June 2025 | German Aerospace Center

Offshore wind farms
Secure at sea

Space weather
Frolicking fire foxes light up the heavens!

Cover image

There are many variables that can make an aircraft more efficient, quieter and more climate-compatible. One of the most important is the engine – particularly the propulsion system. Today's long-haul aircraft fly with shrouded jet engines, while propellers are used for short-haul routes. Although propellers are generally more efficient, they are not suitable for long distances. For 20 years, DLR has been developing innovative propulsion systems. Technologies such as the shrouded propfan (CRISP) shown here combine the best of both worlds: they are designed to be more efficient than jet engines while quieter than conventional propellers.

DLRmagazine
177 online

DLRmagazine | June 2025

DLR

magazine

#177

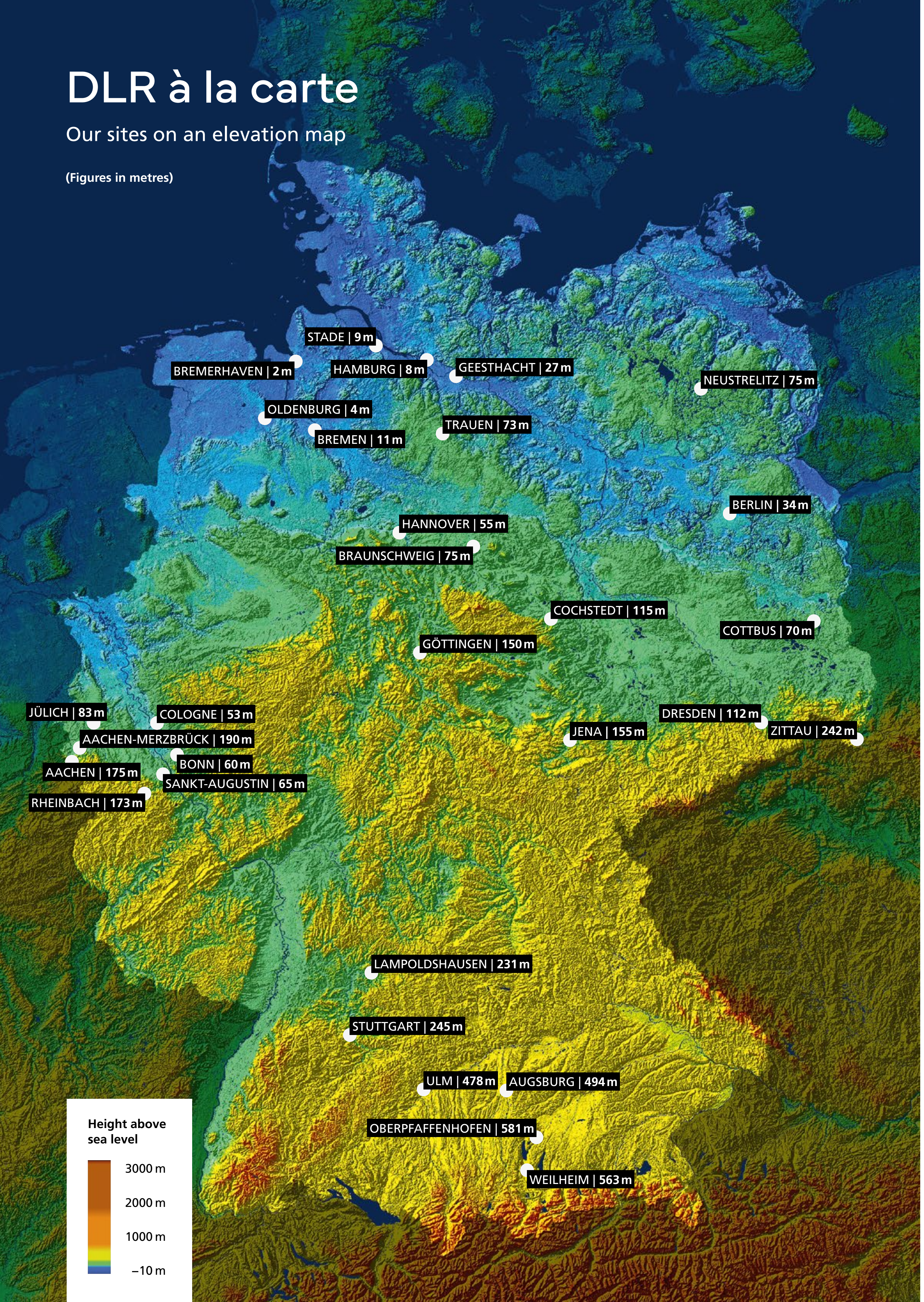
Opening up new propulsion concepts

The latest trends in propeller technology

DLR à la carte

Our sites on an elevation map

(Figures in metres)



At altitude

DLR's 30 sites shown on an elevation map. The 'front-runners' are our colleagues in Oberpfaffenhofen, at 581 metres above sea level. Elevation data was acquired by the TerraSAR-X and TanDEM-X twin satellites, which orbit Earth at an altitude of approximately 500 kilometres, using radar instruments to scan the planet's surface.

More information about the mission

IMPRINT

DLRmagazine – the magazine of the German Aerospace Center

Publisher: DLR German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt e.V.)

Editorial team: Andreas Schütz (legally responsible for editorial content), Julia Heil and Stefanie Huland (editorial management), Michael Müller, and Rosa Jesse (English-language editor, EJR-Quartz BV)

DLR Corporate Communications
Linder Höhe, 51147 Cologne, Germany
Phone: +49 2203 601-2116
Email: info-dlr@dlr.de
Web: dlr.de/en
Instagram: @dlren

Printing: AZ Druck und Datentechnik GmbH, 87437 Kempten, Germany

Print date: 6 May 2025

Design: raufeld

ISSN 2190-0108

Read online:
dlr.de/en/media/publications/magazines

Order online:
dlr.de/en/magazine-subscription

Contact: **magazin@dlr.de**

Map: DLR; Illustrations: Martin Rümmele/raufeld

Editorial

Dear reader,

Do you recognise us? After ten years, the DLRmagazine has a fresh new look – our content now has more space. What hasn't changed is our commitment to bringing you exciting stories from DLR. As always, this issue features interviews, reports, background pieces and beautiful images from the fields of aeronautics, space, energy, transport and security. What do you think of our new design?
We'd love to hear from you:
magazin@dlr.de

Wishing you an enjoyable journey through this issue,
Your editorial team

Jens Berdermann
Acting Head of the DLR Institute for Solar-Terrestrial Physics

"Right now, we are once again experiencing a period of increased solar activity. We are monitoring the situation and providing data via our IMPC space weather service to help protect critical infrastructure".

More on page 24

"Given the striking design, I was surprised to learn that the physics behind the rotor ship Buckau – the Magnus effect – is actually quite simple."

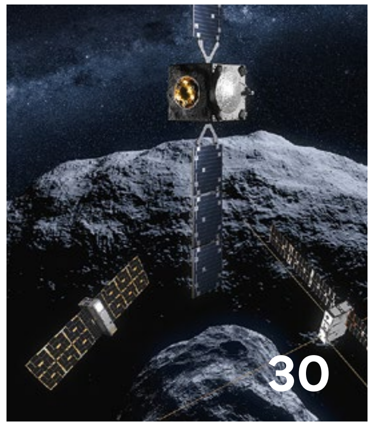
More on page 54

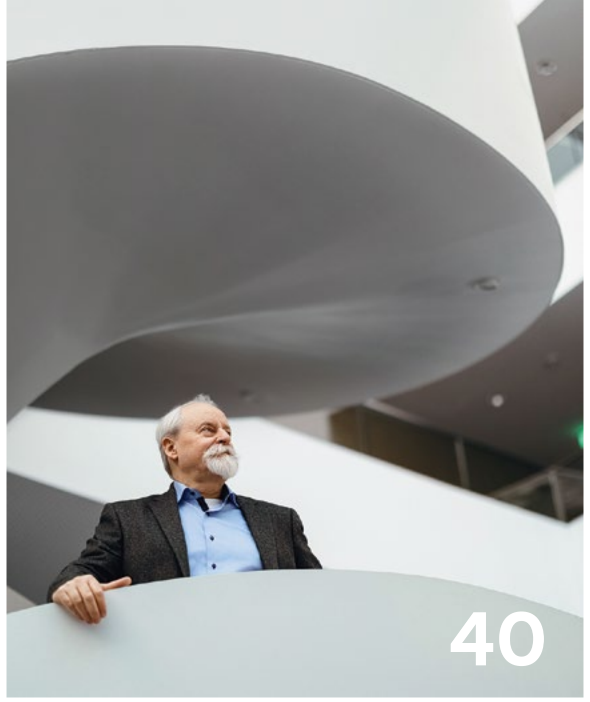
Jessika Wichner
Head of the DLR Central Archive

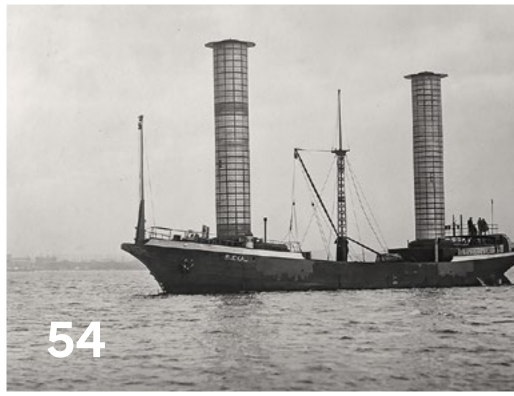
Frank Sill Torres
Head of the DLR Institute for the Protection of Maritime Infrastructures

"Offshore wind turbines generate nearly five percent of our energy. If they fail, the impact is noticeable."

More on page 18

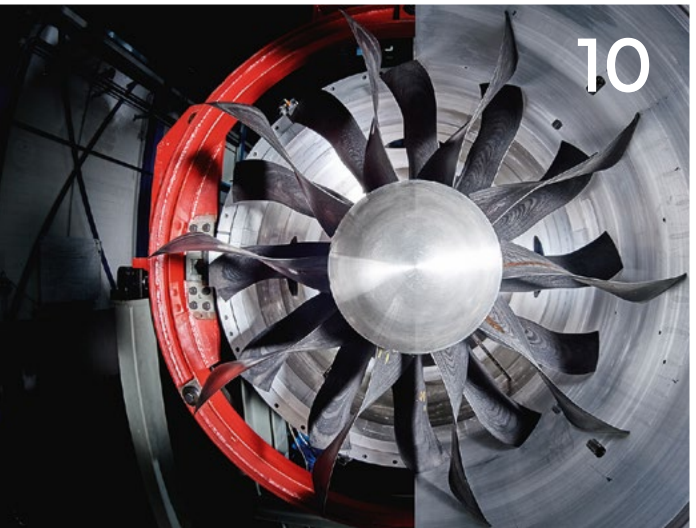






Contents

DLRmagazine 177



DLR robot Rollin' Justin (right) and ESA rover Interact

Adaptable robots that safely yield

OBERPFAFFENHOFEN: The use of robots in human environments is rapidly increasing. As a result, their ability to yield with flexibility is becoming ever more important. The capacity to adapt to changing circumstances can mean the difference between safe operations and potential hazards – such as collisions with people. At the DLR Institute of Robotics and Mechatronics, researchers have developed an approach in which robots flexibly yield without springing back to their original position – similar to how humans behave when working together on practical tasks. The result is improved safety and effectiveness – a step that could help accelerate the integration of robots into everyday life.

New sensors

UEDEM: Germany's Space Situational Awareness Centre is set to receive new sensors by 2027 to track and precisely measure space debris. The data collected will be used to generate a clearer map of near-Earth space and support decision-making in the event of potential collisions. The centre is jointly operated by the German Space Agency at DLR and the Bundeswehr Space Command.

Blue Ghost delivers data from the Moon

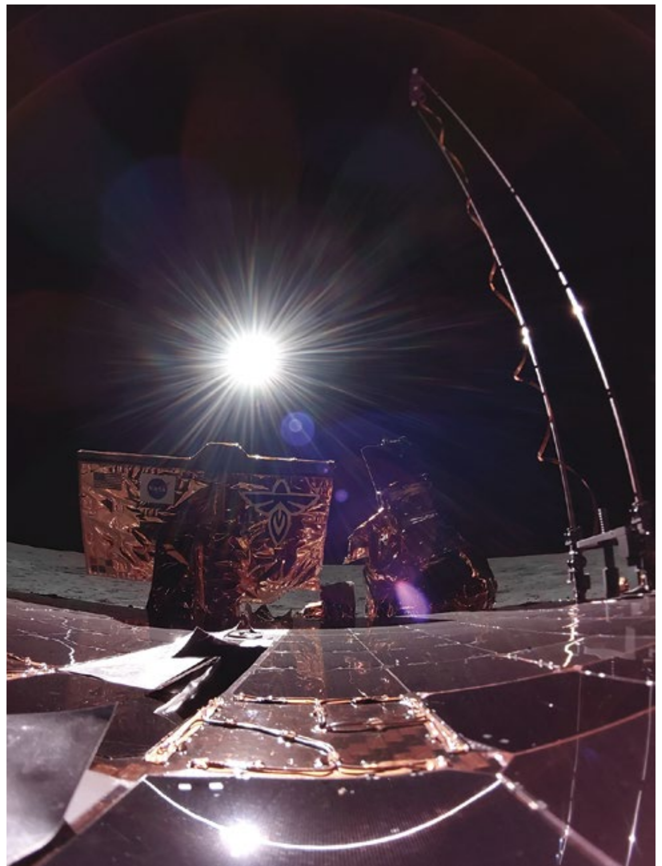
Mission spends two weeks exploring Mare Crisium

For a fortnight, the Blue Ghost lander collected data on the Moon. The mission, from private New Space company Firefly Aerospace, is part of NASA's Commercial Lunar Payload Services (CLPS) initiative. On 2 March 2025, Blue Ghost landed fully autonomously in Mare Crisium – an impact basin filled with solidified lava in the northeast of the Moon's near side.

Instruments deliver the goods

The lander carried ten scientific and technical instruments, all of which were successfully activated. DLR is involved in the LISTER (Lunar Instrumentation for Subsurface Thermal Exploration with Rapidity) experiment, which investigated heat flow from the Moon's interior. The electronics used to measure temperature and thermal conductivity are based on DLR's HP³ (Heat Flow and Physical Properties Package), originally developed for NASA's InSight Mars mission.

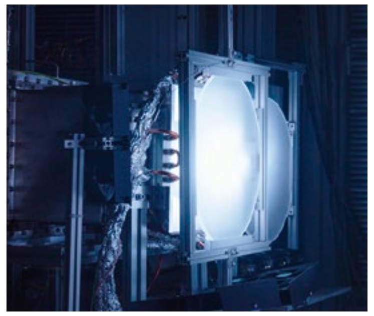
On 14 March, Blue Ghost even captured images of a total solar eclipse – as Earth moved in front of the Sun and obscured it. The probe also delivered data on how lunar dust creates a glow on the Moon's horizon when backlit by the setting Sun. Blue Ghost also examined the fine, electrostatically charged lunar dust known as regolith. Over the course of the mission, the spacecraft transmitted 119 gigabytes of data to Earth, including 51 gigabytes of scientific and technical measurements. The data is currently being analysed and will support both general lunar science and future Moon missions.



Blue Ghost's first view of the solar eclipse on 14 March. The glowing ring of light reflected on the solar panel (below) shows Earth beginning to block the Sun.

Raw materials with solar energy

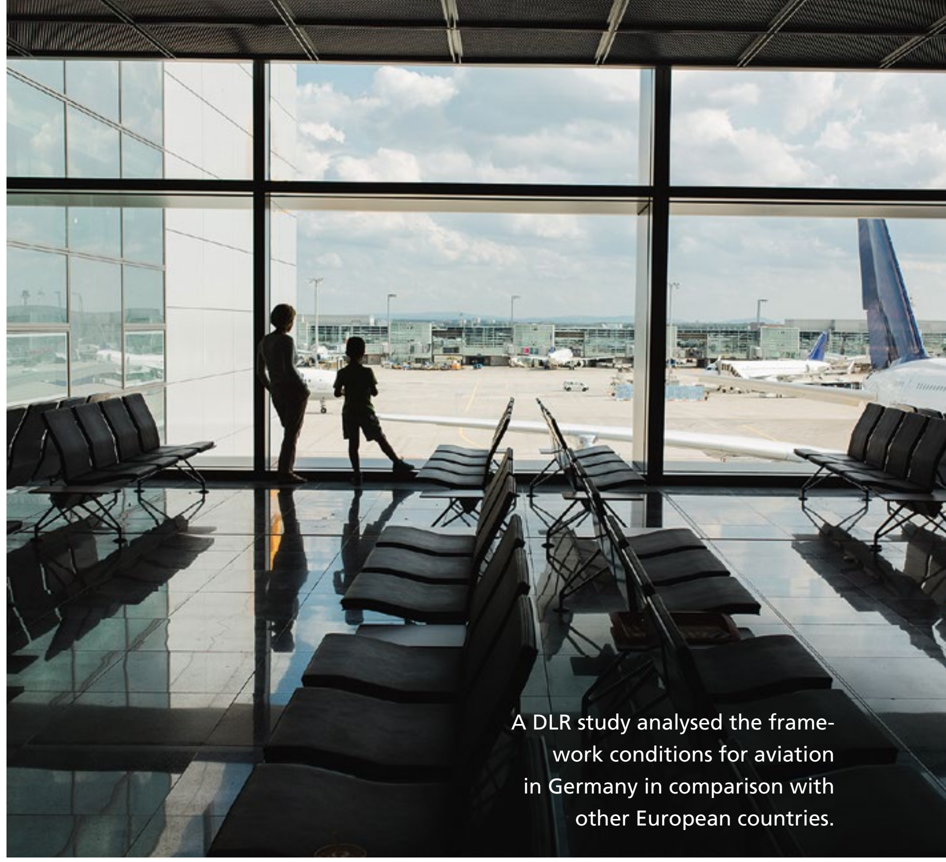
COLOGNE: Many of the chemical raw materials used to produce plastics, fuels and fertilisers are traditionally derived from crude oil and natural gas. As part of the EU's FlowPhotoChem project, the DLR Institute of Future Fuels, together with stakeholders from industry and research, has developed and tested a demonstration plant that can produce ethylene – a key chemical feedstock – in a more climate-compatible way. The plant consists of three interconnected modules that use concentrated solar radiation to generate ethylene from water and carbon dioxide.



Irradiating the FlowPhotoChem reactors in DLR's high-flux solar simulator in Cologne.

17

DLR_School_Labs now exist across Germany, giving young people the opportunity to conduct their very own research. The newest facility opened in Zittau on 15 May. The programme includes experiments on sustainable energy, advanced materials, industrial processes and environmental research.



A DLR study analysed the framework conditions for aviation in Germany in comparison with other European countries.

A slower recovery for aviation in Germany

DLR study examines location costs

On behalf of the Federal Ministry for Digital and Transport, DLR has produced a comprehensive report on location-related costs in the German aviation sector, published in March 2025. The analysis, conducted by the DLR Institute of Air Transport, examines aviation conditions in Germany compared with other European countries and identifies potential measures to improve competitiveness. The findings show that aviation in Germany is recovering more slowly than in many other parts of Europe. While passenger numbers in Germany reached approximately 80 percent of pre-pandemic levels in 2024, several other countries have almost fully returned to pre-COVID figures.

Multiple contributing factors

One key factor is high location costs such as taxes, fees and airport charges, which are particularly high in Germany, the Netherlands, the UK and Austria. In Germany, these costs rose by 38 percent between 2019 and 2024, compared with a European average increase of 26 percent.

However, the study concludes that high location costs alone do not explain Germany's slower recovery. Weak economic performance, changing travel behaviour – especially a shift towards rail for domestic journeys – and structural changes in the aviation sector, including market consolidation within Germany, have also had an impact.

Further contributing factors include geopolitical developments such as airspace restrictions due to the war in Ukraine and bottlenecks caused by skilled labour shortages and delayed aircraft deliveries.

New research vessel commissioned

GEESTHACHT: DLR has commissioned the Lloyd Werft shipyard to build a new research vessel. The ocean-going ship will measure 48 metres long and 11 metres wide, with a draught of 3.2 metres. The vessel will serve as a platform for research into low-carbon, climate-compatible shipping technologies, focusing on hydrogen-based fuels and battery systems.

Solutions for the last mile

BRAUNSCHWEIG: The German Federal Ministry for Digital and Transport is providing 35 million euros in funding for the IMoGer project (Innovative Modular Mobility Made in Germany), led by DLR. The project aims to integrate public transport and parcel delivery using modular electric vehicles. This holistic approach to mobility addresses challenges for the so-called 'last mile'. The concept will be trialled in Braunschweig with a small fleet of U-Shifts: automated, modular vehicles developed by DLR.

