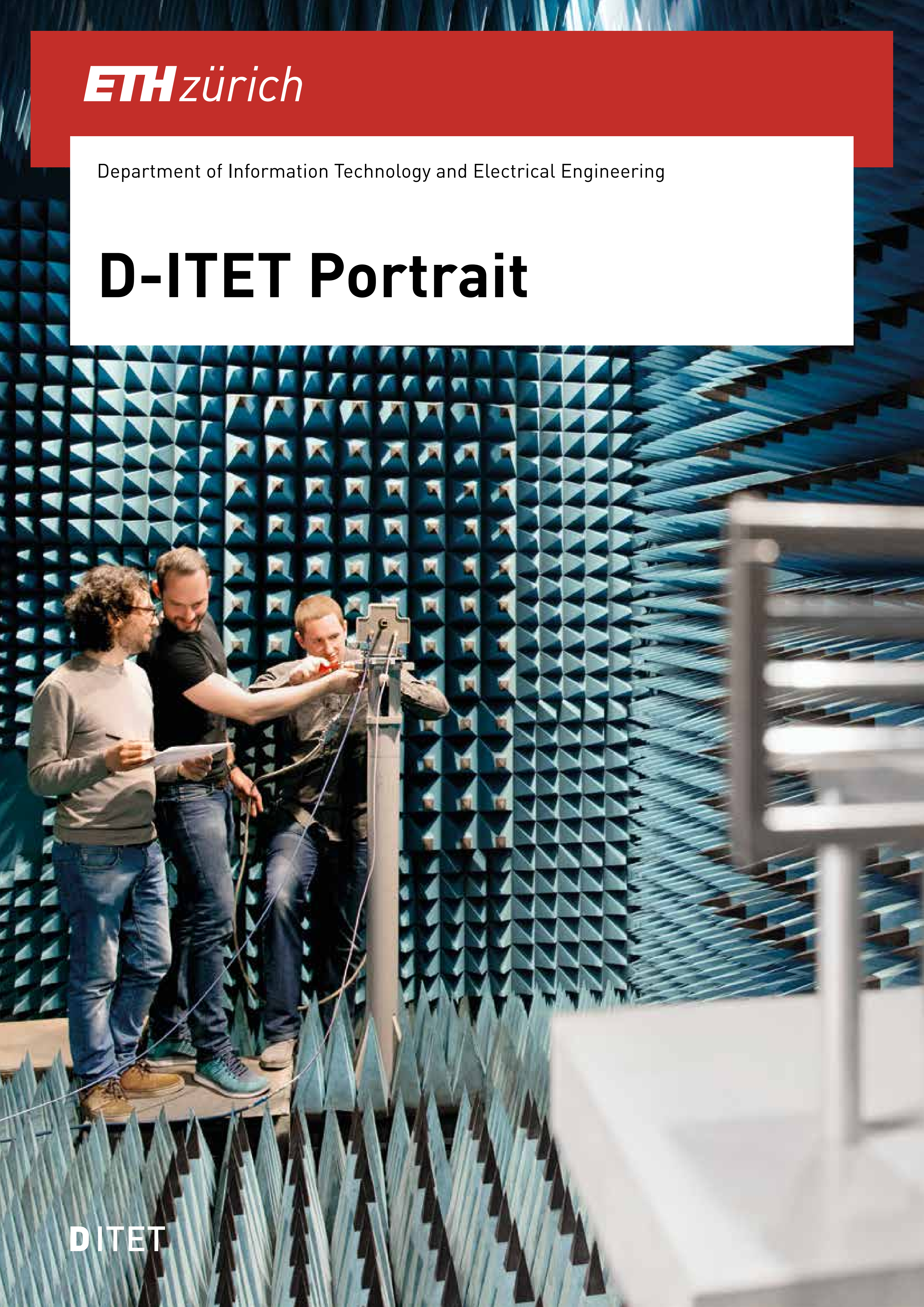
ETH zürich

Department of Information Technology and Electrical Engineering

D-ITET Portrait



DITET

Content

Cover photo: Setup for the research project "Plasmonic Silicon Organic Hybrid (PLASILOR)", Institute of Electromagnetic Fields

Department Management from left to right: Prof. Juerg Leuthold, Prof. Christian Franck, Prof. John Lygeros, Prof. Klaas Prüssmann

Welcome to D-ITET

The field of electrical engineering and information technology is having an ever-increasing influence on the development of our society.

Known for our first-class research and top-quality education, all of us at the Department of Information Technology and Electrical Engineering (D-ITET) devote our strengths to addressing complex challenges that confront our world in the fields of information and communication, electronics and photonics, energy, and health.

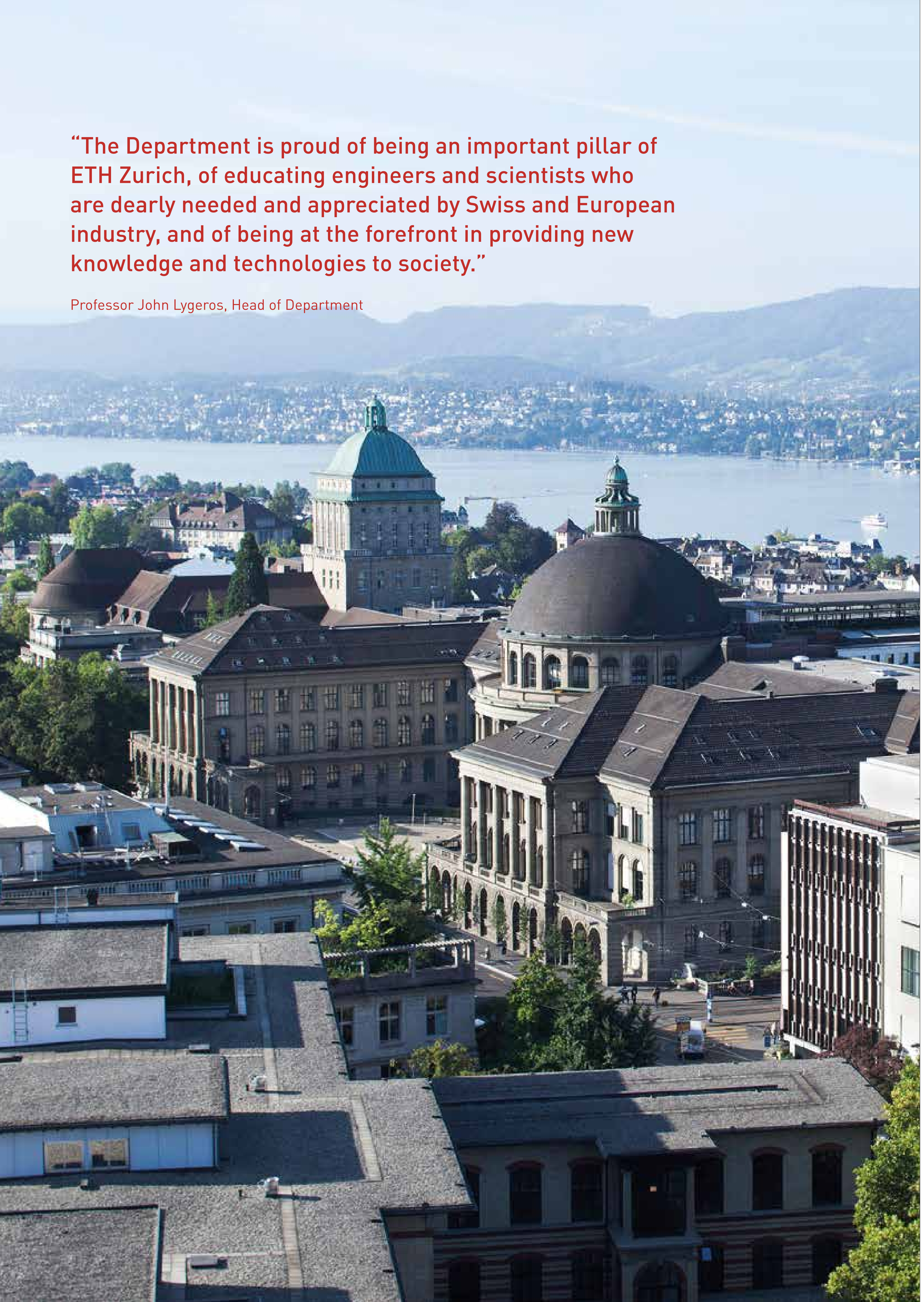
The spirit of discovery and innovation in our team allows us to identify new problems and research areas at an early stage. We also benefit from a strong international network, as D-ITET collaborates worldwide with leading universities, research institutes and industry partners. Finally, our excellent facilities and flexible organisation at ETH Zurich provide a powerful framework for research and teaching at D-ITET. Thanks in part to all of these strengths, our graduates are extraordinary individuals who have gained the knowledge and the skills to leave their mark on the world.

