Engineering The Future

There is an urgent need for innovation in science and technology – globally, but especially in South Africa, as the economic powerhouse in Africa. But this will only be sustainable if the country can also bridge the "innovation chasm" and transform innovation and research into commercially viable products and services and create new industries to drive economic growth.

Research at UCT contributes to cutting-edge developments in various technologies and scientific discoveries, from information and communications technology and biotechnology to mining beneficiation, that are crucial to the advancement of the South African economy.

With a fast-developing economy pursuing sustainable growth, the South African national research and development strategy has come to emphasise innovation – in particular, commercially viable innovation of relevance to economic growth and wealth creation. This requires a substantial investment in the development of new technologies and capacity that will enable the country to convert its undisputed research expertise into social and economic advantages.

Bridging the innovation chasm is a national imperative and it demands a collaborative response from government, industry and universities.

As one of the country's leading universities, UCT is deeply committed to this national research and development strategy and to pursuing sustainable development.

The Faculty of Engineering & the Built Environment at UCT is very active in this regard and is rated as one of the finest on the continent. It has the highest number of NRF-rated engineering academics in South Africa and has strong links with industry and government agencies, which provide significant funding for a variety of research projects.

The faculty is recognised as a world leader in key engineering technologies such as synthesis gas technology, fuel cell technology and hydrogen.

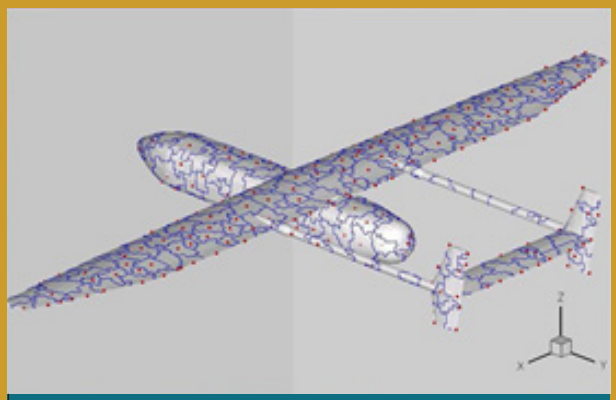
To strengthen this already strong research focus, UCT was awarded two new South African Research Chairs in Engineering in 2012, one in Reaction Engineering and the other in Industrial Computational Fluid Dynamics. These new Chairs, together with existing research programmes spanning UCT's strategic initiatives and research groupings, will actively support the broad South African process industries: the bioprocess, chemical, energy, food, petrochemical and mineral-processing industries, which represent a substantial component of the nation's gross domestic product. Whereas manufacturing is the largest contributor to national GDP, chemical manufacturing is the largest sub-sector and UCT is at the forefront of driving innovation in this area.

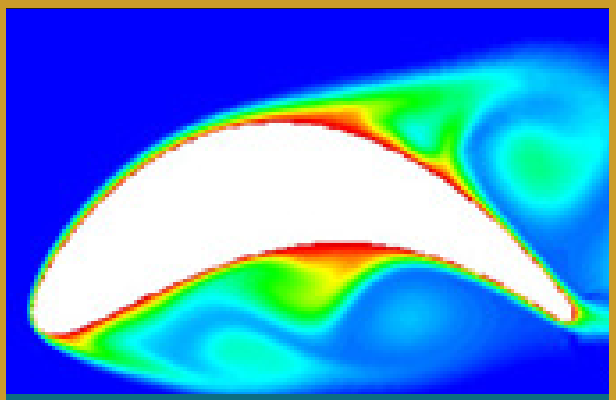
There is also a strong emphasis on sustainability research as well as on developing green technology, such as wind-turbine technology and solar energy, amongst others. Another interesting focus with a global component is on impacts and explosions. Two current major worldwide concerns are unexploded landmines and protection against terrorist activity. Highly publicised acts of terrorism such as 9/11 and, most recently, the Boston marathon bombing, have raised awareness of the increased need for protection, and UCT's Blast Impact and Survivability Research Unit is leading a number of projects which seek to study the effect of explosive devices.

