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# NEULAND INTERACTIVE



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# WHERE KNOWLEDGE MAKES IMPACT



**PROF. DR.**  
**JAN S. HESTHAVEN**



**PROF. DR.**  
**THOMAS HIRTH**

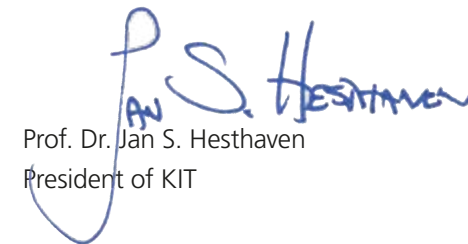
## DEAR READERS,

How do we want to live, work and conduct research in the future? These questions shape not only public debate, but also everyday life at KIT. Innovation arises where we combine scientific excellence with entrepreneurial courage – and where visionary ideas are turned into specific applications. It is precisely this synergy that gives our research projects and spin-offs their distinctive dynamic.

In this year's edition of the NEULAND Magazine, we provide insights into developments that shape tomorrow's cities and society. The spectrum ranges from novel optical materials and AI-driven solutions for greater sustainability, as well as energy and resource efficiency, to a future that will improve our quality of life. You will also meet founders new standards with

their start-ups – whether through cutting-edge lighting solutions or tools for trustworthy AI. In addition, we introduce projects that rethink the energy system in a more integrated way, make cities more climate-resilient or drive the digital transformation of industry and society. The city of tomorrow is already taking shape today – growing from ideas we are currently researching, developing and implementing.

The NEULAND Magazine serves as a showcase for this diversity: it illustrates how scientific creativity turns into



Prof. Dr. Jan S. Hesthaven  
President of KIT

tangible innovations. At the same time, it makes clear that the future is not created in a single institution, but emerges from the collaboration of many bright minds, bold actions and open partnerships – here at KIT and far beyond.

We invite you to explore the featured topics, draw inspiration and join us in looking to the future.

We hope you enjoy reading NEULAND.



Prof. Dr. Thomas Hirth  
Vice President Transfer and International Affairs





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## SCIENCE FOR IMPACT – RESEARCH FOR INDUSTRY AND SOCIETY

As a member of the Helmholtz Association, KIT plays a leading role in everything from knowledge acquisition to application. The synergy between basic research, engineering, and applied research offers extraordinary potential and drives scientific progress and social change.

This is the heart of “Science for Impact”,  
President Jan S. Hesthaven’s vision  
for the future of KIT, which was published in 2025.



KNOWLEDGE WEEK NEULAND 2025



FUTURE SPACE FOR  
SUSTAINABILITY AND SCIENCE



HUMANOID ROBOT AT THE  
LEBENSILFHE DAYCARE CENTER



Innovation thrives on breaking patterns of conventional thinking, creativity, and the courage to challenge the status quo. By empowering individuals to explore the unknown and challenge the known, we create an environment where transformative ideas can flourish and mature.

The path to innovation is rarely linear. It is filled with trials, unexpected turns, and moments of doubt. In a supporting ecosystem, challenges become opportunities. Embracing failure as a learning experience and cultivating

an entrepreneurial spirit is essential to enabling innovation.

At the forefront of groundbreaking discoveries and transformative ideas, KIT supports cutting-edge research, patents, spin-offs, start-ups and real-world labs. We actively enable an ecosystem that bridges science and engineering, entrepreneurship and industry, and policymakers and civil society to transition ideas and fundamental discoveries into tangible societal benefits.

(Excerpt from “Science for Impact”)



• Further information





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## HIGHLIGHTS

### 200 YEARS OF KIT

#### A FESTIVE START TO THE ANNIVERSARY YEAR

→ In 2025, KIT celebrated its 200th anniversary – a year full of retrospectives, highlights and outlooks. The festivities were kicked off with a grand ceremony in the Schwarzwaldhalle in Karlsruhe, that brought together experts from science, politics and industry. Speeches, cinematic reviews and statements from politics and science emphasized the role KIT takes on as a driving force for technological development and social progress. The evening honored 200 years of research tradition and innovative strength and took the anniversary as an opportunity to build the bridge between history and the future.



### ANNIVERSARY EXHIBITION – “200 YEARS OF KIT – 100 OBJECTS. PARTS OF A WHOLE.”

→ A large anniversary exhibition opened its doors at ZKM and invited visitors on a curated journey through two centuries of science and technology history. Research results, teaching traditions and everyday objects were condensed into a vivid picture, using 100 selected objects, personal anecdotes and interactive stations. The exhibition combined historical finds with approaches that gave visitors of all age groups insight into scientific work and its social relevance.



### HANDS-ON SCIENCE AT THE OPEN DAY

→ A lively science mile on campus: Faculties, research groups and college clubs offered tours, experiments, talks and advice for prospective students. Around 23,000 people took the opportunity to enter laboratories, try out projects and directly talk to researchers – this impressively shows how closely KIT links research, teaching and the public sphere. The open day was also part of the nine-day Karlsruhe science festival EFFEKTE.





NEULAND KNOWLEDGE WEEK – NEW PERSPECTIVES ON KNOWLEDGE TRANSFER

→ The NEULAND Knowledge Week at Kronenplatz in Karlsruhe brought together transfer actors, companies, start-ups and society. Multi-day events, keynotes, and interactive booths showed how research leads to products and services – and how science actively shapes dialogue and connects development processes with society.



NXTGN – START-UP PLATFORM AND REGIONAL INNOVATION STRATEGY

→ As part of the new NXTGN Startup Factory, the KIT-Gründerschmiede plays a crucial role within the growth of technology-driven spin-offs in Baden-Württemberg. The initiative combines support services for high-tech start-ups aiming to translate research results into marketable solutions more quickly and to achieve significant effects in employment in future-oriented industries by 2030 and beyond.

VISUALIZATION OF RESEARCH  
REIMAGINED: DRONE SHOW AT KIT

→ A special event combined cuisine, conversation, and enactment: At the “Dîner au KIT,” guests came together outdoors on campus while a light and drone show lit up the sky above Karlsruhe. The show told the story of KIT – from its founding to current research topics – and visualized the connection between technology, art and public communication in astounding images.



RESEARCH IN THE SPOTLIGHT  
AT THE KARLSRUHE LIGHT FESTIVAL

→ Research became a visual event at this year’s lighting show “Schlosslichtspiele” at the Karlsruhe Castle: Video installations and projections highlighted scientific milestones and made findings and research topics emotionally tangible in a large-scale format. This artistic interpretation of scientific topics helped to reach new audiences and made the anniversary accessible to a more culturally-oriented audience.





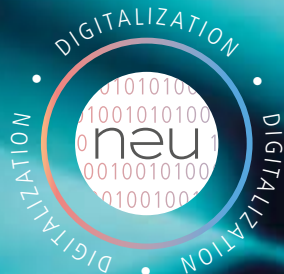
# EXAMINING THE BLACKBOX AI

**GOAL**  
To develop validation tools for artificial intelligence to enable companies in the European Economic Area to use algorithms safely

**APPLICATION**  
Testing procedures for AI applications in sensitive areas such as medicine, mobility and human resources, but also beyond

**FOUNDER**  
Yunus Bulut, Michael Graf,  
Gert Paczynski

THE SPIN-OFF VALIDATOR DEVELOPS METHODS FOR RELIABLY TESTING AI APPLICATIONS, THEREBY BUILDING TRUST IN A TECHNOLOGY THAT INCREASINGLY SHAPES OUR LIVES.



Trust, but verify

Artificial Intelligence (AI) promises efficiency and progress – yet many people feel uneasy about working with it. We get into an autonomous taxi and trust that the vehicle knows the way and takes us safely to our destination. Companies use AI-powered tools to review job applications and hope that the algorithms will find the right person while acting fairly and objectively. In both cases, however, it remains unclear how exactly these decisions are made. Studies show that mistrust is especially high in sensitive areas such as human resources, autonomous driving or medical applications. Who guarantees that a system won't act differently under pressure? The KIT spin-off Validaitor tackles this very mistrust. Rather than relying on blind faith, the founders' software works like airport security checks: it scans the AI, checks algorithms for robustness, fairness and reliability, among other things, and thus makes the „black box“ more transparent.



YUNUS BULUT

Chief Executive Officer  
and Co-founder



GERT PACZYNSKI

Chief Revenue Officer  
and Co-founder



MICHAEL GRAF

Chief Technology Officer  
and Co-founder

Operationalization instead of certification

„When I first heard about the risks associated with Artificial Intelligence, I immediately realized that this was a very serious matter. My first thought was: Maybe I should develop a toolkit to make it easier for development teams to test AI,“ recalls founder Yunus Bulut. Within six years, a personal concern turned into a toolkit, the toolkit turned into a platform and the platform turned into a KIT spin-off: Validaitor. What drives him and his team is not pure tech fascination, but the question of how trust can be built in a technology that often works in the dark. When algorithms decide about people in areas such as medicine, mobility or human resources, trust alone is not enough – controllable, reproducible checks are needed. Numerous proposals, guidelines and even laws already exist, but they often remain abstract. Validaitor aims to close this gap by offering verification processes not as one-off audits, but as an integral part of everyday development and operations. „It's not just about possible external certification, but about operationalizing these quality assurance processes directly within the company,“ says Co-founder and CRO Gert Paczyński and Chief Revenue Officer. „We bring developers, compliance and risk teams together in one platform, standardize workflows and integrate tests directly into the development process.“ →

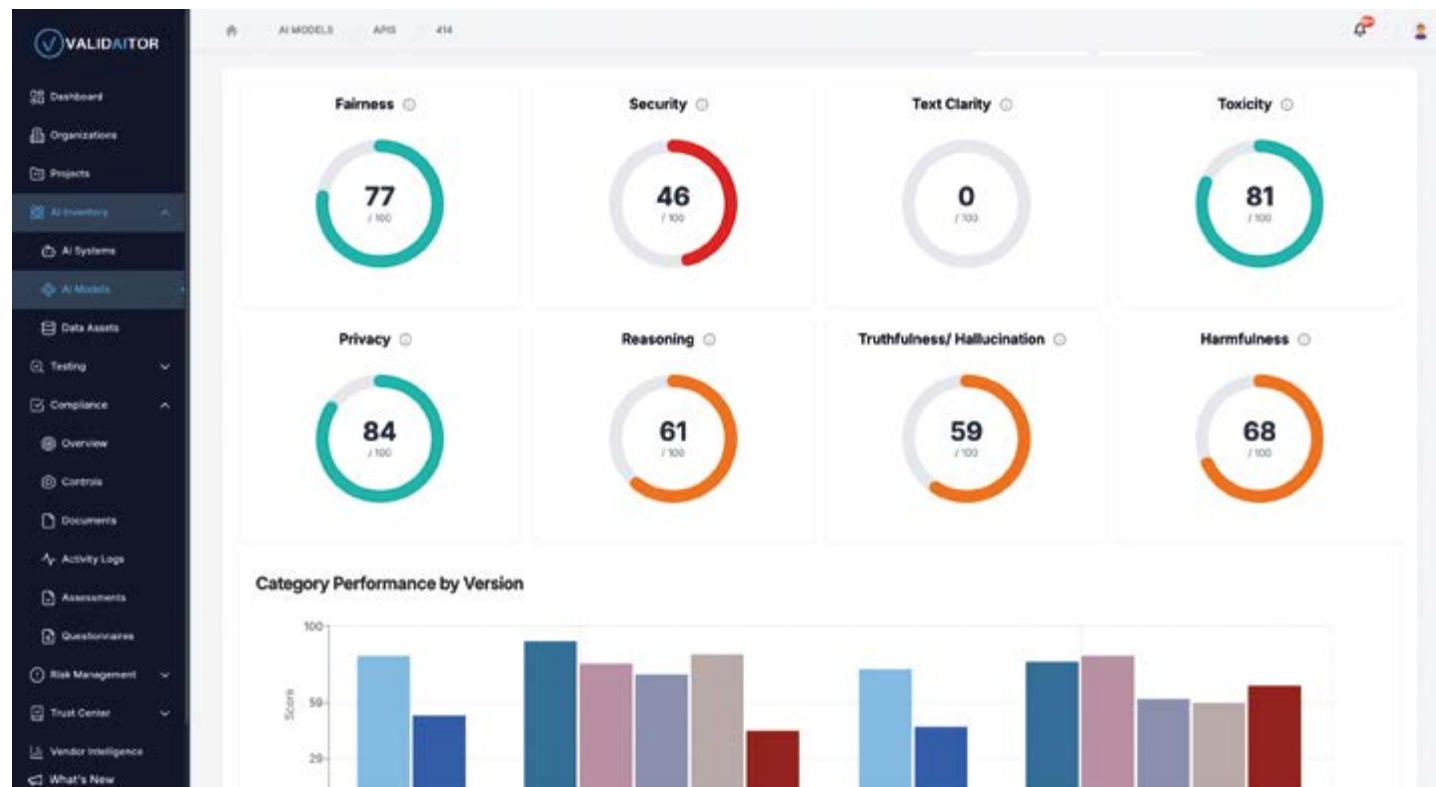


HOW VALIDAITOR WORKS

Artificial intelligence makes more and more decisions in our everyday lives, but often remains a black box for outsiders.

