Energy security
What makes our energy system secure and resilient?

Airport research
Infographic special

Cover image

With precision, this robotic arm moves between the blades of an engine to inspect it and repair any damage – saving time and costs. Until now, engines had to be disassembled for such a procedure. Researchers at the DLR Institute of Maintenance, Repair and Overhaul see great potential in using robots for aircraft maintenance. They are testing this minimally invasive inspection and repair method on a former Pearl 700 development engine on loan from Rolls-Royce Germany.

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DLR magazine

#180

Precise as a surgeon

Robots in maintenance

DLR à la carte

Germany in June 2025

Cloud-free

Clear skies over Germany? Not quite! This map combines images from the Sentinel-2 satellite taken over the course of a month, using only those without clouds. The Earth Observation Center (EOC) at DLR produces a map like this every month. These maps can be used anywhere that monitoring changes to Earth's surface yields valuable insights – for example, during droughts. Comparing maps year-on-year proves particularly revealing.

Direct to the DLR GeoService

IMPRINT

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What drives us...

"With our robots, we aim to repair aircraft without taking them apart. We think of the hangar like an operating theatre; the smaller the procedure, the faster our patients are back in the air."

Read more on page 10

Florian Heilemann
Institute of Maintenance, Repair and Overhaul

Joséphine Koffler
Institute of Maintenance, Repair and Overhaul

"We observe the Earth from space with incredible precision, but understanding the impact of what we send into space remains a challenge. That's exactly where my work begins."

Read more on page 20

"Anyone who wants a secure and resilient energy system mustn't examine just one possible future, but many conceivable futures."

Read more on page 40

Carsten Agert
Institute of Networked Energy Systems

Jessika Wichner
Head of the DLR Central Archive

"Exploring DLR's history is a journey through the first half of the 20th century, encountering 'old acquaintances' on the way to new goals."

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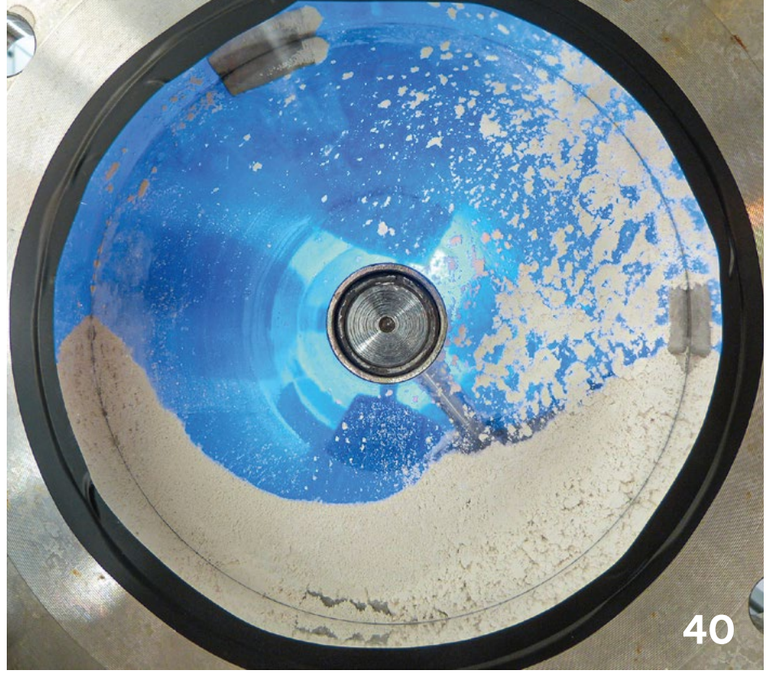
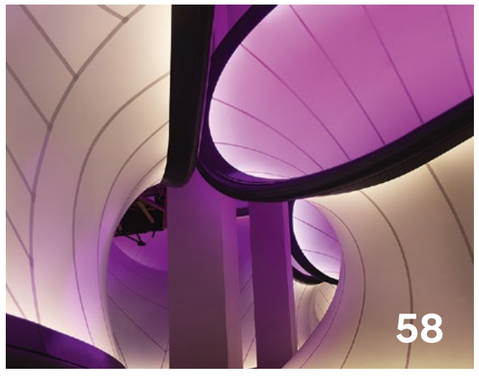




New test bench

BREMEN: DLR has constructed a test bench to investigate innovative control surfaces for aircraft wings. The tests contribute to the development of energy-efficient high-aspect-ratio wings, which are significantly more elastic than conventional designs. Intelligent control surfaces play a key role here, quickly and precisely reducing the loads acting on the wings. Up to three control surfaces can be tested simultaneously on the new test rig, which can simulate flight manoeuvres and wind gusts in real time.

High-aspect-ratio wing with multi-functional control surfaces

6

million kilometres – that is the estimated length of interstellar comet 3I/ATLAS's tail. The Juice (Jupiter Icy Moons Explorer) probe came unexpectedly close to the comet during its journey to Jupiter and used the opportunity to take images and measurements.

Test system for solar calcination

Cement powered by solar energy

DLR is developing an environmentally compatible method for producing cement

The cement industry is one of the world's largest emitters of carbon dioxide (CO_2), responsible for approximately eight percent of global emissions. Approximately 60 percent of these emissions arise from the calcination of limestone – a critical process step that demands large amounts of energy and high temperatures. Currently, the heat required is generated almost exclusively using fossil fuels.

Cutting emissions

In the CemSol project, researchers at the DLR Institute of Future Fuels are instead using high-temperature solar thermal heat, which could reduce dependence on fossil fuels. In the European Union, this approach would be particularly attractive in the southern regions. The research team is using the 'calcium looping process', in which the CO_2 released during calcination is reabsorbed into the lime. Depending on the location, CemSol could cut more than 90 percent of CO_2 emissions across the entire cement production process. A further advantage is that this calcination method is a true material cycle: no waste is produced, and there is no loss. Calcium oxide is converted back into calcium carbonate, which is then calcined again without any loss of cement quality.

Successful test in the solar simulator

As part of the project, researchers built an experimental test system to evaluate the reactor concept at a scale close to that relevant for industrial applications. The system was tested in DLR's Synlight solar simulator.

Images: p. 06 DLR; p. 07 NASA (above), stock.adobe.com/Andreas Gruhl (below)

Automation in local public transport

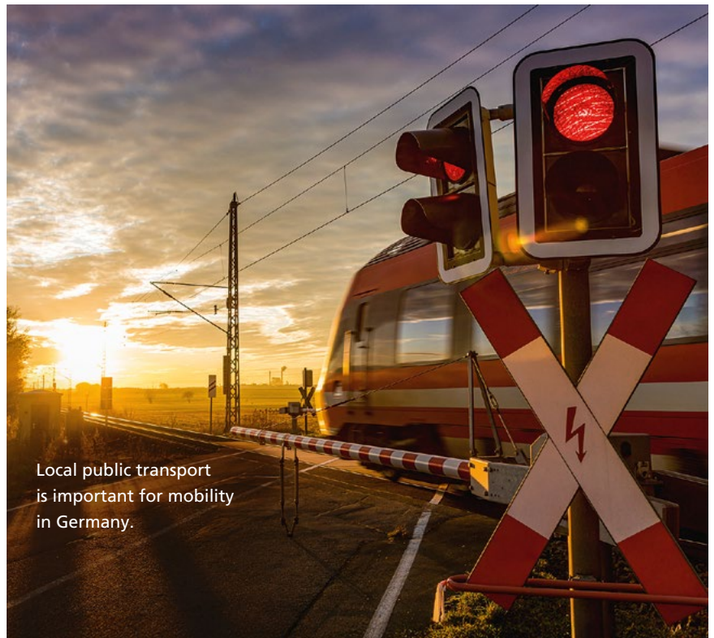
DLR white paper shows how local public transport can become more affordable and appealing

In a recent study, DLR researchers demonstrate how automation on roads and rail could make local public transport more attractive and affordable. They examined technological developments and the economic effects of using automated vehicles to expand both the public transport network and mobility services. Based on this, they formulated recommendations for action over the next five to ten years.

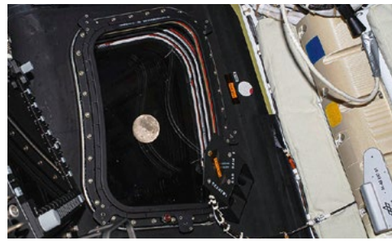
Promoting model regions and real-world labs

The study finds that automation will be crucial for a stable and efficient transport system in the near future. In rural areas in particular, it can help to secure and expand service provision. "To accelerate implementation, we must now scale up model regions and real-world testing environments, and modernise the regulatory framework to enable faster approvals," says Meike Jipp, DLR Divisional Board Member for Energy and Transport.

The researchers also see great potential in combining automated rail and road transport. According to DLR's transport research calculations, this could reduce operating costs by up to 33 percent on the railways and by more than 50 percent in road-based on-demand transport. At the same time, automation would create new fields of activity and professions: in the teleoperation of vehicles, maintenance and software operations. The researchers also anticipate positive knock-on effects for Germany as a business location.



Local public transport is important for mobility in Germany.



View of the Moon from the Orion capsule, with DLR's M-42 EXT radiation detector in the foreground.

So close to the Moon

MOON: As part of NASA's Artemis II mission, humans flew to the Moon for the first time in nearly 55 years. After a series of delays, the spacecraft launched from the Kennedy Space Center in Florida in April, followed by a splashdown in the Pacific Ocean almost ten days later. The lunar flyby of the four-person crew in the Orion spacecraft – propelled by the European Service Module (ESM) – lays the foundation for the next milestones in the Artemis programme. Also on board was DLR's M-42 EXT radiation detector, developed at the Institute of Aerospace Medicine. During the flight, four of these DLR dosimeters measured radiation exposure from heavy ions at variously shielded locations in the spacecraft. These particles are considered particularly hazardous to health during long space missions.

Thousands of scenarios

STUTTGART: More than 11,000 scenarios for the German energy system were considered in the modelling workflow developed by researchers from the Institute of Networked Energy Systems as part of the UNSEEN project. Until now, such complex analyses have been based on only a few dozen variants. With supercomputing, it was possible to analyse factors such as costs, security of supply, land use, climate protection, environmental impacts and electricity prices.

Change in the DLR Executive Board

COLOGNE: On 1 April 2026, Stéphane Beemelmans took up the post of Deputy Chair of the DLR Executive Board. Beemelmans brings extensive experience as a manager of complex processes in the public sector. He previously served, among other things, as state secretary at the German Federal Ministry of Defence and as managing director of 'PD – Berater der öffentlichen Hand'. He succeeds Klaus Hamacher, who held the position for 20 years.

A floating laboratory

BREMEN/FLENSBURG/KIEL: DLR is currently building a seagoing technology platform for investigating various maritime research questions. These include climate-compatible propulsion systems, autonomous navigation and projects in the field of security and defence research. The platform will be 48 metres long and 11.5 metres wide, accommodating up to 20 people. Multi-day research voyages will take place primarily in the North and Baltic Seas. Following the start of construction in February, the hull is currently being built in Flensburg, with transfer to the Lloyd Werft shipyard in Bremerhaven planned for autumn 2026. The ship's home port will be Kiel.

The seagoing platform will undertake research voyages in the North and Baltic Seas.

New findings on contrail formation

Soot emissions are not the only factor

Recent findings in atmospheric research show that, in addition to soot emissions, small liquid particles also play a significant role in the formation of contrails. In 2023, DLR carried out measurement flights with its Falcon 20E research aircraft and an Airbus A321neo, in collaboration with Airbus and CFM International. The results have now been published in the journal Nature.

Causes of ice crystal formation

Contrail cirrus clouds make a significant contribution to the climate impact of aviation. Until now, it was assumed that soot particles control the number of ice crystals in contrails and thus accelerate their formation. Our new findings mark a paradigm shift.

Modern lean-burn engines reduce soot emissions. During the NEOFUELS/VOLCAN measurement campaign, researchers examined contrails from these engines in flight for the first time. Surprisingly, the number of ice crystals far exceeded the number of soot particles measured in the exhaust gases. Unexpectedly, the researchers observed a large number of liquid particles.

Fuels with low sulphur content led to a reduction in the number of ice crystals. With low-sulphur fuels, volatile organic compounds and lubricating oil vapours become increasingly important in forming new particles.

View from the DLR Falcon 20E of the Airbus A321neo (above). Ice particle sensor under the Falcon wing (below).

Image: DLR

My work at DLR

Tobias Treichl

I am currently developing a simulation model at the DLR Institute of Flight Systems to investigate how humans and machines physically interact. This involves, among other things, examining the effects of turbulence on pilots as they control an aircraft with a joystick. Originally, I studied mechanical engineering. DLR offers a globally unique laboratory environment where I can test and realise my ideas. I particularly enjoy the variety in my work, which ranges from hardware programming and simulation to conducting studies.

Join our fascination – DLR's careers website

Researchers at the DLR Institute of Maintenance, Repair and Overhaul are testing minimally invasive inspection and repair techniques on a former Rolls-Royce Germany Pearl 700 development engine. The ultimate goal is to eventually service an engine directly on the aircraft without having to disassemble it.

Precise as a surgeon

Endoscopic robots inspect and repair in the tightest spaces

by Philipp Czogalla

When you hear the term ‘ultrasound scan’, you likely think of a visit to the doctor. For physicians, ultrasound diagnosis is a quick, non-invasive method to produce an image of the inside of the human body. This image must be interpreted, but in many cases serves as a starting point for further diagnostics.

Ultrasound is however also used in aviation, with the primary goal of detecting irregularities in materials – such as cracks or delaminations, where entire layers separate – which could worsen if ignored. However, the technique places enormous demands on maintenance personnel. Since ultrasound scanners must be manually guided over a component, calm, patience and concentration are essential. Moreover, expertise is required to recognise any anomalies that come up. If an inspection is repeated later to assess how a defect has developed, it must first be relocated. Finding a tiny, invisible crack on a fuselage segment several metres long – which is often painted a single colour – is not only difficult but also poses a risk. What if a new defect is mistaken for the old one – and the old one effectively missed?

To make such inspections simpler and safer, researchers at the DLR Institute of Maintenance, Repair and Overhaul in Hamburg are developing robot-assisted ultrasound testing, using contactless methods.

There are various methods for transmitting ultrasound pulses to a component. In one, a piezoelectric ceramic is bonded to the component’s surface, causing the material to vibrate through mechanical impulses. Another uses a laser to generate very short, high-intensity light pulses, causing the material to rhythmically heat and cool. This heating causes the material to expand slightly in a wave-like pattern.