Today we are a community of nearly 2,000 researchers, students and staff from more than 40 countries. As we expand our programmes in the future, we look forward to sharing our vision and increasing collaboration with our students and partners worldwide.

Professor John Lygeros
Head of Department

"The Department is proud of being an important pillar of ETH Zurich, of educating engineers and scientists who are dearly needed and appreciated by Swiss and European industry, and of being at the forefront in providing new knowledge and technologies to society."

Professor John Lygeros, Head of Department



Our Department as part of ETH Zurich

ETH Zurich is well-known for its excellent education, for its ground-breaking fundamental research, and for translating research results directly into practice. D-ITET is a large department of ETH Zurich, and our faculty members are world-renowned experts who pursue pioneering work in information technology and electrical engineering. ETH Zurich regularly appears at the top of international rankings as one of the best universities and its position in the field of electrical engineering is even higher.

D-ITET has made major and lasting research contributions during its history, opening up new fields of research in the areas of bioelectronics, bioimaging, high-speed electronics, nanophotonics, ubiquitous computing, and mobile and ad-hoc networks. Our researchers' ground-breaking work is recognised around the world and has earned them numerous prestigious prizes.

We foster multidisciplinary cooperation among the members of D-ITET and the other departments of ETH Zurich, as well as with academic and industrial partners in Switzerland and worldwide. Acting as an engine of innovation, we pass our knowledge on to major companies, small and medium enterprises, and D-ITET spin-off companies. Our department is active in many cross-disciplinary research centres and initiatives.

D-ITET works in close cooperation with partners in the life sciences. For example, it runs joint biosensors, bioelectronics and bioimaging laboratories, as well as a joint doctoral programme with the University of Zurich. In medical technology, we foster strong partnerships with the University Hospital Zurich and other renowned medical institutions.

Our world-class laboratory infrastructure and high-tech equipment provide excellent conditions for top-level research. D-ITET is an inspiring place for scientists and students.

The ability to constantly adapt to new requirements is one of the keys to the Department's success. Our broad expertise and strong partnerships enable us to respond to new challenges and to continue setting standards in research and education.

D-ITET facts and figures
All data as at December 2016

1,748 students
including:
401 doctoral students
730 Bachelor's students
576 Master's students
41 exchange students

37 professors
7 adjunct professors
4 research areas
17 laboratories

10 ERC grants
7 SNF professorships

CHF **75.0 million** in spending including CHF **54.8 million** core funding from the Federal Government

55 spin-offs since 1997

9 in THE ranking 2016, Electrical and Electronic Engineering
12 in ARWU ranking 2016, Electrical & Electronic Engineering
7 in QS ranking 2016, Electrical & Electronic Engineering


Prof. Luca Benini


Prof. Jürgen Biela


Prof. Helmut Bölcskei


Prof. Colombo Bolognesi


Prof. Gian-Luca Bona


Prof. Florian Dörfler


Prof. Christian Franck


Prof. Orçun Göksel


Prof. Benjamin Grewe


Prof. Ulrike Grossner


Prof. Richard Hahnloser


Prof. Qiuting Huang

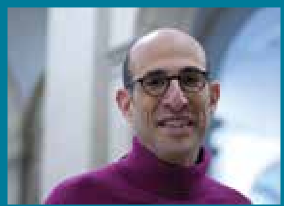

Prof. Gabriela Hug


Prof. Maryam Kamgarpour


Prof. Johann W. Kolar


Prof. Ender Konukoglu


Prof. Sebastian Kozerke

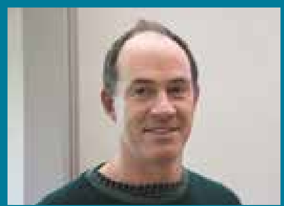

Prof. Amos Lapidoth


Prof. Juerg Leuthold


Prof. Hans-Andrea Loeliger


Prof. Mathieu Luisier


Prof. John Lygeros


Prof. Kevan A. C. Martin


Prof. Lukas Novotny


Prof. Klaas Prüssmann


Prof. Markus Rudin


Prof. Marco Stampanoni

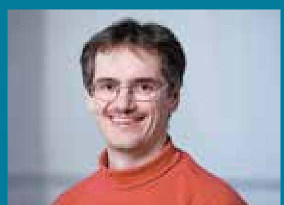

Prof. Klaas Enno Stephan


Prof. Lothar Thiele


Prof. Gerhard Tröster


Prof. Luc Van Gool


Prof. Laurent Vanbever


Prof. János Vörös


Prof. Roger Wattenhofer


Prof. Armin Wittneben


Prof. Vanessa Wood


Prof. Mehmet Fatih Yanik

Our faculty

Research at D-ITET is conducted by 17 laboratories. The guiding principle of all D-ITET laboratories is to encourage excellence and diversity in thinking, and to foster collaboration and innovation across traditional knowledge barriers.

Integrated Systems Laboratory
Prof. Luca Benini, digital circuits and systems
Prof. Qiuting Huang, analogue and mixed-signal design
Prof. Mathieu Luisier, computer-based modelling of nanostructures
Prof. Vanessa Wood, materials and device engineering
Adj. Prof. Hubert Kaeslin, microelectronics design centre
Adj. Prof. Niels Kuster, bioelectromagnetics and EMC
Adj. Prof. Andreas Schenk, nano-device physics

Electronics Laboratory
Prof. Gerhard Tröster, digital systems
Adj. Prof. Anton Gunzinger, supercomputing systems

Millimeter-Wave Electronics Laboratory
Prof. Colombo Bolognesi, high-speed electronics

Institute of Electromagnetic Fields
Prof. Juerg Leuthold, photonics and communications

Photonics Laboratory
Prof. Lukas Novotny, photonics

Photonics Laboratory, Empa
Prof. Gian-Luca Bona, photonics
Adj. Prof. Ayodhya N. Tiwari, thin films and photovoltaics

Communication Technology Laboratory
Prof. Helmut Bölcskei, communication theory
Prof. Armin Wittneben, wireless communications

Automatic Control Laboratory
Prof. Florian Dörfler, complex systems control
Prof. John Lygeros, control and computation
Prof. Maryam Kamgarpour, control systems
Adj. Prof. Roy Smith, control systems and automation

Computer Engineering and Networks Laboratory
Prof. Lothar Thiele, computer engineering
Prof. Laurent Vanbever, networked systems
Prof. Roger Wattenhofer, distributed computing

Signal and Information Processing Laboratory
Prof. Amos Lapidoth, information theory
Prof. Hans-Andrea Loeliger, signal processing

Computer Vision Laboratory
Prof. Orçun Göksel, computer-assisted applications in medicine
Prof. Ender Konukoglu, biomedical image computing
Prof. Luc Van Gool, computer vision

Institute for Power Systems & High Voltage Technology
Prof. Christian Franck, high voltage engineering
Prof. Gabriela Hug, electric power systems

Laboratory for High Power Electronic Systems
Prof. Jürgen Biela, high power electronic systems

Power Electronic Systems Laboratory
Prof. Johann W. Kolar, power electronic systems

Advanced Power Semiconductor Laboratory
Prof. Ulrike Grossner, power semiconductors

Institute of Neuroinformatics
Prof. Benjamin Grewe, systems and circuits neuroinformatics
Prof. Richard Hahnloser, systems neurosciences
Prof. Kevan A. C. Martin, system neurophysiology
Prof. Mehmet Fatih Yanik, neurotechnology
Adj. Prof. Tobias Delbrück, neuromorphic engineering

Institute for Biomedical Engineering
Prof. Sebastian Kozerke, biomedical imaging
Prof. Klaas Prüssmann, bioimaging
Prof. Markus Rudin, molecular imaging and functional pharmacology
Prof. Marco Stampanoni, X-ray imaging
Prof. Klaas Enno Stephan, translational neuromodeling
Prof. János Vörös, biosensors and bioelectronics

Our research: The needs of society in focus

Research at D-ITET addresses the global challenges of sustainable energy, healthcare and information management for the world's growing population. These priorities are reflected in four core research areas: Electronics and Photonics, Information and Communication, Energy, and Biomedical Engineering and Neuroinformatics.

Electronics and Photonics

The global trend towards a green and sustainable society is a driving force for future electronics and photonics. In addition, the market is rapidly evolving in the direction of Industry 4.0 and the Internet of Things. Research at D-ITET focuses on the key enabling technologies to sustain these megatrends: faster, lower-power integrated optical and electronic nanostructures and devices, advanced batteries, solid-state lighting (LEDs), high efficiency photovoltaic cells, flexible electronics, high-speed and low-power communication circuits, green computing systems, and embedded electronics.

Information and Communication

Research in this area deals with multiple challenges, such as the massive and growing amounts of data that need to be processed quickly and intelligently, as well as the ever-growing complexity of computers and networks plus their permeability to inside or outside attacks. Another essential task lies in developing new materials for nanoelectronics, large-scale statistical modelling, processing, and learning. In addition, advancements in neuroscience rely strongly on the development of novel electronics and modelling tools.