Without transparent, traceable testing, the risk of wrong decisions, misuse and loss of trust rises – especially for companies that lack in-house testing expertise.

Validaitor provides an integrated platform that automatically assesses the risks of AI projects, performs appropriate tests and documents the results transparently in accordance with applicable regulations (e.g. the EU AI Act).



**THE TESTING DASHBOARD VISUALIZES TEST RUNS, BENCHMARKS AND QUALITY METRICS FOR AN AI MODEL – FOR EXAMPLE, USERS CAN SELECT AND RUN TESTS OR VIEW RESULTS IMMEDIATELY.**

### The Platform as a Control Hub

Validaitor’s solution is an integrated platform that combines test tools, governance modules, risk-management features and a public trust center on a single interface. Users can select and run commands within a single platform without having to stitch together multiple disparate tools. The workflow is deliberately simple: Users register a project and provide metadata, such as the intended use, deployment context or affected stakeholders. The platform automatically suggests appropriate, risk-aligned tests and supports their execution - covering documentation, workflow integration and linking test results to compliance requirements. It includes dedicated Compliance Assessments that take into account regulations such as the EU AI Act and AI-specific ISO standards. In addition, it offers management functionalities such as an AI model/system registry, enabling traceable versioning and metadata tracking of machine-learning models. Beyond the technology, the platform saves time: automation eases the ever-tightening development resources, streamlines testing and prevents companies from losing valuable time in the fast-moving AI landscape.

### From Proof of Concept to Standard

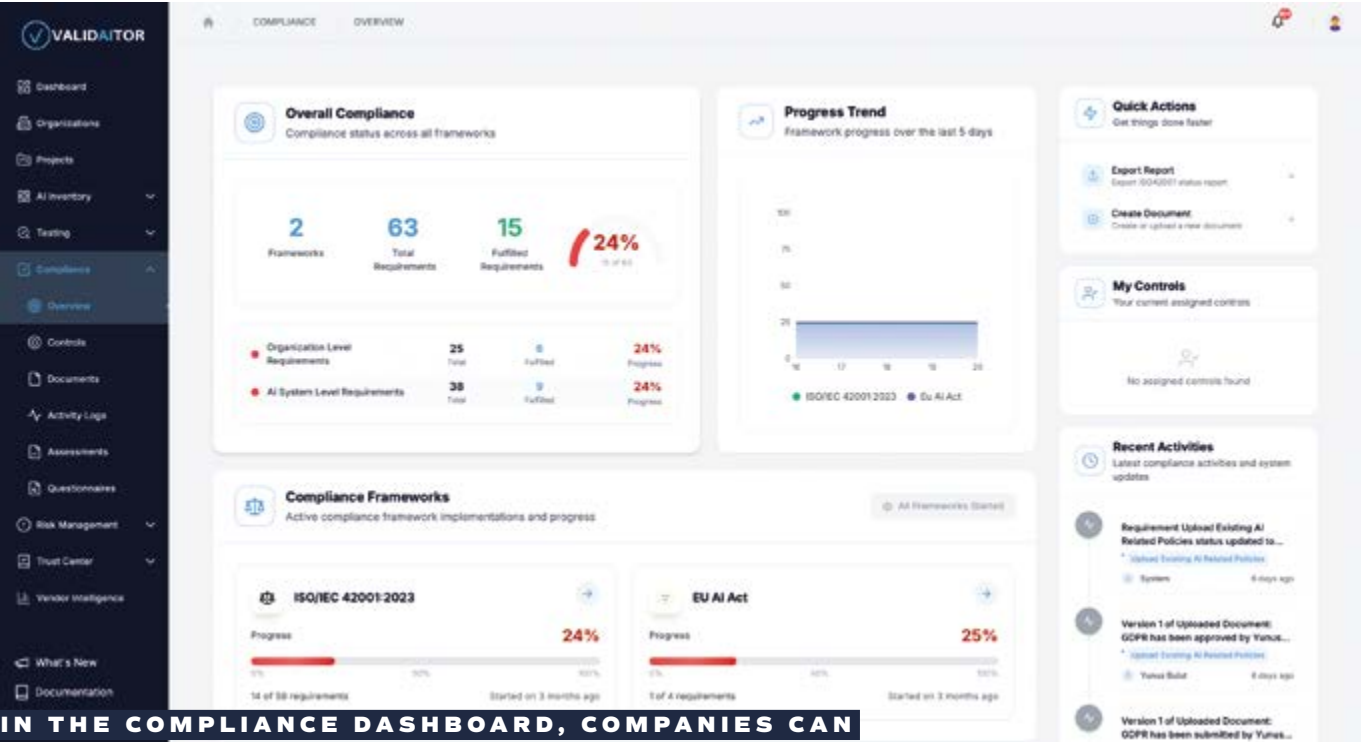
What started as a project has now reached market readiness: With the help of funding from the Federal Ministry of Research, Technology and Space (BMFTR), support from the KIT-Gründerschmiede and an initial venture-capital round, the team has brought the platform to market maturity. Validaitor has been operating as a company since September 2024, has expanded its headcount to a team of 11 and already counts its first paying customers – from SMEs and government agencies to forensic authorities in Germany. In the second funding phase, „Startup Secure“, the spin-off plans to scale further, refine its product and expand market access, aiming to be fully compliant with the upcoming regulatory requirements slated for mid-2026. The strength of Validaitor lies in its promise: trust is important, control makes it resilient. For many small and medium-sized enterprises that lack dedicated AI security teams, this means more specific safety – compliance becomes manageable, tests repeatable and results transparent. In the short term this protects against poor decisions and legal risks. In the →



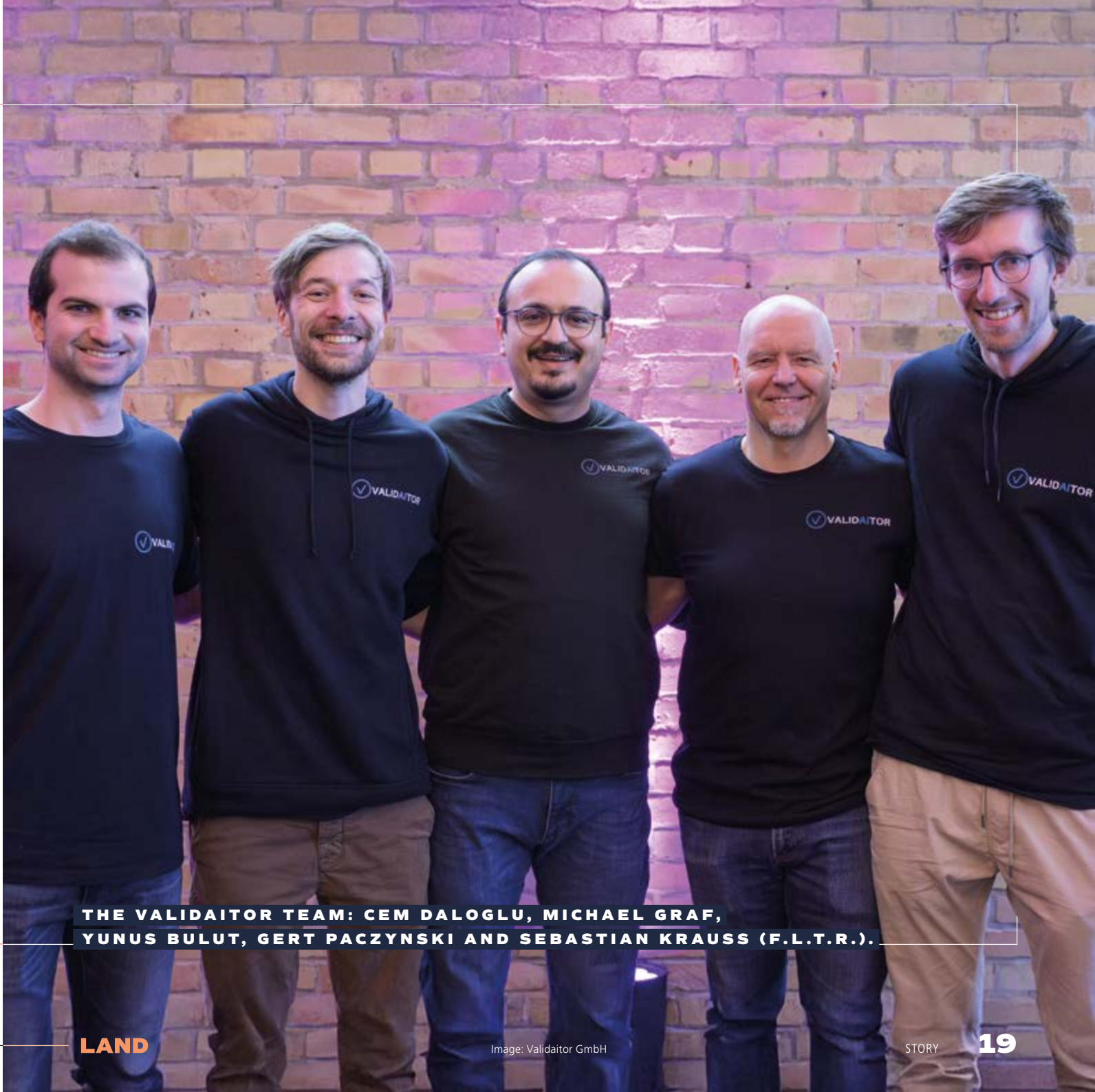
long term the integrated approach could become a widely adopted practice that makes AI decisions comprehensible to users and the public – not just as an academic ideal, but as an everyday reality. And that, according to Yunus and Gert, is exactly what society needs right now. ←



• Further information



**IN THE COMPLIANCE DASHBOARD, COMPANIES CAN AUTOMATICALLY CHECK THEIR AI SYSTEMS AGAINST REQUIREMENTS SUCH AS THE EU AI ACT OR ISO STANDARDS.**



**THE VALIDATOR TEAM: CEM DALOGLU, MICHAEL GRAF, YUNUS BULUT, GERT PACZYNSKI AND SEBASTIAN KRAUSS (F.L.T.R.).**

INSPECTION: PROTECTION  
AGAINST FAKE SHOPS

→ THROUGH EARLY DETECTION

Manipulated websites and fake shops are often impossible for site owners to detect: Many small and medium-sized enterprises lack the technical resources to identify security gaps or determine whether their site has been hacked. For those affected, this leads to reputational damage, financial losses and confused customers. The BMFTR-funded **INSPECTION** project has developed a comprehensive solution. The consortium, comprising the KIT research group SECUSO and the companies mindUp Web + Intelligence GmbH and BDO AG, combines automated web analysis for detecting compromised sites with targeted notification strategies and practical awareness measures. The solution includes among other things, systematic monitoring of search-engine results, human-centered design approaches for effective communication and comprehensive incident-response procedures. During the project period, website operators were proactively informed by INSPECTION and simultaneously received specific guidance on remediation and future protection. As a result, companies can strengthen their digital security, minimize damage and maintain the trust of their customers.



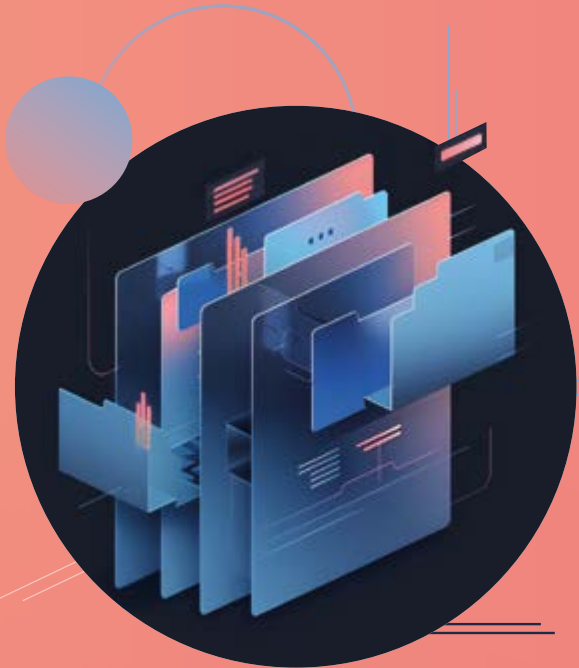
A digital shield: AI-driven analysis detects manipulated websites and warns operators of cyberattacks.



• Further information

NEXTSTEPHR: AI-SUPPORTED  
RECRUITING FOR INCREASED  
EFFICIENCY

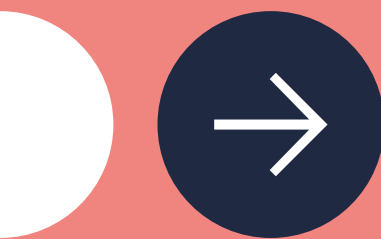
→ The lack of skilled workers poses a central challenge for companies: How can they find qualified new employees? Many companies get lost in the jungle of various job portals, optimize job ads based on gut feeling and miss out on passive, high-potential candidates. The KIT startup **NextStepHR** solves this problem with artificial intelligence. The innovative platform automates complex recruiting processes and provides data-based decision support for channel selection. The system automatically selects the most suitable job portals, tailors job ads to the target audience, and intelligently manages incoming applications. Most importantly, the AI solution also reaches passive candidates – people who aren’t actively looking for a job but possess strong potential. As a result, companies can recruit more cheaply, faster and more efficiently – while remaining fully compliant with data-privacy regulations. For the first time, NextStepHR gives businesses comprehensive transparency into the many recruitment options available and streamlines the entire application process through data-driven automation.