Making the invisible visible

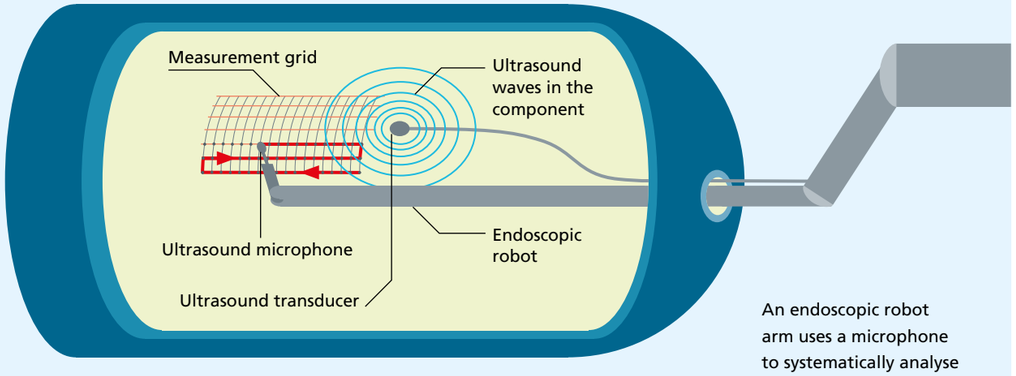
The resulting sounds are very faint and very high-frequency. At up to two million hertz, they are as inaudible to humans as they are even to bats. Highly specialised laser ultrasound microphones can, however, record these sounds. When such microphones are guided by a robot, a large number of measurement points can be targeted with precision. The result is an image that reveals even the smallest irregularities in the component, allowing initial assessments of the nature of the anomaly.

> ”With aluminium, you can see cracks on the surface of the aircraft skin at an early stage. With CFRP structures, we have to make the invisible visible.”
>
> **Caspar Wasle, Institute of Maintenance, Repair and Overhaul**

This technique will become increasingly important in the future for new carbon fibre reinforced polymer (CFRP) materials, as delaminations could otherwise go undetected. “With aluminium, cracks on the surface of the aircraft skin can be spotted early on”, emphasises Caspar Wasle. “With CFRP structures, we have to make the invisible visible.” Together with his colleagues, Wasle has already examined a miniature hydrogen tank using a robot-guided ultrasonic microphone – a unique undertaking in the field of ‘maintenance, repair and overhaul’ (MRO). The team was also able to detect damage on the back side of the material, in areas that would be inaccessible during routine maintenance.

Robot-assisted ultrasound inspection not only operates without fatigue and delivers accurate results; it also provides location data that enables the precise localisation of damage to the component. This traceability is key to the effectiveness of all subsequent measures – a true game-changer for MRO. This makes it possible, first of all, to report any anomalies to manufacturers with precise location data, meaning they can incorporate this information into future designs. Secondly, it allows for recurring observational inspections of specific problem areas. “At present, ultrasound data is often still treated as disposable,” says Wasle. “We record it in such quantity and quality that we can monitor its development.”

Detecting material damage with sound



An endoscopic robot arm uses a microphone to systematically analyse how ultrasound waves propagate through the component.

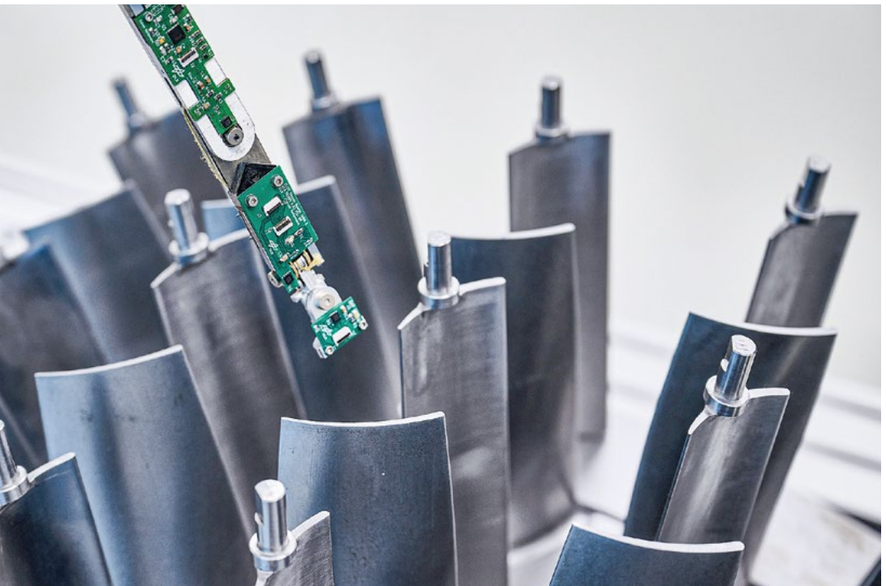
DLR researcher Caspar Wasle prepares a robot for an ultrasound examination (left).

An endoscopic robot automatically inspects a component with ultrasound (below).

Images: (centre and bottom) ZAL/Daniel Reinhardt

Florian Heilemann in the robotics area of the project laboratory of the Institute of Maintenance, Repair and Overhaul.

Elise has a modular design. The length of the endoscopic arm and the number of joints are variable, and its movements are controlled via cables which are housed in the cylindrical control module.



Magnetic field sensors allow Elise's swivel joints to be precisely aligned. Once the endoscope has been inserted into a component, it is essential to know exactly where it is to avoid collisions.

Image: (above) ZAL/Daniel Reinhardt

Endoscopic and autonomous

At first glance, it looks rather unremarkable. Although, judging by the name – Elise – 'she' might be more appropriate. Slim and rod-shaped, Elise is equipped with three joints at the end that allow free movement of the head. This movement is achieved using cables, based on the 'antagonistic' principle. Imagine it like a human arm, which is also moved by opposing muscles – biceps and triceps. The robot's head can accommodate sensors or tools, depending on requirements. But Elise's special feature is its ability to operate endoscopically, reaching difficult-to-access areas inside an aircraft for minimally invasive inspection.

Florian Heilemann, who designed Elise, drew inspiration from surgical robots. In medicine, robots are already used to perform minimally invasive operations on humans and must therefore meet comparable requirements in terms of precision and reliability. But there is a crucial difference. In medicine, robots are currently teleoperated – remotely controlled – by doctors, usually based on a camera image. Elise, however, is designed to perform autonomous inspection and repair tasks. This is a significant step. While medical personnel can reposition the robot head if it is not in the correct position, Elise should be able to operate 'blind', always knowing precisely where it is and the alignment of its three joints.

To enable this kind of absolute positioning, Heilemann uses 'discrete rotary joints' with magnetic field sensors. These can determine the joint's exact deflection angles at any time, even after an interruption, so the operator always knows exactly what Elise is looking at. Locating the joints has further advantages, as changes in the tendon length do not affect how the mechanism behaves, and tendons can be pre-tensioned to set the joint's stiffness.

This allows the robot to exert defined forces and also to detect when it encounters an obstacle inside. In such cases, the cable tension increases sharply and the robot provides feedback. The tendons run along the robot arm to a compact control unit, where they are wound up by small electric motors. From here, the collected data is transmitted wirelessly. The entire design is modular, and the length of individual sections can be adapted to requirements, as can the number of joints. Another detail: Elise's arm has a semi-circular cross-section. This allows for easy routing of cables that transmit sensor data to the control unit. This simple design enables flexible deployment with short setup times.

> "We think of the hangar like an operating theatre. The smaller the procedure, the faster our patient is back in the air."
>
> **Florian Heilemann, Institute of Maintenance, Repair and Overhaul**

In aviation, many application scenarios are possible. Inspections are often carried out in situ, which means that the component remains in its original position. Elise could, for example, inspect an engine without it having to be removed from the wing or dismantled. This can save many hours of work and help to avoid errors. "We think of the hangar like an operating theatre," says Heilemann. "The smaller the procedure, the faster our patient is back in the air."

Tiny meteorite craters

Inspection is, however, only one side of the coin. In the future, endoscopic robots are also set to carry out repairs in hard-to-reach areas. Researchers have already set their sights on a particularly complex problem: the robot-assisted autonomous profiling of compressor blades in the engine. The basic problem is easily explained: an aircraft engine is constructed in stages, with the large fan (with the large blades) only visible at the front, and behind it numerous compressor and turbine stages in several rows, with many small rotor blades (rotating) and stator blades (fixed) that guide the airflow. These blades, often only a few centimetres long, are subject to immense stresses during flight. They withstand compressive and tensile forces, extreme temperature fluctuations and, in some cases, rotate at supersonic speeds. At such speeds, sand and dust particles striking the blades act like tiny meteorites pelting the material. Even water droplets leave their mark.

This is particularly problematic for the first row of high-pressure compressor blades. They bear the brunt of the impact, yet are crucial to the engine's efficient operation. "You can think of these blades like kitchen knives," explains DLR researcher Fabian Wieczorek. "When they are blunt, they no longer cut cleanly through the air." The result is an approximately 0.1 percent increase in kerosene consumption. That may not sound like much, but on a single long-haul flight consuming 200 tonnes of kerosene, it amounts to an extra 200 kilograms. On top of that, a few extra litres of kerosene are needed to carry those 200 kilograms. After all, in aviation, every extra kilogram means more fuel consumption.

If blunt compressor blades are such a problem, what could be more logical than sharpening them? Unfortunately, this currently requires disassembling the entire engine – a mammoth task that costs many hours of labour and a lot of money, and is therefore often only carried out during scheduled maintenance intervals.

Sharpening 30 knives – with your eyes closed

In the aviation research project GreenMES (Green Mobile Engine Services), DLR and Lufthansa Technik, the Institute of Aircraft Production Technology at the Hamburg University of Technology (TUHH) and the company IT Concepts are working on automatically sharpening the blades of a high-pressure compressor stage using a robot, without having to disassemble the engine. The first compressor stage has more than 30 rotor blades, so to dramatise a little, the goal is akin to having a machine sharpen 30 very expensive knives directly in the kitchen drawer, without opening it more than a few centimetres and with your eyes closed.

This is how it is supposed to work: First, a robotic arm guides a tool carrier equipped with a 3D camera into the engine's maintenance opening. This is only possible if it executes a precisely calculated curved movement. The robot head manoeuvres through a narrow opening between several fixed guide vanes and reaches the first rotor blade. This blade is then measured in three dimensions, creating a high-resolution 3D model. Particular attention is paid to the blade's leading edge. Here, tiny craters can be seen – the result of particles impacting the metal at supersonic speeds. Surgical precision is then required: the robot uses a grinding tool to wear down the blade with precisely planned yet minimal movements of the robotic arm. DLR researcher Wieczorek is programming software for this process, which includes monitoring and controlling the grinding process and features a functional user interface. The grinding and visual inspection process is repeated several times until the nominal profile is restored.

> "You can think of these blades like kitchen knives. When they are blunt, they no longer cut cleanly through the air."
>
> **Fabian Wieczorek, Institute of Maintenance, Repair and Overhaul**

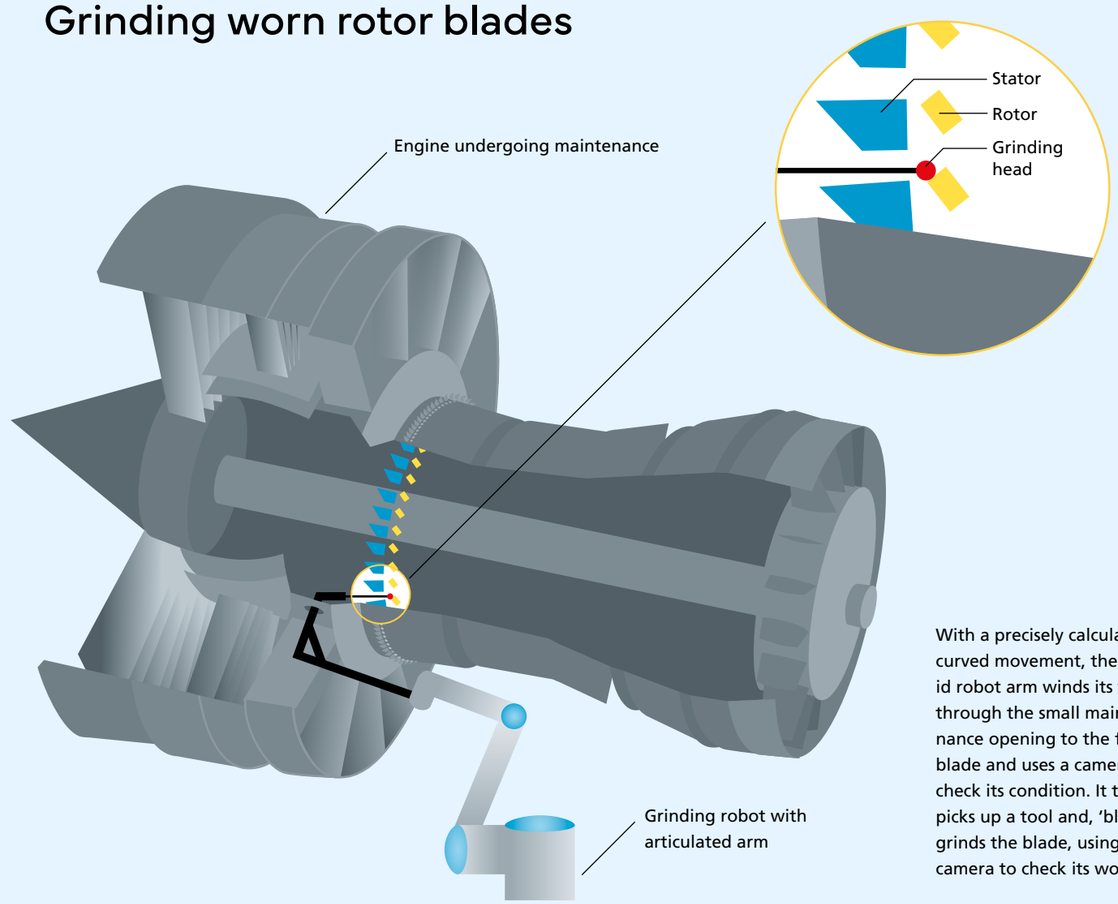
Precise motion planning of the robot is crucial, as the leading edge has a radius of just 0.3 millimetres. This also explains why the tool carrier is designed as a very rigid structure without joints, as the precision required would otherwise be impossible to achieve. The key factor here is repeat accuracy. The robot does not need to know its exact location; it only needs to move the tool precisely to the position it had previously identified with the camera.

This makes it clear that robots can only realise their full potential and simplify maintenance processes if hardware and software development go hand in hand. In an environment like MRO, where often only tiny access openings are available for high-precision measurements, corrective interventions and the documentation of results, endoscopic robots come into their own and have the potential to sustainably transform the MRO industry.

Philipp Czogalla is responsible for communications at the Institute of Maintenance, Repair and Overhaul. He is always delighted when colleagues show him their latest inventions.

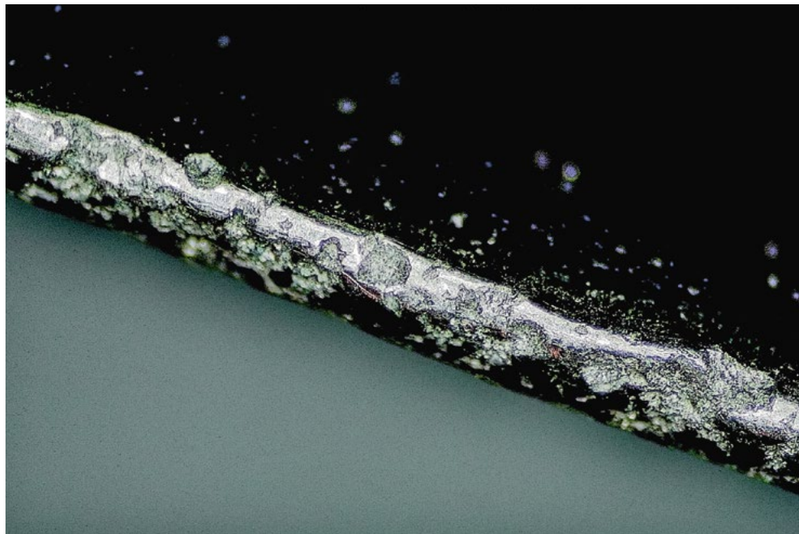
LAUNCH
Robotics

Grinding worn rotor blades



With a precisely calculated curved movement, the rigid robot arm winds its way through the small maintenance opening to the first blade and uses a camera to check its condition. It then picks up a tool and, 'blind', grinds the blade, using the camera to check its work.