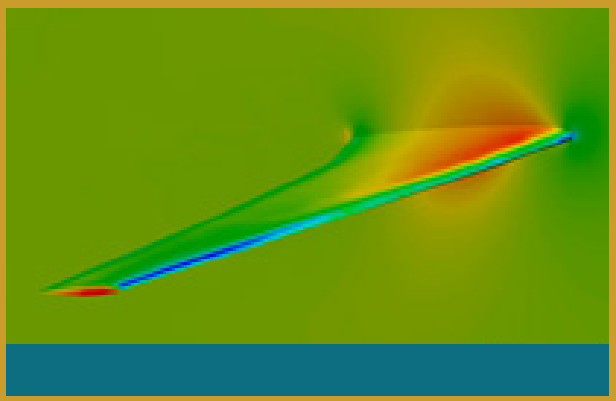
Bridging the innovation chasm is a national imperative and it demands a collaborative response from government, industry and universities. Advances in engineering at UCT are made possible by significant investment from government via the DST/NRF SARChI Chairs, a Centre of Excellence as well as a national Centre of Competence, and the Department of Trade and Industry's Technology and Human Resources for Industry Programme (THRIP), which provides critical industry partnerships.

Working with such partners, UCT plans to continue to rise to the challenge of transforming innovation and research into commercially viable products and services and creating new industries to drive economic growth on the continent.

Pushing the Boundaries of Manufacturing and Design: It's Elemental, Dr Watson ...







Graphical representations of output from computational fluid dynamics analyses conducted using the Elemental software to investigate flows over wing profiles and stresses on an aircraft wing and fuselage.

Computational Fluid Dynamics (CFD) is an exciting new computer-based technology that provides insight into the dynamics of fluid flow, enabling the building of a model to represent a system or device, with accurate prediction of the detailed fluid dynamics offering unprecedented insight and allowing opportunities for virtual prototyping that would be otherwise too costly in the "real" world.

The global commercial CFD software market currently generates over R5.6 billion annually

UCT's Department of Mechanical Engineering is home to an "all South African" CFD code dubbed "*Elemental*". Pioneered by Professor Arnaud Malan in 1999, *Elemental* is already supporting next-generation aircraft design, and Airbus, one of the leading aircraft manufacturers, "found the *Elemental* code to be scientifically innovative while outperforming competing codes by a significant margin, particularly in terms of accuracy". *Elemental* also plays a pivotal role in the European Union FP7 project "Future Fast Aeroelastic Simulation Technologies".

The global commercial CFD software market currently generates over R5.6 billion annually and is one of the fastest-growing fields in engineering. It is becoming the de facto standard strategic design tool in sectors ranging from biomedical devices and power generation to aircraft design and the space industry.

The technology will spawn two UCT spin-out companies – Numerus Technologies (Pty) Ltd and Elemental IP Holdings (Pty) Ltd – during 2013, which will allow South Africa to enter lucrative software and modern technology markets, and which will be well positioned to ride Cape Town's International Design Capital 2014 wave.

Elemental software forms the basis for the DST/NRF SARChI Research Chair in Industrial CFD, which was awarded to UCT in 2012. This will not only contribute to the commercialisation drive, but will support the UCT initiative to further world-class CFD research and technology development.

The Pressing Matter of Mine-water Clean-up

The treatment and disposal of water in the mining sector is a ticking time bomb increasingly threatening South African cities and surrounding communities while garnering the focus of both media and legislative bodies. The success of the research project Refining the BIOX and ASTER processes for Gold, led by Professor Susan Harrison and Dr Rob van Hille of UCT's Centre for Bioprocess Engineering Research in the Department of Chemical Engineering, is therefore no small feat.

South African scientists and engineers – leading the development of bioprocesses for gold recovery from sulphidic ores – have in the past achieved the worldwide commercialisation of BIOX™, a hydrometallurgical process in which micro-organisms oxidise iron and sulphur within the gold mineral concentrate. The outcome is soluble ferric iron and acid that leach sulphidic minerals from the concentrate, leaving gold accessible for extraction with a cyanide solution.

This latest research at UCT focuses on refining this technology to improve performance and robustness, with a particular focus on process intensification through the use of modern molecular tools for tracking the microbial consortium present in the process.

