MAY 2023 DLRmagazine 172

Cover image

Earth's neighbouring planet, Mars, has already been fairly thoroughly analysed. Numerous spacecraft and rovers have explored and continue to explore its surface. The situation is quite different for the martian moons Phobos and Deimos. In particular, their origin is still a mystery. The Japanese Aerospace Exploration Agency (JAXA) Martian Moons eXploration (MMX) mission, which is scheduled to launch in 2024, should provide the answer to this question. To do so, the mission will for the first time deliver a rover and a sample retrieval module onto the surface of Phobos. The rover has been developed and constructed in a close cooperation between DLR and the French space agency CNES. This partnership will also operate the rover. Eight DLR institutes and facilities are involved.

Image: JAXA

Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center

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DLRmagazine

of DLR, the German Aerospace Center · No. 172 · May 2023

HEAD OVER HEELS INTO ADVENTURE

THE MMX MISSION WILL EXPLORE THE MARTIAN MOONS

More topics

About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10,000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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DLR STATEMENT

DLR's Campus Collection

As you may remember, at the end of 2022 we conducted a survey to understand your level of satisfaction with DLRmagazine and gather suggestions for improvements. The response was excellent, with over 500 subscribers taking part. Apart from the enthusiastic participation, we were very happy to see that the majority of subscribers read almost every issue of the magazine. And most of you read it in print form: so, print still works! You shared ideas on what we can improve in the future, including new sections such as pages for children, picture puzzles, surveys, fun facts… You also urged us to be bolder in the design. We are delighted to take your suggestions on board and are planning a relaunch during the coming year. We hope you are as excited as we are to see how DLRmagazine will develop.

We would like to take this opportunity to thank all the readers who took the time to participate in the survey. This valuable feedback is vital to ensuring that we keep our finger on the pulse and not only continue to provide you with exciting articles on DLR research topics, but also capture the passion of our researchers and showcase the benefits of scientific projects for everyday life.

Ten lucky winners have been selected from all the readers who participated in the survey and will receive t-shirts from the new DLR Campus Collection. Many thanks to the Society of Friends of DLR e.V. for kindly supporting the prize draw. Whether you read the magazine for professional or personal reasons, we hope you continue to enjoy DLRmagazine for many years to come.

EDITORIAL

Dear reader,

Humans are driven by curiosity. We want to know how things work, we want to explore new things, and we are rarely satisfied with what we have achieved. This is especially true for the research professions. When we explore distant planets with scientific instruments, we not only learn more about their formation and development, but also something about Earth's past. The Martian Moons eXploration (MMX) mission will investigate Phobos and Deimos, the moons that orbit the Red Planet. In the last issue of DLRmagazine, we reported on the mystery posed by the origins of these moons. This time, MMX is the cover story because in January, we had the opportunity to visit Toulouse to see a rover developed by DLR and the French space agency, CNES, as part of the mission. The rover will land on one of the two moons and, in a first for Mars research, it will uncover the characteristics of the moon in detail. In the summer, the rover will be shipped to Japan to be integrated into the 'mother' spacecraft ready for the launch, which is planned for 2024.

Inside this issue is another piece about unchartered territory, but in a far more urgent context. DLR scientist Matthias Geßner and his colleague Jörg Brauchle travelled to Türkiye in February, immediately after the devastating earthquakes, to support the relief work with their technical expertise. They mapped the badly affected city of Kırıkhan from the air and shared the information with international aid organisations. Read the article to find out in impressive detail how they used their drone for mapping flights with the DLR Modular Aerial Camera System (MACS) and learn about their experiences – both personal and professional – in the disaster region.

Within these pages you will also find articles on test-driving the world's most environmentally friendly car, a collaborative design approach to developing aircraft, a system that can detect fungal pathogens in vineyards at an early stage, and much more…

Happy reading!