IMoGer visualisation featuring two U-Shift vehicles

Cutting-edge European research under German leadership

GARTEUR links international aviation research

Germany currently holds the two-year chair of the GARTEUR (Group for Aeronautical Research and Technology in EURope), an international aeronautical research network. As the oldest European-level research network for leading aeronautical nations, GARTEUR serves as an independent organisation for scientific collaboration in civil and military aviation research. "The network offers an opportunity to harness synergies at both civil and military levels," says Jan Bode, Head of the Aviation Research Project Management Agency and current chair of the GARTEUR Council.

Network goals

Key objectives for the German term as chair include integrating GARTEUR's international expertise into the wider aeronautical research community and relevant international forums. One early milestone achieved has been the new cooperation with ICAS (the International Council of the Aeronautical Sciences).

During this period, the Aviation Research Project Management Agency is also acting as the administrator of the GARTEUR Secretariat, serving as the central point of contact for the network's research groups and overseeing the coordination, monitoring and evaluation of their scientific activities.

The Aviation Research Project Management Agency coordinates research activities within the GARTEUR network.

Image: Max_Leitmeier_Schwarzbild (top)

The Edutainer

"I only ever want to present things that I find fascinating myself. I think that's the basic requirement when you're sharing knowledge… it has to be something that sparks your enthusiasm, something you're passionate about – where your eyes light up when you talk about it. That's the best way to convey a subject to others!"

Sina Kürtz, Online and Media Officer in DLR's youth development team

Listen to the **FORSCHtellungsgespräch** podcast (in German) at **dlr.de/podcast** and on all major streaming platforms. It's also available as a video on YouTube and Spotify.

Image: Bolzphotography

DLR is conducting research into high-performance propulsion systems, such as the shrouded propfan (CRISP) shown here – a combination of a ducted turbofan engine and a propeller. The open-fan engine featured on the following pages marks another step toward highly efficient aircraft propulsion.

Opening up new propulsion concepts

The latest trends in propeller technology

by Michael Müller

Serious engineering work on contra-rotating open rotors for aircraft propulsion dates back to the late 1940s, particularly as a means to enhance fuel efficiency and extend the endurance of long-range bombers and maritime patrol aircraft. In modern civil aviation, open contra-rotating designs gained renewed attention during the oil crisis of the 1970s as a way to reduce fuel consumption compared with conventional propellers. In 1989, General Electric‘s GE36 became the first demonstrator engine featuring two contra-rotating rotors, integrated into a research aircraft and tested in flight. However, projects like this were shelved when the oil crisis came to an end, and the status quo remained: propeller-driven aircraft for short-haul flights and shrouded turbofan engines for long-haul travel. Open rotors have not yet been adopted in aviation – not yet, because regardless of economic ups and downs, researchers at various DLR institutes have been exploring new approaches to engine design for around 20 years, from Contra-Rotating Open Rotor (CROR) concepts to rotor-stator combinations.

The grand objective

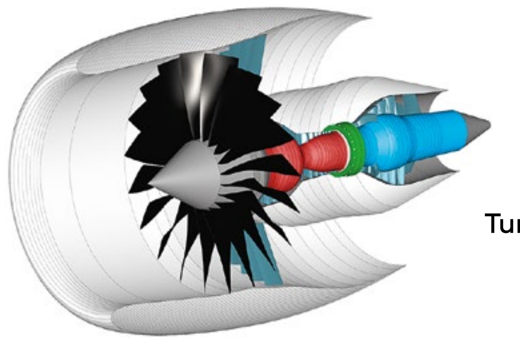
Today, the goal is politically driven: to reduce aviation's environmental impact by increasing efficiency. The European Union's Clean Aviation Joint Undertaking research and innovation programme stipulates, among other things, that propulsion efficiency should increase by at least 30 percent over the next 25 years compared to 2020 levels. Researchers see one way to achieve this in the further development of aircraft engines – reviving interest in the once-abandoned concept of contra-rotating open rotors, a technology that is particularly promising for use in medium-range aircraft.

At the DLR Institutes of Propulsion Technology in Cologne and Aerodynamics and Flow Technology in Braunschweig, researchers are exploring open rotor designs across several projects. Their work spans classic propellers (turboprops), contra-rotating open concepts (propfans) and shrouded designs (turbofans).

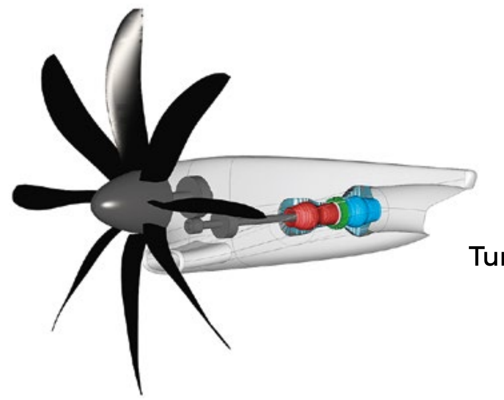
Open versus shrouded

The situation is complex: different aircraft require different types of engines, so there is no one-size-fits-all approach to improving efficiency. For short-haul flights carrying up to 50 passengers, propeller-driven aircraft remain the preferred option, cruising at approximately 500 kilometres per hour. If longer distances are involved, where passengers require more space, an aircraft needs to fly faster. An Airbus A320, for instance, typically

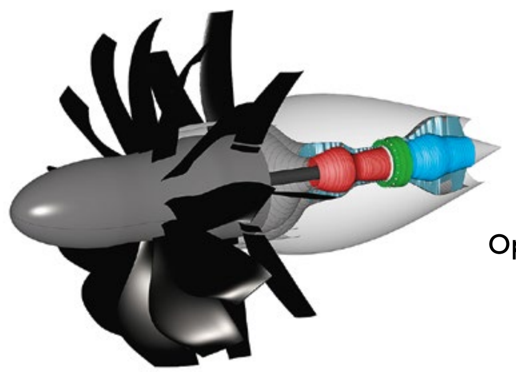
Engines – what's what?



Turbofan



Turboprop



Open fan

■	Propulsor
■	Compressor
■	Combustor
■	Turbine

Today's medium- and long-haul aircraft are powered by shrouded jet engines (turbofans). On short-haul routes, classic propellers (turboprops) are commonly used. Counter-rotating, open engines (open fans) are not yet in operation.

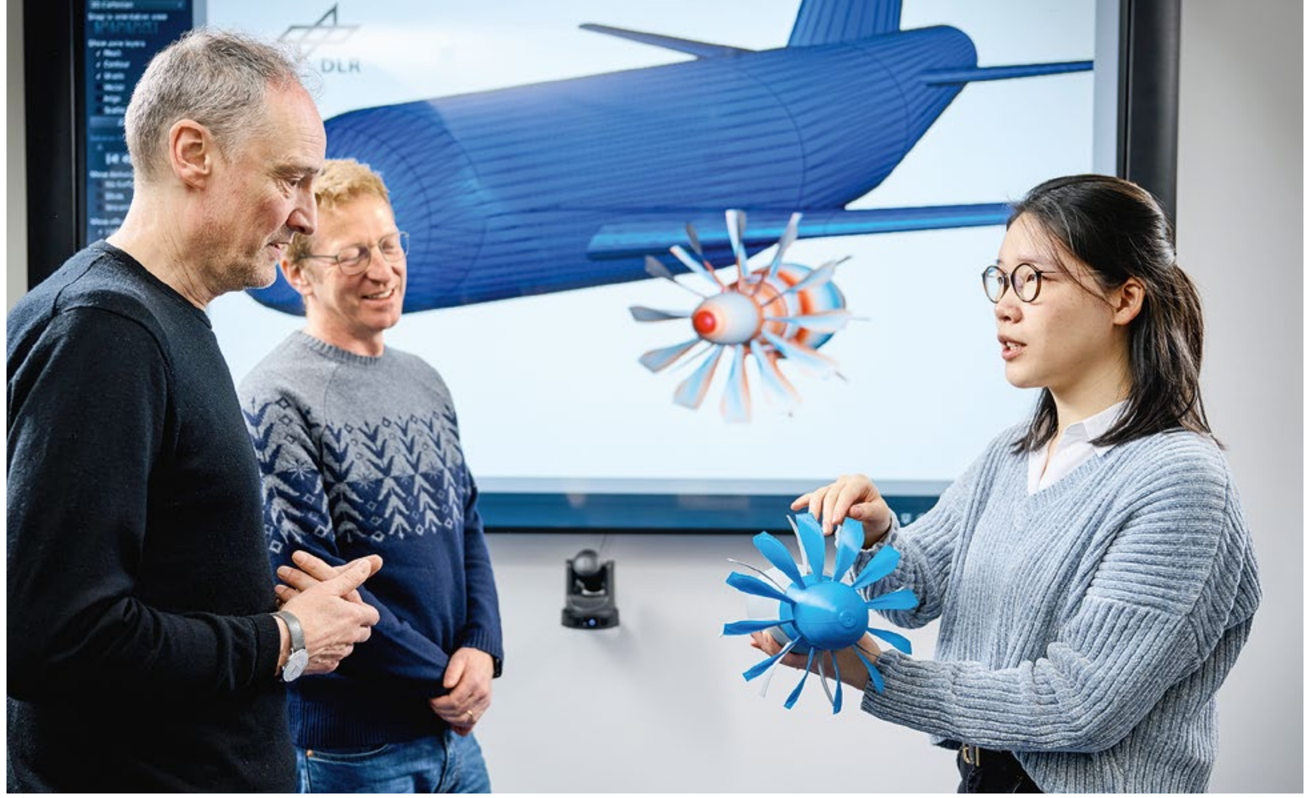


Image: DLR

From left: Rainer Schnell, Christian Frey and Carola Rovira Sala from the DLR Institute of Propulsion Technology with a 3D model of the open fan

carries around 180 passengers and cruises at approximately 750 kilometres per hour – speeds that conventional propellers (turboprops) cannot achieve. While turboprops are generally more efficient than turbofans, their propulsion efficiency declines significantly at high speeds.

This is why turbofans – the familiar, shrouded jet engines – are used for medium- and long-haul routes. To generate the same thrust as an A320's two-metre-diameter turbofan engine, a conventional turboprop would theoretically need to be so large that it wouldn't fit beneath or above the wings. It would also be nearly impossible to integrate it with the tailcone. A smaller propeller could compensate by turning much faster to produce the required thrust. However, rotor blade speeds can only be increased up to a certain point, beyond which the mechanical load on the rotor blades becomes excessive, reducing efficiency and increasing noise.

Dilemma solved

To address this, researchers devised a way to convert the otherwise-wasted swirl energy into thrust – similar in principle to how braking energy in cars is repurposed for propulsion. In the new open-fan concept, a rotor was developed with blades specifically designed for high speeds to prevent such energy losses. A stator – with non-rotating blades – positioned downstream of the rotor, captures and converts the swirl energy into additional thrust. This approach makes the system even more efficient than a comparable turbofan engine, partly because eliminating the fan casing reduces drag.

> "Even under strongly varying wind loads, the rotor must remain stable at all times."
>
> **Carola Rovira Sala, DLR Institute of Propulsion Technology**

However, this concept also significantly loses efficiency at speeds above 800 kilometres per hour due to increasing frictional forces. A conventional gas turbine core engine is needed to drive open rotors. This must be small and highly efficient at the same time – a challenge that the DLR Institute of Propulsion Technology is dedicated to addressing.

Noise emissions and aerodynamic integration

As part of the EU project PANDORA*, and under the lead of Universidad Politécnica de Madrid, DLR researchers – working together with consortium members Safran Aircraft Engines as well as École Centrale de Lyon and Imperial College London – are developing a new rotor-stator concept. Initially, they designed the structure and performance of the

* The project has received funding from the European Union's Horizon research and innovation programme under grant agreement No 101096156.

engine using novel, highly advanced numerical algorithms in virtual computer models. They are now constructing a model to be tested in the aeroacoustic low-speed wind tunnel at DLR's site in Braunschweig, operated by the German-Dutch Wind Tunnels Foundation.

But power and efficiency are only part of the mission; noise and aerodynamic integration present significant challenges for propulsion engineers and aerodynamicists. Rainer Schnell from the Institute of Propulsion Technology explains: "Without the shroud, a lot of protection is lost. That's why our research focuses on designing an open rotor that remains structurally stable in all flight conditions. It must also produce no more noise than today's jet engines while being highly efficient during long-distance cruising."

Certification requirements must also be met, which influences key design decisions. Rotor blades, for instance, must meet minimum thickness standards for structural stability, which comes at the expense of efficiency. The rotor's behaviour across different flight phases is another critical factor. Carola Rovira Sala from the Institute of Propulsion Technology highlights this challenge: "During take-off, the angle of attack – the angle at which air flows into the engine – can reach up to 20 degrees. Even under strongly varying wind loads, the rotor must remain stable at all times."

Individually adjustable stator blades

For propulsion systems featuring open rotors or propellers, careful consideration of the aerodynamic effects caused by their integration into the overall aircraft design is essential. As part of the European research programme Clean Sky 2, the DLR Institute of Aerodynamics and Flow Technology is collaborating with Airbus and Safran to investigate how different open-rotor concepts affect airflow around the wings and engine mounts – particularly in terms of lift and drag. Researchers first analysed the engine's behaviour in isolation, then at various angles of attack. Using specialised flow simulation software, they began by modelling the aerodynamics of a complete, non-powered aircraft design on a computer. They then introduced virtual engine nacelles beneath the wings – initially without rotor blades, then with blades and, finally, with thrust applied.

During these simulations, one issue quickly became apparent: at high angles of attack, such as those experienced during take-off, the aerodynamic performance of some of the stator blades was adversely affected. This could impact the overall efficiency of the engine and lead to vibrations and noise.

This finding prompted Arne Stürmer and his team at the Institute of Aerodynamics and Flow Technology to rethink the stator configuration for the open-fan propulsion system. Rather than setting all stator blades at the same pitch angle, they are now exploring a design in which each blade has an individually optimised angle. This adjustment aims to mitigate unfavourable aerodynamic effects at high angles of attack and improve overall propulsion system efficiency.

View into the low-speed wind tunnel in Braunschweig

These findings underscore the importance of early simulations when developing new aircraft and propulsion systems. By identifying aerodynamic challenges early on, researchers can implement targeted solutions before moving to physical prototypes.

Compromise – the key to success

For both an open-fan engine and propeller-driven aircraft, the direction of rotor rotation is an important design choice. In an engine manufacturer's ideal world, each aircraft wing would have an engine with rotors turning in the same direction. The advantage? Only one type of engine would need to be certified.

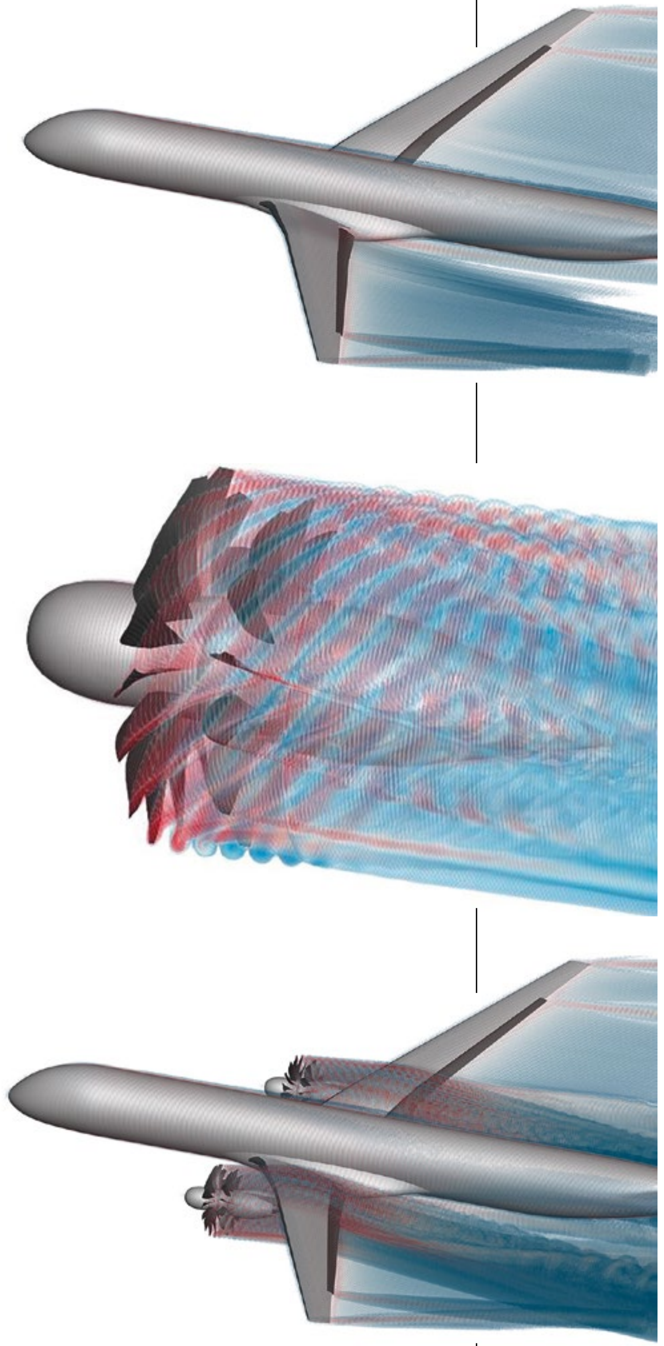
However, a symmetrical design – with the rotors on each wing turning in opposite directions – has advantages in terms of the overall aerodynamic performance of the aircraft. But this comes with higher costs both in production and maintenance, as separate spare parts – such as rotor blades – must be stocked for both the left and right engines. In theory, the stator could fully recover the swirl and thereby eliminate the impact of rotor rotation on the wing. This requires appropriate studies on stator design.

Arne Stürmer concludes on the complex integration of the propulsion system: "With open rotors, the most aerodynamically efficient position for the propulsion system almost never aligns with the most efficient design for the aircraft body. Everyone involved must work together to find the best compromise for the overall system."

Theory and practice

As the development of open rotor-stator designs progresses, DLR experts agree that computer simulations – no matter how advanced – are not sufficient on their own. Real-world testing is essential. Last year, initial wind tunnel trials were carried out in a collaboration between Airbus and Safran – a promising first step toward making the next generation of passenger aircraft powered by open fan engines a reality. At the end of 2025, a new cooperation project between DLR and Airbus will begin, focusing on the low-noise, efficient integration of an open fan into an aircraft. This will take the open-fan concept from the computer and into the wind tunnel.

Michael Müller is an editor in DLR Communications. Since childhood – when he saw the Space Shuttle on the back of a Boeing 747 at Cologne Bonn Airport – he has been fascinated by research and development in aeronautics and space.



Numerical flow simulations are a key tool in engine integration. Combining a low-drag aircraft with a highly efficient open fan does not automatically result in a successful commercial aircraft, due to the complexity of aerodynamic interactions that need to be accounted for.

Breaking the boundaries of knowledge

2025 is the United Nations' International Year of Quantum Science and Technology. A journey through time reveals how the historic milestones of quantum physics are reflected in DLR's research today.

1994

PETER SHOR PRESENTS HIS QUANTUM ALGORITHM

The security of classical data encryption relies on the laborious process of breaking large numbers down into primes. Conventional computers fail at this task when numbers become too large. The Shor algorithm solves this problem very efficiently using quantum superposition and entanglement.

TODAY: **QUANTUM COMPUTING APPLICATIONS**

DLR is working with industry to investigate practical, real-world applications for quantum computing. These include the optimisation of flight routes, mission planning and the aerodynamic behaviour of aircraft. Quantum computing could also be applied in the energy, transport and connected mobility sectors, as well as Earth observation and materials research.

1981

RICHARD P. FEYNMAN CONCEPTUALISES THE QUANTUM COMPUTER

Qubits are the basic units of information in quantum computing. Unlike classical bits, which are limited to a value of only 0 or 1, qubits can also exist in a superposition – a combination of both 0 and 1, resulting in all values in between. The calculations of quantum computers follow the laws of quantum physics. Superpositions and entangled quantum states of qubits enable special algorithms that can solve problems far beyond any conventional computer.

TODAY: **FROM PROTOTYPE TO APP**

Quantum computers offer enormous opportunities for business, industry and research, as they can process huge amounts of data and enable complex simulations. Through its Quantum Computing Initiative (DLR QCI), DLR is driving forward the industrialisation of quantum computers and identifying practical applications.

1960

THEODORE MAIMAN BUILDS THE FIRST LASER

A laser produces a beam of light with a specific wavelength. It consists of a laser-active medium, a resonator and an energy source. The energy source excites atoms in the medium to emit light, and the resonator repeatedly reflects this light back through the laser medium. When the light hits atoms in an excited state, they in turn emit light in the same direction – producing a focused, high-intensity beam.

TODAY: **OPTICAL CLOCKS SET NEW TIME STANDARDS**

DLR is developing and testing space-grade laser clocks for satellite navigation and communication with centimetre-level accuracy. DLR institutes are also building laser interferometers that can measure the distance between satellites to within a few billionths of a millimetre.

