Zurich University
of Applied Sciences

School of Engineering

Research and Development An Overview

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BSc students working on the IMPE's pilot pervaporative separator for recycling organic solvents.

Interdisciplinary approach

The ZHAW School of Engineering focuses its research on areas determined by the needs of industry and society. The School works with its business and institutional partners to develop innovative, scientifically robust solutions. These projects are the result of practically oriented collaboration between 13 specialised institutes and centres. Most of this interdisciplinary research is conducted in the fields of energy, mobility, information technology and health. Our projects in the fields of energy transformation, medical technology and transport analysis make a significant contribution to research in areas that are of particular relevance to the future.

These collaborations with business partners and institutions are also advantageous to our students, who are not only able to work on topical projects but also benefit from the close links between research and teaching. Practically focused, application-oriented bachelor and master's degree theses are an important component of the ZHAW School of Engineering's education concept.

Applied research and development

In the context of their application-oriented research and development work, the Institutes and Centres offer their business partners the following cooperation models:

Funded projects (Innosuisse, EU) Collaboration with business partners most commonly takes the form of funded projects supported by the Innosuisse (Swiss Innovation Agency). The work on these projects is usually carried out by scientific assistants under the supervision of faculty members. A typical project will involve between one and three person-years of work. The schedule and objectives of the project are defined with the business partner when the project application is prepared. The results generated by the project are made available to the business partner.

Project assignments/bachelor theses (PA/BT) These provide business partners with an economical and simple way of acquiring initial experience of new technologies or of having specific questions analysed. Teams of two usually work on these project assignments and bachelor theses. PAs are carried out in the autumn semester and involve 360 person-hours (ph) of work, while BTs are carried out in the spring semester and involve a workload of 720 ph.

Master's project assignments/master's theses (MP/MT) During the course of their studies, master's degree students complete two master's project assignments – involving 270 and 450 ph of work respectively – and a master's thesis (MT) with a scope of 810 ph. Both types of assignment are carried out by individual students and generally commence at the beginning of a semester. These assignments address demanding problems arising in industry.

Mandated projects The ZHAW School of Engineering is also happy to carry out research and development projects for its business partners. These allow the business partner complete freedom in specifying the objectives and schedule of the project. The entire cost of such projects is borne by the business partner.

Longer-term cooperation agreements These enable business partners to commission R&D work, teaching and other services (such as coaching and consultancy) from the ZHAW School of Engineering. The services provided are specified in a master agreement.

IMS employees work on a power-assisted exoskeleton.

Making data usable is
the InIT's core skill.

Institute of Applied
Information Technology (InIT)

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Institute of Applied Information technology (InIT)

The InIT researches and develops smart information technologies, systems and services designed to ensure that information can be used simply, securely and at any time. The InIT has a broad range of expertise in distributed information systems with a focus on five key areas. It is in these key areas that the Institute offers its services and works with companies on innovative R&D projects. The InIT also operates a number of dedicated labs. The labs apply the Institute's expertise in selected fields from one or more of its key areas, and in some instances also from other Institutes, both for use in R&D projects and as a service offering to business partners.

Software Systems This key area revolves around the development of software and software architectures as well as the processing of natural language. Its activities are focused on:

Software Engineering includes topics such as agile software development and the fully automated generation of executable software based on graphic models (model-driven software development). Within the domain of software architectures, we explore realisation approaches for current techniques of distributed processing and storage (e.g. micro services, blockchain or Internet of Things) as well as architecture concepts for the integration of mixed reality systems.

Text Analytics & Dialogue Systems is concerned with technologies required for the processing of natural language. By combining methods from the fields of linguistics, natural language processing (NLP) and artificial intelligence, we endeavour to enable human-machine natural language communication. Among other things, we work on topics such as text classification (e.g. sentiment analysis), chat bots and natural language generation.

Human Information Interaction This key area explores innovative natural interaction concepts between users and digital information, focusing on the following topics:

Mobile Usability This deals with the user-centric development of mobile applications and services which use the sensor technologies and interactive capabilities of current and future mobile devices to optimise usability and deliver the most appealing user experience possible.

ICT Accessibility deals with barrier-free access to information for elderly and disabled people. This work involves evaluating and developing suitable tools both for the internet and increasingly also for mobile devices.

Visual Computing examines how images can be transformed into 3D models that are as realistic as possible and used in mixed-reality scenarios, principally in medical and industrial applications. Visual Computing also develops virtual-reality and augmented-reality applications and simulators.

Human Information Interaction operates the Mobile Usability Lab, the ICT Accessibility Lab and the Visual Computing Lab.

Information Security This key area deals with the security of information in distributed information systems and the individual systems they comprise. Its work is focused on:

Secure Applications and Systems This involves the development of secure software and services, with particular emphasis on online and mobile applications. One example of the InIT's work in this area is the analysis and extension of methods and tools for secure software, services development and security testing. Where necessary, the InIT also develops new security mechanisms.

Information Infrastructure Protection safeguards conventional and cloud-based IT infrastucture. Its objectives are to identify potential attacks at an

Institute of Applied
Information Technology (InIT)

early stage and to detect attacks which have already occurred, through monitoring for example. The InIT also works on methods and tools used in risk assessment and risk engineering for IT infrastructure.

Information Security operates the Security Analysis and Testing Lab.

Information Engineering This key area is concerned with fundamental problems in the field of data science and counts among the founders of the ZHAW's Datalab.

Information Retrieval covers all facets of unstructured and semi structured data-based search. This namely encompasses natural language processing including cross-language retrieval, multimedia retrieval, categorisation, recommender services, question answering and topic/trend/event detection.

Databases, Information Systems and Data Warehousing is all about the processing of structured information and big data, particularly its efficient storage, management and retrieval to facilitate data-driven decision-making support. One issue focuses on the development of natural-language interfaces with databases in order to enable human-like communication. Other issues explore the application of machine learning algorithms for data management problems such as query optimisation and data fusion.

Artificial Intelligence and Machine Learning concentrates on the design and analysis of intelligent systems using machine learning methods, specifically deep learning and reinforcement learning. A particular focus lies on the execution of pattern recognition tasks in areas such as predictive maintenance, document analysis, object classification and detection in computer vision or speaker recognition. The overarching objective remains working towards the practical applicability and robustness of algorithms for both small and large data volumes as well as the interpretability of results.

Service Engineering This key area explores the scalable and reliable implementation of modern, complex services. It focuses on the following areas:

Cloud Computing revolves around the automated provision, operation and use of configurable and highly scalable and elastic IT resources on a pay-per-use basis. In addition to the virtualisation of infrastructure (computer, network, storage), this includes platform services for the automated provision of applications (continuous multi-stage/multi-cloud deployment) in various runtime systems (VM, OS container, unikernel), the provision of scalable backend services (DB, messaging, storage) and the monitoring of services (e.g. health management) and applications.

Cloud Robotics works with the integration of robotics applications into complex networked services. The use of elastic cloud systems enables the expansion of robotic skills (processing power, environment information, artificial intelligence) as well as their management and co-ordination. Coding frameworks and automation services assist developers in the integration of robots in services without the need of in-depth knowledge on a device level.

Service Prototyping studies the implementation and validation of complex services in a cloud-based environment. Besides the migration of existing services, the main focus is the development of modern application architectures (cloud native applications, micro services, serverless computing), the provision of tools for the faultless implementation of complex applications, the experimental validation of cloud-based service concepts and their monetisation (cloud accounting and billing).

This key area is operated by the InIT Cloud Computing Lab and the Service Protoyping Lab.

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Information Technology (InIT)

The labs at a glance

Datalab In collaboration with other institutes and centres, the Datalab explores relevant issues in the field of data science and its associated technologies and concepts.

The **ICT-Accessibility Lab** deals with barrier-free interaction and access to information for the elderly and people with an impairment. Thanks to its extensive expertise in the area of website, document and mobile app accessibility, the lab can provide expert advice on the subject. The lab evaluates website and app accessibility and develops tools and plugins to make PDFs accessible.

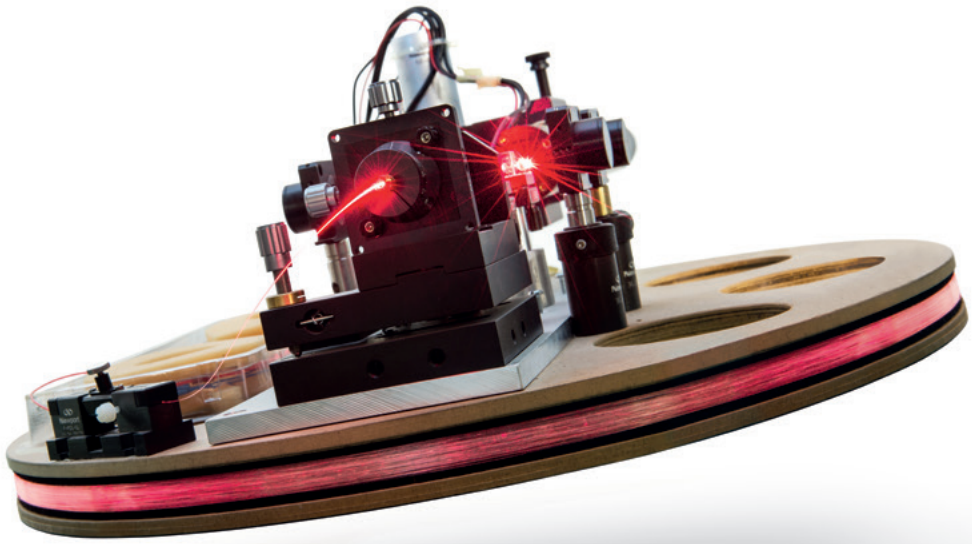
The **InIT Cloud Computing Lab** is concerned with the automated provision and use of an elastic IT infrastructure and provides services related to the installation, operation and monitoring of cloud applications and services. Cloud Robotics enables the integration of robots in complex networked services.