Associated with this process is the more recently launched ASTER™ process for microbial remediation of residual cyanide and thiocyanate formed in the gold-recovery process.

Another key issue surrounding the mining industry is that of responsible mine closures following cessation of mining activities. The ASTER™ process is linked to both the BIOX™ process for remediation of its effluents and the maximisation of water recycle towards zero emissions, as well as associated precious metal extractions using other upstream technologies followed by extraction with cyanide

The research, funded through Goldfields, has been presented in China, Germany and the USA, with a range of journal papers in preparation, in addition to industrial application of its findings.

Getting the Mining – Cost – Environment Balance Right

South Africa's mineral resources are being depleted, making it necessary to find ways to extract metals from increasingly lower-grade resources. This requires technologies with low energy and processing inputs that provide a balance between resource beneficiation, cost efficiency and environmental impact.

Heap bioleaching technologies can do this, in addition to having the potential to process waste rock displaced in the mining operation. The technology uses available iron and sulphide as an energy source, and provides leaching agents for metal extraction from low-grade ore that is crushed and stacked in large heaps, which are irrigated and aerated so that micro-organisms grow on the rock surface.

South Africa has played an important role in the development of technology for "hot heaps" operating under thermophilic conditions – relatively high temperatures that cause certain bacteria to grow. This UCT project focuses on understanding the micro-environments established within the heap that can be manipulated to intensify the leaching process. Through use of custom-designed equipment, this project has presented the first rigorous characterisation of microbial growth rates on whole ore under temperatures ranging from ambient to 65˚.

The project, now completed, was funded by BHP-Billiton and led by Professor Susan Harrison, who holds the NRF/DST SARChI Research Chair in Bioprocess Engineering Research. A team of researchers from the Centre for Bioprocess Engineering Research in the Department of Chemical Engineering have contributed to this cross-disciplinary study, along with Dr Rob van Hille, Associate Professor Jochen Petersen, Emmanuel Ngoma, Nathan van Wyk, Lucinda Bromfield, Frances Pocock and Lukhanya Mekuto, Cambridge University's Dr Andy Sederman, UCT PhD graduate Marijke Fagan, and Imperial College London's Professors Jan Cilliers and Peter Lee.

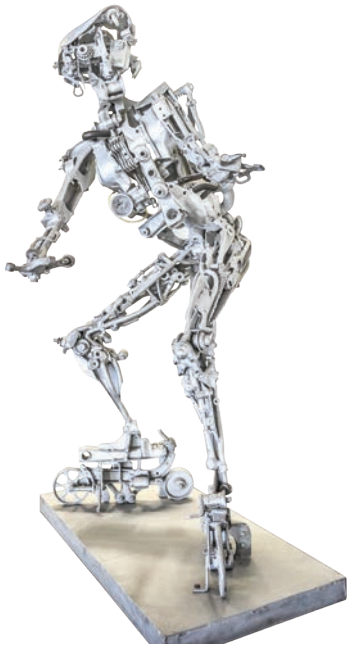
Five journal papers were published and a further six were prepared for publication in 2013.

Cooking up a storm:

Adding Value To South Africa's Process Industries

The Department of Chemical Engineering is recognised locally and internationally as the leading academic department of its kind in Africa. It has cemented a reputation for unique research programmes and projects that meet the challenges posed by a highly developed industrialised era.

UCT's Department of Chemical Engineering helps to keep South Africa at the forefront of emerging technologies in various important economic sectors such as mining, water management, bioenergy and renewable energy, greenhouse gas emission reductions and pharmaceutical developments regarding insulin and antiretroviral medication.



Research in the department has grown significantly over the last ten years, with postgraduate numbers doubling from 92 in 2002 to 185 in 2012. The department hosts four university-accredited research groupings: the Crystallization and Precipitation Research Unit and the Centres for Bioprocess Engineering Research, Catalysis Research and Minerals Processing Research. There are also two DST/NRF SARChI Chairs (Bioprocess Engineering and Minerals Beneficiation), the DST/NRF Centre of Excellence in Catalysis, and the DST Competence Centre in Hydrogen and Fuel Cells, as well as one of the university's Signature Research Themes in Minerals to Metals.

The goal is for South Africa to supply 25% of the future global fuel-cell market with novel, locally developed and fabricated platinum-group metal catalysts by 2020.