1935

EINSTEIN-PODOLSKY-ROSEN PARADOX – SPOOKY ACTION AT A DISTANCE

The EPR paradox shows that two entangled quantum objects can be superimposed and connected in such a way that the state of the overall system can no longer be described as a combination of two individual quantum objects. Instead, they behave like a single quantum entity. Measuring one object immediately determines the state of the other, no matter how far apart they are – a phenomenon Einstein famously called "spooky action at a distance".

TODAY: **THE PARADOX IN QUANTUM COMPUTING AND QUANTUM COMMUNICATION**

Quantum entanglement is at the heart of quantum computing's high performance. In the secure transmission of data via quantum communication, entangled quanta (such as photons) are the key to reading encoded information. Their quantum states cannot be copied without detection, making them ideal for secure data transfer. DLR is conducting research into quantum computing and communication, including their interconnection in a quantum internet. DLR is also developing laser-based transmission and reception terminals for quantum communication and quantum memory.

1925

GOUDSMIT, UHLENBECK AND PAULI – ELECTRON SPIN

Spin is a fundamental quantum property of all elementary particles. Mathematically, spin resembles a mechanical rotational movement – but without a moving mass. Spin is the source of magnetism and can be used to explain the shell structure of atomic electron configurations, the spectra of atoms and the macroscopic properties of matter.

TODAY: **SENSORS AND COMPUTERS WITH SPIN**

DLR is researching quantum sensors based on spin for electric and magnetic fields. These sensors are so sensitive that they can detect Earth's magnetic field in space, the magnetic field of a single atom and even brain waves with high precision. Some spins can also serve as information carriers in quantum computers, known as qubits.

Images: Adobe Stock/Erika/AI-generated

1924

THE BOSE-EINSTEIN CONDENSATE

A Bose-Einstein condensate is a state of matter formed when a gas of bosons is cooled to just a few millionths of a kelvin above absolute zero. These bosons have an integer spin, and at this extreme ultracold temperature, all atoms enter the same quantum state. The gas cloud then behaves like a single, large 'superatom'. The first experimental proof of this phenomenon came in 1995.

TODAY: **COLD ATOMS FOR SENSORS AND COMMUNICATION**

DLR and NASA are planning to send the BECCAL (Bose-Einstein Condensate Cold Atom Laboratory) experimental platform to the International Space Station (ISS). Researchers worldwide will then be able to conduct experiments with Bose-Einstein condensates in microgravity. The aim is to use these in, for example, quantum sensors, but applications range from Earth observation and testing satellite navigation to quantum communication and fundamental theories such as general relativity.

1924

LOUIS DE BROGLIE'S MATTER WAVES AND WAVE-PARTICLE DUALITY

Matter also exhibits wave-like properties – a phenomenon evident at the atomic level. Waves propagate through space and can be measured at multiple locations simultaneously. Particles, by contrast, can only be located in one place at a time. Quantum objects however exhibit both wave and particle characteristics: they possess momentum and wavelength.

TODAY: **USING MATTER WAVES TO EXPLORE NEW MATERIALS**

DLR is developing new methods for materials research using the diffraction of matter waves from atomic beams. This non-destructive method reveals the properties of membranes just a few atomic layers thick – ideal for highly compact electronic components.

1905

ALBERT EINSTEIN EXPLAINS THE PHOTOELECTRIC EFFECT

Einstein develops his theory based on Max Planck's quantum hypothesis: in the photoelectric effect, light knocks electrons out of metals. This demonstrates that light must possess particle-like properties in addition to behaving as a wave.

TODAY: **FROM PHOTOELECTRIC EFFECT TO IMAGE**

Modern cameras operate on the basis of an internal photoelectric effect, converting light into electrical signals. DLR develops highly specialised multispectral cameras and high-speed electronics for connected mobility, communication and navigation, climate and disaster protection, and space missions like the High Resolution Stereo Camera on board Mars Express.

Featured topic:
Quantum technologies

Secure at sea

DLR is researching ways to protect offshore wind farms against attack

by Denise Nüssle

Image: Doti/Matthias Ibeler

DISCOVER
Offshore wind farms

Alpha Ventus, Amrumbank West, Albatros and Wikinger – these intriguingly named offshore wind farms lie far from the nearest coast, reliably generating electricity in the fierce gales of the North and Baltic Seas. Their only visitors are the crews who come by ship or helicopter for servicing, maintenance and safety checks. A team from the DLR Institute for the Protection of Maritime Infrastructures is developing know-how and technologies to better protect these offshore wind farms against security threats, making them pioneers in a field that, due to recent events, is attracting increasing public attention.

Massive expansion planned

In the summer of 2024, Germany's approximately 30 wind farms had a capacity of almost nine gigawatts – equivalent to half a dozen medium-sized nuclear power plants and contributing between four and five percent of Germany's total energy production. An ambitious expansion of offshore wind energy is planned for Germany and Europe due to growing electricity demands: for electromobility, the development of a hydrogen economy and the climate-compatible transformation of the industrial and heating sectors. As a renewable resource, wind offers a promising option for power generation and allows Germany to become less dependent on imports. Coupled with the fact that the North Sea is one of the windiest expanses of water in the world, it is perhaps no surprise that Germany's offshore wind power capacity is to be tripled by 2030 and increased sevenfold by 2045 – enough to cover more than 25 percent of Germany's projected energy needs.

Critical infrastructure under threat

In addition to investment costs, which can run into many billions of euros, many offshore wind farms are also considered part of critical infrastructure – but to some extent, they are out of sight and out of mind. "Offshore wind farms are far away. You don't see them, so they're not really on our radar. Nevertheless, they already produce so much electricity that a major outage could impact our energy system," explains Frank Sill Torres, Acting Director of the DLR Institute for the Protection of Maritime Infrastructures in Bremerhaven. "We protect power plants and substations comprehensively on land with security concepts, fences, access restrictions, monitoring systems, and so on. Now we need to do more of this for our maritime infrastructure, including offshore wind farms. These facilities may be harder to reach, but they're not inaccessible."

Since 2022, the European Union has required operators of critical infrastructure to better protect their assets against security threats and boost their resilience. Such stewardship is intended to increase resistance to disruptive events, such as espionage, sabotage and terrorist attacks. In Germany, the KRITIS Umbrella Act is intended to ensure the implementation of this European regulation in the near future, requiring operators of offshore wind farms to address the security of their facilities, conduct risk analyses and take appropriate precautions. "So far, there haven't been any specific security standards or practices for this area," adds Sill Torres. "At the same time, the pressure to act has increased considerably due to events like the attack on the Nord Stream pipelines and the acts of sabotage against data cables in the Baltic Sea."

DLR – an international pioneer

With its Institute for the Protection of Maritime Infrastructures, DLR has been conducting research in this field since 2017. Policymakers, security

Using DLR's uncrewed superARTIS helicopter, tests were conducted at EnBW's Schwienau II wind farm to assess communication between the drone, wind turbine and control centre.

Overview of offshore wind energy projects, as of June 2024

Map: German Offshore Wind Energy Foundation

authorities and companies turn to DLR for its expertise and to collaborate with the specialist institute. "Maritime infrastructures are complex systems," continues Sill Torres. "At DLR, we examine these system's capabilities to prepare for, withstand and learn from critical events. To measure, evaluate and improve these capabilities, we develop computer-based methods and create comprehensive, generalised models of critical infrastructure. This allows us to simulate how dangerous situations arise and unfold, and then investigate their potential impacts. Based on our findings, we come up with recommendations on how best to act and respond most effectively."

The team led by Frank Sill Torres is particularly interested in what happens during major events and outages of critical infrastructure. When it comes to offshore wind farms, this might involve the failure of a converter platform, which plays a central role by minimising losses and simplifying the transmission of electrical energy from the turbines to the mainland. "Our simulations and models allow us to determine the impact of a majorly damaging event on energy production and how long it would take to resolve a disruption. We can also calculate the probability of certain scenarios this way," Sill Torres explains. To investigate the effects of such events on the power grid, the team is collaborating with the Energy Systems Analysis department at the DLR Institute of Networked Energy Systems in Oldenburg.

Offshore wind farms – a first practical example

For the still-young DLR institute in Bremerhaven, which has more than 60 employees, offshore wind turbine installations represent a first concrete application area for its research. Sea-borne wind farms share many characteristics with other maritime infrastructures, albeit not as large and complex as, for example, a seaport.

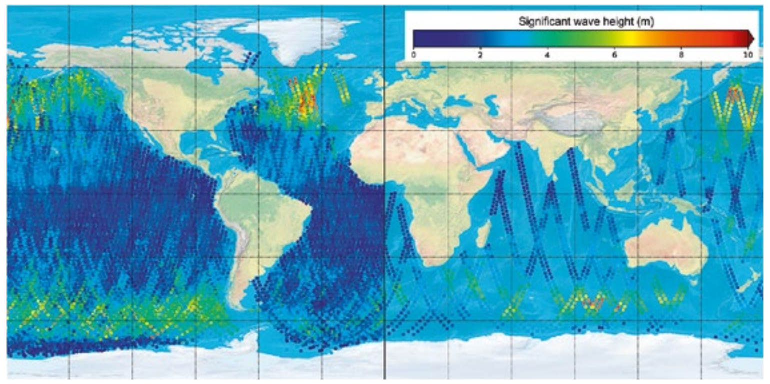
Three factors define the basic security situation for offshore wind farms. First, potential hazards can come from many directions – the sea surface, underwater, or from the air – but security measures such as fences or barriers are difficult to implement at sea. Second, the constant, comprehensive monitoring of wind farms is a challenge due to their location and weather conditions, compounded by the fact that it takes longer than on land for emergency responders or security forces to reach the scene – even by helicopter. Third, many stakeholders are involved in their construction, operation and maintenance, including the owners, manufacturers, and

DRONES FOR TRANSPORTING GOODS

Drones have proven to be important aids in inspecting onshore and offshore wind farms. In the future, they could also transport tools, materials and possibly even personnel – tasks that have so far only been performed by ships and crewed helicopters. This will require state-of-the-art technology, a high degree of automation and seamless operational integration. The Upcoming Drones Windfarm research project, run by the DLR Institute of Flight Systems and energy provider EnBW, is exploring solutions for drone-based transport. The goal is for drones to carry loads of up to 200 kilograms quickly and autonomously over distances of 100 kilometres to offshore wind farms. One highlight of the project was the Offshore Drone Challenge in June 2024. Held at the DLR National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt, the event saw international drone manufacturers and operators demonstrate their technical solutions in a model mission. Drones were tested on flight manoeuvres, such as picking up and dropping off loads, as well as beyond-visual-line-of-sight (BVLOS) operations, in which drones must function entirely automatically. To support this, DLR experts set up a temporary geozone to expand drone operations – a previously unheard-of testing environment.

Watch a Youtube video on the Offshore Drone Challenge (in German)

Flight tests at the Schwienau II wind farm



Coverage of the world's oceans by the Copernicus Sentinel-1 radar satellite on 1 February 2021 (right) and for the entire month of February 2021 (left). Colours indicate wave heights derived from radar data.

NEW ALGORITHM RECORDS SEA SWELL

The DLR Martime Safety and Security Lab in Bremen is developing algorithms based on satellite radar imagery that can measure the height of waves with a world-beating accuracy of approximately 25 centimetres, as well as their period. Up-to-date information and forecasts of sea swell are essential for coastal protection, shipping and the construction of offshore wind farms. As part of the ESA-funded CCI Sea State project, the entire archive of the Copernicus Sentinel-1 satellite was processed and compared with not only buoy and model data, but also algorithms from other leading global institutions. The findings are especially important for areas where on-site measurement data is unavailable.

Wind farm in the Baltic Sea off the Danish coast

installation companies of turbines, converter platforms and cables, as well as providers of operations, control, maintenance and security services.

Detecting risks early and creating room for action

Detecting and assessing potentially hazardous situations at an early stage is hugely important for the protection of maritime infrastructure. Frank Sill Torres' team can draw on a wealth of expertise to determine which approaches are best suited to the detection of anomalies and hazards, relying primarily on technologies and expertise from DLR's aeronautics and space research divisions.

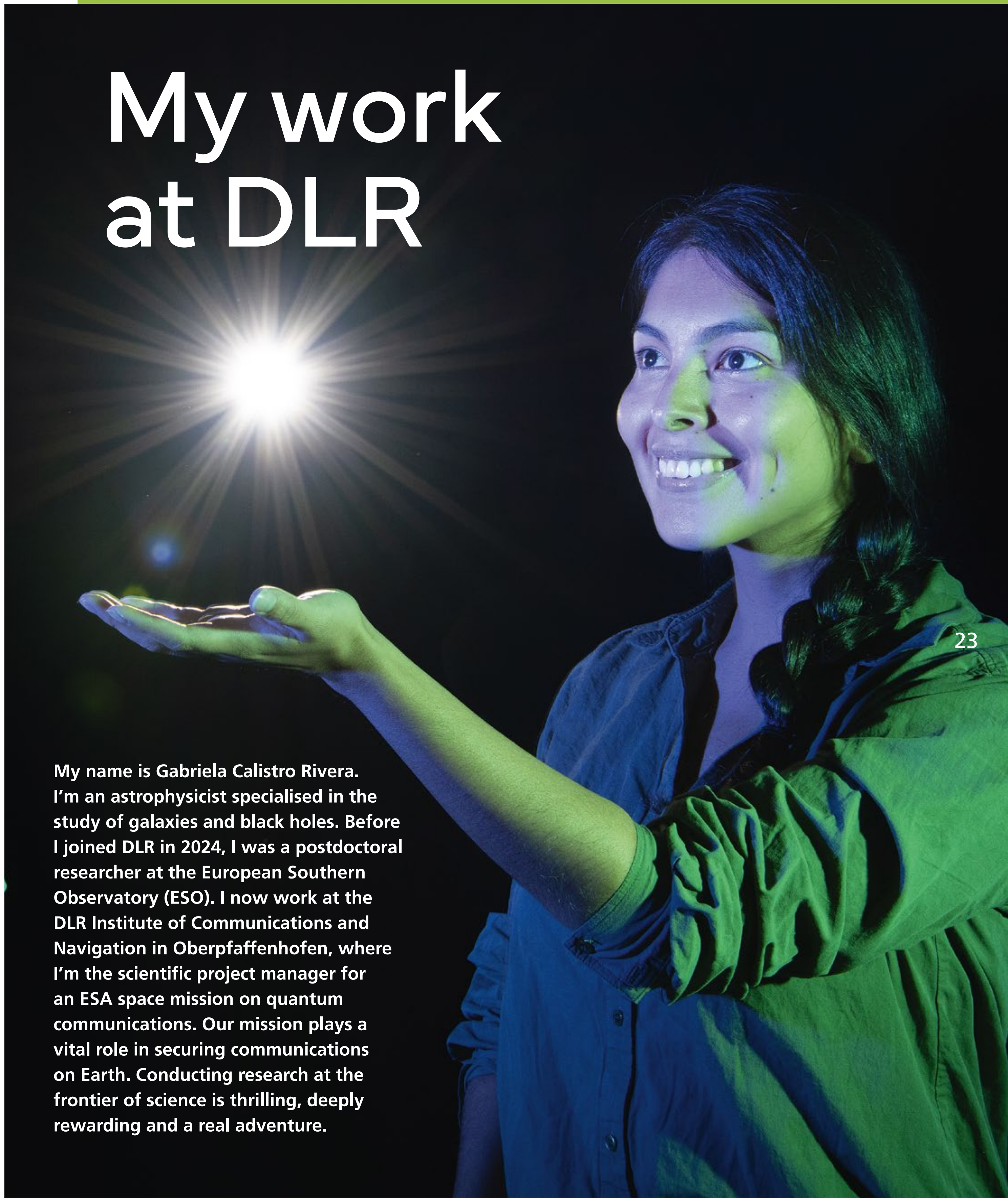
Using highly specialised camera, radar or laser sensors, large areas can be monitored from the air with aircraft, drones or satellites. "Our expertise can be deployed very effectively to protect maritime infrastructure," says Sill Torres, referencing the wide-ranging synergies within DLR. "On top of that, we're well versed in merging the large volumes of data collected by these sensors and evaluating them using state-of-the-art IT and artificial intelligence methods." For maritime applications like offshore wind, sensor systems could be mounted directly onto platforms, or installed on board small, autonomous or remotely controlled submarines to monitor the area. DLR is discussing these ideas with sensor manufacturers, who may benefit from the fact that adapting their existing systems for maritime applications will open up an entirely new market.

"Our overarching goal is to develop technologies that enable us to efficiently monitor and assess the situation at offshore wind farms, and use this information to support those responsible for making critical decisions," Sill Torres concludes. The findings from this research can also be used for developing security concepts and architectures, along with training security forces. "In this way, DLR is building up reliable, science-driven knowledge, and playing a decisive role in shaping the field of maritime infrastructure protection – which is of immense technological, political and economic importance."

Denise Nüssle is a press editor at DLR, reporting primarily on research in the fields of energy and transport. Despite being a landlubber living in southwest Germany, she enjoys fishing out fascinating DLR topics from the maritime world.

Image: BWE/Christian Hinsch (p. 22 bottom)

Image: DLR



My work at DLR

My name is Gabriela Calistro Rivera. I'm an astrophysicist specialised in the study of galaxies and black holes. Before I joined DLR in 2024, I was a postdoctoral researcher at the European Southern Observatory (ESO). I now work at the DLR Institute of Communications and Navigation in Oberpfaffenhofen, where I'm the scientific project manager for an ESA space mission on quantum communications. Our mission plays a vital role in securing communications on Earth. Conducting research at the frontier of science is thrilling, deeply rewarding and a real adventure.

Join our fascination –
create the world of tomorrow

Image: Getty Images/Svenn-Inge Sellesbakk

Frolicking fire foxes light up the heavens!

In Neustrelitz, DLR is investigating space weather

by Melanie-Konstanze Wiese

Green, red and violet lights flicker across the sky – by turns fascinatingly beautiful, mysterious and even menacing. Throughout history, people have interpreted the Northern Lights in different ways: as heroic apparitions, the souls of the deceased or fire foxes racing through the sky, creating sparks as their tails brush over the mountaintops. Some even saw them as bad omens of events to come. Today, scientists understand the origins of the aurora – the visible effects on Earth of what we call space weather. And yet, there are still many open questions, which the DLR Institute of Solar-Terrestrial Physics in Neustrelitz is working to answer.

The Sun at its peak

In recent months, auroras have been visible not only in the polar regions but also across parts of Germany, the UK, the Netherlands, Spain, the US and even Australia. The reason for this? The Sun has been particularly active of late.

Observations of our star date back to antiquity, revealing dark spots on its bright surface. With the advent of the first telescopes, astronomers were able to count and document these sunspots, eventually discovering that their number rose and fell in an eleven-year cycle. Since 1755, astronomers have tracked these cycles, using sunspot numbers as an indicator of solar activity. According to this count, the Sun is currently in Solar Cycle 25, and reached its latest peak in October 2024.

Sunspots appear dark because they are cooler than the surrounding solar surface and emit less visible light. We now know they form where loops of magnetic field lines pierce the Sun's surface. Periods with many sunspots are associated with heightened solar activity and an increased number of solar eruptions, such as coronal mass ejections which hurl vast quantities of charged particles – primarily electrons and protons – into space. When these particles encounter Earth's magnetic field, they are directed towards the magnetic poles, where the field is strongest. There, at altitudes of approximately 80 to 500 kilometres, they can penetrate the upper atmosphere and collide with oxygen and nitrogen molecules. These collisions excite the molecules, causing them to absorb energy. As the molecules return to their normal state, they release this energy in the form of light. This is what we see as the Northern – or Southern – Lights.

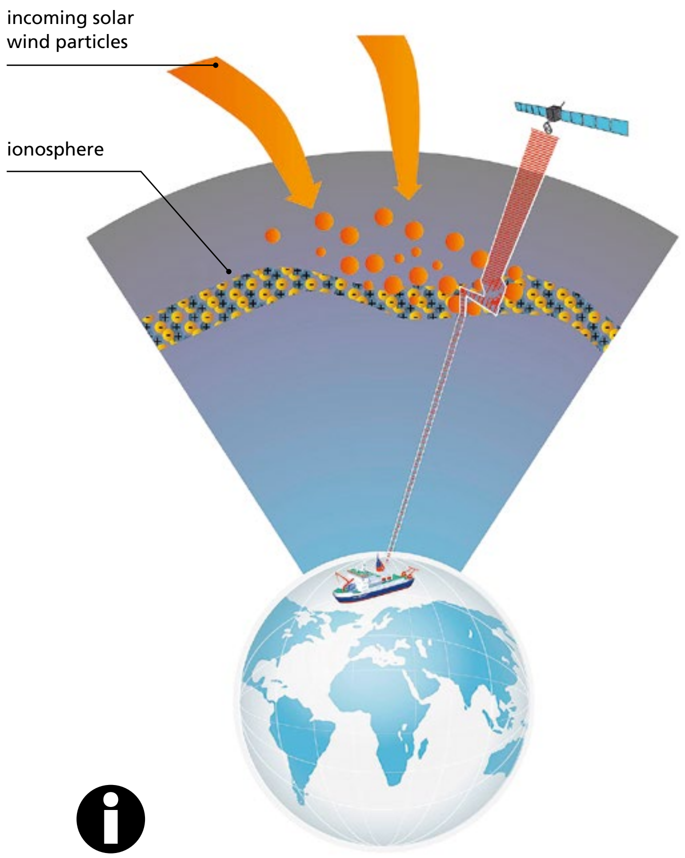
The colour of the aurora depends on which gas molecules are excited during the process and at what altitude: green auroras come from oxygen at approximately 100 kilometres; red from oxygen at over 200 kilometres; and blue or violet from nitrogen.