The **Mobile Usability Lab** focuses on the latest interaction modalities (language, gestures) and the user-centred development of mobile applications and services. The sensor technology and interaction capabilities of current as well as future mobile devices is used effectively to achieve the best user experience possible.

Security Analysis and Testing Lab The Security Analysis and Testing Lab conducts research on methods and tools in the areas of conceptual security analysis and manual and automated security testing for applications and IT systems.

The **Service Prototyping Lab** explores the effective implementation and validation of complex cloud-based services. This includes the further development of modern cloud-native application architectures such as micro services and serverless computing as well as the provision of tools for the implementation, validation and monetisation of cloud-based services.

The **Visual Computing Lab** works with the creation, processing and analysis of digital images. By combining the subject areas of computer graphics and computer vision, innovative augmented reality, virtual reality and data visualisation solutions are developed in an applied research setting.



Assembling a fibre optic gyroscope in the laboratory to measure infinitessimally small rotations.

Institute of Applied Mathematics
and Physics (IAMP)

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Institute of Applied Mathematics and Physics (IAMP)

In addition to training future engineers in the foundations of mathematics and physics, the IAMP's core tasks also include carrying out challenging research and development projects. These projects focus on addressing problems that are of economic or societal relevance with solutions whose costs can be amortised over a short period of time.

Applied Optics Research activities in this key area are focused on developing measurement processes for motion and position analysis, examining fluorescence and developing apparatus for its analysis in biomedical diagnostics, process analysis and environmental analysis. Applied Optics also develops optical spectroscopy processes and analyses effects under coherent light for use in measurement technology applications. The work carried out ranges from theoretical calculations and simulations to experimental laboratory constructions, prototypes, and small-scale production of optical devices.

Medical and Biophysics Activities in this key area range from medical imaging and instrumentation to optical diagnostics and analytics and the development of optimised cancer therapies. In medical physics, the focus is on developing and optimising X-ray diagnostic processes, new concepts, methods and measurement technologies in radiation protection and phantom sensations in radio oncology and MRI. Biophysics focuses on issues arising in medical analytics, serology and pharmacology. Work in this area includes characterising and modelling antigen-antibody interactions, protein-protein and peptide-protein interactions and the solution properties of insulins.

Security-critical Systems This key area is concerned with the development and application of quantitative and formal methods used in risk analysis and the security certification of complex, security-relevant socio-technological systems. Particular emphasis is also placed on questions relating to the functional security of programmable electronic systems. The methods developed here are used to meet regulatory requirements in the railway, automotive, mechanical engineering, medical products, process and defence industries.

Applied Complex Systems Science This key area develops case-specific applications for problems which cannot be efficiently addressed with standard solutions. The range of methods used encompasses object-oriented modelling, stochastic differential equations, statistical physics, morphological computing and evolutionary algorithms. Using high-performance computers, these methods are used to optimise processes for customers and partners in areas such as thermophoto-voltaic equipment, combined oncology therapies, mechanical screening in asphalt production or robot control.

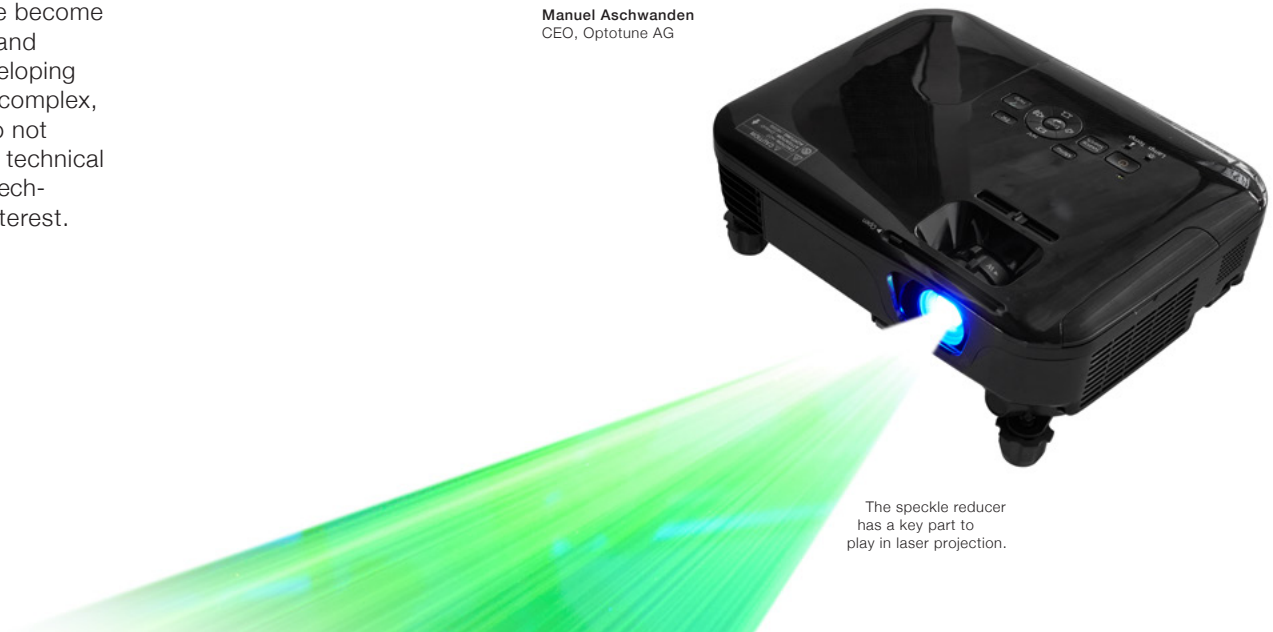
Computational and Algorithmic Science Computational science methods such as modelling, simulation, optimisation and visualisation have become an essential part of the solution processes applied to scientific and technical problems. This key area concentrates its efforts on developing and implementing customer-specific solutions for algorithmically complex, calculation-intensive problems for which standard approaches do not yield satisfactory results and on transforming application-specific technical knowledge into robust and efficient applications. Error estimation techniques for numerical algorithms are another area of particular interest.

Innosuisse project creates pristine laser projection

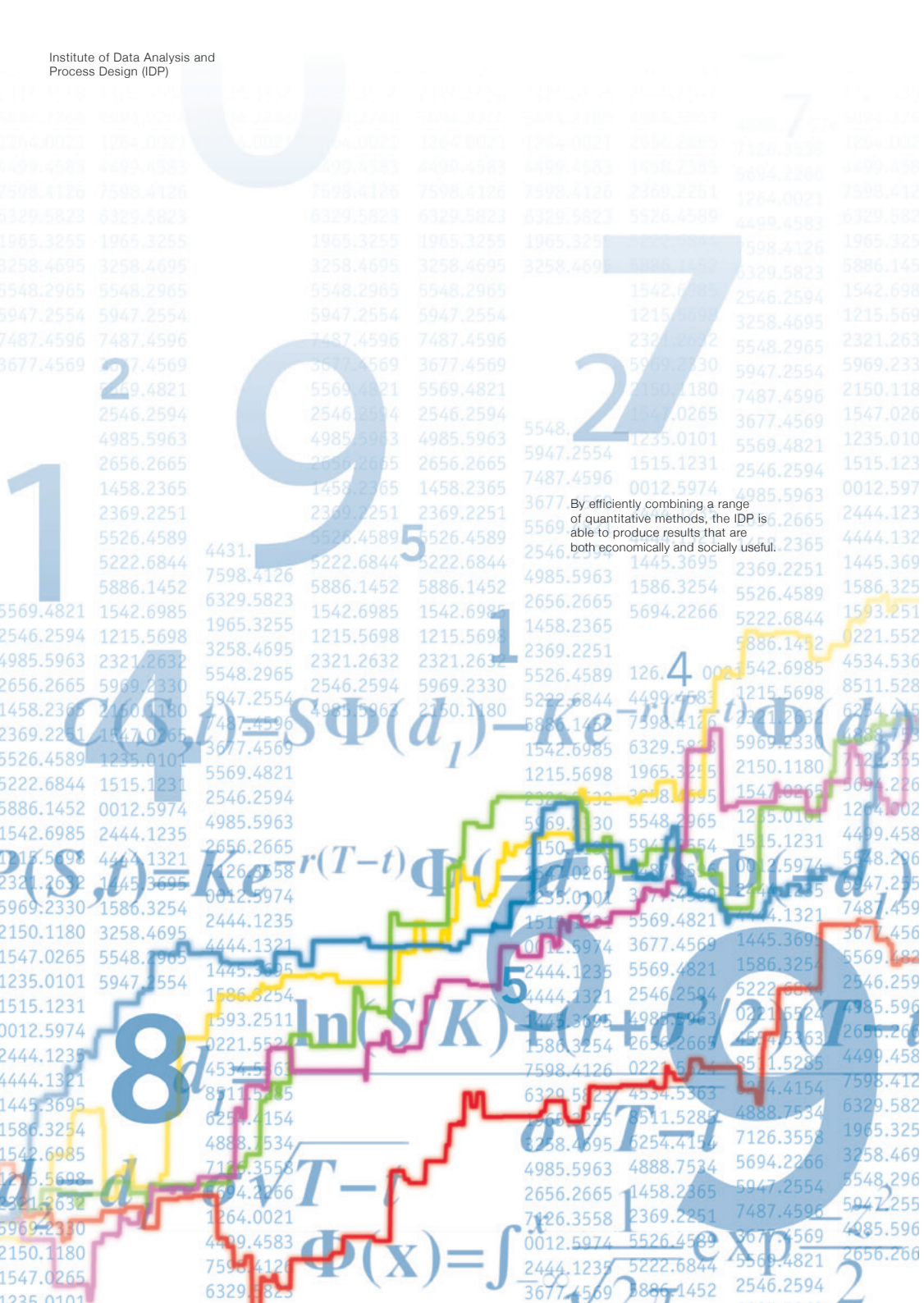
Working in collaboration with Optotune AG, the IAMP developed the basis for high-quality image projection using laser technology. The result of this Innosuisse-funded project is the speckle reducer, a diffuser activated by electroactive translucent polymers. This optical diffuser blurs the speckles typically associated with laser projection on their way to the screen, thus eliminating distracting image interference. After less than two years in development, the speckle reducer was launched on the market. Given the large and growing number of uses for laser projection, the product's success seems assured. Today, it is already in use in both miniature medical cameras and cinema projectors. The advantages of laser projectors are considerable – particularly for cinema operators – since their maintenance costs are substantially lower than those for conventional projectors. They also use about one fifth of the electricity consumed by their conventional counterparts. Another potential application for this technology is in car head-up displays.