The DST/NRF Centre of Excellence in Catalysis (c*change) is a virtual research programme of national scope and significance, with multidisciplinary participants from ten higher-education institutions. Its core focus is the field of catalysis science – a critical industrial technology underpinning the South African economy. This includes the Fischer-Tropsch process, that converts coal and natural gas to liquid fuels, which currently provides 40% of South Africa's liquid-fuels requirements. In

April 2012, c*change hosted the country's first syngas convention, marking another important step in the path to cementing the country's pre-eminence in this area.

The work of c*change also feeds into the National Hydrogen and Fuel Cells Technologies Flagship project, branded as Hydrogen South Africa (HySA), that is seeking to establish South Africa as one of the few nations that export high-value products into the growing international hydrogen and fuel-cells markets. Recognising the importance of the potential role of hydrogen in the economy, the South African government has established three competency centres nationwide under the HySA banner. HySA/Catalysis, based at UCT and co-hosted by Mintek, has been mandated to develop the competency, skilled workforce, and ultimately the manufacturing industry to support a hydrogen economy in South Africa. Current research focuses on alternative energy sources that are locally produced.

Platinum-group metals are key catalytic materials in hydrogen fuel cells and South Africa is strategically situated, possessing 75% of the world's platinum reserves. The goal is for South Africa to supply 25% of the future global fuel-cell market with novel, locally developed and fabricated platinum-group metal catalysts by 2020, thereby diversifying the applications of the nation's platinum-group metal resources and promoting socio-economic benefits through value addition to its key natural resources.

Another major research focus in the department that is attracting international attention is in bioprocess engineering. UCT has a long track record of research in bioprocess engineering dating from the late 1960s. The bioprocess engineering research grouping was formalised as an accredited unit, BERU, in 2001 and its accreditation was upgraded to the Centre for Bioprocess Engineering Research (CeBER) in 2008. CeBER's vision is to be a cross-disciplinary research enterprise, developing the nation's bioprocess engineers, providing new insights into bioprocesses and bioproducts and becoming global leaders in selected relevant research niches.

One of the main research areas in CeBER is bioleaching, a process where microbes are used as biocatalysts to convert metal compounds into their soluble forms. This leaching process is an alternative economical method for the recovery of metals such as copper, zinc and gold from low-grade mineral ores, with low investment and operation costs.

CeBER also strives to address environmental issues primarily related to water. Current projects consider acid rock drainage prevention through enhanced management of waste materials and remediation as well as emerging

technologies for renewable energy generation and greenhouse gas emission reductions.

Also concerned with the elimination of waste is the Centre for Minerals Research, a multidisciplinary, inter-departmental research centre located within Chemical Engineering focusing on the processes of froth flotation, comminution and classification. Inefficiencies in these processes translate into both an enormous loss of revenue and an unnecessary waste of the world's valuable and steadily declining mineral reserves.

All these activities play a crucial role in ensuring that UCT contributes towards keeping South African science healthy and competitive. More importantly, the emphasis on sustainability and capacity development throughout is also playing to the national imperative to bridge the innovation chasm in the country. It is this that will be the real engine for innovation at UCT in the years to come.

Research Project

Keeping the Lights On

Rolling blackouts will continue to plague South Africa unless the country's brightest sparks establish research solutions to stabilise and control the nation's power systems.

UCT's Department of Electrical Engineering is investigating ways to transmit more power in a reliable and efficient way with the use of High Voltage Direct Current (HVDC) transmission lines, parallel to High Voltage Alternating Current (HVAC) transmission lines. Using HVDC offers economic and technological advantages compared to using HVAC alone. The hybrid system brings new challenges of its own and focus has been on the interactions between HVAC and HVDC, and the effect of line length on the stability of the system.

A research team led by UCT's Professor Komla Folly are now involved with the second phase of the project. Their research investigates a broader application of this concept to a new Smart Grid and deals with the potential outcomes of introducing more renewable energy sources and technologies to the grid, which would result in a more complex power system that would become increasingly difficult to control. Maintaining the security and stability of the system is critical to achieving a reliable power supply, along with sustainable development of the electric power industry and the nation's economic growth.