In the GreenMES project, a robot is being developed to grind the compressor blades of engines in situ, making them efficient again. This means the engine no longer needs to be completely disassembled for grinding, saving time and costs.



Moonscape: Under the microscope it is clear to see what dust and water have done to the compressor blade.

Microalgae on a mission

Here on Earth, breathable air is taken for granted. In space, it's a different story. For humans to travel in space, complex technology must provide and sustain their air in order for them to breathe. Onboard spacecraft, this task is handled by the Environmental Control and Life Support System. The Technical University of Munich has developed a photobio-reactor system that uses microalgae, which perform photosynthesis and convert the carbon dioxide exhaled by humans back into oxygen. This image shows a section of the system where the algae are suspended in a nutrient solution into which air is intro-duced. The method was tested in the FLEXhab space habitat at the LUNA Analog Facility in Cologne, jointly operated by DLR and ESA. In FLEXhab, oxygen and carbon dioxide levels in the air can be continuously measured under controlled conditions, making it ideal for testing this potential space system.

The data detective

Joséphine Koffler analyses satellite data in the name of sustainability

by Max Braun

Researchers are seeking solutions to reduce space debris in Earth's orbit. Future space missions aim to shed light on what exactly happens when a satellite burns up in the atmosphere.

Joséphine Koffler from the DLR Institute of Maintenance, Repair and Overhaul is researching concepts for more sustainable satellites.

Images: p. 20 Georg Wendt; p. 21 ESA

Joséphine Koffler has been fascinated by the world above us from an early age. She grew up near Strasbourg Airport, with the constant roar of aircraft in her ears. At 17, she sat in the cockpit of a small aircraft for the first time, and by 23 she had earned her light aircraft pilot's licence. For just under three years now, the materials scientist has also been concerned with objects that orbit Earth far above aircraft.

At the DLR Institute of Maintenance, Repair and Overhaul, the French-born researcher is exploring how we can use satellites in Earth orbit in a more sustainable and longer-lasting way. "I first read about space debris during an internship," recalls Koffler. "I hadn't realised before just how many small and large fragments are orbiting Earth, or that the fascinating technology we send into space leaves behind so much debris." In most cases, these are decommissioned satellites or fragments of old rocket stages. Currently, there are approximately 1.2 million pieces larger than one centimetre in orbit – all of which pose a threat to active satellites. The crucial question, therefore, is: How can we ensure that as little new space debris as possible is generated in the future?

A whole lifetime

To answer this question, Koffler uses what is known as a Life Cycle Assessment (LCA). What makes this standardised methodology particularly valuable is its versatility. Any imaginable product can be assessed for sustainability using an LCA – from a yoghurt pot to a satellite. The method helps researchers to measure the ecological footprint of a product across its entire life cycle. For a satellite, this would encompass everything from the extraction of raw materials and production to its launch into space, its operation and eventual end of life in Earth's orbit. The analysis reveals which stages of the life cycle have the greatest environmental impact. "Our job is to provide engineers with relevant information for the design, construction and operation of satellites. This way, we ensure that we do not create new environmental problems in space that we will have to solve again in 10 or 20 years," explains the Hamburg-based scientist.

Detective work in a data jungle

To begin her analysis, Koffler collects data on every component of a satellite. She has to dive deep into global supply chains and the properties of aluminium, titanium and carbon-fibre-reinforced plastics – materials that make up most modern satellites. Like a detective, she searches for reliable data on water consumption in titanium production or the toxicity of burning aluminium. She combs through countless databases and research papers. "The biggest challenge in my work is the availability and quality of data," she explains. Information is often incomplete, either because it is classified or simply because no figures are yet available for certain materials.

No room for gut feeling

The reward for this painstaking research is the complete picture that emerges at the end of Koffler's analysis. Often, the numbers paint a picture that completely overturns previous assumptions. For a long time, for example, satellite design focused on ensuring that satellites burn up as completely as possible on re-entry into the atmosphere, before reaching Earth's surface. However, a comprehensive Life Cycle Assessment has shown that the environmental impact of burning up entirely is actually greater than simply letting a satellite fall into the ocean. This is because modern satellites are predominantly made of aluminium, which releases harmful aluminium oxide when exposed to high heat. "What is essential is invisible to the eye," wrote the French writer and pilot Antoine de Saint-Exupéry in his world-famous novel The Little Prince. "I think this sentence applies to my work in many ways," says the French scientist about her research.

Recently, wood has also been discussed as a sustainable material for satellite construction. Although certain materials are perceived as environmentally compatible, their use is not automatically better for the planet. "Sometimes, new materials simply shift the environmental impact to a different phase of the life cycle or into a different environmental category," explains Koffler. Speaking to her about sustainability, it becomes clear that, unlike her hobby in the cockpit, her research leaves no room for gut feeling.

In her analyses, Joséphine Koffler delves deep into databases on global supply chains and space materials.

Learning from aviation

Although the Life Cycle Assessment provides a reliable framework, Koffler finds herself pioneering new approaches time and again when working on satellites designed to operate for as long as possible. "Satellites aren't yet built to be repaired or refuelled in orbit, but this could extend their lifespan," she explains. After all, a satellite's mission almost always ends with either a fault or an empty fuel tank. Once the high-tech satellite is defective or runs dry, a replacement must be launched into space. Researchers aim to end this single-use approach by introducing a completely new maintenance phase in orbit – one in which satellites could be refuelled and, if necessary, repaired to prolong their operational life. The idea is inspired by the aviation industry, where Koffler spent several years working both as a researcher and flight attendant. Particularly in commercial aviation, maintenance and servicing are fundamental components of the product's life. Regular checks not only ensure the safety of passengers but also keep aircraft in service for decades.

In space, there is not yet an established procedure for what is known as 'on-orbit servicing'. Before satellites can be adapted for such a 'pit stop' in Earth's orbit, Koffler first needs to determine under what circumstances the transition is actually worthwhile. To do this, she is searching for the ecological 'break-even point'. In practical terms, this means: How many satellites would an orbital refuelling station or repair facility in Earth orbit need to service before it has offset its own environmental impact?

Until a true circular economy in space is established, Koffler still has plenty more calculations and environmental data to analyse. In her personal life, she also ensures the meals she serves are resource-efficient, and enjoys preparing them using refurbished, second-hand kitchen appliances. "You can already find a lot of information online about the water and land consumption of individual foods," she says. And that requires far less research than compiling data for an entire satellite.

Max Braun is a trainee in DLR Communications and an enthusiastic second-hand shopper. He thinks it's wonderful that science is now looking to extend the lifespan of satellites.

Image: Georg Wendt

The team from the Technische Universität Braunschweig took second place in 2024 with their design for the VoltAirs-95 short-haul aircraft.

Image: TU Braunschweig/VoltAirs-95

For creative minds

Over the past ten years, students have been developing new aviation concepts in the DLR Design Challenge

GET INVOLVED

At the start of each year, the task for the Design Challenge is published. Registration is possible up to two weeks before the kick-off event in March through the responsible department at each university, either individually or as a team.

It's all about technical knowledge, creativity, teamwork – and, of course, fun. In the DLR Design Challenge, students develop ideas for new aircraft concepts. Since the first call for entries in 2017, the competition has inspired designs for hydrogen-powered aircraft, parcel delivery drones, aircraft for fighting forest fires and more.

How it works

Every year, DLR sets a new challenge based on current aviation topics. Over four months, teams of up to six members develop their concepts, working out the technical and economic aspects like performance, costs and operations. At the end, they present their results to an expert panel of institute directors, chaired by DLR's Divisional Board Member for Aeronautics.

Creative, yet feasible

Above all, the overall concept must be convincing. Even at the preliminary design stage, teams consider the current state of technological development and the requirements – such as certification – that must be met. To master this challenging task, various disciplines must be integrated.

The winning teams get to present their designs at prestigious national and international aviation conferences. This year, for the first time, the 17 registered teams will be supported by mentors from DLR's aeronautics institutes, receiving expert guidance in areas such as preliminary aircraft design and propulsion architectures. Their task: design the demonstrator of the future.

OVERVIEW OF TOPICS AND WINNING CONCEPTS

2017

TOPIC:
Aircraft of the future – a quiet, low-emission passenger aircraft for at least 200 people or an energy-efficient supersonic aircraft, both to be realised by 2035

WINNER:
The Urban Liner from the Technical University of Munich has a single engine mounted at the rear between the tail fins. It is designed to reduce energy consumption by up to 50 percent.

2018

TOPIC:
Environmentally compatible flying of tomorrow – designs with significantly lower fuel consumption and emissions

WINNER:
eRAY, developed by a team at the Technical University of Munich, is based on a fully integrated turbo-electric propulsion system featuring several electrically driven fans along the wings and an additional engine at the rear of the fuselage.

2019

TOPIC:
Regional aircraft – concepts for small aircraft that can be flexibly deployed for cargo and passenger transport, both autonomous and piloted

WINNER:
HyBird, a small aircraft from the University of Stuttgart, uses a serial hybrid propulsion system and electrically driven propellers on the wings and tail tips. It was built at DLR as a demonstrator and underwent test flights in 2023.

2020

TOPIC:
Parcel delivery – autonomous and reliable aerial systems for delivering goods in urban areas

WINNER:
The Urban Ray uncrewed aerial system from RWTH Aachen University features a blended wing body design, where the fuselage merges seamlessly into the wings. It is fully autonomous, electrically powered and has rotors for both hover and forward flight.

2021

TOPIC:
Hydrogen-powered aircraft – a hydrogen-fuelled short- to medium-haul aircraft with a capacity of 150 passengers. Key considerations included atmospheric impact and overall energy consumption.

WINNER:
HyZero from RWTH Aachen University is powered exclusively by liquid hydrogen and generates electricity via fuel cells. Its high-aspect-ratio wings reduce aerodynamic drag.

2022

TOPIC:
Fighting wildfires – a concept for a fleet of firefighting aircraft capable of working together and with ground units

WINNER:
INFERNO, developed by the University of Stuttgart, uses eight horizontal rotors for vertical take-off and landing and two propellers for forward flight. It features a hybrid-electric propulsion system and flies on sustainable aviation fuels.

2023

TOPIC:
Aircraft for restoring internet connectivity during disasters – designs should ensure communication channels and perform Earth observation while operating as part of a fleet within an integrated system

WINNER:
The Sentinel System concept from DHBW Ravensburg relies on proven technology and is designed to fly for up to 50 hours continuously without reliance on satellite navigation.

2024

TOPIC:
Climate-compatible short-haul aircraft – an environmentally sound and economical aircraft serving a predefined network of European regional routes, for entry into service by 2050

WINNER:
The CHARGE short-haul aircraft developed by TU Berlin is powered exclusively by batteries. It is designed to carry 110 passengers over distances of up to 894 kilometres.

2025

TOPIC:
Innovative rescue aircraft – an emergency evacuation aircraft capable of carrying up to 19 people and suitable for a variety of operational scenarios

WINNER:
In 2025, two concepts shared the top prize: AETHER from FH Aachen University of Applied Sciences and ASCLERA from RWTH Aachen University. AETHER is a versatile twin-engine turboprop air ambulance with a flexible cabin layout. ASCLERA features an advanced flap and flight control system to enable operation from short runways.

2026

TOPIC:
Demonstrator of the future – an aircraft designed to test future aviation technologies. The final event and awards ceremony will take place on 20 August in Hamburg.

THE COMPETITION IN NUMBERS:

70
teams have participated over the last ten years

16
universities have taken part (and continue to do so)

398
students have contemplated and continue to ponder new aviation concepts

20
participants subsequently found employment at DLR

Direct to the DLR Design Challenge website

Only flying for real is better

In the AVES hall, various aircraft can be simulated with remarkable realism

by Daniel Beckmann

Like a round peg in a square hole – a sweeping glass front offers a view into the simulator hall.

Modules can be integrated into fixed (top left) and movable (bottom right) simulation platforms.

Image: DLR

The simulator is used to refine displays, controls and the interaction between the flight model and the individual behaviour of the cockpit crew.

Through the large glass front of the otherwise dark grey, cubic building, you see a brightly lit hall, at the centre of which stands a sphere, several storeys high. Even from the outside, the Air Vehicle Simulator (AVES) facility at the DLR Institute of Flight Systems in Braunschweig sparks curiosity. Upon entering, the interplay of geometric shapes, radiant light and stark contrasts continues. The atmosphere feels almost clinical, like a cleanroom. The white-grey modules surrounding the space are striking in size, yet their purpose is not immediately apparent. It is only on closer inspection that aircraft-like inscriptions and components become visible.

Stepping into the modules, you are instantly immersed in a different environment: darker, more confined and densely packed with coloured switches and displays. Taking a seat in a fully functional cockpit, you feel immediately transported into an aircraft ready for take-off. This immersion is no side effect but a central goal of the facility. Holger Duda from the DLR Institute of Flight Systems, who is responsible for AVES, puts it this way: “The goal is for you to forget you’re sitting in a simulator.”

AVES is unique worldwide due to its versatility, networking capability and scientific and technical focus. The facility delivers highly realistic simulations of a wide range of aircraft and mission profiles – as well as new concepts for flight controls, approach procedures and assistance systems. Various cockpits and workstations are available to researchers, flight crews and development and engineering teams. Some are stationary in the hall, but most can be integrated into the spherical, movable simulator platform at its centre. Their applications are diverse, but they all share a high degree of flexibility for both software and hardware, exceptional simulation quality and a focus on human factors.

From simulation to reality – and back

The Low Noise Augmentation System (LNAS) demonstrates just how closely simulation and real-world flight testing are intertwined. In this project, assistance systems help pilots perform quieter approach procedures – for example by delaying the deployment of the landing flaps and landing gear as long as possible.

Development began in the authentic Airbus A320 cockpit module at AVES. Simulation results were supplemented with noise maps produced by DLR in collaboration with stakeholders at selected airports. Displays, controls and the interaction between the flight model and individual behaviour of the cockpit crew were refined until the procedure could be seamlessly integrated into real flight operations. “We can develop

the technology for LNAS almost entirely within AVES," says Duda. The approaches were then tested at Frankfurt and Zurich airports using DLR's Airbus A320 ATRA research aircraft and were subsequently adopted by Lufthansa for scheduled operations.

The simulator also serves as a key development environment for DLR's ISTAR research aircraft, a modified Dassault Falcon 2000LX. The aircraft is intended to test automated cockpit systems, assistance functions and optimised flight procedures. However, before any major modifications or software adjustments are made, teams from various DLR departments develop and test the relevant concepts in the simulator. The realistic replication of the cockpit and flight characteristics creates a familiar environment for the crew. Standard procedures are carried out routinely from muscle memory, while new systems can be specifically observed and evaluated.