An algorithm finds the best talent: How AI can optimize job ads and make application processes more efficient.



• Further information



# THE WHISPER OF RIVERS

HOW AN ARTIFICIAL INTELLIGENCE  
LISTENS TO THE SOFT MURMUR  
OF WATER AND PROVIDES  
AN EARLY WARNING BEFORE  
IT TURNS INTO A ROARING FLOOD.

## GOAL

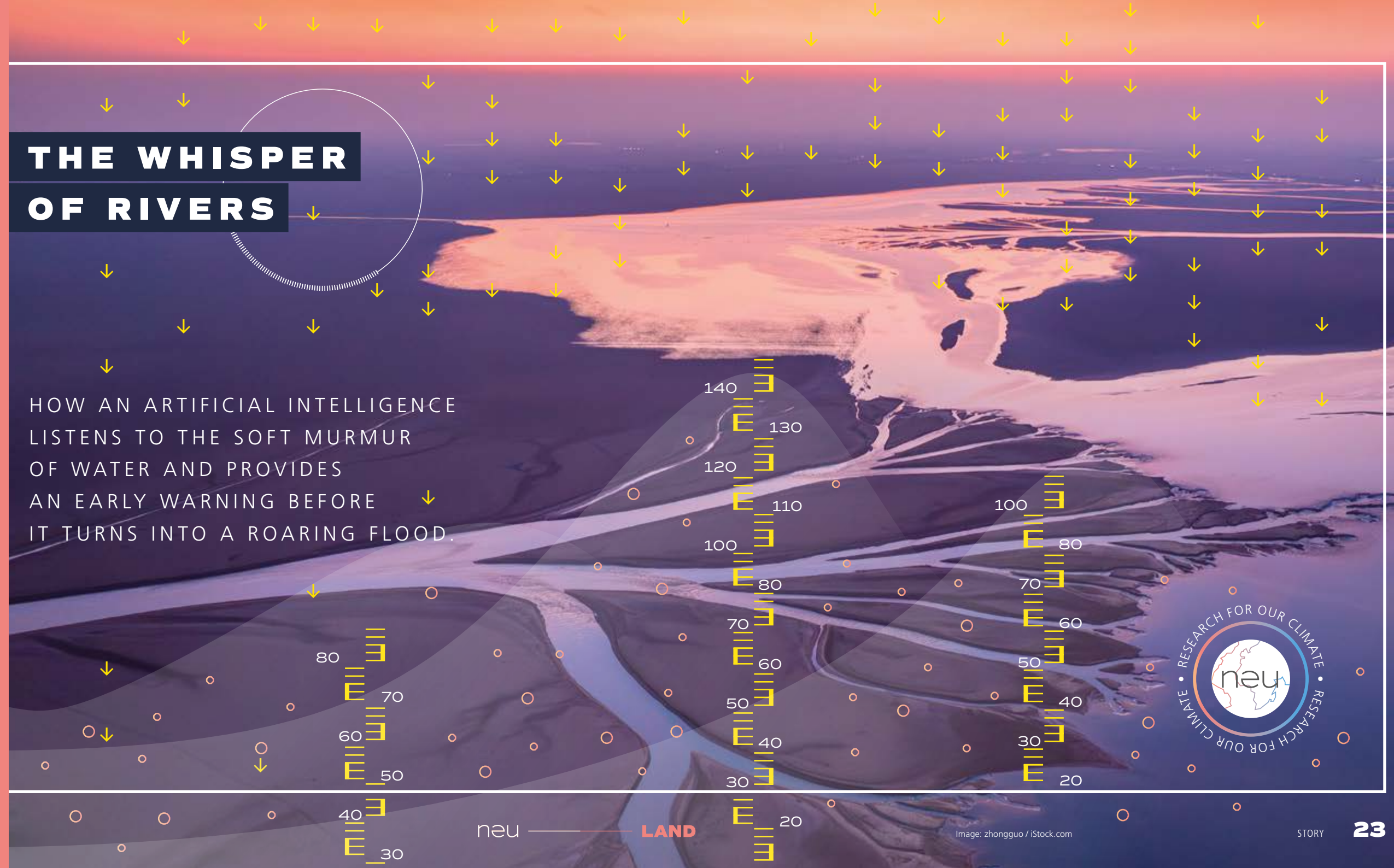
Development of an AI-driven  
flood-forecasting system to  
improve weather prediction,  
runoff modeling and early warnings  
for extreme weather events

## APPLICATION

Implementation in German flood-  
forecasting centers with special  
focus on small river catchments

## PROJECT PARTNER

Karlsruhe Institute of Technology  
(KIT); German Weather Service  
(DWD); State Office for Nature,  
Climate and Environment North  
Rhine-Westphalia; State Office  
for the Environment Rhineland-  
Palatinate



When Appearances Deceive

Small rivers are often seen as modest idylls: Lush green along their banks, the gentle babble of water exuding calm, and a leisurely walk offers the chance to spot a variety of wildlife that calls the stream home. But these seemingly harmless waterways are one of the hidden hazards of our time. Sometimes all it takes is a rise in water level after a summer thunderstorm or a stray cloudburst hitting a valley basin. Small streams in particular react incredibly fast to heavy rain and can turn into raging torrents within minutes or a few hours. These fast-reacting catchments are characterized by short lead times, high uncertainties and a huge damage potential.

Giving the Whisper a Voice

The KI-HopE-De research project aims to understand that whisper of the rivers and give it a voice that can warn in time. „We are researching and developing modern methods of artificial intelligence for use in river basins smaller than 500 km² throughout Germany. This approach enables us to potentially build a uniform →



**DR.**  
**RALF LORITZ**

Head of the junior research group  
“Energy and information flows in hydrological systems”  
at the Institute for Water and  
Environment (IWU) at KIT

THE PROJECT COLLECTS WATER LEVEL, FLOW AND PRECIPITATION DATA IN REAL TIME AND INTEGRATES IT INTO AI MODELS. THE AIM IS TO USE THIS DATA TO DEVELOP RELIABLE WARNING SIGNALS BEFORE SMALL RIVERS BECOME MAJOR HAZARDS.



HOW **KI-HOPE-DE** WORKS

Small rivers are like sleeping giants: Harmless in everyday life, but overwhelming during heavy rainfall. Water levels rise rapidly, often catching residents and emergency services off guard.

Climate change and growing frequency of extreme weather events will amplify this risk in the future. Lead times are becoming drastically shorter, pushing current models to their limits.

KI-HopE-De gathers and integrates hydrological data from all over Germany, trains AI models and enables early warnings to protect communities from disaster in time.



**THE KI-HOPE-DE RESEARCH TEAM AT KIT: TOGETHER WITH THE GERMAN WEATHER SERVICE AND SEVERAL STATE AGENCIES, THE GROUP LED BY DR. RALF LORITZ (THIRD FROM LEFT) AND UWE EHRET (RIGHT FROM RALF LORITZ) IS DEVELOPING AI MODELS DESIGNED TO IMPROVE FLOOD FORECASTING IN SMALL CATCHMENT AREAS.**

forecast for all of Germany and thus improve the prediction of extreme weather events,” says Dr. Ralf Loritz, junior research group leader of the „Energy and information flows in hydrological systems“ group at the Institute for Water and Environment (IWU) at KIT. His motivation? The PhD-trained hydrologist, cites curiosity as his driving force: „With the increasing use of AI, my fascination with how these models work has grown. This, in turn, has led to a pragmatic attitude: What adds value in other areas could also provide valuable support in hydrology. I then pursued this as a post-doc and later with my early-career team, and the results confirmed my hunch. My research has shown that these models are very good at mapping hydrological conditions and rivers.“

#### **Using AI to Combat Disaster**

What began as scientific curiosity is now becoming a tangible project with KI-HopE-De. Together with fellow KIT researchers from the Institute for Meteorology and Climate Research (Prof. Dr. Peter Knippertz), the German Weather Service and →

various state agencies, Loritz and his colleague Dr. Uwe Ehret from IWU want to fight potential catastrophes with AI. The project's name reflects its ambition to achieve what conventional models cannot deliver in small river basins. Loritz explains: „Traditional, physics-based models are used for large rivers. These models calculate water levels and discharge and are very accurate. However, they are complex to set up, often optimized for a single catchment or river, and heavily dependent on reliable precipitation forecasts. Where meteorology becomes imprecise, such as in locally limited thunderstorms, they reach their limits.“ A classic model calculates a fixed amount of rainfall. This is exactly where KI-HopE-De steps in. Machine-learning models trained across many rivers learn patterns from historical water level and precipitation data, allowing them to statistically incorporate the uncertainty of multiple weather scenarios. Even uncertain forecasts, such as wide ranges of expected rainfall, can be turned into useful runoff predictions. The result is an AI-driven flood-forecasting system that can provide crucial guidance when lead times are short. „The models

learn directly from national scale hydro-meteorological dataset allowing them to cope with the amount of work involved, to deal with uncertainties more effectively and to enable forecasts for areas spanning multiple states,“ reports Loritz.

### **The Data Lake as a Foundation**

One of the goals is hence the creation of a single, nationwide dataset. Water-level records, runoff, precipitation, temperature, wind speed, land-use – all stored in one database. So far, these measurement series in Germany are often fragmented: State agencies, associations, subgroups or regional councils each manage their own data. For researchers, this has resulted in numerous data-request negotiations, incompatible formats and often limited access. Loritz emphasizes: „No one really knows what measurements we carry out in Germany in the field of environment and water. The creation of a hydro-meteorological uniform data set for Germany is therefore an important milestone. Through the cooperation of partners from research, industry and the public sector, we can collect

a large amount of data for better research. Even if the project does not receive follow-up funding in the end, we would still have this important treasure trove of data. For research, for future projects and for better risk assessment.“

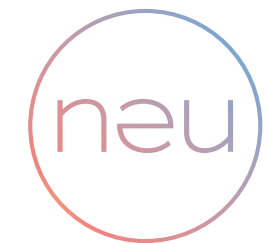
### **From Lab to Control Room**

However, KI-HopE-De is not purely a showcase research project: Initial data sets and simple models for North Rhine-Westphalia, Rhineland-Palatinate and Baden-Württemberg already exist and have been handed over for implementation to flood-forecasting centers. To ensure the algorithms can be used smoothly and transferred from theory to practice, researchers are training staff from the state agencies in workshops. Implementation requires care: Server failures or delayed weather data are real risks when AI is embedded into operational forecasting chains. „A lot can be demonstrated in the laboratory – the question is how these results can be confirmed in practice, where nothing can go wrong because property damage or, in the worst case, human lives are at stake,“ says Loritz,

looking toward the first test phases. This is a question that the project aims to answer within the remaining two-year timeframe. The whisper of the rivers remains – but now it is audible: KI-HopE-De creates a voice that turns fragmented data into a coherent whole. ←



• Further information



## DIGITAL CONSTRUCTION FOR A CIRCULAR ECONOMY

→ The construction industry accounts for over 40 percent of global CO<sub>2</sub> emissions – an enormous lever for climate protection. The Chair of Digital Design and Fabrication (DDF) professorship at KIT, headed by Prof. Moritz Dörstelmann, is developing revolutionary approaches for sustainable construction: by digitally re-interpreting historic craft techniques, entirely new construction methods are emerging that rely on locally sourced, renewable materials. The interdisciplinary team blends traditional timber-frame principles with modern manufacturing technologies to create **hybrid load-bearing structures made of wood, willow-clay composite and flax fibers**. Computer-based design workflows and AI-supported planning tools allow the assessment of complex interactions already during the design phase. Consequently, not only structural aspects are taken into account, but also complete material cycles – from re-wetting degraded peatlands and cultivating willow to low-energy on-site processing. This holistic approach diversifies the portfolio of renewable building resources and reduces dependence on wood as the primary construction material, paving the way for a circular economy in construction while unlocking an entirely new architectural design repertoire.



Sustainable architecture meets high-tech:  
Digital designs and natural materials shape  
resource-efficient buildings.



