/wet-cooled systems in order to maximise power/process plant efficiency/output and minimise water consumption. A typical wet-cooled power plant has a water consumption of about 2,5 litres/kWh of generated power, whereas a dry-cooled power station requires negligible water. Combining wet- and dry-cooling can therefore be advantageous in reducing power generation costs. The continuous advancements in computer technology and software now additionally provide powerful new tools which can be used in conjunction with the excellent laboratory facilities to improve cooling system designs.

To satisfy the ever increasing world-wide demand, new power plants are constantly being built, such as Eskom's Medupi and Kusile, the world's two largest dry-cooled power stations, at a capital cost per plant of about R120 billion. Small improvements in design can result in a measurable reduction in capital cost and lead to savings over the life of the power plant due to increased plant efficiency and a corresponding reduction in pollution. Similar improvements can be achieved in the case of nuclear and solar power plants, large air-cooled systems for liquefying gas (LNG), etc.

The potential increase in ambient air temperature due to global warming and a corresponding reduction of rainfall in many parts of the world pose an increasing challenge to the development of effective industrial cooling systems for the future.

1. *Natural draught wet-cooling towers.*
2. *Air-cooled steam condenser at Matimba, currently the world's largest direct dry-cooled power station.*
3. *Computational fluid dynamics plots of calculated conditions in a natural draught cooling tower.*



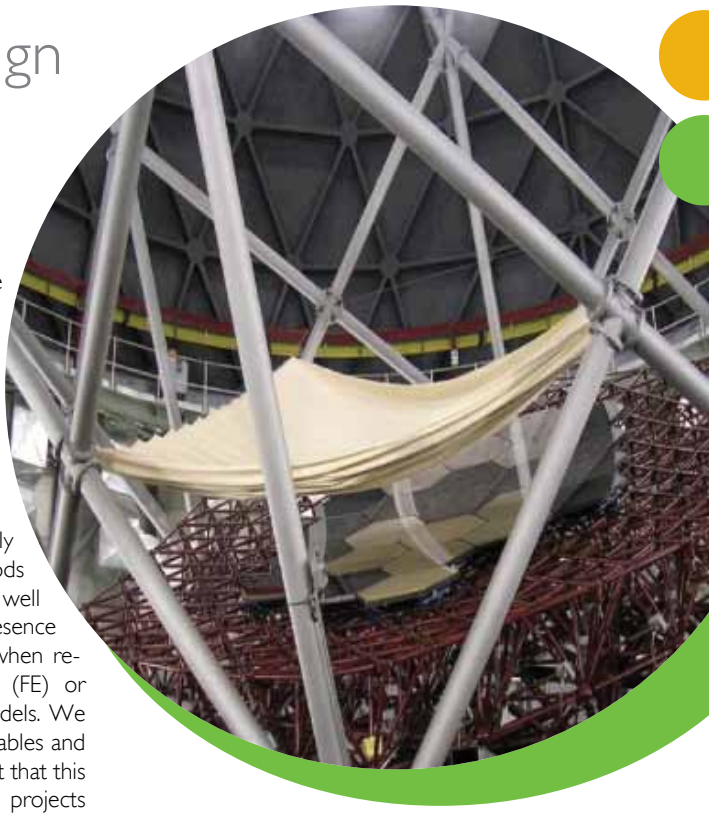
Numerical Design Optimisation Group

The activities of this research group centre around the development of algorithms for optimal design and the application of these and other methods to engineering problems of practical importance; "other methods" being state-of-the-art commercial and academic programmes and tools.

On the algorithmic side, we are particularly interested in the development of methods for very large-scale optimal design, as well as methods that are robust in the presence of the typical discontinuities that arise when re-meshing is required in finite element (FE) or computational fluid dynamics (CFD) models. We are able to handle millions of design variables and millions of simultaneous constraints, albeit that this is for sparse problems. Active research projects include handling non-convexity, and providing for the efficient modelling of local stress constraints in FE meshes, which is a difficult, very large-scale problem.

