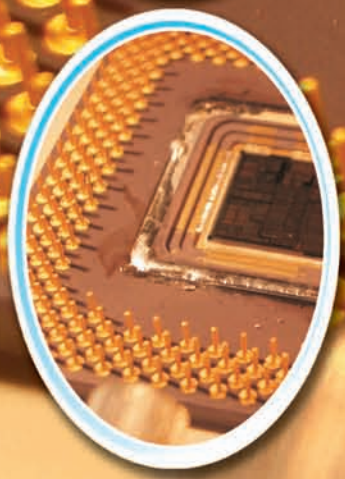
FACULTY OF ENGINEERING



RESEARCH BROCHURE

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Mission

The Faculty of Engineering's Mission is to serve as a cost-effective source of excellent technical expertise, through

- teaching
- research and
- service to industry and the community.

Vision

With its vision statement, Stellenbosch University commits itself to an outward-orientated role within South Africa, in Africa, and globally.

Stellenbosch University:

- Is an academic institution of excellence and a respected knowledge partner.
- Contributes towards building the scientific, technological, and intellectual capacity of Africa.
- Is an active role-player in the development of the South African society.
- Has a campus culture that welcomes a diversity of people and ideas.
- Promotes Afrikaans as a language of teaching and science in a multilingual context.

Introduction

We take pride in showcasing the research of the Faculty of Engineering and we pay tribute to the immense dedication and talent of our many teams of researchers, all deeply committed to a common vision. Collaboration with the Faculty of Engineering at Stellenbosch University means collaboration with a learning and research centre of international standard.

The Faculty of Engineering at Stellenbosch University is at the forefront of basic and applied research, and enjoys international recognition for its work. By focusing on cutting-edge and inter-disciplinary research, the Faculty is experiencing strong growth in its research and postgraduate programmes.

Research activities are supported by quality staff, world-class experimental laboratories, computational facilities and research infrastructure. We attract students of the highest calibre, and our postgraduate students can expect to be supervised by top-notch researchers and academics who share their knowledge in a collegial environment.

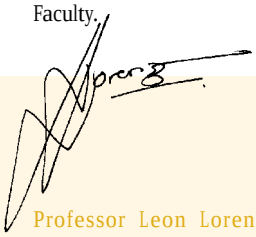
Our Faculty is research intensive and is one of the largest contributors to Stellenbosch University's research income. Research and teaching in the five academic departments is augmented by four major research Centres and two Institutes of international standing, with research groups in these units being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

The Faculty of Engineering is a national leader in the field of research, especially in obtaining funding from organisations such as THRIP (Technology and Human Resources 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.

Our researchers are very successful in supplying high-level engineering expertise to industry and postgraduate students. The Faculty of Engineering celebrated its 60th anniversary in 2004. Some of our achievements over the last few years include:

- Almost 30% of our academic staff has been rated by the National Research Foundation. One of our researchers is rated in the A category which is the top rating one can achieve.
- Successful continuing education with more than a third of our students enrolled in postgraduate programmes.
- Our success in knowledge and technology transfer is reflected in the large number of commercial research contracts requested and the resulting establishment of spin-off companies.
- Our expertise is acknowledged world-wide and our researchers are requested to do consultation work for both national and international industries on a regular basis.
- Our researchers have received numerous prestigious awards for their outstanding work.

We look forward to welcoming you as a research partner, collaborator, supporter or postgraduate student to this world-class Faculty.



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Centre of Process Engineering

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Centre for Civil Engineering (CCE)

The Centre for Civil Engineering (CCE) 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 Civil Engineering do contract research and contract consultation to the business world outside the University. The CCE does not usually employ any staff; it merely uses and supports the academic Department of Civil Engineering. The expertise offered by the CCE thus correlates exactly with the expertise of the Department of Civil Engineering.

Research in the Department of Civil Engineering is undertaken in five main areas through the Centre for Civil Engineering and its associated Institutes, i.e. Transport Technology, Structural Engineering and Water Engineering.

Research areas

- Structural reliability analysis and development of construction codes.
- Advanced cement-based construction materials and structures.
- Engineering process modelling for the pre-construction phase of large construction projects.
- Transportation and pavement engineering.
- Water engineering, including hydraulic engineering, hydrology, water resources and water services.

The research efforts in structural engineering are based on expertise in structural mechanics and dynamics, structural reliability and computational mechanics. The following integrated research programmes exploit these foundations of structural engineering:

- Structural reliability.
- Design code development.
- Cement-based materials.
- Design for earthquake loading.