One key objective is to retrofit the traditionally hydromechanically controlled research aircraft with an additional digital fly-by-wire control system. Data protocols, interfaces and reliability can thus be tested in advance in the simulator – efficiently and without any risk to people or equipment. The developments made on the ground are then verified in real flight tests. Furthermore, the simulator can be used to model completely different types of aircraft: from continuously variable landing flaps and particularly sleek wings to entirely new aircraft concepts. "We can, for example, simulate a conceptual modern blended wing body airliner," explains Duda.

But the exchange works both ways, as measurement data from real research flights also flows back into the simulation software, continuously improving the models. In some areas, these models now achieve a level of accuracy comparable to, or even surpassing, those of manufacturers or training simulators. Industrial companies, such as suppliers of software, avionics or control systems, also draw on this long-standing transfer expertise to extensively test and optimise new products with DLR before they are launched on the market.

Enhanced perception during operation

In the module representing the cockpit in DLR's EC135 research helicopter, the focus is not only on new control technology but also on the integration of new assistance systems. One example is the use of augmented reality technologies via a 'HoloLens' – a pair of transparent glasses that project additional information directly into the pilot's field of vision. During certain flight manoeuvres, helicopters fly at low altitudes through complex environments in close proximity to power lines, buildings and vegetation, or through low-lying fog – at significant risk. But digitally overlaid flight paths and obstacle warnings from lidar sensors assist with navigation and enhance safety even in poor visibility.

Helicopters require particularly precise simulation, as they can enter highly sensitive flight states such as hovering. In previous projects, DLR experts replaced conventional control systems with 'fly-by-light' technology, where control commands are transmitted via fibre-optic cables rather than copper cables or even mechanical linkages. Here too, development began in the AVES simulator before being transferred to the real Flying Helicopter Simulator – DLR's EC135.

Workload and passenger comfort

AVES's latest simulator replicates the cockpit of a Deutsche Aircraft D328. Apart from the basic physical controls, the cockpit is dominated by large-format displays. These are increasingly becoming standard in modern aircraft and allow for a high degree of flexibility in displaying functions and information. Among other things, the module is used to research single-pilot operations in civil aviation. In addition to safety-related issues, the workload on individual crew members plays a central role; fatigue, monotonous phases or additional tasks must be managed effectively. DLR is developing assistance systems that, for example, use artificial intelligence to reduce workload, increase alertness through visual or auditory signals, and improve situational awareness in the cockpit. Organisational, physical and psychological aspects such as shift and rest periods, monotony and stimulation are also considered in the studies.

The sphere mentioned at the outset plays a special role: More than 60 computers and 15 projectors create a 240-degree field of view and set the module – and its occupants – in motion. In many experiments, this 'motion simulator' uses rolling and side-to-side movements to convey a realistic sense of flight attitudes or turbulence. However, its full potential is realised when the cabin module is integrated. Up to 16 participants can take part in studies within this movable passenger cabin. Research here focuses on passenger comfort, such as the perception of turbulence or the acceptance of virtual exterior views. In place of traditional windows, the cabin has monitors that display the outside world based on live camera feeds. Virtual reality headsets are also used, which can visualise completely different environments or even the view 'through' the aircraft. It is here that the real world merges most vividly with virtual and augmented reality.

With its intense immersion, modular architecture, high degree of realism and the close integration of simulation and real flight operations, AVES offers an exceptional research environment for studying the interface between humans and machines. Nowhere else can the future of aviation be experienced more realistically.

Daniel Beckmann is an aviation enthusiast and is responsible for DLR's corporate design. Compared to his home flight simulator, his experience in AVES was an intense workout.

Images: (centre and bottom) DLR

A320 cockpit module with additional displays, including those for the LNAS pilot assistance system.

Virtual windows convey a selected external view.

The ISTAR cockpit module offers spacious operator positions to influence the simulation and scenery.

Get moving!

These transport helicopters are extremely fast – reaching speeds of up to 450 kilometres per hour. For comparison, conventional helicopters typically reach maximum speeds below 300 kilometres per hour. The concept for this High-Speed Rotorcraft, or HSR, was developed at the DLR Institute of Flight Systems. Many countries are currently investigating such concepts for medium-weight transport helicopters with increased flight speeds. What makes the HSR special is its use of wings, propellers and control surfaces. In conventional helicopters, the main rotor generates both lift and thrust, but compound rotorcraft such as the HSR transfer some of the helicopter's lift to the wings. This allows the rotor to extend its operating limits. These medium-sized transport helicopters are intended to match current models in terms of payload capacity and range – but fly significantly faster.

At the heart of mobility

DLR's airport research is about more than just technology

Airports are hubs of global mobility. They connect people, markets and ideas, and shape the development of entire regions and economies. However, growth in air traffic also presents challenges: noise, emissions, land use and complex operational processes must be designed in such a way that airports are economically viable, climate-compatible and acceptable to local residents.

DLR institutes study airports as complex systems: from operations on the ground and in the air to infrastructure and regulation, all the way through to their impact on the environment, economy and society. We develop new technologies, optimise processes and analyse how planned measures will affect airport operations. Our research provides the scientific basis for decision-making in politics, the aviation industry and wider industry.

"The next five years will be the critical implementation phase for airports."

Markus Fischer, DLR Divisional Board Member for Aeronautics

With questions asked by the editorial team

Image: DLR

Dr Fischer, how will airports evolve in the future?

Airports of the future will no longer be just runways and taxiways, but highly networked, digitally controlled mobility hubs that operate with emission-free ground vehicles, AI-optimised flight paths and energy-efficient infrastructure. Airports will become climate-compatible nodes in the mobility system of tomorrow – quiet, emission-free and digitally interconnected.

What role does DLR research play in this, and how do we determine what to research?

DLR research is the architect of this transformation. We select topics based on their potential for climate impact, their greatest system relevance and their economic viability – always in close dialogue with industry, policymakers and society.

What changes do you expect to see over the next five years?

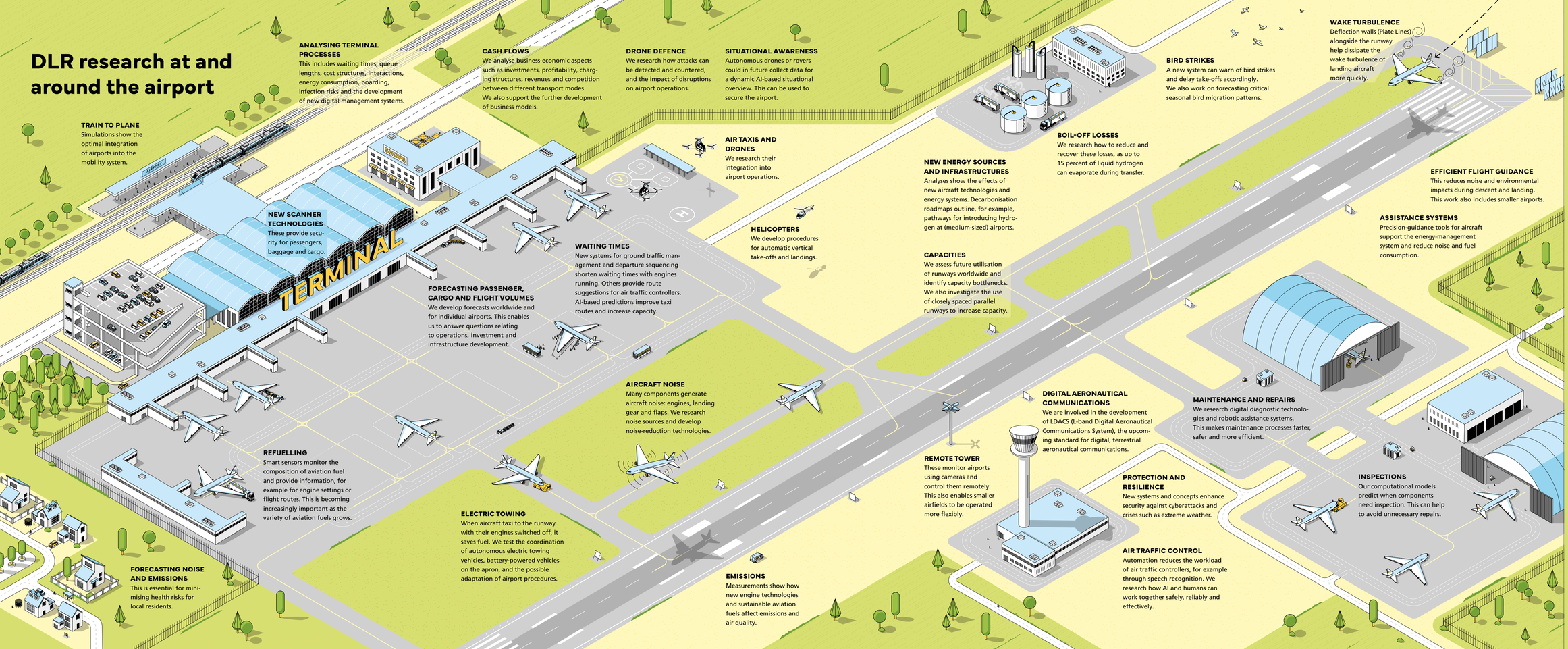
The next five years will be the critical implementation phase. We are putting in place the digital infrastructure, the regulatory framework and the first demonstrators that will make aviation climate-compatible by 2050. Through the close integration of research, industry and policymakers, we are creating the conditions for improvements that are already becoming visible today and shaping everyday operations at our airports – zero-emission taxiing, the use of sustainable aviation fuels (SAF), climate-optimised flight routes and digital twins.

Thank you for the interview.

OPEN UP AND DIVE IN

Infographic on DLR airport research

DLR research at and around the airport



ANALYSING TERMINAL PROCESSES
This includes waiting times, queue lengths, cost structures, interactions, energy consumption, boarding, infection risks and the development of new digital management systems.

CASH FLOWS
We analyse business-economic aspects such as investments, profitability, charging structures, revenues and competition between different transport modes. We also support the further development of business models.

DRONE DEFENCE
We research how attacks can be detected and countered, and the impact of disruptions on airport operations.

SITUATIONAL AWARENESS
Autonomous drones or rovers could in future collect data for a dynamic AI-based situational overview. This can be used to secure the airport.

TRAIN TO PLANE
Simulations show the optimal integration of airports into the mobility system.

NEW SCANNER TECHNOLOGIES
These provide security for passengers, baggage and cargo.

AIR TAXIS AND DRONES
We research their integration into airport operations.

HELICOPTERS
We develop procedures for automatic vertical take-offs and landings.

WAITING TIMES
New systems for ground traffic management and departure sequencing shorten waiting times with engines running. Others provide route suggestions for air traffic controllers. AI-based predictions improve taxi routes and increase capacity.

FORECASTING PASSENGER, CARGO AND FLIGHT VOLUMES
We develop forecasts worldwide and for individual airports. This enables us to answer questions relating to operations, investment and infrastructure development.

AIRCRAFT NOISE
Many components generate aircraft noise: engines, landing gear and flaps. We research noise sources and develop noise-reduction technologies.

REFUELLING
Smart sensors monitor the composition of aviation fuel and provide information, for example for engine settings or flight routes. This is becoming increasingly important as the variety of aviation fuels grows.

ELECTRIC TOWING
When aircraft taxi to the runway with their engines switched off, it saves fuel. We test the coordination of autonomous electric towing vehicles, battery-powered vehicles on the apron, and the possible adaptation of airport procedures.

FORECASTING NOISE AND EMISSIONS
This is essential for minimising health risks for local residents.

EMISSIONS
Measurements show how new engine technologies and sustainable aviation fuels affect emissions and air quality.

NEW ENERGY SOURCES AND INFRASTRUCTURES
Analyses show the effects of new aircraft technologies and energy systems. Decarbonisation roadmaps outline, for example, pathways for introducing hydrogen at (medium-sized) airports.

CAPACITIES
We assess future utilisation of runways worldwide and identify capacity bottlenecks. We also investigate the use of closely spaced parallel runways to increase capacity.

BOIL-OFF LOSSES
We research how to reduce and recover these losses, as up to 15 percent of liquid hydrogen can evaporate during transfer.

BIRD STRIKES
A new system can warn of bird strikes and delay take-offs accordingly. We also work on forecasting critical seasonal bird migration patterns.

WAKE TURBULENCE
Deflection walls (Plate Lines) alongside the runway help dissipate the wake turbulence of landing aircraft more quickly.

EFFICIENT FLIGHT GUIDANCE
This reduces noise and environmental impacts during descent and landing. This work also includes smaller airports.

ASSISTANCE SYSTEMS
Precision-guidance tools for aircraft support the energy-management system and reduce noise and fuel consumption.

DIGITAL AERONAUTICAL COMMUNICATIONS
We are involved in the development of LDACS (L-band Digital Aeronautical Communications System), the upcoming standard for digital, terrestrial aeronautical communications.

REMOTE TOWER
These monitor airports using cameras and control them remotely. This also enables smaller airfields to be operated more flexibly.

MAINTENANCE AND REPAIRS
We research digital diagnostic technologies and robotic assistance systems. This makes maintenance processes faster, safer and more efficient.

PROTECTION AND RESILIENCE
New systems and concepts enhance security against cyberattacks and crises such as extreme weather.

INSPECTIONS
Our computational models predict when components need inspection. This can help to avoid unnecessary repairs.

AIR TRAFFIC CONTROL
Automation reduces the workload of air traffic controllers, for example through speech recognition. We research how AI and humans can work together safely, reliably and effectively.

Understanding, managing and shaping air transport

ECONOMICS
We conduct economic analyses of the drivers and impacts of air transport, as well as the role of airports as engines for regional development and growth. We also consider effects on society, value added and employment.

REGULATION
With economic analyses, we support policy decisions such as taxation, slot allocation and night-flight restrictions. We identify options for more efficient regulation – including efficiency potential and disincentives.

MARKET POTENTIAL
We compare the performance of different airlines and airports and optimise processes and business models.

AIRPORT MANAGEMENT
We research the collaboration between airports, airlines, ground handling services and air traffic control, as well as ways of improving the performance of the overall system. 'What-if' analyses help in managing exceptional situations.

Take a deep breath!

Researchers test newly developed procedures and support systems for towing aircraft to the runway in the tower simulator, together with air traffic controllers.

Image: DLR

Reducing the emission of climate-damaging gases and slowing climate change are among the greatest challenges of our time. This becomes particularly demanding at locations where many transport routes converge. Airports are highly sensitive hubs, subject to strict safety requirements and tightly scheduled operations. Approximately 83 percent of emissions at airports are generated by flight operations and passenger transport, but the airport itself, its buildings and the technology used contribute as well. Germany's airports have set themselves the ambitious target of becoming climate-neutral by 2045.

An immediate climate impact

Since 2023, the DLR project 'THOR – Towards Zero Emission Airports' has been investigating how this goal can be achieved. The focus is not on distant future technologies or basic research, but on concrete, actionable measures. The approach: existing technologies are intelligently combined, operational processes are oriented around climate impact, and all effects are considered holistically.

Direct to the project results

The aircraft themselves provide a telling example. The engines of modern aeroplanes are true powerhouses. An Airbus A320, for instance, delivers a total output of approximately 60,000 horsepower. Yet this enormous power is not needed when taxiing on the ground: on their way to the runway, aircraft rarely move any faster than cars in city traffic. So why not use existing aircraft tugs to tow planes to the runway? While this sounds simple in theory, it is highly complex in practice. Aircraft must start their engines well in advance of take-off to check that all operating parameters are in the green. At the same time, sufficient personnel and vehicles are needed to cover the often long distances on the airport grounds. Through new planning methods and intelligent coordination of towing operations, DLR was able to demonstrate in an extensive trial campaign, together with air traffic controllers, that the concept works. At Hamburg Airport, for example, it could save approximately 28 tonnes of carbon dioxide daily.