Your Editorial team

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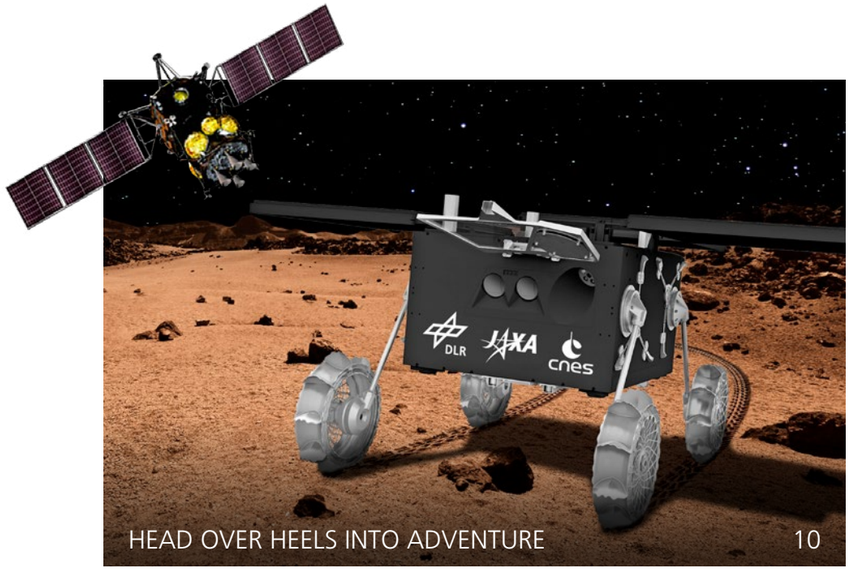

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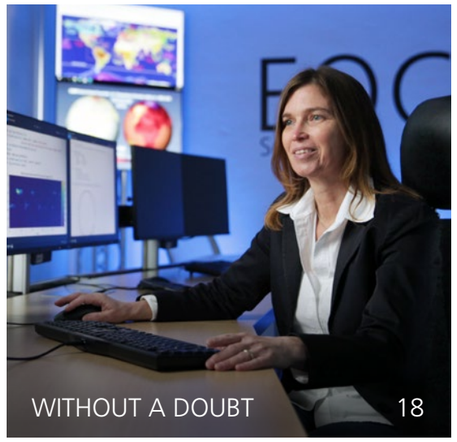
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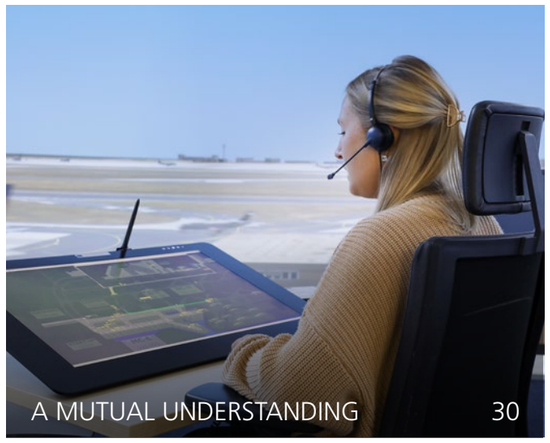
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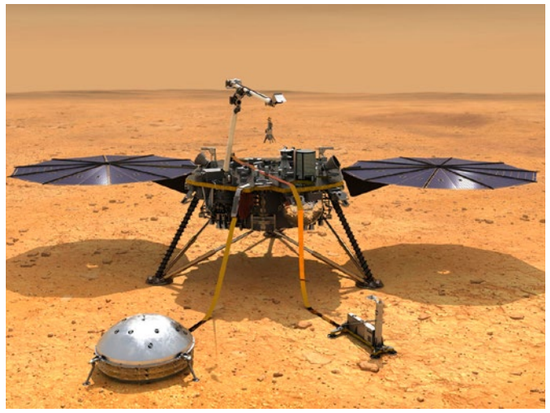
IN BRIEF

