TOGETHER
from Idea to Innovation



Catalogue of Competences, Services and Solutions
of the Jožef Stefan Institute
for Industry

Content

Science and business hand in hand 3
Health 5
Culture, Creativity and Inclusive Society 21
Civil Security for Society 25
Digital, Industry and Space 31
Climate, Energy and Mobility 55
Food, Bioeconomy, Natural Resources, Agriculture and Environment 75

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Research departments of the Jožef Stefan Institute

Physics
Theoretical Physics (F1)
Low and Medium Energy Physics (F2)
Thin Films and Surfaces (F3)
Surface Engineering (F4)
Condensed Matter Physics (F5)
Gaseous Electronics (F6)
Complex Matter (F7)
Reactor Physics (F8)
Experimental Particle Physics (F9)

Chemistry and Biochemistry
Biochemistry and Molecular Biology (B1)
Molecular and Biomedical Sciences (B2)
Biotechnology (B3)
Inorganic Chemistry and Technology (K1)
Extreme Conditions Chemistry (K2)
Physical and Organic Chemistry (K3)
Electronic Ceramics (K5)
Nanostructured Materials (K7)
Synthesis of Materials (K8)
Advanced Materials (K9)
Environmental Sciences (O2)

Electronics and Information Technologies
Automation, Biocybernetics and Robotics (E1)
Systems and Control (E2)
Artificial Intelligence (E3)
Open Computer Systems and Networks (E5)
Communication Systems (E6)
Computer Systems (E7)
Knowledge Technologies (E8)
Intelligent Systems (E9)

Reactor Engineering and Energetics
Reactor Engineering (R4)

Research centres of the Jožef Stefan Institute

Centre for Electron Microscopy and Microanalysis (CEMM)
Energy Efficiency Centre (EEC)
Networking Infrastructure Centre (CMI)
International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)
Milan Čopič Nuclear Training Centre (ICJT)
Reactor Infrastructure Centre (RIC)
Scientific Information Centre Library (ZIC)
Centre for Research innovation partnership (CRIP)

Science and business hand in hand

Artificial intelligence, advanced materials, green technologies, energy innovations, and digital solutions are now an integral part of our everyday lives – we encounter them at every turn. These very fields have been the focus of pioneering research by our colleagues at the Jožef Stefan Institute for decades. Through our discoveries, methods, and technologies, we actively co-shape scientific and technological progress at national, European, and global levels. Many of our research outcomes have successfully transitioned into practice in domestic and international companies, driving real change.

Innovations from the Jožef Stefan Institute help companies gain a competitive edge: more efficient and cost-effective production, reduced resource consumption, a more environmentally friendly footprint, tailored digital solutions, new products and services, higher quality, and tangible savings.

We can collaborate in the ways that best suit your needs. The most common forms include:

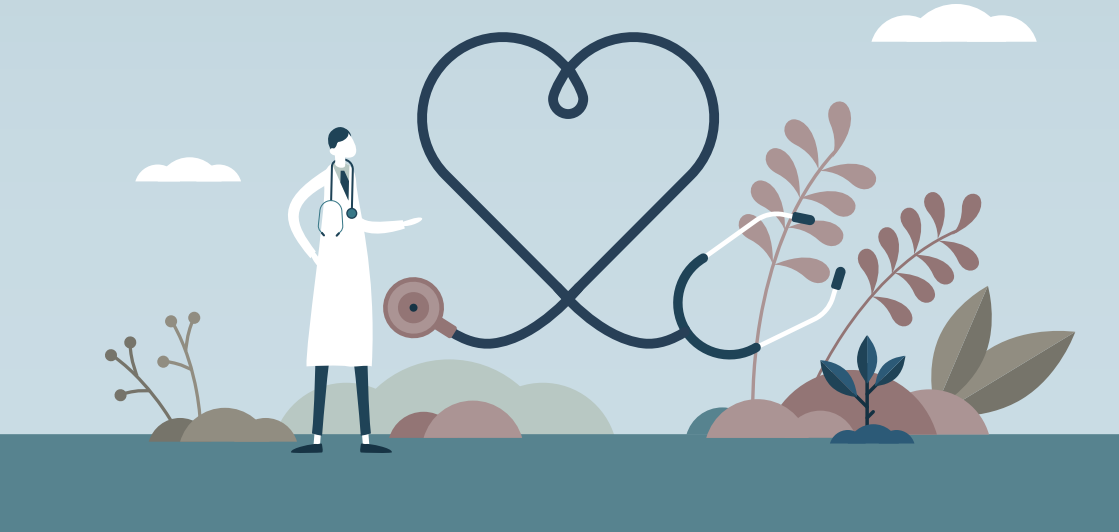
- Short-term contractual research for quick, targeted solutions to specific challenges;
- Medium- and long-term projects with larger investments, where we jointly develop breakthrough solutions with high potential;
- Licensing of intellectual property for direct use of our technologies;
- Establishing spin-off and spin-out companies, where our researchers turn their ideas into successful businesses;
- Participation in national and international research and development projects.

In this brochure, we outline a selection of current innovations, technologies, and services that can serve as the foundation for partnership with you. Our doors are always open to collaborations in other areas as well. Together, we can create a sustainable, innovative, and successful future.

Prof. Dr. Leon Cizelj,
Director of the Jožef Stefan Institute

Science and entrepreneurship together on the path to success!

Health



This section covers improving and protecting the health and well-being of citizens by generating new knowledge and developing innovative solutions to prevent, diagnose, monitor, treat and cure diseases. This includes developing health tools, technologies, and digital solutions, mitigating health risks, protecting populations and promoting good health and well-being in general and at work. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least sixteen departments, covering such diverse sectors as biochemistry, chemistry, environment, physics, and information technologies.

If you come across any technology in the Health section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.

Human Biomonitoring and Wellbeing 7
General Physiology and Biocybernetics 8
Biomaterials and Implants 9
Antimicrobial Research and Disease Prevention 10
Probiotics, Neurodegenerative Diseases and Cancer 13
E-solutions for Medicine 14
Sample Analysis in Crystals and Solutions 16
Pharmaceuticals and New Drugs 17
Decontamination and Removal of Pollutants 19



Human biomonitoring (HBM) and exposure assessment for safer products and workplaces

We design and conduct HBM studies (blood, urine, hair), develop and validate analytical methods for elements and their species (Hg, Se, Pb, As, etc.), other chemicals and emerging organic contaminants, establish traceable QA/QC systems, and quantify links between exposure and health outcomes. We support companies in worker monitoring, risk assessment, regulatory compliance and the design of safer materials and processes.

Department of Environmental Sciences (O2)

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www

Assessment of individual exposure to urban stressors

We have developed a comprehensive methodology for assessing individual exposure to urban stressors, covering all stages from study design to final analysis, interpretation and dissemination of results. The methodology combines data from wearable sensors, geolocation records, air quality measurements, noise levels, and other environmental factors. A key feature of our approach is the use of participatory methods based on the principles of citizen science, enabling the collection of more representative data while increasing community awareness and engagement. Within respective projects we also investigate the effects of urban stressors on cognitive performance and overall well-being. Our expertise includes big data analysis, the development of advanced models linking environmental and personal data, and effective communication of results to diverse stakeholders – from local communities to policymakers – with the aim of supporting sustainable and health-promoting urban planning.

Department of Environmental Sciences (O2)

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www

Optimising ventilation efficiency in workplaces

Ensuring optimal indoor air quality (IAQ) in workplaces is essential for employee health, comfort, and productivity. The proposed protocol integrates short-term, real-time IAQ monitoring with simulation-based modelling to assess building airtightness and optimise ventilation efficiency, whether mechanical, natural, or hybrid. This approach maintains energy efficiency while ensuring a healthy indoor environment, high ventilation performance, and

Department of Environmental Sciences (O2)

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overall building sustainability. By dynamically adjusting ventilation rates based on real-time pollutant concentrations and occupancy data, we prevent both under- and over-ventilation, thereby reducing unnecessary energy use while maintaining compliance with IAQ standards. Smart, adaptive ventilation strategies are therefore kay to achieving energy efficiency targets and supporting employee health and well-being in modern workplaces.

General Physiology and Biocybernetics

Prevention of metabolic syndrome

Metabolic syndrome is defined as a combination of at least three of the following conditions: abdominal obesity, high blood pressure, elevated blood sugar levels, high serum triglycerides, and low levels of high-density lipoprotein (HDL) cholesterol in the blood. People with metabolic syndrome have a twofold higher risk of cardiovascular disease compared with those without the syndrome. In addition, the risk of type 2 diabetes increases by approximately fivefold. Due to its high prevalence (20–30% of the population, i.e. 130 million European citizens), metabolic syndrome accounts for an increasingly large share of cardiovascular risk worldwide and is associated with significantly higher mortality.

Our research is focused on developing a wearable device that combines three different sensors for monitoring and preventing metabolic syndrome.

Department of Automation, Biocybernetics and Robotics (E1)

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Mitigation of inactivity-induced loss of muscle and bone mass

The research objectives of the newly established PlanHab laboratory, accredited by the European Space Agency, are twofold:

1. to study the adaptation of physiological systems to inactivity,
2. and to evaluate and develop technologies and strategies for preventing muscle and bone loss, particularly for astronauts on future flights to the Moon and Mars.

Department of Automation, Biocybernetics and Robotics (E1)

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Wearable robotic devices for movement support and musculoskeletal load reduction

We develop human-centred wearable robotic devices to support movement in work, sports, and rehabilitation. We combine whole-body motion capture, muscle activity and brain signals with advanced motor control models to quantitatively assess musculoskeletal loading and the effects of robotic assistance. Our core expertise is co-design and evaluation of wearable solutions with end users in realistic conditions, including ergonomic assessment, adaptive human-in-the-loop control algorithms and personalised assistance tailored to individual movement strategies and limitations.

Department of Automation, Biocybernetics and Robotics (E1)

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Biomaterials and Implants

Preparation and processing of materials of biological origin

The fabrication of biomaterials and the precise tuning of their surface properties are essential for ensuring an appropriate biological response. Our department has advanced expertise in processing polymeric, composite, and metallic materials, allowing us to optimize surface characteristics such as roughness, wettability, chemical composition, corrosion resistance, and ion release.
For surface modification, we employ a range of environmentally friendly technologies, including gas plasma treatment, electrochemical and plasma anodization, and hydrothermal processes. To create specific geometries and biomaterial formulations, we also use a bioprinter capable of producing polymer composites enriched with natural bioactive compounds or even human cells, thereby significantly enhancing the biocompatibility and biological performance of the materials.

Department of Surface Engineering (F4)

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Biomedical materials

Research on metallic materials used in orthopaedic and dental applications is vital for the safe, long-term operation of implants in the human body. We are engaged in research on corrosion, metal damage under simulated physiological conditions, analysis of metal ion release, and morphological and chemical analysis of the surface. We are leading an interdisciplinary project to develop new titanium alloys with antibacterial properties using additive manufacturing.

Department of Physical and Organic Chemistry (K3)

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Processing and *in-vitro* characterisation of dental ceramics

Our group investigates the processing and *in-vitro* characterization of dental ceramics with a focus on materials for prosthetic dentistry. We study powders, glasses and glass-ceramics, with a special focus on zirconia-based ceramics, emphasizing their mechanical performance, microstructural control, and sintering behavior. In addition, we explore additive manufacturing routes to enable the fabrication of complex, patient-specific dental restorations.

Department for Nanostructured Materials (K7)

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Antimicrobial Research and Disease Prevention

Bioactive and antimicrobial materials

We study ceramic, hybrid, and nanostructured materials with bioactive and antimicrobial functionalities that enable controlled interaction with biological environments. The work focuses on surface functionalisation, topography, and chemical composition governing cell behaviour, healing responses, and microbial inhibition. Through tailored synthesis, ceramic 3D printing, and advanced characterisation, we develop materials suitable for medical implants, protective coatings, and other biomedical applications where biocompatibility, stability, and controlled functionality are essential.

Department for Advanced Materials (K9)

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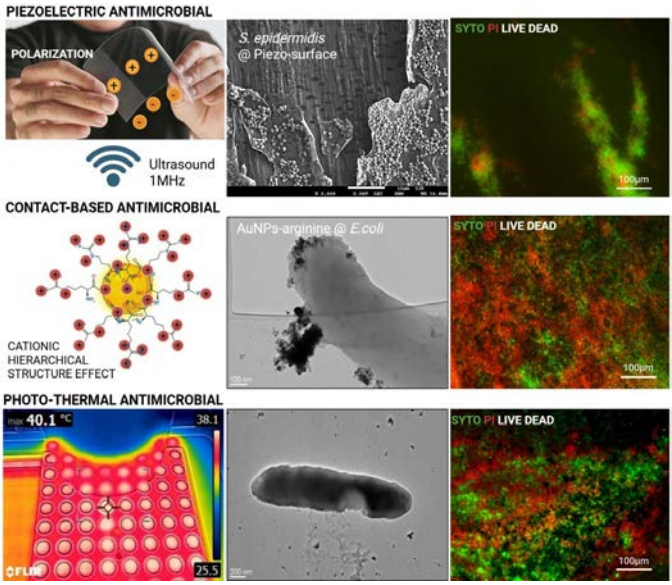

Characterization of surface thin films and thin-layer coatings

Surface thin films, such as bacterial biofilms and various biocompatible layers, and surface thin film coatings, such as protective coatings against corrosion, degradation, mechanical wear, etc., play an increasingly important role in many fields. Research into such systems in our laboratory is carried out using techniques for the preparation and characterization of Langmuir-Blodgett films (LB films), optical microscopy at the Brewster angle (BAM) and spectroscopic ellipsometry (365 - 1600 nm). Ellipsometric measurements are performed in collaboration with the Nanocenter.