"The flexible, easy-going collaboration with the IAMP was a key factor enabling us to develop a commercially successful product in a very short time. The speckle reducer is one of two main products accounting for a significant proportion of Optotune's turnover."

Manuel Aschwanden
CEO, Optotune AG



The speckle reducer has a key part to play in laser projection.



By efficiently combining a range of quantitative methods, the IDP is able to produce results that are both economically and socially useful.

Institute of Data Analysis and
Process Design (IDP)

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Institute of Data Analysis and Process Design (IDP)

The IDP draws on and efficiently combines the methods of statistical data analysis, stochastic calculus, mathematical optimisation and risk modelling. The Institute uses these mathematical disciplines to develop algorithms and tools providing better methods of describing, controlling and optimising complex processes and systems.

Business Engineering and Operations Management Optimally designed corporate and operational processes are critical to a company's success. That is why this key area focuses its efforts on developing methods and tools for the design and optimisation of company processes relating to customers, suppliers and markets. Besides production and logistics processes, we also pay particular attention to processes used in service provision in environments such as hospitals, call centres or transport companies. Decision-support tools for management in complex situations are a key part of our research work, be they for optimal customer management or for maximising the utility of long-lasting technical infrastructure, to cite but two examples. The ability to make correct and purposeful use of the plethora of data now available is a critical factor in this regard.

Finance, Risk Management and Econometrics While the economy is a complex system to which quantitative analysis and modelling can be applied, it places onerous demands on the methods and models used. The IDP's research in this area focuses on financial instrument modelling (return, risk and dependencies), portfolio optimisation, integrated risk management and economic and financial time-series forecasting. Its applications range from high-frequency trading to economic forecasts. The success of our work is largely attributable to our interdisciplinary approach and our collaborations with other research institutions, regulatory authorities and the private sector, both nationally and internationally.

Data Analysis and Statistics All the work carried out in this area is focused on transforming data into usable knowledge, a major challenge in today's information age. Technically correct data analysis and purposeful interpretation of its results often yields new insights which support evidence-based decisions and customer-oriented action. Our expertise is in statistical and data-analysis methods and experimental design. We have substantial applications experience in a wide range of fields including business analytics, customer relationship management, measurement and testing technology, quality control, environment and transport, laboratory analytics, biostatistics and health. In collaboration with the Institute of Applied Information Technology (InIT), we also operate the interdisciplinary DataLab, which takes up innovative ideas in data science and big data analytics and puts them to practical use.

Transport and Traffic Engineering Continuous increases both in mobility and in the complexity of transport systems have increased the demands placed on the stability, sustainability, affordability and safety of these systems. That is why research in this key area is focused on the development and implementation of methods for analysing and evaluating transport systems and for designing and operating them in an optimal way. A variety of quantitative methods are used, ranging from the collation and statistical analysis of traffic data to the modelling and simulation of traffic systems and to the development of indicators for the evaluation of traffic systems. The key objective here is to work with clients and research partners to achieve optimal planning of traffic systems which can be operated efficiently, safely and substainably.

Innosuisse project for inventory management of unit load devices in international air transport

Unit load devices (ULDs) are the standard containers used for loading luggage and cargo onto aircraft. For airlines, maintaining a dedicated ULD inventory represents a substantial cost. For that reason, many airlines have outsourced the management of their ULDs to independent ULD providers.

As part of an Innosuisse project, the IDP is developing a decision-support tool for an independent ULD provider. One part of the task is to define the quantity of ULDs needed each day in order to guarantee a defined service level over a given planning period. The other part involves managing the ULDs in such a way that operationally optimal quantities are maintained at the stations.

To meet these objectives, the IDP is using its expertise in the fields of modelling and simulation, statistical data analysis, operations management and operations research.

Standard ULDs being loaded onto an aircraft.

The IMES uses a number of dynamic testing devices.

The IEFE's work is focused on the efficient extraction, utilisation, storage and distribution of energy.

Institute of Energy Systems
and Fluid Engineering (IEFE)

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Institute of Energy Systems and Fluid Engineering (IEFE)

Thanks to its technical expertise, the IEFE is making an important contribution to the development of new energy-efficient systems, methods, processes and equipment. The IEFE focuses its work on three strategic areas – energy efficiency, renewable energy, and energy storage and networks. Work in these areas is carried out by specialised groups in the fields of photovoltaics, wind power, thermal processes, energy systems and cooling technology, fluid engineering, model-based process optimisation, thermal and electrical energy storage and networks. Besides being enhanced through work on applied research projects with industry partners, this know-how is also systematically imparted to students.

Energy efficiency *Optimising and developing energy-efficient industrial processes and equipment* Society and industry today are technology intensive and their demand for energy is constantly rising. In order to prevent energy shortages, the Swiss Confederation plans a massive reduction in energy usage in Switzerland. The IEFE is using its specialised knowledge and modern laboratories to assist its industrial partners in meeting these binding objectives.

Improved energy efficiency is an ideal method for achieving a lasting reduction in energy consumption while also saving costs. The IEFE is developing systems for evaluating the energy consumption of industrial infrastructure and for optimising the thermal and electrical energy efficiency of industrial production processes and equipment. In close collaboration with its partners, the IEFE is working on solutions which make the best possible use of energy, thus minimising energy waste.

Renewable energy *Increasing installed renewable-energy capacity*
Sustainable energy supplies are in greater demand than ever. That is hardly surprising, since renewable energies regenerate themselves quickly and are inexhaustible. The IEFE has recognised this trend and is engaged in a wide range of projects aimed at optimising the processes which use renewable energy. The Institute's main activities here are in the areas of photovoltaics, thermal processes and wind power. Through its work on projects such as state-of-the-art solar modules, the IEFE is playing its part in developing sustainable renewable energy solutions. Besides making the Institute's industry partners independent of fossil fuel and imported energy, these projects also respond to society's greater awareness of the need for environmental and climate protection.

Energy storage and networks *Improving the integration of fluctuating renewable-energy output into the energy-distribution system* Renewable energies will be a major component in the energy mix of tomorrow. Their output is, however, subject to fluctuation. In the case of solar and wind power, for example, the amount of electricity fed into the grid depends on the weather. Since the demand for energy, on the other hand, is constant, the IEFE is looking for economically viable and environmentally sustainable solutions which will balance out the time intervals between energy production and consumption. The IEFE's work in this area is focused on finding better ways of integrating fluctuating renewable energy output into the energy supply system. Thus, in the field of energy storage and networks, the IEFE is also working on increasing the proportion of total Swiss energy consumption which is provided by renewable energies.

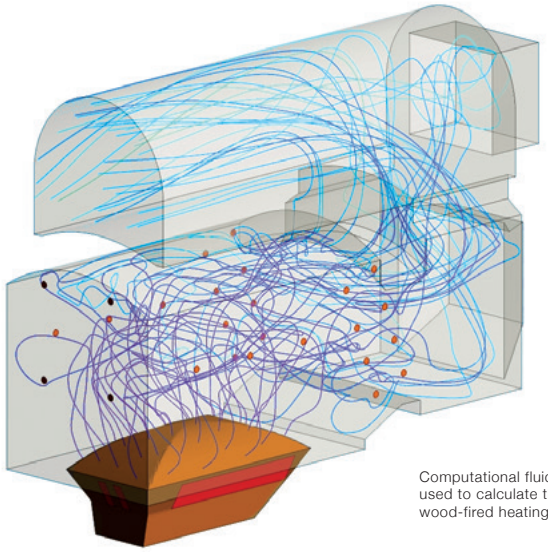
Innosuisse project to optimise grate firing

Schmid AG worked in collaboration with the IEFE on a two-year project which received financial support from the Innosuisse. The objective was to increase the overall effectiveness of the Schmid UTSR/K550-900 kW moving grate firing system so that it would burn wood even more efficiently and sustainably. The IEFE used such state-of-the-art technologies as CFD large-eddy simulation, thermography and laser measurement to develop appropriate optimisation methods.

Over the course of the project, the overall effectiveness of the grate firing system was increased by 2.3 percent, while its auxiliary energy usage was cut by 3 percent. Thanks to a variety of experimental analyses, Schmid AG was able to test the proposed improvements in real-world conditions.

"Solutions-oriented, goal-focused and constructive are the words which best describe our collaboration with the IEFE throughout this project. We, and the IEFE, have gained a host of new insights, some of which are already being used in our products."