Solar events with consequences for Earth

In addition to creating this beautiful light show, solar activity can have serious consequences for life on Earth. While Earth's magnetic field protects us from the continuous stream of charged particles known as the solar wind, major events – known as solar storms – can overwhelm this shield and cause major disruptions to technological systems including satellites, navigation services like GPS, communications systems and power grids.

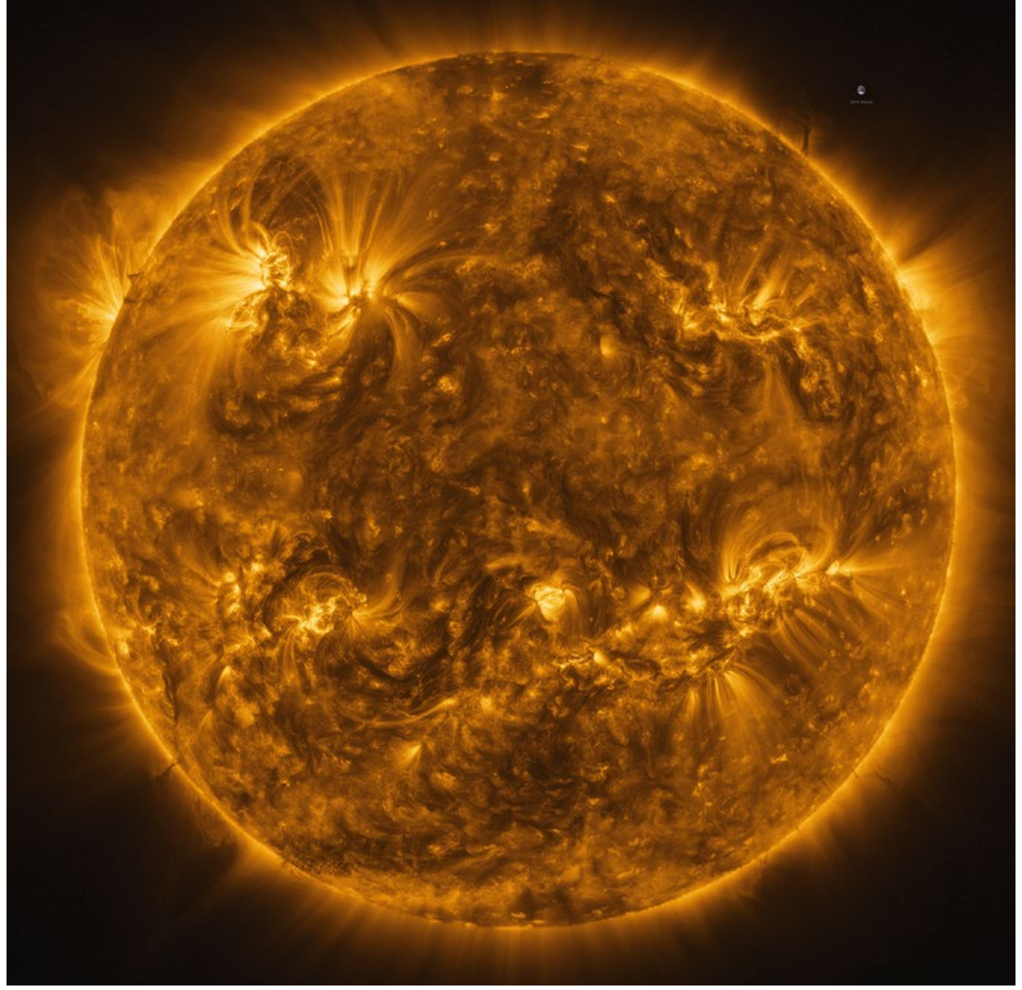
Data from millions of kilometres away

To make reliable predictions and prepare for extreme events, DLR researchers at the Institute of Solar-Terrestrial Physics in Neustrelitz study the influence of



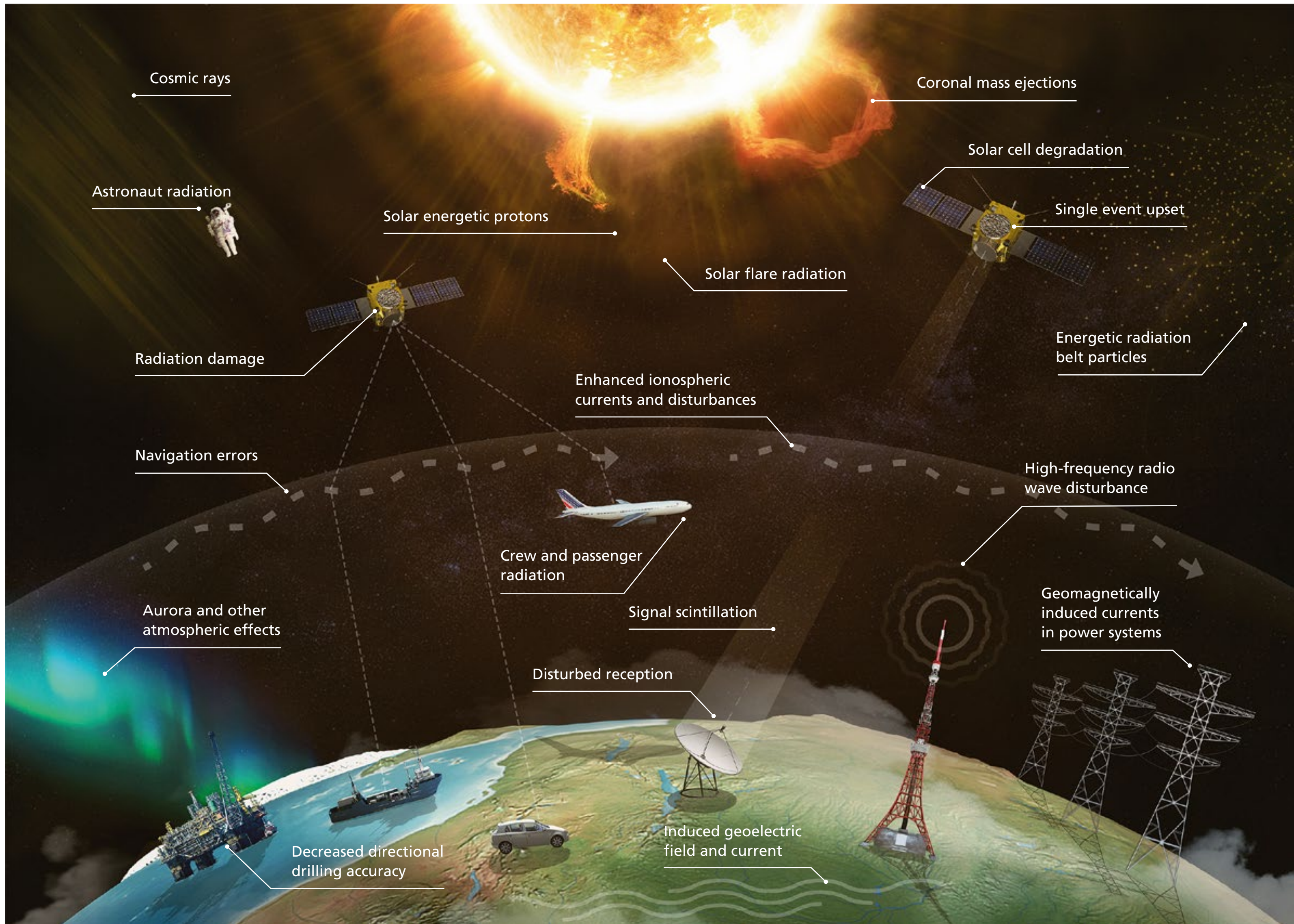
AS THE SOLAR WIND STRIKES EARTH

When electrically charged particles from the solar wind, accelerated by solar storms, strike Earth's ionosphere with force, they knock electrons off gas atoms and molecules – turning them into charged particles known as ions. This process, called ionisation, disrupts radio signals travelling from satellites to Earth. Navigation systems are particularly affected and can become inaccurate or even stop working for a short time.



The Sun is 150 million kilometres from Earth. Its surface reaches 5500 degrees Celsius, but its core is far hotter – up to 15 million degrees.

Space weather and its effects



Images: ESA/NASA (top), ESA (bottom)

Antennas have been in operation at the DLR site in Neustrelitz for over 100 years. Among other things, they receive signals from a satellite monitoring solar activity 1.5 million kilometres away.

When the electrically charged particles from a solar storm collide with Earth's magnetic field, the effects can be both visible and tangible.

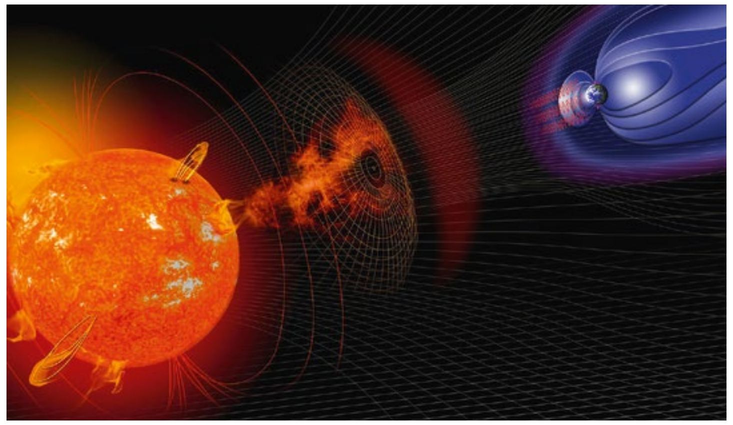


Image: NASA (bottom)

space weather on technical systems and services. They continuously monitor solar activity using satellites such as the Advanced Composition Explorer (ACE) and the Deep Space Climate Observatory (DSCOVR).

These satellites transmit data from a distance of 1.5 million kilometres, some of which is received directly at the German Remote Sensing Data Center in Neustrelitz. They are positioned at Lagrange point 1 (L1), one of several points in space where the gravitational pull of the Sun and Earth, combined with a satellite's centrifugal force, are in balance. This allows satellites positioned here to maintain a stable position relative to both celestial bodies. Researchers also use data from satellites that measure the solar wind – the constant stream of charged particles emitted by the Sun. These measurements are crucial for understanding how the solar wind affects Earth.

Space weather influences complex processes in the upper atmosphere, specifically the interconnected system of the ionosphere, thermosphere and magnetosphere. Researchers at the Neustrelitz institute, located in the northeastern German state of Mecklenburg-Western Pomerania, investigate the properties of these atmospheric regions and how they interact. By developing physics-based models, they can simulate the movement, distribution and impact of these solar particle streams, and ultimately forecast near-Earth space conditions and their potential effects on technical infrastructure.

Though the institute was only founded in May 2019, it already plays a leading role in Germany – for example, by hosting the National Space Weather Workshop, where experts meet regularly to exchange knowledge and provide information and advice to government bodies and businesses. Space weather researchers at Neustrelitz are also active on the international stage. Within the United Nations Committee on the Peaceful Uses of Outer Space, the institute coordinates Germany's participation in the International Initiative on Space Weather and provides data for global space weather forecasting.

The importance of accurate forecasts

A quick look at the possible impacts of solar storms shows just how crucial space weather science and reliable timely forecasts have become for our technology-dependent society. One example is the risk posed to communication systems that rely on radio signals – such as those used on aircraft, ships or in military operations. In extreme cases, disturbances can last for days, causing major problems. GPS signals, which are a type of radio wave, travel through the ionosphere – the ionised portion of the upper atmosphere. Changes in electron density can cause positioning systems to give inaccurate location data or even fail entirely.

Powerful solar storms can disrupt Earth's magnetic field and trigger geomagnetic storms. These can induce electric currents in power lines, damaging transformers and other parts of the power grid. In severe cases, this can lead to widespread power outages lasting for days or even weeks. One example is the Quebec blackout of 1989, when a solar storm knocked out the power grid in Canada and left millions without electricity.

Typically, scientists have about one day's warning before a solar storm reaches Earth – not much time for protective action. This makes early and accurate predictions all the more important, so that appropriate measures can be taken. For example, information about expected measurement inaccuracies can be passed on to the relevant companies and authorities. Switching off satellites can also be a protective measure.

Blind spots in space research

Although forecasting accuracy has improved in recent years thanks to better models and technology, the complexity of space weather still presents major challenges. In particular, many physical processes in Earth's upper atmosphere are still not fully understood. One reason is the lack of data on the thermosphere – the layer of Earth's atmosphere that extends from approximately 90 to 500 kilometres in altitude, where auroras form and temperatures rise sharply due to the absorption of solar radiation. Most of the ionosphere lies within this region, and, between 100 and 300 kilometres in particular, the thermosphere remains insufficiently characterised due to limited measurements and the complexity of space weather interactions.

Forecasts could be further improved if researchers were able to determine the arrival time and intensity of solar activity at an earlier stage. For this, parameters such as speed, proton density and properties of the interplanetary magnetic field would need to be determined earlier, ideally already at L1. Additional observations from the Lagrange points L4 and L5 would also advance this research.

One ray of hope is the European Space Agency's Vigil mission – a space observatory that will monitor solar activity from Lagrange point 5, trailing Earth in its orbit. There, it will carry instruments from NASA, NOAA and others, to observe the 'side' of the Sun, detecting solar activity before it rotates into view from Earth – providing earlier warnings of potentially disruptive space weather. The launch of this first-ever mission to L5 is currently planned for 2031.

Melanie-Konstanze Wiese is responsible for communications at DLR locations in Berlin, Cottbus, Dresden, Jena, Neustrelitz and Zittau. With the onset of the solar maximum, media interest in the aurora has also increased.

SPACE WEATHER FORECASTS

The Ionosphere Monitoring and Prediction Center (IMPC), developed and operated by DLR, provides near-real-time data and forecasts on the current state of the ionosphere, along with corresponding alerts. As the successor to the established Space Weather Application Center – Ionosphere (SWACI), the IMPC offers significantly improved ionospheric weather data and forecasts, while also complementing the SWACI long-term data archive.

Here you can find weather information from the IMPC.

Out of the way!

Protecting Earth from asteroid impact

by Ulrich Köhler

The Hera spacecraft (centre) will deploy two small satellites: Milani (left) and Juventas (right).

Image: ESA/Science Office

A massive crash, silent in the cosmic vacuum of our Solar System: nearly three years ago, in September 2022, NASA's DART spacecraft slammed into the roughly 150-metre-wide asteroid Dimorphos at a speed of approximately 22,000 kilometres per hour – exactly as planned. Scientists refer to this dryly as a 'targeted kinetic impact'. Next year, the European Space Agency's Hera mission will investigate what that impact has actually achieved.

DART – the Double Asteroid Redirection Test – was designed to see whether a collision could alter the path of Dimorphos, which orbits the Didymos asteroid five times its size. The results were astonishing: measured from Earth, the impact shortened Dimorphos' orbit by more than half an hour – far more than the ten minutes most experts had predicted. Mission accomplished? Certainly, but that 30-minute deflection measured does not alone provide us with enough knowledge should our survival on Earth ever depend on changing the path of a sizeable asteroid.

That's why scientists are now taking a much closer look at what this collision – between a modern high-tech tin can from Earth and a 4.5-billion-year-old primordial rock from the asteroid belt, 11 million kilometres away – actually did. To this end, the European Hera spacecraft was launched on 7 October 2024. It will reach Didymos and Dimorphos in late 2026 to observe and measure the changes caused by DART. The goal is nothing less than improving the safety of our planet. The key phrase here: planetary defence – the effort to protect Earth from one of the bigger threats from space.

What happens if an asteroid hits Earth?

It wouldn't necessarily be the end of the world, but the impact of an asteroid several hundred metres in diameter could still be one of the greatest natural disasters in human history – perhaps even the greatest. The good news is that astronomers have not currently found any bodies in the Solar System measuring more than 100 metres in diameter on a collision course with Earth within this century. Given that there are over 36,000 near-Earth objects (NEOs) this size or larger, this provides some reassurance. In almost all cases, the highly elliptical orbits of these solar-orbiting objects have been very precisely determined, so experts don't get nervous when even a huge asteroid is forecast to whizz past Earth closer than the geostationary satellites orbiting at a distance of just 36,000 kilometres. One such example is the 340-metre-wide Apophis, which will pass by in 2029. Another is 2024-YR4, discovered in late 2024 and estimated to be between 50 and 90 metres wide: for some weeks it was thought that it could potentially collide with Earth, but there is currently a less than one percent chance of this happening. It's more likely now that it would hit the Moon.

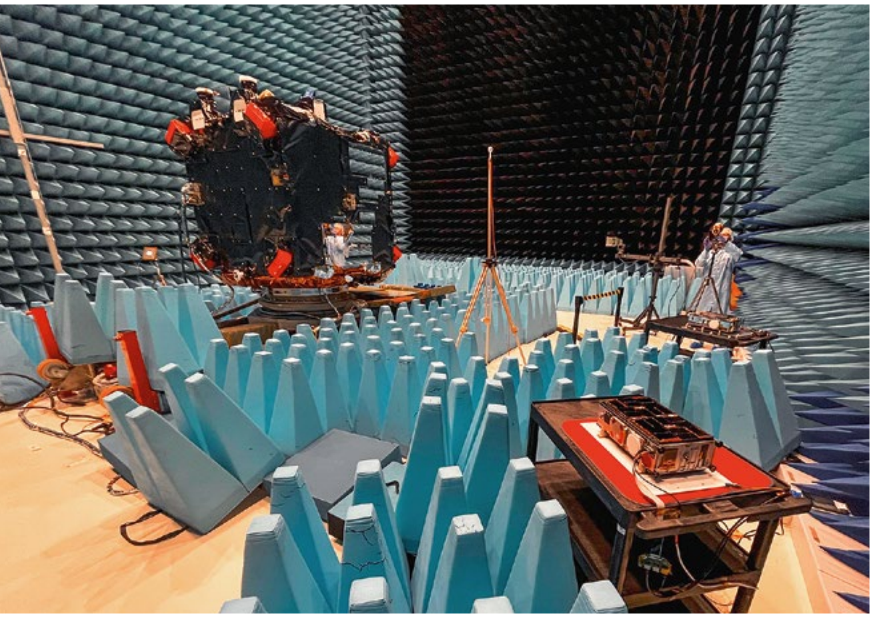
A matter of time

But with more than 36,000 NEOs out there, it's only a matter of time before one of them strikes. Earth is relatively large – and eventually, another collision with one of these rocky, often carbon-rich and sometimes metallic mini-worlds is bound to happen. The real danger lies in their speed – and Earth's – creating immense destructive potential, especially in head-on collisions. After all, even though we can't perceive it, Earth is orbiting the Sun at 30 kilometres per second. If an asteroid meets it head-on at the same speed, their combined velocity reaches up to 60 kilometres per second – roughly 220,000 kilometres per hour; or Leipzig to Dresden in two seconds. Such an asteroid, penetrating the atmosphere and crashing into Earth's surface, would have catastrophic consequences.

Small bodies under ten metres in diameter tend to disintegrate in the increasingly compressed air of their entry channel, causing a violent explosion in the stratosphere. In 1908, an intruder less than 100 metres wide destroyed an uninhabited forest area near the Podkamennaya Tunguska River in Siberia, after exploding at an altitude of 20 kilometres. Millions of trees were flattened, snapped like matchsticks, over an area the size of Luxembourg. Had the asteroid arrived just an hour later on the same trajectory, Earth's rotation would have brought a catastrophe of immeasurable proportions to St. Petersburg.

Bad news for the dinosaurs, great for us

Perhaps the best-known asteroid strike was the truly Earth-changing Chicxulub event 66 million years ago, when a space rock perhaps 15 kilometres in diameter struck near the Yucatán Peninsula. The global effects were devastating: dust and aerosols in the atmosphere blocked sunlight, causing temperatures to drop so drastically that large, cold-blooded reptiles could not survive. But their loss was our gain. That moment – at the boundary between the Cretaceous and the Tertiary periods, between the



The radio connection between Hera (left) and the small satellites Milani (right, in the foreground) and Juventas (further back) is tested in the Maxwell test chamber.