Complementary to the rigorous mathematical programming methods mentioned above, stochastic artificial intelligence or AI methods have enjoyed much attention world-wide. These developments have not passed us by; we are actively developing methods within this framework, which include contributions to the development and theory of particle swarm optimisation algorithms, genetic algorithms and neural networks.

On the application side, we have recently been involved in the optimal design of components and using numerical optimisation methods and techniques for correlating numerical models with experimental data. Applications include the Square Kilometre Array (SKA) antenna structure, the mirror support truss structure for the Southern African Large Telescope (SALT), airfoil shape optimisation for wind turbines, design of a cowling for an underwater turbine and fluid-structure interaction problems. Many of these problems require supporting technologies like high performance computing (HPC) and approximation or meta-modelling techniques.



Optimal design of a support truss for the Southern African Large Telescope.

Solar Thermal Energy Research Group (STERG)

Solar thermal energy research has been ongoing at Stellenbosch University since the late 1970s. Over thirty years, the Department of Mechanical and Mechatronic Engineering has been active in research on solar collectors or in closely complementary areas such as world-leading dry cooling research and internationally highly cited work on the solar chimney concept.

At present STERG is the only formal university research group in South Africa focused on utility scale power and other products requiring solar thermal energy. STERG is represented in the Southern African Solar Thermal and Electricity Association (SASTELA) as founding executive committee representative for academia. STERG is directly affiliated with the Centre for Renewable and Sustainable Energy Studies (CRSES) at Stellenbosch University. Primary sponsors are the South African Department of Science and Technology (DST), Sasol Technology, the Stellenbosch University HOPE Project and Eskom.

The primary project of the research group centres on the SUNSPOT concept, a highly efficient solar power plant cycle that aims to provide dispatchable power regionally in Southern Africa. The SUNSPOT cycle is based on the central receiver concentrating solar power (CSP) plant concept, capable of achieving high temperatures, where much of the energy is stored for use at night or during cloudy conditions. The world-leading research in dry cooling is applied to this concept, which can be hybridised to guarantee power delivery on demand.

A secondary, but important, project is the development of the linear Fresnel reflector (LFR) system. The LFR is much simpler in construction and maintenance and is complementary to the central receiver type, its future role being in the provision of community power and heat, as well as the potential for pre-heating of existing fossil power plants.

Solar resource assessment and measurement is the third major project in STERG, through partnership with CRSES. It is critically important to understand the solar resource prior to funding multibillion rand solar power plants. STERG and CRSES are the only national entities to provide this service and continuously improve solar resource knowledge through research, using satellite data and ground measurement stations.

STERG also conducts research in solar water heating (SWH). Through sponsorship by the Austrian government, STERG operates the only SWH test facility in the Western Cape, used to train students and assist local industry in improving their products. STERG has recently deployed an expanded solar roof laboratory of 1 000 m^2.

1. *First solar roof laboratory housing the solar water heater testing facility.*
2. *Pyranometer measuring the solar irradiance.*
3. *Improving living conditions in informal settlement shacks with better design.*

SOLAR THERMAL ENERGY RESEARCH GROUP

Anglo American Platinum Centre for Process Monitoring

Bioprocessing

Mineral Processing

Process Systems Engineering

Separation Technology

www.chemeng.sun.ac.za

Anglo American Platinum Centre for Process Monitoring

The Anglo American Platinum Centre for Process Monitoring culminated from close collaboration between industry and academia, and endorses the longstanding relationship between the Department of Process Engineering at Stellenbosch University and Anglo American Platinum. Since its inception in 2008, the Centre has been intimately involved in application engineering, research and development relating to data-based approaches to process identification, condition monitoring and decision support. A number of ready-made software solutions are the fruits of this labour.