Department for Complex Matter (F7)

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Antimicrobial and anti-biofilm activity

We are researching new approaches to the management of bacterial biofilms. We analyse the antimicrobial and anti-biofilm efficacy of substances using traditional microbiological methods (minimum inhibitory concentration, crystal violet staining, colony counting) and modern techniques (effects on growth parameters, fluorescence microscopy, 3D microscopy), including appropriate data processing. We work with microorganisms of safety levels 1 and 2, including clinically relevant pathogenic bacteria.

Department of Biotechnology (B3)

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Materials for removing biofilms using magnetic fields

Bacterial biofilms are resistant microbial communities that are protected from antibiotics in a polymer matrix, making their removal quite ineffective. Magneto-mechanical removal has proven to be a promising approach, which we have also protected with a filed patent application (EP4559314A1). In this approach, anisotropic magnetic particles are exposed to a rotating magnetic

Department for Materials Synthesis (K8)

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field, which causes them to rotate in a controlled manner. The generated forces created by these rotating particles physically break down the structural components of the biofilm. Increasing the permeability of the biofilm, facilitating the penetration of antibiotics and ultimately leading to effective biofilm removal even in highly restricted areas.

Drug Delivery and Biofilm Management

Using colloid biology principles, we develop systems for targeted drug delivery and controlled biofilm formation or removal. By engineering microbial and biohybrid structures, we support new antimicrobial strategies, probiotic formulations, and medical device coatings.

Department of Environmental Sciences (O2)

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Inactivation of microorganisms in water

Technological water is sometimes contaminated with microorganisms (viruses, bacteria, bacterial spores, or molds), and therefore needs to be sterilized before being released into the environment. Sterilization by boiling is not practical, while disinfection methods such as chlorination leave toxic residues in the water that decompose only slowly. We have developed a method for the inactivation of microorganisms in water at room temperature without the use of additional chemicals. The method is currently suitable for the purification of small volumes of water (a few hundred liters per day), with the possibility of scaling up.

Department of Surface Engineering (F4)

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Respiratory droplet detection for reduction of respiratory disease transmission

AeroDrops is a device for selective detection of individual respiratory droplets of humans and animals in the air, which are responsible for the transmission of respiratory diseases. The device is small, portable, with low energy consumption; it can be used independently or integrated into the ventilation system. Recommended use is in kindergartens, schools, hospitals, nursing homes and where there is a risk of epidemic outbreaks.

Department of Solid State Physics (F5)

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Evaluation of probiotics

Bacteria with beneficial effects on human health are becoming increasingly important. The evaluation of probiotic bacteria includes testing their viability, growth, and survival in gastric juice, intestinal juice, or other media. Their activity can also be studied using various cell models (immune cells, intestinal epithelial cells), where adhesion, cytotoxicity, and the release of inflammatory cytokines can be monitored.

Department of Biotechnology (B3)

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2D and 3D cell models for biocompatibility analysis and therapy development

We perform research and development analyses for the pharmaceutical and biotechnology industries in the field of neurodegenerative diseases and regenerative medicine. We work with advanced cell models (genetically modified cell lines and 3D neurospheroids from human and mouse cells) that better mimic the processes in the nervous system. For our partners, we can perform the following in particular:

- Testing of compounds in 3D models: assessment of efficacy and potential toxicity in a more physiologically relevant environment.
- Identification of early, therapeutically manageable processes, candidate biomarkers, and potential drug targets.
- Modeling of patient-specific mechanisms of neural stress, tissue damage, and regeneration.
- Combined gene and protein analysis (multi-omics approach) to detect early changes in cells.

We adapt protocols and models to the needs of the project and, upon agreement, incorporate them into our partners' existing development processes (from early target selection to support in the development of candidate molecules).

Department of Biotechnology (B3)

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3D tumor–immune models and toxicity assessment

We design and optimize physiologically relevant biological models that emulate the tumor microenvironment to study toxicity, drug delivery, and tumor–immune interactions. Our platforms include 3D tumor spheroids and organoids, co-cultures with primary or immune cell lines (e.g., T cells, NK cells, macrophages), and flow-adapted systems that capture gradients, extracellular matrix, and cell–cell signaling. We measure responses with 3D / confocal imaging, flow cytometry, viability / cytotoxicity assays, cytokine profiling, and growth analysis, supported by rigorous data processing. Work is conducted under standard cell-culture safety practices (BSL-1 and BSL-2), using clinically relevant tumor (patient samples) and immune cell types.

Department of Biotechnology (B3)

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E-solutions for Medicine

Wireless Medical Monitoring

Modern healthcare increasingly relies on continuous and reliable physiological monitoring. We design wireless sensing and communication platforms for medical monitoring, including wearable devices capable of capturing high-resolution physiological data. Our research work includes ultra-low-power signal acquisition and robust wireless connectivity to support patient supervision.

Department of Communication Systems (E6)

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Biomedical signal processing

Development of algorithms for reliable analysis of complex signals such as ECG, EMG, and data from modern wearable sensors. By identifying hidden patterns within these signals, we improve diagnostic accuracy, enable early detection of health risks, and support the development of personalized therapeutic approaches. Our goal is to create intelligent medical solutions that assist healthcare professionals in decision-making and contribute to more efficient, reliable, and patient-centered care.

Computer Systems Department (E7)

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Management of chronic diseases and decision support for health professionals

We develop artificial intelligence methods for interpretation of wearable and contact-free sensor data (physiological signals, behaviour, mental states). We use these and other data in solutions for self-management of chronic diseases, including mental health conditions, using large language models among other technologies. We also develop risk-prediction models and decision-support tools for health professionals.

Department of Intelligent Systems (E9)

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www

Research in the field of rare diseases

We connect different fields of science and healthcare to conduct research on rare diseases. We focus on data and artificial intelligence that can help us understand the complexity of rare diseases. With our network of contacts in the clinical environment, we are also working on transferring knowledge from research to the clinical environment. As an example, we have developed the Rare Diseases Observatory, whose main goal is to improve access to information for all stakeholders in the rare disease community. In its pilot version, it presents 16 rare neurodevelopmental syndromes, showing their occurrence in real time in global media, social media, and scientific publications.

International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)

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www

Trustworthy predictive healthcare

We develop explainable predictive models for disease diagnosis and progression. Our analysis provides insights into which biomarker interactions are important at the cohort level, as well as personalized explanations for each patient that contribute to disease diagnosis or progression.

www

Computer Systems Department (E7)

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Personalised rehabilitation support for improved quality of life

The department's AI expertise in the health field includes specialized medical extraction models and advanced data-anonymization capabilities that use customizable, large language model (LLM)-powered strategies to protect sensitive patient

Department for Artificial Intelligence (E3)

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information. Automated pipelines can extract text from medical documents, anonymize it according to user-defined rules, and securely store the processed outputs. This expertise also covers training specialized medical extraction models and deploying entity-extraction techniques using both language models and large language models. In addition, it includes evaluating and optimizing OCR methods to reliably process and analyze medical records.

Sample Analysis in Crystals and Solutions

Structural analysis of crystalline samples at the atomic and molecular level

Crystal structure determination of crystalline samples using X-ray diffraction on single crystals or using 3D electron diffraction on powders. The analysis can also be performed on samples that are sensitive to air and stable only at low temperatures.

Extreme Conditions Chemistry Laboratory ECCL (K2)

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Analysis of samples in solutions

Analysis of samples in solutions using nuclear magnetic resonance (NMR) which can measure a wide range of elements (1H, 19F, 13C, 31P, 129Xe) at room or low temperature. Characterization of samples and determination of structures using 1D and 2D NMR spectroscopy for sample solutions. Analysis can also be performed on samples that are sensitive to air and stable only at low temperatures, above –80 °C. The instrument is specially adapted for measurements of samples containing fluorine.

Extreme Conditions Chemistry Laboratory ECCL (K2)

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Sample analysis using Raman spectroscopy

Sample analysis using Raman spectroscopy at temperatures from –196 to 150 °C also includes Raman mapping with high spatial and spectral resolution, which allows the study of sample homogeneity and the distribution of various chemical species.

Extreme Conditions Chemistry Laboratory ECCL (K2)

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Analysis of tissues, medical materials and pharmaceutical products via magnetic resonance imaging (MRI)

Magnetic resonance imaging (MRI) can be performed with special equipment at spatial resolutions approaching optical microscopy, while maintaining the advantages of contrast imaging and non-invasiveness known from clinical MRI. Our method can therefore be very interesting for precise spatial imaging of tissues, various materials used in medicine, as well as for the analysis of pharmaceutical products.

Department of Solid State Physics (F5)

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Analysis of biomolecular interactions in the context of development of new pharmaceutical compounds

- Available equipment: quartz crystal microbalance with dissipation monitoring, label-free method.
- Operation: in aqueous environment.
- Detection range (in aqueous environment): ~250 nm from the substrate.
- Experiments: real-time studies of biomolecular interactions, high-throughput drug screening on adsorbed target with small sample quantities.

Department of Solid State Physics (F5)

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Nano-formulations in medicine and nutrition

For the successful and safe delivery of active ingredients, stable and biocompatible delivery systems are required. We develop and evaluate numerous formulations - inorganic (magnetic, gold, SiO_2...) and organic nanoparticles, and vesicles based on cell membranes. The key is to evaluate the developed systems in terms of formulation stability, encapsulation efficiency, and morphological changes using numerous, complementary methods. We perform photo-thermal therapy on samples and preclinical models.

Department for Nanostructured Materials (K7)

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Production, separation and radiolabelling of radionuclides for medical purposes

We are developing technologies and methods for the production, separation and radiolabelling of new radionuclides for therapeutic and diagnostic purposes. The methods are suitable for testing new suitable radionuclides for use in medical purposes for the therapy and diagnosis of various diseases.

Department of Environmental Sciences (O2)

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Development of analytical methods for biopharmaceuticals

We have expertise in the development of analytical methods for biopharmaceuticals, with a focus on understanding and quantifying protein stability, aggregation, and particulate impurities. Our current work centers on designing sensitive measurement strategies and integrating advanced optical and microfluidic approaches to address complex characterization challenges. We are skilled at creating tailored analytical workflows for specific formulations and can develop custom hardware solutions when existing tools are insufficient.

Department for Complex Matter (F7)

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Stability, pharmacokinetics, and monitoring of therapeutic concentrations of active pharmaceutical ingredients in preclinical and clinical studies

We support translational research by developing advanced analytical methods to understand the behaviour of active pharmaceutical ingredients in biological systems. We conduct stability studies to assess the influence of various factors, including matrix, temperature, light, and other physical factors, on active components. We also perform studies of biodegradation and microsomal metabolism.

In addition, we develop and optimize methodologies for monitoring therapeutic concentrations of active compounds in blood and other biological matrices, both in preclinical models and in clinical studies involving humans and veterinary medicine.

Department of Environmental Sciences (O2)

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Characterization of solid contaminants in water systems

Advanced SEM/TEM/EDS, XRD, FTIR, and Raman spectroscopic analyses for identifying and characterizing solid contaminants in water. We determine particle morphology and composition, to support the assessment of microplastic pollution and other particulate impurities in aquatic environments.

Department for Nanostructured Materials (K7)

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Decomposition of hazardous organic pollutants in water

Process water sometimes contains small amounts of environmentally hazardous organic impurities such as pesticides, herbicides, antibiotics, organic toxins, etc. We have developed a method for the decomposition of organic impurities at room temperature without the use of additional chemicals. The method is currently suitable for the purification of small volumes of water (a few hundred liters per day), with the possibility of scaling up.

Department of Surface Engineering (F4)

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Improved wastewater treatment

In light of renewed Urban Wastewater Treatment Directive that includes > 80 % removal of indicator micropollutants in municipal WWTP, several treatment technologies including algal ponds and atmospheric pressure plasma treatment in combination with common treatment technologies (activated sludge, O3, active carbon) can be explored.

Department of Environmental Sciences (O2)

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Plasma technologies for water purification, disinfection and biomedical applications

We develop advanced cold-plasma technologies for the degradation of toxins, genotoxic contaminants and microbiological loads in water and enviroment. Our expertise includes plasma chemistry, toxicological characterization of transformation products and the development of plasmonic sensors for DNA damage detection. We also develop plasma-activated liquids for efficient medical disinfection and contribute to next-generation nanomedicine diagnostics.

Laboratory of Gaseous Electronics (F6)

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Culture, Creativity and Inclusive Society



This section focuses on safeguarding the cultural heritage and promoting socio-economic transformations that contribute to inclusion and growth. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least four departments, covering such diverse sectors as environment, physics, and information technologies.

If you come across any technology in the Culture, Creativity, and Society section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.



Citizen science, open data, and communication of environmental risks

We co-develop participatory monitoring activities (e.g., air and water quality) with communities and municipalities, prepare user-friendly protocols and training, and create interactive data visualizations. We support companies and local stakeholders in improving social acceptance of projects, preparing Environmental, Social, and Governance (ESG) reports, and communicating environmental impacts transparently.

Department of Environmental Sciences (O2)

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Advanced natural language processing

With decades of expertise in media monitoring and NLP, we harness cutting-edge large language models, embedding technologies, and deep learning methods to turn vast flows of multilingual news and social media content into clear insights.

Leveraging frameworks developed in flagship projects such as EMMA and EMBEDDIA, we enable real-time categorisation, summarisation, cross-language analysis and comment moderation — even for under-represented languages and rapidly moving media streams.

Department of Knowledge Technologies (E8)

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Digital twin of online social networks

The department is contributing its AI expertise to the study of democratic debates online by developing a digital twin of an online social network and populating it using generative artificial intelligence. The large scale simulations are used to analyze the effects of specific platform design and ranking algorithms on opinion dynamics and the quality of discourse. The findings produce evidence-based recommendations for regulatory innovations regarding online social networks and enhance digital citizenship by participatory methods.