• Further information

Image: Midjourney

## HALO: ACCURATE WINTER-STORM FORECASTS

→ Winter storms cause billions of euros in damage every year across Europe with wind speeds of up to 180 kilometers per hour. The small-scale processes that generate such extreme winds have not yet been explicitly mapped in weather forecast models – a critical shortcoming for reliable extreme weather warnings. In a project supported by the Federal Ministry of Research, Technology and Space (BMFTR), KIT, led by Dr. Julian Quinting from the Institute for Meteorology and Climate Research (IMKTRO), coordinates a measurement campaign called „NAWDIC“ (North Atlantic Waveguide, Dry Intrusion and Downstream Impact Campaign) together with other German and international research institutions and weather services. In early 2026 a first-ever comprehensive survey of weather systems over the North Atlantic was carried out. Using the German research aircraft **HALO** (High Altitude and Long Range Research Aircraft) and the mobile observation platform KITcube, researchers are collecting high-resolution data on wind, humidity, temperature and cloud cover. Coordinated flights through low-pressure areas provide continuous spatial coverage of the remote North Atlantic region, where routine operational observations are rare. The insights will, in the long term, enable more precise weather forecasts and more reliable extreme-weather warnings – a decisive contribution to protecting societies from future storm damage.

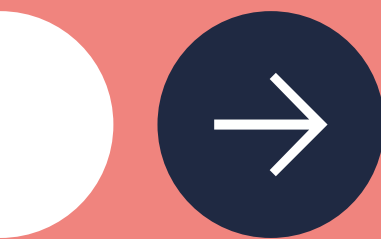


The HALO research aircraft flying  
over the North Atlantic provides  
measurement data from the air,  
thereby helping to improve storm  
forecasts and extreme-weather  
warnings.



• Further information

Image: Midjourney



## GOAL

HaptXDeep is developing an AI system that enables robots to learn human-like skills quickly without extensive programming through intuitive imitation learning

## APPLICATION

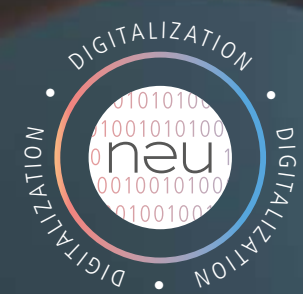
Adaptable robots for the dynamic production and manufacturing processes for the circular economy and demographic changes

## PROJECT PARTNER

Karlsruhe Institute of Technology (KIT), University of Stuttgart, funded by InnovationCampus Future Mobility (ICM)

# EDUCATIONAL REFORM FOR ROBOTS - INTERACTIVE IMITATION LEARNING INSTEAD OF PROGRAMMING

HOW A NEW AI-BASED LEARNING SYSTEM ENABLES ROBOTS TO MASTER TASKS AS INTUITIVELY AS PEOPLE – RESHAPING THE INDUSTRY OF THE FUTURE.



Teaching and Learning

The supervisor demonstrates, the apprentice watches, tries, makes mistakes, gets corrected – and after a few repetitions, the movement is stored in the muscle memory. For centuries, master craftsmen and women have passed on their knowledge by showing apprentices how it’s done. The “learning by doing” principle has shaped entire generations. Today, the laboratory of the Institute for Material Handling and Logistics (IFL) at KIT has an “apprentice” that has no muscles and no experience. It is merely a high-tech robot system made up of sensors, motorized joints and algorithms. Yet, it is supposed to learn just like in a training workshop. “Our vision is that a robot can be trained in a few hours, and can easily and quickly adapt to any new task or changes in the dynamic manufacturing process,” says Professor Rania Rayyes, who leads the AI & Robotics research group at IFL. →



PROF. DR.-ING.  
RANIA RAYYES

Head of AI and Robotics (AIR) research group at  
Institute for Material Handling and Logistics (IFL)



HOW HAPTxDEEP WORKS

The robot hand is controlled by a human via a teleoperated glove. At IFL, an AI system is being developed that uses collected sensor data directly from the hardware to learn the task.

After just a few demonstrations, the robot performs the task autonomously, with the human intervening solely to correct errors. The AI system uses these targeted corrections to improve the robot’s performance.

The goal of the AI system is to enable robot manipulation without lengthy programming and to allow robots to adapt better to changes in dynamic manufacturing.

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HAPTxDEEP SHOWS HOW MODERN ROBOTICS AND AI WORK TOGETHER TO SOLVE REAL-WORLD PROBLEMS – FROM SKILLS SHORTAGE TO SUSTAINABLE PRODUCTION. THE SYSTEM IS NOT ONLY A TECHNICAL SETUP, BUT ALSO A PLATFORM FOR INTERACTIVE LEARNING. SMALL AND MEDIUM-SIZED ENTERPRISES IN PARTICULAR COULD BENEFIT, AS THEY HAVE NOT BEEN ABLE TO AFFORD ROBOTICS EXPERTS UNTIL NOW.

LAND

Images: Daniel Kubus · Amadeus Bramsiepe / KIT

STORY

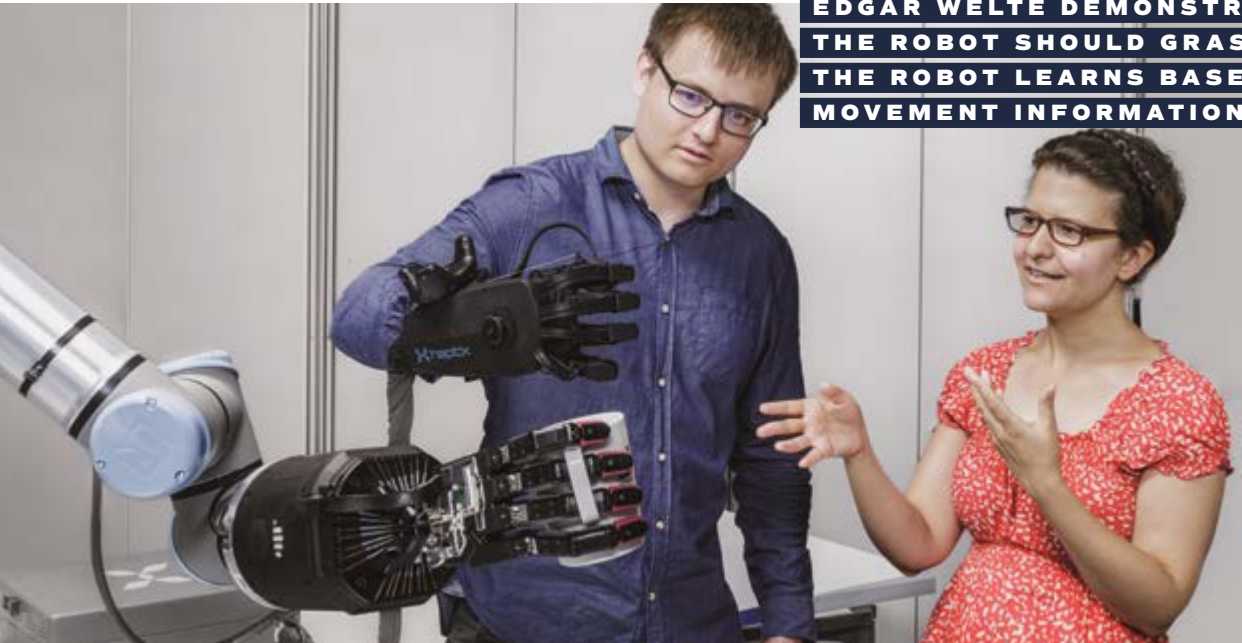


### The New School of Robotics

What sounds like a human-machine illusion is already becoming reality at KIT. In the HaptXDeep project, Rayyes and her team are developing an AI system for robots that no longer requires laborious programming of new skills, but where the skills can be learned intuitively and immediately by imitation – just like an apprentice. A tele-operated glove, controlled by humans, replaces the theory on a blackboard and a state-of-the-art robotic hand replaces the workbench. Doctoral researcher Edgar Welte demonstrates: he slides the HaptX glove over his hand

and moves his fingers – the robot hand, equipped with tactile sensors, mirrors the motion. Grasp, rotate, swing, place. After only a few demonstrations, the gripping robot can act autonomously and complete the task. This newly developed system for adaptive robot automation is built on a learning process that is astonishingly close to the human one: learning by imitating and repeating. “If the robot makes mistakes, humans can intervene and correct them. These corrections are particularly valuable for learning,” emphasizes Welte.

**USING A TELEOPERATIONAL GLOVE, EDGAR WELTE DEMONSTRATES HOW THE ROBOT SHOULD GRASP A CUP. THE ROBOT LEARNS BASED ON THE MOVEMENT INFORMATION.**



### Hands that Shape the Future

The controlling glove not only transfers the human hand’s movements to the robot, it also sends valuable touch information back with physical feedback. “When the robot hand encounters resistance, the human feels what the robot feels – a kind of ‘tactile dialogue’ between human and machine. We use all this information in the interaction to train our AI system so that the robot can evaluate the tactile feedback generated by the objects and adapt its grip accordingly,” explains researcher Welte. “An important research question to be answered: what is the most intuitive way for a person to teach a robot?” Rayyes said. To find out, the team runs user studies that compare different teaching interfaces – such as a haptic glove, camera-based hand tracking, and virtual reality setups. During these user studies, the participants are tasked with performing different manipulation tasks with the robot in a teleoperation setting, where the robot is fully controlled by the user, effectively showing the task to the robot. “The objective of this comparison is not only the speed or success rate of the task fulfillment. We also measure how quickly people learn the interface, and how safe and comfortable it feels,” Welte explains.



**EDGAR WELTE**

Doctoral researcher at  
AI & Robotics research group at IFL

### Industry under Reform Pressure

As with any reform, the starting point is not a machine, but a problem larger than technology: Industry is facing a growing shortage of skilled workers, the shift towards a circular economy and increasingly diverse products. “We need AI-enabled robots that seamlessly integrate flexibility and intelligence to support dynamic manufacturing processes without an expert having →



to reprogram everything each time, rather robots should be able to adapt quickly to the changes in the environments, the tasks or the products.

### New Skills for Model Students

Many robots in industrial automation are model students of an old school: they can execute a task perfectly as long as nothing changes. But in modern factories, everything is in flux. A used component returns to the line: scratches, deformations, different generations, unknown conditions. Every recycled product is unique. "Currently, most of the robots in industry are still preprogrammed in the traditional way. In circular productions like remanufacturing, we cannot reprogram the robot each time to adapt to every single change, and this is what we are currently researching within the SFB DFG project 'Circular Factory', a big collaborative project at KIT," says Rayyes.

### Why Humans Learn Fast – Robots Don't (Yet)

A human does not need to know every screwdriver on the planet to understand how to hold and use it. Our brain is a master of generalization: a handful of examples are enough to infer the underlying rules. For AI this is still a major hurdle. Many systems require massive data sets

before they grasp what is obvious to people: that blue is similar to green, that a used machine feels different from a new one, yet still demands the same task. Robotics now faces the challenge of shortening these long learning phases without compromising safety and reliability. "A new type of learning, as we are researching at HaptXDeep, could change that – and finally make scalable automation possible for smaller businesses," Welte affirms.

### From Human Hand to Robotic Gripper

Many complex manipulation tasks are demonstrated with highly dexterous robot hands, while factories often rely on simple, rugged parallel-jaw grippers. The team at KIT is working to close that gap. Recent work uses large-scale vision models trained on internet video to learn to grasp a new object from a short RGB video of a human demonstration. By combining knowledge of how humans grasp objects and which parts of the hand are in contact with them, the system can propose realistic grasp poses for a parallel-jaw gripper. Building on this, future research will focus on methods that transfer manipulation skills from dexterous robot hands to industrial grippers – so that skills learned in the lab can be transferred to reliable factory hardware with minimal extra effort.

### Ahead of the Curriculum

"We use uncertainty as a learning signal. This approach, known as uncertainty-aware learning, primarily helps robots to act more safely, robustly, and reliably because they always take their own uncertainty into account in addition to an action or perception," Rayyes explains, "The AI systems we developed within the SFB project Circular Factory, show that the robot can adapt to new objects and changes in the task very quickly". In situations of high uncertainty, robots can fail, slow down or stop. It is a closed-loop learning system in which the robot, in a sense, develops its own sense of body awareness. And perhaps one day it will be taken for granted that robots are no longer programmed but trained. ←



• Further information



• Video



An excavator with an H<sub>2</sub> engine: The PoWer project demonstrates how low-emission off-road drives will shape the construction sites of the future.



• Further information

**HYDROGEN POWER  
FOR CONSTRUCTION AND  
AGRICULTURAL MACHINERY**

→ Whether on construction sites, in agriculture, or in material handling, high-performance engines are indispensable. To make these engines climate-friendly in the future, the **PoWer** project at KIT is working together with industry partners to develop hydrogen-fuelled powertrains for off-road vehicles. Coordinated by MAHLE, three institutes at KIT are investigating how hydrogen can be used efficiently and safely in combustion engines. Their research covers optimal combustion processes, exhaust gas after-treatment, and material compatibility. The goal is to create robust systems that remain reliable under the continuous, heavy load conditions typical of off-road operation. The project is supported by TÜV Rheinland and the German Federal Ministry for Economic Affairs and Climate Protection, which is funding the the three year project with roughly €5 million. PoWer could thus pave the way for low emission powertrains in excavators, combine harvesters and other utility vehicles – a crucial step toward decarbonising heavy machinery beyond the road.