Energy

Maintaining a secure and reliable energy supply is widely regarded as one of the most important intellectual and technological challenges of the 21st century. Governments around the world have set ambitious climatic goals, requiring society to increase its integration of renewable energy resources and use energy more efficiently. At the same time, supplies of electrical energy need to provide highly stable levels of availability and reliability.

Biomedical Engineering and Neuroinformatics

Biomedical engineering at D-ITET is guided by the overarching goal of advancing healthcare. Combining electronics with biological principles is essential for advanced clinical applications in all areas of medicine, from prevention and diagnostics to therapy and rehabilitation. Combining life sciences with engineering principles continues to create intriguing opportunities for basic research, healthcare, and the enhancement of daily life.

D-ITET Professors at a retreat at Lake Zurich

“My work revolves around synthetic optimisation of semi-conductor nanocrystals. I aim to optimise their luminescence properties, starting from low-toxic heavy-metal-free compositions. I benefit a lot from the multidisciplinary environment at D-ITET.”

Olesya Yarema, doctoral student, Integrated Systems Laboratory (Nanoelectronics lab)

Electronics and Photonics

The area of Electronics and Photonics covers research in materials, integration technologies and circuits, as well as design methodologies for electronic and photonic devices and systems. Its aim is to push forward the state of the art in current technologies and bring greater understanding to the possibilities for new materials as well as novel device and system concepts.

In the upcoming decades, the economic importance of electronics and photonics will ensure they remain at the forefront of research in applied science and engineering. Our goal is to find new approaches to technology designed for developing components and systems for future electronic applications. On the component level, our research includes the miniaturisation of electronic and photonic components plus improvements in their energy-efficiency, as well as the use of new materials and processes (such as nanoelectronics and organic electronics). Where system development is concerned, we focus on the realisation of green computers and networks, embedded electronics, and smart environments.

At D-ITET, the following laboratories operate in the area of Electronics and Photonics:

Integrated Systems Laboratory
Prof. Luca Benini, Prof. Qiuting Huang, Prof. Mathieu Luisier, Prof. Vanessa Wood, Adj. Prof. Hubert Kaeslin, Adj. Prof. Niels Kuster, Adj. Prof. Andreas Schenk

The scientific activities conducted at the Integrated Systems Laboratory centre on the analysis, design and testing of radio frequency, analogue and digital integrated circuits as well as systems-on-chip. Further activities include the theory, numerical modelling and physical characterisation of semiconductor technologies and devices, plus analysing and simulating bioelectromagnetic objects and systems.

Electronics Laboratory
Prof. Gerhard Tröster, Adj. Prof. Anton Gunzinger

The Electronics Laboratory focuses on miniaturised mobile and flexible electronics, thin-film technology as well as sensor platforms, signal sensor fusion and applied machine learning. It capitalises on this expertise in designing wearable computers capable of smart assistance.

Millimeter-Wave Electronics Laboratory
Prof. Colombo Bolognesi

The research activities of the Millimeter-Wave Electronics Laboratory focus on III-V compound semiconductor devices and processes, from modern sub-terahertz applications to all-electronic terahertz sources.

Institute of Electromagnetic Fields
Prof. Juerg Leuthold

The research activities of the Institute of Electromagnetic Fields centre on devices and applications relying on electromagnetic fields. The Institute covers all wavelengths from optical and THz down to the radio frequency range. Applications include optical and wireless communications and sensing. The team is organised in a way that is designed to cover the whole value chain, from the conception of a novel device to in-house fabrication at clean room premises, right through to system level testing up to 1 Tbit/s and beyond.

Photonics Laboratory
Prof. Lukas Novotny

The Photonics Laboratory studies and explores the interaction of light with nanostructured materials, focusing especially on controlling and enhancing the light-matter interaction with suitably engineered nanostructures, such as optical antennas or resonators. Application areas include optical sensing and metrology, photodetectors, and light-emitting devices.

Photonics Laboratory, Empa
Prof. Gian-Luca Bona, Adj. Prof. Ayodhya N. Tiwari

The laboratory, located at Empa, conducts research focused on optical fibres and planar waveguides for communication and sensor applications. As well as developing new materials and process technologies, the laboratory explores the limits of analytical techniques for optical characterisation, aiming to push beyond them. They also develop new inorganic thin-film photovoltaic cells on flexible substrates (such as CIGS, CdTe, kesterites, perovskites).

Sensor technologies for musical instruments

From teaching and practising support to pain prevention

From a technical point of view, the parameters involved in instrumental music-making and teaching are mainly audible and visible ones. Parameters like force, pressure and coordination – which are millisecond occurrences – are also important, but a lack of technology available for handling them means they are not yet an everyday part of playing or teaching music. Tobias Grosshauser and his colleagues from the Electronics Laboratory are focusing on these parameters, in addition to audio and video analysis, in order to not only support teaching and improve practice efficiency, but also detect fatigue and prevent pain. Achieving this involves equipping musicians or musicals instruments with several sensors. These new sensor setups are evaluated using amateur musicians, students of several music universities around the world, and professionals. Another goal of using sensors is to make it easier to integrate conventional musical instruments into electronic music environments through support for common data formats like MIDI and OSC.

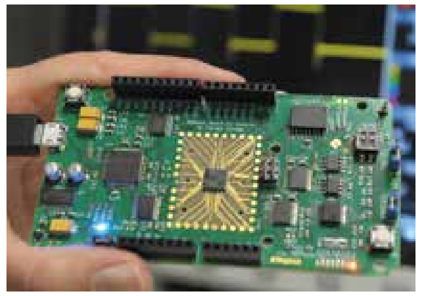
www.ife.ee.ethz.ch/research/music-technology

Computational nanoelectronics

Nanoelectronics on the computer test bench

Electronic components are only a few nanometres (billionth of a metre) in size. The tinier their dimensions become, however, the harder they are to manufacture: quantum mechanical effects such as the tunnelling of electrons through potential barriers start to manifest themselves at the nanometre scale and affect the characteristics of nanoelectronic devices. Prof. Mathieu Luisier has spent over ten years developing a software programme called OMEN, dedicated to the simulation of future transistors and other nanocomponents whose size does not exceed a few nanometres. His work is supported by the CSCS supercomputer "Piz Daint", which helps to predict what happens when the composition, form and size of the underlying materials change in the nanoworld. Luisier and his team use the unique capabilities of their quantum simulator OMEN to study electron transport at the atomic level and shed light on the physics of nano-devices. The modelling approach they implement combines concepts from materials science, physics and, of course, electrical engineering.

www.iis.ee.ethz.ch/research/research-groups/nano-tcad



Open-source microprocessor

PULPino

In the future, it will be easier and cheaper for developers at universities and SMEs to build wearable microelectronic devices and chips thanks to the PULPino open-source processor, which has been developed by the Digital Circuits and Systems Group led by Prof. Luca Benini in collaboration with the University of Bologna. The processor is designed for battery-powered devices with extremely low energy consumption. A processor of this kind could be used in small devices like smartwatches, sensors for monitoring physiological functions (which can communicate with a heart rate monitor, for instance) or sensors for the Internet of Things.

www.pulp-platform.org

Nanoelectronics and nanophotonics

Demystifying nanocrystal solar cells

Scientists are focusing on nanometre-sized crystals with excellent optical properties for the next generation of solar cells. However, developing nanocrystal-based solar cells is challenging. Prof. Vanessa Wood conducted an extensive study of nanocrystal solar cells, which are fabricated and characterised in her laboratories at ETH Zurich. She and her team were able to describe the electron transport in these types of cells via a generally applicable physical model for the first time. The model will give scientists in this field of research a better understanding of the physical processes inside nanocrystal solar cells and enable them to improve solar cell efficiency.

www.iis.ee.ethz.ch/research/research-groups/nano-electronics-and-nano-photonics

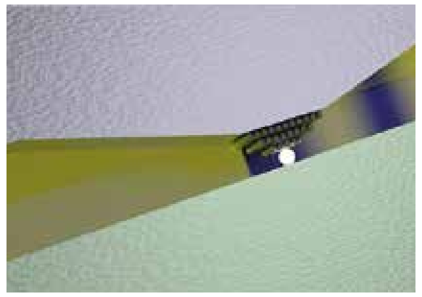
Electronics and Photonics

Plasmonics

Plasmonic colour filters for industrial applications

The interaction of light with metallic nanostructures can lead to resonant excitations of free electrons, so-called plasmons. Plasmonics refers to the study and exploitation of the optical response of metal nanostructures. It is characterised by strong optical near-field enhancements and high spatial field confinements. Furthermore, it allows the spectral properties of light and its phase to be controlled on length-scales smaller than the wavelength, opening up the possibility of generating colours with unique properties. In comparison to dyes, the colour appearance can be varied by factors such as the angle of incidence or the polarisation of incident light. Such precise control of colour is essential for applications such as optical security or imaging. The project includes developing and realising plasmonic colour filters of this kind using fabrication processes that are in compliance with large-scale industrial manufacturing. The work is a collaboration between the Photonics Laboratory, led by Lukas Novotny, and CSEM.