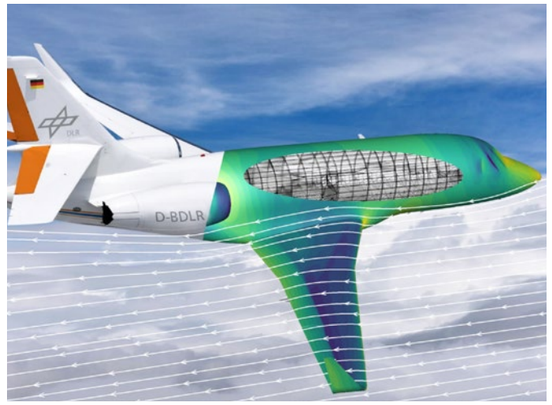
INSIGHT MARS MISSION RETIRES

In December 2022, after more than four years, the US National Aeronautics and Space Administration (NASA) declared the end of the InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) mission on Mars. The mission provided data on the heat budget and seismic activity inside the planet to obtain information about its structure and thermal evolution. The main instruments for these measurements were DLR's Heat Flow and Physical Properties Package (HP^3) and the Seismic Experiment for Interior Structures (SEIS) from the French space agency CNES. Even though HP^3 was not able to penetrate several metres into the martian soil as planned, InSight buried the measuring probe just below the surface, where it collected data on the mechanical and thermal properties of the martian soil. The recordings of the marsquakes acquired be SEIS were of enormous scientific value. With the data, the researchers were able to measure the average thickness of the crust, which is between 24 and 72 kilometres, and is thus somewhat thinner than previous, more indirect investigations had shown. The mission ended because InSight's solar-powered batteries ran out of energy.



NASA/JPL-Caltech

Artist impression of the Mars InSight lander at its deployment site in Elysium Planitia



Flow simulation of DLR's ISTAR research aircraft

IMPROVING AIRCRAFT WITH FLOW SIMULATIONS

Computational fluid dynamics (CFD) combines applied mathematics, physics and high-performance computing. It contributes to a better understanding of how air moves over complex structures. Together, Airbus, DLR and France's ONERA are exploring how high-performance computing can improve the understanding of the relationship between aerodynamics and aircraft efficiency. DLR and ONERA have been working with Airbus for decades. In the past, both research partners had worked with their own computer codes, which form the foundation of the CFD simulations. Although the codes were effective in their own right, there was limited communication between the different development teams. In the future, the experts plan to extend the code to current and future Airbus research projects and develop it further together.

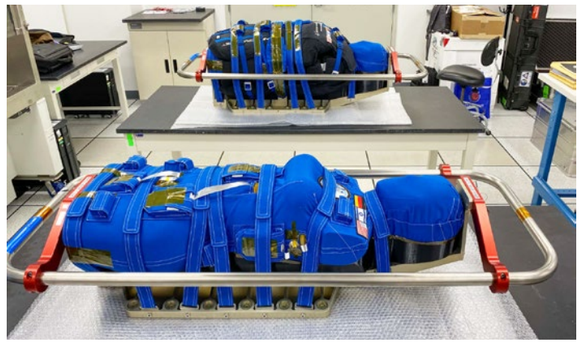
FUELS FROM NORTH AFRICA AND THE MIDDLE EAST

The Middle East and North Africa have enormous potential when it comes to supplying Germany and Europe with hydrogen and synthetic fuels from renewable resources. This has been demonstrated in a joint MENA Fuels Study by DLR, the Wuppertal Institute and the IZES. The generation potential of renewable energies in these regions is more than 400,000 terawatt hours per year. The use of solar energy in the form of photovoltaics and concentrating solar thermal power is particularly promising. Almost all countries in the MENA (Middle East and North Africa) region have significant potential to produce synthetic fuels at low cost. In the most favourable locations, production costs could be between 1.92 and 2.65 euros per litre in 2030 – and between 1.22 and 1.65 euros per litre in 2050.

SENER

The NOORo III solar thermal tower power plant in Morocco

PHANTOMS RETURN FROM THE MOON



There are 34 active radiation measuring devices distributed in the measuring mannequins, as well as over 12,000 crystals that serve as passive detectors.

Helga and Zohar have returned to DLR. The two measuring mannequins from DLR and the Israeli Space Agency ISA flew to the Moon on board the Orion spacecraft as part of NASA's Artemis I mission. Orion's journey lasted a total of 25 days, two weeks of which were spent in orbit around Earth's natural satellite. The so-called phantoms of DLR's MARE mission mimic the tissue of the female body, including the organs. The acquired data will provide insights into the radiation exposure to the female body during a flight to the Moon and back, the associated risk of cancer, and effective countermeasures. Zohar wore a radiation protection vest for this purpose. The data on cancer risk in men has already been extensively researched. With MARE, the focus is now on female astronauts and on narrowing the gender data gap.

NEW DLR INSTITUTE RESEARCHES AUTONOMOUS DRIVING

The DLR Institute of Systems Engineering for Future Mobility opened in Oldenburg, Lower Saxony.