Intelligent use of SAF

Another example illustrates just how significant small changes can be. Sustainable aviation fuels (SAF) are widely regarded as key to more climate-compatible flying. However, they are currently only available in limited quantities. For this reason, the EU initially mandates a two-percent SAF blend, which is set to gradually increase to 70 percent by 2050. Researchers in the THOR project took a different approach: instead of distributing the scarce fuel evenly across all flights, they investigated where it would have the greatest impact. The result: by using SAF specifically on the five percent of flights with the highest climate impact, emissions could be reduced by approximately 30 percent more than with an even distribution.

In addition to these measures, researchers from participating DLR institutes have examined many other approaches: from the use of hydrogen at airports to environmentally optimised management of delays and cancellations, to reducing energy consumption in terminals. All of these elements were finally combined into a comprehensive plan for the future – a roadmap for the climate-neutral airport. This plan was discussed and further refined in collaboration with the German Airports Association (Arbeitsgemeinschaft Deutscher Verkehrsflughäfen; ADV), major German airports such as Cologne/Bonn, Munich and Berlin, and various airlines.

The results show that the path to climate neutrality is not a single major breakthrough, but a multitude of carefully considered, coordinated steps.

Florian Piekert has spent many years at the Institute of Flight Guidance, researching how airports can be made more efficient and resilient through smart management, decision-making and safety concepts.

“Our energy system must become more independent!”

Carsten Agert on the security and resilience of our energy system

Interview by Denise Nüssle

Image: DLR

Over the past 25 years, our energy system has undergone a fundamental transformation, primarily due to the expansion of renewable energies and the phase-out of nuclear power. At the same time, the wars in Ukraine and Iran highlight just how dependent Germany and Europe remain on oil and gas. In times of crisis, sharply rising energy prices place enormous strain on the economy and society. Added to this are new threats such as sabotage and cyberattacks. In the face of these challenges, what is needed to make our energy system safer and more resilient? Carsten Agert, Director of the DLR Institute of Networked Energy Systems, discusses this in the interview.

What do we mean by a secure and resilient energy system?

The energy system is an essential foundation of our society. It is only during major outages – such as the one in Berlin earlier this year, caused by a cable fire – that we realise how indispensable a functioning energy supply really is. That is why we must focus more on the resilience and security of our energy system. Resilience refers to the ability to compensate for disruptions, maintain functionality even under difficult conditions, and learn and adapt over time. Security, in this context, means protection against threats such as cyberattacks or sabotage.

The energy system encompasses far more than just electricity – a fact we often forget. It is also vital for mobility and communication, enabling the transport of goods and providing us with heat. The more we replace fossil fuels with electricity from renewable sources, the more efficiently and across sectors we can operate: electricity, heat, gas supply and the associated areas of consumption – most notably transport – all become closely intertwined. This gives us greater flexibility in energy use, extending deep into industrial processes – something that was not possible with the previous parallel structures for electricity, oil and gas.

What has changed in recent years, and what challenges does this bring up?

Essentially, the focus in developing our energy system has shifted. Until recently, the main concerns were affordability and climate protection. Now, security and resilience have also moved to the top of the agenda. This presents us with a dual challenge, as the transformation of the energy system is taking place while it remains in operation. Nevertheless, there must be no major outages. Given the current security situation, we also need to engage much more seriously with the protection of facilities and infrastructure.

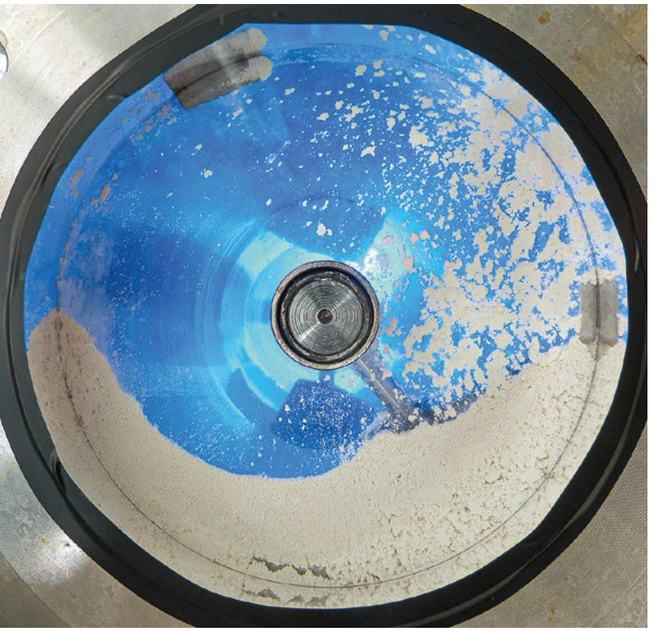
Compared to the past, our energy system now involves a greater number and variety of actors generating and feeding electrical energy into the grid. The share of energy from renewable sources can fluctuate daily, seasonally and due to weather conditions. As a result, we need more and more flexible storage solutions and a modern infrastructure. This infrastructure must intelligently connect the components of the system with one another and with other sectors – such as transport and industry. Managing and regulating such an energy system is also considerably more demanding.

At the same time, political decisions are pending on the strategic direction we take, both technologically and economically – for example, on the hydrogen economy and heat supply. Investments in the energy sector are long-term commitments, and projects cannot be delivered overnight. Facilities and infrastructure will remain in operation for decades and will usually only pay off in the medium to long term. That is why reliable regulatory frameworks are essential.

CARSTEN AGERT

has been active in energy research for 28 years and, as a physicist, has worked on topics including solar cell materials, fuel cell systems, electrical energy technologies and system analysis. He regularly advises policymakers at the federal and state level on energy-related decisions in various capacities. For many years now, he has relied on fossil fuels for just one thing: his Indian Motorcycle.

Carnot batteries store electricity in the form of heat. DLR and the CHESTER consortium (Compressed Heat Energy Storage for Energy from Renewable sources) are constructing the world’s first Carnot battery based on steam power processes.



View into the reactor of a thermochemical quicklime storage system (left). Heat is released through the chemical reaction of quicklime and water. With such systems, buildings can be heated flexibly and independently of oil and gas.

DLR is researching various applications for hydrogen, for example the operation of fuel cells. Hydrogen is suitable both for energy storage and for efficient use in industrial settings (right).

Diesel generators are currently often used in disaster response operations. As part of the RESCUE project (below), a consortium of industry and research is developing an emergency power generator based on a fuel cell that can run on either hydrogen or methanol. DLR is testing this in collaboration with the THW.

Image: p. 42 (bottom) THW

Many of our studies and research projects culminate in what we call, in technical terms, 'transformation pathways': scientifically grounded assessments of the options available to us for further developing our energy system. In doing so, we provide policymakers and industry with a sound basis for making robust, future-proof decisions.

What significance do raw materials and their availability have?

Many future technologies in the energy and mobility sectors require a wide variety of resources and raw materials. These include usable water and suitable land, as well as rare earths and metals such as lithium. The latter are scarce in Germany and Europe and we must purchase them on the global market. Here, we need to do far more to prevent structural dependencies. The same applies to manufactured products. We import a considerable share of systems and components into the European Union, such as solar panels, battery cells and wind turbines, that already contain these scarce raw materials. A comprehensive resilience strategy must therefore consider that supply bottlenecks can occur not only at the raw material level but also at other points along the value chain.

At DLR, we are investigating the availability and recycling potential of key raw materials. To do this, we are developing highly complex computer models that allow us to simulate which raw materials could face supply shortages under certain conditions, and what dependencies and economic consequences might result.

What must our society, policymakers and industry be prepared for?

Geopolitical conflicts show that we must consider energy security, the long-term management of natural resources and economic stability together. Resilience means reducing our dependence on individual supplier countries or critical raw materials. At the same time, we need to diversify our energy sources and trading relationships and strategically expand our own production and infrastructure capacities. We must also design energy systems that can better absorb short-term shocks, such as supply disruptions, price spikes or damaged infrastructure. At DLR, for example, we have developed detailed models of electricity and gas networks that we use to research future, more resilient system architectures. We are also actively engaged in the increasing automation and digitalisation of our electricity grids, developing methods and design strategies that enable crisis-proof operation.

The economic viability of an energy system is just as important. A system is not resilient if it is not financially sustainable or competitive in the long term. And we must not forget: social acceptance and public participation are also fundamental.

> "Compared to fossil raw materials, sunlight and wind are far more widely distributed worldwide. This gives us considerably greater flexibility in choosing our trading partners."
>
> **Carsten Agert, DLR Institute of Networked Energy Systems**

What role do fossil fuels and renewables play in the resilience of our energy systems?

By far the most important factor in a secure and resilient energy system is the energy itself. Every kilowatt-hour we generate ourselves makes us a little less dependent on global risks. Sunlight and wind are resources available in abundance in Germany and across Europe. They are readily available – regardless of acute geopolitical crises, trade wars or disrupted supply chains.

As a densely populated industrial nation, we will still not be able to meet our entire energy demand domestically. But that is not the primary goal. Rather, it is about working with our European partners to reliably interconnect electricity and hydrogen grid infrastructures, and establish energy import agreements with reliable third countries. Compared to fossil fuels, sunlight and wind are far more widely distributed worldwide. This gives us considerably greater flexibility in choosing our trading partners.

In terms of security and resilience, is a decentralised or a centralised energy system better?

Neither is inherently superior. Decentralised structures with regional, renewable generation, storage and flexibility options increase resilience against disruptions and reduce dependence on individual large-scale installations. In a crisis, they could allow sections of the grid to continue operating independently on a temporary basis. However, this is technically extremely demanding and is therefore a focus of our research.

Centralised structures, such as inter-regional grids, large storage facilities and power plants, offer advantages in terms of scale and

efficiency, and can compensate for regional fluctuations. This enhances the stability of the overall system, particularly during major supply shortages or seasonal variations such as prolonged periods of low wind and solar power. High resilience and security are therefore best achieved through an intelligent combination of both approaches: decentralised diversification combined with inter-regional connectivity – including at the European level.

How do DLR's current research projects contribute to making our energy system more resilient and secure?

We are investigating, for example, how energy systems and subsystems can be designed and operated to be as resistant as possible to external influences – and we are developing the technologies needed to achieve it. In particular, this includes sector coupling between energy and transport. We also analyse how extreme situations in the energy sector can affect markets and supply chains, allowing us to reliably assess the key bottlenecks and vulnerabilities in the system – right up to a pan-European, cross-sector level. To do this, we use highly complex computer models and simulations developed at DLR.

Another example is the development of technologies that minimise the likelihood of blackouts. Should a blackout nevertheless occur, these technologies enable a rapid 'black start' – even in increasingly complex energy systems. This refers to the ability of power stations and storage facilities to restart independently after a complete power failure, without an external energy supply from the grid, enabling the restoration of the grid.

Together with the DLR Institute of Engineering Thermodynamics, we are currently working very concretely and practically with industry, academia and civil protection – specifically the Federal Agency of Technical Relief, or Technisches Hilfswerk (THW) – to develop and comprehensively test a reliable and efficient 'dual-fuel system' for use in natural disasters. A central component of this innovative emergency power unit is a fuel cell specially designed for this purpose. Its key feature is that it can run on either hydrogen or methanol, providing two fuel options in an emergency – each with very different advantages and disadvantages in terms of production, storage and transport.

At present, the energy supply of many civil protection facilities still relies heavily on fossil fuels. Reducing this dependence requires new, fail-safe infrastructure that is, where possible, capable of operating off-grid. The advantage of this fuel cell system is its high efficiency and flexibility in fuel and power. Our goal is to have developed a prototype of such a system by the end of the project – all integrated into an easily transportable container.

The safety of energy grids is tested in the control centre of the DLR_NESTEC research laboratory.

Image: DLR

Denise Nüssle is a press editor at DLR, reporting mainly on research in the fields of energy and transport. Even during her studies, she was interested in the connections between security and energy.

Image: DLR

The future starts here

The INNOspace Masters competition

by Daniel Plaßmann

Star Trek fans know the drill: if you get injured on the starship Enterprise, you head to the sickbay. There, your wound is closed in seconds with a skin regenerator. Reality, however, looks rather different: in zero gravity, open wounds heal very slowly. If someone is injured on the International Space Station ISS or during a potential Mars mission, serious complications can arise.

Yet the solution to this problem is closer than you might think. It may not be as elegant as in Star Trek, but for the 2020s, it is quite impressive. Its name is StellarHeal, and it involves filling wounds with haemostatic fibres and specialised cells, allowing them to heal quickly and cleanly.

The idea is so promising that it is a winner of the annual international INNOspace Masters innovation competition. Fellow winners include FibreCoat's ultra-lightweight shield which protects people and electronics from cosmic radiation in space; the Plasma Rocket Company's electric high-thrust plasma propulsion system for missions to Mars; and Yank Technologies' concept for wirelessly charging lunar and Martian rovers, even in the most challenging conditions.

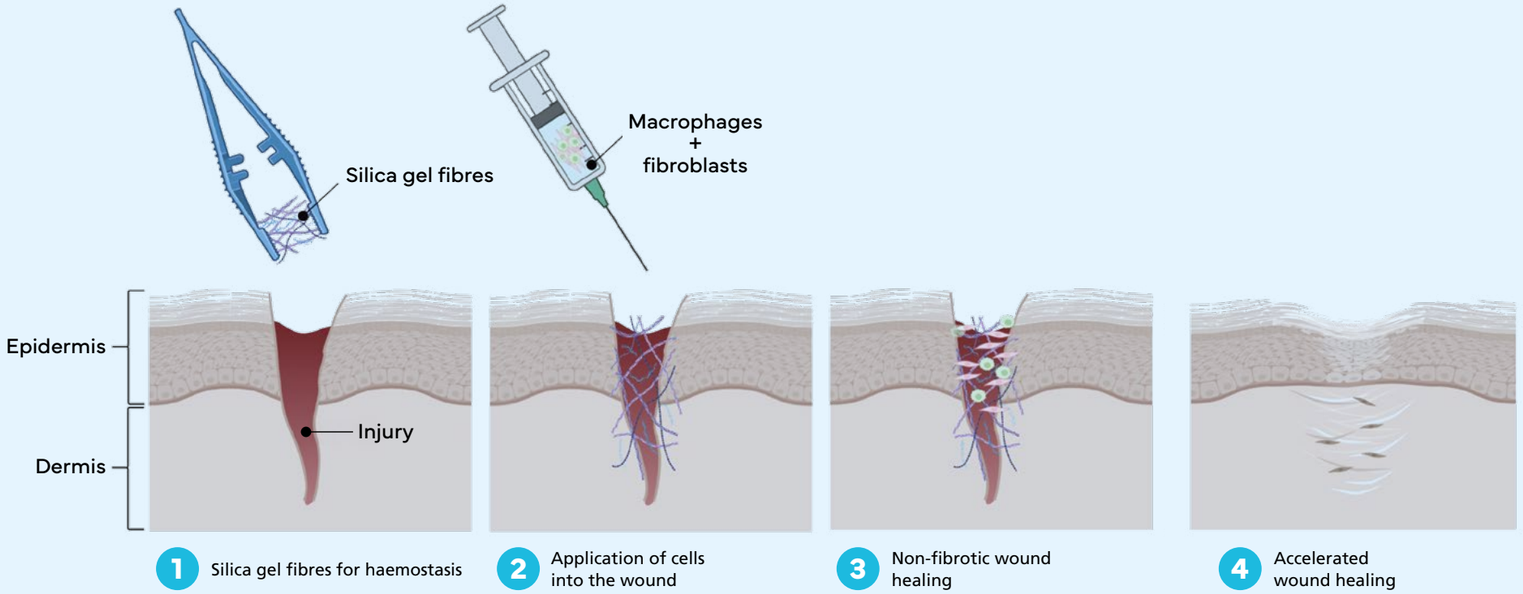
One competition, many themes

The German Space Agency at DLR launched the INNOspace Masters competition in 2015 and is currently supported in its implementation by DLR Projektträger and the Institut für qualifizierende Innovationsforschung und -beratung (IQIB; in English the Institute for Qualifying Innovation Research and Consulting). Since then, the competition has awarded a total of 14.17 million euros in prize money and funding, producing more than 130 winners. Currently, around 20 new winners are added each year: in the six different competition categories, or 'challenges', the top three winners are selected annually. The most prestigious award is that of 'Overall Winner'.