**NEARLY COMPLETE  
DEGRADATION OF  
ETERNAL CHEMICALS**

→ Per- and polyfluoroalkyl substances (PFAS) are considered “forever chemicals” because, depending on the specific compound class, they can accumulate in the environment and pose health risks. In contrast to fluoropolymers, sometimes referred to as “polymeric PFAS” which are considered immobile and non-bio-accumulative and are used in medical devices, semiconductors, aerospace, the automotive industry and chemical processing, “Low-molecular PFAS” are found in a wide range of consumer products. Typical examples are water repellent finishes on textiles, clothing, and paper (e.g., pizza boxes, burger trays, parchment paper). The PFAS substance group comprises roughly 10,000 individual substances, of which fluoropolymers represent only a small sub-group of 38 compounds. Until now it was unclear whether and to what extent low-molecular PFAS could be released into the environment during the incineration of fluoropolymers. Researchers at KIT have now demonstrated in the **BRENDA** pilot-combustion chamber of a power plant that European municipal waste incineration standards break down fluoropolymers almost completely. At temperatures of 860 degrees Celsius and a residence time of two seconds, the

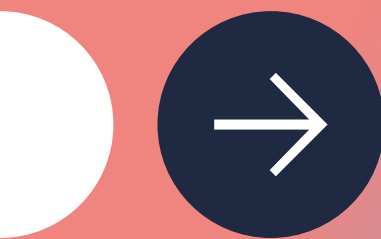


In high-temperature experiments, researchers of KIT show that fluoropolymers can be almost completely destroyed at temperatures above 850 °C – an important contribution to reducing “forever chemicals.”

researchers achieved a fluorine-related degradation rate of more than 99.99 percent. Raising the temperature to 1,095 degrees Celsius did not result in a significant further improvement. The test mixture used in the chamber represented 80 percent of the fluoropolymers used worldwide, including Teflon® (PTFE) and PFA. The fluorine contained in these polymers was converted to inorganic fluorine compounds with a recovery rate of over 95 percent and was captured within the plant’s abatement system. The results show that modern waste incineration plants can eliminate fluoropolymers almost completely – a crucial block for dealing with this challenging group of substances.



• Further information



## GOAL

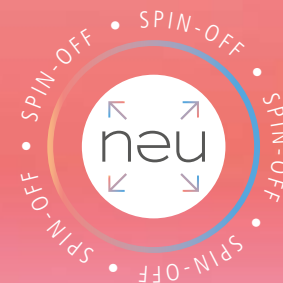
To produce optical coatings faster, more flexible and more sustainable – using a printing process instead of vacuum chambers

## APPLICATION

From smartphone cameras and displays to windows, sensors and laser protection systems – the range of applications is broad

## FOUNDER

Dr. Qiaoshuang Zhang, Dr. Qihao Jin, Dr. Jan Fischer, Prof. Dr. Uli Lemmer



# THE PANCAKE FORMULA

HOW THE SPIN-OFF RHEOO IS BRINGING A NEW RECIPE TO THE MANUFACTURING PROCESS FOR OPTICAL COATINGS AND FILTERS.





## Making Pancakes in the Nanoworld

Optical coatings are invisible in everyday life, yet they are everywhere: on eyeglass lenses, displays or camera lenses. They prevent reflections, let certain wavelengths pass or block them through a filter effect. Technically speaking, they consist of many artificial glass and/or polymer layers stacked on top of each other – each layer is about 1/1000th the diameter of a human hair, i.e., nanometer range. Founder Qiaoshuang Zhang illustrates: “The layer structure can be compared to a stack of pancakes. Only instead of flour, eggs and milk, it consists of many layers of transparent optical materials, each about 100 nanometers thick.” Until now these multilayer stacks have been produced in prolonged vacuum processes. First the chamber is evacuated, then the product can be coated layer by layer in a complex vapor deposition process. “The process takes several hours to days, the coating dimension is limited to the size of the chamber and materials such as plastics can contaminate the equipment,” Zhang explains.



**DR.**  
**QIAOSHUANG**  
**ZHANG**

Co-founder Rheoo GmbH

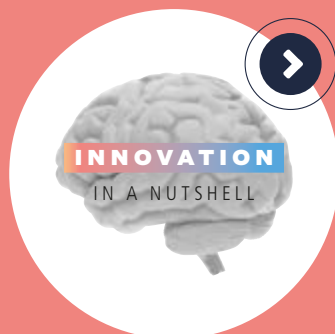
The process is not very flexible and working under vacuum conditions is also energy-intensive and expensive. Mass production therefore quickly hits its limits. Scaling requires an entire factory floor full of vacuum chambers – hardly an ideal scaling solution. The Karlsruhe-based spin-off Rheoo has however found a new “recipe”. Instead of preparing the pancake stacks in a vacuum, they print the layers using an inkjet printer.

## From the PhD to Rheoo

The idea originated during Zhang’s doctoral work at the Light Technology Institute (LTI) at KIT, where she worked on micro- and nanofabrication for optical elements. Initial research results and the enthusiastic response at industry trade fairs sparked curiosity – and not just for her. “We quickly realized that there was huge demand for an efficient solution,” recalls Zhang. Together with her colleague Qihao Jin, she decided to turn the research successes into practice. With support from the EXIST Research Transfer, they founded Rheoo in 2024 and have since set up a small, automated production line equipped with printing hardware.

## From Vacuum to Inkjet Printing

Rheoo’s inkjet process allows digital patterns to be scanned in and coated with pinpoint accuracy only where they are actually needed. “We can coat specific areas, structure them flexibly and even work directly on plastic or sensors – in other words, on substrates that would not be compatible with vacuum processes,” explains Zhang. The big advantage: Inkjet printing has long been established as a proven, high-precision technology – used for OLED displays, solar cells and printed electronics. It can be integrated into existing production lines without having to rebuild entire production environments, giving industry new degrees of freedom: faster cycles, flexible surfaces, precise structures and all with significantly lower energy and cost consumption. Zhang sums it up: “Targeted, locally limited printing means there is no unnecessary waste and the process takes minutes instead of hours. In addition, our process requires significantly less energy because we do not rely on vacuum.” Compared to previous processes, this seems like a small but decisive lever – nanometer work with a big effect. →



## HOW RHEOO WORKS

Optical coatings are everywhere – on eyeglass lenses, displays, sensors etc. However, their production is energyintensive, expensive and inflexible.

To make production more innovative, the spin-off Rheoo has developed a vacuum-free inkjet printing process.

This enables digitally controlled creation of optical coatings and filters, resulting in virtually waste-free, energy-efficient, fast and highly flexible manufacturing.



### From Lab Test to Production Line

The founding team has already proven that the technology works. The current challenge is to transfer the technology from the laboratory to industrial scale. The team including third Co-founder Jan Fischer presently aims to refine Rheoo's automated production line, in which robots shuttle samples between the printer and post processing stations. "We are currently working on an intermediate step between research and fully automated mass production," explains Fischer. "This is a challenge because all the equipment has to work together perfectly. Our goal is to achieve reproducible quality, make it measurable and continuously improve the processes."



**DR.**

**JAN FISCHER**

Co-founder Rheoo GmbH

### From Pilot Project to Market

Simultaneously, the team is conducting application-specific feasibility studies with pilot customers from various industries. Although the focus is still on tests and prototypes, the objective is clear: move from feasibility to market launch. "We are in intensive discussions with our partners to determine what the next step will be and how we can achieve a successful market entry," Zhang says. Potential applications range from simple anti-reflective coatings for displays and cameras to complex multi-layer systems for sensor technology, medical devices →



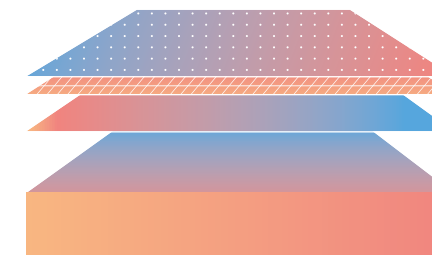
**RHEOO'S INKJET PROCESS ENABLES PRECISE OPTICAL COATINGS WITHOUT A VACUUM CHAMBER – PRINTED LAYER BY LAYER INSTEAD OF VAPOR-DEPOSITED.**

**PRECISION WORK IN THE NANOMETER RANGE: IN THE LABORATORY, THE RHEOO TEAM TESTS NEW MATERIAL FORMULATIONS AND PRINTING PROCESSES FOR REPRODUCIBLE COATING RESULTS.**



**DR.**  
**QIHAO JIN**

Co-founder Rheoo GmbH

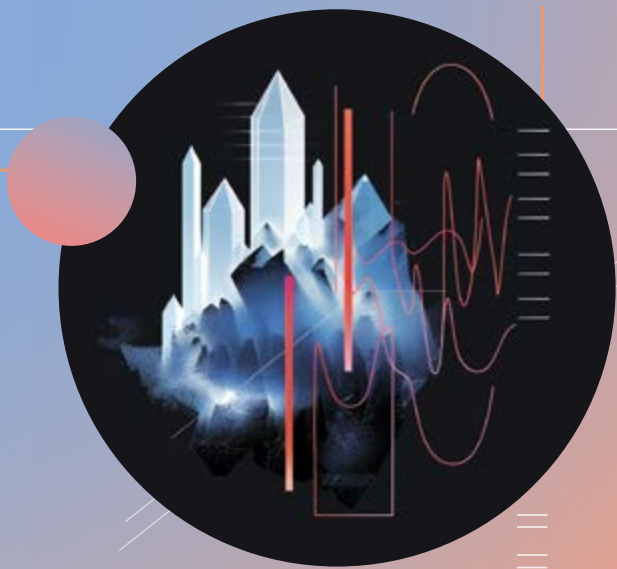


• Further information

and communication technology. "There are very simple coatings with only one layer, like a single pancake, but also very complicated variants with many layers, like a whole stack of pancakes," says Zhang, describing the range. The team is deliberately starting with simple coatings for anti-reflective effects, as found in cameras and displays, and then progressing step by step toward more complex systems such as window applications. "From a simple pancake to a stack of pancakes," Zhang adds with a smile. In the long term, Rheoo wants to expand its reach: market entry within the next two years, followed by a growing portfolio and stable revenues. Whether through direct sales or licensing models, the direction is clear: "Our technology can not only provide better images on displays or cameras, but also contribute to resource-efficient production – from Karlsruhe to the world," Zhang concludes. ←

PHOTONIC SPACE-TIME  
CRYSTALS: A REVOLUTION  
FOR OPTICAL TECHNOLOGIES

→ The development of high-performance optical materials for wireless communication and laser technology has gained new momentum in recent years with the proposal to use photonic time crystals. These materials periodically change their properties in time on a scale comparable to the oscillation period of light. If such materials were available, light could be converted between different frequencies and amplified with very high efficiency. However, there is a major challenge: Conventional photonic time crystals require strong, rapid periodic modulations of their material parameters in order to amplify light effectively. This significantly limits their practical use. Researchers at KIT led by Professor Carsten Rockstuhl from the Institute of Theoretical Solid State Physics (TFP) and the Institute of Nanotechnology (INT), together with international partners, have developed a groundbreaking solution: **photonic space-time crystals**. These four-dimensional materials combine spatial structures made of silicon spheres with temporal periodic properties, thus creating optimal resonances for light-matter interaction. As a result, light can be amplified regardless of its direction of propagation direction and over a significant frequency range –



A novel material principle makes it possible to amplify light efficiently — with great potential for data transmission and laser applications.

something that was previously impossible. This innovative approach provides precise control of optical properties and opens new pathways for optical information processing. The added spatial structuring could be the missing piece that makes photonic time crystals suitable for practical use in the future, substantially enhancing both communication and laser technologies.



• Further information

HELMHOLTZ STUDY:  
ROADMAP FOR THE ENERGY  
TRANSITION FOR 2045

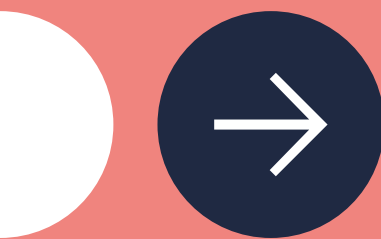
→ Germany's **energy transition target** for 2045 faces complex challenges: Current scenarios often consider only technical and economic factors, while overlooking social and institutional aspects. This limited view can lead to unrealistic planning and decision-making, thereby jeopardizing public acceptance of the transformation. Researchers from KIT, DLR and Forschungszentrum Jülich have developed an integrative scenario methodology that incorporates key sustainability dimensions into the assessment of the energy transition. Their analysis of four distinct scenarios shows that electricity demand will nearly double by 2045 and that installed renewable energy capacity will have to more than triple. The core strategy is the electrification of production and transport processes, complemented by green hydrogen and more flexible power grids. The study also takes into account socio-economic side effects such as structural change in energy-intensive industries and potential burdens on low-income households. This provides decision-makers with a more realistic basis for the sustainable overhaul of the German energy system.



A look at Germany's energy future: Researchers develop scenarios for a sustainable and socially acceptable transformation.