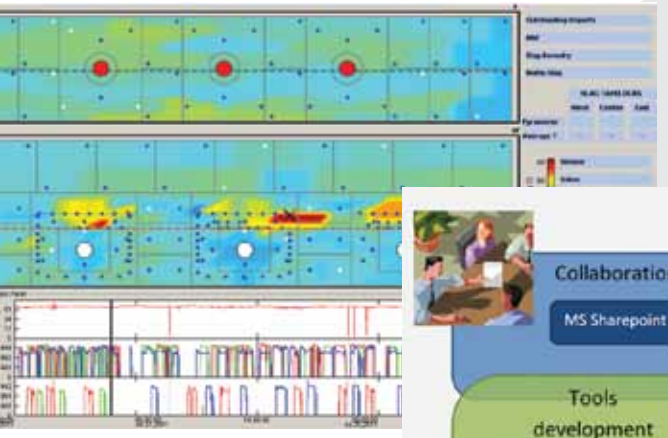
Currently, the primary focus of the Centre is the design and implementation of process monitoring and fault diagnostic systems to support the automated monitoring and control of operations at Anglo American Platinum plants. By analysing data in real time, variations in the plant processes can be identified and controlled timeously, thus preventing or limiting the damage such variations can cause. In addition, automated monitoring of the plant operations will also serve as a basis for the continuous improvement of these processes.

An industrial sponsorship by StatSoft, as well as collaboration with Opti-Num Solutions, enhances the ability of researchers at the Centre to use statistical analysis and modelling techniques employed in mining the data, and enabling the development of subsequent quality control software.

1. *A soft sensor for the monitoring of the thermal condition of an industrial smelting furnace.*

2. *A diagrammatic representation of the computational infrastrucutre of the Centre.*

www.sun.ac.za/cpm



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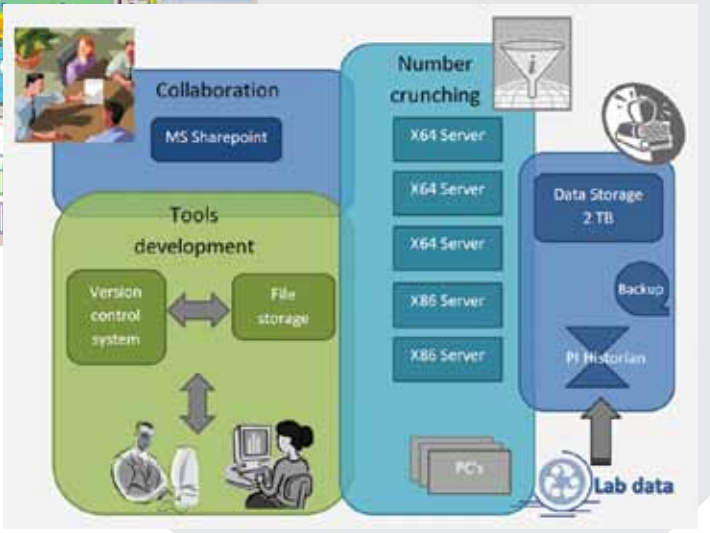


2

Bioprocessing

Biotechnology encompasses two major research areas, i.e. plant biomass conversion to chemical and energy products, and bioprocess engineering, directed at the application of engineering principles to optimise biological processes.

Plant biomass conversion in a biorefinery

Plant biomass is widely considered as the only sustainable future source of carbon for the production of chemicals and energy, to replace present fossil-based resources. Conversion of plant biomass to energy products such as liquid fuels, electricity, charcoal and industrial heating is considered a key intervention for greenhouse gas emission mitigation by South Africa's coal-heavy industries. Furthermore, the fractionation of biomass into valuable feedstocks and products for further processing has the potential to replace many fossil-derived chemical products of existing petrochemical industries. Both biological and thermochemical methods for such conversion of plant biomass are used, with development of biorefinery concepts incorporating analyses of energy efficiency, economics and life cycle.

Bioprocess development

Development of bioprocesses for the production of alcohols, enzymes, organic acids and pharmaceutical proteins is pursued within the research group, some of which within the biorefinery concept. Strain development for these products involves genetic engineering, process development with preferred organisms, applications development for some of the enzyme products, and quality assessment by academic and industrial partners.