The discipline which concerns itself with the scientific foundation of computer applications in civil engineering is called civil engineering informatics. Its aim is to make the theoretical foundations of civil engineering operationally useful in engineering practice. Just like steel and concrete, information is a raw material that is created, changed and transferred in large volumes during the course of engineering projects. Towards equipping civil engineers for this task, civil engineering informatics treats the technologies, methods, models and processes applicable to all branches of civil engineering in a systematic way.

Transportation research is being undertaken in the fields of road safety, intelligent transportation systems, traffic engineering, public transport modelling, transportation planning and pavement engineering. Many projects on the effect of road features on the accident rate have been completed and are still being undertaken. Other research projects have been completed in the areas of freeway capacity and vehicle speeds.

Cutting-edge structural analysis technology applied to improve the quality of life of a KwaZulu-Natal rural community. The Institute for Structural Engineering at Stellenbosch University was approached by consulting engineers to undertake a comprehensive finite element analysis of the innovative stress ribbon type structure for the pedestrian bridge - a first for the African continent and at 150 m span, equal to the longest span in the world for this type of structure.

The research activities in pavement engineering have historically been centred on flexible pavements and asphaltic and unbound materials. Over the past two decades, the Division has done research on a national and international level, sometimes in cooperation with other research institutions such as the CSIR, Delft University of Technology and others. In recent years, the Model Mobile Load Simulator (MMLS3), which was developed in the Division, has emerged as a powerful research tool for performance-related research and model validation.

The Model Mobile Load Simulator (MMLS10) that was developed in the Institute for Transport Technology. From the left are Prof Jan Wium (structural designer), Johan Müller (electromechanical and system designer), Michael Franzen (Petrel Engineering) and Prof Fred Hugo (researcher and project manager).

Recent research in geotechnical engineering was done in the field of uncertainty in reliability-based design of pile foundations. The study characterised model uncertainty in static pile design formulae. The generated statistics were used to calibrate partial resistance factors in a reliability-based framework for the range of appropriate levels of reliability, and resistance factors for limit state pile design were recommended.

Hydraulic engineering research includes the fields of coastal engineering and river hydraulics. Stellenbosch University is the only university in South Africa where coastal engineering is taught and also holds the only chair in this field, sponsored by the National Ports Authority. The Department has a long history with research in river hydraulics which includes analytical, mathematical modelling and/or physical models.

The scarcity of water underlines an important research focus: management and modelling of water demand, water resources and return flows. Research in this field is aimed at better understanding how water is used and how the effectiveness of the supply-demand-waste cycle could be improved. The work includes investigation into alternative water resources such as groundwater, desalination, wastewater re-use and the impact of climate change on water resources. The economic value of water demand management is also researched.

Water demand management is being looked into as an alternative to water resource development. In this regard the Department tries to evaluate the aspects playing an important role regarding the decision-making process required for effective water usage to facilitate a viable decision on a local authority level. End-use modelling of water use and return flow is viewed as an essential part of the research in this field. End-use modelling leads to a better understanding of how water is used and returned and it provides increased resolution when studying the supply-demand-waste cycle.

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Structural Reliability Analysis & Development of Construction Codes

Structural reliability forms the basis for assessing the performance of structures through probabilistic reliability modelling. Such techniques are used primarily to gauge procedures for analysis and design of structures, derive insight on various sources of uncertainty, complement experimental and theoretical structural research and ultimately to derive codified design procedures.

The four major activities of this research project are the contributions to the revision of the South African structural loading code SANS 10160, contributions to the revision of the South African concrete construction code SANS 10100, actions induced by fire on building structures, the assessment of the feasibility of using Eurocode EN 1993 as the primary reference code for the following revision of the South African steel construction code SANS 10162, and the development of a South African code of practice for the design of water-retaining concrete structures.

The contributions towards the revision of the South African loading code require substantial fundamental research and investigations into the reliability framework for the basis of design, including the implementation of geotechnical loadings and accidental design situations as well as design-assisted by testing. Specific activities include the reliability assessment of alternative load combinations schemes, partial factors and specified actions including imposed roof loads, wind actions, actions induced by cranes and machinery and seismic actions including design guidelines for effective design against seismic actions. The scope of the code is extended through the inclusion of actions during execution, thermal actions as well as geotechnical actions. The introduction of geotechnical actions requires fundamental investigations into the limit state design procedures for geotechnical structures. An assessment of serviceability criteria forms a fundamental part of the revision of the loading code.