Before highly automated and autonomous means of transport are approved, it must be ensured that they are safe and trustworthy. The DLR Institute of Systems Engineering for Future Mobility in Oldenburg, which was inaugurated on 31 January 2023, investigates the trustworthiness of IT systems for highly automated and autonomous driving. The researchers focus not only on road traffic, but also on shipping and rail traffic as well as aviation. Behind the rather abstract term 'systems engineering' is the ability to develop complex products such as ships or aeroplanes efficiently and without errors. Many of the components of such products use machine learning and artificial intelligence. However, there is often no way to prove safety and trustworthiness. The DLR Institute is working on methods to efficiently develop and test complex systems. Companies, test facilities and certification authorities urgently need these methods to make their products for highly automated and autonomous driving safer and to approve them.

REGIONAL NEWS

BERLIN: In the project Networked Mobility for Liveable Places (VMo4Orte), DLR is developing and testing solution modules for a forward-looking transformation of the transport system under the leadership of the Institute of Transport Research. To this end, the researchers are developing new mobility concepts. These should be climate-friendly, competitive, demand-oriented and geared towards local people.

BRAUNSCHWEIG: In the future, DLR will work more closely with the federal government's Autobahn GmbH in the area of automated and connected driving. One topic, for example, is the networking of automated vehicles with each other and with the traffic infrastructure. This is the only way they can communicate with each other.

COCHSTEDT: In the future, we will see more drones in the airspace. In order to integrate a large number of them safely and efficiently into the existing air traffic management system, research and industry are working on a uniform EU concept for a drone airspace, known as U-space. DLR is setting up a U-space airspace for drones in the form of a real laboratory at the National Experimental Test Center for Unmanned Aircraft Systems.

COLOGNE: Together with the German Air Force, the DLR Institute of Aerospace Medicine inaugurated the Competence Centre for Aerospace Medicine on 26 January. Here, for example, research is conducted into the physiological and psychological mechanisms that serve as the basis for the requirements placed on flying personnel in the German Armed Forces. In turn, DLR researchers receive direct feedback from the field.

COTTBUS: On 2 March, DLR opened a DLR_School_Lab together with the BTU Cottbus-Senftenberg. Here, schoolchildren can carry out experiments themselves. These deal with the topics of aerodynamics, fluid dynamics, space flight, energy, electrified aviation propulsion systems and low-CO2 industrial processes.

HAMBURG: At the ZAL TechCenter, more than 30 partners from industry and science are currently working under one roof on 26,000 square metres – including the DLR Institute for System Architectures in Aeronautics, the DLR Institute of Maintenance, Repair and Overhaul, Airbus, Lufthansa Technik, Diehl, Dassault Systèmes, Fraunhofer and the Hamburg universities. The TechCenter is to be expanded by 8000 square metres by 2024.

MANNHEIM: From April to October, the Federal Garden Show will take place on the former Spinelli military site in Mannheim's north-east and in the Luisenpark. DLR will present the autonomous, electric vehicle concept U-Shift there.

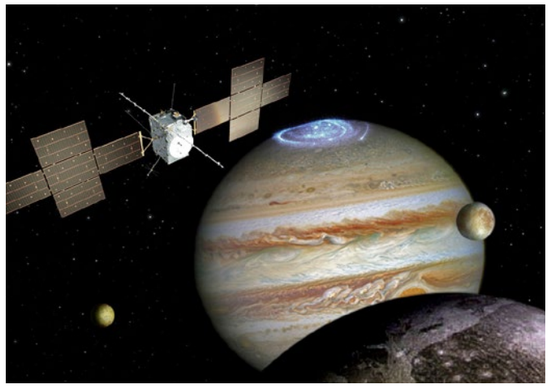
DLR.DE/EN
VISIT THE DLR PORTAL FOR THE LATEST NEWS

All articles can be viewed online in the news archive with images or videos.

DLR.de/news

AN UNPRECEDENTED JOURNEY TO JUPITER

The Jupiter ICy Moons Explorer (JUICE) spacecraft launched on 14 April 2023 from the European spaceport in French Guiana. JUICE's unique journey will see it pass by Earth, the Moon and Venus before reaching Jupiter in July 2031. Once there, it will orbit around the gas giant and complete 35 close flybys of Jupiter's icy moons between July 2031 and November 2034. The JANUS camera system will be used to photograph the surfaces of Jupiter's moons Callisto, Ganymede, and Europa – sometimes at very high resolution. The Ganymede Laser Altimeter (GALA) will be used to measure the tidal deformation of Ganymede's ice crust to provide evidence for the existence of a global ocean at depths of approximately 100 kilometres. GALA was developed under the leadership of the DLR Institute of Planetary Research. In December 2034, JUICE will become the first spacecraft ever to transition from an orbit around another planet to an orbit around one of its moons.