Bioprocess engineering

Bioprocess Engineering is directed towards the development of bioprocesses where conversion from raw materials to products is mediated by biocatalysts (enzymes or microorganisms). Research is conducted into a diversity of bioprocesses to optimise biocatalyst performance through various configurations and strategies. Current research foci centre on health, food security and environmental issues with projects relating to the production of antimicrobials effective against human and plant disease as well as the elimination of oil contamination. Opportunities are examined to exploit hydrocarbon by-products from gas-to-liquid technologies using high-speed photography and image analysis to design and scale up these bioprocesses.

1. *Postgraduate students conducting research on the bioconversion of raw materials into value added products (e.g. antimicrobial agents).*

2. *An instrumented bioreactor with internal light source and camera for measurement of bubble surface area using high-speed photography and image analysis.*

Mineral Processing

The South African mining and mineral processing industries directly contribute more than 7% to the national GDP, and form a major part of the national economy. As ore bodies become harder to mine and their grade decreases, the challenge intensifies to develop more efficient processes for metal recovery to meet continuing world demand. At the same time, competition for scarce water resources and the need to reduce consumption of fossil fuels while remaining financially viable in a tighter economy offers the opportunity for innovative process development. Research focuses on process modelling and development, primarily in the areas of physical processing, pyrometallurgy and hydrometallurgy. Most of the projects undertaken by the Mineral Processing group are industrially-relevant and sponsored and range from fundamental studies to process development.

Physical processing

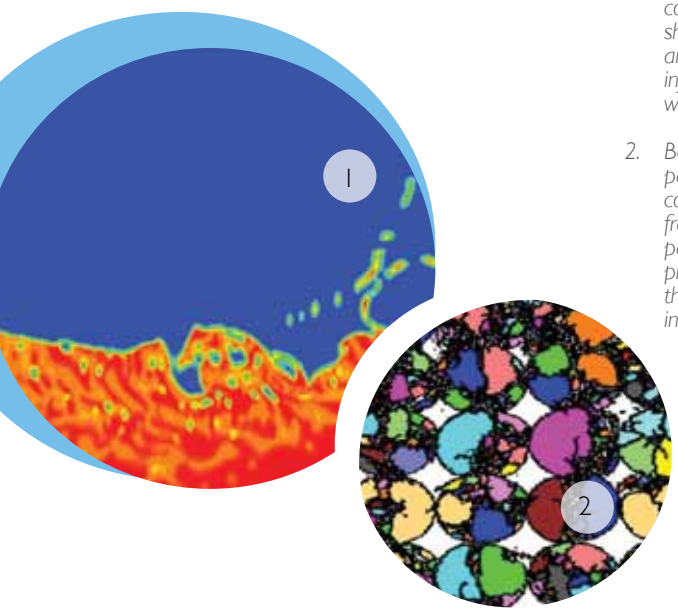
Research into physical processing of ores focuses on understanding new technologies that offer improved liberation of valuable minerals at reduced energy consumption. Methods such as computational fluid dynamics and bonded particle modelling, allied with fundamental property-based models, are being used to develop and understand cutting-edge technologies, such as confined bed crushing, microwave treatment and coarse particle flotation.

Pyrometallurgy

Pyrometallurgy forms the foundation of many metal extraction processes. Research in this area focuses on modelling, optimisation and control of pyrometallurgical processes. Computational fluid dynamics plays a key role in this, while fundamental high temperature thermochemical studies complement the work, which is important for understanding furnaces, converters and ladle operations. The metallurgical phenomena inside furnaces are studied using a combination of cold physical models, miniature high-temperature models, computer models and empirical models based on industrial process data.

Hydrometallurgy

Hydrometallurgical processing offers the opportunity to eliminate energy intensive smelting operations, and such approaches are particularly attractive for treating lower grade ore bodies. Studies on leaching and carrier phase extraction methods are a significant part of the development and modelling of new, low-energy hydrometallurgical processes for the recovery of both precious and base metals. The various leaching operations involved in the extraction of platinum group metals are being investigated in both fundamental and applied modelling and experimental studies. At the same time, development of new industrial hydrometallurgical routes to improve product purity forms the basis for a number of research projects.