The revision of the South African concrete construction code SANS 10100 will be based on Eurocode 1992. Fundamental investigations into the specifications and models of the code are conducted.

The current practice in fire engineering in South Africa has been investigated. Code provisions in Eurocode EN 1991-1-2 *Actions on structures exposed to fire* as well as EN 1993-1-2 *General rules - Structural fire design for steel structures* have been studied. A literature survey on fire loading and structural design for fire has been completed. A reliability model for simply supported composite steel/concrete beams under fire loading has been developed.

The feasibility of using the EN 1993 *Design of steel structures* code as a possible reference code for the next revision of SANS 10162:2005 is investigated. Comparisons regarding member capacities as well as design effort are established.

A project to develop a standard for the design of water-retaining structures was initiated, with funding provided by the Water Research Commission. Although water is an important national resource, no design standard is available that takes account of local conditions, construction materials and technologies, including structural design standards for buildings and civil engineering infrastructure. The project involves both close interaction with practice in terms of design, construction and water resource authorities; and investigations on technical issues such as cracking and durability of water-retaining structures.

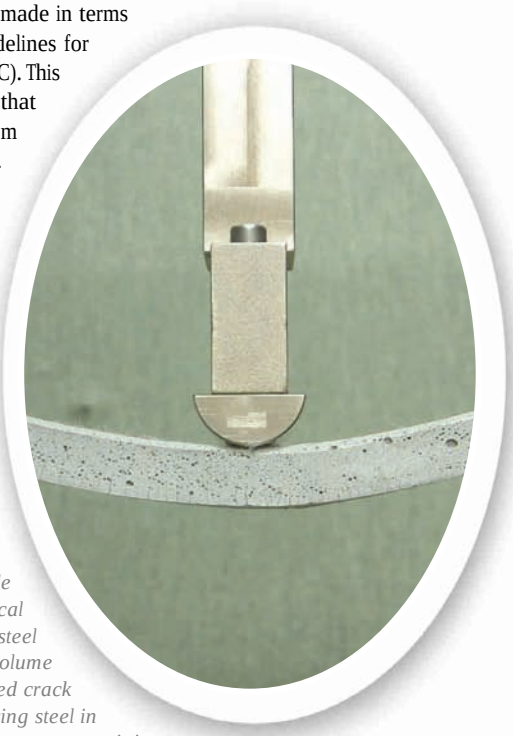
Advanced Cement-based Construction Materials & Structures

The civil engineering/construction industry in South Africa is challenged with a significantly increased national demand for infrastructure and residential structures. The challenge includes to increase the total number of skilled members in this industry, but also to derive improved technologies, materials and rationality of design procedures. The latter refers to alternative procedures for efficient, fast construction. However, equally important is that long-term, life cycle considerations govern in choice of construction materials and design. Durable materials and construction invariably reduce overall construction and maintenance cost considered over the 50 -100 year design life of typical civil engineering structures.

In this Research Group within the Division of Structural Engineering, the above quest is addressed by a research programme focused on durable construction materials, improved and standardised design and construction methods, and sound, rational design standards, calibrated to South African conditions. A group of 10 to 15 postgraduate students participate yearly, including candidates at MScEng through post-doctoral level. Strong interaction between these three themes is strived at, to ensure that comprehensive understanding of advanced materials is translated into appropriate manufacturing processes and specific structural applications that exploit the improved mechanical performance, and rational design guidelines and rules.

A particular focus is on advanced cement-based materials. Recent major international improvements are ultra-high strength concrete and self-compacting concrete. These developments have introduced the era of tailor-made concrete, i.e. the ability to design cement-based composites to required performance, be it ultra-high strength in compression, tension or flexure, or ductility. A current international drive is to develop high performance fibre-reinforced concretes (HPFRC). In this research group a strong contribution has been made in terms of development, characterisation and derivation of design guidelines for fibre-reinforced strain hardening cement-based composites (SHCC). This class of materials has extreme ductility in tension, approaching that of steel. The tensile strength can be engineered in a range from moderate to high, governed by structural performance demand.

Current research studies production processes, including standard mixing and casting, as well as extrusion as a suitable process for prefabrication in the striving to improve quality and production speed. A further focus is on the time-dependent behaviour, relevant for civil engineering structures under sustained loading. The preservation of the inherent crack control of SHCC in time is essential to maintain the structural durability. The mechanisms of time-dependence are considered and described, in order to reach a prediction capability. The derivation of rational design guidelines for these advanced materials in various environmental and mechanical actions to which civil engineering structures may be exposed, is an ongoing activity.