Image: ESA/F. Perez Lissi

THE HERA ASTEROID MISSION

Hera is Europe's contribution to the Asteroid Impact & Deflection Assessment (AIDA) initiative from NASA and ESA. The mission, launched on 7 October 2024, aims to study the Didymos/Dimorphos binary asteroid system. ESA awarded the contract for building the probe to Bremen-based company OHB. At a cost of 130 million euros, Hera is a relatively low-cost deep space mission. As the largest financial contributor, Germany is contributing 37.5 percent of the costs, alongside 14 other ESA Member States. Countless technical and scientific elements of Hera also come from Germany. The German Space Agency at DLR is coordinating all of these national contributions, supported by funding from the Federal Ministry for Economic Affairs and Climate Action.

Mesozoic and Cenozoic eras – marked the dawn of the age of mammals, and eventually, us.

It is well known that the 'Homo' genus evolved into 'Homo sapiens', who, for almost 70 years now, have been venturing into space and exploring Earth's immediate cosmic neighbourhood with specially developed equipment. It is sheer coincidence that since the dawn of the space age in 1957, and even in the period since 1801 – when the first asteroid, the 1000-kilometre-wide Ceres was discovered by Giuseppe Piazzi of Palermo – no NEO has been detected that poses a threat to Earth. Of course, past good luck is not guaranteed to continue – but fortunately humanity may soon have access to space technology capable of preventing the catastrophe of a cosmic collision between Earth and a hazardous asteroid.

Hera to shed light in the dark

So back to the DART and Hera missions – the first to test the practical implementation of asteroid defence ideas and concepts developed over several decades. First of all, we don't know enough about the asteroids that could potentially cause catastrophic impacts. In addition to investigating the consequences of the DART collision, Hera will seek new insights into the characteristics of small yet potentially dangerous asteroids. This European mission will also be the first to closely examine a tandem asteroid, known as a binary system, orbiting the Sun on a path that crosses Earth's orbit.

Recent asteroid missions have made an astonishing observation: small asteroids, just a few hundred metres to a few kilometres in diameter, do not appear to be rock-solid. Instead, they seem to be a conglomeration of loosely piled components, weakly bound and full of cavities – what experts call 'rubble piles'. If this were the rule rather than the exception, it would have consequences for the explosion scenario upon entering Earth's atmosphere: such a body could result in a surface-impact explosion scenario analogous to a shotgun burst.

The threat of binary systems

Another interesting phenomenon is that a large proportion of bodies in the main asteroid belt between Mars and Jupiter appear to be such binary systems of two (or more) small bodies orbiting each other. Model calculations suggest that up to one-fifth of asteroids less than one kilometre in diameter could exist in these configurations – a phenomenon that is only partially understood.

DISCOVER
Asteroid defence

The Hera spacecraft

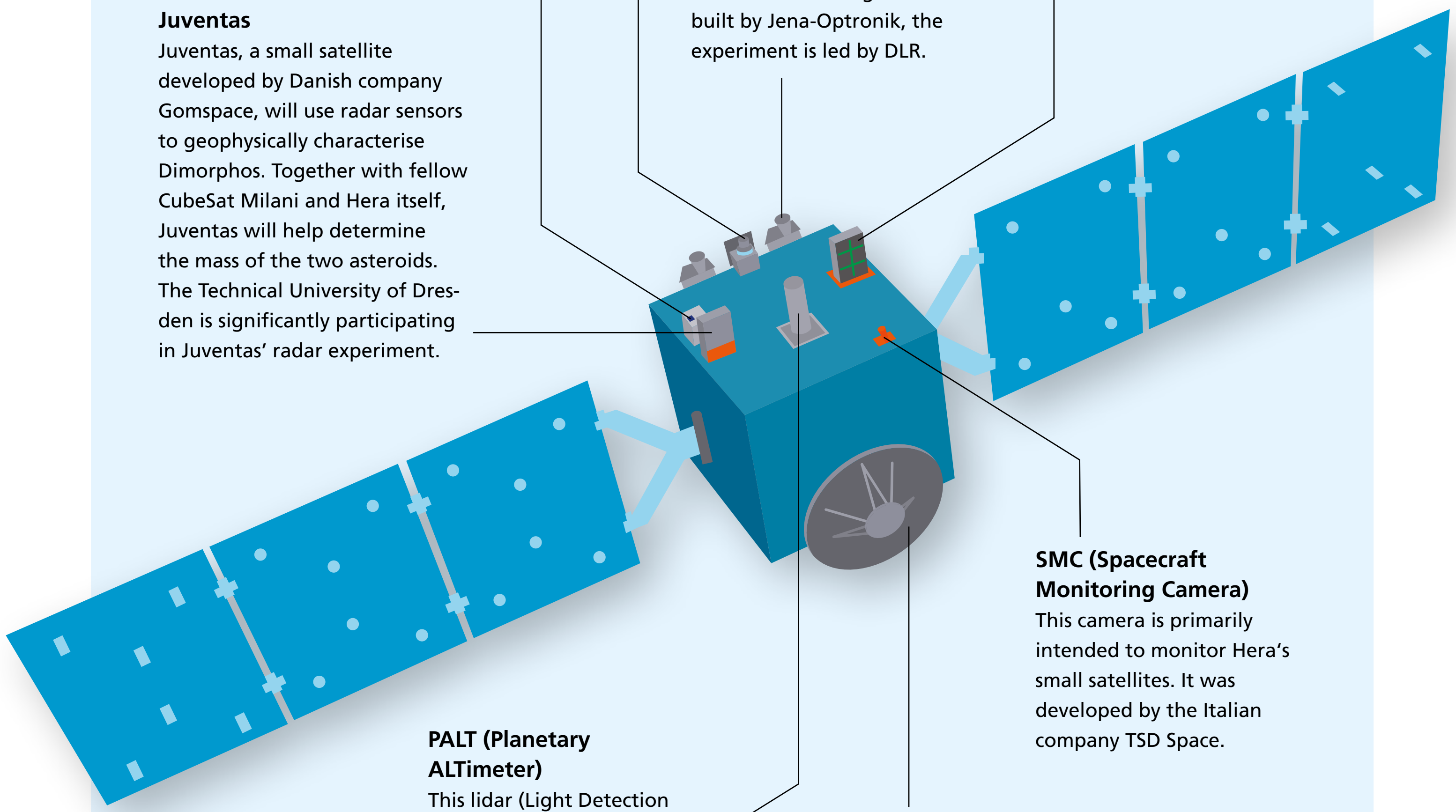
TIRI (Thermal Infrared Imager)
The thermal infrared spectrometer from the Japanese space agency (JAXA) will measure the asteroids' surface temperature.

Milani
This small satellite is roughly the size of a shoebox, and will conduct hyperspectral measurements to analyse the mineral composition of Dimorphos and Didymos. Milani was developed by a consortium of companies, universities and research institutes from Italy, Finland and the Czech Republic, and was built by Italian company Tyvak.

HyperScout-H
This spectrometer, developed by Cosine Research in the Netherlands, will provide data on the asteroids' geological composition.

AFC (Asteroid Framing Camera)
Two identical cameras provide images of the asteroids in visible light wavelengths. They are also used for navigation. Developed by the Max Planck Institute for Solar System Research in Göttingen and built by Jena-Optronik, the experiment is led by DLR.

Juventas
Juventas, a small satellite developed by Danish company Gomspace, will use radar sensors to geophysically characterise Dimorphos. Together with fellow CubeSat Milani and Hera itself, Juventas will help determine the mass of the two asteroids. The Technical University of Dresden is significantly participating in Juventas' radar experiment.



SMC (Spacecraft Monitoring Camera)
This camera is primarily intended to monitor Hera's small satellites. It was developed by the Italian company TSD Space.

PALT (Planetary ALTimeter)
This lidar (Light Detection and Ranging) instrument uses a laser beam to measure the distance to the asteroids, thus supporting navigation. It was principally developed by the Portuguese company Efacec.

Antenna
Hera's antenna is 1.2 metres in diameter and is made of carbon fibre-reinforced plastic instead of aluminium. Manufactured by Munich-based company HPS, it will ensure that Hera's data reaches Earth.

Source graphic: iopscience.iop.org

Illustration of the Hera spacecraft between Didymos, approximately 800-metres-wide, and its smaller companion Dimorphos. The DART space probe slammed into Dimorphos in September 2022, successfully altering its orbit.

Brace for impact! A mosaic of the last images from the DART probe before it hit Dimorphos. The asteroid's 'rubble-pile' morphology is clearly visible.

One explanation could be that the rotation speed of such bodies gradually increases due to exposure to sunlight and the delayed release of heat, and photons with it, during the asteroid night. If a rotational speed threshold is crossed that ensures the stability of such loosely connected bodies, a smaller fragment may split off. But what does this mean for asteroid deflection? Will we need to plan differently if two objects, rather than one, are suddenly on a collision course with Earth? In the Didymos/Dimorphos binary system, the larger body, Didymos, rotates on its own axis at almost exactly this assumed stability limit. What happens if Didymos and similar bodies begin spinning faster and cross that limit? Hera is expected to provide important insights into precisely this area.

The ESA mission is named after the Greek goddess Hera, one of Zeus's (many) lovers, to whom various protective roles are attributed. Thanks to space technology, protecting Earth from asteroid impacts is now truly within reach, and we might well join Gauls from the Asterix comics in appealing to the gods to 'keep the sky from falling on our heads' – at least until humanity has devised, tested and rolled out reliable methods for deflecting any Earth-bound asteroids that may be identified in the future. Experts estimate that a body the size of Dimorphos hits Earth roughly once every few thousand years. That seems like a lot of time, but as an ancient stargazer might have put it: tempus fugit.

Ulrich Köhler is a planetary geologist at the DLR Institute of Space Research. Having grown up near the Nördlinger Ries – a 25-kilometre crater torn into the Swabian Jura by a kilometre-wide asteroid 15 million years ago – he is fascinated by the subject of asteroids crossing Earth's orbit.

Images: ESA (top); NASA/Johns Hopkins University APL (bottom)

Heavy trucks need supercharging

DLR Projektträger is facilitating the race to find the right charging technology for electric trucks

by Jens Erler and Lovis Krüger

This eTGX is the first vehicle from MAN to be fitted with the Megawatt Charging System

Image: MAN

Just a few moments ago, Hubert Aiwanger, Bavaria's State Minister of Economic Affairs, Regional Development and Energy, plugged a heavy goods vehicle (HGV) into the mains power supply. With this simple act, the first demonstration of the NEFTON research project's Megawatt Charging System began – in front of an audience of 200 guests from the worlds of politics, science, business and media. Next to the vehicle itself, a display shows the charging rate. The cable connecting the truck to the charging station is as thick as an arm and must be constantly cooled. After all, in just three hours, it transmits roughly as much electricity as a three-person household consumes in an entire year. This huge capacity means the large battery in an electric semi-truck (also known as an articulated lorry) can be charged in under 30 minutes – a significant milestone in the quest for climate-neutral freight transport by road.

Climate transition held up in traffic

While greenhouse gas emissions are steadily falling in the energy and industrial sectors, transport remains a problem. In Germany, the transport sector accounts for approximately one-fifth of emissions. Although electric cars are gradually becoming a common sight on the roads, electric HGVs – or e-trucks – are still rare. Yet the commercial vehicle sector is precisely where a switch to greener power could deliver the greatest benefits. A single semi-truck, on average, churns out as much greenhouse gas in one year as 50 cars. In total, heavy-duty vehicles are responsible for more than five percent of Germany's total greenhouse gas emissions. If large trucks on German roads are electrified, half of freight transport emissions could be eliminated.

Most passenger and freight trains in Germany already run on renewable electricity. However, quickly shifting a significant portion of freight from road to rail is only possible to a limited extent, due to a lack of capacity in the rail network. To make freight transport more climate-compatible in the short term and to achieve the national climate goals set for 2030 and 2040, the focus must therefore be on approaches that directly address road freight transport.

Electric trucks are ready to go

The good news: At the IAA Transportation 2024, the most important trade fair for com-

THE MEGAWATT CHARGING SYSTEM

The Megawatt Charging System (MCS) is a new direct-current (DC) charging standard specifically tailored to trucks and other heavy-duty commercial vehicles. Under development since 2018, MCS is designed to deliver up to ten times the charging capacity (3.75 megawatts) of a conventional electric vehicle fast charger. The waste heat generated by electrical currents, which can reach up to 3000 amps, is dissipated via large, actively cooled DC contacts and cables. The first production vehicles and charging stations equipped with MCS are expected to be launched later this year.

mercial vehicles, all major manufacturers showcased electric semi-trucks with a range of approximately 500 kilometres. The hefty batteries installed in these vehicles store enough energy to haul even large trailers long distances across Europe.

Only one problem remains unsolved: it takes too long to charge these giant batteries. To make e-trucks practical on a large scale, a substantial recharge must be achievable during a driver's 45-minute rest break – and standard charging stations can't deliver that. That's why researchers in projects like NEFTON are developing faster charging systems – and their results are promising.

The charging technology race

With its Elektro-Mobil (Electric Mobility) programme, Germany's Federal Ministry for Economic Affairs and Climate Action is funding the most promising charging technology solutions. DLR Projektträger is coordinating the programme, moderating the race to develop market-ready technologies and supporting researchers in funded collaborative projects. These include wireless inductive charging systems, overhead lines and bidirectional charging technologies. In bidirectional systems, electric cars and trucks can not only draw power from the grid but also feed it back – transforming them into mobile energy storage units. This technology could allow fleet operators and haulage companies to generate income even from parked vehicles. The greatest hopes, however, rest on two other charging technologies: the Megawatt Charging System (MCS) and swappable batteries. Through the NEFTON collaborative project, MAN, the Technical University of Munich and five other collaborators have been working on the Megawatt Charging System, which was unveiled to the public last summer.

Vehicle manufacturers prefer cable-based charging systems like the MCS. Indeed, one current objective of the Elektro-Mobil funding programme is to identify technologies that can complement cable-based fast charging and allow for synergies between them. That's because there is one issue with the Megawatt Charging System: charging parks with dozens of trucks – each drawing some 1000 kilowatts of power at the same time – place a major strain on electricity grids. It may be five years or more until sufficient grid connections can

Image: DLR

"If fleet operators store and sell self-generated solar power from their own warehouse rooftops, or trade energy on the electricity market, this can reduce the total cost of e-trucks and make the power grid more resilient to disruptions."

Michael Schier, Head of Department at the DLR Institute of Vehicle Concepts

be provided. Even today, Germany lacks thousands of truck parking spaces – and future charging infrastructure will further increase the space required for parked semi-trucks.

Researchers in the eHaul project are working on an alternative that could bypass grid bottlenecks altogether. The research consortium – composed of TU Berlin, Bosch and five other parties – is funded through the Elektro-Mobil programme and receives support from DLR Projektträger. Instead of charging vehicles while stationary, eHaul is developing an automated battery-swapping system that replaces depleted batteries with fully charged ones. This concept has seen major success in China since 2020, where roughly one in two e-trucks is now fitted with swappable batteries – and ever more are obtaining approval to do so. Stefanie Marker, who heads the eHaul research project at TU Berlin, explains: "Fast charging and battery swapping should not be seen as competing options. They can coexist and help pave the way for reliable long-distance electric transport. Ideally, battery-swapping stations will act as a transitional solution until nationwide grid expansion is complete – and remain useful on routes where charging infrastructure is still lacking". However, a swapping system requires additional batteries to be kept on hand, and there is currently no common technical standard.

Nevertheless, one thing is certain: the race to develop the future infrastructure for electric trucks is in full swing. Once the right technology is found, the transformation of freight transport can get under way at full speed.

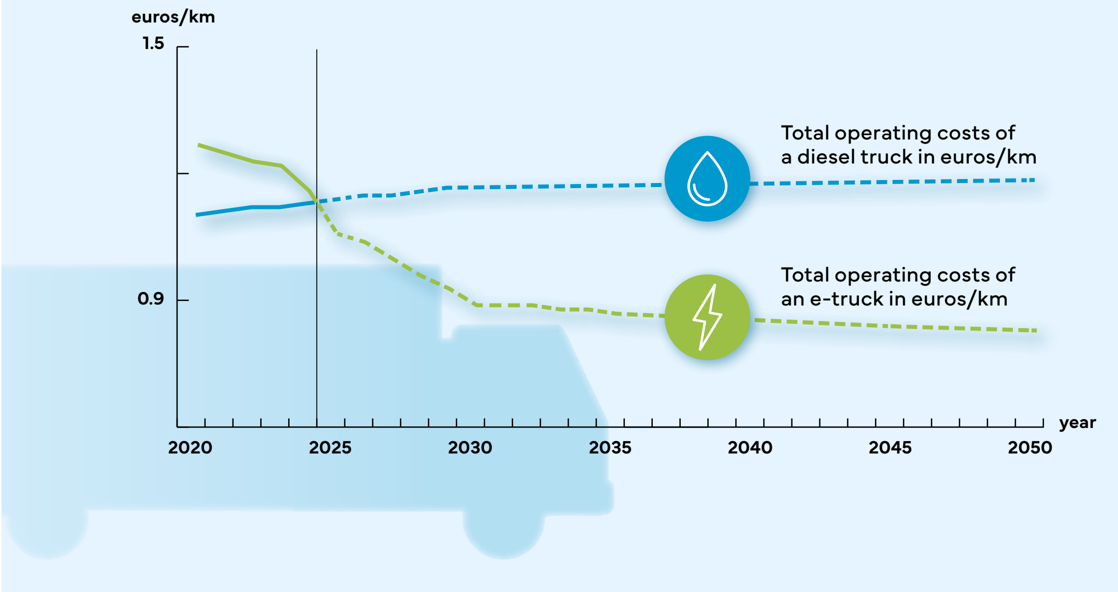
When will e-trucks conquer the market?

Unlike passenger cars, semi-trucks aren't sold on emotion – they're sold on numbers. Logistics companies, facing tough competition and operating under narrow margins, operate strictly in line with economic logic. As soon as the total cost of purchasing, operating and reselling an e-truck – along with charging infrastructure at their own depots – drops below that of a conventional diesel truck, they will gladly make the switch, provided the charging systems can be integrated smoothly into their operations. For German freight companies, the financial balance could start tipping in favour of e-trucks as early as this year. A typical semi-truck covers approximately 600 to 800 kilometres a day. In eight years, it will have travelled about one million kilometres, and reached the end of its useful life. Freight operators renew their fleet based on this cycle, so once e-trucks gain the cost advantage, Germany's commercial vehicle fleet could be fully electrified within a decade.

Jens Erler is a scientific advisor on electromobility at DLR Projektträger and is also committed to the energy transition in his private life. **Lovis Krüger** works in corporate communications at DLR Projektträger and is a keen cyclist.

Comparing operating costs: e-truck vs. diesel truck

Model calculation by the DLR Institute of Vehicle Concepts



The total cost of purchasing and operating electric trucks could fall below that of diesel vehicles as early as 2025. Alongside technological advances, road toll exemptions for e-trucks and the rising price of carbon dioxide are important factors in this cost transition, as shown by a scenario analysis from the DLR Institute of Vehicle Concepts.

Moon dust in the spotlight

Clouds of fine dust shimmer in the beam of a spotlight. But this is no ordinary dust – it's deceptively similar to lunar regolith, or Moon dust. This photo was taken during one of the first experiments in the LUNA hall, which DLR and the European Space Agency (ESA) opened in Cologne in September 2024. Apart from the temperature and vacuum, conditions here closely resemble those on the lunar surface, allowing astronauts and robots to prepare for future missions to the Moon. The DLR Institute of Communications and Navigation has used LUNA to investigate how payload boxes, sensors, rovers and exploration crews can be connected together to form a network – exchanging signals that could be used for both communication and navigation. The swarm navigation system developed by the institute can assist in exploring the surface of the Moon or Mars, and can also help improve orientation in places on Earth, such as lava caves, where satellite navigation is unavailable.