• Further information



# GREEN AIR CONDITIONING SYSTEMS

HOW URBAN  
GREENERY IN THE  
UPPER RHINE PLAIN  
CAN SURVIVE IN THE  
LONG TERM – ENSURING  
OUR CITIES REMAIN  
WORTH LIVING IN

## GOAL

To make cities climate-resilient and worth living through smart tree planning using sensor technology, dendroecological analyses and public participation

## APPLICATION

Data collection on tree health, climate effects and acceptance for informed recommendations on planting, maintenance and urban planning

## PROJECT PARTNER

ITAS/KIT, IMK-IFU/KIT (Campus Alpin), JKIP/KIT, IMTEK/University of Freiburg, Chair of Forest Growth and Dendroecology and the Institute of Psychology at the University of Freiburg



**Plant dieback: the great leak in urban nature**

On hot summer days, many air conditioners in cities run at full speed. But the most effective cooling devices have been right on our doorstep all the time – tall, deeply rooted and with a dense leaf canopy. Urban trees: they provide shade and noticeably lower the temperature in their surroundings. They are not only natural cooling units, but have also always been places of encounter and respite: from the rural lime tree to the plane tree in ancient Athens. But urban greenery is under pressure. Heat, drought, disease and sealed land prevent trees and bushes from reaching their ecological potential and cause them to die.

**Searching for clues in the Upper Rhine Plain**

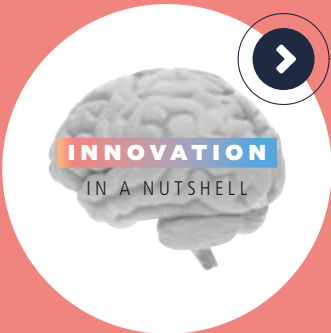
In Karlsruhe and Freiburg, the drought years of 2018 and 2019 made clear how vulnerable young plantings are: “For several years now, around 30 percent of newly planted young trees have been dying. These losses are not only ecologically painful, they are also expensive and high-maintenance, because each →



**DR.**

**SOMIDH SAHA**

Research group leader at the Institute for Technology Assessment and Systems Analysis (ITAS) at KIT



Cities are getting hotter in the summer: heat waves, sealed surfaces and stressed trees reduce quality of life and health.

HOW **ZUKAMAS** WORKS

Without sufficiently sound urban greenery, there is a lack of shade, cooling and fresh air – rising temperatures have serious consequences for people and the environment.

The project ZUKAMAS is researching which tree species remain healthy in the long term and which care concepts ensure an urban environment worth living in.

neu

LAND

**PROJECT MANAGER DR. SOMIDH SAHA CHECKS THE CONDITION OF URBAN TREES IN KARLSRUHE. THE MEASUREMENTS ARE INTENDED TO HELP ADAPT CARE AND IRRIGATION SPECIFICALLY TO CLIMATE CHANGE.**

Images: Amadeus Bramsiepe / KIT

STORY



## MORE THAN ZUKAMAS - URBAN AND PERI-URBAN FORESTS NETWORK

In addition to ZUKAMAS, researchers are working on other projects designed to make urban and peri-urban forests of cities and adjoining areas more climate-resilient. Urban and peri-urban forests include individual trees along streets, in parks, courtyards, plazas, gardens, cemeteries, as well as trees in forests within city boundaries or near cities.

Those projects are:

### URBORETUM

Records and digitizes the tree landscapes of Karlsruhe, Freiburg, Mannheim, and Heidelberg – including a “digital twin” of over 45,000 trees. Innovative sensors and acoustic tomography are used to detect damage inside the trunks without felling the trees. Growth, sap flow, fine root development and impact of irrigation on potential future tree species are being observed.

The goal: more precise care, development of climate-adapted arboriculture, fewer unnecessary fellings and, in the long term, digital management of urban green spaces. URBORETUM is an Innovation Cluster led by KIT with involvement of University of Freiburg, Central Institute of Mental Health of Mannheim (affiliated to University Clinic

of Heidelberg), City of Karlsruhe, digital twin company, greeHill Deutschland GmbH of Hannover, and Rinntech-Metriwerk GmbH & Co. KG of Heidelberg.

The cluster is funded by the Federal Ministry of Research, Technology, and Space (BMFTR) under the program “Regional innovation groups for climate-friendly forestry and wood industry (REGULUS)”.

### UT-UBGI (URBAN TRANSFORMATION TOWARDS BLUE-GREEN INFRASTRUCTURE)

Tested in Leipzig and other cities, this project explores how green and blue infrastructure – for example vegetation and water – can be better linked. The focus here is not only on cooling and climate, but also on the connection to social and planning processes. The goal: cities worth living, where green spaces and water areas work hand in hand. The project partners are KIT (ITAS and IIP), UFZ-Leipzig, and GERICS of Helmholtz Zentrum Hereon. The project is funded by the Helmholtz Association.

tree costs the city several thousand euros and must be planned carefully before it is allowed to take root,” says Dr. Somidh Saha, research group leader at the Institute for Technology Assessment and Systems Analysis (ITAS). These figures are more than just statistics: they represent missed investments, gaps in the urban landscape, and people who will have to do without the green cityscape, shades and coolness of trees in the future. In the project “Future-oriented climate change management for urban green spaces” (ZUKAMAS), KIT is conducting research together with other partners along the Upper Rhine Plain to determine which tree species, forms of care and planning tools will keep urban trees resilient despite climate change – so that they can continue to provide cooling, create meeting places and make our cities worth living in for future generations. The research area was deliberately chosen: the Upper Rhine Plain is one of the most heavily affected regions in Germany when it comes to heat and drought. “What we are testing here serves as a model for many other cities along the Rhine and Elbe,” says Saha.

### High tech meets root systems

A walk through the neighborhood is not enough to assess the health of the trees. Instead, high-tech equipment is used. Sensors measure water uptake, trunk growth and microclimate in real time. Dendroecological analyses

provide insights into the reactions of different tree species to historical drought events. Molecular studies show how plant hormones respond to stress and how this affects resilience. At the same time, researchers are collecting data on the perception and acceptance of urban greenery. Which tree species are popular within the population? Where do people want more greenery? And how can new green neighborhoods be prevented from exacerbating social imbalances? “Our philosophy is to take a holistic view of the development of urban trees – from the lab bench to the street,” says project coordinator Saha, explaining the approach.

### From record to urban planning

The data obtained is used to develop practical recommendations for cities and municipalities. In Karlsruhe and Freiburg, researchers are working closely with the horticultural authorities to test specific options for action during the project period – from targeted irrigation of young trees to recommendations for climate-resilient species. ZUKAMAS aims to provide specific recommendations: plant lists, maintenance plans, irrigation strategies and tools for city administrations for tree felling to be carried out less frequently, in a more targeted manner and for valid reasons. Instead of felling trees across the board – a common reaction because authorities →



**AMONG OTHER THINGS, THE PROJECT TEAM RECORDS TRUNK GROWTH, TEMPERATURE AND HUMIDITY DIRECTLY ON THE TREE IN ORDER TO USE THE DATA TO SHOW HOW URBAN TREES REACT TO HEAT AND DROUGHT.**

**USING HIGH-TECH SENSORS AND DENDROECOLOGICAL ANALYSES, RESEARCHERS ARE RECORDING HOW ENVIRONMENTAL STRESS MANIFESTS ITSELF INSIDE THE TREE.**



need to protect themselves legally – data-driven assessments could also show whether a tree is actually in severe danger or can still be saved. This saves costs, conserves resources and preserves old trees that are valuable for the urban climate.

#### **Outlook: workshop, tools, impact**

Ecologist Saha has a clear vision: “We should aim for at least 30 percent green space in the city.” Whether and how this can be achieved politically depends on resources, administrative capacities and the willingness to plan ahead – precisely where ZUKAMAS wants to provide tools. Over the next few months, the project will evaluate the data it has collected. Saha would also like to hold a final workshop with all relevant stakeholders to discuss findings and explore paths of implementation. Ultimately, it’s not just about planting trees in the short term, but integrating them into the urban infrastructure in the long term – and thus preserving the city’s green air conditioning system: for cooling, quality of life and health. ←



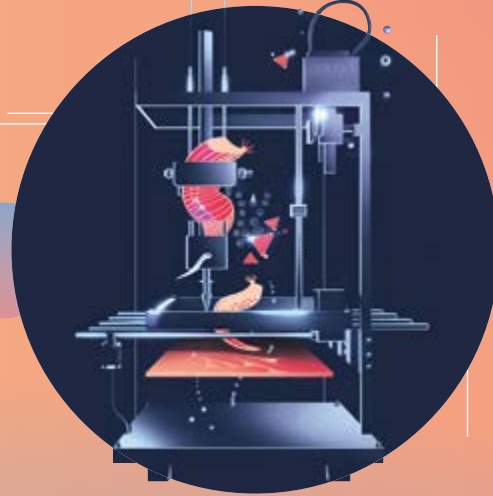
• Further information



**SENSITIVE MEASURING SYSTEMS SHOW HOW QUICKLY TREES ABSORB WATER AFTER A PERIOD OF RAIN IN SUMMER.**

## HYBRID EXTRUSION PRINTING: STRUCTURED MEAT ANALOGUES FROM THE 3D PRINTER

→ Developing meat substitutes that convincingly mimic both the flavour and the texture of real meat remains a central challenge for food engineering. A team from the Institute of Process Engineering in Life Sciences Food Process Engineering (BLT-LVT) is working on a promising solution: In a process known as hybrid extrusion printing, protein-rich and fat-rich phases are printed side by side in a controlled manner, allowing the replication of complex, **meat-like structures**. The goal is to recreate the characteristic arrangement of „muscle“ and „fat“ in such a way that the bite, juiciness and mouthfeel closely match those of conventional meat products – while maintaining high production efficiency and low material waste. The method combines process engineering expertise with tailored food formulations and could help lift sustainable alternatives to animal meat into higher quality levels. The research team received an award at the NEULAND Innovation Contest and sees great potential for transfer and scaling.



A novel 3D printing process combines plant proteins and fats to create realistic, sustainable meat alternatives.



• Further information

## REACTUNE: INTELLIGENT REACTOR DESIGN OPTIMIZATION - FROM CONCEPT TO PRODUCTION

→ In the chemical industry, reactors play an important role in process engineering. Developing and producing reactors with complex geometries usually takes months and requires profound expertise. ReactTUNE, software for intelligent reactor design optimization developed by Mertcan Kaya and Professor Christoph Klahn from the Institute for Micro Process Engineering at KIT (IMVT), reduces the time required for reactor design to 45 minutes. “It can be used to develop complex equipment quickly and efficiently even with little design knowledge,” Klahn said. “Users simply specify their requirements and ReactTUNE uses them to calculate the optimum reactor geometry. The result is an industry-standard 3D printable file that can easily be produced with the appropriate production equipment.” The process is enabled by a combination of computer-aided design and numerical simulation. The researchers have already successfully used the software in methanol synthesis, and they have validated the process at laboratory scale in real conditions. Now they are expanding the software’s range of uses and planning a spin-off.



ReactTUNE was awarded first place in the Ideas Prize category at the NEULAND innovation competition in 2025.



• Further information

## WORKSPACE EUROPE:

CONNECTING IDEAS,  
EMPOWERING PEOPLE,  
FINDING SOLUTIONS TOGETHER

THE EU.FFICIENT CO-CREATION  
PLATFORM COMBINES RESEARCHERS,  
COMPANIES AND THE PUBLIC SECTOR  
IN A DIGITAL WORKSPACE – SO THAT  
GOOD IDEAS CAN GROW INTO  
TANGIBLE SOLUTIONS.



Ideas do not emerge from an ivory tower – they are born where people with different perspectives come together. The new online co-creation platform EU.FFICIENT is built exactly on that promise: It aims to connect experts from academia, industry and public administration so that joint solutions can be shaped faster and transferred into practice. The platform works like a social media platform: Profiles, topic-specific communities, news feeds, chat functions, learning modules and small challenges are designed to keep collaboration alive beyond the first contact and turn it into specific projects. Users can therefore organize themselves in moderated groups, known as communities of expert facilitators, in which relevant content is shared and exchanges can give rise to concrete work packages for new projects.

EU.FFICIENT was launched in 2024 and is funded under Horizon Europe. The consortium includes partners from nine countries, including IPEK – the Institute of Product Engineering at KIT, which played a key role in the conception and methodological development of the platform's design. The goal of the project is not purely to create a network, but

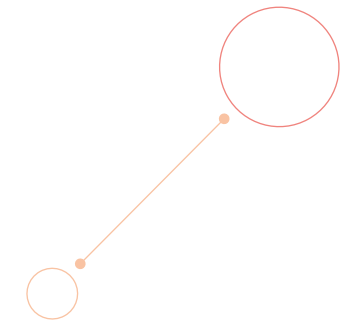


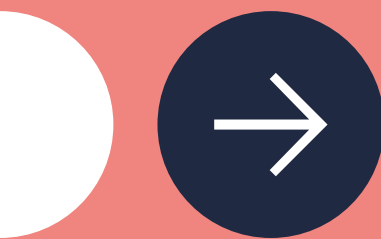
rather a usable space for transfer. Annika Bastian from IPEK sums up the project: "Structured exchange and targeted networking create added value for all involved – a step towards sustainable technology transfer at the European level."