SHCC materials developed in this Group alter the usually brittle nature of concrete, as illustrated by the bend ability of a typical example in the figure. Note that this sample does not have steel reinforcement, but only polymeric fibres at relatively low volume proportion (2%). This bending is accompanied by self-controlled crack widths. This gives SHCC the potential of protecting reinforcing steel in traditional reinforced concrete structures, by using SHCC in cover zones on existing structures in repair strategies, or as outer layers in prefabricated composite structural elements for new structures.

Engineering Process Modelling for the Pre-construction Phase of Large Construction Projects

The engineering process for large projects, for example the development of a new mine, a harbour, or an industrial development area, requires an extensive preparation phase. Fundamental aspects are:

- A complete description of sets of data like technical drawings, three-dimensional digital models or partial models that have to be produced during the execution of the engineering process.
- Engineering tasks that have to be executed to produce these data sets.
- Information about persons involved in the process.
- Tools that are used to execute the processes.

This information is captured on different levels of detail, and it is used in different software systems, for example scheduling systems, workflow systems and document management systems. At the present time, project planners and managers use their experience and expert knowledge to plan and schedule the engineering process. However, there is no underlying theory that guarantees the consistency of the planned process.

A specific technique with a sound mathematical basis that can be used to model engineering processes has been developed. The modelling technique covers the three most important aspects of engineering processes, namely quality of sets of data, time, and money. The technique is independent of the approach chosen to execute a project (2-D or 3-D planning), and a pilot computer implementation has been developed to illustrate the advantages of the model. The current model is capable of providing a consistent logical sequence of tasks and the associated loading of personnel and software tools, the evolution of the status of the data sets, the cost of achieving the data quality milestones, and a time-template that can serve as a basis for the project schedule.

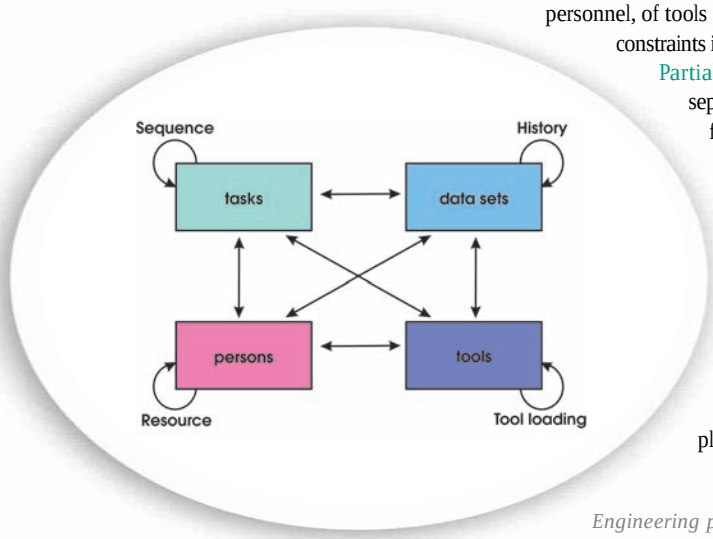
The current pilot implementation will be further enhanced through adding the user interface and certain functionalities which would allow the technique to be tested on a full-scale project with large numbers of tasks, persons, datasets and tools. The following functionalities will be added:

Input side: Input pre-processing based on templates and allowing for work breakdown areas, filtering of specified relationships and error checking.

Effect of modification: Functionalities for visualising and quantifying the effect of subsequent modifications.

Capacity constraints: One of the outputs of the process model is the loading of personnel and tools resulting from the computed logical sequence of tasks. However, it may turn out that there are constraints on the availability of personnel, of tools or of both. The inclusion of such capacity constraints into the process model will be investigated.

Partial models: An ability is required to work separately on partial models which respectively focus on specific areas of a project, and to integrate the partial models into a single consistent model.



Engineering process model relations.

It is envisaged that the process modelling technique will prove to be an invaluable tool in the planning and management of large engineering projects, with huge potential for extending the model for integration with existing software systems and to cover the planning of construction activities.

Contents

Transportation & Pavement Research

Transportation research is being undertaken in the fields of road safety, intelligent transportation systems, public transport modelling and transportation planning, with the main thrust in the field of road safety.