Winners of the German Space Agency at DLR Challenge in the 2024 INNOspace Masters competition at the final event in Berlin; on the left, the StellarHeal team.

EXPLORE
INNOspace Masters

How wound treatment works in microgravity



Ideas submitted span specific space technologies, medicine, environmental protection, energy and mobility, as well as security, software and digitalisation. Submissions include concepts for transferring technology and know-how from other industries into the space sector (spin-in) and from the space sector to other industries (spin-off). The StellarHeal example illustrates this well: while the wound-healing procedure is being developed specifically for space, it can also help treat people with chronic wounds on Earth – a classic spin-off.

StellarHeal's invention uses haemostatic fibres and specialised cells to heal wounds quickly and cleanly – for use in space and here on Earth.

Innovations for space drive progress on Earth

The German Space Agency at DLR launched the INNOspace® initiative back in 2013. "We founded INNOspace because we recognised that the innovative power of space can have an impact far beyond the sector itself," recalls Franziska Zeitler, Head of the Innovation and New Markets department at the German Space Agency at DLR. "I am particularly pleased that we have succeeded in making technologies from space usable for new applications on Earth – and at the same time bringing innovative ideas from other sectors into space. This has accelerated technology transfer, opened up new markets and strengthened Germany as a hub for innovation and space", Zeitler continues. The initiative includes conferences, expert workshops, and the INNOspaceEXPO 'ALL.täglich!' – a travelling exhibition showcasing innovations from space for Earth, such as a technology for detecting planets that also enables early detection of skin cancer. Three technology and cooperation networks that promote collaboration between the automotive, agricultural and health sectors with the space industry are also part of the initiative.

The INNOspace Masters is another key component. The German Space Agency at DLR currently organises the competition in collaboration with ESA, the ESA Business Incubation Centres in Germany, the ESA Business Applications and Space Solutions commercialisation programme and the companies Airbus, OHB and Mercedes-Benz. Participants can submit their ideas in one of six challenges. Eligible participants include large companies, SMEs, start-ups, research institutions, universities and individuals – depending on the challenge, from Germany, Europe and worldwide. Winners are announced at the final event in Berlin at the end of the year, with total funding of 2.4 million euros awarded. "While the prize money and funding play a significant role," explains Anja Simon, Project Manager of INNOspace Masters at the German Space Agency at DLR, "our competition focuses on the shared journey of winners and challenge partners to turn ideas into market-ready applications or services."

Graphic: p. 46 ILK Dresden; Photo: p. 47 David von Becker

Journey to innovative ideas

In 2026, the German Space Agency at DLR is organising the competition for the third consecutive year in cooperation with IQIB and DLR Projektträger. While IQIB is responsible for running the competition and project coordination, DLR Projektträger handles marketing, communication and organising the final event. To make it as easy as possible for participants to submit their ideas and for partners to evaluate submissions efficiently, a new online platform has been set up. In 2026, 864 participants from 38 countries submitted 313 project ideas – a new submission record for the third year in a row! "In this international competition, it is particularly challenging to reach and motivate researchers and innovators worldwide to participate," explains Rebekka Freitag-Li, Project Manager at DLR Projektträger. "To achieve this, we not only activated the established networks of DLR Projektträger across all five continents, but also successfully expanded the competition's communication and promotion into the digital sphere."

ATTEND THE FINAL EVENT

The final event will take place on 12 November 2026 at the Futurium in Berlin. In addition to honouring the winners, a special highlight awaits: the 10th anniversary of INNOspace Masters. Register here:

Direct to the INNOspace Masters website

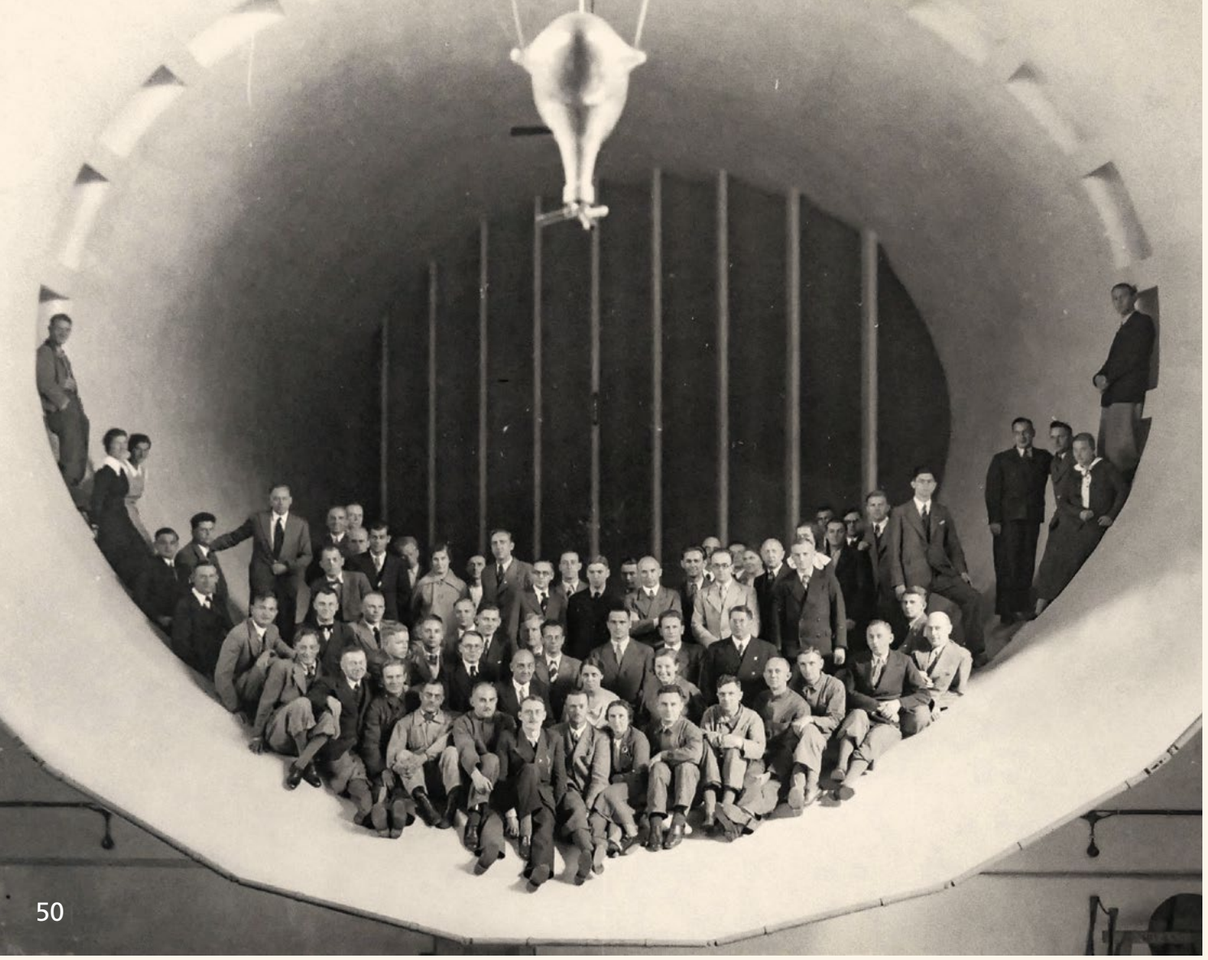
Together, DLR Projektträger and the German Space Agency at DLR coach the winners to help them present their ideas in the best possible way – both to the jury and the audience at the final event. The top three from each challenge come to Bonn for the 'Winner's Pitch', where both the German Space Agency at DLR and DLR Projektträger are based. The two-day event has three objectives: the first day focuses on pitch training; on the second day, the Overall Winner of the competition is determined. To this end, participants present their ideas as pitches to a jury representing all challenge partners. Both days also serve to help winners network with each other. "For us as a team, it was a fantastic experience," summarises Felix Schmidt of FibreCoat, one of the two Overall Winners in 2025. "We particularly enjoyed the pitch training with the experts, where we could test how convincing our project arguments were based on their feedback."

Incidentally, the songs to which the winners of the individual challenges take the stage at the final event are the theme tunes from various Star Trek series. Perhaps a small incentive to implement ideas that seem like the future today – just like StellarHeal.

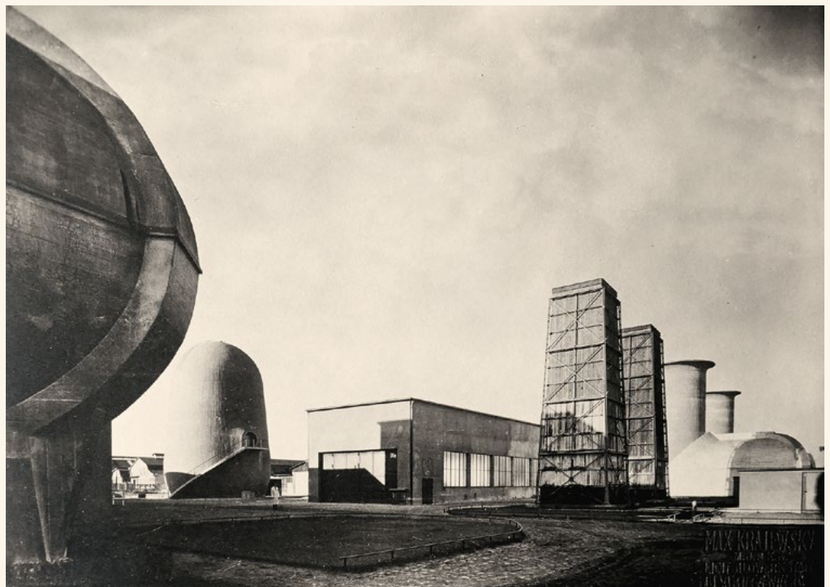
Daniel Plaßmann is a scientific officer at DLR Projektträger and a huge science fiction fan in his private life.

Smart and single

If you're not deeply immersed in railway research, you might not notice what's missing from this image: an axle shaft that rigidly connects the two wheels. The importance of this component is often most noticeable – and audible – on tight bends, where the outer wheel has a longer path to travel than the inner wheel and so needs to turn faster, but is held back by its connection to the inner wheel. The result is wear on the wheel and rail, as well as frequent loud squealing noises. Thanks to advanced mechatronics, the wheels of the new railway running gear shown here can be controlled independently of one another, with high precision. This primarily saves space: without an axle shaft, the vehicle floor can be positioned at platform level to provide step-free access for passengers. It also saves weight: the structure and materials used, including in the drive motors, are optimised to be as light as possible. Less weight means lower energy consumption and a greater payload capacity. This prototype was developed and built by the DLR Institute of Vehicle Concepts, with initial tests on the test bench in Oberpfaffenhofen proving a success.



Employees of the German Aviation Research Institute (Deutsche Versuchsanstalt für Luftfahrt; DVL) in the large wind tunnel, circa 1937



The DVL site in Berlin-Adlershof, also in 1937: a large wind tunnel (far left), a spin wind tunnel (the concrete 'egg', left) and a soundproofed engine test stand (far right). These three test facilities were built on the DVL site between 1932 and 1936 and still stand today.

Images: DLR

A contribution to collective memory

Re-examining the history behind DLR

by Julia Heil

Today, DLR is one of the largest non-university research centres in Germany. More than 11,000 people work here across a wide variety of disciplines. They are also part of a long research tradition, as DLR looks back on almost 120 years of history with predecessor organisations that held similarly prominent positions. When the Institute of Model Testing of the Motorised Airship Study Society (Modellversuchsanstalt der Motorluftschiff-Studiengesellschaft; MVA) was founded in Göttingen in 1907, it was one of the world's first institutions for aeronautical research. Ludwig Prandtl, who developed his boundary layer theory in 1904 – a crucial foundation of fluid dynamics – was appointed its director. The MVA later became the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA). Here and in other predecessor organisations, the theoretical and experimental foundations were explored without which modern aviation would not be possible. One example is the swept wing, now standard on commercial aircraft.

However, these institutions were also active participants across eras marked by war and injustice. At times, military and political interests severely restricted their scientific autonomy. A number of studies on specific aspects and questions of this period already exist, such as Helmuth Trischler's postdoctoral thesis 'Luft- und Raumfahrtforschung in Deutschland 1900–1970: Politische Geschichte einer Wissenschaft' (in English, Aerospace Research in Germany 1900—1970: Political History of a Science). However, until now, a comprehensive study that also considers the archival material released since the early 1990s has been lacking. "As DLR, we are committed to our responsibility not only to document our past but also to learn from it," says Anke Kaysser-Pyzalla, Chair of the DLR Executive Board. "Our goal is to process this history for ourselves and for the public, making it transparent. In doing so, we want to raise awareness of the challenges facing science and technology in different eras." In 2023, a project was launched to examine the history of DLR, with the aim of providing the most complete and comprehensive analysis possible of the years up to 1945. The first results are now available.

From the earliest beginnings to the end of the Second World War

The research period begins in 1907 with the founding of the MVA. "To understand how aeronautical research developed in Germany, it is necessary to also examine the history of DLR's predecessors," says Jessika Wichner, who heads DLR's Central Archive and, together with Jens Wucherpfennig and Daniel Beckmann, is responsible for implementing this historical research project on behalf of DLR. Beckmann is responsible for DLR's corporate design, while Wucherpfennig oversees communications at the Göttingen and Hanover locations. "The results are more extensive than we anticipated

because the historians involved unearthed new material in external archives that we were previously unaware of," Wucherpfennig adds.

In the eight sub-projects of the historical research, which were commissioned across Europe, researchers are examining both specific time periods and the history of DLR's predecessor organisations during the First World War, the Weimar Republic and the National Socialist era. These sub-projects were carried out by historical research agencies and individual historians. An advisory board of volunteers, established specifically for the project, ensured the transparency and independence of the research findings. To this end, regular meetings were held with the researchers and DLR. Some advisory board members hold senior positions in museums or as university chairs.