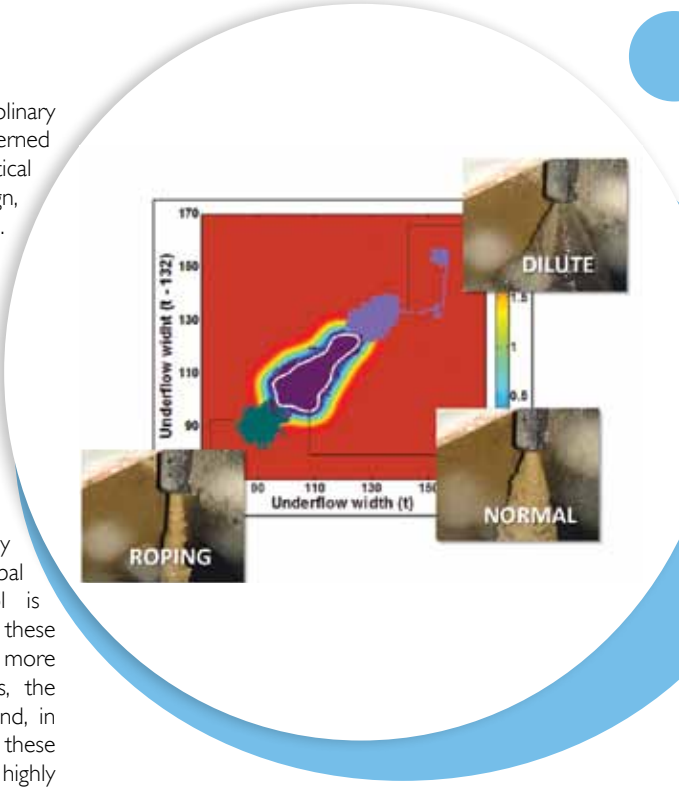


1. *Simulation of flow patterns in pyrometallurgical converters using computational fluid dynamics showing mixing of phases and splashing. The analysis allows the design of improved gas injection systems for the converters, which are widely used in the platinum industry.*

2. *Bonded particle modelling reveals the fracture patterns in ore particles when subjected to confined bed compression. By comparing fragments resulting from compression of particles that have been subjected to different pre-treatment methods it is possible to estimate the benefits of new technologies designed to improve the liberation of valuable minerals.*

Process Systems Engineering

Process Systems Engineering is an interdisciplinary field within Chemical Engineering concerned with computational methods for mathematical modelling and simulation, process design, process control, and process optimisation. The Department of Process Engineering currently focuses on process monitoring and fault diagnosis, the development of smart sensors and development and applications of algorithms able to learn from plant data.



Monitoring a hydrocyclone by means of image analysis.

Process monitoring and fault diagnosis

Manufacturing and process industries today face stiff challenges in the form of increasing energy costs, increasingly stringent environmental regulations, and global competition. Although advanced control is widely recognised as essential to meeting these challenges, implementation is hindered by more complex, larger-scale circuit configurations, the tendency towards plant-wide integration and, in some cases, a lack of trained personnel. In these environments, where process operations are highly automated, the use of algorithms to detect and classify abnormal trends in process measurements is critically important. With their ability to deal with nonlinearities and large volumes of data, machine learning methods offer a promising approach to the development of advanced fault diagnostic systems. As a result, rapid advances have recently been made in this direction.

Development of smart sensors

Although great strides have been made in instrumentation and sensor infrastructure, many important process variables remain difficult to measure or to infer from other measurements. The successful application of many advanced sensors thus depends on data analytical technology to extract useful information from potentially complex patterns or raw signals. These could be high resolution images of flotation froths or particles on conveyor belts, wide ranging spectra of solutions or slurries, acoustic signals generated in arc furnaces or electrochemical signals in corrosion systems. Development of these technologies dovetails well with the Department's expertise in pattern recognition and learning from data algorithms.

Learning from data

Modern instrumentation allows the generation of prodigious volumes of process data, of limited use without appropriate processing. Computational methods designed to automate learning from data can be used to develop process automation systems. In this Department, the focus is on the development of process analytical technology, as well as application thereof in the process industries.