Roland Schmid, HTL Engineer
Head of Technology, Schmid Group



Computational fluid dynamics are used to calculate the heat flows in a wood-fired heating appliance.

Taking a ride on the IMES bike simulator is a convincingly realistic experience.

Institute of Mechanical
Systems (IMES)

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Institute of Mechanical Systems (IMES)

IMES's principal research and development expertise is in the field of structures subjected to high levels of mechanical strain. Its focus is on biomechanical engineering, light frame construction and applied mechanics. In addition to developing and testing components, IMES also carries out analytical and experimental simulations.

Biomechanical Engineering In the field of biomechanical engineering, IMES analyses the functional and dynamic characteristics of the human musculoskeletal system. The insights thus gained are used in the development and validation of implants and surgical instruments. The analysis and development of implants is carried out in close collaboration with doctors and manufacturers, thus ensuring that problems can be identified and addressed at an early stage. Prototype implants are experimentally tested in an ISO 17025 accredited laboratory to ensure that they meet the specified functional requirements and can withstand the anticipated strains. IMES conducts all its analysis in accordance with current ISO standards. For innovative products, the Institute works with the client to develop and validate appropriate testing procedures. The auxiliary equipment needed for these tests is designed by IMES and assembled in its own workshop. In addition to its work on orthopaedic products, the Institute has also focused its attention on developing its expertise in ergonomics and patient support systems. This has enabled it to use 3D motion measurement systems, force platforms and EMG muscular activity measurement systems to characterise the interaction between human and machine.

Light frame construction Sparing use of material and energy resources and a focus on minimising costs both require building components designed for optimal weight. Many of the functions used in vehicles, aircraft and automation technology can only be achieved by using extremely strong and light materials and components designed to weigh as little as possible. By using adaptive materials and structures, it is possible to calibrate the dynamic characteristics of light frame designs so that they are exactly tailored to the frequency spectrum of the strains to which they will be exposed. This not only makes the designs more effective,

but also enables them to respond appropriately to the non-linear behaviour of aerodynamic and hydrodynamic loads. IMES carries out development work from concept phase to acceptance testing, supporting the client with its technical expertise at every step of the process.

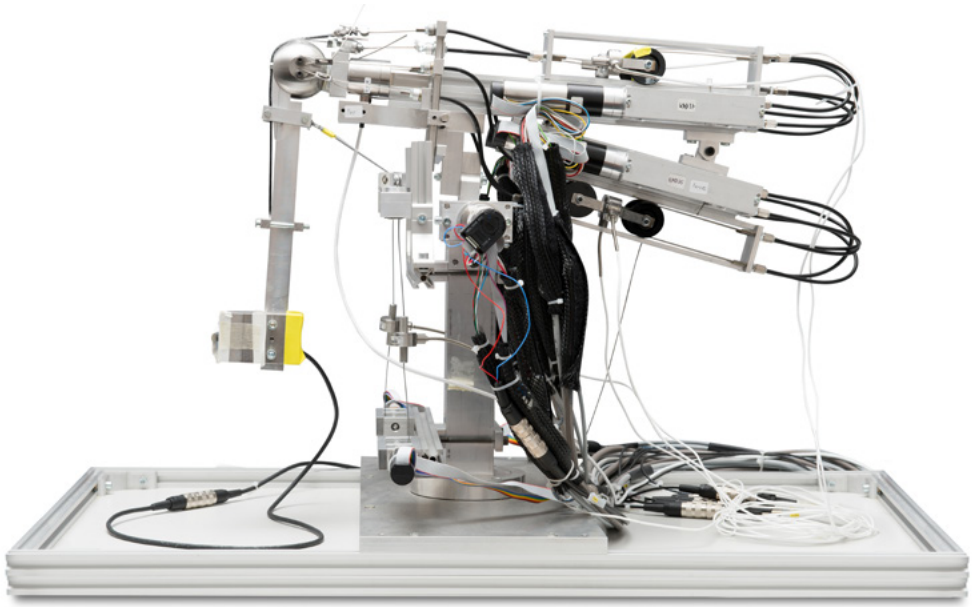
Applied Mechanics Mechanical components often operate in extreme conditions. Turbine rotors, for example, are subjected to thermo-mechanical strain when running at high temperatures. Their material becomes fatigued due to a combination of alternating loads and changing temperatures. Components are also often induced to oscillate when in operation, resulting in material fatigue and the formation of cracks. IMES simulates the behaviour of components under static and dynamic loads and in oscillating states and validates the results of these tests experimentally. Working with its industrial partners, the Institute optimises components and analyses damage to them. IMES is also able to analyse the non-linear elastic and time-dependent behaviour of materials such as rubber-like substances and plastics when they are subjected to mechanical strain. The material-specific metrics required for these tests are determined experimentally. In carrying out this work, IMES is creating a sound basis for the optimal development of mechanical components and systems.

Shoulder simulator project

IMES's experimental shoulder simulator is used to analyse the biomechanical charcteristics of the human shoulder. The simulator can direct real muscular forces in such a way that the upper arm and, in particular, the shoulder joint can be mobilised. This makes it possible to conduct fundamental research on the forces that muscles and joints apply to the shoulder under real-life conditions. The simulator can also be used to test the functional and stability characteristics of orthopaedic and osteosynthetic products applied to the upper arm.

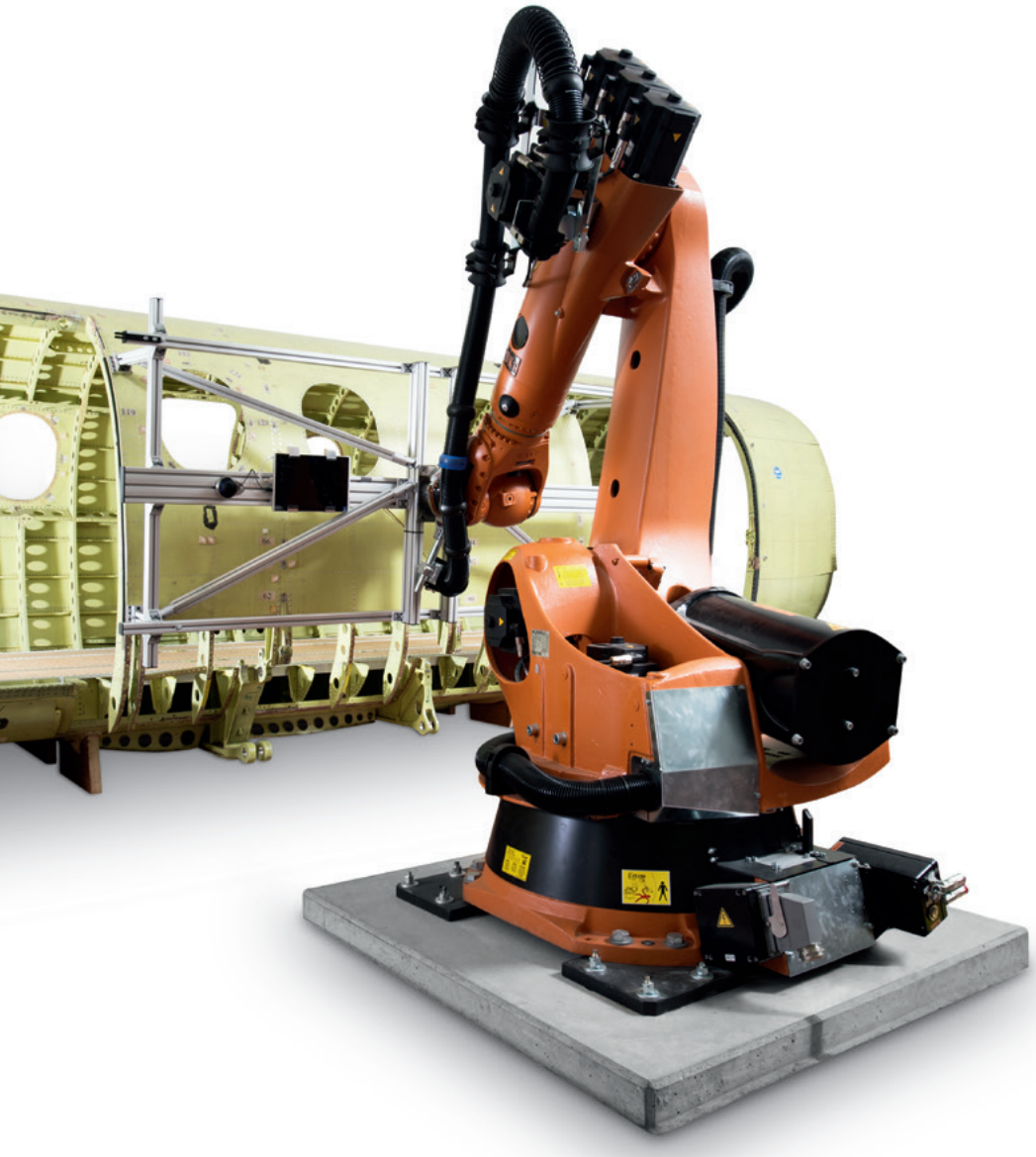
"The shoulder simulator can help to optimise medical products by subjecting them to experimental testing under the most life-like conditions possible"

Frank Dallmann, Group Manager, Upper Extremities Development, Mathys AG, Bettlach



The simulator makes it possible to analyse the forces at work in the human shoulder.

As part of its work on optimising a repair process for aircraft engine parts, the IMPE uses a servohydraulic testing system to carry out material fatigue analysis.



JILAS can lift heavy loads and place them exactly where they need to go.