In addition, researchers are mindful that HVDC transmission systems and renewable energy technologies that are available in Africa, but underutilised at present, have the potential to be developed for commercialisation and to create the type of "green jobs" crucial for moving towards a green economy.

Project collaboration included researchers at UCT, the University of KwaZulu-Natal and Cape Peninsula University of Technology, as well as at universities elsewhere in Africa, and in Asia, the USA and Canada. Eskom and Zeta Power Consulting provided industry collaboration. The project was funded by the Department of Trade and Industry's Technology and Human Resources for Industry Programme. Over the course of the project, 15 MSc and two PhD students have graduated, of whom 98% are black and three are female. Several conference papers and journal articles have been published between 2010 and 2012.

Associate Professor Genevieve Langdon

Impacts are a part of daily life, ranging from minor bumps to devastating explosions. Associate Professor Genevieve Langdon, who leads the Blast Performance of Novel Lightweight Materials project in the Department of Mechanical Engineering, seeks to study the effect of explosive devices.

Her primary focus is on the response of lightweight materials and structures to blast loading. This includes materials such as fibre-reinforced polymeric composites, textile concrete, hybrid metal-composite structures, sandwich panels, and cellular materials such as honeycombs and foams.

Her primary focus is on the response of lightweight materials and structures to blast loading.

Unlike traditional steel structures, lightweight materials absorb energy through a wide range of different failure mechanisms and often recover much of their original shape once the pressure is removed. This makes understanding the changing behaviour of lightweight materials particularly important and challenging.

She was also involved in the setting up of an apprenticeship programme that seeks to boost skills in the engineering sector.

Associate Professor Langdon completed a fellowship, funded by the 1851 Royal Commission, at the Blast Impact and Survivability Research Unit at UCT and worked at the University of Liverpool Impact Research Centre from 1999 to 2004. As part of her role at UCT, she was also involved in the setting up of an apprenticeship programme – UCT's first – in the Department of Mechanical Engineering that seeks to boost skills in the engineering sector by offering internships to newly qualified interns in the industry. She is also a founding member of the new South African Young Academy of Science – a group that is designed to bridge the gap between the more senior and well-established Academy of Science of South Africa and the up-and-coming young scientists who may well be future leaders in their fields.

Researcher Profile

Associate Professor Hans Beushausen

Associate Professor Hans Beushausen of the Department of Civil Engineering received the UCT College of Fellows Young Researcher Award in 2012 for his research on concrete durability, performance assessment of concrete structures, and repair systems for concrete structures.

He is the founding member and unit leader of the Concrete Materials and Structural Integrity Research Unit at UCT, which focuses on concrete infrastructure performance and renewal. He has supervised or co-supervised more than 35 postgraduate students in the last five years, 21 of whom have graduated to date.

Within South Africa and other African countries, Associate Professor Beushausen is recognised as a leading researcher in his field. In addition, he has supervised or conducted about 200 consulting projects between 2010 and 2012. Among his clients were the South African National Roads Agency, Eskom, the Namibian Ports Authority, and the Namibian Water Authority.

In March 2012, he was awarded the Wason Medal for Materials Research, together with Professor Mark Alexander and Mike Otieno.

Research Groupings
associated with this theme

Sasol Advanced Fuels Laboratory

The Sasol Advanced Fuels Laboratory (SAFL) was established in 2002 to actualise Sasol's future-oriented fuels research relating to combustion and emissions from automotive and aviation engines. A parallel goal was the development of human-resource capacity to meet Sasol's and South Africa's future technology needs. SAFL activities for the past year are reflected in five master's degree graduations and seven conference/journal publications. In addition, the appointment of a senior chemistry research leader has expanded the discipline base at the SAFL from being predominantly mechanical engineering to include a chemistry/chemical engineering capability as well. Capital investment at the SAFL has been substantially augmented with the recent acquisition of a sophisticated single-cylinder test engine that is representative of next-generation automotive technology.