www.photonics.ethz.ch / www.csem.ch

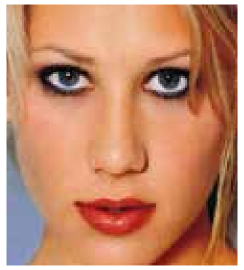


Photonics and communication

Switching light with a silver atom

Researchers working under Juerg Leuthold, Professor of Photonics and Communications, have created the world's smallest integrated optical switch. The switch is based on the voltage-induced displacement of one or more silver atoms in the narrow gap between a silver and a platinum plate. Applying a small voltage causes an atom to relocate, turning the switch on or off. In data centres, these light switches might one day replace today's large modulators, which convert the information that is originally available in electrical form into optical signals.

www.ief.ee.ethz.ch

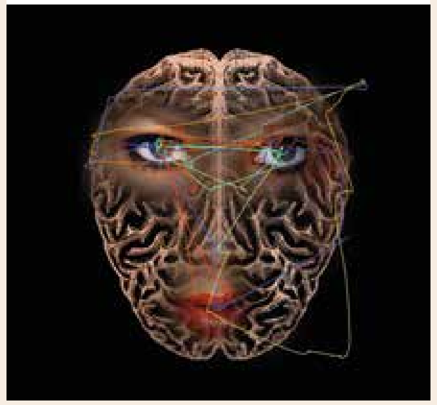


Mobile eye tracker

Seeing (?) Anna

During our every waking second, we move our eyes between 3 and 5 times towards interesting details in the environment. However, the images collected as a result of this are far from perfect. The resolution of our vision drops quickly away from the centre of our gaze. Despite this, our brain is still able to create a sharp and continuous view of the world. The picture below shows the eye movements that take place while a person is looking at Anna Kournikova (original picture above). Only the parts of the image that are actually sharp are shown – the rest is filled in by our brain. The study of "oculomotor behaviour" provides a deep insight into the functioning of the brain. In their project, researcher David Mack and his colleagues are building a mobile, head-mounted eye tracker in cooperation with the University Hospital Zurich. The ultimate goal of this project is to analyse eye movements during driving to provide an objective measure of the ability to drive in the elderly.

www.iis.ee.ethz.ch/research/research-groups/analog-and-mixed-signal-design



"The PermaSense project combines the infrastructures we design to support reliable wireless communication for long-term data collection, with the knowledge and expertise of geologists and glaciologists. They leverage the data we provide to deepen the general understanding of alpine regions, and eventually predict their evolution."

Romain Jacob, doctoral student, Computer Engineering and Networks Laboratory

Information and Communication

Information and communication technology continues to transform the ways in which we communicate, work, play, and build machinery. Constantly improving wired and wireless communication options, especially those powered by the Internet and related technologies, drive the development of new networking and computing technologies.

The D-ITET researchers active in this area strive for excellence by combining theoretical research into fundamental problems with applied research on high impact, real-world applications. This synergy is accomplished in part by fostering collaborations among the faculty within the area of ICT and with other colleagues at D-ITET and beyond.

Research in the field of information and communication at D-ITET is focused on signal and image processing, control systems, information theory, distributed computing, wireless networks, and Internet technologies, and is carried out by the following laboratories:

Communication Technology Laboratory
Prof. Helmut Bölcskei, Prof. Armin Wittneben

The Communication Technology Laboratory, consisting of the Communication Theory Group and the Wireless Communications Group, is active in the areas of communication systems, information theory, and signal processing.

Automatic Control Laboratory
Prof. Florian Dörfler, Prof. John Lygeros, Prof. Maryam Kamgarpour, Adj. Prof. Roy Smith

This laboratory has an extensive research record in both the theory and application of control technology. The research interests are loosely divided into five categories: theory, computation, energy, applications and "team projects".

Computer Engineering and Networks Laboratory
Prof. Lothar Thiele, Prof. Laurent Vanbever, Prof. Roger Wattenhofer

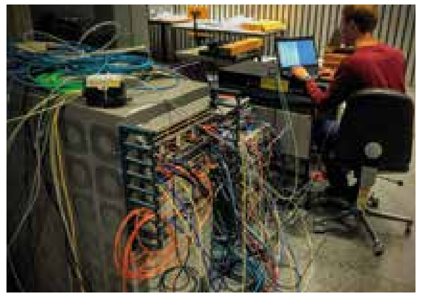
This laboratory integrates the research work of the Computer Engineering Group (with a focus on design, engineering methodologies and tools for networked embedded systems and software), the Networked Systems Group (which primarily focuses on software-defined networking), and the Distributed Computing Group (with an interest in a variety of algorithmic and systems aspects in computer science and information technology).

Signal and Information Processing Laboratory
Prof. Amos Lapidoth, Prof. Hans-Andrea Loeliger

The Signal and Information Processing Laboratory focuses on research and education in the areas of information theory, error-correcting codes and their application in communication systems, and model-based detection/estimation in communications and other application areas as well as in signal processing with analogue circuits.

Computer Vision Laboratory
Prof. Orçun Göksel, Prof. Ender Konukoglu, Prof. Luc Van Gool

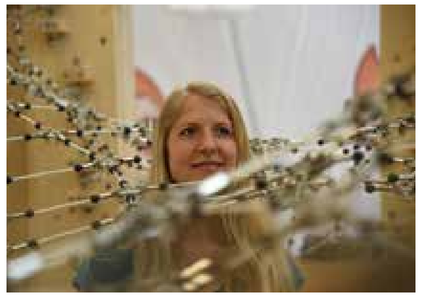
The Computer Vision Laboratory works on the computer-based interpretation of 2D and 3D image data sets from conventional and non-conventional image sources. The laboratory performs research in the fields of medical image analysis and visualisation, object recognition, gesture analysis, tracking, plus scene understanding and modelling.



Networked systems

Improving the Internet by putting theory into practice

Two times the volume of the great wall of China: That's the volume of information exchanged on the Internet each day, assuming one gigabyte equals a coffee mug. Given these mind-blowing numbers, it may come as a surprise that the Internet infrastructure is still extremely fragile, mainly because of the impact of human operations. The Networked Systems Group led by Prof. Laurent Vanbever aims to address these challenges through automation designed to make networks more flexible, more reliable and better-performing. Specifically, it designs and implements demonstrably correct techniques and tools in order to solve complex network management problems stemming from practical situations. While they believe in the value of building theoretical foundations, they always look for creative ways to apply these results to the real world. nsg.ee.ethz.ch



Systems and control

Controlling the form of an architectural cable net for light-weight construction

In architecture, doubly-curved thin concrete shells are very efficient, light-weight structures that save a lot of material and energy. Their construction is very difficult, however, as they require a complicated supporting structure (formwork). Yvonne Stürz and her colleagues from the Automatic Control Laboratory, in collaboration with the Block Research Group (D-ARCH), are working on the development of an innovative, simpler flexible formwork, consisting of a rigid frame and a tensioned cable net – as shown in the picture. Fabric layers and the concrete go on top of it. Imprecisions in the construction process make it very difficult to achieve the designed form of the shell. The form is crucial, however, as it is optimised for structural properties such as stability. The form of the cable net is therefore controlled during its construction. An optimisation-based control algorithm tells the group which boundary edges need to be shortened or lengthened (via turnbuckles connecting the net to the frame) in order to bring the cable net closer to the design.

control.ee.ethz.ch

Communication

Data storage for eternity

Researchers are searching for new ways to store large volumes of data over the long term. Due to its longevity and enormous information density, they are particularly interested in a storage medium found in nature: the genetic material DNA. Unfortunately, DNA can be problematic to retrieve: chemical degradation and mistakes in DNA synthesis (writing) and sequencing (reading) can induce errors. Now, however, researchers have revealed how long-term, error-free storage of information can be achieved. This involves first encapsulating the information-bearing segments of DNA in silica (quartz) and then using an algorithm in order to correct errors in the data obtained from the DNA. Reinhard Heckel from the Communication Technology Laboratory developed a scheme to correct these errors based on Reed-Solomon codes, which are also used in the transmission of data over long distances. www.nari.ee.ethz.ch