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Institute of Mechatronic Systems (IMS)

Working in close cooperation with its national and international partners in industry and academia, the IMS carries out innovative R&D projects in the fields of robotics and automation, control engineering and advanced control, powertrain technology and power electronics, systems engineering and industry 4.0.

Robotics and Automation In today's modern industrial society, robots and automated equipment relieve human beings of tasks that are monotonous and hazardous to health. Automation also helps to reduce energy costs and make industrial processes more efficient. The IMS focuses its work in this area on developing sophisticated applications that go beyond current industrial standards. Systems based on direct cooperation between humans and robots are a key part of this work.

Control Engineering and Advanced Control From aircraft autopilot systems to vehicle engine-management appliances and heating and cooling plants, control systems are always used in situations where a given metric reading is expected to elicit a defined response. In the case of mechatronic systems, it is critical to ensure that all the various subcomponents (mechanical components, actuators, sensors and control devices) are optimally calibrated with each other. For that reason, the IMS concentrates its efforts in this area on detailed mathematical systems description and on developing appropriate control algorithms for industrial applications.

Powertrain Technology and Power Electronics deals with the transformation of electrical energy into energy in the form needed by the user and with the conversion of electrical current into power. Both activities are critical to the overall flow of energy, from generation to consumption, not only in our day-to-day lives but in industry as well. The IMS focuses its work in this area on developing power switches for alternative energy and designing optimised powertrains for electric vehicles and electric motor controllers for use in mechanical engineering applications.

Systems Engineering A methodical, integrative product development process is of critical importance when developing mechatronic products. Only by taking a holistic approach is it possible to apply innovative ideas and to design systems that are optimal right down to the last detail. The work carried out by the IMS in this area is focused on applying highly effective methods and tools to the product development process. By using unconventional actuators and sensors, the IMS is able to develop innovative solutions that are both economical and robust.

Industry 4.0 The digitalisation of production processes brings together humans, devices, machines and companies through data and digital representation of real-life components. Concepts such as the industrial internet, digital production platforms, smart factory and digital twin are crucial for the competitiveness of companies - regardless of size. The “SmartPro 4.0” Swiss Digital Learning Factory is an industry 4.0 production system equipped with professional components used as a learning lab and demonstrator in teaching as well as in research and development. The example of an assembly plant serves the purpose of demonstrating all aspects of industry 4.0 production and the hardware and software-based replication, trial, examination and simulation of its interconnectedness within the value chain. The aim of the Smart Factory field lab is to operate a platform with our industry partners where researchers, industrial companies and students have the opportunity to try out new industry 4.0 concepts, test them in practical applications and simultaneously deepen their knowledge of the subject. With this project, we are able to realise a new form of digitalisation within teaching and R&D which has both learning about industrial work and processes and the creation of new, transferable knowledge for the industry at its heart.

EU Robo-Mate project

The Robo-Mate project is engaged in developing an intuitively guidable exoskeleton which will help industrial workers to lift and carry heavy objects. In particular, Robo-Mate should thus be able to prevent damage to the musculoskeletal system and to minimise the substantial societal costs resulting therefrom.

The Robo-Mate concept is based on direct interaction between human and machine, so as to make the most of the particular strengths of both. The human contributes intelligence and intuition, while the artificial exoskeleton delivers power and precision. The greatest challenge is to make the exoskeleton intuitively guidable. With its complex combination of highly diverse mechanical, electronic and IT modules, Robo-Mate provides a shining example of state-of-the-art mechatronics.

This IMS-led project is being carried out in conjunction with twelve industrial and university partners from seven European countries. Because the know-how contributed by each of the partners is complementary, optimal use can be made of their specific expertise at every project stage.

In future, Robo-Mate will lend industrial workers a helping hand.

The INE's research focuses on the interaction between technology, the economy and society.

Institute of Sustainable
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Institute of Sustainable Development (INE)

Shaping a sustainable future is a major challenge. The INE is playing its part in meeting that challenge through its application-oriented research on the interaction between technology, the economy and society. This work applies social science methods such as system dynamics, foresight, experiments, expert interviews, opinion surveys, multi-criteria analysis and spatial statistics.

Sustainable Energy Systems How can energy systems be designed to meet the numerous demands placed on them in a sustainable manner? The INE identifies topics that are relevant to the future and uses these to evaluate the development of technologies and their acceptance. It examines the needs and behaviour of individuals in order to develop design principles for sustainable energy regions and innovative business models.

Sustainable Transport Systems How can individual mobility and overarching logistic processes be designed so as to enhance economic competitiveness and minimise the burdens placed on the population and the environment? The INE provides the contextual and systems expertise required to address these questions. It formulates future requirements for technologies, mobility systems and transport networks. It also evaluates the potential of promising future technologies and innovative transport concepts. Based on the results of this work, the INE formulates recommendations for sustainable mobility.

Risk management and Technology Assessment The INE's work in this area is focused on the following questions. How can risks in a company or organisation be identified as comprehensively as possible? From what standpoint should risks be evaluated? How can stakeholder interests be taken into account in the risk management process? How can capability maturity models be used to modularise the initial implementation and subsequent development of a risk management process? What is integrated risk management? How can technologies be comprehensively evaluated?

Institute of Sustainable Development (INE)
Illustrative project

SCCER CREST

As part of the Swiss Coordinated Energy Research action plan, the Innosuisse provides financial support for the Swiss Competence Centers for Energy Research (SCCER), a network of research competence centres at a number of Swiss universities. Their objective is to develop additional expertise within universities in order to help make energy transition a reality.

In collaboration with the ZHAW's INE and its Center for Innovation and Entrepreneurship, the Competence Center for Research in Energy, Society and Transition (CREST) formulates policy recommendations on reducing energy consumption, promoting energy innovation and increasing the use of renewable energies. CREST's work encompasses the economy, the environment, legislation and social behaviour. Its objective is to analyse the drivers and barriers affecting energy efficiency, to formulate strategies to enable companies and regions to adapt to the new energy-system imperatives, to design new tools to evaluate political and technological solutions and to develop innovative concepts for energy policy.

SCCER CREST links research groups across Switzerland. It is engaged in filling important research gaps in the energy landscape. This institution will ultimately become one of the world's most important research centres in this area. It will work in close collaboration with its private and public sector partners and with the other SCCERs.

SCCER CREST is focused on developing innovative solutions for the coming energy transition.

SCCER CREST

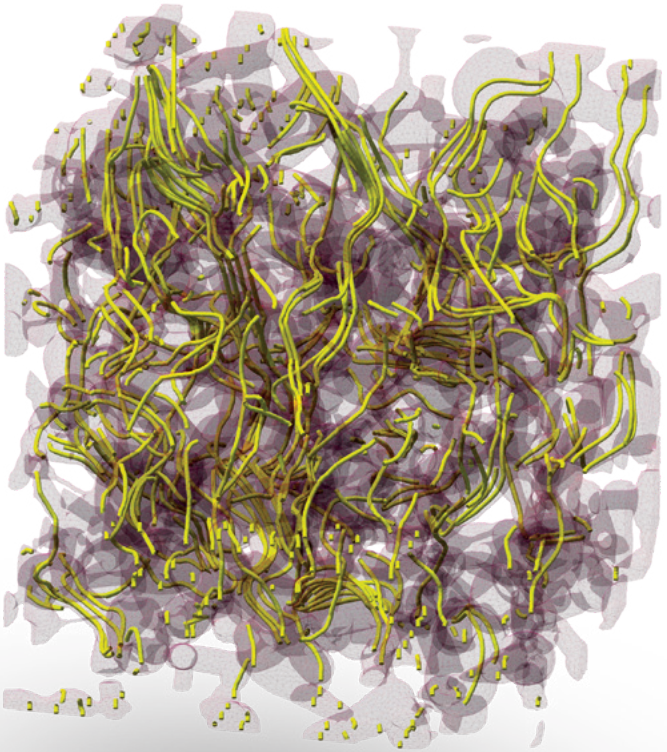
In cooperation with the CTI

Energy
Swiss Competence Centers for Energy Research

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Commission for Technology and Innovation CTI



This picture shows simulated electric current trajectories passing through a section of a microstructured fuel cell electrode measuring only a few micrometres in diameter.

Institute of Computational
Physics (ICP)

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Institute of Computational Physics (ICP)

The ICP is home to a team of physicists, mathematicians and engineers engaged in applying methods and results from fundamental research to problems arising in industry.

For more than 20 years, the ICP has been developing simulation models which yield useful results in a number of application areas. Examples include models for simulating the cooling of chocolate mass during production, crowd movements at major events such as the Zurich Street Parade and the optimal control of fuel cell heating systems. The ICP also operates an optoelectronics laboratory which develops optoelectronic materials and new optical measurement processes.

Together with its partners from the scientific and industrial communities, the ICP devises solutions for concrete problems, such as how to measure coatings without touching them or how to slow down the aging process in fuel cells.