Separation Technology

Various research projects structured around investigations related to measurement and characterisation of fundamental mass-transfer behaviour, thermodynamic modelling and simulation, as well as pilot-plant verification are under way. Unit operations that receive attention include extraction (low and high pressure), distillation, absorption and membrane separation. Besides general analytical instruments and laboratory equipment, the Separation Technology research group owns three supercritical equilibrium cells, an equilibrium cell for measurement of low-pressure VLE and VLLE, three supercritical pilot units, two pilot-scale columns for characterisation of distillation packing and plates, and three pilot-scale columns for characterisation of distillation and absorption behaviour. Student bursaries and funding for projects are largely sponsored by industry (Sasol, Koch Glitch) and THRIP. Current projects include, amongst others:

- hydrodynamic characterisation of column internals such as trays, random packing and structured packing at both atmospheric and high pressure; considering the influence of various parameters on column performance – especially physical properties of liquid and gas
- phase equilibrium/solubility measurements for various supercritical systems, including long-chain alkanes and alcohols (for both binary and ternary systems), and the thermodynamic modelling thereof
- thermodynamic modelling of mixtures containing associating components – especially water-alcohol systems
- VLLE measurement and identification/characterisation of entrainers for azeotropic mixtures – especially water-alcohol systems
- measurement, characterisation and modelling of liquid-phase mass transfer in distillation systems
- characterisation of mass transfer and effective transfer area of packing
- mass transfer efficiency for CO_2 absorption systems
- pilotplant-scale separation of detergent range alkanes and alcohols using supercritical CO_2
- Hydothermal gasification of industrial waste sludge

1. *Pilot plant for hydrodynamic characterisation of distillation column internals.*

2. *Measurement of vapour-liquid-liquid phase equilibria.*

CENTRES AND INSTITUTES

Centre for Civil Engineering

Centre for Electrical and Electronic Engineering

Institute for Industrial Engineering

Institute for Thermodynamics and Mechanics

Centre for Process Engineering

Centre for Renewable and Sustainable Energy Studies

Centre for Civil Engineering

www.civeng.sun.ac.za

Through this Centre, fundamental and applied research is performed in several specialist fields within Civil Engineering. Major subdivisions are the Institute for Structural Engineering (ISE), the Institute for Transport Technology (ITT) and the Institute for Water and Environmental Engineering (IWE). Research activity over the wide spectrum of Civil Engineering has recently surged, along with postgraduate student enrolment. Current active research fields are:

Institute for Structural Engineering (ISE)
- Civil engineering informatics
- Structural Engineering
  Building and construction materials and materials science; Computational mechanics; Earthquake engineering; Structural design; Structural dynamics; Structural mechanics; Structural optimisation; Structural reliability; Sustainable construction

Institute for Transport Technology (ITT)
- Construction engineering and management
- Construction contract law; Construction risk management; Facility management; and Infrastructure asset management
- Infrastructure procurement
- Geotechnical engineering
- Engineering geology; Geographical information systems; Geotechnics
- Road pavements
- Pavement materials; Pavement engineering
- Transportation engineering
- Intelligent transport systems; Road safety; Traffic engineering

Institute for Water and Environmental Engineering (IWE)
- Coastal engineering
- Harbour engineering
- Environmental engineering
- Flood hydrology
- Hydraulic structures
- Hydraulics
- Pipeline and pump station design
- River hydraulics and storm water
- Urban water services
- Water purification
- Water resource development

National and international collaboration and leadership in academic, industrial and research bodies provide research students and clients of the Centre for Civil Engineering the benefit of national and international expertise. Included are the Concrete Society of Southern Africa (CSSA), Engineering Construction Risk Institute (ECRI), International Association of Bridge and Structural Engineering (IABSE), International Commission on Large Dams (ICOLD), Transportation Research Board (TRB), World Association for Sedimentation and Erosion Research, of which members of the Centre of Civil Engineering are key members, varying from active members, chairmen, Vice-President (IABSE), and President (CSSA).