Many projects on the effect of road features and driver behaviour on the accident rate have been completed and are still being undertaken. The way that the road geometry (width, curves and gradients) plays a role in the safety of a specific road has been investigated for all the roads in the Western Cape and KwaZulu-Natal. Another study concentrated on the effect of the riding quality (roughness) of a road on the accident rate thereof. Other research projects have been completed in the areas of freeway capacity and level of service, vehicle speeds on gradients and on horizontal curves and the recognition of vehicle movements by means of video image processing. A new exciting project concentrates on the tracking of minibus taxis by means of the latest communication and location equipment.

The research activities in the Pavement Engineering Division have been historically centred around flexible pavements and asphaltic and unbound materials. Over the past two decades, the Division has acquired suitable equipment to support such research that has been undertaken on a national and international level, sometimes in cooperation with other research institutions such as CSIR, Delft University of Technology, University of Wisconsin at Madison, and others.

A laboratory foam plant and Raschig bitumen-emulsion mill have enabled specialist research to be carried out in cold mix formulations, mix design procedures, material characterisation and performance testing. The outcomes of this research have played an important role in the South African roads industry, where the use of cold mixes for rehabilitation and recycling projects has burgeoned in the past decade.

The Superpave Gyratory Compactor (SGC) of the Transportation Division is used for investigations of cold mix and hot mix asphalt (HMA) to determine compactibility and mix volumetrics at different levels of compaction energy. As with the foam plant and emulsion plant, the SGC is only one of three such devices in South Africa and the only such device located at a tertiary institution.

A Material Testing System (MTS), which is a servo-hydraulic, static and dynamic press, has facilitated research into a broad spectrum of pavement materials, from granular to asphaltic.

In recent years, the Model Mobile Load Simulator (MMLS3), which was developed by Professor Fred Hugo in the Division, has emerged as a powerful research tool for performance-related research and model validation. This third-scale accelerated pavement testing device has been used for laboratory research and field testing of a variety of pavement materials and surfacing seals. The research outputs from MMLS3 testing in the Division have received international recognition.

A large triaxial apparatus has been developed for the testing of unbound and lightly bound pavement materials incorporating coarse aggregate. This apparatus is capable of testing 300 mm diameter and 600 mm high specimens and is enabling more accurate material models to be developed.

Large Triaxial for granular material specimens 300 mm diameter and 600 mm high.

Water Engineering

The Department of Civil Engineering has the largest hydraulic laboratory in Africa where basic research and contract research are carried out in the fields of river hydraulics and coastal engineering. Mathematical modelling is however also used extensively to research river hydrodynamic and coastal engineering problems.

River hydraulics

Recent research focused on:

- Management of reservoir sedimentation.
- The impacts of dams on the river geomorphology and the design of artificial flood releases from dams.
- Hydraulics of sediment dynamics in estuaries, to determine the reserve and for water resources management.
- Design of fishways for South African conditions.
- Positioning and design of river diversion works on rivers to limit sedimentation.
- Dam hydraulics.

The Berg River Dam spillway and outlet works.

Coastal engineering

Stellenbosch University is the only university in Southern Africa where coastal engineering research is carried out.

Current research focuses on:

- Optimisation of placement of concrete armour units for the construction of wave breaking structures (armour units include Dolos, Core-Lock, etc.).
- Optimisation of jet-type dredging pump.
- Current-wave interaction to determine the formation of freak waves in the Agulhas Ocean current on the main shipping route along the South African east coast.
- Hydraulics and sediment transport of intakes and outfalls of power stations.

Hydrology and water resources development

The different factors to be considered in flood determination methods are constantly being evaluated to determine their relevance. Specific factors such as rainfall intensities and area reduction factors are being evaluated with local data to determine the relevance of the use of regional data. The expected impact of climate change on floods has been evaluated.

Design techniques for road surface drainage have been updated and adopted as design practice, to be used as the national standard in South Africa.

Water services

Research in this field includes:

- Estimating non-domestic municipal water demand in South Africa. Analysis of measured water meter readings from the national water consumption archive of the Water Research Commission.
- Correlating end-use estimates of demand based on contingent evaluation to actual measured water use, including extension of the concept to apply the Internet as water demand management tool for residential customers in South Africa.
- Analysis of water savings: A case study of the 2004-2005 water restrictions in Cape Town, South Africa.
- Residential lawn water use in South Africa.
- Modelling domestic sewer flow from residential dwellings, including the response to changes in indoor, outdoor and hot water demand.
- The development of South African water demand guidelines with stand size as independent variable.
- The direct, untreated re-use of grey water in serviced, residential areas of South Africa.