The ICP has four key areas of research and development:
– Sensor technology and measurement systems
– Electrochemical cells and microstructures
– Organic electronics and photovoltaics
– Multiphysics modelling

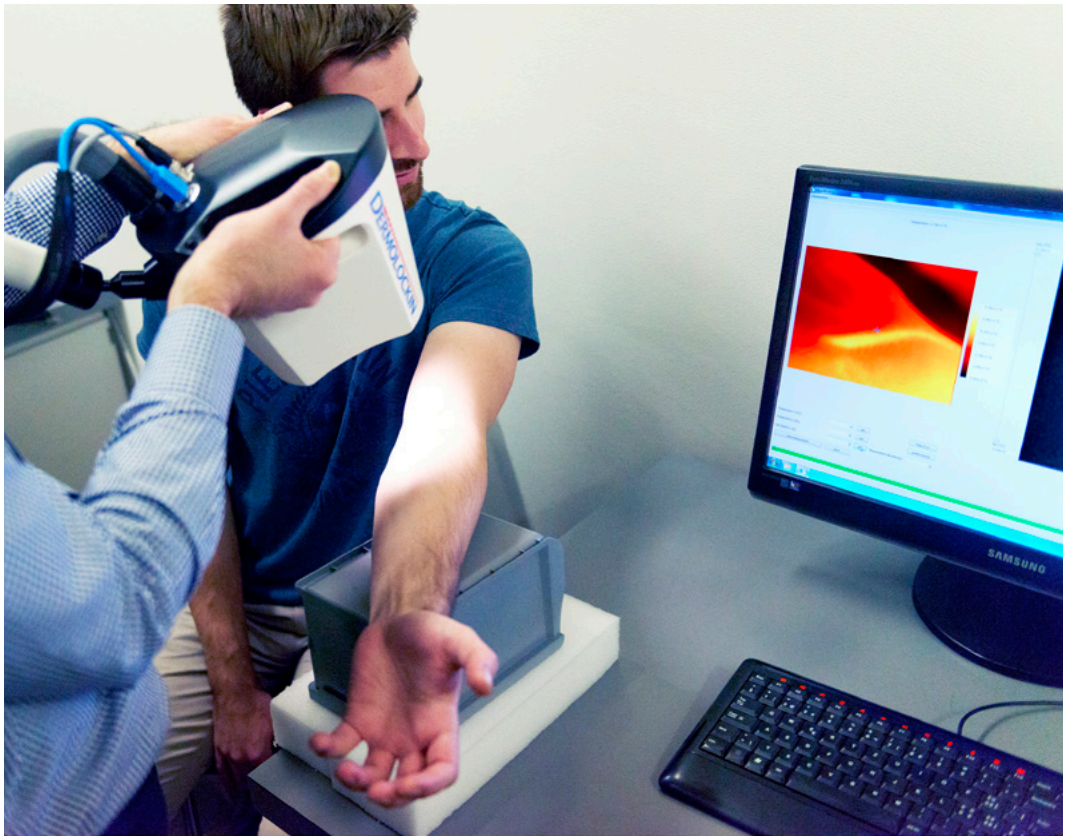
six spin off companies:
– NM Numerical Modelling AG, *www.nmtec.ch*
– FLUXiM AG, *www.fluxim.com*
– Winterthur Instruments GmbH, *www.winterthurinstruments.com*
– NanoLockin, *www.nanolockin.ch*
– Opus Néoi, *www.skinobi.com*
– Zarawind, *www.zarawind.com*

and three numerical software packages:
– FE multiphysics SESES, *www.nmtec.ch*
– Optoelectronics SETFOS, *www.fluxim.com*
– Electrochemistry PECSIM, *www.pecsim.ch*

Additional information is available from the ICP Research Report, which is published online every year.

Detecting diseased skin using high tech

ICP researchers have developed a device for the non-contact examination of skin areas with an infrared camera, thus enabling the early, inexpensive as well as laser and radiation-free detection of skin problems. Doctors can, for instance, measure the depth of skin burns and determine whether the skin will be able to heal itself. The technology required is called thermography. Thanks to its ability to detect even the smallest cracks and lesions, this method has already proved its worth in the quality assurance of aeroplane components. Now, this high-tech system can be used to examine human skin. During the measurement, a temperature-modulated airflow stimulates the skin, while an infrared camera records the temperature fluctuations provoked on the skin surface. The developed software processes the measured data and displays the results as images on a tablet computer. Based on these images, trained medical experts can then differentiate healthy from diseased skin areas.



Institute of Computational Physics (ICP)
Illustrative project

Industrial communications solutions are one of the InES's areas of expertise.

Institute of Embedded
Systems (InES)

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Institute of Embedded Systems (InES)

Distributed embedded systems and communication solutions for industry are the InES's key areas of expertise. The Institute develops hardware and software components for use in networks, as well as methods and tools for secure systems development. Thanks to its high-quality reference implementations, the InES is able to provide rapid, low-risk access to innovative and economical solutions and to transfer technology to its industrial clients efficiently.

Communication Network Engineering The overall functionality of a distributed system often requires rapid and reliable deterministic communication between distributed devices and precise synchronisation between networked nodes. The research work carried out by the InES in this area encompasses the development, optimisation and verification of internationally standardised protocols as well as their adaptation to application- and client-specific systems.

Secure and Dependable Systems and Networks The number of applications whose malfunctioning could jeopardise lives and property is increasing. To address these risks, the InES is carrying out R&D work on special hardware and software designs, development processes and tools. Standardised methods and designs should substantially reduce the high costs and significant investments of time usually associated with ensuring functional security and reliability.

Internet of Things The Internet of Things (IoT) seamlessly interconnects objects, products and machines. The resulting benefits include increased productivity, reduced waste of resources and enhanced security. In addition, IoT enables completely new services and business models. The InES has broad and proven project experience in designing reliable networks of low-cost, energy-efficient IoT nodes, in authenticating those nodes and in providing the technology needed to operate the various connections securely.

Autarkic Systems These are systems which perform their functions with virtually no external support. They can be independent of electrical current, no communication and no external computing. Autarkic embedded systems are operated by appropriate microcontroller systems and run on an optimised energy budget. They do not require new batteries and derive the electrical energy they need from sources in their environment such as light, heat, motion or radio waves. Typically they either function without any communication at all or via wireless links.

Low-Power Wireless Embedded Systems These systems are driving the development of a whole range of new applications, products and services. The transformative potential of this technology can be seen in Industry 4.0 and the Internet of Things, where for economic reasons the large number of objects involved can only be linked to each other wirelessly. To support its work in developing energy-optimising methods and technologies, the InES maintains close contacts with chip manufacturers, who are increasingly combining microcontrollers with wireless systems.

System on Chip (SoC) Design This technology combines microprocessors, function-specific peripheral or codec components and, usually, a field-programmable gate array on one single silicon chip. This makes it possible to manufacture extremely powerful, flexible and cheap systems with high data processing and data transmission speeds. The focus of the InES's work in this key area is on the interaction between hardware and software within SoCs, with particular emphasis on the architecture, design and programming of SoCs with freely programmable logic.

Realtime Platforms Originally developed for smartphones and tablet computers, high-performance, hybrid multi-core processors are now increasingly being used in embedded systems. Because they contain a number of different processor cores (CPUs, GPUs and DSPs), they are particularly suitable for calculation-intensive applications such as video, audio and multimedia processing or rapid measurement systems which do not require additional dedicated hardware. Real-time operating systems and optimal process distribution across a number of different cores, each with its own programming model, are the key challenges in this area.

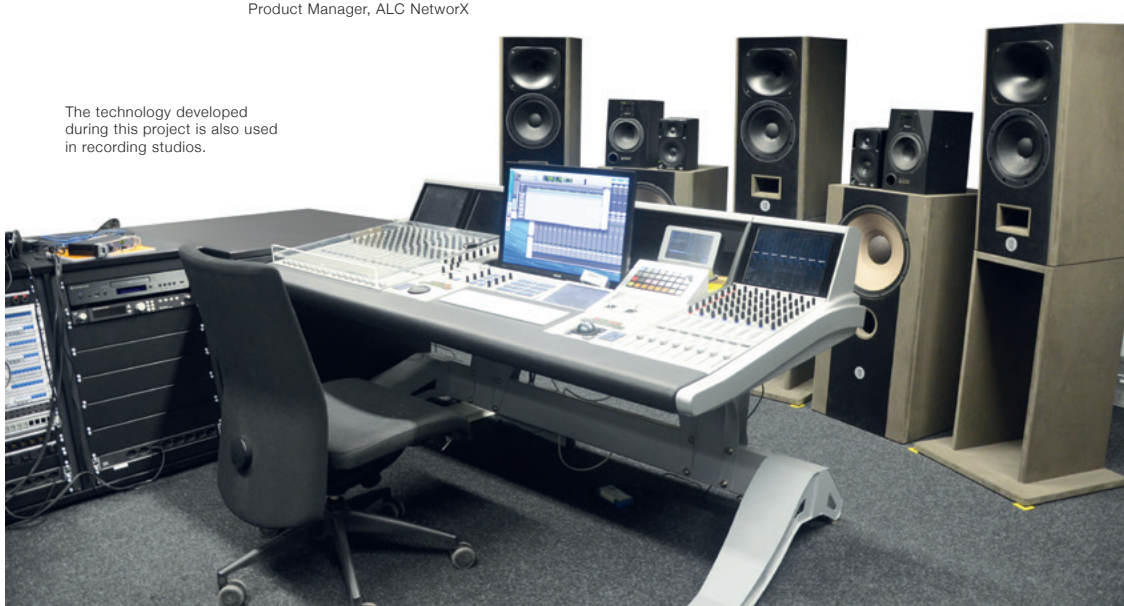
Media over IP project

Professional media service providers such as radio broadcasters and production studios use systems which distribute audio, video and protocol data in real time. These systems link studios, broadcasting centres, event venues and outside broadcast units to each other. At present, specialised proprietary systems are used for this purpose. The purpose of the Media over IP project was to develop an open technology for transmitting Media data in real time. This new methodology is based on specific IP protocols and standardised ethernet network technology. Because all the components are precisely synchronised, it is possible to transmit an unlimited number of media clocks in almost perfectly matched phases. The system is also notable for its extremely low transmission latency and the high level of transmission reliability it achieves thanks to its simultaneous use of two independent signal paths. Now christened RAVENNA, the technology is being marketed by the Lawo subsidiary ALC NetworX and is meeting with wide market acceptance. More than 40 audio firms have now joined the RAVENNA partner network.