Distributed computing

Bitcoin & blockchain

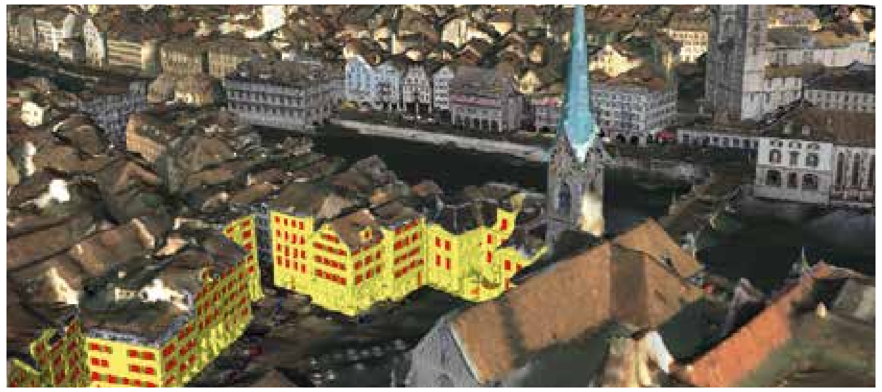
While Bitcoin is used to buy just about everything, from alpaca socks to flights into space, it still faces some major challenges: How can it scale to handle truly global adoption? How can we enforce security? How can we improve on the overall experience? The Distributed Computing Group led by Prof. Roger Wattenhofer is researching the various aspects of Bitcoin. For instance, they are trying to solve Bitcoin's notorious scalability issues with newly developed peer-to-peer micropayment channels. Apart from Bitcoin, they also study blockchain-based systems and blockchain alternatives in a more general context. www.disco.ethz.ch

Autonomous decision-making

What came first, localisation or autonomy?

The answer, of course, is both and neither. A fleet of nano-quadcopters, the Crazyflies, are demonstrating that autonomous decision-making methods are applicable beyond the walls of a lab. Crazyflies carry the latest in sensing and computing hardware, and represent autonomous flying robots that are both inherently challenging to control and awesome to watch. The researchers at the Automatic Control Laboratory are aiming to have a swarm of Crazyflies making decisions on their own, all by communicating with the others to cooperatively tackle a task such as flying in formation. To ensure their autonomy, the researchers also work on algorithms to improve their abilities of precise localisation, using Ultra-Wide-Band technology.

control.ee.ethz.ch

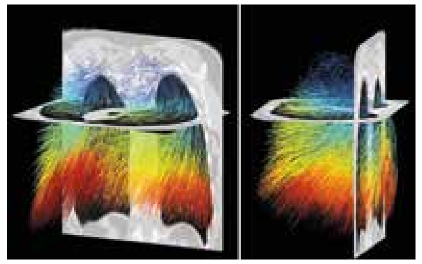


Computer vision and scene understanding

VarCity (Variation & the City)

3D city models have many applications, such as urban design, navigation, property ads, movies and video games. This project, led by Prof. Luc Van Gool of the Computer Vision Laboratory, aims to produce models of this kind from photographs both faster and with more detail than before. As the work involved often needs to be repeated in order to update a city model regularly, compact models need to be produced efficiently. The researchers process images of real cities automatically and expeditiously to create parametrised and semantic 3D models, in which streets, buildings and vegetation are shown distinctly and numbers of storeys as well as positions and shapes of windows, doors and balconies are recognised and encoded. They also fill their static 3D models with dynamic content by extracting special events and traffic flows from images, and by generating a city-scale motion and activity model. So you can take a virtual tour of the Münsterhof in Zurich and see a video summary of recent events there, or check out volumes of traffic densities along your children's route to school.

www.varcity.eu

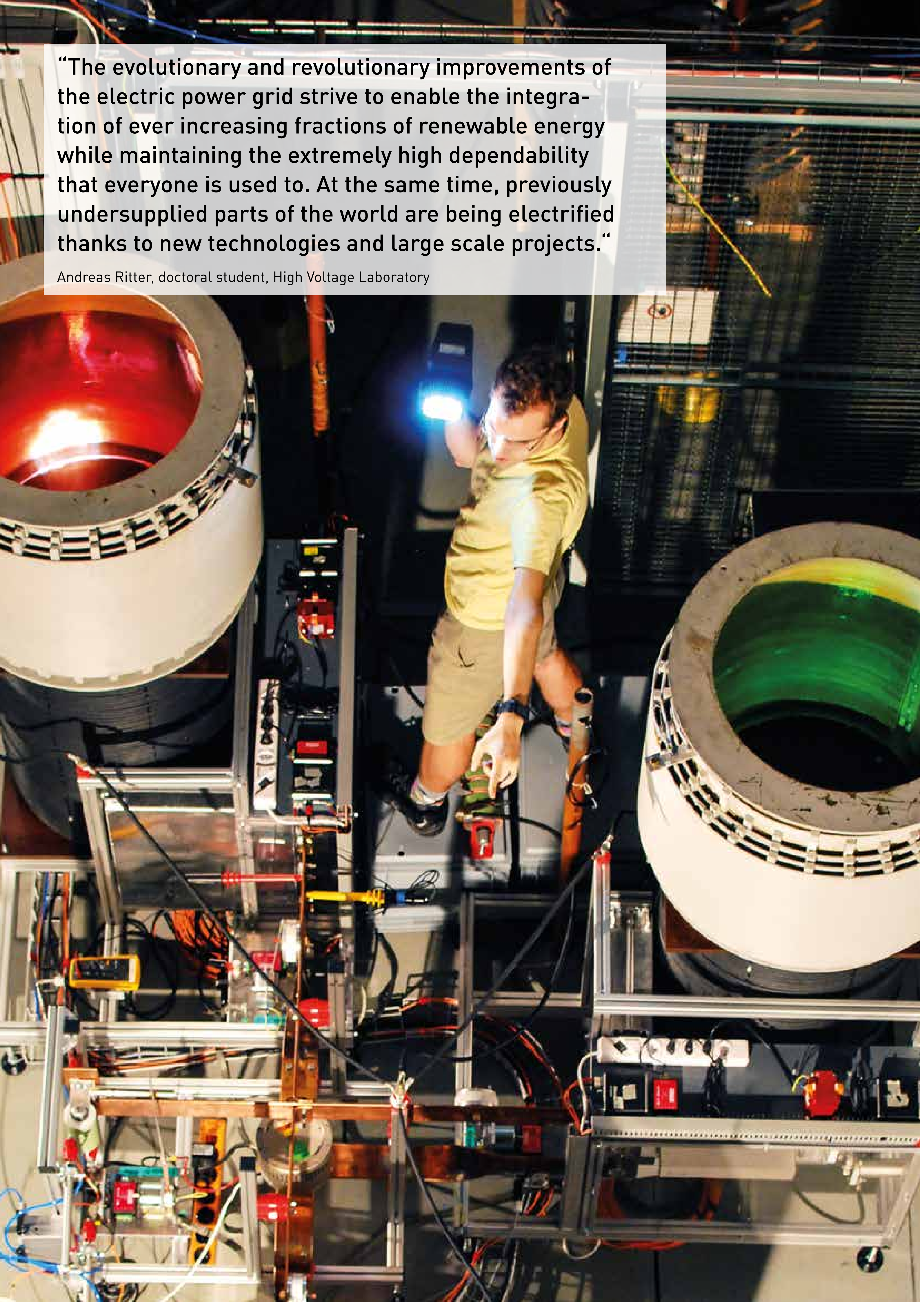


Extracting human lung motion during breathing

Accurate lung motion extraction

Accurate quantification of lung motion during breathing is essential for thoracic radiotherapy to improve treatment planning and guidance, as well as for the diagnosis of lung abnormalities. Registration is a common tool to find correspondences between images and estimate motion. A fully automatic image registration method was developed for extracting lung motion from 3D X-ray computed tomography scans acquired during inhale and exhale breath-holds by researchers in the Computer-assisted Applications in Medicine (CAiM) Group led by Prof. Orçun Göksel. In a public challenge, the developed method estimated motion with an accuracy of 0.9 to 1.0 mm, establishing a new state of the art in this field. Additionally, this method does not rely on organ masks – a key strength, since many conventional methods require lung masks to avoid errors at sliding interfaces; for example, between lungs and ribcage, where motion is not smooth. At 1 to 3 minutes per registration, it is also relatively fast, making it applicable in daily clinical use.

www.caim.ee.ethz.ch



"The evolutionary and revolutionary improvements of the electric power grid strive to enable the integration of ever increasing fractions of renewable energy while maintaining the extremely high dependability that everyone is used to. At the same time, previously undersupplied parts of the world are being electrified thanks to new technologies and large scale projects."

Andreas Ritter, doctoral student, High Voltage Laboratory

Energy

D-ITET views technologies that will result in a sustainable energy supply as a major priority, given the critical role they are set to play in maintaining strong economic growth and security in the 21st century and beyond. With this in mind, the Department's research focuses on the development of smart grids for efficient energy supply and distribution and for integrating renewable energy sources and power electronics converter systems. It also conducts fundamental research in multi-objective converter optimisation, advanced power semiconductors, environmentally friendly insulating materials, and highly reliable power semiconductor packaging.