Image: DLR

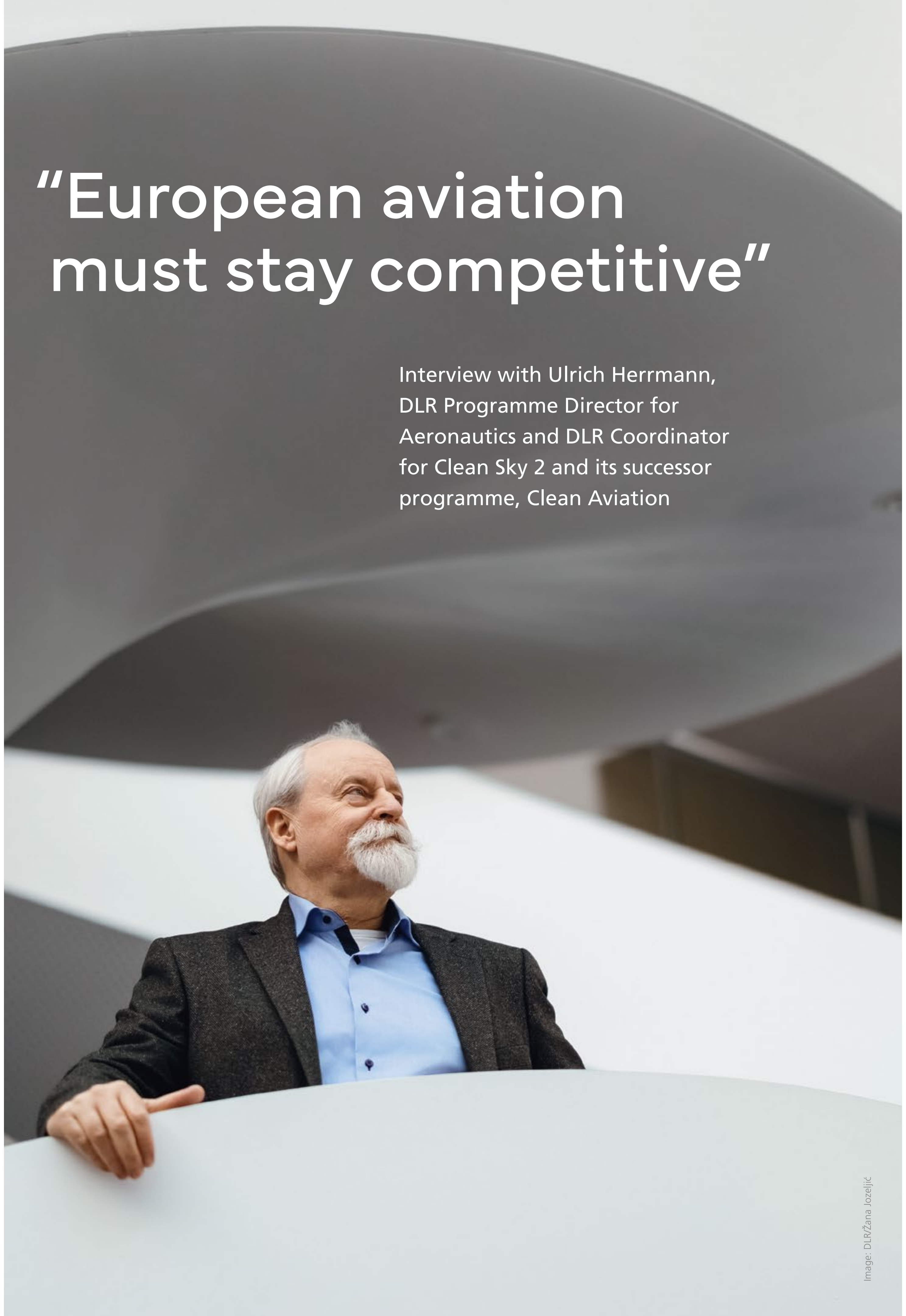


Image: DLR/Žana Jozeljić

"European aviation must stay competitive"

Interview with Ulrich Herrmann, DLR Programme Director for Aeronautics and DLR Coordinator for Clean Sky 2 and its successor programme, Clean Aviation

Clean Sky 2 was Europe's largest aviation research programme. Over ten years, DLR explored potential solutions for climate-neutral aviation.

What was this major research programme about?

Clean Sky 2, its predecessor Clean Sky and its successor Clean Aviation (launched in 2023), are major initiatives of the European Commission. The core idea behind these programmes is to ensure that European aviation remains competitive and becomes climate-neutral by 2050. At the start of Clean Sky, about 20 years ago, we realised that while we were conducting a great deal of research, we lacked large-scale flight experiments or integrated prototypes – known as demonstrators. To close this gap, more than 800 European aviation organisations joined forces to work on these research programmes – ranging from large industrial companies to small- and medium-sized enterprises, universities and research organisations like DLR. Clean Sky 2 was funded with 1.7 billion euros, with DLR, – the fifth-largest recipient – granted over 80 million euros. This funding supported the development of more than 100 demonstrators and approximately 1000 technologies across nine main projects. In total, DLR has been involved in 27 projects.

Can you give some examples?

We conducted research into solutions for commercial aircraft, business jets and even helicopters. This included the aircraft themselves, but also their components – wings, fuselage, tail units, engines and cabins. The programme also looked at production technology, simulation processes and improving measurement techniques. Our research into laminar flow during cruise flight proved particularly interesting. When flying, we ideally want a high level of laminar flow – that is, minimal frictional resistance – over the wings or engine nacelles. If components can be designed in such a way that they are surrounded by laminar rather than turbulent airflow, this reduces drag and fuel consumption. Another project, the Multi-Functional Fuselage Demonstrator (MFFD), aimed at reducing the weight of the fuselage and enabling automated production, with DLR playing a prominent role. In fact, the fuselage demonstrator was awarded the prestigious JEC Composites Innovation Award in early 2025. DLR was also responsible for the overarching task of analysing and evaluating all the technology contributing to Clean Sky 2. These findings are compiled using the 'Technology Evaluator'.

That's quite a lot! Which are your favourite results?

In addition to the RACER helicopter and MFFD, the installation and commissioning of the compressor test bench as part of the 2ShaftCompressor project were stand-out moments personally for me. With hardware developed at DLR in Cologne, we created an essential test facility for German industry – just like the new turbine test bench in Göttingen. Achieving all of this within the timeframe of the programme was a mammoth task, but we made it happen.

Another example was our work on the 'laminarisation' of commercial aircraft in collaboration with Airbus and Dassault. This technology had not yet been developed far enough to represent a viable business case – so, a worthwhile investment – or to be integrated into production aircraft. We've come a long way in this area to make that possible.

I was also particularly impressed to see our ISTAR research aircraft flying with artificial icing, in collaboration with Dassault. Ice build-up on the leading edges of aircraft wings is dangerous and can render aircraft unmanoeuvrable, so strict certification regulations have been introduced to address this. We used ISTAR to perform in-flight measurements showing how flight characteristics and performance change due to simulated icing. While flights with ice accretion had been conducted during the certification of this aircraft type, Dassault did not collect data on control or performance changes. Our new data forms the basis for comparing the real-life behaviour of aircraft under icing conditions with digital simulations. In the future, this could allow some certifications to be carried out by computer simulation, saving many costly and dangerous flight test hours.

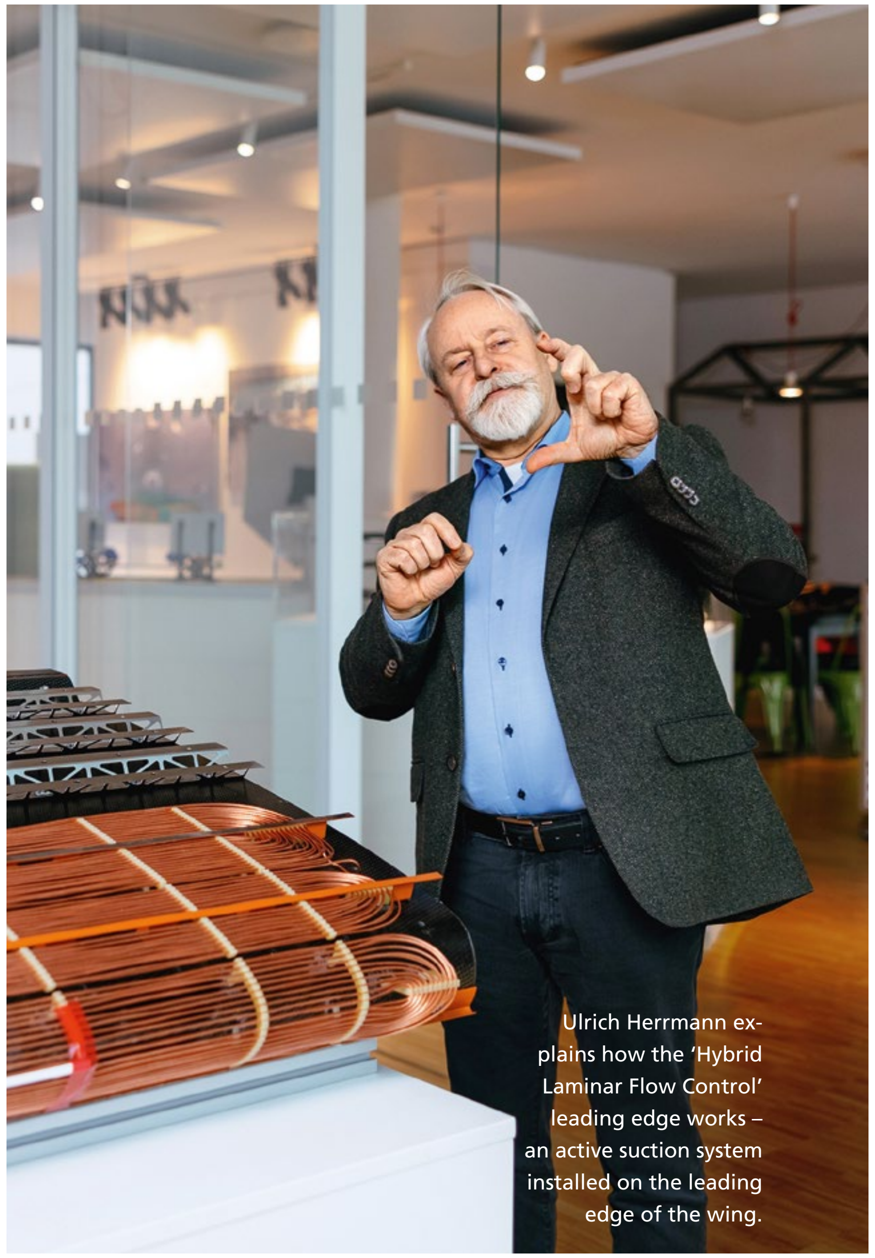
Which results do you think will have the most significant impact on aviation?

Take the aircraft market: an A320 can remain in service for up to 40 years, meaning the product and innovation cycles are correspondingly long. For a new aircraft generation to be launched successfully, sufficient gains in weight reduction, drag reduction and fuel savings are particularly promising. Production costs also play an important role. Back to our aircraft – while a new flap design on the wing can be implemented relatively quickly, a hybrid laminar system has to be part of a completely new wing design – a major financial risk for manufacturers. Through our work and developments, we've been able to demonstrate the conditions under which such a system can be operated economically.

What's your takeaway from Clean Sky 2?
I'd say that we – and by that I mean all DLR employees involved in Clean Sky 2 – fulfilled our task 110 percent. We solved problems and significantly advanced technologies so that manufacturers can integrate them into their aircraft. Whether everything comes into fruition will depend on factors like global market competition – which is out of DLR's hands.

One challenge in Europe will be to offer new, environmentally compatible aircraft which consume less fuel – at competitive prices. I'm noticing that manufacturers are starting to properly consider environmental impact now that they have a host of promising new technologies at their disposal that will enable them to implement this step economically. The aeronautics community has once again shown that we can achieve a lot in Europe if we pull together.

How will the public benefit from the programme?
The next generation of commercial aircraft, which will come onto the market from around 2035, will incorporate many of the technologies developed in Clean Sky and Clean Sky 2. I'm certain of that. In concrete terms, it could be that the outer part of the wing on a new commercial aircraft replacing the A320 may benefit from laminar flow to reduce drag. There will be new types of engines that are larger and more efficient. This will result in quieter cabins due to measures like active noise cancelling – thanks to a technique you may be familiar with from your headphones – and structural changes that prevent sound from spreading from its source into the cabin. DLR has also been working on new materials and production techniques that could reduce costs. Ultimately, our research is geared towards making aircraft so environmentally compatible that air travel in the future will be possible even under more stringent environmental regulations.



Ulrich Herrmann explains how the 'Hybrid Laminar Flow Control' leading edge works – an active suction system installed on the leading edge of the wing.

Clean Aviation, the successor programme, is already underway …
If aviation is to be climate neutral by 2050, the key decisions and concepts must be finalised by 2035. That's quite soon, so that's what the Clean Aviation programme is focusing on. As such, our research these days isn't geared towards helicopters or business jets; instead, the focus is on commercial aircraft and their engines. We're doing less research on cabins and wings but looking more at overall systems. To bring new aircraft into service as quickly as possible, Clean Aviation is also involved in the certification of new technologies from the very outset.

Are you once again coordinating the project at DLR?
Yes – I see my role as something like clearing a trail through the EU jungle. It's wonderful to work with so many highly motivated people, and I want to ensure that they get the resources they need to turn their constructive ideas into environmentally compatible and viable technologies together with European stakeholders.

This interview was conducted by **Julia Heil** – an editor who joined DLR Corporate Communications shortly after the launch of Clean Sky 2.

Image: DLR/Zana Jozeljić

Technology Evaluator

The results of Clean Sky 2

Europe's Clean Sky 2 programme was a major collaborative technology research effort dedicated to realising more environmentally compatible, and quieter, air transport. One of the projects was the Technology Evaluator, which assessed technologies and demonstrators in a holistic way. Data for the respective analyses was supplied by industry to the DLR Institute of System Architectures in Aeronautics, which carried out the evaluations for the operation of individual aircraft (mission level). The DLR Institute of Air Transport, together with stakeholders such as Cranfield University and the Netherlands Aerospace Centre, then extrapolated this data to the operation of entire airports (airport level) and to global air transport in Europe up to 2050 (air transport system level).

The results show that, without the use of Clean Sky 2 technologies, carbon dioxide emissions from air transport in Europe would increase by approximately 43 percent from 2019 to 2050. By contrast, the use of Clean Sky 2 technologies – even without switching to alternative energy sources – could limit this increase to just 23 percent. In terms of aircraft noise, a reduction of up to 44 percent in effective perceived noise is achievable. The Technology Evaluator also shows positive effects on employment and gross added value in both the European and global aviation sectors.

GOALS OF CLEAN SKY 2*

$-CO_2$
$-NO_x$
(noise)

Reduction of each
20–30%

* refers to technologies developed at mission level, compared to typical aircraft from the year 2014

EVALUATION LEVELS

MISSION LEVEL
Impact on individual flight operations

AIRPORT LEVEL
Potential savings in the operation of entire airports

AIR TRANSPORT SYSTEM LEVEL
Effects on the global air transport system by 2050

MISSION LEVEL ASSESSMENT

	$-CO_2$	$-NO_x$	(noise)
Long-haul	–18.2%	–44.9%	–20.1%
Medium-haul	–25.8 to –30.4%	–2.3 to –5.1%	–11.5 to –16.3%
Short-haul	–25 to –32.5%	–44 to –60%	+14 to –44%

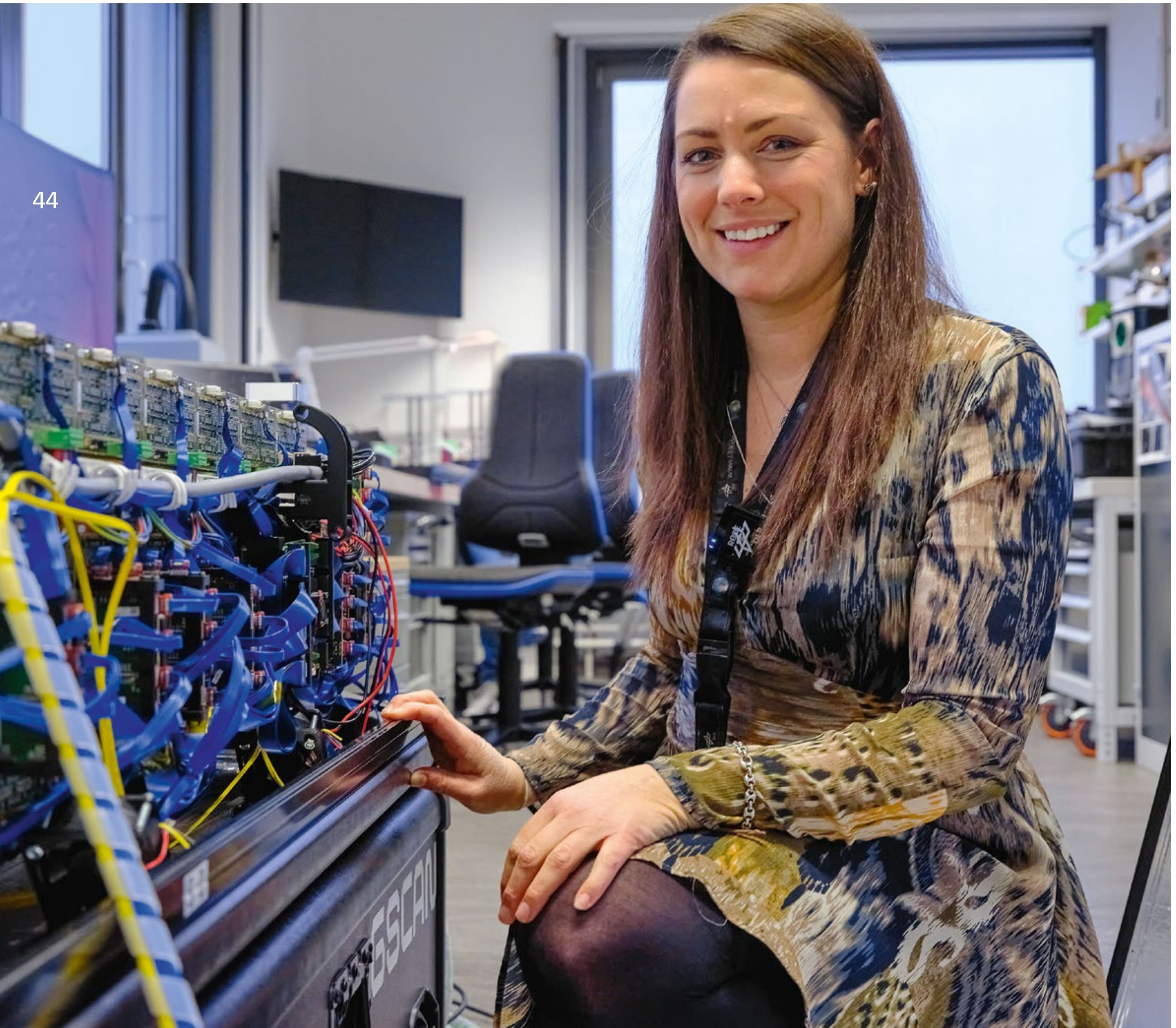
Final report from the Technology Evaluator, including additional findings

Graphic: Clean Aviation

Revealing a hidden world

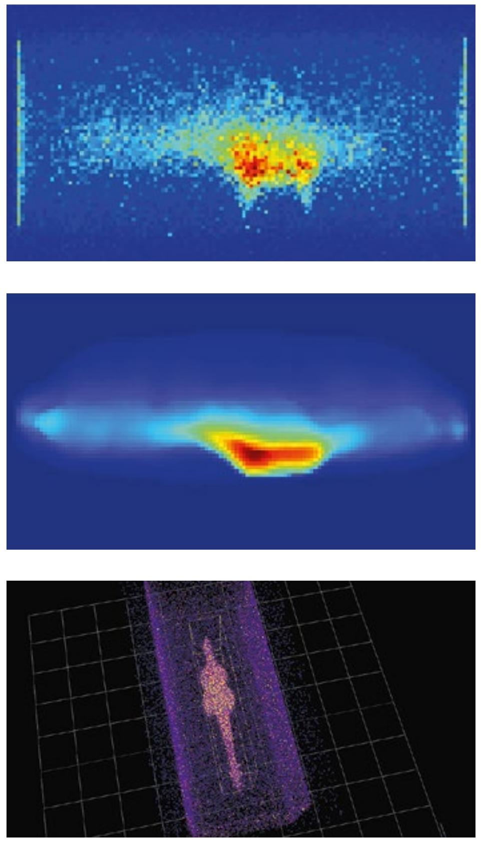
Meet Sarah Barnes, expert in muon tomography

by Lukas Lenz



Sarah Barnes from the DLR Institute for the Protection of Maritime Infrastructures is investigating possible applications of muons. These elementary particles are part of cosmic radiation and are therefore present everywhere.

Images: p. 44: DLR; p. 45: DLR/Felix Sattler



A scanner that uses naturally occurring muon radiation can reveal, in just a few minutes, what lies hidden inside a shipping container – including its contents and shape.

"Even as we stand here talking, thousands of muons are passing through our bodies," explains Sarah Barnes, a researcher at the DLR Institute for the Protection of Maritime Infrastructures, calmly pointing to her office – part laboratory, part warehouse. Colourful cables stick out from shelves and walls on the left, while a few desks with computers are arranged on the right. "These only came in yesterday," says the British-born scientist, referring to two black boxes stacked in the middle of the room. "Detector plates for muon tomography."