In practical terms, this means whoever submits a question, for example a small or medium-sized enterprise facing a technological hurdle, finds potential partners, mentors and specific learning opportunities on the platform. It invites users to share their own challenges and work together to plan prototypes and field trials iteratively. Instead of stopping at the initial exchange, contacts can be made on the EU.FFICIENT platform so that an idea can gradually develop into a joint project. Those who have little experience with transdisciplinary work or specific areas of technology receive additional support: Live training sessions, on-site events, workshop templates and short e-learning courses show how heterogeneous teams can successfully work together and how an idea can grow into a pilot. A self-assessment module helps users to assess their own knowledge-level and suggests tailored learning offers. Thus EU.FFICIENT becomes more than a meeting place: It is a workspace plus learning lab where collected results and materials remain in the community and can be reused by others. But beware: Strict community rules ensure that members only share what they are allowed to share.

EU.FFICIENT was developed iteratively with user feedback and real-world testing. It is intended to be a living ecosystem that will continuously grow on an open-

source basis. With the launch of the platform, four communities were initially started: Advanced Manufacturing, Mobility, HealthTech, and AI/ Digital – areas in which research and practice need to be particularly closely interlinked. In the short and medium term, thousands of experts should be reached, and in the long term, the project aims to connect experts in dozens of countries. For researchers and transfer actors, this offers a practical opportunity: Those who want not only to inform but also co-design will find tools and partners here to turn ideas into real applications. An open creative space – and the more diverse hands work together, the greater the chance that good ideas will become real solutions. ←





# PRECISE FLASH AGAINST THE TUMOR

HOW TINY ACCELERATORS  
MAKE TUMOR TREATMENTS  
SIGNIFICANTLY MORE PRECISE  
AND SPARE HEALTHY TISSUE.

## GOAL

Development of ultra-compact,  
light-driven electron accelerators  
for more efficient radiotherapy  
of cancer patients

## APPLICATION

In-situ applications for  
endoscopic ultra-short electron  
pulses delivered directly at the  
tumor to spare healthy tissue  
and reduce side effects

## FOUNDER

Institute for Beam Physics  
and Technology (IBPT) at KIT,  
German Cancer Research Center  
(DKFZ), funded by the Carl Zeiss  
Foundation





### A Thunderstorm inside the Body

In the middle of the human body, for a split second, a flash of light strikes. Not a rough beam from a distance, but a precise, lightning-fast spark that strikes only where it is supposed to. No thunder, no visible spectacle. Just a minimally invasive procedure and a tumor that is hit directly while the surrounding tissue remains unharmed. This image visualizes one of the great hopes of modern radiotherapy: a treatment applied directly to the tumor, as precise and brief as a lightning bolt, instead of a series of external irradiations. This is exactly what researchers at KIT together with the German Cancer Research Center (DKFZ) are working on. In the project “Ultracompact Electron Accelerators for Internal Radiotherapy” (UCART), they are developing hair-fine electron accelerators that generate endoscopic ultra-short pulses right next to the tumor.

### When High-Tech Hits its Limits

Radiotherapy is indispensable for most cancer patients, but it has its limits. Two-thirds of all patients receive radiation at some point during the course of their cancer treatment, and the trend is rising. Today’s devices are large, heavy, expensive and cannot be used everywhere. A linear accelerator, as found in hospitals, requires significant concrete shielding, a stable power supply, specially

trained staff and several million euros of investment. Even considering the most widespread of those instruments of treatment, there are only around 15,000 such installations worldwide, but roughly 80,000 would be needed to provide adequate treatment for all patients. Added to this is the fundamental problem of the classic treatment method: the radiation must travel from the outside through healthy tissue to reach the tumor. Each session therefore puts unnecessary stress on the body, causes side effects and lengthens treatment. This burden follows many patients not only physically but also psychologically for weeks. It quickly becomes clear that conventional methods are reaching their limits.

### Co-creation Instead of Lab Bubble

Rather than developing a technical concept first and then looking for an application, the project team led by Prof. Dr. Anke-Susanne Müller from the Institute for Beam Physics and Technology (IBPT) at KIT chose a different approach. The institute director recalls: “The collaboration with the German Cancer Research Center and the Heidelberg Ion Beam Therapy Center came about through a joint application. We asked ourselves where and how we could make a difference with our knowledge. Above all, it was important to us not to do this separately, but to work



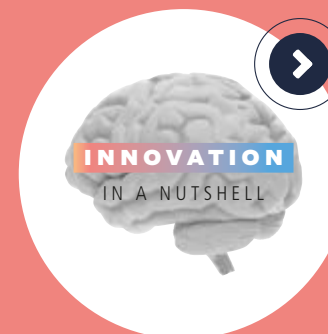
**PROF. DR.  
ANKE-SUSANNE  
MÜLLER**

Institute for Beam Physics and Technology (IBPT) at KIT

together with the medical community from the outset in order to achieve an impact later on.” Already during the planning stage, they are considering which types of tumors are reachable, how an endoscope would have to be guided and how patients can benefit. No laboratory bubble, but co-creation from day one – physics and medicine in direct exchange, not as successive disciplines. The research partners’ goal: an ultra-compact electron accelerator that does not irradiate from the outside, but acts directly inside the body.

### A Lightning Strike that Leaves a Trace

The idea is astonishingly simple yet highly complex: An accelerator system measuring just a few millimeters is guided directly to the tumor via an endoscope. There it generates an ultra-short electron pulse – a tiny, controlled flash that hits only the tumor and spares the surrounding tissue. No continuous beam, but a selective energy input in the millisecond range. The underlying technology sounds like science fiction: A gas is ionized, forming →



Many cancer patients receive radiotherapy, which targets tumor cells but often also damages surrounding healthy tissue.

#### HOW UCART WORKS

This often leads to side effects, long recovery periods and limits the use of modern radiotherapy, especially in sensitive body regions.

UCART develops ultra-compact, light-driven electron accelerators that are designed to endoscopically irradiate tumors with pinpoint precision while sparing healthy tissue.



**THE PROJECT WAS ACCEPTED INTO THE CARL ZEISS FOUNDATION'S WILDCARD PROGRAM AS AN "UNCONVENTIONAL RESEARCH PROJECT." FROM LEFT TO RIGHT: PROF. OLIVER JÄKEL (DKFZ), PROF. ANKE-SUSANNE MÜLLER (KIT), PROF. MATTHIAS FUCHS (KIT).**

Image: Carl-Zeiss-Stiftung

a plasma that creates extremely strong electric fields. In this temporary structure, the electrons are accelerated within a microscopically short distance. Where conventional systems require meters, a fraction of a millimeter suffices here. The energy source? A laser pulse – millions of times more efficient than large devices. The result: high-tech that is more accessible, flexible and patient-centred. UCART operates without permanent radioactive sources and the system can be switched on and off. No shielded chambers, no specialized staff. The patient themselves essentially become the shielding and the treatment could take place in an ordinary practice. This also has psychological advantages: no enclosed room, no endless waiting, no feeling of isolation.

#### Research in Real-Time Dialogue

The researchers have already reached important milestones: the electron distribution for the ultra-short pulses can be generated precisely and first irradiation profiles have been simulated and tested in treatment plans. A proof of principle shows that the system works theoretically and practically in simulation. Next steps are miniaturization and practical implementation. This includes designing the tiny accelerators so that they can be reliably integrated into an endoscope, incorporating all necessary components

and making them manageable for clinical staff. In parallel, researchers are evaluating which tumors are particularly suitable for safe, targeted treatment.

#### A Visionary Look at the Storm

UCART is not only intended to work in simulations, but later to be used in clinical practice. The goal is a scalable, energy-efficient and patient-friendly system – a precision tool that makes radiotherapy more accessible, gentler and more flexible, without reliance on large infrastructure. To achieve this, researchers are working closely with the medical and industrial sectors. "Surprisingly, the watchmaking industry is also helping us," says Müller. Precision engineering that is normally used for the micromechanics of high-quality timepieces, is applied here in an extremely small space. Radiotherapy has long been an uncontrolled natural phenomenon, a continuous bombardment that affects both tumors and healthy tissue. UCART wants to reverse that storm. A tiny, precise lightning strike directly at the tumor as the start of a new era of cancer therapy: gentler, more patient-centred and accessible to more people. ←



• Further information

**NOXON:  
INTELLIGENT BRACES SUPPORT  
THE HEALING PROCESS**

→ Back pain or knee pain often requires a long rehabilitation. The start-up **Noxon** develops intelligent braces with printed biosensors that make healing processes visible and accelerate them. The sensors capture muscle activity through the skin and transmit the data to an app. This allows patients to work with their doctors to tailor their treatment plan individually. The sensor technology is produced with resource-saving printing processes, making it flexible, stretchable and cost-effective. Noxon tested its first prototypes with shirts for analyzing back pain. The focus has now shifted to knee braces that support recovery after injuries or surgeries. In the long term, the team wants to personalize manufacturing using 3D scans: within one minute, the biosensor technology should be adaptable to the respective body part. With this technology, Noxon wants to enable new mobility for those affected and improve orthopedic treatment in a sustainable way.



Smart textile with printed sensors: a flexible bandage measures muscle activity and displays healing progress in an app.



• Further information

**SUPERSENSORS  
FOR MEDICAL DIAGNOSTICS**

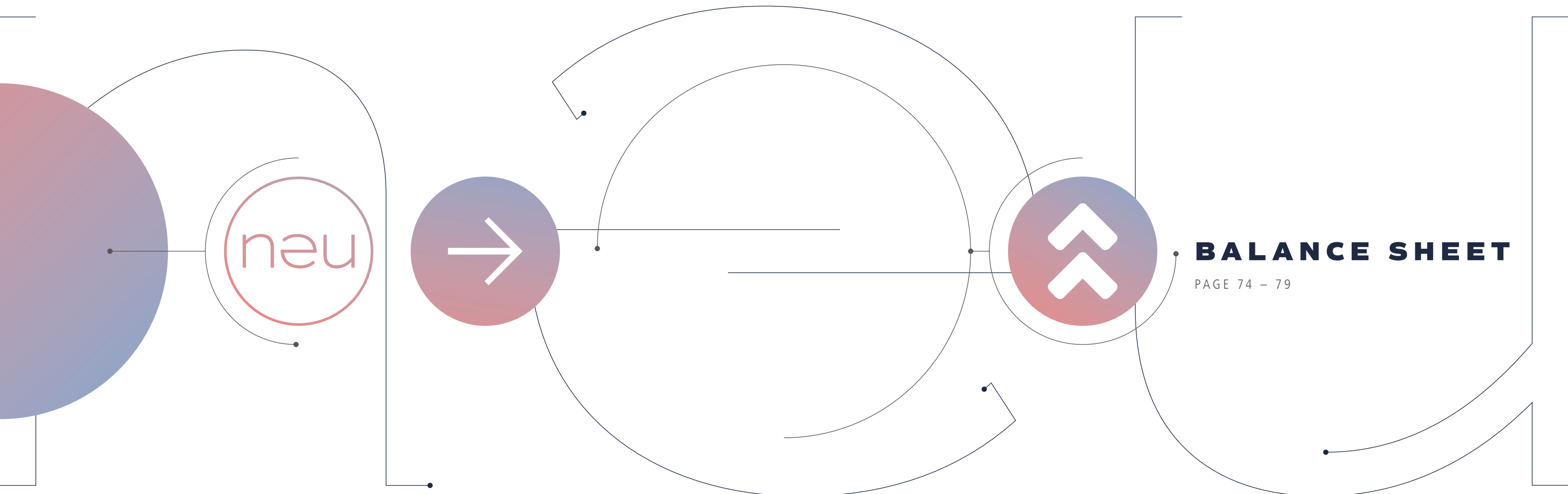
→ In the **SupraSense** project, Dr. Frank Biedermann and his team at KIT are developing novel sensor technologies, known as “SupraSensors”, for applications in medical diagnostics. These biomimetic sensors are based on hybrid-zeolitic materials whose binding pockets are specifically modulated with cofactors in order to create receptors that act like enzyme-active sites. The goal is to examine liquid samples such as urine, saliva or blood directly for molecular markers, for example metabolites such as neurotransmitters or amino acids that reflect the circadian rhythm and can serve as early indicators for cardiovascular diseases, inflammation or sepsis. The combination of molecular recognition through novel material chemistry and Deep learning–based analysis is expected to provide high sensitivity and selectivity – while also allowing simple manufacturing. Funded by the European Research Council, the project has been receiving approximately two million euros over five years as an ERC Consolidator Grant since 2022.



Microscopic sensor materials detect biomarkers in bodily fluids — for precise diagnostics in real time.