The internationally leading research conducted by the Energy team at D-ITET is focused on realising a new electrical energy transmission and distribution system, which will be highly efficient, stable, reliable, economically viable and intelligent, and will interconnect largely renewable energy sources, storage systems and active loads. Based on expertise extending from the system level to base technologies, new transformative concepts are being developed using a concerted and comprehensive approach that is identifying and demonstrating options for developing innovative technologies for international industrial partners.

The interdisciplinary knowledge base and excellent research environment form the basis for first-rate training, resulting in creative engineers and researchers who possess solid fundamental knowledge and an outstanding capacity for abstraction. This leads to excellent performance and leadership on a global scale.

The D-ITET laboratories below cover everything from transmission and distribution all the way to consumption:

Institute for Power Systems & High Voltage Technology
Prof. Christian Franck, Prof. Gabriela Hug

The High Voltage Laboratory conducts research into technologies for the sustainable electrical energy supplies of the future, particularly focusing on electrical energy transmission: HVDC and switching technology, as well as gaseous and solid high voltage insulation. The scientific field of the Power Systems Laboratory is the analysis and design of electrical and integrated energy systems, including their planning, design and operation.

Laboratory for High Power Electronic Systems
Prof. Jürgen Biela

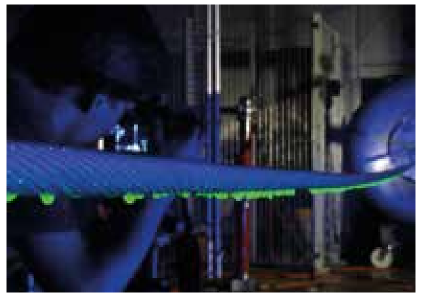
The research at the Laboratory for High Power Electronic Systems focuses on the modelling, optimisation and design of high-power converter systems, including operation at medium voltages required in areas such as future energy distribution for renewable energy sources or traction applications. Another major area of its research is solid-state pulse modulator systems for medical applications or accelerators (Paul Scherrer Institute, CERN).

Power Electronic Systems Laboratory
Prof. Johann W. Kolar

The research at the Power Electronic Systems Laboratory opens up new fields of application and drives the innovation of power electronics systems in close partnership with international industry. Its main research areas are ultra-compact/ultra-efficient converter systems as well as ultra-high-speed and bearing-free drive concepts. The results of the theoretical considerations are translated into advanced hardware demonstrators in order to allow a direct and comprehensive comparison with existing industrial concepts.

Advanced Power Semiconductor Laboratory
Prof. Ulrike Grossner

The research of the Advanced Power Semiconductor Laboratory is focused on the optimisation, design, characterisation and production of advanced power semiconductor devices and their modules, using emerging wide-bandgap power semiconductors aimed at very high performance and long-term reliability. In collaboration with the Paul Scherrer Institute and Empa, the laboratory works towards novel technologies and processes for power semiconductor components and highly integrated power module packaging. These will be implemented in the new generation of power electronic systems, which represent a key enabler for the highly efficient use of electric energy in the future.



Power transmission technology

High voltage water drops

The researchers at the High Voltage Laboratory, led by Prof. Christian Franck, are investigating the environmental effects of a novel type of power transmission technology: hybrid AC/DC transmission. The main idea is to convert existing AC transmission corridors (the prevailing type of power transmission technology in Europe today) to systems in which AC and DC lines are used on the same tower. This has the potential to significantly increase the power throughput of an existing corridor and may delay or prevent the need to construct new overhead lines. The concept will be implemented in Germany in the coming years in a project called "Ultranet" – the first of its kind worldwide. The research team is supporting this project by investigating fundamental effects in the areas of electromagnetic fields and noise emissions. Water on the lines plays a crucial role with regard to these effects. The team is therefore analysing the distribution and shape of water drops by adding a UV-sensitive substance to the water.

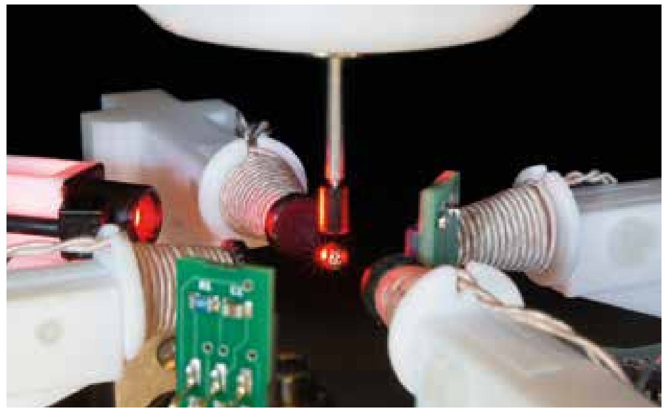
www.hvl.ee.ethz.ch

Electric power systems

Driven to optimise the grid

The existing power grids and their controls are designed for traditional power supplies, making them too inflexible as they essentially involve power flowing from central power plants to the consumer. The electrical power grids of the future will be much more distributed, with renewable generation and storage resources spread throughout the system and consumers becoming active grid participants. Coordinating all these elements in real time requires sophisticated control systems capable of balancing supply and demand in the grid. A research focus of the Power Systems Laboratory, led by Professor Gabriela Hug and working in collaboration with other groups at ETH Zurich, is on developing a modelling platform that simulates interactions among distributed resources, but also involving the bulk power grid. The platform also makes it possible to study the impacts of market design and policy decisions on grid operations. The laboratory derives methods that enable intelligent local and coordinated decision-making concerning the distributed resources, and optimal planning for future power grids.

www.psl.ee.ethz.ch



World record

No (speed) limit

The Power Electronic Systems Laboratory, led by Prof. Johann W. Kolar, researches magnetic bearings that enable effects such as the contactless levitation of rotors in electric machines without friction. Bearings offer benefits to the biopharmaceutical and semiconductor industries, and are well-suited to high rotational speeds. Exploring new territories in magnetic bearings research, the laboratory has developed an electric motor reaching rotational speeds of more than 40,000,000 revolutions per minute (through the doctoral research project of Marcel Schuck) – the world record for the highest rotational speed ever achieved by a machine of this kind and more than 100 times faster than a dental drill. To achieve such high speeds, a very small steel sphere with a diameter of less than 1 mm is used as a rotor. At full speed, a point on the equator of the sphere reaches more than 3,000 km/h. The system that has been developed can be used in materials testing applications, and the underlying research is paving the way for ultra-compact and highly efficient electrical drives – an essential element in a sustainable energy future.

www.pes.ee.ethz.ch

Solid-state transformers

Energy routing for future trains, ships and smart grids

The next generation of high-speed trains, more-electric ships, and all-electric aircraft or medium-voltage DC collecting grids for offshore wind farms requires electrical isolation between medium-voltage systems and low-voltage systems in a very confined space. Compared to conventional solutions employing passive low-frequency transformers, new medium-frequency solid-state transformers (SSTs) based on highly scalable multi-cell converter systems and/or innovative silicon carbide (SiC) power semiconductors offer unprecedented performance in terms of efficiency and power density. The Power Electronic Systems Laboratory is driving the research in this area, taking a holistic approach based on multi-objective optimisation and considering a wide range of aspects – including, but not limited to, topologies (such as single-cell versus multi-cell approaches), efficiency, power density, isolation, protection, control, reliability, and costs, as well as the design and testing of hardware prototype systems.

www.pes.ee.ethz.ch

High Power Electronic Systems

Ultrafast charging station

Electric vehicles in combination with renewable energy sources have the potential to substantially reduce the greenhouse gas emissions caused by private methods of transport. However, the range of electric vehicles available is still limited due to the energy density of rechargeable batteries and long charging times. With the aim of drastically reducing recharging times, the High Power Electronic Systems Laboratory run by Prof. Jürgen Biela is working on concepts for ultrafast charging stations, which will make it possible to charge electric vehicles in a matter of minutes. To achieve such short recharging times, a high charging power of several hundred kilowatts is necessary. To avoid exposing the electrical grid to excessive stress or disturbance from the rapid charging process, a stationary battery is included in the fast charging station. This stationary energy storage system can also be used as an intermediate storage facility for smart grid applications, thus increasing the station's cost-effectiveness.