Department for Artificial Intelligence (E3)

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Advanced analytical methods for material traceability and consumer products safety

Through analysis and elemental characterization research, we support authentication of materials and consumer products, contributing to cultural heritage protection and safety assurance. Our competencies include spectroscopic and surface-analysis methods for identifying material composition and aging processes, which are useful in museums, restoration workflows and safety investigations.

Laboratory of Gaseous Electronics (F6)

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International mentorship programme Open Education for a Better World (OE4BW)

The international mentorship programme »Open Education for a Better World (OE4BW)« promotes the development of open educational resources (OERs) for a more inclusive society and better, fairer access to knowledge. It connects researchers, educators, mentors and mentees worldwide and provides structured mentorship support for the development of OERs in artificial intelligence, health, education and sustainable development. The program is also suitable for companies and organizations that would like to train their employees through the development and use of open digital educational resources tailored to modern knowledge and competences.

International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)

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Inclusive participatory approaches based on citizen science principles

Our expertise is based on participatory methods grounded in the principles of citizen science, which enable citizens to actively engage in knowledge creation and evaluation of their environment. Our participatory frameworks include the development of tailored ICT infrastructure to facilitate participants' engagement through the use of digital tools. This approach increases the relevance and quality of data and ensures that the voices of diverse community groups reach decision-makers and inform policy and practice.

We collaborate with local communities, organizations, and policymakers in the co-creation of research and solutions, emphasizing their engagement and awareness. Our expertise combines data collection and analysis, communication, and participatory methods, aiming to promote an inclusive society where science serves the needs of all citizens.

Department of Environmental Sciences (02)

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Civil Security for Society



This section responds to the challenges arising from persistent security threats, including cyber-crime, as well as natural and man-made disasters, aiming to build safe and disaster-resilient societies. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least seven departments, covering such diverse sectors as chemistry, environment, physics, and information technologies.

If you come across any technology in the Civil Security section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.

Environmental Forensics..... 27
Radiation and Thermal Protection 27
Infrastructure and Cyber Security 28



Environmental Forensics

Environmental forensics and rapid analytics in chemical incidents

We operate the Ecological Laboratory with a Mobile Unit (ELME) for Chemical Accidents. We provide rapid analyses and isotopic fingerprinting to determine the origin of pollution, develop field sampling protocols, assess environmental impacts, and support decision-making (e.g., in cases of releases into air or water). We also implement monitoring of municipal and industrial flows (e.g., wastewater) for early warning and compliance verification.

Department of Environmental Sciences (O2)

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Plasma-based disinfection, water safety, and advanced sensing technologies

We develop systems for disinfection of thermally sensitive equipment using plasma-activated liquids, sensors for early contamination detection, and methods for removing hazardous substances from environmental and industrial systems. Our solutions support reliable operation of critical infrastructure, rapid risk detection and reduction of public exposure to harmful compounds.

Laboratory of Gaseous Electronics (F6)

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Radiation and Thermal Protection

Protection of humans, animals, and the environment from ionizing radiation

The Mobile Radiological Laboratory (MRL) ELME is a team of highly specialized experts who, in the event of an emergency involving radioactive materials, independently and professionally carry out the following tasks in the field:

- measuring dose rate, detecting and identifying potentially hazardous sources;
- determining and marking the boundaries of contaminated areas;
- determining when radiological danger has ceased;
- collecting samples for analyses and examinations;
- determining the presence of radioactive iodine in the thyroid;
- directing, coordinating, and implementing protective measures;
- carrying out decontamination and assessing its effectiveness.

Department of Low and Medium Energy Physics (F2)

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For this purpose, the MRL is equipped with two high-resolution germanium spectrometers, NaI and LaBr spectrometers, a neutron detector, two ionization chambers, dose-rate and surface-contamination meters, an in-motion dose-rate measurement system, personal protective equipment and personal dosimeters, sampling equipment and rapid sample-preparation tools, communication equipment, and various computers.

Evaluation of thermal characteristics of protective clothing

We have developed various simulators (see image below) for the evaluation of the thermal and evaporative resistance of protective clothing. We collaborate with military partners (MORS, UK MOD, Swedish Armed Forces, etc.) and industry (e.g., Tiger Cat, Gore, Kimberley-Clark) in the development and evaluation of clothing systems, footwear, and gloves.



Department of Automation, Biocybernetics and Robotics (E1)

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www

Infrastructure and Cyber Security

Reliability of critical infrastructure operations

Based on the participation in EU projects we research methods for safety evaluation (risk assessment) of diverse threats to e.g. critical infrastructure, in relation to modelling their interdependencies, crisis communication, and cooperation of stakeholders at the levels of industrial plants, the crisis sector, and national/cross border connections.

Department of Inorganic Chemistry and Technology (K1)

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www www

AI-based detection of wireless signal anomalies and faults

Large-scale networked infrastructures must withstand failures, disruptions, and cyber threats. We develop AI modules capable of detecting anomalies in received signal patterns, network behaviour, and radio environments. These systems identify faults, malicious interference, unexpected disruptions, and degraded performance conditions in real time. They serve as components of digital twins for network security, enabling automatic mitigation strategies.

Department of Communication Systems (E6)

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Reliable communications in emergencies and high-risk environments

Civil protection and emergency response depend on robust and resilient communication infrastructures. Our research focuses on developing reliable wireless communication solutions that can operate effectively during crises, including in tunnels, collapsed buildings, rural areas, and disaster zones. Using advanced deterministic and hybrid propagation models, we predict signal behaviour in complex environments and design architectures that remain operational under adverse conditions.

Department of Communication Systems (E6)

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Artificial intelligence for cyber security

The increasing complexity of information systems and constant threats in the digital environment require advanced approaches to data and infrastructure protection. Artificial intelligence is becoming a key tool for automated detection of cyber attacks, anomaly analysis, and rapid response to security incidents. Our research and development focus on models and solutions that enable the identification of malicious activities, detection of vulnerabilities, and support for security experts. Application areas include information system security and critical infrastructure protection.

Laboratory for Open Systems and Networks (E5)

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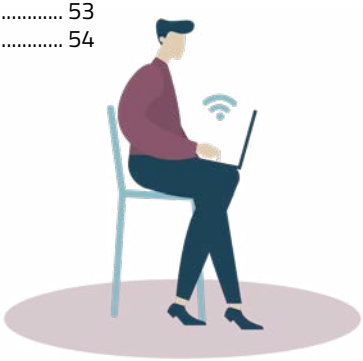
Digital, Industry and Space



This section focuses on developing competitive, reliable, digital, and sustainable (low-carbon and circular) industries as well as developing advanced materials, space technologies, and cutting-edge quantum technologies fueling the development and use of artificial intelligence, which will provide the basis for advances and innovation in global challenges to society. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least twenty-three departments, covering such diverse sectors as chemistry, environment, energy, physics, and information technologies.

If you come across any technology in the Digital, Industry and Space section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.

Wireless Networks 33
Neural Networks and Machine Learning 34
Artificial Intelligence 35
Control and Optimisation 38
Robotics in Manufacturing 41
Carbon Footprint and Decarbonisation 43
Materials: Extraction of Chemical Elements 44
Materials: Ceramics Processing 44
New Materials 45
Materials: Surfaces and Coatings 48
Materials: Characterisation 50
Resilience and Lifetime of Materials 53
Space 54



Wireless sensing and localisation techniques

Precise sensing and localisation are essential for modern industrial automation, robotics, and next-generation communication systems. Our department develops advanced wireless localisation, sensing, and integrated sensing and communication (ISAC) techniques. These methods enable high-accuracy tracking of assets, robots, and autonomous devices. We also research environment-aware localisation systems that combine channel state information, environmental modelling, and AI-driven inference to improve robustness and accuracy. These techniques support applications such as indoor navigation, industrial systems and digital twins.

Department of Communication Systems (E6)

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Radio-propagation modelling and planning of wireless networks

Accurate modelling is essential for the design of modern wireless systems. We develop advanced propagation modelling tools, combining ray tracing with statistical models, that allow precise network planning. Our GRASS-RaPlaT tool is used in research and supports virtual testing, scenario evaluation, and design optimization. This ensures that communication infrastructures perform predictably in real-world deployments and also enables digital twins.

Department of Communication Systems (E6)

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Meshless methods for numerical solving of systems of partial differential equations

Industrial design and engineering require modelling and simulations that can handle complex geometries and rapidly changing conditions. Our research develops meshless and hp-adaptive numerical methods that solve partial differential equations efficiently on arbitrary shapes without needing structured meshes. These methods are well-suited for modelling numerous problems like heat flow, material deformation, etc. They enable high-fidelity simulations even when geometric complexity is high.

Department of Communication Systems (E6)

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Modular Internet-of-things (IoT) platforms for sensing

We develop modular sensor platforms, such as VESNA, that support flexible sensing, edge processing, and reliable communication in different environments. We are mainly focused on advancing smart infrastructures through innovative signal processing, time series modelling, and AI-driven decision-making, including representation learning, deep learning, clustering, and classification. This enhances accessibility, usability, and efficiency in networked embedded systems.

Department of Communication Systems (E6)

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www www

Neural Networks and Machine Learning

Implementations of fast neural networks

With the use of neural network quantization techniques, we can simultaneously reduce memory requirements and speed-up their execution. With appropriate procedures, quantized neural networks can achieve the same results as non-quantized ones. Such quantized networks are particularly suitable for hardware implementation (FPGA) as well as for less powerful processor systems (microcontrollers).

Computer Systems Department (E7)

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Automated machine learning and optimization

Instead of running an entire set of ML algorithms, we train a metamodel to identify the best ML pipeline for a given application. In addition, we automatically select the large language model that will deliver the optimal results on your data.

Computer Systems Department (E7)

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Demand forecasting

The development of advanced machine learning models for demand forecasting and anomaly detection in time-series data, with a focus on model robustness and explainability. These data-driven approaches enable companies to make better decisions and optimize processes, applicable in production planning, inventory

Computer Systems Department (E7)

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management, enhancing customer services, logistics optimization, predictive equipment maintenance, and rapidly adapting to changes in demand and market conditions.

Machine learning in the astronomy domain

Use of machine-learning models of varying complexity to analyze time-series photometric and spectroscopic data from space- and ground-based telescopes. Development of physics-informed and explainable models tailored to specific data types and available computational resources. Modeling of instrumental systematics (e.g., in échelle spectrographs), stellar variability, periodic signals, and anomalies. Applications include detection of weak or single events (transits, eclipses, flares), precise radial-velocity extraction across multiple nights, joint inference of stellar and planetary parameters, and bias-aware population studies.

Computer Systems Department (E7)

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Artificial Intelligence

AI research and development

Our department has extensive knowledge and expertise in the field of artificial intelligence. Our main areas of research include data analysis with emphasis on text, web and cross-modal data, scalable real-time data analysis, visualization of complex data, semantic technologies and language technologies. Our work within various European and national projects has included such use cases as the development of an AI observatory and the development of digital twins in manufacturing.

Department for Artificial Intelligence (E3)

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AI Tools Radar – AI tools for the public sector, media, and judiciary

AI Tools Radar is a multilingual digital platform collecting and mapping AI tools used in the public sector, media, and judiciary. Companies and organizations can leverage the platform to:

- identify AI tools relevant to government, media and legal applications
- compare features, capabilities and compliance of AI solutions
- support responsible, transparent and ethical adoption of AI
- stay informed about emerging AI technologies and market trends.

Explore AI Tools Radar to gain insights, enhance your AI offer and connect with decision-makers in sectors driving public impact.

International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)

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Democratizing AI workflows at the network edge

We develop machine learning operations (MLOps) techniques and tools for distributed training and inference on the computing continuum. We proposed NAOMI, a solution for democratizing AI / ML workflows at the network edge designed based on those requirements. Guided by the functionality and overlap analysis of the O-RAN AI / ML workflow architecture and MLOps systems, coupled with the survey of open-source AI / ML tools, we develop a modular, scalable, and distributed hardware architecture-independent solution. NAOMI leverages state-of-the-art open-source tools and can be deployed on distributed clusters of heterogeneous devices. The proposed solutions are crucial in systems where optimization of performance, latency, and resource consumption is required.

Department of Communication Systems (E6)

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Energy cost of artificial intelligence lifecycle

Artificial Intelligence (AI) is being incorporated in several optimization, scheduling, orchestration as well as in native communication network functions. While this paradigm shift results in increased energy consumption, quantifying the end-to-end energy consumption of adding intelligence to such systems is particularly challenging. Conventional metrics focus on either communication, computation infrastructure, or model development. To address this, we propose a new metric, the Energy Cost of AI Lifecycle (eCAL) of one AI model in a system. eCAL captures the energy consumption throughout the development and deployment of an AI-model providing intelligence in a wireless communication network by analyzing the complexity of data collection and manipulation in individual components and

Department of Communication Systems (E6)

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deriving overall and per-bit energy consumption. Additionally, we have developed a modular and extendable open-source simulation tool to enable researchers, practitioners, and engineers to calculate the end-to-end energy cost with various configurations and across various systems, ensuring adaptability to diverse use cases.

Intelligent infrastructure orchestration

We develop intelligent infrastructure orchestration techniques that use AI for infrastructure orchestration (AIOps) on the computing continuum. We approach the problem with agentic AI and/or multi-agent techniques. For instance, we proposed the Multi-Agent Reinforcement Learning-based In-place Scaling Engine (MARLISE) that enables seamless, dynamic, reactive control with in-place resource scaling. We develop our solution using two Deep Reinforcement Learning algorithms: Deep Q-Network (DQN), and Proximal Policy Optimization (PPO). We analyze each version of the proposed MARLISE solution using dynamic workloads, demonstrating their ability to ensure low response times of microservices and scalability. Our results show that MARLISE-based approaches outperform the heuristic method in managing resource elasticity while maintaining microservice response times and achieving higher resource efficiency. The proposed solutions can be used for auto-scaling microservices, workload balancing, and resource optimization in next-generation networks.