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Centre for Catalysis Research

The Centre for Catalysis Research concerns itself with both fundamental and applied research and development in the general field of heterogeneous catalysis – encompassing all of catalyst synthesis, physico-chemical characterisation and performance evaluation for industrially interesting chemical conversions. The principal fields of investigation include Fischer-Tropsch synthesis, zeolite/acid catalysis (especially as applied to hydrocracking and the transformation of phenols and derivatives) and catalysis by platinum-group metals and gold. In addition, the Centre for Catalysis Research is the host laboratory for the DST/NRF Centre of Excellence in Catalysis (c*change) and the DST Competence Centre in Hydrogen and Fuel Cell Catalysis.

Director: Professor JCQ Fletcher
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Blast Impact and Survivability Research Unit

The Department of Mechanical Engineering has been involved in impact dynamics for over 25 years. The Blast Impact and Survivability Research Unit (BISRU) has developed experimental facilities which include a blast chamber, a selection of drop testers, material characterisation systems, and a sled tester for impact biomechanics. This collection of equipment is unique in that no other university laboratory worldwide has this full suite of facilities in one area. The research activities are aimed at promoting the study and understanding of impact dynamics through projects at senior undergraduate level and master's, doctoral and postdoctoral levels. The research objectives are to reduce the risk of injuries and to save lives through fundamental principles of science and engineering. BISRU currently has several international interactions through collaborative projects with universities in Australia, Argentina, Europe and the USA.

Director: Professor G Nurick
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Concrete Materials and Structural Integrity Research Unit

The Concrete Materials and Structural Integrity Research Unit at the University of Cape Town has been developing technologies and procedures for the design and assessment of concrete structures for more than 20 years. The unit has had a marked focus on infrastructure performance and renewal, largely in response to industry needs.

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Centre for Materials Engineering

The Centre for Materials Engineering strives to educate and train students in techniques and fundamentals in the broad field of Materials Engineering. It also seeks to serve a wide range of engineering activities, giving advice concerning material processing, properties and performance, while maintaining an international profile for its research. The research activities of the centre are aimed at addressing national needs in terms of both the provision of technological solutions and the development of skilled graduates.

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Centre for Minerals Research

The Centre for Minerals Research is a multidisciplinary, inter-departmental research centre based in the Department of Chemical Engineering. The focus of research is on the processes of comminution, classification, and froth flotation, arguably the most important unit operations in mineral beneficiation. The primary objective of the centre is to investigate the above research areas at both an industrial (applied) level and a laboratory (fundamental) level, so as to develop predictive models for describing the performance of industrial units and circuits. The centre enjoys excellent international collaborations with all the world's leading mining companies.

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DST/NRF Centres of Excellence