"Our collaboration with the InES on the Media over IP project was extremely pleasant and successful. Thanks to the high level of technical expertise of the staff working on project, we were able to meet the objectives we had set ourselves."

Andreas Hildebrand, Senior
Product Manager, ALC NetworX

The technology developed during this project is also used in recording studios.



Burning a ceramic
membrane element

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Institute of Materials and Process Engineering (IMPE)

The IMPE has comprehensive expertise in materials science and process engineering. The combination of these two disciplines enables the Institute to develop innovative materials, coatings and manufacturing methods and to design new processes and equipment. The IMPE collaborates closely with its partners at every stage of their project, from initial idea to development and to ultimate production implementation.

Examples of this work include materials used to increase component longevity or fuel cell efficiency, coatings to prevent ice formation on wind turbines or to increase the resistance of exposed surfaces to wear and tear, reactive adhesives for joining textile surfaces together and methods and processes for methanation, fuel conditioning, exhaust treatment and chemical energy storage.

Some 40 staff are employed in research and development work at the IMPE, principally in materials research, surface finishing and process development. Work in all three of these areas makes significant use of nanotechnology.

Materials Functional polymers and polymer blends, adhesives, hybrid polymer-ceramic materials, high-performance ceramics, advanced carbon composites, high-temperature metallic materials, catalytic converter systems, smart materials, material fatigue and damage analysis.

Surface finishing Polymer coatings (lacquers and paints), sol-gel coatings, hybrid coatings, adhesive agents and adhesive technology, ceramic and metal coatings, surface functionalisation, surface nanostructuring (for catalytic converters) and tribology.

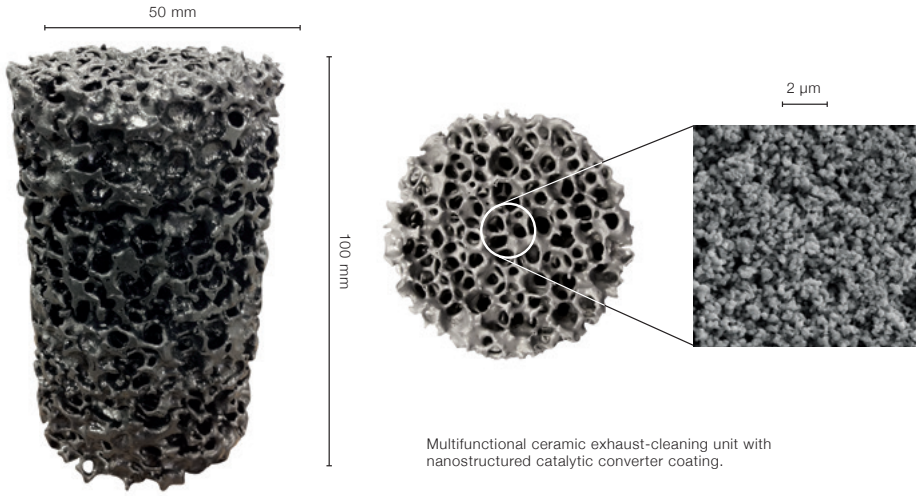
Process development Membrane separation processes, separation and enrichment through sorption, power to gas / methanation / fuel processing, exhaust treatment, joining technology (mechanical, adhesive and welding-based), heat treatment, particle and powder synthesis, ceramic moulding, coating, compounding and extrusion, additive manufacturing.

Partners working with the IMPE on joint R&D projects or service mandates have the benefit of an ultramodern infrastructure for the development, testing, analysis and characterisation of materials and coatings and for process technologies. Thanks to the national and international cooperations in which it engages, the IMPE is constantly expanding the scope of its expertise.

A member of IMPE staff uses X-ray photoelectron spectroscopy to determine the characteristics of a surface.

Innosuisse project for the development of ceramic exhaust-cleaning filters for fuel cell heating appliances

For many years, the IMPE has worked with the Winterthur-based company Hexis on the development and optimisation of its fuel cell technology. In a joint project financially supported by the Innosuisse, Hexis and the IMPE developed and carried out long-term peformance testing on a new type of multifunctional, catalytic exhaust treatment system for fuel cell heating appliances based on functionally coated, low-pressure-loss ceramic components. The project provided an ideal opportunity to apply the IMPE's combined expertise and resources in the fields of materials development, process engineering and analytics.
By working in the laboratory to improve the process used for producing ceramic materials, it was possible to develop new types of filter elements which were then evaluated under simulated operational conditions using testing equipment developed by the laboratory. A chemical analysis was also carried out, which yielded precise indications of the performance attributes of the new materials. On completion of the project, the IMPE was able to provide Hexis with a product which will be put to the test in its latest generation of appliances.



Multifunctional ceramic exhaust-cleaning unit with nanostructured catalytic converter coating.

Digital signal processing is a key area of the ISC's work.

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Institute of Signal Processing and Wireless Communications (ISC)

The ISC develops hardware and software solutions for use in communications and measurement systems. Its focus is on optimising the signal path from the antenna or sensor to the digital evaluation device. Working in close collaboration with its industry partners, the ISC uses its theoretical know-how and long-standing product design experience to develop innovative solutions. The ISC's research and development work is focused on the following three key areas:

High-frequency Electronics The focus here is on RF transmitter, receiver and antenna design, RF measurement technology, analogue signal processing, low-noise electronics and low-power electronics.

Communications Engineering and Wireless Communication primarily deals with physical wireless communication. Research in this area covers processes such as data compression, error correction mechanisms, modulation processes, media access processes and radio propagation. The solutions developed range from software-defined radio structures to commercially available system-on-chip modules. In recent years, the ISC has accumulated a wealth of systems know-how in RFID, Bluetooth-Smart, WLAN, DAB, GPS and ADS-B technologies.

Digital Signals Processing In this key area, the ISC focuses its efforts on the design and simulation of algorithms for processing audio, video and measurement signals of all types and on their efficient implementation in a variety of microcontrollers, signal processors, CPLDs and FPGAs.

Mobile multilateration system for aircraft location

Working in collaboration with Skyguide, Switzerland's air navigation services provider, the ISC has developed a mobile system for determining the position of aircraft. Unlike radar-based systems, this technology uses multilateration to determine the position of an aircraft. The system uses a set of receiver stations in different locations to detect the messages that the aircraft transmits automatically and then uses the differences in transmission times to calculate the position of the aircraft to an accuracy of about eight metres.

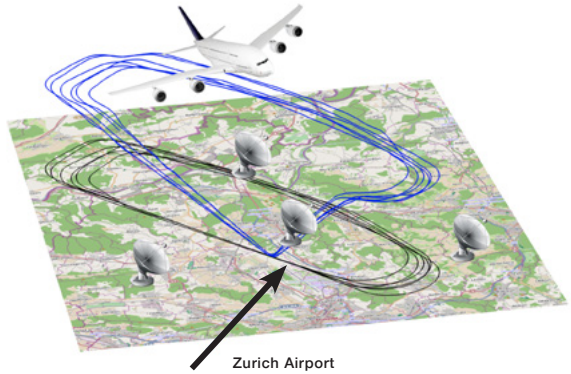
The special characteristics of this location system include the fact that it is mobile, can be transported by one person and, should it be deployed in a remote location, can also operated by battery power for a prolonged period of time. Thanks to its high degree of accuracy and its low cost, the system has the potential to be used for a whole range of practical purposes, such as developing new aircraft noise models or providing support to airport radar.

This interdisciplinary project involved work on a range of exciting questions in the fields of wireless communication, high-frequency electronics, microcontroller-based digital signal processing, FPGAs and PC parallel computing.