Department of Communication Systems (E6)

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Digital twins, data platforms, and AI for measurements

We connect sensor networks (stationary, mobile, low-cost) with laboratory metrology, build data pipelines with integrated QA/QC, and develop models and AI tools for pollution forecasting and process optimization. We assist companies in data integration (IoT–LIMS), ensuring measurement traceability and compliance with standards.

Department of Environmental Sciences (O2)

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Observatories for monitoring the impact of AI on sustainable development

At IRCAI, we develop analytical platforms to monitor AI's impact on sustainable development. Our SDG Observatory collects and analyses data from global news, scientific publications, AI policies, educational resources, and innovation ecosystems. In collaboration with UNESCO and experts, we also develop thematic observatories, including the Landslides Observatory, OER Observatory, COP30 MetAmazonia Observatory, and ELIAS Migration Observatory.

International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)

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Learning and training on artificial intelligence (example: E-learning collection "Trustworthy and Democratic AI")

The e-learning collection is designed with high replicability in mind. Interested stakeholders, such as public administrations, policy makers, educators, and companies, can collaborate with us to implement tailored learning and training initiatives. We offer a flexible portfolio that includes e-learning materials, structured online courses, and interactive training workshops, all adaptable to specific needs and contexts. By covering diverse aspects of AI, such as ethics, governance, transparency, and democratic principles, we enable stakeholders to build capacity and foster responsible AI adoption. Replicability is further supported by the open-access nature of the resources, allowing continuous customization and integration into local strategies and policy frameworks.

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Control and Optimisation

Non-invasive End-of-Line quality inspection of electric motors

Development and implementation of fully automated End-of-Line (EOL) quality inspection systems for electric motor production. Inspections are performed in a non-invasive manner by measuring electrical parameters, vibration signals, and acoustic signals during test runs. Using advanced signal processing techniques, such as digital filtering, FFT analysis, and nonlinear transformations, features are extracted to detect and isolate potential faults. Integration to the information infrastructure in accordance with Industry 4.0 principles.

Department of Systems and Control (E2)

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Process control, automation and diagnostics

We perform research and development projects in the field of digitization, control, automation and diagnostics of various processes (manufacturing, chemical and process industry, steel industry, etc.). Expertise in the field of process modeling and system approach to automation, diagnostics and process control design, as well as the Industry 4.0 concept. A wide list of domestic and international references. Support and collaboration in preparation of research and development project for domestic and international tenders.

Department of Systems and Control (E2)

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Advanced numerical simulations of multiphase flows and heat transfer in complex systems

We develop and apply advanced numerical models for turbulent single- and multiphase flows, including boiling and heat transfer under extreme conditions. We use open-source (OpenFOAM) and commercial CFD codes, as well as in-house hybrid models validated with experimental data. Our expertise includes optimization of components in energy and process systems using computational simulations, as well as validation and uncertainty assessment.

Department of Reactor Engineering (R4)

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Accurate velocity measurements in fluids

Understanding velocity fields in single- and two-phase flows is essential for analyzing and optimizing advanced fluid systems, from vehicle aerodynamics to high-performance cooling solutions. At the THELMA laboratory, we specialize in high-resolution optical flow-measurement techniques, primarily PIV (particle image velocimetry) in PTV (particle tracking velocimetry), which enable reliable acquisition of velocity fields with exceptional temporal and spatial resolution (down to 20 micrometres). Our expertise includes the preparation of experimental setups, image-data processing, interfacial-surface reconstruction, and the development of robust methods for characterizing complex flows in both research and industrial applications.

Department of Reactor Engineering (R4)

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Optimization in engineering design, manufacturing and logistics

Many challenges in engineering design, manufacturing and logistics can be formulated as optimization problems, where the task is to find the best solution among numerous alternatives with respect to a given criterion. For solving such problems, we develop advanced optimization procedures based on the use of stochastic algorithms and mathematical programming solvers. Examples of practical applications include computer-aided product design, tuning of production process parameters, finding optimal schedules and transport routes. Deploying the solutions, the customers reduce costs, improve the quality of products and services, and contribute to environmental sustainability.

Department of Intelligent Systems (E9)

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Optimization of production and product efficiency

Optimization methods improve the efficiency of production processes, reduce energy and material consumption, and increase the quality of end products. Research and development focus on the use of advanced mathematical models, artificial intelligence methods, and (single/multi)- criterion optimization approaches to finding solutions in complex industrial environments. The emphasis is on algorithms that adapt to changing conditions in production and on the integration of optimization procedures into control and decision-making systems. Areas of application include production line optimization, production process planning, inventory management, energy efficiency of industrial equipment, and product design optimization.

Computer Systems Department (E7)

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Solving Optimization Problems with Quantum Devices

We use quantum algorithms and quantum annealers to find optimal solutions to complex problems where classical methods often fail. We develop models that exploit quantum superposition and entanglement to address combinatorial and industrial challenges more efficiently. Such approaches can, for example, optimize logistics routes, production scheduling, or energy-grid management, providing companies with direct benefits such as reduced operational costs, shorter execution times, and improved overall efficiency.

Department for Complex Matter (F7)

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AI-powered robotics for manufacturing and service tasks

Our research on AI-powered robotic solutions is focused on supporting modern industrial production and service tasks. We employ large foundation models, such as language and vision-language models, for understanding instructions, perceiving the environment, task planning, monitoring, and control. Large language models enable easier robot programming and support for operators, while vision-language models link images and text for quality control and object manipulation. We integrate learning and control into robust control loops that ensure safe and reliable operation of robotic systems in industrial and natural environments. Our approach enables the automation of applications that cannot be automated using standard robotics approaches.

Department of Automation, Biocybernetics and Robotics (E1)

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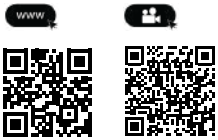

Reconfigurable robotic cells for small-batch and customized production

Reconfigurable robotic cells for small-batch and customized production enable industrial manufacturing to rapidly adapt to shortened product life cycles and frequent changes in product types. Building on the experience from projects such as ReconCell and ReconCycle, we develop modular cells that combine innovative reconfigurable hardware modules (fixtures, actuators, interchangeable grippers, measurement sensors) with ROS-based software and a digital twin of the cell in a simulation environment. This approach allows fast design, programming, and validation of new assembly tasks in simulation, with quick transfer of solutions to the real environment and minimal manual setup. The goal is to make it economically viable for companies to automate even small-batch and "few-of-a-kind" processes, thereby increasing productivity, quality, and competitiveness.

Department of Automation, Biocybernetics and Robotics (E1)

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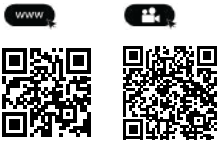

Intelligent control systems for next-generation collaborative robotics

Seamless assurance of safe and efficient collaboration between humans and robots is becoming a key requirement of modern robotic systems. Consequently, the field of intelligent control and physical interaction is developing extremely rapidly and is of great importance for practical applications. Research and development

Department of Automation, Biocybernetics and Robotics (E1)

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are focused primarily on robust contact detection, impedance control, ergodic motion, and learning-based methods that enable robots to exhibit adaptive behavior in real time. An important part of this work is the development of advanced and energy-efficient actuation approaches that improve the safety and responsiveness of robots during physical interaction. Application areas include industrial collaborative systems, medical and rehabilitation robotics, and advanced service robotic solutions.

www www

Human-centred industrial and collaborative robotics

At the Laboratory for Neuromechanics and Biorobotics (NBR) we develop methods for safe physical human–robot collaboration in industrial settings. Our work focuses on advanced sensing of human movement, modelling of interaction forces, and the design of adaptive control algorithms for collaborative industrial robots. We employ machine learning, reinforcement learning and sensor fusion to achieve motion planning and robot control that respond intelligently to human variability, posture, load and task dynamics. We support companies in deploying human-centred robotic solutions ranging from task and ergonomic analysis to prototype development and experimental validation with real workers on the production line.

Department of Automation, Biocybernetics and Robotics (E1)

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www

Humanoid robotics for industrial production

Humanoid robots in industrial production rely on programming by demonstration, where human workers physically guide the robot, teleoperate it, or show tasks in VR so that the robot can learn trajectories, forces, and task sequences directly from expert behavior. This approach is especially promising for complex industrial tasks such as assembly, machine tending, palletizing, and tool use, where explicit programming would be too time-consuming and fragile. By combining demonstration-based learning with perception and force control, humanoid robots can gradually adapt demonstrated skills to new parts, layouts, and fixtures, making them suitable for high-mix, low-volume production.

Department of Automation, Biocybernetics and Robotics (E1)

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www

Robot manipulation of deformable objects

Deformable objects, such as cloth, fabric, wires and cables but also, for example, food, demand special skill in detecting and manipulation because such objects change shape and often self-occlude. We are developing and testing methods for robot manipulation of deformable objects for production and services, with an emphasis od adaptable processes in a unified robotic cell for various shapes, sizes and properties of deformable materials.

Department of Automation, Biocybernetics and Robotics (E1)

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Carbon Footprint and Decarbonisation

Preparation of plans for decarbonization in companies / organizations

The European Union and its member states, including Slovenia, have committed to reducing greenhouse gas emissions and have set ambitious goals with the ultimate goal of net zero GHG emissions by 2050. The experts of the Center for Energy Efficiency (IJS-CEU) advise companies / organizations in preparing plans for the decarbonization of their operations, namely by preparing various models for the preparation of measures to reduce emissions, by determining model assumptions taking into account internal (company) and external (EU, state, environment) influences and evaluation of measures.

Energy Efficiency Centre EEC

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Calculation of the carbon footprint or greenhouse gas (GHG) emissions

The carbon footprint has become a key metric for organisations when reporting greenhouse gas (GHG) emissions from their operations, as well as at the project or product level. In calculating and reporting their carbon footprint, companies often face challenges related to preparing reliable input data and selecting appropriate emission factors—particularly for Scope 3 under the GHG Protocol. Experts at the Centre for Energy Efficiency (IJS-CEU) support companies in developing carbon-footprint methodologies, performing calculations, and understanding emissions across their value chains (Scope 3). We also assist with reporting in accordance with non-financial reporting legislation and with preparing action plans to reduce GHG emissions.

Energy Efficiency Centre EEC

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Materials: Extraction of Chemical Elements

Technological solutions for the extraction of rare earths from primary and secondary sources

Advanced hydrometallurgical techniques are used for extraction. In the next stage, the rare-earth elements are separated or purified using ion exchange, solvent extraction, and membrane processes.

Department of Inorganic Chemistry and Technology (K1)

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Development and installation of a pilot process for the extraction of tantalum and niobium from primary sources

We have developed a new method for leaching tantalum and niobium from coltan ore concentrates, where niobium is then purified and separated from tantalum through a multi-stage process. The new process achieves high purity of both metal hydroxides.

Department of Inorganic Chemistry and Technology (K1)

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Materials: Ceramics Processing

Additive manufacturing (AM) of ceramic components

Our group specializes in additive manufacturing of ceramics and composites, with expertise spanning the entire process chain from design for additive manufacturing to final sintered components. We select the most suitable AM technique based on material and application requirements, optimizing geometries for performance and manufacturability. Our capabilities include preparation of high-quality feedstocks such as ceramic suspensions and filaments, along with established debinding and sintering cycles that ensure dense, defect-free parts.

Department for Nanostructured Materials (K7)

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Additive manufacturing of advanced ceramic components

Our research focuses on additive manufacturing, particularly ceramic 3D printing, enabling the fabrication of complex geometries and functionally tailored ceramic components. We study the preparation of printing formulations, rheology, sintering behaviour, and microstructure development to achieve high-precision printing,

Department for Advanced Materials (K9)

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mechanical stability, and functional reliability under demanding conditions. These capabilities support the development of ceramic parts for high-temperature applications, electronic substrates, micro-reactors, and other components requiring a combination of intricate shapes, robustness, and functional adaptability.

Advanced sintering of ceramics

Our group focuses on advanced sintering of ceramics, combining experimental and computational approaches to optimize densification and microstructural control. Besides traditional sintering approaches we use conventional Spark Plasma Sintering, using pressure and current, to consolidate nanostructured ceramics and composites with improved properties. In parallel, we develop and study fast sintering techniques for additively manufactured, complex-shaped components, supported by detailed microstructural characterization and finite element modeling.

Department for Nanostructured Materials (K7)

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New Materials

Fluorinated materials for use in batteries, optics, or catalysis

Synthesis of fluorine-containing materials and tailored fluorination of materials for use, for example, in modern battery systems, optics or catalysis.

Extreme Conditions Chemistry Laboratory ECCL (K2)

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Design and characterisation of soft materials with controlled mechanical response

Our research focuses on the development of soft programmable materials, with an emphasis on liquid crystal elastomers, polymer composites and dispersions. We investigate how internal stresses, anisotropy and the architecture of the polymer network determine the mechanical response, deformation pathways and stability of such systems. In this context, we design materials with predefined functional states, for example with controlled transitions between shapes or mechanical properties. These approaches are useful for developing soft actuators, adaptable elements and components with precisely tuned mechanical responses, which is important in industrial applications where repeatability and reliability are essential.

Department of Solid State Physics (F5)

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Ion implantation for engineering quantum centers in diamonds

In two beamlines of the ion accelerator, we enable the implantation of low-energy (keV) ions just beneath the sample surface, as well as high-energy (MeV) ions several micrometres deep into the material. Through precise focusing and control of the ion beam, we achieve transverse positional accuracy in the submicron range. This method enables the creation of isolated quantum centers in diamond and other materials for applications in quantum technologies.