• Further information



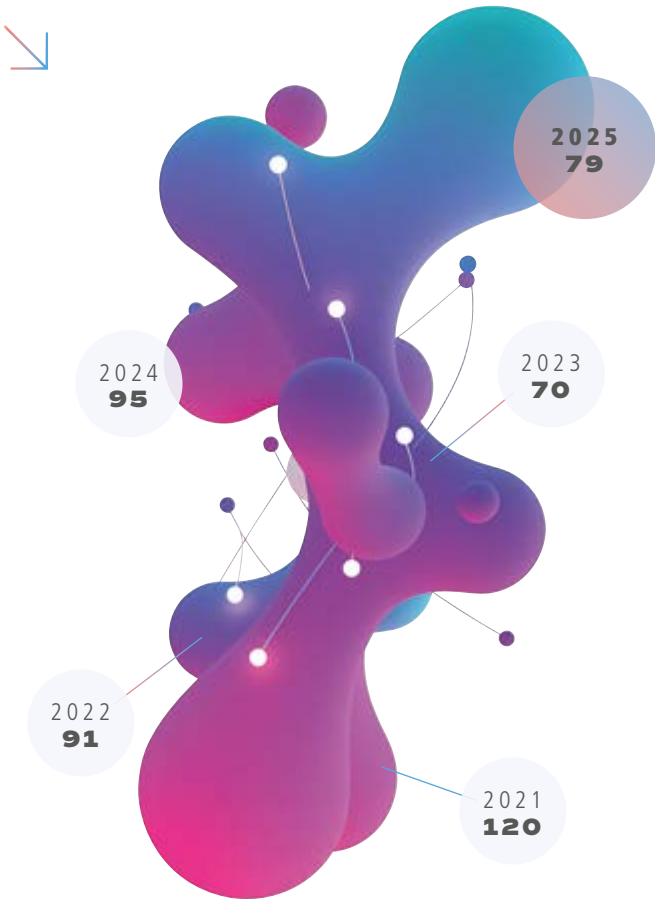
# **BALANCE SHEET**

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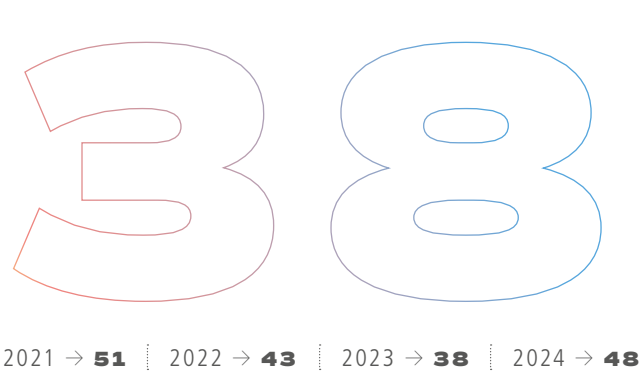


INNOVATION INDICATORS

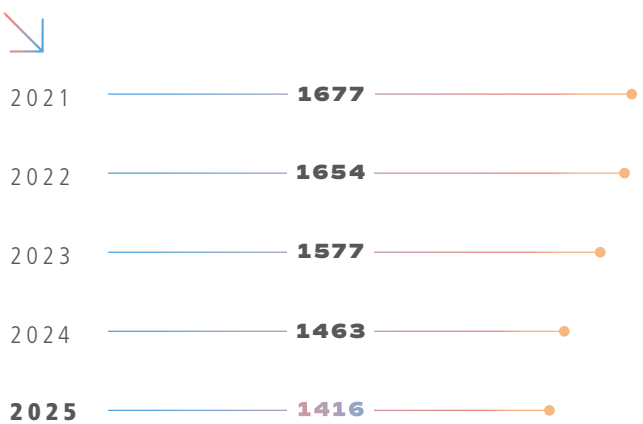
INVENTION DISCLOSURES



PATENT APPLICATIONS 2025



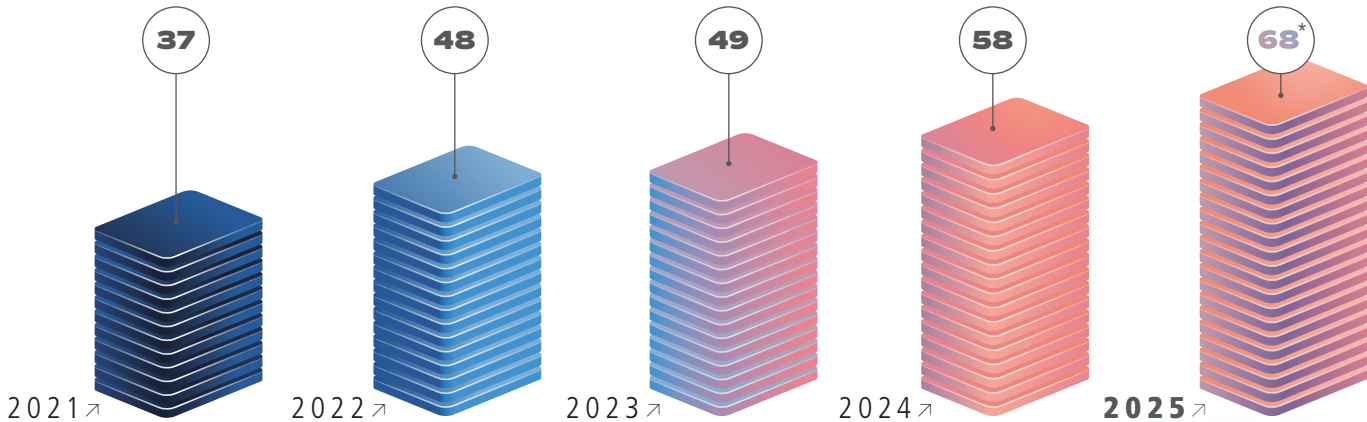
IP PORTFOLIO



FOR A DETAILED EXPLANATION OF THE KEY FIGURES, PLEASE VISIT OUR WEBSITE.

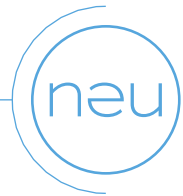
COMPANY FOUNDATIONS

\*INCLUDING 17 SPIN-OFFS AND 51 START-UPS OF ALL LEGAL FORMS



# AWARDS

AWARDS FOR EMPLOYEES AND START-UPS OF KIT – FOR INNOVATIVE PROJECTS  
AND PRODUCTS FROM JANUARY 1 TO DECEMBER 31, 2025 ➤



| AWARD                                                   | SPONSOR                                                             | AWARD WINNER                                                                         |                                                                                         |
|---------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------|
| 22. CyberChampions Awards                               | CyberLab Karlsruhe                                                  | Reasonance (High Potential), Desoltik (Best Concept), ONINO (Publikumspreis)         | KIT Startup                                                                             |
| Academy Prizes in the Mathematical and Natural Sciences | The Göttingen Academy of Sciences and Humanities in Lower Saxony    | TT-Prof. Dr. Manuel Krannich                                                         | Institute of Algebra and Geometry (IAG)                                                 |
| Best Scientific Image Contest 2025                      | Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren e.V. | Dr. Thomas van de Kamp, Jenny Hein                                                   | Institute for Photon Science and Synchrotron Radiation (IPS)                            |
| Breakthrough Prize in Fundamental Physics               | Breakthrough Prize Foundation                                       | Prof. Dr. Markus Klute as part of the CMS collaboration                              | Institute of Experimental Particle Physics (ETP)                                        |
| COPSS 2025 Emerging Leader Award                        | Committee of Presidents of Statistical Societies                    | Prof. Dr. Nadja Klein                                                                | Scientific Computing Center (SCC)                                                       |
| DIN Excellence Price                                    | Deutsches Institut für Normung e.V.                                 | Dr. Karl-Friedrich Ziegahn                                                           | KIT Distinguished Senior Fellow                                                         |
| VDI Medal of Honor                                      | VDI – The Association of German Engineers                           | Prof. Dr.-Ing. Albert Albers                                                         | Institute of Product Engineering (IPEK)                                                 |
| Baden-Württemberg Start-up Award                        | Sparkassen-Verband Baden-Württemberg                                | SquareNeo Solutions (2nd place)                                                      | KIT Startup                                                                             |
| Hector Fellow Award                                     | Hector Foundation                                                   | Prof. Dr. Stefanie Dehnen                                                            | Institute of Nanotechnology (INT)                                                       |
| Heinrich-Hertz-Prize                                    | EnBW Foundation and KIT                                             | Prof. Dr. Jürgen Janek                                                               | Institute of Nanotechnology (INT)/BASF Joint Laboratory (BELLA)/University of Gießen    |
| Hermann-Credner-Prize                                   | Deutsche Geologische Gesellschaft – Geologische Vereinigung (DGGV)  | Dr. Benjamin Busch                                                                   | Institute of Applied Geosciences (AGW) – Chair of Structural Geology and Tectonics      |
| NEO2025 Innovation Award                                | Karlsruhe TechnologyRegion (TRK)                                    | Prefiro GmbH (Publikumspreis)                                                        | KIT Startup                                                                             |
| NEULAND Innovation Awards, Transfer Prize               | KIT Foundation                                                      | Dr. Robin Gröble, Dr. Alexander Marsteller, Dr. Florian Priester                     | Tritium Laboratory Karlsruhe (TLK), smolsys Ltd. Switzerland                            |
| NEULAND Innovation Awards, Idea Prize                   | KIT Foundation                                                      | 1st Prize: ReactUNE – M.Sc. Mertcan Kaya, Prof. Dr.-Ing. Christoph Klahn             | Institute for Micro Process Engineering (IMVT)                                          |
| NEULAND Innovation Awards, Idea Prize                   | KIT Foundation                                                      | 2nd Prize: Hybrid extrusion printing – Markus Fischer, Nico Leister, Laurids Pernice | Institute of Process Engineering in Life Sciences (BLT), Food Process Engineering (LVT) |

| AWARD                                                                         | SPONSOR                                                               | AWARD WINNER                                                                                 |                                                      |
|-------------------------------------------------------------------------------|-----------------------------------------------------------------------|----------------------------------------------------------------------------------------------|------------------------------------------------------|
| NEULAND Innovation Awards, Idea Prize                                         | KIT Foundation                                                        | 3rd Prize: CeraMMAM – Chantal-Liv Lehmann, Johannes Schubert, Prof. Dr.-Ing. Frederik Zanger | wbk Institute of Production Science                  |
| International Dr. Barbara Mez-Starck-Prize                                    | Dr. Barbara Mez-Starck Foundation                                     | Prof. Dr. Maximilian Fichtner                                                                | Helmholtz Institute Ulm (HIU)                        |
| IUPAC 2025 Award for Distinguished Women In Chemistry or Chemical Engineering | International Union of Pure and Applied Chemistry (IUPAC)             | Prof. Dr. Stefanie Dehnen                                                                    | Institute of Nanotechnology (INT)                    |
| Karl Heinz Beckurts-Prize                                                     | Karl Heinz Beckurts Foundation                                        | Prof. Dr.-Ing. Christian Koos                                                                | Institute of Photonics and Quantum Electronics (IPQ) |
| L'Oréal-UNESCO For Women in Science Awards                                    | L'Oréal, the German UNESCO Commission and the German Humboldt Network | Dr. Jingyuan Xu                                                                              | Institute of Microstructure Technology (IMT)         |
| Lothar-Spät-Award                                                             | Lothar Späth Award Foundation                                         | Rement GmbH (2nd place)                                                                      | KIT Startup                                          |
| Manfred Fuchs-Prize                                                           | Heidelberg Academy of Sciences and Humanities                         | TT-Prof. Dr. Pascal Friederich                                                               | Institute of Theoretical Informatics (ITI)           |
| Mitchell Prize                                                                | The International Society for Bayesian Analysis                       | Prof. Dr. Nadja Klein, Clara Hoffmann                                                        | Scientific Computing Center (SCC)                    |
| Viktor & Sigrid Dulger Foundation Ecology Prize                               | Heidelberg Academy of Sciences and Humanities                         | Dr. Gan Huang                                                                                | Institute of Microstructure Technology (IMT)         |
| Rise Europe Most Significant Startups 2025                                    | UnternehmerTUM GmbH                                                   | Semorai GmbH                                                                                 | KIT Startup                                          |
| Road to START Summit 2025                                                     | START Stuttgart                                                       | Prefiro GmbH                                                                                 | KIT Startup                                          |
| Stage Two (Movement Award)                                                    | Stage Two Network                                                     | Rement GmbH                                                                                  | KIT Startup                                          |
| Start-up BW Pitch-competition                                                 | Start-up BW                                                           | Rement GmbH (3rd place)                                                                      | KIT Startup                                          |
| t3n AI Startup Award                                                          | t3n digital pioneers                                                  | Prefiro GmbH                                                                                 | KIT Startup                                          |
| TIME Magazine Best Inventions of 2025                                         | Time Magazine                                                         | Kamedi GmbH                                                                                  | KIT Startup                                          |
| TIME Magazine Top Green Tech Companies 2025                                   | Time Magazine                                                         | INERATEC GmbH                                                                                | KIT Startup                                          |

# IMPRINT



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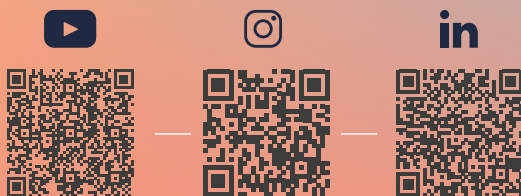
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