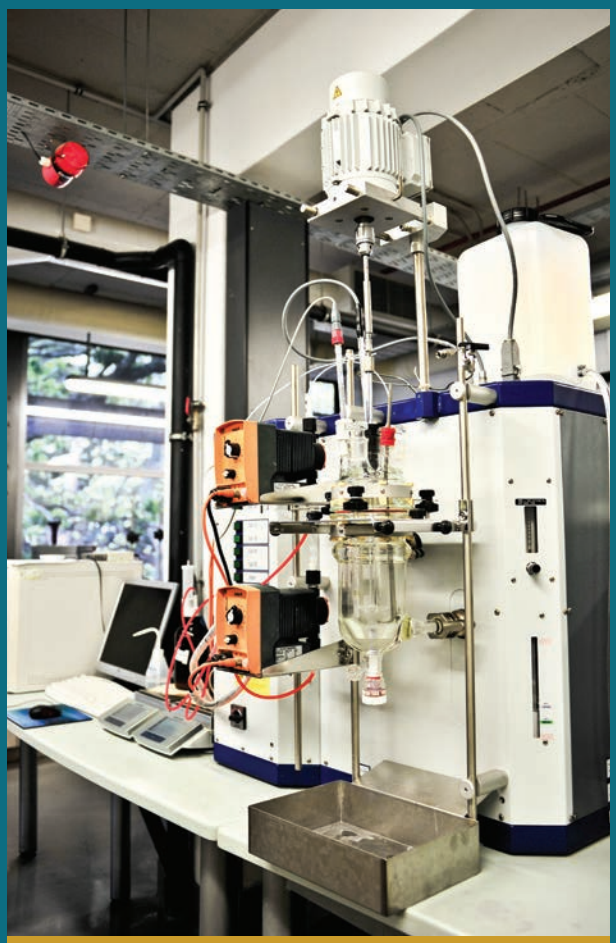
DST/NRF SARChI Chairs

associated with this theme

DST/NRF Centre of Excellence in Catalysis, c*change

The DST/NRF Centre of Excellence in Catalysis, c*change, is hosted by the Centre for Catalysis Research at the Department of Chemical Engineering. During 2012, the c*change team comprised 51 postgraduate students (82% of them South African students, of whom 45% and 76% were female and black, respectively), 12 postdoctoral researchers, and 25 academics from 16 research groupings in 10 participating South African higher-education institutions. A total of 21 projects were funded during the course of 2012, of which 13 were multi-institutional and/or inter-disciplinary ones. The centre was also awarded a DST/NRF SARChI Chair in catalysis

Subsequent to its 2011 participation as a co-organiser of the European Federation of Catalysis Societies Summer School in the Netherlands, c*change has organised a similar three-day Autumn School during 2012. The Autumn School was followed by the c*change Syngas Convention.



Professor Jean-Paul Franzidis

Minerals Beneficiation

Professor Jean-Paul Franzidis obtained his PhD from the Open University in the United Kingdom. He joined the Department of Chemical Engineering at UCT in 1983. His research career has been in various aspects of mineral (including coal) beneficiation, especially flotation. In 1996 he moved to the University of Queensland, Australia, to lead the world's largest collaborative mineral-processing research project, the AMIRA P9 project, which received numerous awards for both research and research methodology. His flotation research led to the development of a steady-state flotation circuit simulator, JKSimFloat, which has been applied to over 150 flotation operations worldwide. From 2003 to 2007 he was Chief Investigator of two large Australian Research Council Linkage grants. In 2007 he returned to UCT to direct the newly formed Minerals to Metals Signature Theme. He was awarded the SARChI Chair in Minerals Beneficiation in 2008.

Bioprocess Engineering

Professor Sue Harrison of the Department of Chemical Engineering holds the DST/NRF Research Chair in Bioprocess Engineering and is the director of the Centre for Bioprocess Engineering Research (CeBER). Her research interests include bioprocess engineering spanning bacterial, fungal, archael and algal bioprocesses with application in biohydrometallurgy, acid mine drainage prevention, maximising resource productivity, wastewater biorefineries, bioenergy products, biocommodities from wastes, fine chemicals, neutraceuticals and expression of niche peptides and proteins. Professor Harrison has a strong interest in minimising the environmental burden associated with processes. Components of research involving clean products and processes and bioremediation processes are currently being focused explicitly around sustainable process engineering to complement a teaching interest in sustainable development in process industries.

DST/NRF SARChI Chairs

associated with this theme

Professor Sue Harrison's presentation at TEDxCapeTown 2012 focused on the potential of integrated bioprocesses to be used to enhance resource productivity. By using resources efficiently, overall demand is reduced, as are wastes requiring assimilation.

Catalysis

The DST/NRF Centre of Excellence in Catalysis, c*change, has been awarded a SARChI Chair in Catalysis, which is expected to boost the scientific output of the centre. The Chair, which has not yet been filled, will focus on the field of preparation and characterisation of nano-materials and assist various activities throughout the centre, with the expectation that this will provide a mechanism of bringing the research of c*change to the level of world-class excellence.

Reaction Engineering

UCT was awarded a SARChI Chair in Reaction Engineering in 2012 and a recruitment process to fill this Chair is currently under way. Reaction engineering comprises all physico-chemical transformations, the design of equipment for their mediation and the integration of such units into complete industrial processes. This Chair is expected to establish competencies and human capacity development; and undertake novel research in South Africa.

Industrial Computational Fluid Dynamics

UCT was awarded a SARChI Chair in Industrial Computational Fluid Dynamics (CFD) in 2012. The recruitment of a candidate is under way and it is envisaged that the Chair will grow the CFD field to develop a CFD technology niche that will empower and serve engineers in industry to develop improved products. CFD is today a widely used strategic tool, with the current market size estimated at R5.6 billion annually. It is also one of the most scientifically rigorous and fastest-developing fields in engineering.