Department of Low and Medium Energy Physics (F2)

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www

Development of materials for magneto/electro-optic sensors

For the successful automation of production processes and the development of smart cities, buildings or autonomous driving, we constantly need new sensors. We are developing nanomaterials that exhibit a nonlinear optical response in a liquid medium, which can be exploited in magneto-optical sensors, e.g., for detecting and measuring rotation, magnetic or electric fields. When such substances are embedded in optical fibers, the sensors are also suitable for use in hazardous (toxic, explosive, high voltage) environments.

Department for Materials Synthesis (K8)

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www

Quantum Device Materials

We collaborate with the Center of Excellence Nanocenter and Google Quantum AI to characterize, engineer, and optimize materials used in superconducting qubits, resonators, and hybrid quantum circuits.

www

Department for Complex Matter (F7)

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Ultrafast and ultraefficient computer memory

We are developing a new type of computer memory (the charge-configuration memristor, CCM), which is based on an electrically induced phase transition in a quantum material. Owing to its exceptional energy efficiency and its ability to operate at low temperatures, this memory is highly promising for integration into advanced control systems for quantum processors.

Department for Complex Matter (F7)

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Quantum materials for quantum technologies

Expertise in the synthesis and tailored crystal growth of quantum materials, including oxide and fluoride systems. Expertise in structural characterization (using PXRD and SCXRD with both lab- and synchrotron-based sources), and analysis of magnetic properties (using magnetic susceptibility, neutron scattering, etc), providing insights into structure–property relationships of materials for quantum technologies.

Electronic Ceramics Department (K5)

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Plasma-enabled advanced industrial technologies and next-generation nanomaterials

F6 specializes in novel plasma processes for synthesis of nanomaterials, advanced supercapacitors, metal alloys and functional surfaces. We conduct research in plasma and quantum structures, field emission from nanostructures, optoelectronics and advanced vacuum science. Our expertise includes materials for extreme environments, high-precision sensors and plasma-enabled materials for space and fusion technologies.

Laboratory of Gaseous Electronics (F6)

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Quantum simulation of materials and chemical reactions using quantum devices

We develop quantum models and algorithms for predicting material properties and simulating chemical reactions, which are essential tools for designing new compounds, catalysts and functional materials. We use advanced quantum architectures, such as neutral atoms, trapped ions and quantum annealers, to perform simulations that exceed the capabilities of classical computers.

Department for Complex Matter (F7)

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Ultrafast XUV/EUV Light modulators

Our research enables the design of ultrafast light modulators based on photo-induced structural transitions in quantum materials. These systems are promising for next-generation lithography, communication, and photonics applications.

Department for Complex Matter (F7)

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Computational modeling of quantum many-body dynamics

We use quantum algorithms and quantum annealers to find optimal solutions in complex problems where classical methods often fail. We develop models that exploit quantum superposition and entanglement to tackle combinatorial and industrial challenges more efficiently.

Department for Complex Matter (F7)

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www

Materials: Surfaces and Coatings

Short-term treatment of materials for improved coating adhesion

The surfaces of many materials are not suitable for the deposition of another material, for example in printing, gluing, or metallization. We are developing treatment processes that enable optimal adhesion through the modification of surface properties. Each type of material requires a specifically adapted procedure. Some of our solutions have been patented.

Department of Surface Engineering (F4)

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www

Oxide electronics and functional thin films

We investigate oxide semiconductors, piezoelectric and ferroelectric materials, as well as functional thin films prepared by pulsed laser deposition. The focus is on developing materials and heterostructures with controlled electrical and dielectric properties suitable for sensing, microelectronic components, dielectric elements, and advanced actuator and detection systems. Using state-of-the-art microscopy and spectroscopic methods, we establish structure–property relationships that support the development of stable, reliable, and miniaturised electronic solutions.

Department for Advanced Materials (K9)

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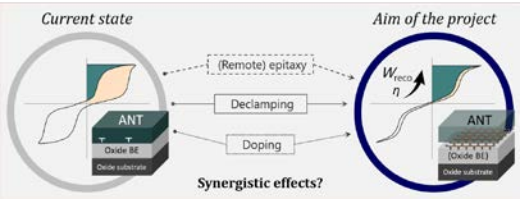



Deposition of hard protective coatings on tools

We deposit hard protective coatings such as TiN, TiAlN, TiAlSiN and others, on cutting and forming tools. The tool dimensions are limited to dia400x400, while the substrate material may be cemented carbide or steel (provided the tempering temperature was above 450 °C).

Department of Thin Films and Surfaces (F3)

miha.cekada@ijs.si

Preparation of coatings and functional layers in aerosol

Deposition of various functional layers and coatings from powders. The thickness of the deposited layers is usually a few micrometres, and the coatings can be applied to different substrates.

A few examples:

- corrosion-resistant coatings,
- ceramic or polymer coatings,
- metal coatings for electrodes,
- and functional coatings.

Electronic Ceramics Department (K5)

hana.ursic@ijs.si

Corrosion protection and self-cleaning effect

We can apply an ultra-thin, invisible layer of material onto workpieces and final products that reduces and, in many cases, prevents corrosion. In some cases, the coating almost completely prevents the adhesion of impurities or allows them to be easily removed from the surface of treated products.

Department of Surface Engineering (F4)

gregor.primc@ijs.si

Advanced analytics of surfaces and thin films on industrial samples

Industry often encounters cases where a certain problem (e.g. scrap, interruption, warranty claim) is connected to the quality of the surface. Easier cases can be solved in-house while more difficult issues require advanced analytical techniques. We can offer characterization of mechanical properties, surface topography and chemical composition, both on homogeneous bulk samples as well as on those coated by a thin film.

Department of Thin Films and Surfaces (F3)

miha.cekada@ijs.si

Structural analysis of crystalline samples at the atomic and molecular level

Crystal structure determination of crystalline samples using X-ray diffraction on single crystals or using 3D electron diffraction on powders. The analysis can also be performed on samples that are sensitive to air and stable only at low temperatures.

Extreme Conditions Chemistry Laboratory ECCL (K2)

matic.lozinsek@ijs.si

Material analysis with accelerated ion beams

At the beamlines of the "Tandetron" ion accelerator, we perform material characterization using various ion-beam analytical techniques (PIXE/PIGE, RBS, NRA, SIMS), which enable precise determination of elemental composition, depth profiles, and thin-film thicknesses. These methods enable analysis of bulk material without the need for complex sample preparation. By using focused ion beams, we achieve spatial resolution down to the micrometre scale.

Low and Medium Energy Physics (F2)

primoz.pelicon@ijs.si

Analysis of samples in solutions

Analysis of samples in solutions using nuclear magnetic resonance (NMR) which can measure a wide range of elements (1H, 19F, 13C, 31P, 129Xe) at room or low temperature. Characterization of samples and determination of structures using 1D and 2D NMR spectroscopy for sample solutions. Analysis can also be performed on samples that are sensitive to air and stable only at low temperatures, above –80 °C. The instrument is specially adapted for measurements of samples containing fluorine.

Extreme Conditions Chemistry Laboratory (K2)

miha.virant@ijs.si

Sample analysis using Raman spectroscopy

Sample analysis using Raman spectroscopy at temperatures from –196 to 150 °C also includes Raman mapping with high spatial and spectral resolution, which allows the study of sample homogeneity and the distribution of various chemical species.

Extreme Conditions Chemistry Laboratory ECCL (K2)

kristian.radan@ijs.si

Development of optical devices

We offer expertise in the development and manufacturing of optical devices, with a focus on translating customer needs into practical, high-performance optical solutions. Our capabilities include designing complete optical systems, optimizing them through simulation and experimental validation, and rapidly building functional prototypes. This integrated approach allows us to address complex optical challenges and deliver manufacturable, reliable devices tailored to specific applications. In the past, we have developed several optical devices for industrial partners, ranging from those operating on the microscale (light absorption meter for determining the concentration of a specific substance in a microfluidic channel; development of microscopic and mesoscopic imaging methods) to those operating on the macroscale (investigation of local optical properties on large surfaces of various materials).

Department for Complex Matter (F7)

natan.osterman@ijs.si

Structural, morphological and chemical characterization of inorganic materials with advanced electron microscopy techniques

Advanced electron microscopy techniques enable comprehensive structural, morphological and chemical characterization of inorganic materials. While scanning electron microscopy (SEM) enables such investigations at the micron level, transmission electron microscopy (TEM) enables the investigation of materials at the subatomic level and enables analyses such as grain boundary investigations, inclusions, the determination of planar defects and dislocations in various minerals, and in-situ experiments.

Centre for Electron Microscopy and Microanalysis CEMM

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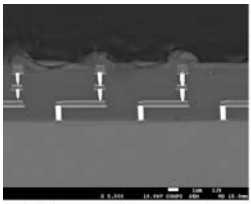
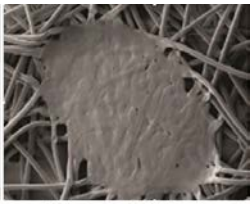
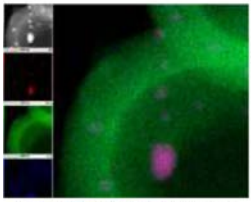
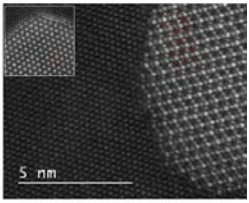

SEM micrograph of circuit cross-section.


SEM micrograph of facial mask.


TEM micrograph of composite nanoparticles.



High-resolution TEM micrograph of Al alloy.

Primary packaging analysis

Comprehensive characterization of primary packaging materials is performed using advanced CT and SEM/EDS methods. Analyses include glass delamination propensity studies, dimensional evaluation and container closure integrity testing of vials and determination of thickness and composition of stoppers. Additionally, morphological analysis and elemental composition analysis of filtered vial solutions and freeze-dried samples is carried out to assess the effects of storage and lyophilization processes.

Department for Nanostructured Materials (K7)

matejka.podlogar@ijs.si

Atomic force microscopy of functional elements

Characterization of materials and components at the nanoscale, including surface roughness, local electrical conductivity mapping, and determination of mechanical, magnetic, or piezoelectric properties using atomic force microscopy techniques (AFM/CAFM/AM-FM/MFM/PFM).

Electronic Ceramics Department (K5)

hana.ursic@ijs.si

www

Characterization of materials via magnetometry

Magnetic materials are a key resource in the technological and sustainable development of society. Our equipment allows for characterization of magnetic materials via SQUID or SQUID-VSM magnetometry in a large range of magnetic fields (up to 7 T) and in a large range of temperatures (1.8 K to 400 K or – 271 °C to +127 °C). The most common uses are measurements of temperature dependent magnetic susceptibility (to detect the magnetic transitions of materials), measurements of M(H) isothermal hysteresis loops and experiments in an alternating magnetic field (AC magnetometry, 0.1 Hz to 1000 Hz, amplitude to 1 mT). Also possible are experiments in small magnetic fields (the background reduced to 1 μT) or in an extended temperature range up to 1000 K (730 °C).

Department of Solid State Physics (F5)

primoz.kozelj@ijs.si

Advanced characterization of complex materials and fast processes

We specialize in cutting-edge experimental methods for studying advanced materials, including ultrafast pump-probe spectroscopy, precision optical and combined opto-electrical measurements, and real-time signal analysis. We offer custom measurement solutions, integration of multi-instrument systems, which enable detailed insight into structural, electronic, and dynamical properties of materials relevant for industrial R&D and high-performance applications.

Department for Complex Matter (F7)

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www

Resilience and Lifetime of Materials

Corrosion resistance of metallurgical and additively manufactured materials for the low-carbon and circular economy

Contemporary industries for low-carbon and circular applications use metallurgical, additively produced and recycled metallic materials. The corrosion resistance of these materials in harsh, demanding environments is crucial to their longevity, safe operation, functional requirements, and environmental suitability. We offer a variety of corrosion protection strategies, including corrosion inhibitors and inorganic, organic, and superhydrophobic coatings. Analyses of morphological, chemical and functional properties are available.

Department of Physical and Organic Chemistry (K3)

ingrid.milosev@ijs.si

www www

Structural mechanics analyses and lifetime prediction of critical components

We develop multi-scale models for prediction of material aging, micro-mechanical damage, and fatigue of components in nuclear and thermal energy systems. Our expertise includes deterministic and probabilistic analyses, lifetime assessment of components, and validation with experimental data. These analyses are essential for the development and prediction of long-term operation of nuclear reactors and other high-temperature systems.

Department of Reactor Engineering (R4)

samir.elshawish@ijs.si

www

Space

Development of miniature spaceflight mass spectrometers

Developing instruments for spaceflight requires specialized expertise in making a device as lightweight and energy-efficient as possible while ensuring it can withstand high accelerations, vibration, extreme temperature fluctuations, and ionizing radiation. At the same time, the instrument's analytical performance must remain comparable to that of laboratory systems. Our instruments are based on quadrupole ion-trap technology, and can be used to analyze both gaseous and liquid samples.

Department of Low and Medium Energy Physics (F2)

jurij.simcic@ijs.si

www

Miniature piezoelectric valve for sampling of planetary atmospheres

A valve designed for sampling planetary atmospheres must withstand pressure differences of up to 100 bar while precisely regulating the gas flow fed through it into a mass analyzer operating under vacuum. The device must be reliable, weigh under 100 grams, and respond to external changes within a millisecond, all without altering the composition of the gas passing through it.

Department of Low and Medium Energy Physics (F2)

jurij.simcic@ijs.si

www

Climate, Energy and Mobility



This section addresses climate change by aiming to better understand its causes, evolution, risks and impacts, and by making cities, the energy systems and supplies, and the transport sector more environment-friendly, more efficient and competitive, smarter, safer and more resilient. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least nineteen departments, covering such diverse sectors as chemistry, environment, energy, physics, and information technologies.