www.hpe.ee.ethz.ch

Power semiconductors

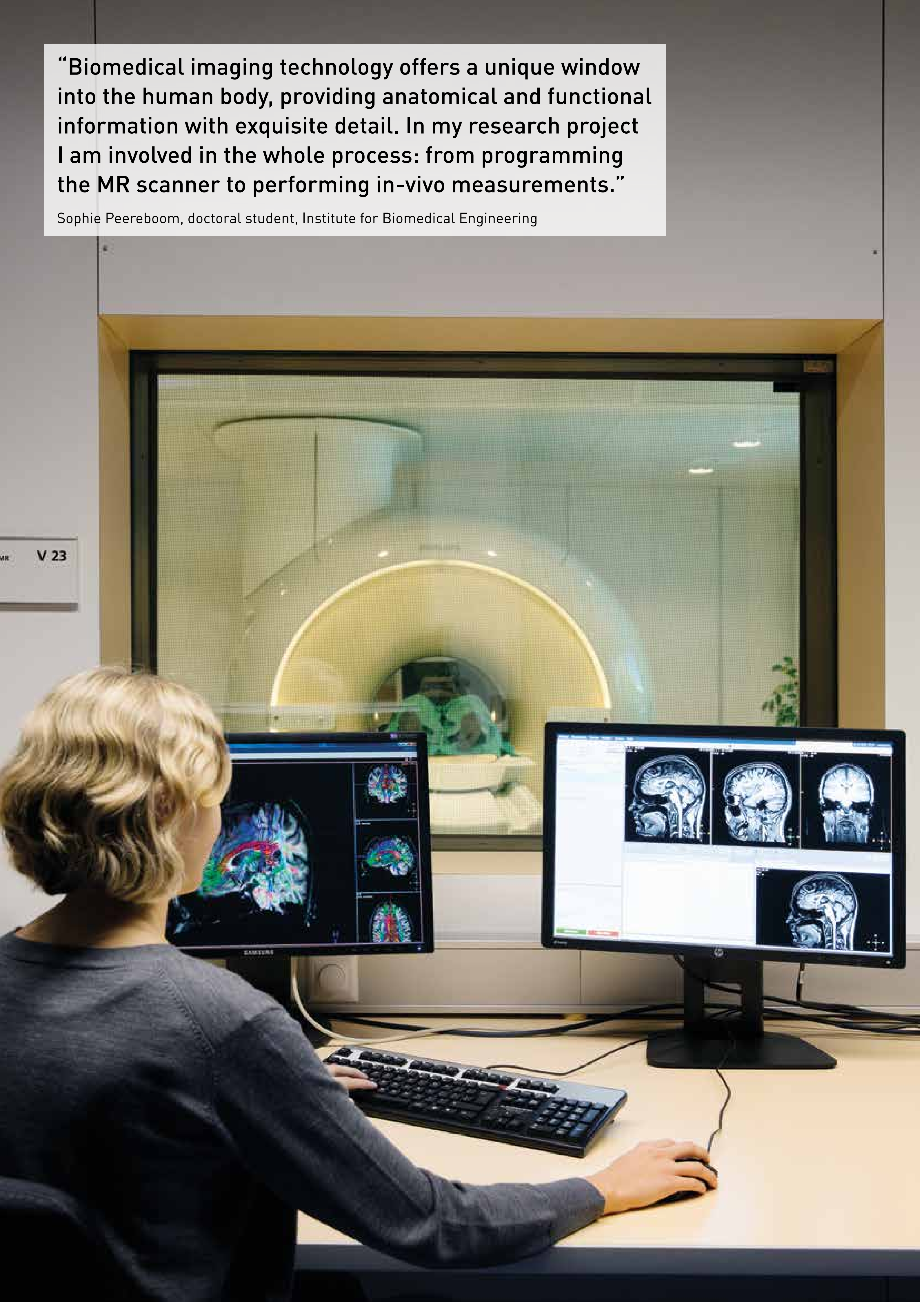
Multi-physics modelling of power modules

Designing power semiconductor devices and modules is a highly multi-disciplinary field that requires strong collaborations between material scientists, physicists and power electronics engineers. A goal of this research project, conducted by the Advanced Power Semiconductor Laboratory under Prof. Ulrike Grossner, is to create a computational core that will enable efficient multi-physics modelling of power modules during the design process, simultaneously taking into account the thermal, electrical and electromagnetic aspects. The first modelling examples demonstrate that the multi-domain modelling approach developed in the laboratory and the measurements match up extremely closely. The researchers are aiming to create a powerful tool for the virtual design of power modules, enabling engineers to gain a deep insight in the electrical, thermal and electromagnetic performance of advanced power semiconductor packages developed in the course of implementing wide-bandgap semiconductor devices in power electronic systems.

www.aps.ee.ethz.ch

"Biomedical imaging technology offers a unique window into the human body, providing anatomical and functional information with exquisite detail. In my research project I am involved in the whole process: from programming the MR scanner to performing in-vivo measurements."

Sophie Peereboom, doctoral student, Institute for Biomedical Engineering



Biomedical Engineering and Neuroinformatics

Biomedical engineering and neuroinformatics is guided by the overarching goal of advancing healthcare. At D-ITET, we focus on the interaction between biological and technical systems, with emphasis on bioimaging, image-based modelling, bioelectronics and understanding the working principles of complex neural systems.

The combination of life sciences and engineering principles continues to create intriguing perspectives for basic research, healthcare and the enhancement of daily life. It continues to boost our understanding of how living systems function as well as our ability to control, support and repair organisms from single cells to the human body. Electrical engineering and information technology are at the heart of this effort. Electronics is currently the only technology platform that comes even close to matching biological systems in terms of complexity, flexibility and miniaturisation.

Our mission is to bridge the traditionally separate realms of biological and technical systems, to advance the understanding of live organisms and their nervous systems, and to leverage methods of observation and interfacing for use in medical diagnostics, therapy monitoring and support devices. In order to accomplish this mission, we cultivate strong partnerships with the University of Zurich and the University Hospital Zurich, as well as other renowned institutions.

To these ends, D-ITET focuses on four areas that best exploit its core expertise: bioimaging, bioelectronics, neurotechnology and neuroinformatics. Research in these fields ranges from basic science to technology development and clinical investigations.

Institute of Neuroinformatics

Prof. Benjamin Grewe, Prof. Richard Hahnloser, Prof. Kevan A. C. Martin, Prof. Mehmet Fatih Yanik, Adj. Prof. Tobias Delbrück

The Institute of Neuroinformatics was established at the University of Zurich and ETH Zurich in 1995. Its mission is to discover the key principles by which brains work and to implement these in artificial systems that interact intelligently with the real world.

Institute for Biomedical Engineering

Prof. Sebastian Kozerke, Prof. Klaas Prüssmann, Prof. Markus Rudin, Prof. Marco Stampanoni, Prof. Klaas Enno Stephan, Prof. János Vörös

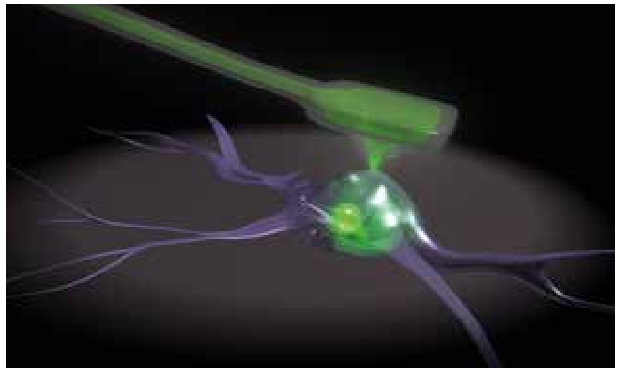
The Institute for Biomedical Engineering is a joint institution of ETH Zurich and the University of Zurich. The research focuses on some of the most exciting themes at today's interfaces between electrical engineering, biology and medicine. This ranges from advancing sophisticated imaging and sensing techniques to developing assays for computational psychiatry and validating diagnostic tools in custom-designed clinical facilities.

Newly developed sensor with broad applications

High-precision magnetic field sensing

Researchers working with Prof. Klaas Prüssmann from the Institute for Biomedical Engineering have succeeded in measuring high magnetic fields with unprecedented precision. Strong magnets are in widespread use in medical imaging, chemical structure analysis and particle accelerators. But the measurement of high magnetic fields is conventionally limited to relatively coarse resolution. The sensor that has now been developed is based on nuclear magnetic resonance (NMR) in a water droplet, enhanced by tailored magnetostatics and ultra-sensitive radiofrequency detection. It records fluctuations of multiple-tesla fields with precisions up to one part per trillion (10^{-12}), making it roughly a thousand times more sensitive than previous techniques. Ongoing applications include studies of nuclear and electronic magnetism, precision control of magnet systems, and the exploration of medical uses such as touch-free observations of the human heart at work.

www.mrtm.ethz.ch



Cytosurge

The world's smallest automated syringe

Tomaso Zambelli from the Laboratory of Biosensors and Bioelectronics has invented a force-controlled nano-syringe with which biomolecules like DNA, proteins and metabolites can be injected into or retrieved from an individual cell without compromising its viability. In addition to biological applications, the tool can also be used for local chemical patterning of surfaces as well as additive manufacturing of metal micro-objects. The technology has been developed into a marketable product via the start-up company Cytosurge AG.