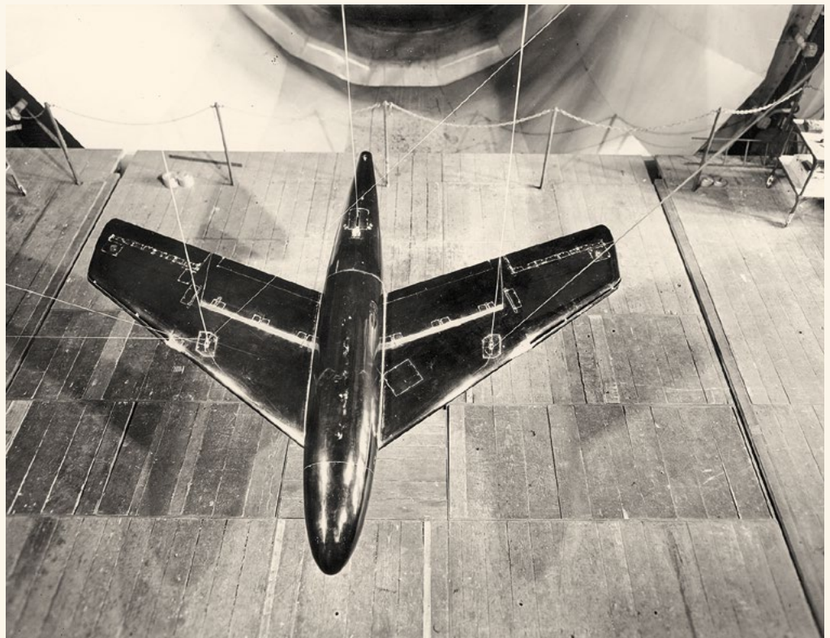
Closing gaps in research

"While we cannot learn directly from history, the findings of historical research and projects of this kind help us recognise parallels, for example in the relationship between politics and science," says Helmuth Trischler. "This knowledge flows into the collective memory of our society and, in particular, helps to protect the resilience of research and the autonomy of science against political interference, which we are unfortunately witnessing again worldwide today." The historian of technology was responsible for the research department at the Deutsches Museum in Munich for many years and worked on two sub-projects as part of the historical analysis. Four sub-projects have already resulted in comprehensive monographs, with a fifth due to be completed by the end of 2026. The aim was to provide as comprehensive a portrayal as possible of each period, presenting both the scientific and technical achievements as well as the integration into the Nazi regime. "Our aim is not to topple luminaries such as Ludwig Prandtl from their pedestals or deny their achievements, but rather to take a more nuanced view of the interconnections between science and politics," adds Trischler.

History for the future

In addition to the five monographs, two illustrated books have been produced during the course of the project. These are scheduled for publication by the end of 2026. The results of another sub-project form the basis for the concept of an exhibition and accompanying catalogue. From summer 2026, the printed monographs will be available from specialist scientific publisher Cuvillier Verlag, and from 2027 available as a free, open-access download from their website. The entire project on the historical examination of DLR's history up to 1945 is set to be completed by the end of 2026.

Julia Heil works in communications at DLR. As an avowed bookworm, she has a particular fondness for historical topics.



Model of a Messerschmitt Me 263 with swept wings in the AVA wind tunnel, 1941 (left)

Two researchers in the wind tunnel of the Hermann Göring Aviation Research Institute (Luftfahrtforschungsanstalt Hermann Göring; LFA), 1930s (right)

Images: DLR

Sub-projects of DLR's historical research

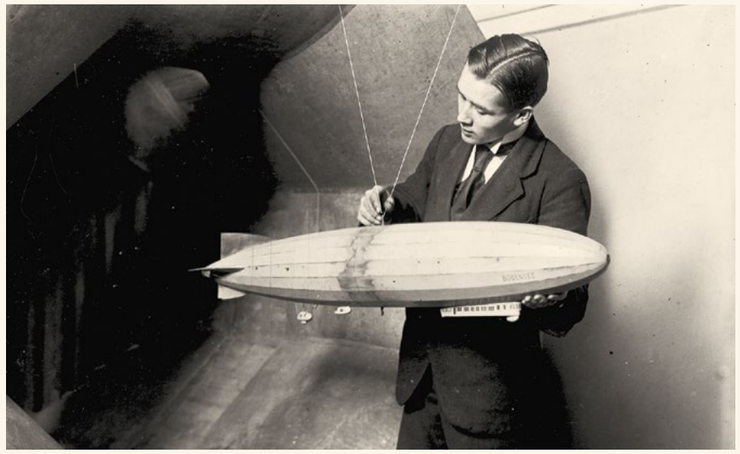
These four monographs will be available in printed form from summer 2026 (in German), and a fifth from 2027.

Between World War I, the Treaty of Versailles and rearmament: military and civil aviation research at the Aerodynamics Research Institute in Göttingen, 1918 to 1933

(Monograph by Michael Kamp)

After the First World War, the victorious Allied powers imposed a series of prohibitions and restrictions on Germany through the Treaty of Versailles to prevent military rearmament. These also affected aviation and applied to the Institute of Model Testing of the Motorised Airship Study Society, founded in 1907 but renamed the Aerodynamics Research Institute (Aerodynamische Versuchsanstalt; AVA) in 1920. Despite this, the DLR predecessor continued its research activities, as demonstrated by the results of this study.

Militarily relevant work continued indirectly through civil aviation projects, industrial collaborations and even related fields such as automotive engineering and wind energy research. As a result, aerodynamic knowledge was not only preserved but further developed during the interwar period. This was made possible by institutional and personnel continuity within the organisation, which formed the basis for the subsequent expansion of aviation research under National Socialism. The AVA was closely networked with government bodies, military actors, industrial companies and scientific institutions. There was also broad consensus among politicians, scientists and sections of society that aviation was strategically important for Germany's national strength. Overall, the history of the AVA illustrates how closely intertwined scientific research, political frameworks and military interests were during the interwar period.



Model of the LZ 120 Bodensee airship in the AVA wind tunnel, circa 1920. It was the first airship to be built after the First World War. In 1921, it had to be handed over to Italy as part of reparations.

Images: DLR

Research and testing for a nation of aviation: the German Aviation Research Institute during the German Empire and Weimar Republic

(Monograph by Helmuth Trischler)

The German Aviation Research Institute (DVL) was a central institution for aviation research from 1912 to 1945. From its founding, it was clear that it was intended to assume the role of a national research and testing institute. The DVL combined scientific findings with technical testing tasks. During the First World War, the institution came under considerable military influence, which restricted its scientific autonomy. Only toward the end of the war were parts of its research operations expanded again. Nevertheless, an institutional and financial crisis loomed for the DVL after the war. With the economic stabilisation of the Weimar Republic, organisational and personnel restructuring began. During this period, the institution recruited qualified scientists and established an excellent reputation in aviation research. For example, all prototype testing for new aircraft was conducted through the DVL.

Persecution, human experimentation, forced labour: injustice in the predecessors of the German Aerospace Center, 1933 to 1945

(Monograph by Christian Rohrer, Ina Deppe, Robert Kieselbach and Christian Schwartz)

The predecessor organisations of DLR were also involved in carrying out forced labour and cruel human experiments. The research carried out by the Institute of Aviation Medicine within the German Aviation Research Institute (DVL) was closely linked to military aviation requirements. Self-experiments and experiments on volunteer test subjects, such as high-altitude testing, were conducted here. More gravely, some aviation physicians were also involved in altitude and hypothermia experiments carried out on prisoners from the Dachau concentration camp. The study also describes how DLR's predecessors treated Jewish employees and those persecuted for political reasons. The use of forced labour is also addressed: the study reconstructs the scale, origins and areas of deployment of foreign labourers in the facilities of DLR's predecessors. It also analyses camp structures and living and working conditions, as well as forms of control, repression and exploitation. The combination of institutional analysis with biographical case studies brings to light both structural frameworks and individual scope for action and responsibility.

Higher, faster, further – slower: innovations and their processes in the predecessors of the German Aerospace Center, 1933 to 1945

(Monograph by Matthias Georgi, Lukas Wollscheid, Johannes von Wintzingerode and Marc Schmidt)

During the Nazi era, research carried out by DLR's predecessor organisations was closely integrated with military and defence policy objectives. This is demonstrated by the findings of this study. Research areas such as the development of swept wings for high-speed aircraft, work on jet engines and investigations into rotary-wing technology make it clear that scientific research was closely linked to industrial collaborations and military requirements. The institutions also researched applications with a distinctly military focus, such as the development of nitrous oxide injection ('GM 1') to boost the performance of aircraft engines at high altitudes or acoustic location techniques. Many of these projects were a direct response to specific demands of aerial warfare and were frequently carried out in close collaboration with industrial companies and military authorities. In addition to basic research, DLR's predecessor institutions were involved in various ways in the development and testing of new technologies for aerial warfare.

Aviation research under National Socialism: mobilisation of a scientific field

(Monograph by Helmuth Trischler)

This study traces the expansion of DLR's predecessor institutions into by far the largest research complex in the 'Third Reich'. It focuses first on the dynamic interplay of cooperation and competition among the predecessor institutions and, second, on their entanglements with politics and the military, industry and society. The results reveal a nuanced picture of the conditions, mindsets and practices involved in generating and applying aviation-related knowledge during the Nazi era.

The history of the DVG from 1908 to 1945 and the development of the FFO from 1937 to 1945

(Illustrated book by Markus Schreiber)

This illustrated book documents, through some 200 photographs and texts, the history of the Gräfelfing Wireless Telegraphic and Air Electricity Test Station (Drahtlostelegraphische und Luftelektrische Versuchsstation Gräfelfing; DVG) and the Oberpfaffenhofen Aeronautical Radio Research Institute (Flugfunk Forschungsinstitut Oberpfaffenhofen; FFO). The focus is on the work of their founder, physicist Max Dieckmann, and the development of aviation radio, direction-finding and radar research. The book combines visual sources with new research findings on institutional development, particularly shedding new light on the role of Dieckmann.

Key players, experimental facilities and equipment in the predecessor organisations of DLR, 1933 to 1945

(Illustrated book by Andreas Lehmann and Thomas Prüfer)

This illustrated book focuses on institutions such as the AVA, DVL, DFL/LFA, DVG and FFO. It combines visual sources with a thematic overview of key research areas – ranging from flow research and engine research to radar and aviation medicine – and places them in the context of Nazi aviation policy.

The joinery workshop at the Hermann Göring Institute of Aviation Research in Braunschweig, circa 1940

The DVL aircraft hangar in Berlin-Adlershof with some of the institute's research aircraft (1941/42). In the background, the former Johannisthal airfield is visible.

Images: DLR

"As DLR, we are committed to our responsibility not only to document our past but also to learn from it. Our goal is to process this history for ourselves and for the public, making it transparent. In doing so, we want to raise awareness of the challenges facing science and technology in different eras."

Anke Kaysser-Pyzalla,
Chair of the DLR Executive Board

Collaborative research: German aviation science in the context of rearmament, 1933 to 1945

(Exhibition and catalogue by Andreas Lehmann and Thomas Prüfer)

What was the relationship between German aviation research and war and armament? This question is the focus of the exhibition and accompanying catalogue, developed as part of this sub-project. Organised chronologically, it covers the period from the end of the First World War through rearmament in the 'Third Reich' to the Second World War and the post-war era. Case studies, documents and research findings illustrate the interplay between science, the military and politics, highlighting just how closely these three were intertwined during this period.

From steam to space

Getting lost in Europe's most visited science and technology museum

by Rosa Jesse

In the Science Museum's 'Mathematics: The Winton Gallery', designed by Zaha Hadid Architects, an 1872 tide-predicting computer stands in front of a sculptural depiction of airflow around a plane.

Images: Sonny Malhotra

LANDING
Museum visit

The Science Museum in London is vast. I visited on a Saturday, not yet aware that a full-blown flu was brewing. Whether it was the fever or the whirlwind visit up and down the historic building and its more than 300,000 items on display, the experience was inspiring, exhausting and slightly surreal – I'll soon be going back.

Stepping inside, visitors first enter the Energy Hall, dominated by solid, heavy machines that powered the industrial revolution. Exhibition texts talk of the might of steam, and it's amazing to imagine hot clouds bringing these giant brutes to life.

Big questions for little people

Like steam, I rose to the top of the building, intending to then work my way down and see every inch. Where I really got into the science spirit was the interactive Wonderlab: The Equinor Gallery, designed for children and on the top floor. Here, a giant Tesla coil crackles with lightning, a rotating platform orbits children around a central star while charismatic 'explainers' talk them through the Solar System and dry ice whizzes across a pool, creating mesmerising shock fronts and trails. I lingered over a plume of air shooting up from a table, designing paper planes to hover in the stream – competing, and losing, against squealing children. Nearby, a dark magnetic liquid is manipulated into a spiky sphere and a loop of rope is flung up in a chaotic, unexplained dance: "... a mystery until someone like you can solve it."

Nothing's really explained in the Wonderlab and in there I craved more context. Yet, as my visit progressed, I missed this chance to observe strange things, poke them and guess at what's going on – a reminder that getting the 'right answer' fast isn't always the point.

Cakes, codes and careers

After a quick tour of three exhibits – Information Age, Making the Modern World and Medicine: The Wellcome Gallery – I developed a severe case of 'museum legs'. It is impossible to take in, or even convey, the sheer amount of science, stuff and stories in the Science Museum in one visit or one article. A stop in the Gallery Café was needed, which offers a 'Science afternoon tea': "bridging science and design in a culinary twist".

Cake-fuelled, I ventured down to Technicians: The David Sainsbury Gallery, showcasing the variety and appeal of careers in technical fields. I virtually welded a roller-coaster track, wrote a code that controls a real robot arm and learnt about jobs in film-set lighting and wind turbine maintenance. Signs throughout say "Join us" and "Our skills make a difference", and it's easy to imagine the inspiring impact on young visitors.

Space – my final frontier

My final stop was the Space gallery on the ground floor, where a rotating globe morphed from the Sun into the planets and moons of the Solar System, narrated by descriptions of their alien properties and humanity's plans to explore them. Here you'll find spacecraft, rocket engines, spacesuits, a piece of the Moon and a sample from asteroid Ryugu. Knackered and moved, I soaked it all in and thought back to the steam machines from earlier in the day, and yet light-years away.

If you're in London, the Science Museum is a must. But plan ahead, or risk sensory overload. Even on a Saturday, only the children's sections felt crowded – and they're well worth a visit even if you're officially an adult!

Rosa Jesse is an editor at EJR-Quartz, responsible for the English DLR magazine. She left the museum inspired to ponder a little more and resist immediately Googling.

SCIENCE MUSEUM LONDON

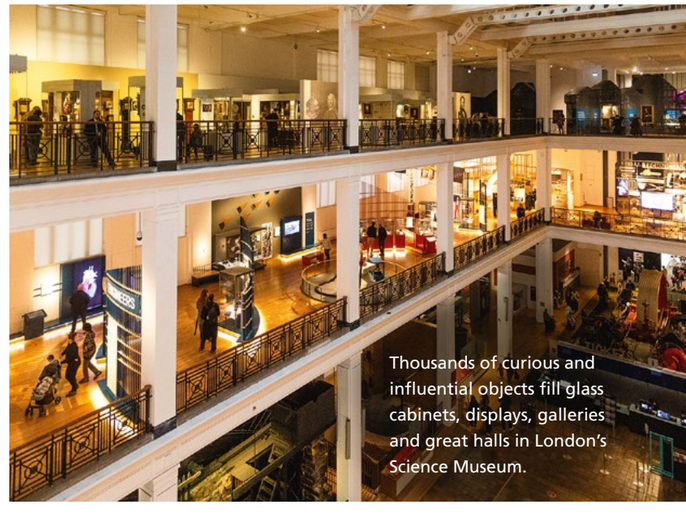
Address:
Exhibition Road,
South Kensington,
London, SW7 2DD
England

Opening hours:
Daily, 10 AM–6 PM

General admission price:
General admission is free, but advance online reservation is required.