If you come across any technology in the Climate, Energy and Mobility section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.

Energy Networks 57
Energy Storage 59
New Energy Sources 63
Sustainable Materials 64
Sample Analysis and Material Characterisation 66
Decontamination 67
Energy Strategy 69
Urban Planning 70
Traffic and Mobility 71

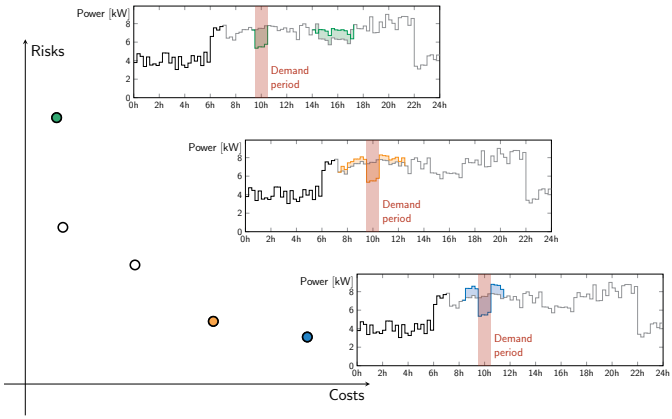


Advanced control and optimization for energy-efficient systems

We design advanced single- and multiobjective optimization algorithms that improve the performance, flexibility and sustainability of complex energy systems. We focus on developing optimization solutions intended for model predictive control, enabling smarter, data-driven decisions for energy-efficient and climate-neutral operation. Our work supports next-generation energy infrastructures with enhanced demand-side flexibility and strengthened grid stability, helping systems adapt to dynamic conditions and contributing to a resilient, low-emission future.

Department of Intelligent Systems (E9)

tea.tusar@ijs.si



Energy consumption forecasting

The development of methods for forecasting energy consumption based on time-series data, taking into account weather, operational, and other contextual influences. These approaches enable more efficient energy management and process optimization, applicable in households to reduce costs, in industrial processes and factories to improve energy efficiency, by energy companies for production and distribution planning, and for better integration of renewable energy sources and reduction of environmental impact.

Computer Systems Department (E7)

gasper.petelin@ijs.si

Machine learning in energy and mobility

We offer comprehensive expertise in machine learning, encompassing both structured and unstructured data environments, including data in form of time series, which are frequently used in solutions for energy production and consumption forecasting, as well as explanations and predicions of mobility related phenomena. We offer development and application of advanced machine learning techniques also to a diverse range of other problem domains.

Department of Knowledge Technologies (E8)

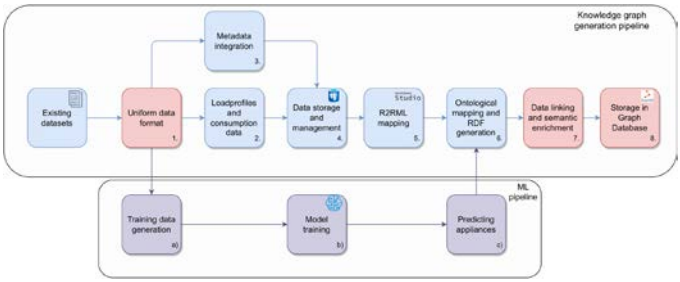
martin.znidarsic@ijs.si

Data driven household electricity digital twin

We develop data driven digital twins and retrieval augment generation (RAG)-based interactions with them. For instance, we developed a knowledge graph generated from a set of raw datasets containing electricity consumption data from multiple regions and households. The data is preprocessed and harmonized to generate a knowledge graph containing information about the households, appliances, and electricity consumption. We also provide a model training pipeline that can be used to train a model for on/off appliance classification. Knowledge-based digital twins, coupled with AI, may also empower humans to understand aspects of the system through natural language interaction in view of planning and policy making. We study the capabilities of ChatGPT, Gemini and Llama in answering electricity related questions.

Department of Communication Systems (E6)

carolina.fortuna@ijs.si



Dynamic thermal rating and smart energy grid analytics

The modernization of electrical grids demands advanced monitoring and predictive analytics. We develop dynamic thermal rating (DTR) systems—including the DiTeR platform—used

Department of Communication Systems (E6)

by national transmission operators to optimize power line utilization in real time. Our models integrate weather data, complex terrain effects, numerical simulations, and forecasting to provide actionable operational insights. These technologies increase grid resilience, efficiency, and sustainability.

gregor.kosec@ijs.si

IoT-Based Monitoring for Energy Systems

We develop distributed sensor networks for monitoring energy usage, mobility patterns, and infrastructure conditions. Using AI-based time-series analysis, our solutions detect anomalies, optimize resource use, and support predictive maintenance in energy and transport infrastructures. These solutions form core components of smart-grid ecosystems and intelligent mobility systems.

Department of Communication Systems (E6)

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Energy Storage

Fluorinated materials for use in batteries, optics, or catalysis

Synthesis of fluorine-containing materials and tailored fluorination of materials for use, for example, in modern battery systems, optics or catalysis.

Extreme Conditions Chemistry Laboratory ECCL (K2)

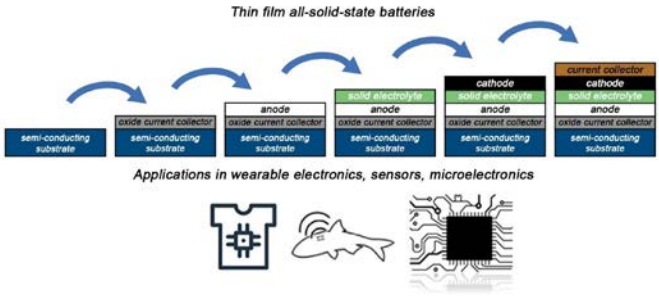
kristian.radan@ijs.si

Materials for energy storage and electrochemical systems

We develop ceramic, composite, and hybrid materials for batteries, supercapacitors, and other electrochemical devices, with a focus on enhancing ionic conductivity, cycling stability, and thermal robustness. Particular attention is given to optimising electrode–electrolyte interfaces and employing energy-efficient material preparation routes. The research supports next-generation energy solutions for electric mobility, stationary storage, and high-performance electrochemical systems.

Department for Advanced Materials (K9)

matjaz.spreitzer@ijs.si



Battery performance analysis with magnetic resonance imaging (MRI)

Studying battery performance using high spatial resolution magnetic resonance imaging (MRI) can be an interesting tool for studying dendrite growth during charging of batteries with a metal anode, as well as for analyzing their structure. The method allows for dynamic spatial imaging of batteries in operando.

Department of Solid State Physics (F5)

igor.sersa@ijs.si

Hydrogen-based energy storage solution

Solid oxide cells (SOC) show significant promise as a hydrogen-based energy storage solution for renewable energy systems. Our work focuses on preparing and shaping materials for SOCs and developing SOC prototypes. For fabrication, we employ established methods such as tape casting and screen printing. In parallel, we are advancing characterization techniques, including electrochemical impedance spectroscopy, to study performance and reliability. Our research is enhanced by finite element modeling, which supports development of SOC technology.

Electronic Ceramics Department (K5)

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kostja.makarovic@ijs.si
barbara.malic@ijs.si

Materials for green hydrogen technologies

We develop multi-metal compounds, metal oxide heterostructures, and thin film composites for green hydrogen production through electrocatalytic, photocatalytic, and photo-electrocatalytic water-splitting.

The work focuses on gaining a fundamental understanding of

Odsek za raziskave sodobnih materialov (K9)

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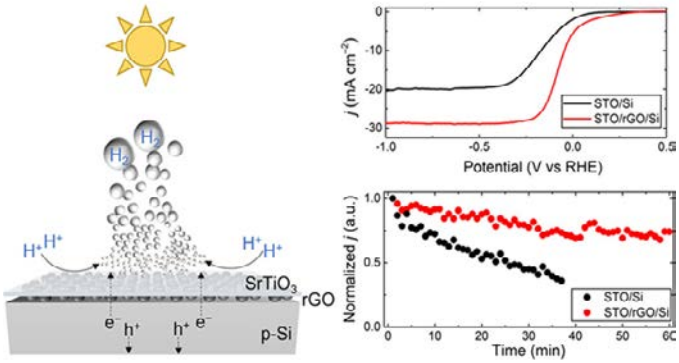
marjeta.macek@ijs.si

materials growth mechanisms to tailor their catalytic properties, stability, and selectivity for desired water-splitting reactions. We also focus on the development of electrodes that can sustain the harsh environment of low-grade and saline water in advanced seawater-based electrolyzers. Through advanced microstructural analysis, tailored synthesis, and energy-efficient processing, we create materials that support long-term stability and high performance within the emerging green hydrogen economy.



Materials for energy storage, hydrogen technologies and sustainable plasma processing

Our R&D focuses on new materials for next-generation supercapacitors, aluminium-ion batteries, and hydrogen energy storage. We develop layers for hydrogen permeability control in demanding environments and low-carbon plasma processes for surface modification and synthesis of energy-efficient materials. The work supports the green transition and development of sustainable industrial technologies.

Laboratory of Gaseous Electronics (F6)

uros.cvelbar@ijs.si

Development of catalysts for electrified hydrogen storage in chemicals

Storing hydrogen in chemical compounds offers a promising route to reduce costs and simplify the transport and storage of this key energy carrier in the green transition. Current research focuses on developing new catalysts that enable contactless heating, safe operation, and rapid establishment of reaction conditions through magnetic heating of the catalytic layer. This approach allows dynamic and flexible synthesis of various hydrogen storage

Department for Materials Synthesis (K8)

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media—such as ammonia, methanol, liquid organic hydrogen carriers, and bio-based compounds—powered by renewable electricity.

Nanostructural characterization of catalysts

The development of new processes for storing renewable energy (e.g., hydrogen production and storage in chemical compounds, fuel production from waste biomass) and processes for degrading pollutants in the environment (e.g., photocatalytic wastewater treatment) is based on the use of heterogeneous catalysts. Catalyst are in fact nanostructured composite materials consisting of a support material coated with catalytic nanoparticles. Expertise in nanostructural characterization using advanced electron microscopy techniques is crucial in the development of catalysts.

Department for Materials Synthesis (K8)

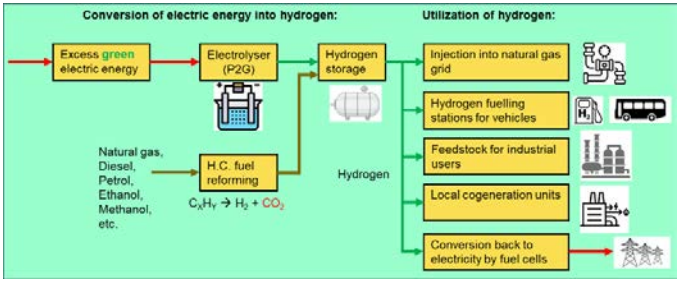
darko.makovec@ijs.si

Expertise in the field of hydrogen technologies

We participate in the design of systems based on hydrogen technologies (fuel cells, electrolyzers, hydrogen storage tanks) for the needs of energy storage, conversion of excess electricity, balancing of the electric grids, energy and heat supply of buildings. With the help of techno-economic digital twins (simulation models), we provide support in the design, sizing and operation of systems. We have a wide reference list (Slovenian and international development projects).

Department of Systems and Control (E2)

gregor.dolanc@ijs.si



Microbial fuel cells and bioelectrochemical systems

Our research integrates electroactive microbes with conductive materials to enhance microbial fuel cells and bioelectrochemical systems. By controlling cell–surface interactions, we improve electron transfer, stability, and performance for sustainable energy generation and coupling with the waste removal.

Department of Environmental Sciences (O2)

ales.lapanje@ijs.si
tomaz.rijavec@ijs.si



Creation and characterization of defects in the crystal structure of materials and the influence on the behaviour of hydrogen isotopes

Materials can be irradiated with heavy ions produced by an ion accelerator at various temperatures, thereby simulating lattice defects similar to those that will be generated by neutron irradiation in materials used in future fusion or next-generation fission reactors. Using ion-beam techniques, we can dynamically study how these defects influence the behaviour and retention of hydrogen isotopes in such materials. The concentration of hydrogen isotopes under different irradiation conditions can significantly affect the long-term evolution of material properties, such as hydrogen-induced embrittlement and reduced diffusivity.

Department of Low and Medium Energy Physics (F2)

sabina.markelj@ijs.si



Materials for extreme conditions: developing components for the future fusion reactors

The group develops advanced materials for the most thermally and mechanically loaded components of fusion reactors, such as the divertor. Research focuses on high-temperature composites with excellent thermal shock resistance. Special attention is given to sintering processes, and microstructural characterization, as well as to studying material behavior under extreme heat fluxes and simulated fusion environments.

Department for Nanostructured Materials (K7)

petra.jenus@ijs.si



Reliability and risk analyses of complex energy systems

We perform integrated deterministic safety analyses of nuclear facilities and other critical infrastructure systems. We develop methods for uncertainty assessment, sensitivity analyses, and modelling of various transient events and accident scenarios in energy systems. Our expertise provides support to industry in risk assessment, preparation of safety and regulatory documentation, and strategic analyses.

Department of Reactor Engineering (R4)

andrej.prosek@ijs.si

www

Sustainable Materials

Corrosion resistance of materials for a sustainable society

The green transition to reduce dependence on fossil fuels and combat global warming is accelerating the need for sustainable materials in energy applications and mobility. We offer corrosion-resistance analyses of critical materials, such as magnetic materials, under demanding conditions. We deal with corrosion protection of the most vital technological alloys used in transport and mobility, such as aluminium, magnesium and copper alloys and various steels.

Department of Physical and Organic Chemistry (K3)

ingrid.milosev@ijs.si

www www

Ceramic materials and technologies for specific applications

Preparation of bulk ceramics, layer and multilayer structures using various techniques such as screen printing, tape casting, ink-jet printing, and aerosol deposition.