Barnes is a muon researcher. At DLR, she studies these elementary particles which are present all around us and form part of what is known as cosmic radiation. This high-energy particle radiation originates from deep space – from black holes, supernovae or even our own Sun. It reaches Earth's atmosphere in the form of protons, where it triggers the formation of many additional particles: electrons, protons, neutrons – and muons. This shower of new particles rains down on Earth's surface, and from here Barnes aims to use the muons that fall to examine objects tomographically – making hidden objects visible. The principle is similar to radiology – except that, unlike artificially-generated X-rays, naturally-occurring muons in cosmic radiation don't come with negative health impacts.

Beyond the limits of X-rays

This new technology opens up a wide range of applications. For example, a muon scanner could be used to inspect the integrity of bridges without having to close them to traffic. In industry, prototypes made of particularly dense materials could be examined without having to disassemble them into their component parts. Muon tomography could also be used to check the condition of nuclear waste containers – providing vital information on whether the containers and their contents are still intact, which is important for long-term interim storage and necessary final disposal.

The technique is currently being used by archaeologists, helping them search for hidden chambers inside pyramids or to 'see' inside ancient urns that are too fragile to open. In geology, muon tomography is used to observe volcanic chambers and anticipate potential eruptions. At DLR, another application is currently under the spotlight: researchers in the EU-funded SilentBorder project are working on a muon tomograph to scan shipping containers.

A journey at nearly the speed of light

To conduct tomography, Barnes uses two opposing detector plates – known as hodoscopes. Each consists of three double layers of fibres arranged perpendicularly to each other. When a muon passes through one of the fibres, a flash of light is generated, which is recorded by a computer. This allows the position of the muon in the detectors to be determined. As the muon travels through the material, between the scanner plates, the muon is very slightly deflected from its path. "This happens almost at the

Sarah Barnes and her colleague Maximilian Pérez Prada investigate the readout electronics of the muon detector.

speed of light," Barnes explains. The scanner measures the tiny variation between the elementary particle's entry and exit angles, and complex algorithms and machine learning methods process the data to create an accurate three-dimensional image of what lies between the hodoscopes. Based on how the muons are scattered, it is even possible to infer which materials are located where.

Active and passive methods

In imaging, a distinction is made between active and passive techniques. Active methods emit radiation that is then measured – such as ultrasound and X-rays. Passive methods, by contrast, use either radiation already being emitted by an object – such as temperature distributions revealed by a thermal imaging camera – or radiation that is already present, such as cosmic rays. One advantage of passive processes is their low energy consumption. A muon scanner panel consumes only about 100 watts – as much as a powerful laptop. What's more, muon tomography enables three-dimensional imaging of the objects under investigation, which is otherwise only possible using complex and expensive techniques like computed tomography. The downside is the time required to scan very large objects, since the number of muons in cosmic radiation is limited. The rule is: the higher the resolution of the image required, the more muons must be tracked.

SILENTBORDER

SilentBorder is an EU-funded project in which DLR researchers, together with colleagues at nine European universities, companies and public authorities, are developing an intelligent, cost-effective protoype scanner. The goal is for shipping containers to pass through the scanner in just two to five minutes – similar to baggage screening at airports. Since naturally occurring muon radiation poses no additional health risks, researchers hope to create a procedure that is more flexible, less bureaucratic and free from concerns about radiation regulations.

Less red tape, more security

Muon scanners may also help reduce bureaucracy, since radiation protection regulations for handling artificial sources of radiation would no longer apply. No special safety precautions need to be taken or documented, making the technology easier to use than, say, X-ray equipment.

At container ports, currently only two to ten percent of all containers are randomly checked for illegal goods. Various methods are used for this purpose, the most common being X-ray scans and manual inspections, that require containers to be opened. In some cases, sniffer dogs are deployed to detect drugs or people. All of these methods are time-consuming and costly.

At the end of our conversation, Sarah Barnes shares a glimpse of the future: "We hope that our work will lead to the first muon scanners being installed in ports within five to ten years. The long-term dream is a large-scale muon scanning system that shipping containers pass through directly after unloading – scanned automatically in a few minutes, just like luggage at the airport – and without any radiation exposure."

Lukas Lenz is a working student in DLR communications. For this story, he took a deep dive into the physics of matter for a close-up look at muons in action.

Image: DLR

Image: Getty Images/Matthew Micah Wright

Flying lighter

Intelligent load control saves fuel and protects the environment

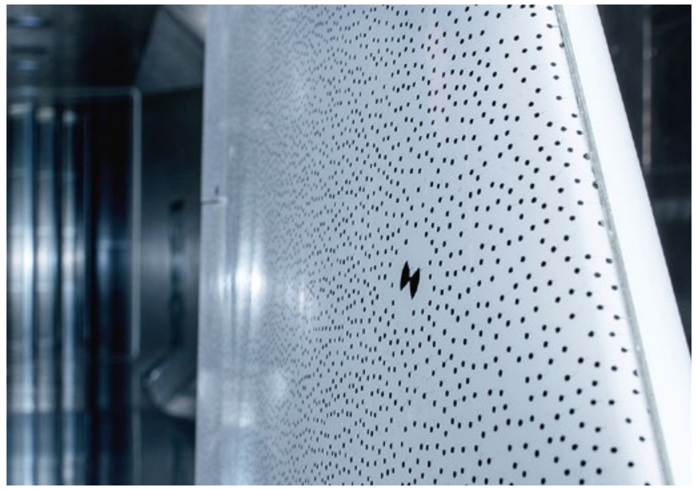
by Vera Koopmann

Ladies and gentlemen, we are expecting some light to moderate turbulence ahead. Please return to your seats and ensure your seatbelts are properly fastened." Frequent flyers will be familiar with this announcement, made when an aircraft flies through changing air layers or encounters stormy conditions and gusts of wind. What passengers experience as an unpleasant jolt are forces – 'loads' – acting on the structure of the aircraft, in addition to the normal stresses of flight. To withstand these forces, structures must be robust, which means relatively heavy with a trade-off in higher fuel consumption and less efficient flying. However, technology could soon address this problem – with the arrival of intelligent load control.

How does intelligent load control work?

In the DLR project oLAF (optimal load-adaptive aircraft), researchers are working to identify and reduce additional structural loads. Until now, aircraft have been built sturdy enough to passively withstand turbulence. State-of-the-art load control systems, on the other hand, operate actively: "You

A 1.75-metre-long glass fibre wing was tested in the low-speed wind tunnel in Braunschweig for the oLAF project (bottom). The small dots (right) are optical sensors in a measuring system used to precisely calculate the deformation of the wing under load. Moderate turbulence generates loads between 0.5 and 1.5 g.



can imagine it like the suspension in a car that compensates for bumps in the road. While conventional shock absorbers react passively to potholes, an active, adaptive suspension system works proactively – detecting changes and compensating for them in a targeted manner. This is exactly how our system works in the air: it reacts to gusts in real time and reduces additional loads on the aircraft," explains Lars Reimer, Project Manager at the DLR Institute of Aerodynamics and Flow Technology. "By integrating this innovative load control, we can develop lighter, more efficient aircraft configurations without compromising safety, and while also improving passenger comfort."

Load control from day one

In principle, the idea of active load control is not entirely new – many types of aircraft already have systems that counteract gusts and the loads associated with manoeuvring. However, these are usually only introduced after the basic aircraft design has been completed, when hardly any changes to the structure are possible. "In oLAF, we have integrated the technology from the very beginning of the design phase," emphasises Reimer. Using computer simulations, the project team compared a modern aircraft with current technology against a design featuring this innovative load control system. The result showed that active load control not only has the potential to make wings lighter, but also improves them aerodynamically.

From simulation to wind tunnel

In the next step, the researchers tested a lightweight wing in a low-speed wind tunnel. "Our flexible wing was equipped with movable flaps and spoilers, which we tested using a specially developed gust generator," explains Wolf Krüger, co-project lead at the DLR Institute of Aeroelasticity. The goal was to analyse the forces acting on the wing when the trailing-edge flaps are deployed by the intelligent load control system to counteract the loads, and when they are not.

The DLR team compared the resulting oscillations of the wing under different scenarios, with and without the load control system activated. "With active load control, the wing deformed significantly less, and the load at the wing root was reduced by up to 80 percent," reports Krüger.

Economical and sustainable

The results from both simulations and tests show the great potential for savings that such systems offer. "With oLAF, we found that intelligent load control systems, if incorporated early in the aircraft design, can reduce an aircraft's fuel consumption by up to 7.2 percent," Reimer summarises. For a typical long-haul aircraft, this equates to several tonnes of kerosene per flight – enough to save millions of euros annually and significantly reduce carbon dioxide emissions. A reduction in materials and fuel consumption not only reduces the burden on the environment but also brings economic benefits. In concrete terms, this means an increase in economic efficiency of up to seven percent due to lower consumption – even considering the potentially higher maintenance costs. "While we initially saw load control as a method for weight reduction, we now see it as a key to wings with better aerodynamics and higher efficiency," says a delighted Reimer.

From ground to air

To enable aircraft to detect turbulence before entering bumpy air, the next project phase will see load reduction technology take to the skies, including on DLR's ISTAR research aircraft. The ISTAR aircraft is equipped with LiDAR (Light Detection and Ranging) sensors, which are able to detect wind fields well in advance. Perhaps the mid-air announcement "Please make sure your seatbelts are securely fastened" will soon be a thing of the past – thanks to intelligent load control and aircraft that think for themselves.

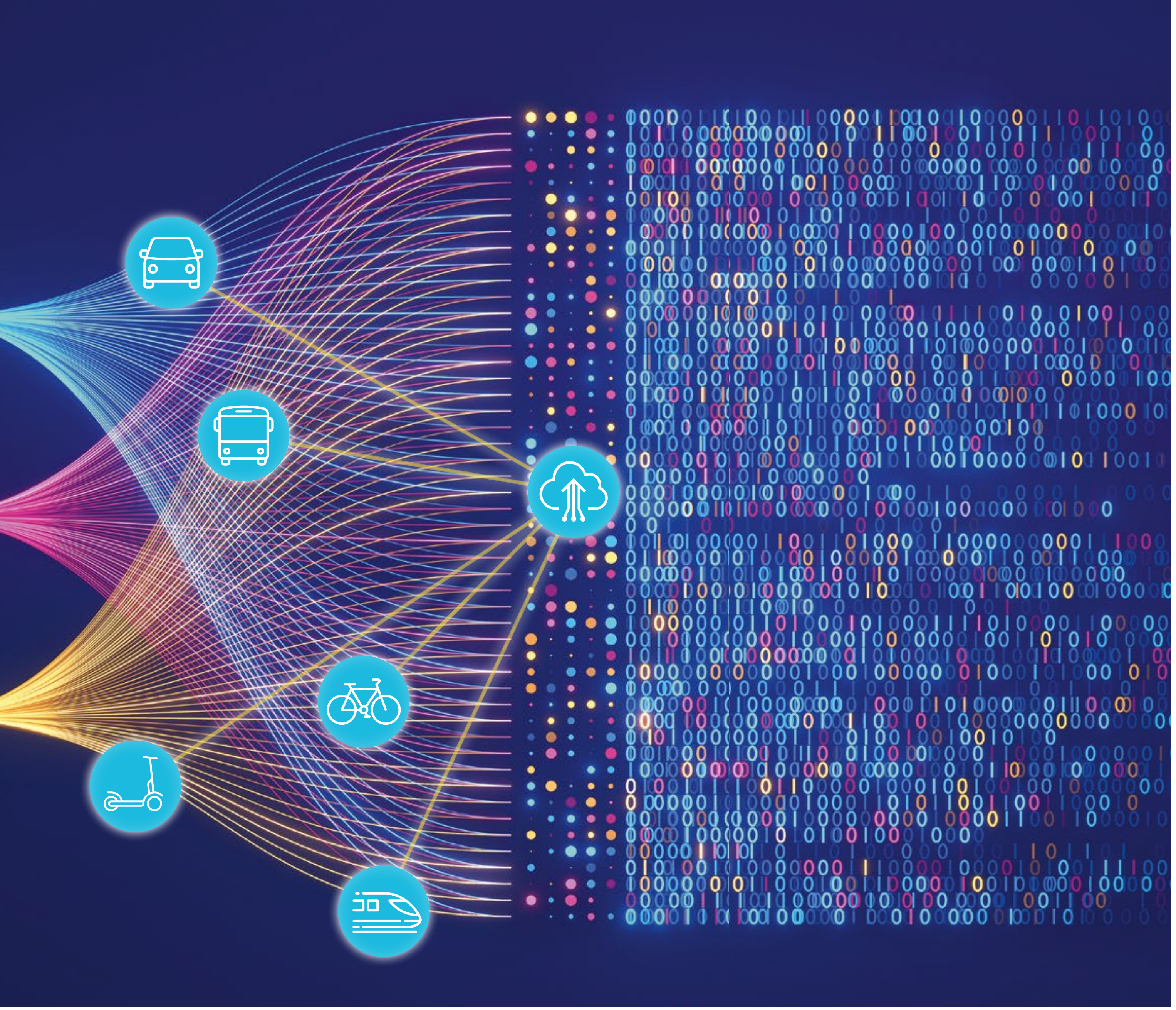
Vera Koopmann is responsible for communications at the DLR Institute of Aerodynamics and Flow Technology. She is fascinated by how engineering and aerodynamics come together to make flying more efficient and environmentally compatible.

"We initially saw load control as a method for weight reduction. Now we see it as a key to improved aerodynamics and greater efficiency."

Lars Reimer, Project Manager at the DLR Institute of Aerodynamics and Flow Technology

Image: DLR

Opening new doors to data spaces



Base-X enables seamless connections for sustainable mobility

by Katja Lenz

What exactly are data spaces? Figuratively speaking, they can be described as a series of rooms containing everything you need, sorted with meticulous precision. These spaces can only be accessed by individuals who have the right key and can verify their identity; they alone have the authority to add items or set up new rooms. Since an incredible amount of material is stored in these facilities and often needs to be quickly combined, the rooms are interconnected – virtually, of course. In the words of DLR researcher Maximilian Stäbler: "A data space enables the trustworthy implementation of data-based applications and business models. It offers everyone involved a high degree of flexibility and autonomy". Stäbler leads the Base-X project at the DLR Institute for AI Safety and Security. "Base-X," he continues, "is a comprehensive technical solution that integrates transport systems, mobility services and infrastructure into an interconnected ecosystem to enable seamless, efficient and sustainable transport solutions for both urban and rural areas".

DLR INSTITUTE FOR AI SAFETY AND SECURITY

The DLR Institute for AI Safety and Security researches and develops AI-related methods, processes, algorithms and technologies. These are used in the fields of energy, transport, aeronautics and space, as well as other sectors relevant to Germany as a centre for science and industry. The Institute focuses particularly on areas such as cybersecurity and automation in mobility and logistics.

Quickly connecting data

Base-X is extremely flexible, which makes it ideal for a wide range of applications – a 'jack of all trades' in the world of data spaces. The first pilot projects are underway in Hamburg and Ulm, and in Daegu, South Korea. At all three locations, Base-X is being used to bring together various types of data that previously had not been connected or weren't designed for integrated use. The goal is to streamline the linking of datasets, so that commuters, for example, won't have to switch between apps when transferring from different modes of transport – such as when getting off a train and onto a bike or e-scooter. Intermodal transport is a highly complex use case, but one that is well suited to Base-X. Data from all the different providers is kept available and neatly organised in the relevant 'rooms', but cannot be transferred to a common application. Returning to the room analogy, knowing your way around one room doesn't mean you can find your way around another, which may have a different organisational logic. What Base-X does in this scenario is provide the right signage, smooths out any uneven steps and installs extra security locks as required. In other words, it acts as a matchmaking platform: participants decide for themselves how the data they provide can be used and for what purposes. Rather than serving as a channel for transferring data itself, Base-X points the way to the right data source and ensures that the data transfer is carried out in accordance with agreed rules.

Images: p. 50: Getty Images/NicoElNino; p. 51: DLR

There is a lot of scope for using Base-X in the field of mobility. For example, it could be used to assist with road maintenance: in the future, every vehicle fitted with a camera could play a part in surveying the streets. This would require software to analyse and label the images and videos captured on camera – and of course a data space where the output could be stored and made available for further use. What kind of road damage has been spotted? Is it a pothole? Where is the damage? What does it look like? How urgently does it need to be repaired? With the help of Base-X, data collected could easily be harnessed to help resolve these issues. This use case is currently being implemented by the Institute for AI Safety and Security, in collaboration with industry and the municipal authorities of Hamburg, Ulm and Daegu.

Maximilian Stäbler and Frank Köster, Head of the DLR Institute for AI Safety and Security, are keen to take Base-X further, building new collaborations and using digital infrastructure with a particular focus on enhancing data-driven mobility solutions. With this in mind, the researchers recently paid a visit to South Korea. "This international cooperation underlines not only the scalability of our approach, but also its potential for real-world applications," says Stäbler. Base-X has also been supporting industry in developing interoperable and scalable solutions. "From our perspective," adds Köster, "Base-X is helping us take a crucial step towards a confident digital future."

ABOUT BASE-X

Base-X emerged from the Gaia-X 4 Future Mobility project family. Over three and a half years, 80 companies and research institutes worked on more than 20 use cases – all relating to mobility. The DLR Institute for AI Safety and Security is responsible for coordinating this project family. Gaia-X is a European initiative aimed at creating a powerful, secure and competitive data infrastructure. Base-X combines existing data and service infrastructures seamlessly with Gaia-X-compliant data spaces and ecosystems. The aim of Gaia-X is to create a transparent and open digital environment where data and services can be easily and securely accessed and exchanged.

Katja Lenz is a press editor in the DLR Communications department.

Maximilian Stäbler from the DLR Institute for AI Safety and Security

Stars, galaxies and a touch of nostalgia

A day at the Bochum Planetarium

by Claudio Steffes-tun

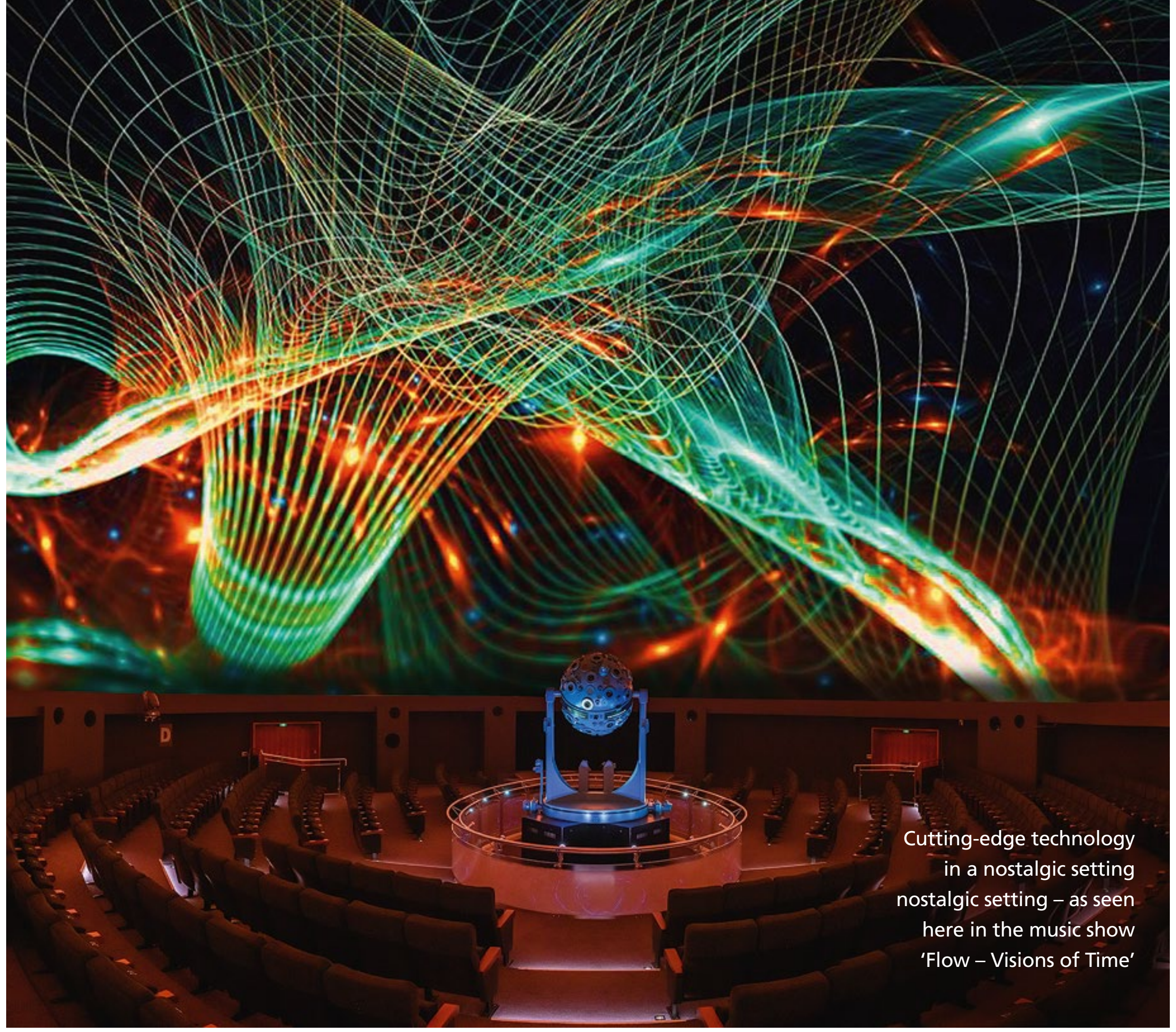
The Bochum Planetarium is perched atop a small hill. To get there, visitors ascend a narrow path to the listed building. Dating from 1964, the retro architecture recalls a bygone era. Green moss has since reclaimed the once-white dome, and a plaque beside the main entrance bears the inscription 'Denkmal' (historical monument). Inside, a fascinating world opens up, paving the way to the stars.