Wonderlab prices:
£17 Day Pass / £24 Annual Pass.
Book early for discounts; family discounts apply.
Ages 3 and under go free.

Direct to the Science Museum website



Thousands of curious and influential objects fill glass cabinets, displays, galleries and great halls in London's Science Museum.

A light-as-popcorn ode to science

When a film begins with the premise that humanity must be saved from an alien threat, one expects the usual Hollywood disaster fare. However, the cinematic adaptation of **Andy Weir**'s bestseller **Project Hail Mary** takes a different path: here, the screen is not primarily a stage for generic special effects and a dazzling superstar, but rather a scientific laboratory – one in which two things are proven: the power of the mind and the strength of cooperation.

Ryan Gosling stars as scientist Ryland Grace. Light-years away from Earth, he wakes up alone and without memory aboard a spaceship. As his memory slowly returns, he recalls his critical mission: to prevent the extinction of all life on Earth caused by the dimming of the Sun. In this engaging and surprisingly entertaining race against time – gripping despite its two-and-a-half-hour runtime – Grace receives unexpected help, creating a team forced to go beyond themselves and save not one, but two worlds.

For all its entertainment, there is one downside – the trend towards excessive humour in modern blockbuster cinema, which doesn't spare this mission either. While the protagonist's gallows humour in Weir's novel serves as a coping mechanism, in the film it's omnipresent in that 'Marvelesque' manner: self-deprecating, sarcastic, dry. There are many moments where the existential threat to two civilizations is overshadowed by a laconic quip.

Image: 2025 Sony Pictures Entertainment

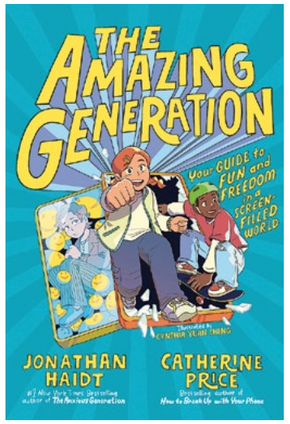
Nevertheless, 'Project Hail Mary' is a very solid sci-fi film, rich in real science and anchored by an intelligent story about a unique partnership – indeed, friendship – in space. Its greatest strength lies in its enthusiasm for the scientific method. Refreshingly, Gosling's Grace is not portrayed as an infallible hero, but as a 'real person' with fears, who must work by trial and error to reach his goal. Sandra Hüller, as the ESA official, embodies the bureaucratic relentlessness required for such a global project, adding narrative depth to the plot. In short, the film is sure to equally entertain sci-fi fans and those interested in hard science.

Philipp Burtscheidt works as an editor in DLR communications and loves it when science meets fiction in the cinema.

THE REAL PATH OF THE MARTIAN

'Project Hail Mary' is the second film adaptation of a science-fiction novel by American author Andy Weir, following 'The Martian' in 2015. To coincide with the cinema release of The Martian, DLR's Institute of Space Research created an animation from real scientific data collected by the Mars Express mission, tracing the route taken by the film's protagonist, Mark Watney, played by Matt Damon.

Direct to the video using Mars Express mission data



The rebellion will not be digitised

Once upon a time, malign wizards created glowing, hypnotic stones that stole people's time, creativity and confidence. Promising fun and connection, they convinced everyone – especially the young – to carry these stones everywhere they went. The promise was hollow. People grew lonelier and more anxious while the wizards became unimaginably rich.

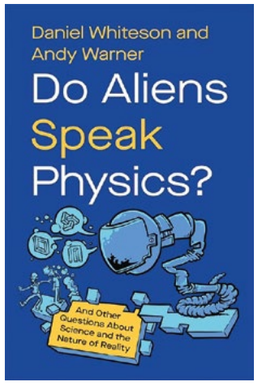
The **Amazing Generation** (**Penguin Books**), by **Jonathan Haidt** and **Catherine Price** and illustrated by **Cynthia Yuan Cheng**, mixes comic book, manifesto and self-help guide. It draws on Haidt's bestselling book 'The Anxious Generation', which argued that smartphones, social media and overprotective parents have led to rising youth mental health problems.

This version speaks directly to tweens, explaining the significance of this period for their malleable brains. The book's 'rebels' are convincingly cool, dumping their phones and gaining real friendships, skills, memories – and the freedom to make mistakes that aren't recorded forever.

It also exposes the dark side of social media companies and the attention economy, showing how apps use the same psychology as gambling machines and how effective they are: US teens now spend two and a half months on their phone every year. The tone stays empathetic rather than scolding, acknowledging that change is difficult while insisting that worthwhile things usually are.

Critics argue the evidence linking social media to youth mental health is contested, and that the book's emphasis on avoidance over moderation is just not realistic. Still, I found it moving and inspiring, if quite sad. No book can speak for all young people, but for those who do feel they're losing in a battle for their own time and attention, this is a rallying cry.

Rosa Jesse is a science editor responsible for the English edition of the DLRmagazine.



An alien's eye view on human science

First contact stories often treat communicating with aliens as difficult but inevitable – resulting in a flood of new information and wisdom that forever changes life on Earth. But is that a foregone conclusion? Might the first aliens we encounter be unwilling or simply unable to illuminate the dark recesses in our understanding? In **Do Aliens Speak Physics? (W. W. Norton & Company) Daniel Whiteson** and **Andy Warner** delve into the strange and speculative world of alien science and communication, exploring how such encounters might unfold – for better or worse.

Whiteson and Warner balance a light, humorous tone with rigorous scientific inquiry, synthesising ideas from across physics, biology, mathematics and philosophy to examine how fundamentally different alien science and communication could be from our own. Narrative examples of hypothetical alien-human encounters bring these abstract concepts to life, while expert quotes clarify the discussions – and disagreements – at their core.

In exploring the dizzying possibilities of alien science, they challenge us to reconsider our most basic assumptions: Would all civilisations use maths to describe physics? Would they have physics at all? How much have Earth's unique circumstances – its location, composition and our own evolution – affected our view of the Universe?

Ultimately, Do Aliens Speak Physics? offers hope for the future of human science, even if we never meet all-knowing aliens to explain the Universe's mysteries. By identifying possible blind spots and roads not taken in our own scientific journey, we could find the answers ourselves – long before aliens get here to show us.

Sarah Leach

Humanity, AI and the struggle for supremacy

Artificial Intelligence: powerful tool to enhance human potential or emerging overlord? It's an urgent question, particularly as AI systems grow ever more powerful and resource-intensive.

In **The AI Paradox: how to make sense of a complex future (Princeton University Press)**, **Virginia Dignum** offers a grounded perspective, addressing AI's actual capabilities and the biased assumptions shaping it. Dignum, a professor of responsible artificial intelligence at Umeå University, Sweden, examines AI through its apparent contradictions – intelligence vs wisdom, efficiency vs justice – and concludes: It's high time to discuss which AI risks are acceptable for individuals and society, and how we distribute them as well as the benefits.

AI, she argues, should not be a substitute for personal agency: "human and artificial intelligence are not only different but also serve different purposes". Machines cannot replace the critical human input of moral reasoning.

To avoid the trap of 'AI solutionism' – the belief that problems can be clearly defined and technology offers exact answers – Dignum implores us to not make AI development a technological arms race but to foster a culture of informed public oversight and democratic governance.

Whether such political oversight can prevail over the staggering sums of money being invested in it remains to be seen. Dignum is, ultimately, an optimist: "It's easy to fall into the trap of viewing AI as inevitable, dictating the terms of our existence. Remember, AI is a human creation and, as such, can and should be guided by human principles and ethics."

Dan Thisdell

Images: Outerlynx

Up close with a comet, and yourself

When the interstellar visitor 3I/ATLAS was discovered in summer 2025, it ignited curiosity about its origins and the cosmic secrets it might carry from beyond our Solar System. But it also inspired a more personal question in the mind of at least one game developer: What if you were sent to investigate it up close?

In **Project Atlas (Outerlynx)**, you step into that very scenario as Commander Simth, handpicked for a secret mission to land on a comet still unknown to most of the world. But nothing goes to plan. The comet changes course, communications from Earth grow increasingly strange, and the weight of isolation starts to warp your perception, making you question everything.

This is a short, quiet experience – closer to an interactive story than a traditional game, so don't expect complex gameplay. Instead, the slow-burn journey keeps you wondering what might happen next, while the sound design – and the silence – reinforce the sense of the vast emptiness of space. The twist at the end is so unexpected it will stay with you long after the game ends.

More than anything, Project Atlas offers a glimpse into the psychological toll of space exploration, where uncertainty and loneliness are as much a part of the mission as rockets and research. Project Atlas was released in February 2026 for PC and is available on Steam. At less than a euro, there is simply no reason not to try it.

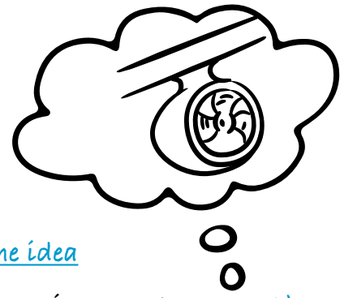
Yasmin Tosta is an English language editor for DLR. Off the clock, she's either buried in a book or a video game – always hoping for a plot twist she never saw coming.

DLR Institute of Propulsion Technology

A good simulation is half the battle

Virtual simulation of engine development and operation

Nyroniq website (German)

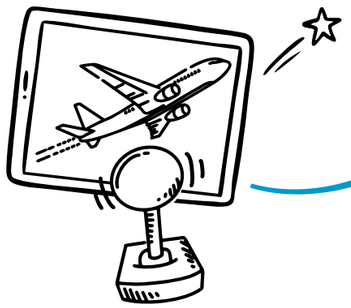


The idea

Nyroniq supports companies to integrate and further develop GTlab into their development processes. Using this software developed at DLR, aircraft engines and gas turbines can be modelled virtually.

The context

From the spark of an idea to the moment a new engine is mounted under an aircraft wing, many years pass. The process can be sped up by shifting as much as possible from the real world to the digital sphere.



Nyroniq makes the world a better place because …

… every step of development can be virtually simulated, from the design of an engine through to its integration and subsequent maintenance. This saves time, money and materials.

The next challenge

Fully integrating GTlab software into a customer's existing design tools before the end of this year.

What leads this robot down the wrong path?

To safely participate in road traffic, autonomous vehicles must reliably recognise traffic signs. To achieve this, they are fed enormous amounts of data. However, if this training data is tampered with – for example, by altering individual pixels in images – the assistance system could be programmed incorrectly. In the worst case, this could be exploited deliberately, causing autonomous vehicles trained in this way to always interpret a stop sign as a give-way sign, or to read a sticker placed on a sign as an instruction to 'go full throttle'. Researchers at the DLR Institute for AI Safety and Security are therefore working to make the algorithms of AI applications immune to this type of data poisoning – so that cars don't get led astray.

Direct to research into safe AI methods

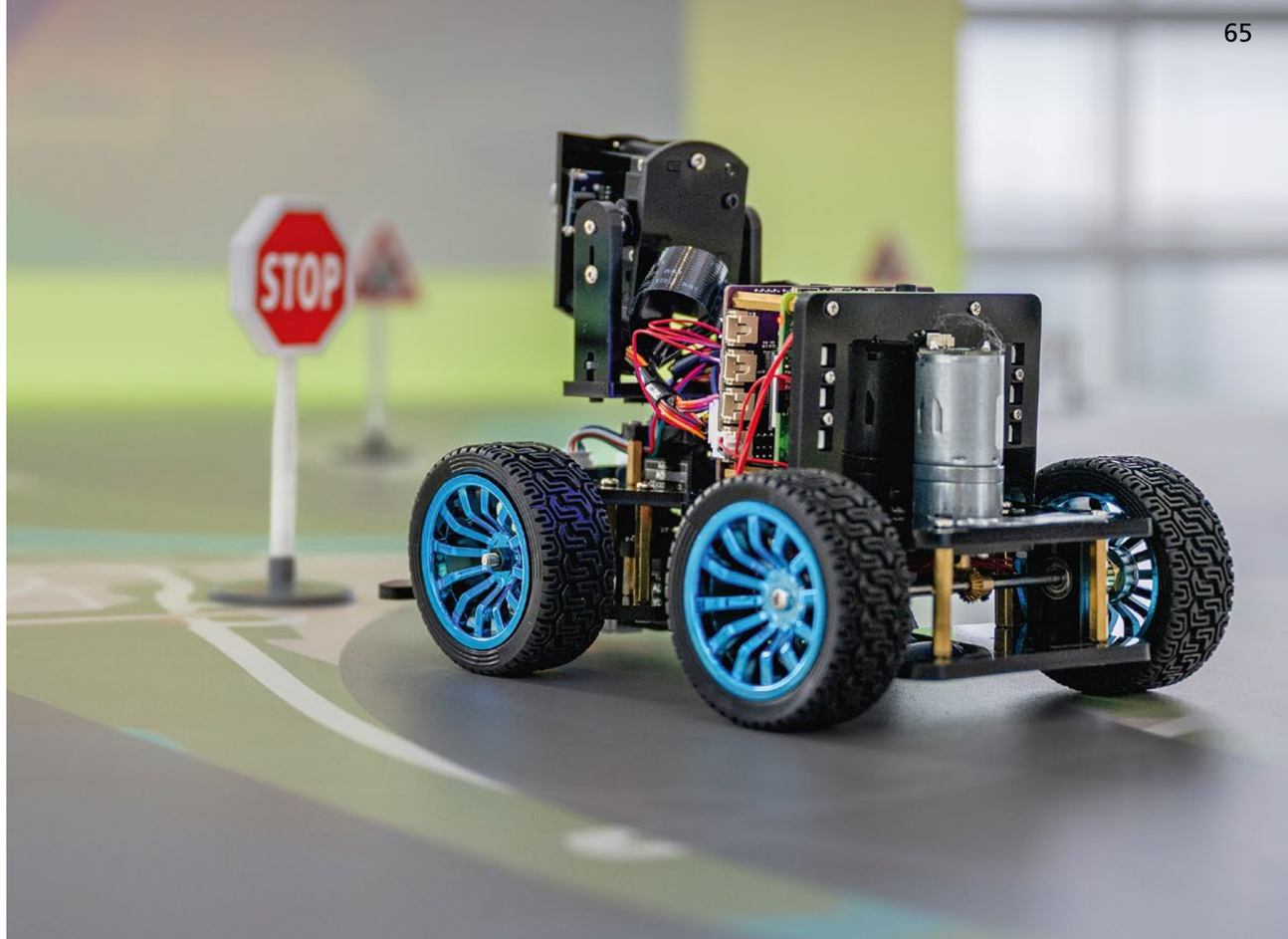


Image: Sofia Wagner/Nyroniq