Centre for Electrical & Electronic Engineering (CEEE)

"Expert skills in Electrical and Electronic Engineering for Industry"

The Centre for Electrical and Electronic Engineering (CEEE) 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 Electrical and Electronic Engineering do contract research and contract consultation to the business world outside the University. The CEEE does not usually employ any staff; it merely uses and supports the academic Department of Electrical and Electronic Engineering. The expertise offered by the CEEE thus correlates exactly with the expertise of the Department of Electrical and Electronic Engineering. The activities of the Department and the Centre are organised into the following groups:

Electronics and electromagnetics

(RF and microwave electronics, antennas, filters, waveguides, distributed elements and active devices, superconductivity.) The RF and antenna laboratories are equipped to do a wide variety of high-frequency measurements using various test sets, signal generators and power supplies. This includes S-Band and X-Band waveguide measurements, an anechoic chamber where antenna measurements can be made in the range of 2 to 20 GHz, and a high-precision rotator and an x-y positioner which can be used for gain and pattern measurements. Training is offered to increase skills in the practical aspects of radio frequency and high-frequency measurement. In addition, this Group has access to powerful computational electromagnetic simulation packages. The cryogenics and nanofabrication laboratories are equipped with deposition, photolithography and ion etching equipment for the fabrication of nano-electronics, as well as cryogenic coolers for testing down to 3 ºK.

Computers and control systems

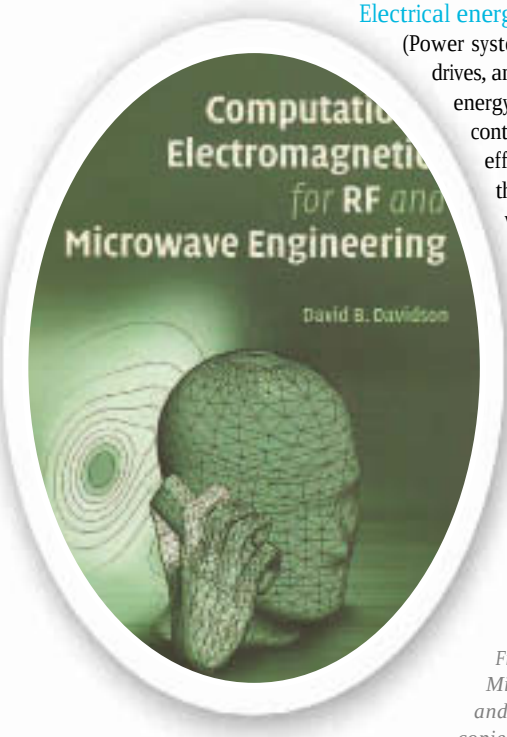
(Aeronautical systems, satellite systems, biomedical electronics, computer/digital systems and control systems.) The electronic systems laboratory (ESL), where the SUNSAT microsatellite was built, offers systems development capability.

Electrical energy systems

(Power systems, high-voltage, power electronics, renewable energy, electrical drives, and electrical vehicles.) Contract research and consultation in electrical energy systems focus broadly on generation, transmission, conversion and control of electrical energy which includes, amongst other things, energy-efficiency, renewable energy and electrical vehicles. Facilities include three large, world-class laboratories concentrating respectively on high-voltage, power electronics and electrical machines. Tests in these laboratories can be done at power and voltage levels of up to 3 MW and 400 kV respectively.

Signal processing

(Speech processing and software definable radios.) The activities of the Digital Signal Processing (DSP) Group are centred on research and development of signal processing and pattern recognition techniques and systems for a wide range of applications, with a strong emphasis on human language technology (HLT) as well as digital communication systems. Theoretical expertise within the DSP Group extends to the fields of statistical and syntactic pattern recognition (with a particular focus on hidden Markov modelling),



Front cover of the book "Computational Electromagnetics for RF and Microwave Engineering" authored by a member of the Electronics and Electromagnetics Group, Prof David Davidson. More than 1 000 copies have been sold world-wide.

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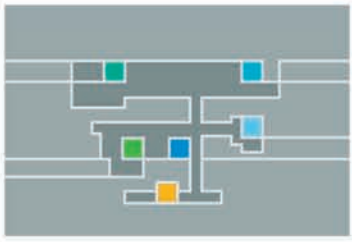

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