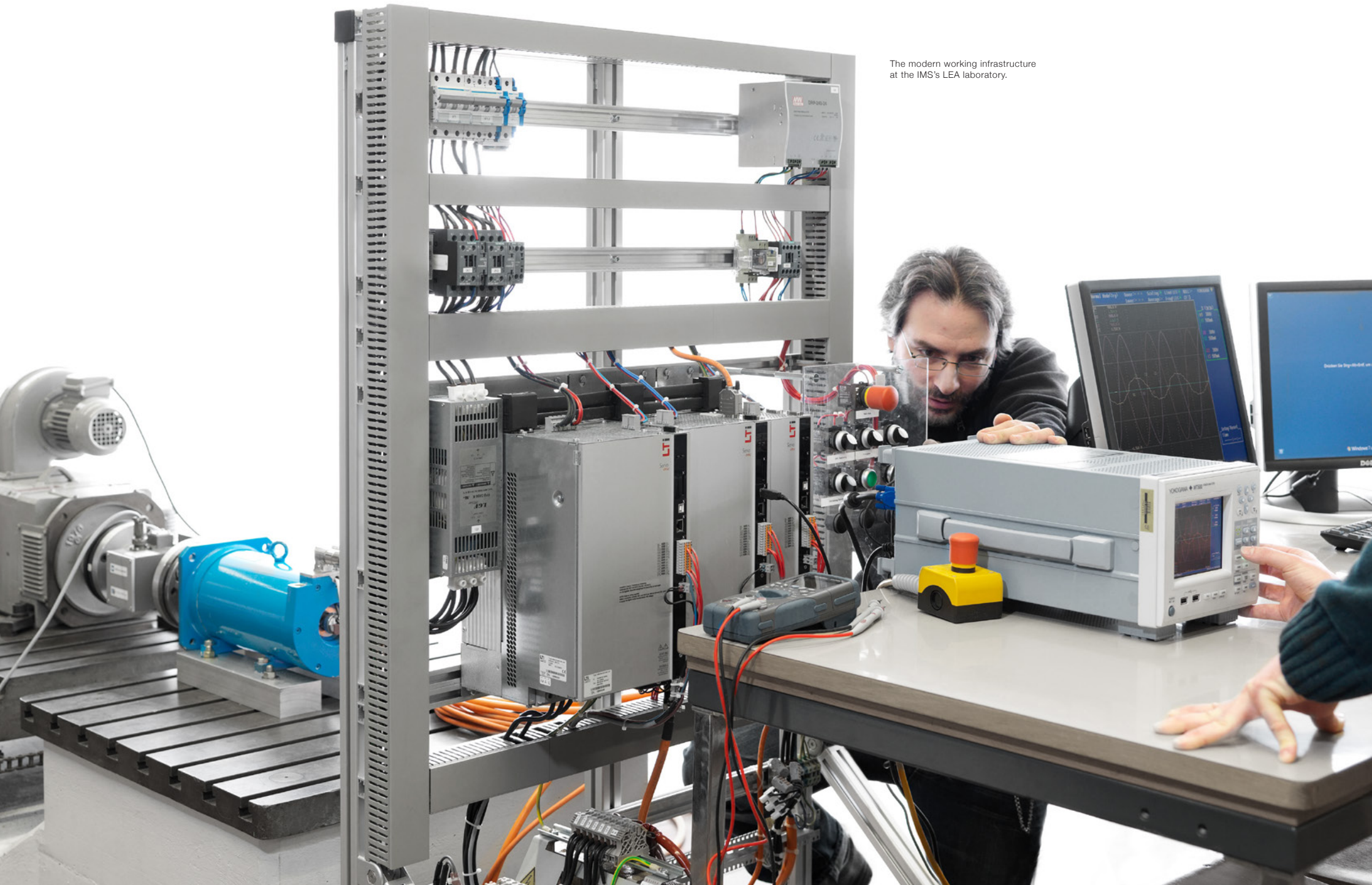
"The professional, flexible and solutions-oriented approach the ISC took to its collaboration with us on this project made it possible to develop a mobile, autonomous multilateration system with limited expenditure of time and resources. In practical deployment, this innovative system ensures that aircraft trajectories can be monitored independently and precisely."

Dr. Maurizio Scaramuzza, Head, CNS Expert
Group, skyguide – swiss air navigation services ltd.

Institute of Signal Processing and Wireless Communications (ISC)
Illustrative project



This mobile location system with its extendable antenna fits into a carrying case and is thus easy to transport.



The modern working infrastructure at the IMS's LEA laboratory.

The ZAV has developed its own wind tunnel, which it uses for both research and teaching purposes.

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Centre for Aviation (ZAV)

The ZAV takes an interdisciplinary approach which enables it to address complex aviation issues under one roof. It combines a range of technologies, methods and fields of knowledge with a view to mastering the challenges posed by future global mobility and to find ways of making it safer and more efficient. To that end, the Centre for Aviation has defined two key strategic areas of activity.

Aircraft Technologies The ZAV's expertise in this key area encompasses computational fluid dynamics, flight testing methods and certification of aircraft flight characteristics and flight performance. Its core competences include aerodynamic analysis, design, measurement and testing. The ZAV also provides certification and verification engineers to advise the aviation industry on the flight characteristics and performance of aircraft and to carry out fatigue life analysis of aircraft structural components.

For small aircraft manufacturers, the costs of developing precise flight dynamics models are generally prohibitive. For that reason, when flight characteristics problems arise, they are often addressed by trial-and-error methods which are heavily dependent on the imagination and experience of the development team. Because today's market demands high levels of aircraft performance, sophisticated predictive capabilities using flight dynamics models and real-time simulators have become indispensable. Thanks to its broad experience with general aviation aircraft and its flight control system and simulation capabilities, the ZAV is in a position to meet these demanding requirements.

The ZAV's human-machine-system team has also developed expertise in the operation of unmanned aircraft (human-drone interaction). This extends to questions relating to staff qualifications and training and to the operation of these aircraft. R&D work is also being carried out on voice-activated cockpit controls. To that end, the ZAV's cockpit simulator is being further developed to serve as a test platform to examine human factors in aviation. An operational voice-activated control system was already successfully implemented in the summer of 2015 and will now be further developed and analysed.

Aviation Operations This key area deals with aviation systems in the field of technology and operations. This includes air traffic management, meteorology and aircraft systems. It also encompasses the analysis of the human factors involved in the aviation working environment and the development of language tests for pilots and air traffic controllers.

Head and eye tracking devices are used to analyse human behaviour and to develop human-factor training courses for air traffic controllers and pilots. These courses are also suitable for use outside the field of aviation. In addition, the Centre for Aviation works very closely with the International Civil Aviation Organisation (ICAO) in order to ensure that the language tests it develops meet the strict criteria defined in the ICAO Language Proficiency Requirements.

The Meteorology and Aviation team examines the effects of weather conditions on aviation. It also develops and deploys measurement and observation systems. In addition to their aeronautical applications, these systems are also used in the field of renewable energy.

Head and eye tracking system for the Human Factors Laboratory

The ZAV's combined head and eye tracking system provides the basis for efficient, real-time evaluation of data on head and eye movements. The measurement systems used hitherto only tracked eye movements. Thanks to the measurement infrastructure developed by ZAV, a person's head movements can now also be efficiently and rapidly evaluated over a prolonged period of time. This system also makes data capture more precise, because the eye tracking data do not need to be coded manually.

At present, the system is in use at the Human Factors Laboratory and in the ReDSim flight simulator. However, since it is designed for mobility, it can also easily be used in other settings. It could, for example, be used to analyse the head and eye movements of an air traffic controller sitting at a radar screen or of a drone pilot operating a monitor. The system's analytical software enables the measurement data to be presented in a readily understandable format and to be interpreted in a manner appropriate to the specific user. The system can, for example, provide statistical evaluations of the user's fixed gaze on predefined areas of interest. Such data can provide insights into the informational utility of displays contained in the cockpit instrument layout, to cite but one example.

The ZAV system captures both head and eye movements.

Innovative methods, tools and processes enable the ZPP to develop visions into products.

Centre for Product and
Process Development (ZPP)

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Centre for Product and Process Development (ZPP)

The ZPP specialises in innovative forms of product and process development, from initial vision to finished product. The common focus of its four key areas of research – Innovation Playground, Innovation Development, 3D-Experience and Advanced Production Technologies – is on designing new methods, tools and processes for innovative product development and efficient manufacturing processes. The research team is actively engaged in teaching and continuing education and also offers client-specific seminars.

Innovation Playground The ZPP's work in this key area is focused on researching and optimising methods for the creative development of ideas and visions at the early stages of product and process development. It encourages its industry partners to engage in out-of-the-box thinking. The playground's motivating infrastructure includes a creative area with an adjoining proto corner, where ideas can be rapidly transformed into tangible prototypes, thus ideally facilitating dialogue between people with different experience perspectives. The deliberately playful approach adopted here creates space for radical solutions. The ZPP also supports its industry partners in the long-term enhancement of their companies' own innovation capabilities and holds regular innovation workshops, both on campus and at company premises.

Innovation Development carries out research on new technological solutions for the challenges facing society and industry. The ZPP develops, implements and tests concepts, functional models and prototypes for new ideas in the fields of energy, mobility, health and Industry 4.0. This work draws on the Centre's expertise in economic and technical feasibility analysis, sustainability analysis, industrial design studies, target costing and risk evaluation. In collaboration with the three other ZPP key areas, Innovation Development conducts research on new structurally optimised machine components and applies new product development methods.

3D-Experience The ZPP's research work in this key area uses state-of-the-art 3D tools and CAx technologies to accelerate innovation and to enhance the quality of products and processes. In its 3D Lab, the ZPP can present the real world in virtual 3D prototypes, which can then be used to create a comprehensive set of ergonomic and haptic evaluations, movement analyses, simulations and high-quality visualisations before a real physical prototype is produced. The research team uses dedicated, client-specific software to optimise the process steps in the CAx applications, from the initial sketch to the complex NC manufacturing programme.

Advanced Production Technologies applies new and efficient manufacturing processes to its research work. The most notable of these are additive manufacturing (3D printing) and subtractive 5-axis machining. Optimising the combined use of these processes in hybrid manufacturing opens up an innovative approach to product development. The ZPP is conducting research on new additive manufacturing processes, notably selective laser melting, as well as developing the machines they require and specifying optimum process parameters. In addition to evaluating suitable areas for the deployment of these processes, the ZPP is also developing high-quality components and products in both metal and plastic. Thanks to its modern laboratory and workshop infrastructure, the Centre is able to set up testing apparatus, prototypes and short production runs both for student work and research and development projects.

Gait trainer project

As a result of a stroke or some other neurological illness, many people are either impeded in their walking or no longer able to walk. In order to help them learn to walk again, these patients' neurological rehabilitation uses automated gait trainers. In conjunction with its corporate partner ABILITY Switzerland, the ZPP has developed a gait trainer of this type. This newly developed device, named LYRA®, differs from existing models in that its simple and economical mechanical structure makes it affordable for small and medium-sized therapy centres and clinics.

"Our vision was to develop a low-cost rehabilitation device specially designed for patients whose mobility is impaired as a result of a neurological illness. The ZPP succeeded in using simple mechancial components to make complex movement possible."

Kean Madjdpour, Co-Founder,
ABILITY Switzerland

The gait trainer helps people to learn to walk again.

3D Mosaic.
Mobile robotics
for outdoor use.

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