Examples:

- bulk ceramics,
- multilayer structures, and micron-thick films for dielectric, piezoelectric, and electrocaloric applications,
- metallic micron-thick films for electrodes, etc.

Electronic Ceramics Department (K5)

hana.ursic@ijs.si

www www

Piezoelectric ceramic materials for sensor, actuator, and ultrasonic applications

We synthesize advanced piezoelectric materials and provide comprehensive characterization of their functional properties. The materials are available in both bulk ceramic and thin-film form. Measurements include both the direct and converse piezoelectric effects, as well as ferroelectric behavior. These materials serve as active components in piezoelectric sensors, transducers, and actuators, and can also be utilized for energy harvesting and storage applications.

Electronic Ceramics Department (K5)

tadej.rojac@ijs.si
barbara.malic@ijs.si
mojca.otonicar@ijs.si

Electrocaloric materials and elements for future cooling applications

New cooling elements based on solid-state cooling are being developed. The electrocaloric temperature change of these elements can be determined. In the future, the elements could be used to cool electronics at the micro level.

Electronic Ceramics Department (K5)

hana.ursic@ijs.si

Green magnets of the future: processing and recycling of rare-earth-free magnets

The group conducts interdisciplinary research on magnets without or with low rare-earth content, focusing on the development of new composite and textured ferrite-based materials with enhanced magnetic properties. Research activities include optimization of sintering, doping, and texturing processes to achieve high density, oriented microstructures, and competitive magnetic performance. Additionally, additive manufacturing of ferrite-based magnets is being explored. A significant part of the group's work is dedicated to the recycling and reuse of ferrite magnets, aiming at sustainable magnet production and promotion of the circular economy.

Department for Nanostructured Materials (K7)

petra.jenus@ijs.si

Thermal insulation materials

We investigate advanced glassy thermal-insulation materials and composites designed to improve the energy and environmental efficiency of building insulation. Particular emphasis is placed on understanding synthesis mechanisms and aging processes, which enables control of porosity, density, microstructure, resistance to degradation, and thermal conductivity. Using modern synthesis methods and advanced characterization, we develop materials and synthesis routes that facilitate the use of waste materials, recycling, reduced energy consumption and the use of green electricity, improved functional properties, and an extended service life of insulation systems.

Department for Advanced Materials (K9)

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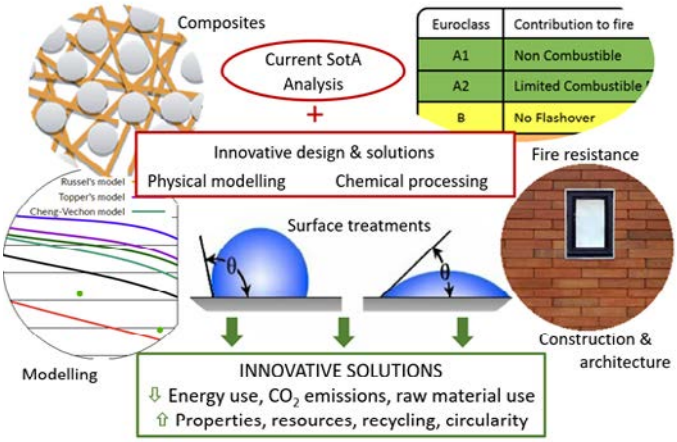

Sample Analysis and Material Characterisation

Structural analysis of crystalline samples at the atomic and molecular level

Crystal structure determination of crystalline samples using X-ray diffraction on single crystals or using 3D electron diffraction on powders. The analysis can also be performed on samples that are sensitive to air and stable only at low temperatures.

Extreme Conditions Chemistry Laboratory ECCL (K2)

matic.lozinsek@ijs.si

Analysis of samples in solutions

Analysis of samples in solutions using nuclear magnetic resonance (NMR) which can measure a wide range of elements (1H, 19F, 13C, 31P, 129Xe) at room or low temperature. Characterization of samples and determination of structures using 1D and 2D NMR spectroscopy for sample solutions. Analysis can also be performed on samples that are sensitive to air and stable only at low temperatures, above –80 °C. The instrument is specially adapted for measurements of samples containing fluorine.

Extreme Conditions Chemistry Laboratory ECCL (K2)

miha.virant@ijs.si

Sample analysis using Raman spectroscopy

Sample analysis using Raman spectroscopy at temperatures from –196 to 150 °C also includes Raman mapping with high spatial and spectral resolution, which allows the study of sample homogeneity and the distribution of various chemical species.

Extreme Conditions Chemistry Laboratory ECCL (K2)

kristian.radan@ijs.si

Comprehensive microstructural and structural characterization of inorganic materials from the macro to the atomic level

Support for the development of inorganic oxide materials through structural analysis, which includes the characterization of surfaces, cross-sections, crystal orientation, chemical composition, and structural defects. This is performed using electron microscopy methods (SEM/EDXS/EBSD/FIB and TEM/STEM/EDXS/EELS).

Electronic Ceramics Department (K5)

andreja.bencan@ijs.si
mojca.otonicar@ijs.si

Decontamination

Emission measurements and impact assessment in the transition to low-carbon technologies

We measure and model air and sediment pollutants (e.g., Hg, particulates, persistent organic pollutants - POPs), assess the impacts of industrial and traffic emissions, and monitor the effectiveness of decarbonization measures. For the energy and

Department of Environmental Sciences (O2)

joze.kotnik@ijs.si
bor.krajnc@ijs.si

mobility sectors, we develop monitoring plans, validate analytical methods, and establish indicators for LCA and ESG frameworks.

Tritium removal from nuclear power plant wastewater

We are developing biological technologies for tritium removal from nuclear power plant wastewater. The advantages of the technologies are that they do not require huge amounts of energy to remove tritium, are carbon neutral, and produce useful by-products such as biohydrogen, ^{18}O, ^{3}He and ^{3}H.

Department of Environmental Sciences (O2)

marko.strok@ijs.si

Characterization of radioactive waste

We are developing methods for determining difficult-to-measure radionuclides in radioactive waste from nuclear power plants. The methods are suitable for characterizing radioactive waste, which allows us to determine the inventory of radionuclides in it, which is important when planning its permanent disposal.

Department of Environmental Sciences (O2)

marko.strok@ijs.si

Purification of liquids through piezocatalysis using ferroelectric materials

Adjusting the composition of ferroelectric and antiferroelectric ceramics to achieve the most efficient degradation of organic pollutants in liquids using ultrasonic vibrations. In addition to tailoring the composition based on the selected pollutant, we also adjust the size and morphology of the ceramic particles, or incorporate them into 2D or 3D structures to enable easier reuse.

Electronic Ceramics Department (K5)

mojca.otonicar@ijs.si

Support for the design and implementation of energy efficiency policies

Support for the design and implementation of energy efficiency policies encompasses a comprehensive set of expert activities aimed at strengthening the capacities of ministries and companies in developing, implementing, and monitoring the impacts of energy measures. These activities include the preparation of in-depth analyses and expert inputs, the development of methodological tools for assessing policy impacts, the formulation of regulatory recommendations, and coordination with relevant stakeholders at the national and sectoral levels. We provide companies with technical and analytical support in preparing energy strategies, identifying cost-effective measures, and ensuring compliance with regulatory requirements. Through high-level expertise and the use of advanced analytical approaches, we contribute to improved decision-making and to the effective achievement of national energy and climate objectives.

Energy Efficiency Centre EEC

stane.merse@ijs.si

Multidisciplinary approach to transport and environmental safety

At the Energy Efficiency Center, we research and apply various aspects of mobility, such as energy, spatial planning, environmental and economic. Sustainable development of the transport sector requires reducing its impacts on society. In this regard, there are two pressing problems: transport and environmental safety. Slovenia is committed to specific goals in both areas, so it makes sense to properly evaluate transport measures for better synergy effects.

Energy Efficiency Centre EEC

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Energy use modelling to support policy and business strategy development

Energy use modelling for various end-use sectors using reference energy models provides robust quantitative support for the development of energy and climate policies as well as strategic planning processes. With advanced modelling approaches, we analyse current trends, assess the impacts of sectoral measures and transition scenarios, and forecast future energy needs, thereby enabling the formulation of data-driven and effectively targeted policies. In addition to national and sectoral modelling, we also develop detailed energy use models at the company level, which support the assessment of sustainability transition impacts, the identification of cost-optimal

low-carbon measures, and the monitoring of progress towards sustainability goals. This integrated modelling approach significantly contributes to informed decision-making and to accelerating the transition towards a low-carbon and energy-efficient economy.

Energy Efficiency Centre EEC

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Compute for Climate Fellowship – AI for climate action

At IRCAI, in collaboration with Amazon Web Services (AWS), we run the global entrepreneurship program Compute for Climate Fellowship, supporting start-ups in developing advanced AI solutions to mitigate climate change. In 2025, the program included 23 companies working in clean energy, sustainable mobility, climate resilience, environmental analytics and more.

International Research Centre on Artificial Intelligence under the auspices of UNESCO (IRCAI)

info@ircai.org

Urban Planning

Spatial analytics and planning with GIS tools

Working with databases that include spatial attributes is carried out using geographic information system (GIS) technologies and software such as ArcGIS Pro/Online and QGIS. These tools enable data processing, visualization, and the execution of advanced (spatial) analyses. With this approach, we can perform multi-criteria analyses of spatially referenced data, identify their characteristics, and meaningfully incorporate them into subsequent phases of spatial planning and other processes. Analysis using GIS tools is a key and widely applicable support element in numerous professional fields, including spatial and energy planning, environmental sciences, natural resource management, transportation, and many other sectors.

Energy Efficiency Centre EEC

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The effect of heat waves on the productivity of workers

Due to global warming, the frequency, duration and magnitude of summer heat waves are increasing. At the Jožef Stefan Institute laboratory in Planica, we simulate 3-D heat waves to understand the cumulatve effect on workers' health and well-being, and also on their work performance.

Department of Automation, Biocybernetics and Robotics (E1)

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Smart cities - Crowd monitoring

Understanding how people move through cities and public infrastructures is essential for inclusive urban planning. Research and development are mainly carried out in the field of modular wireless sensing platforms that unobtrusively monitor occupancy and movement patterns in public spaces while incorporating privacy-preserving mechanisms. We contribute to smart-city ecosystems through intelligent wireless communication, context-aware sensing, localisation techniques and digital twins.

Department of Communication Systems (E6)

tomaz.javornik@ijs.si

www

Traffic and Mobility

Sustainable mobility for employees

We provide consultancy on introducing sustainable commuting methods for employees. The approach is based on a multi-criteria model for analysis in accordance with the principles of sustainable mobility, taking into account physical/environmental, social, and economic factors. The results raise awareness and promote sustainable mobility among employees in organizations, particularly in areas such as car use, e-mobility, cycling, public transport, walking, and similar modes. Through this, organizations can continuously monitor their employees' travel habits and mobility patterns. It supports the planning, implementation, monitoring, and evaluation of measures and activities aimed at improving sustainable mobility within the organization, and demonstrates the current status or progress toward enhancing sustainable mobility.

Department of Environmental Sciences (O2)

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Forecasting traffic flows and densities

Development of advanced machine learning models for short-term and long-term traffic flow forecasting and anomaly detection in mobility.

Computer Systems Department (E7)

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www

Traffic and mobility systems optimization

Optimization of dynamic, non-deterministic, and multi-modal transport systems, with a focus on advanced algorithmic control and real-time decision support on multiple levels and considering multiple objectives. Our research spans intelligent transportation systems, cooperative mobility, fleet-management optimization, and predictive analytics for traffic flow.

Computer Systems Department (E7)

gregor.papa@ijs.si

Advanced fleet management

The department's AI expertise in the mobility field focuses on designing, integrating and demonstrating advanced, intelligent systems for traffic and fleet management. These solutions enable efficient and globally optimal transport of passengers and goods by leveraging real-time data and predictive algorithms. AI supports seamless multimodality and interoperability across different transport modes, ensuring smooth coordination between automated and conventional vehicles. Through dynamic balancing and priority-based vehicle management, such systems optimize traffic flow and enhance overall mobility performance.

Department for Artificial Intelligence (E3)

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Wireless Communications for Smart Mobility

Modern mobility systems rely on reliable wireless communication for safety, automation, and real-time services. We design and evaluate communication systems for smart mobility using advanced propagation modelling and localisation techniques. In our research, we focus on ensuring reliable operation in demanding environments and developing applications for communication, sensing including ISAC (integrated sensing and communication) and localization.

Department of Communication Systems (E6)

tomaz.javornik@ijs.si

Autonomous operation of mobile robots

Reliable and accurate spatial perception of mobile manipulator systems is becoming essential for effective operation in dynamic environments. Therefore, the field of sensor-guided calibration and autonomous operation of mobile manipulators is developing rapidly and gaining importance. Research and development are

focused primarily on multi-sensor fusion, automatic calibration between mobile manipulators, and algorithms that enable these systems to continuously adapt to uncertainties in the environment. Special emphasis is placed on methods that improve manipulation accuracy, spatial understanding, and coordination of mobile manipulator systems. Application areas include industrial logistics, smart production lines, and advanced autonomous robotic platforms in natural environments.

Department of Automation, Biocybernetics and Robotics (E1)

tadej.petric@ijs.si



Food, Bioeconomy, Natural Resources, Agriculture and Environment



This section focuses on reducing environmental degradation, sustaining biodiversity, and management of natural resources. In addition, it covers knowledge creation, innovation and digitalisation in food production as well as transitioning to a low-carbon, resource-efficient circular economy and sustainable bioeconomy. At the Jožef Stefan Institute, research in several fields from this section is carried out in at least fifteen departments, covering such diverse sectors as biochemistry, chemistry, environment, physics, and information technologies.