A strong community involvement is represented by the Technology Research Activity Centre (TRAC). TRAC annually exposes learners to physical science and technology in more than 25 TRAC centres nationally, including large, mini, mobile and satellite laboratories. Of those exposed, several hundred enter tertiary education in science, engineering and technology.

Centre for Electrical and Electronic Engineering (CEEE)

www.ee.sun.ac.za

The CEEE is an organisation that operates under the wing of the Department of Electrical and Electronic Engineering, with a mission of promoting the Department itself whilst at the same time advancing the knowledge and status of its lecturers and students. The CEEE is run by a steering committee reporting to the Faculty Council. The activities of the CEEE are divided among five research units, namely the units for Electrical Energy; Electronics and Electromagnetics; Computers and Control; Cybernetics; and the unit for Signal Processing.

To achieve its mission the CEEE undertakes development and research projects for external organisations in both applied and basic research in all fields of Electrical & Electronic Engineering. With few exceptions, all academic staff are involved with the CEEE and they negotiate and execute external contracts on own initiative. Results appear in the form of products, papers, patents and publications and about three quarters of the contract profits are ploughed back directly to the benefit of the Department of Electrical and Electronic Engineering. Benefits take the form of postgraduate bursaries; research materials; software; foreign travel and the appointment of contract staff. By payment of a levy on the work done, funds are also channelled to the Faculty and the central university.

Besides the income generated by direct contracts, the CEEE is an important partner in the exploitation of other sources of funding, such as government sources via the NRF's SARChI and THRIP programmes. The CEEE activities also involve the

laboratories and workshops of the Department, thereby funding them and their associated technical staff and facilitating acquisition of apparatus and extension of the facilities. Research is also undertaken by the CEEE in collaboration with other academic organisations, both in South Africa and abroad; so that at any given moment research collaboration agreements with at least three or four external universities exist.

Institute for Industrial Engineering (IBi)

www.ie.sun.ac.za

At the Department of Industrial Engineering all research is carried out by the Institute for Industrial Engineering (IBi). The Institute for Industrial Engineering is a business unit with a constitution, a steering committee and a set of accounts in the University, through which the staff of the Department of Industrial Engineering do contract research and contract consultation to the business world outside the University.

The IBi does not usually employ any staff; it merely uses and supports the academic Department of Industrial Engineering.

Research in the Department of Industrial Engineering is undertaken to improve global competitiveness through the IBi and its associated bodies, i.e. Global Competitiveness Centre (GCC) and the Centre for Robotics (SENROB).

The areas of research for improving global competitiveness are:

- Strategic industrial engineering
- Systems engineering
- Applied industrial engineering
- Engineering management
- Maintenance management

Research carried out by the Institute of Industrial Engineering is supported by excellent laboratories and infrastructure, collectively known as IBi Laboratories, a service unit within the IBi. An IBi-laboratory engineer is responsible for all laboratory and research support functions for the Department. The laboratory areas are SENROB, the Rapid Product Development (RPD) workshop, Rapid Product Development (RPD) office area, the Metrology Laboratory, and the Production Laboratory.

The mission of the IBi labs is to provide a long-term, sustainable learning environment for postgraduate researchers and to support undergraduate learning in an industrialised environment.

All short courses, whether part of the existing postgraduate curriculum or otherwise, are presented through the IBi.

Institute for Thermodynamics and Mechanics (ITM)

www.itm.sun.ac.za

The Institute for Thermodynamics and Mechanics (ITM) is the body through which the Department of Mechanical and Mechatronic Engineering offers services to the engineering community. These services include research and development, specialist consulting, laboratory testing and measurement, and continuing professional education. The ITM plays a key role in strengthening the research and teaching activities of the Department and more than 80% of the ITM's turnover is spent directly on academic-related expenses and in support of postgraduate students.