Technology meets the zeitgeist

In the foyer, photographs of distant galaxies give a taste of the shows in the main dome, while a life-size model of an astronaut and a large globe set the scene for our journey into space. And yet, the building retains many of its original features, with the floors, much of the furniture and the wood panelling all dating back to the 1960s.

Before getting started, there's a choice to make: lose yourself in the infinite expanse of the Universe or go on a 'planetary safari'? Once inside the dome, it's time to sit back and be amazed. The planetarium's Star Theatre seats up to 251 people. In the 'Fascinating Universe' show, the audience travels to planets, moons, stars and distant galaxies – all projected to spectacular effect onto the curved dome ceiling. Some images may appear slightly blurry – a result of their authenticity. This is precisely what distinguishes a planetarium from an IMAX.

Bochum Planetarium is one of the most visited in Europe. It also regularly hosts cultural events – such as the Luna Festival in 2018.



Cutting-edge technology in a nostalgic setting nostalgic setting – as seen here in the music show 'Flow – Visions of Time'

Images: Planetarium Bochum

A starry sky made in heaven

The heart of the Bochum Planetarium is the star projector, which brings the night sky to life with astonishing precision. This is where any nostalgia ends, as beneath the protective shell – which may appear historical – lies cutting-edge technology. The analogue Zeiss projector, for example, is complemented by a digital system. "The clarity of the stars is almost impossible to achieve with digital technology," says planetarium director and astrophysicist Susanne Hüttemeister. "But thanks to fibre optics, we can display the stars with a brilliance no digital projection can match."

A place for space enthusiasts of all ages

With more than 300,000 visitors per year, the Bochum Planetarium is one of the most popular in Europe. But it's far more than just a science hub. Later this year, for instance, it will host an experimental concert with the Dresden Symphony Orchestra, in which musicians in India and Bochum will perform together simultaneously. The planetarium also runs a permanent educational programme and is part of the European Space Education Resource Office (ESERO), a European Space Agency initiative run in cooperation with organisations including DLR, Ruhr University Bochum and the University of Bonn. Even astronauts use the planetarium to prepare for future missions to the International Space Station (ISS), practising their orientation skills guided by the constellations.

Into the cosmos

A visit to the Bochum Planetarium is more just a day out – it's a journey into the vastness of space and a reminder of how fragile and special our place in the Universe truly is. The planetarium remains true to its mission: to bring the wonders of the cosmos closer to people and to inspire them with the beauty of the Universe. And if that's not enough, you can even tie the knot here – under a romantic starry sky.

Claudio Steffes-tun is a student trainee in DLR Corporate Communications. He was struck by the passion the planetarium team brings to their work.

PLANETARIUM BOCHUM

Castroper Straße 67
44791 Bochum, Germany

Opening times: Open for scheduled shows, held daily except Mondays. The ticket office opens at least 30 minutes before each show.

Admission:
Single ticket: €10.50
Concession: €7.50
Children: €4

planetarium-bochum.de

Special events for curious minds: The planetarium director gives a talk on current topics in astronomy on the first Thursday of every month.

The rotor ship Buckau in the Port of Kiel, 1924

Wind tunnel investigation of a rotating cylinder at the AVA, around 1923

Images: DLR

FROM THE ARCHIVES
DLR's Central Archive is home to over 50,000 documents. Here, we delve into the depths of this trove of images, papers, certificates and texts. This article presents the Buckau rotor ship – the first in the world to use rotating cylinders for propulsion.

A voyage of rotating cylinders

How fluid dynamics research helped invent a new type of ship propulsion

by Jessika Wichner

On 19 November 1924, a ship slowly manoeuvred through the Port of Kiel. On board were Ludwig Prandtl and Albert Betz from the Aerodynamic Research Institute (AVA) in Göttingen – a predecessor of today's DLR – along with engineer Anton Flettner. The ship, named Buckau, had been a sailing ship for many years, but by now its sails were no more. Instead, to the astonishment of many curious onlookers, two large, rotating cylinders towered over the ship's hull. How could a ship be propelled without any sails, and what were the cylinders for?

To answer these questions, we need to go back in time. In 1852, German physicist Heinrich Gustav Magnus demonstrated that when a rotating cylinder is exposed to an airstream, it is subjected to a 'transverse force'. This same force causes a 'spinning ball' in tennis or table tennis to veer off its straight trajectory, with a slice or topspin shot. Magnus himself was unable to adequately explain the phenomenon – now known as the Magnus effect – as the field of fluid dynamics was still in its infancy.

The Magnus effect in theory and practice

A little over half a century later, Ludwig Prandtl was investigating flows around rotating cylinders in a water channel in Göttingen. Although these investigations initially received little attention, Prandtl revisited his findings after the First World War. At the same time, one of his colleagues, Carl Wieselsberger, was repeating measurements on rotating cylinders in an attempt to uncover the secrets of the Magnus effect. The breakthrough came when Albert Betz – then deputy director of the AVA – developed small, high-speed 'three-phase' electric motors, adding end plates to either end of the cylinder.

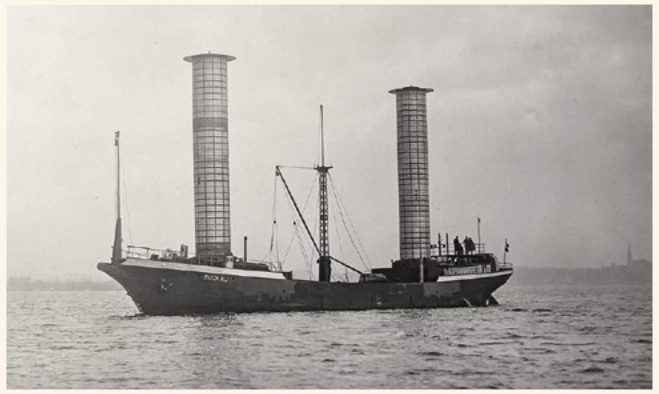
A new way to propel ships

The findings were published by the AVA and caught the attention of Anton Flettner – a prolific engineer with numerous patents to his name – who then came up with the idea of using the Magnus effect to propel ships. Traditional sailing vessels common until then required a large crew and were comparatively expensive to maintain, due to the cost of regularly replacing the rigging. After constructing a small model ship with rotating cylinders and testing it on Berlin's Wannsee lake, Flettner approached the AVA and asked for systematic wind tunnel tests to be conducted.

The AVA's measurements confirmed the potential of rotating cylinders as a source of propulsion, leading Flettner to commission the Germania shipyard in Kiel to refit the Buckau sailing ship according to his specifications. Rather than sail masts, it

Buckau sea trial with Ludwig Prandtl (second from left) on board

The three-masted schooner Buckau before its rotor conversion



Buckau on a test voyage, 1924

now had two cylinders measuring 2.8 metres in diameter and soaring about 18 metres above the deck. Each cylinder was powered by a 7.5-kilowatt electric motor.

Buckau becomes Baden-Baden

The first voyages of the rotor ship took place in mid-October 1924. On 12 November, Ludwig Prandtl and Albert Betz were able to verify for themselves that the ship's propulsion system worked. The press followed the construction and test voyages of the Buckau with great interest and credited Anton Flettner with the invention, without mentioning the AVA's significant theoretical work on the Magnus effect. This led to some disgruntlement at the AVA, especially since Flettner had not informed the research institute that he'd already filed a patent for the application of the Magnus effect in ship propulsion. This prompted AVA researcher Jakob Ackeret – who had been involved in the wind tunnel tests in Göttingen – to publish 'Das Rotorschiff und seine physikalischen Grundlagen' [The Rotor Ship and its Physical Principles]. The book explicitly credited Flettner with the development of the rotor ship, while clearly attributing the preliminary studies to the AVA.

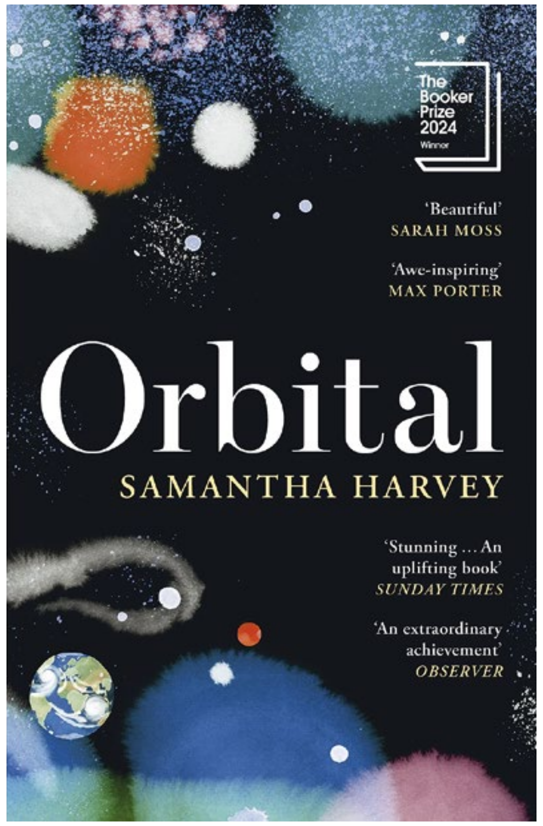
In 1926, the Buckau became the property of Flettner-Rotorschiff GmbH and was renamed the Baden-Baden. After two years, the Baden-Baden was converted back into a three-masted schooner. It sank in a storm in the Caribbean in 1931.

Interestingly, Flettner's rotor ship has enjoyed something of a renaissance over the past decade. The rotating-cylinder propulsion system now supplements conventional engines in modern container ships and ferries – reducing their fuel consumption. The container vessel E-Ship 1, for example, which entered service in 2010, has four Flettner rotors each measuring four metres in diameter and 27 metres high. The rotors operate in tandem with the ship's diesel engines, reducing its fuel use by a quarter.

Jessika Wichner is head of DLR's Central Archive in Göttingen. She is sure that Flettner, Prandtl and the other pioneers would be delighted to know that Flettner rotors have been rediscovered almost 100 years after their invention.

Images: DLR

A journey to a place of longing

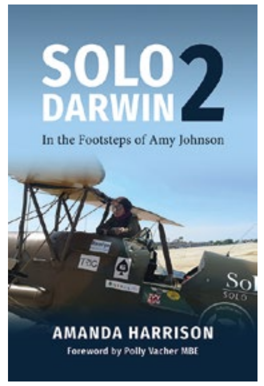


In **Orbital (Vintage)**, British novelist **Samantha Harvey** describes a place of longing, 400 kilometres above our heads – life on the International Space Station ISS. In 16 chapters, or rather orbits, she reflects on a single day aboard the ISS as it circles Earth, bringing us along with it.

Astronauts often spend this time thinking about their families and loved ones back home – and this longing plays an important role in Harvey's novel. In the truest sense of the phrase, all characters onboard the ISS are 'in the same boat' – or rather, spaceship – with similar thoughts and motivations.

This creates an emotional bridge between Earth and the ISS. Overall, the book offers a poetic, sensitive look at an often cold, technological world. For me personally, after several years of distance, it was a moving read and a chance to reflect on my own involvement in three German astronautical ISS missions. A clear recommendation!

Volker Schmid led three ISS missions for DLR and is now senior advisor to the Chair with responsibility for space topics.



Flying a Tiger to Darwin

How many times have you had a dream and thought, "Someday…"?

On 5 May 1930, Amy Johnson left Croydon, south of London, in her Gipsy Moth biplane, 'Jason', flying solo to Australia in under 20 days. Almost exactly 94 years later, **Amanda Harrison** set off from another south London airport, Biggin Hill, in a Tiger Moth – a later model – to follow her hero's route. **Solo2Darwin (Grub Street)** is the candid account of that flight.

Amanda shares all the highs and lows of long-distance flying in a vintage aircraft: a cheering crowd in Romania, soaring through the Carpathian Mountains with an escort of pilots from the local flying club, and heart-pounding moments of being forced to fly low over the Mediterranean Sea in deteriorating weather – not to mention two engine failures.

What makes the book so compelling is Amanda's honesty. Her writing is deeply personal as she reflects on the impact of breast cancer and her father's death – the push she needed to take her from 'someday, one day' to 'today.' She openly shares her fears, frustrations and moments of vulnerability. But her joy – even in adversity – shines through, making this a moving and memorable read.

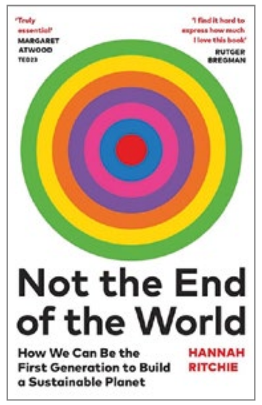
Annabel Cook

Looking fly

For some, it's a way to pass the time when bored; others take part in entire competitions: it's making paper aeroplanes. From the type of paper to the folds and possible attachments, many factors go into the perfect design. And let's not forget: appearance matters.

For those who don't want to send plain white or single-coloured gliders soaring through the air, graphic designer **Trevor Bounford** has come up with something special. In **Kunstflieger (Dumont)**, he blends paper craft with fine art. Fancy folding Hokusai's *Great Wave off Kanagawa* into a paper plane? Or finding the perfect angle to throw a Frida Kahlo self-portrait? Sixteen cut-out designs, inspired by various artists, can be folded into five different models using the included instructions.

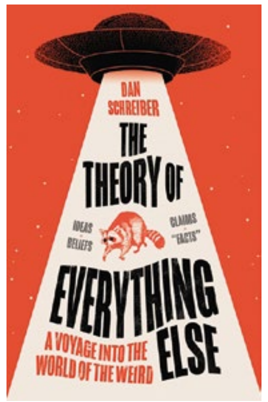
It would have been even better if the sheets were separate or pre-perforated. The plain backsides also mean the planes look rather dull from below – especially given they're designed to perform long flights. Nevertheless, you'll cut a dash at your next paper aeroplane competition with these models – at least in terms of style.
Julia Heil



How data can inspire hope

Hannah Ritchie has set herself an ambitious goal: to bring hope to all those who despair at the current state of the world. And who better to take on that challenge than a senior researcher in the Global Development Programme at the University of Oxford? Her book **Not the End of the World (Chatto & Windus)** – like the website "Our World in Data", on which it is based – is full of 'aha' moments. Ritchie offers specific suggestions for how individuals can take meaningful action, such as the real benefits of wasting less food.

However, readers hoping for a deep dive into climate change may be left wanting, as the author barely addresses geopolitical developments or whether we've already passed key planetary tipping points. Her attempt to inspire optimism through statistics alone only partially succeeds – but the book remains a worthwhile read.
Anja Tröster



Let's hear it for the weirdos

Some discoveries begin with a flash of inspiration, others with pure chance. Author **Dan Schreiber** takes us on a wild ride through the world of fanciful theories and strange stories in his book **The Theory of Everything Else (Mudlark)**. Packed with anecdotes and fun facts, we meet Nobel laureates gone astray, hear from superstitious astronauts and stumble upon bizarre experiments. The short stories come thick and fast, sweeping readers along for the ride.

This book is a must-read for anyone looking to switch off their brain for a while; those seeking major new insights with every chapter will be disappointed. Schreiber celebrates the creativity and fallibility of humanity – even the madcaps who pursue seemingly absurd notions. After all, it's not uncommon for the wildest ideas to lead to real breakthroughs.
Lovis Krüger

Landing on the coffee table

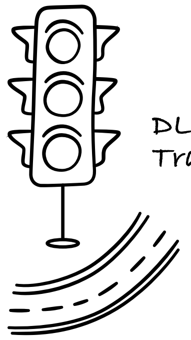
Only 3000 feet left to descend, traffic ahead and the plane isn't yet prepared for landing. "If we don't act smart now, we'll have to make an emergency landing!" I call out to my co-pilot, heart racing. We roll die, discuss our next steps and glance down at the cockpit.

Of course, dice aren't part of the standard cockpit equipment. Nor is the cockpit usually a stylish boardgame sitting atop a coffee table. Nonetheless, our goal – to touch down on the runway safely and on time – has us sweating. In **Sky Team (Kosmos)**, we land at airports all over the world. Pairs of players work together in a virtual cockpit and place dice to activate specific aircraft systems to configure the plane for landing over seven rounds: aligning the wings horizontally, adjusting the engine's thrust, extending the landing gear and flaps, requesting a clear approach corridor via radio, readying the brakes, and, if needed, grabbing a coffee for sharper focus. The array of airports, the hidden luck of the dice and a talking ban at the start of each round ensure the tension builds during the constant descent.

Even if not every procedure is true to life, we get a thrilling sense of the most adrenaline-fuelled phase of a typical flight. Every approach is different, and every flight creates a level of excitement we've rarely experienced in a boardgame. Sky Team was deservedly named Game of the Year in 2024.

Daniel Beckmann is responsible for DLR's corporate design, guiding the organisation's visual identity so it really lands. He's been a keen aviation enthusiast since he was a child – and remains so today.

Images: Kosmos



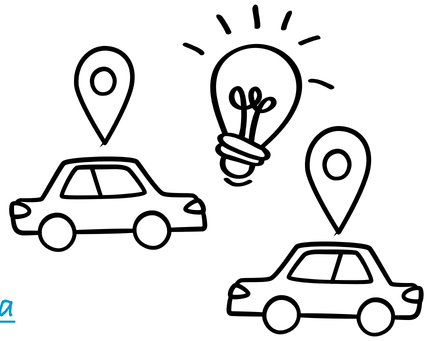
DLR Institute of Transport Research

A great plan

Smart, demand-driven transport planning at the push of a button

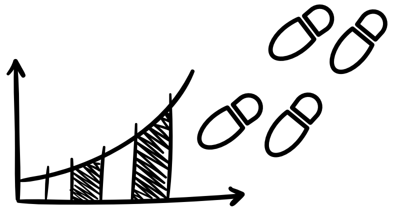
atSTAKE

(in German)



<u>Idea</u>

Software for local authorities to model the impact of new transport services on mobility behaviour, facilitating strategic planning.

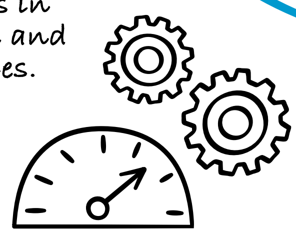


<u>Background</u>

The software is based on research conducted at the institute, including studies on transport user behaviour and traffic modelling.

<u>atSTAKE makes the world a better place because ...</u>

... it provides a fast and accurate overview of the demand and acceptance of transport services. This allows local authorities to instantly assess the potential impact and success of different measures. The result: targeted investments in the transport system and improved local services.



<u>The next challenge</u>

Secure the next paying customers.

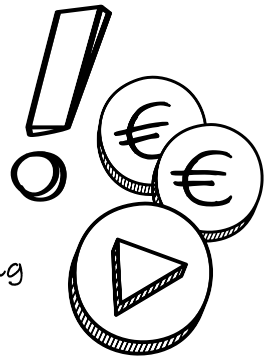


Image: atSTAKE

What's a 60-metre antenna doing in space?

YouTube video on 25 years of SRTM (German, English subtitles available)

Some 25 years ago, on 11 February 2000, the Shuttle Radar Topography Mission (SRTM) was launched – a joint project of NASA, the Italian Space Agency ASI and DLR. Its goal was to create the first near-global, high-resolution 3D map of Earth's surface. To achieve this, the Space Shuttle Endeavour was equipped with two antennas: a transmit-and-receive antenna located in the payload bay, and a second receive antenna mounted at the end of a 60-metre-long mast, which was extended out into space. Over 11 days, Endeavour orbited Earth 160 times, while its transmit antenna sent radar signals to Earth's surface which were reflected back and captured by both receivers. The long mast ensured that the two receive antennas remained in stable but slightly different positions. This enabled researchers to generate an elevation model of Earth's surface – just as we humans rely on two eyes to perceive depth in three dimensions. Today, we still have a pair of 'eyes in space' observing Earth: the twin satellites TanDEM-X and TerraSAR-X orbit at an altitude of approximately 500 kilometres, scanning Earth's surface with radar instruments.

Image: DLR/NASA