If you come across any technology in the Food, Bioeconomy and Environment section with potential synergies with your company, or you would just like to check options for cooperation, we invite you to contact researchers listed at the specific area/expertise, or simply write to tehnologije@ijs.si to check what can be achieved together.

Food 77
Elemental Analysis 78
Antimicrobials 80
Environmental Investigation and Decontamination 81
Sustainable Management 83
Artificial Intelligence in Environmental Applications 85



Crop protection and sustainable production

We apply colloid biology to develop microbial consortia that protect plants, enhance nutrient uptake, and stabilize beneficial soil microbiota. This approach supports sustainable crop management and reduces the need for chemical inputs.

Department of Environmental Sciences (02)

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Authenticity, traceability, quality, and safety of food

We developed a traceability system for raw materials and food that includes analysis of stable isotopes of light and heavy elements, elemental composition, a database, and modelling of verification of correct labelling of food, essential oils in plant extracts (organic vs. conventional production; natural vs. synthetic; geographical origin). The methods for chemical safety and quality are also available.

Department of Environmental Sciences (02)

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milena.horvat@ijs.si

Magnetic resonance imaging (MRI) in analysis of food

Water and fats are important components of virtually every food item. Both components can be very effectively detected and their changes can be determined using magnetic resonance imaging (MRI). Virtually every process related to food preparation and processing is associated with these changes, therefore MRI is a very effective tool for analyzing various processes related to food.

Department of Condensed Matter Physics (F5)

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Integrated electrochemical sensors

The development of electrochemical sensors has become crucial for monitoring food and environmental quality. We are developing materials for the production of more sensitive, selective, and stable sensor elements for pesticide detection in water and food samples. Miniature sensor elements are prepared using a printing method.

Electronic Ceramics Department (K5)

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Food natural language processing and food predictive studies

We develop solutions for making your food data interoperable (FAIR data), including named-entity recognition and linking methods, a food-domain large language model (FoodSem), and an agentic approach for unsupervised food normalization. We also fine-tune large language models for recipe nutrient estimation and for assessing the healthiness of a recipe. We also identify relationships between food, nutrition, and biomedicine by generating knowledge graphs from scientific abstracts and predicting mental health or other diseases based on dietary patterns.

Computer Systems Department (E7)

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www

Elemental Analysis

Microscopic particle characterization at high concentrations

In industry, particle size and zeta potential characterization methods based on the principle of light scattering (PALS, DLS) are well known and widespread. However, these methods cannot accurately determine the size and zeta potential in suspensions of microscopic particles at high concentrations. We have developed a new technique based on the principle of differential dynamic microscopy (DDM), which allows the characterization of microscopic particles at high concentrations and more broadly, for example, to characterize dynamics of soft matter in general.

Department for Complex Matter (F7)

andrej.petelin@ijs.si

k_0-INAA multielemental analysis of environmental and food samples

We perform multielemental analysis of environmental and food samples using the k_0-INAA method. The method allows the determination of elemental composition in various environmental and food samples.

www

Department of Environmental Sciences (O2)

radojko.jacimovic@ijs.si

Elemental characterisation of tissues and cells in biological samples

Survival in a changing environment is achieved by a delicate balance between sufficient intake of essential elements and minimal intake of potentially toxic (concentrations of) elements. Using an ion accelerator, focusing lenses and an appropriate detector system, we perform the detection and localization of elements from Na to U in plant and animal samples with micrometer resolution. We offer sample preparation, ion accelerator analysis, spectrum processing and image analysis of the quantitative distribution of elements.

Department of Low and Medium Energy Physics (F2)

paula.pongrac@ijs.si

Isotopes of water and elements for source tracing and resource management

We perform isotopic analyses (H, O, C, N, S, Pb, Sr, etc.) and element speciation to trace water flows, identify sources of pollution, and verify composition within food chains. We provide expertise in sampling design, DGT® and other passive samplers, remediation monitoring, and risk assessment in agriculture and the bio/circular economy.

Department of Environmental Sciences (O2)

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sonja.lojen@ijs.si



Radiolabelling of various chemical elements for the purpose of tracking various biogeochemical processes in the bioeconomy, agriculture and the environment

We are developing methods and technologies for radiolabelling various chemical elements for the purpose of tracking various biogeochemical processes in the bioeconomy, agriculture and the environment.

Department of Environmental Sciences (O2)

marko.strok@ijs.si



Determination of radionuclide content in environmental and food samples

We are developing methods for determining the content of various radionuclides in various food samples as well as in environmental samples. The developed methods are suitable for radiological characterization of various samples, as well as for calculating doses to humans and biota. They also enable tracking of various sources of pollution in the environment.

Department of Environmental Sciences (O2)

marko.strok@ijs.si



Monitoring of isotopic composition of precipitation

Development of the research platform SLONIP (Slovenian Network of Isotopes in Precipitation)'s website with data on the isotopic composition of precipitation in Slovenia presented in in numerical and graphical form together with calculations useful for better understanding of climate change and water resources management.

Department of Environmental Sciences (O2)

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Antimicrobials

Functional characterisation of proteins

We study new bioactive proteins, mainly from fungi, and have established a methodology for their isolation, preparation of recombinant variants (including mutagenesis), and characterisation at the level of basic biochemical properties and bioactivity (effects on bacteria, mammalian cell lines, enzyme activities), as well as their localisation and interactions with other (macro)molecules.

Department of Biotechnology (B3)

jerica.sabotic@ijs.si



Antimicrobial and anti-biofilm activity

We are researching new approaches to the management of bacterial biofilms. We analyse the antimicrobial and anti-biofilm efficacy of substances using traditional microbiological methods (minimum inhibitory concentration, crystal violet staining, colony

Department of Biotechnology (B3)

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counting) and modern techniques (effects on growth parameters, fluorescence microscopy, 3D microscopy), including appropriate data processing. We work with microorganisms of safety levels 1 and 2, including clinically relevant pathogenic bacteria often associated with foodborne infections.

Disinfection and activation of seeds for improved germination

Seeds are usually contaminated with various microorganisms, some located on the surface and others inside. Surface microbes are inactivated through short-term plasma treatment. Plasma treatment of seeds also enhances water absorption, resulting in faster germination. The method is suitable for processing hundreds of kilograms of seeds per hour.

Department of Surface Engineering (F4)

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Environmental Investigation and Decontamination

The use of electron microscopy as an analytical technique for environmental investigations

Structural, morphological and chemical characterization of natural materials in the environment and potential inorganic and organic pollutants in both soil and water. Analysis of sensor materials for environmental applications.

Centre for Electron Microscopy and Microanalysis CEMM

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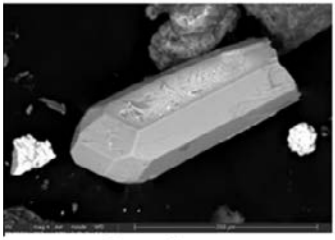
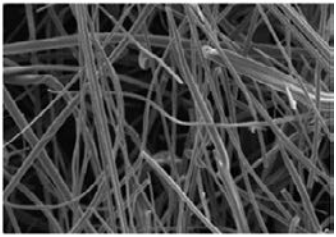
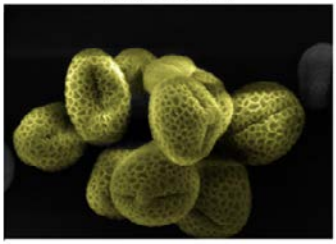


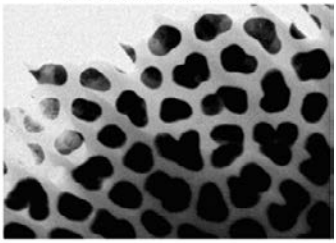
River sediments.



Microplastic fibres in water.



SEM micrograph of pollen.



Cross-section of Fe-Pd nanorods.

Radioactivity measurements in different exposure situations

ISMIS (Infrastructure Group for Ionising Radiation Measurements – Radioactivity Measurements) is a group of laboratories within the F2 and O2 Departments. Using dedicated measurement methods, we determine the concentrations of chemical elements and radioactive isotopes in environmental samples. The measurement methods are accredited according to the ISO/IEC 17025:2017 standard. We continuously update and upgrade the measurement and laboratory equipment. The work is primarily dedicated to studies of biological and geochemical cycles, radiochemistry and radioecology, as well as environmental monitoring.

Department of Low and Medium Energy Physics (F2)

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Gas sensors for detection of low levels of volatile organic compounds

Detecting volatile organic compounds is essential for environmental monitoring, since measuring the presence and concentration of certain compounds allows us to assess air quality, pollution, food freshness, the occurrence of diseases in agriculture, etc. We are investigating new sensor technologies based on nanoporous materials for the specific and accurate detection of volatile organic compounds, which are present at low concentrations (ppb–ppm level). For this purpose, we use electrical measurements based on impedance spectroscopy and optical measurements based on spectroscopic ellipsometry.

Department of Solid State Physics (F5)

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Portable electrochemical sensors for detection of toxic compounds

We develop electrochemical sensors that are portable, small, inexpensive, WI/FI IoT-enabled devices for laboratory and field monitoring of real water samples. The devices are based on a three-electrode system and the working electrode is modified to detect selected analytes, such as toxic organic compounds (benzisothiazolinone), persistent and mobile chemicals (benzotriazole), hormone disruptors (bisphenols), antibiotics (sulfamethoxazole) and biomolecules (polyamines). The devices themselves are robust in extreme and toxic environments (e.g. wastewater).

Department for Nanostructured Materials (K7)

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Plasma-based solutions for food cleaning, water processing and sustainable production

We develop plasma technologies for the removal of cyanotoxins, mycotoxins, genotoxic pollutants and organic contaminants from food or aquatic environments. Our work contributes to the bioeconomy through plasma-enabled catalysis, carbon material conversion and sustainable processing of natural resources. This supports environmentally friendly production chains and responsible resource management.

Laboratory of Gaseous Electronics (F6)

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Biophotoelectrochemical technologies for the removal and degradation of pollutants into products of high economic value

We are developing technologies based on biophotoelectrochemical processes that enable the removal and degradation of various pollutants into products of high economic value.



Department of Environmental Sciences (O2)

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Sustainable Management

Decision support systems and artificial intelligence for sustainable agriculture and environmental management

We are developing advanced decision support systems in the fields of agriculture and environmental management. Our work combines data models, scientific literature, expert knowledge, and artificial intelligence, with a particular focus on the application of large language models for acquiring, structuring, and verifying knowledge about soils, ecosystems, agricultural economics, and sustainable value chains. We are developing user-friendly web interfaces that enable intuitive use of complex models and data platforms, as well as tools for sustainability assessment, ecosystem services evaluation, and environmental impact analysis. Among the developed solutions are: Soil Navigator for supporting soil management, a framework for evaluating green public procurement to strengthen local food systems, Market Avenue Generator for validating business ideas in agronomy, Pathfinder for analyzing the sustainability of value chains in food production, and others. Our technologies connect information science, agronomy, and environmental science, supporting the transition to a digital, circular, and sustainable bioeconomy.

Department of Knowledge Technologies (E8)

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Environment and bioremediation: waste revalorisation through biotechnology

By combining natural microbial diversity with engineered spatial arrangements, we create systems for degradation of pollutants, transformation of plastics, and conversion of waste into valuable bioproducts. Our strategies contribute to a circular bioeconomy and cleaner environment.

Department of Environmental Sciences (O2)

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Wastewater and sludge reuse in agriculture

We perform uptake and risk assessment of crops (edible parts) irrigated with treated wastewater and/or fertilised with stabilised sludge, due to contaminants of emerging concern (CEC). Collaboration is twofold:

- Food/Health: evaluation of uptake of CEC in edible plant parts and associated risk assessment (human health and environment)
- Industry: effect of improved treatment (introduction of quaternary treatment in WWTP) on reduced uptake and minimised risks

Department of Environmental Sciences (O2)

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Smart technologies for pollinator monitoring

Pollinators, such as honeybees, bumblebees, and other insects, provide crucial ecosystem services and are also key players in agriculture. We are developing technologies using smart sensors to track pollinator activity, monitor conditions inside a beehive, and monitor pollinator biodiversity.

Department of Intelligent Systems (E9)

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Communications for remote environments

Connectivity is a major challenge in remote environments. Our research includes robust wireless solutions that ensure reliable long-range, low-power communication between distributed sensors and cloud infrastructures. These communication architectures enable the deployment of advanced sensing systems even in geographically isolated regions and support scalable environmental data collection.

Department of Communication Systems (E6)

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Artificial Intelligence in Environmental Applications

AI-enhanced environmental time-series analysis

Environmental systems produce rich and often noisy sensor data that require sophisticated analysis. We develop AI-based models capable of identifying trends, anomalies, and ecosystem stress indicators across long-term measurements. These techniques can support early warning systems and environmental risk assessment.

Department of Communication Systems (E6)

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Numerical modelling of natural systems and geo-environmental processes

We apply advanced meshless modelling techniques to simulate complex natural processes such as glacier dynamics, and interactions between climate and terrain. These models are used in interdisciplinary collaborations with geologists and geographers and support high-accuracy environmental reconstructions. Our numerical methods help predict environmental changes and guide sustainable resource management.

Department of Communication Systems (E6)

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Information processing and reasoning based on the massive graph representation of extreme data

The department's AI expertise in the environmental field includes advanced graph-based analysis, reasoning, and optimization techniques that support sustainability-focused decision-making. Developed tools enable probabilistic reasoning, graph sampling and efficient graph-operation workflows. The performance can be further enhanced for sustainability by analyzing graph data and processing metrics, enabling scalable, serverless execution across computing infrastructures. These capabilities support use cases such as global environmental foresight, green and sustainable finance, and green AI for the sustainable automotive industry.

Department for Artificial Intelligence (E3)

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