www.lbb.ethz.ch

Neuromorphic engineering and artificial intelligence

Teaching a robot how to hunt with a silicon retina

Neuromorphic engineering means grasping the underlying principles of the brain and implementing them into hardware to achieve fast and intelligent computations. In one of the projects led by Prof. Tobi Delbrück from the Institute of Neuroinformatics, two 40 kg, omnidirectional and fast robots were taught how to catch each other in a predator/prey scenario. The predator robot was equipped with a special silicon retina sensor. This sensor mimics the processing of the human retina by reporting, at high speeds, only changes in luminosity and, therefore, movement. This drives an artificial neural network on the onboard PC, which extracts relevant features in the scene and understands where the other robot (the prey) is. By giving steering directions to the predator, the network makes it possible for it to track and follow its prey at 3 m/s. Even if a human guides the prey with a controller, escape is nearly impossible. The success of this work is pushing researchers to test what we know about the brain and leading to possible applications in self-driving vehicles and even toys.

www.ini.ethz.ch

Biosensors and bioelectronics

Using high-speed MRI to visualise sugar consumption

Cardiovascular diseases are the number-one cause of death worldwide. Researchers led by Prof. Sebastian Kozerke are working on the next generation of non-invasive, MRI based tools to improve diagnosis and therapy for the heart. More precisely, they are developing hyperpolarised MRI contrast agents to visualise how the heart uses energy in real time. Important metabolic molecules can be magnetised using cutting-edge technology.
MR sensitivity increases by more than 35,000 times with this method, making it possible to observe even miniscule amounts of substances. However, this increase in sensitivity is short-lived, and in order to minimise the time before injection, the fittest doctoral student sprints with the hyperpolarised contrast agent (yellow syringe) to the MRI scanner (background), where it is injected into a subject (in the future, this will be a human patient).

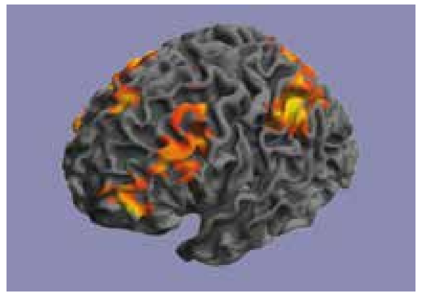
www.cmr.ethz.ch

Three-dimensional and extremely high-resolution films

Renaissance of X-rays

The world's attention has been grabbed by three-dimensional and extremely high-resolution film images showing powerful muscles hidden within the thorax of a fly, which flex and relax 120 times a second. Using joints that are among the most complex in the natural world, these muscles power the insect's wings. The captivating pictures of the bluebottle's flight apparatus are the results of a collaboration between Marco Stampanoni, professor at ETH Zurich and group head at the Paul Scherrer Institute (PSI) in Villigen, and research colleagues at Imperial College London and the University of Oxford. Marco Stampanoni commented on the technology's impact: "The development of this unique imaging technique is paving the way towards functional 3D anatomical studies that will improve our knowledge of complex living biomechanical mechanisms and inspire the design of flying micro devices."

www.biomed.ee.ethz.ch



Translational neuromodeling

Using mathematical models to diagnose schizophrenia

Researchers from the team led by Prof. Klaas Enno Stephan are developing techniques to improve diagnosis and treatment prediction for mental illnesses. The scientists have already demonstrated that it is possible to distinguish patients with schizophrenia from healthy controls by using a mathematical model of brain activity and, more importantly, to subdivide schizophrenia into physiologically distinct subgroups. The model analyses images of brain activity – obtained by functional MRI – and calculates the coupling strengths between selected brain regions. These estimates of brain connectivity reflect the severity of clinical symptoms.
In ongoing studies, the scientists are testing whether similar models could also predict individual treatment responses.

www.tnu.ethz.ch

Studying at D-ITET

D-ITET is a first-class educational institution where teaching is strongly linked to research. Our graduates do cutting-edge research and take leadership positions in the areas of electrical engineering and information technology in Switzerland and worldwide.

D-ITET offers a comprehensive education programme that covers a great many thematic areas in electronics, photonics, information and communication, energy, and biomedical engineering.

The Bachelor's programme
The Bachelor's degree in the Department of Information Technology and Electrical Engineering takes six semesters to complete, in which the necessary foundations in mathematics, physics and computer science as well as the theoretical and methodical foundations of electrical engineering/electronics are taught. The timetable is clearly defined in the first four semesters, but from the fifth semester on there is plenty of room for students to choose whether to focus more on engineering or humanities, and on theory or practice.

The Master's programme
The Master's programme at D-ITET serves to deepen students' specialisations and leads to a qualifying degree. In addition to specific courses, research is an essential part of the Master's degree. The students will find an international, stimulating environment at D-ITET that lays the ideal foundations for their future work environment or for a doctorate. Bachelor's graduates can either enter the consecutive Master's programme directly or apply for one of the many interdisciplinary Master's programmes.

Specialisations
Our main Bachelor's/Master's programme permits specialisation in one of the following areas:
- Communications
- Computers and networks
- Electronics and photonics
- Energy and power electronics
- Systems and control
- Biomedical engineering

Interdisciplinary Master's programmes
We also offer the following interdisciplinary Master's programmes in cooperation with other departments of ETH Zurich:
- Biomedical Engineering
- Energy Science and Technology
- Robotics, Systems and Control
- Micro- and Nanosystems
- Neural Systems and Computation
- Data Science
- Management, Technology and Economics

German and English
While Bachelor's courses are mainly taught in German, all courses at Master's level are taught in English. In the Master's programmes, every student is supported by a professor ("tutor"), who assists the student in the selection of courses. The Master's programmes are also the preferred path towards our doctoral programmes for students who have obtained Bachelor's degrees from outside ETH Zurich.

"I'm studying electrical engineering because I have seen the many great achievements and inventions of electrical engineers over recent years. I think that this will continue into the future and I would like to be a part of it."

Felix B., Master's student at D-ITET

Overview of studies at D-ITET

Bachelor of Science ETH in Electrical Engineering and Information Technology
6 semesters

Foundation programme (Semester 1 - 4)

Semester 1+2, Freshmen

1st + 2nd semester

Mathematics (24 cp*) – Analysis I+II – Linear Algebra – Complex Analysis	**Electrical Engineering** (16 cp) – Networks and Circuits I+II – Digital Circuits	**Physics** (8 cp) – Engineering Mechanics – Physics I	**Informatics** (8 cp) – Informatics I+II	**Practical training** (2 cp) – Compulsory lab courses

Semester 3+4

3rd + 4th semester

Mathematics (16 cp) – Analysis III – Discrete Mathematics – Numerical Methods – Probability Theory and Statistics	**Electrical Engineering** (22 cp) – Electronic Circuits – Semiconductor Devices – Signals and Systems I+II – Electromagnetic Fields and Waves	**Physics** (8 cp) – Physics II	**Informatics** (8 cp) – Computer Engineering I+II	**Practical training** (7 cp) – Compulsory lab courses – Elective lab courses, projects and seminars

Area of specialisation

Semester 5+6

5th + 6th semester

Core courses (min. 30 cp) A selection of courses from the core areas of Electrical Engineering and Information Tech-nology	**Electives** (min. 6 cp) Additional courses from the entire ETH Zurich programme	**Humanities** (6 cp) 2-3 courses in the Department of Humanities, Social and Political Sciences		**Practical training** (min. 12 cp) Elective lab courses, projects and seminars (e.g. group projects, internships in industry etc.)

Gap year, e.g. for an internship in industry (optional)

7th – 9th semester

Master of Science ETH in Electrical Engineering and Information Technology
3 semesters ("consecutive" Master's)

Semester 7+8

Further specialisation in an area of Electrical Engineering and Information Technology (7-8 courses, 2 projects)

Semester 9

Master's Thesis
Six-month full-time academic research project

Interdisciplinary Master's programmes
3 to 4 semesters

- Biomedical Engineering
- Energy Science and Technology
- Robotics, Systems and Control
- Micro- and Nanosystems
- Neural Systems and Computation
- Data Science
- Management, Technology and Economics

Doctoral studies (Dr. sc. ETH Zurich): 4 years (optional)

*** cp = credit points**

Doctoral studies
Each year, over 400 doctoral students are active in ground-breaking research at D-ITET. Doctoral studies take about four to five years (beyond the Master's degree) and result in a thesis with a definite scientific contribution on an international level. Doctoral students are individu-ally supervised by a professor, and they typically hold paid positions with one of the research laboratories of the department.

Continuing education
D-ITET has established a continuing-education pro-gramme for engineers with an academic Master's degree and professional experience. Upon completion, they are awarded a Diploma of Advanced Studies (DAS) in Informa-tion Technology and Electrical Engineering.

More information on our studies can be found in our study brochure and on our website at www.ee.ethz.ch/studies.

Imprint
Please refer to our website for further information:
www.ee.ethz.ch

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