The Department has world-class facilities for conducting research and specialist consulting work in various mechanical and mechatronic engineering fields. The research activities of the Department and ITM usually take place in close collaboration with industry. Clients include companies from the aerospace, automotive, manufacturing, mining and energy sectors. The ITM assists companies in attracting government subsidies for research and development work, such as through the THRIP programme, in which up to 50% of the costs of a project are contributed by the South African government. Combining the research activities of postgraduate students with the research and development activities, often allows companies to enjoy advanced technical resources at a moderate cost, while the students are ensured that their work is relevant to industry.

All academic staff members of the Department of Mechanical and Mechatronic Engineering, most with PhD degrees and many registered as Professional Engineers, are members of the ITM. In this capacity they lead and participate in research and development projects for industry. The research and development work is supported by full-time technical staff members and a number of administrative and support staff in the Department.

The Department also has its own workshop that provides services that include turning, milling (CNC and conventional), sheet metal and welding work for purposes such as the manufacturing of prototypes or equipment for experiments.

Centre for Process Engineering

www.chemeng.sun.ac.za

The Centre for Process Engineering is the research, development and service organisation of the Department of Process Engineering. The Centre was established in 1999 with the aim of making the expertise and knowledge of the personnel and the facilities of the Department available to industry and the interested public.

At the Centre, research and development are grouped under four main themes, viz. Mineral processing, Separation technology, Bioprocess engineering, and Process monitoring and engineering systems, each of which area of specialisation enjoys considerable support from the chemical and metallurgical process industries. Our academic personnel would welcome enquiries about project work, primarily in the areas mentioned above.

The aims of the Centre can be summarised as follows:

- to undertake research and development and new applications in our areas of expertise and to make the results available through workshops, symposia, patents and publications in reputable journals and conference proceedings
- to offer the knowledge and extensive infrastructure of the Department to industry and other academic institutions by means of collaboration in research projects, design and problem solving. Postgraduate students may also benefit by working on real problems relevant to industry
- to provide training to qualified engineers by means of advanced and continued professional education

Centre for Renewable and Sustainable Energy Studies (CRSES)

www.crses.sun.ac.za

Stellenbosch University has well-established research and teaching expertise spanning a wide spectrum in renewable energy, from solar and wind energy to conversion of biomass into liquid fuel. This University has been awarded the responsibility to act as the hub of a postgraduate Programme in Renewable and Sustainable Energy Studies by die Department of Science and Technology. The hub is supplemented by a number of other research groups, chairs and activities forming the spokes of a hub and spoke model.

The Centre for Renewable and Sustainable Energy Studies (CRSES) was established in 2006 and is currently partly funded by the Department of Science and Technology (DST) through the Postgraduate Programme in Renewable and Sustainable Energy Studies. The hub of the Programme is in the Faculty of Engineering at Stellenbosch University in collaboration with other departments and institutes within the University structure, as well as the Sustainability Institute (SI), which is based at Lynedoch outside Stellenbosch.

The primary objective of the Postgraduate Programme in Renewable and Sustainable Energy Studies is to train scientists and engineers. These professionals will have the required technical expertise to unlock the country's renewable energy resources by implementing appropriate technology for sustainable energy utilisation.

Various postgraduate degree programmes in renewable and sustainable energy studies, as well as modules and short courses in renewable and sustainable energy, are offered. Bursaries are available to South African students studying on a full-time basis in the broad field of renewable and sustainable energy studies.

The Centre is also active in contract research and specialist projects. The research areas are:

- Solar thermal energy
- Wind energy
- Bio-energy
- Ocean energy
- Solar photovoltaic systems

The staff complement of CRSES, with its collaborators and supported students, ensure that the mandate of the Programme is met under the guidance of a three-level management structure, namely a strategic Advisory Board, a controlling Management Board and an executing Executive Committee.

CRSES completed its first five-year period in 2011 and the next five-year period commenced in 2012.

Stellenbosch University has been awarded the responsibility to develop expertise in renewable energy technology as part of the Eskom Power Plant Engineering Institute. The initial focus of this work will be on the training of operating and maintenance staff for wind energy as well as the sponsorship of a Chair in Solar Thermal Engineering in the Department of Mechanical and Mechatronic Engineering.

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