ESA/ATG medialab (orbiter); NASA/JPL/DLR (Jupiter, moons)

After an eight-year journey, ESA's JUICE (Jupiter Icy Moons Explorer) spacecraft will reach the Jovian system.

'DANCING' HELICOPTER HELPS REDUCE NOISE

DLR researchers have used flight tests with a CH-53G helicopter of the German Armed Forces to visualise the main cause of noise generated by a heavyweight helicopter in flight. The tests involved flying the aircraft at heights of between two and 12 metres above the ground while recording air vortices on the rotor blades using five cameras. The researchers used a special optical measurement technique developed at DLR called the Background Oriented Schlieren Method (BOS) to observe blade tip vortices during hovering flight. They found that blade tip vortices are the primary cause of noise for larger helicopters. Reducing these vortices could help limit noise generation and reduce the sand or snow whipped up when hovering near the ground, which can obstruct the pilot's view.

The CH-53G helicopter of the German Armed Forces hovering in front of a hangar with a dot pattern

The fully automated tape archive of the German Remote Sensing Data Center in Oberpfaffenhofen

COPERNICUS DATA SPACE ECOSYSTEM

The Copernicus Data Space Ecosystem was presented at the 2023 European Space Conference. It will make all data acquired by the satellites in Europe's Copernicus programme available via a single platform. DLR is part of the European consortium that won the contract for the platform's development. DLR's Earth Observation Center is now developing the IT infrastructure using expertise from its German Satellite Data Archive (D-SDA), which it has used to store satellite data generated by Earth observation missions since 1995. The consortium will combine expertise to develop a system capable of handling the expected 80 petabytes of data produced by the Copernicus missions. The Ecosystem will provide efficient access to current and historical data related to land monitoring, climate change, security and disaster management. Services and products built on Copernicus data will also be available. The new data ecosystem will cement the role of remote sensing as a vital tool for understanding and protecting our planet.

The Valley of the Kings and the city of Luxor

DISCOVERING THE VALLEY OF THE KINGS WITH RADAR

The German radar satellites TerraSAR-X and TanDEM-X recently acquired images of the Valley of the Kings in Egypt to mark the 100th anniversary of the opening of Tutankhamun's burial chamber. The two satellites orbit Earth at an altitude of 514 kilometres and use SAR interferometry to create detailed digital elevation models (DEM) of Earth. The DLR team used the image data to create a DEM of the Valley of the Kings. They enhanced backscatter from Earth's surface to make cities more visible and colourised the image for a more vivid representation. Data from the radar satellites were also used to create a DEM of the Nile Valley at various magnification levels. The Valley of the Kings lies west of the Nile, in the foothills of the Theban Mountains.

ESA COUNCIL MEETING AT MINISTERIAL LEVEL

The 22 Member States of the European Space Agency (ESA) met in Paris in November 2022 to set the course for the future of joint space programmes. The ESA Member States agreed on a budget of 16.9 billion euros, with Germany contributing four billion euros. Germany's contributions included investments in launchers such as Ariane 6, human spaceflight, research in microgravity and space exploration. A particular focus was given to climate protection, industrial competition, New Space and Europe's independence in space. Walther Pelzer, DLR Executive Board Member and Director General of the German Space Agency at DLR, emphasised the essential nature of international cooperation for spaceflight. Space plays an important role in addressing global challenges, such as the Ukraine war, the energy crisis and the climate crisis. At the meeting, Germany assumed the chairmanship of the ESA Council from France and will host the next conference in 2025.

© DLR

The German delegation was headed by Robert Habeck, Federal Minister for Economic Affairs and Climate Action, Anna Christmann, Federal Government Coordinator of German Aerospace Policy, and Walther Pelzer, DLR Executive Board Member and Director General of the German Space Agency at DLR.

ABOVE THE AMAZON RAINFOREST

The CAFE-Brazil research campaign, led by the Max Planck Institute for Chemistry, collected data on chemical processes and cloud condensation in the mostly clean atmosphere in the Amazon rainforest. The project team included researchers from various universities and institutes and used DLR's HALO research aircraft, a Gulfstream G550 equipped with 19 scientific instruments, to measure dozens of atmospheric parameters. The team also collected data using balloons, drones and ground stations. Improving our understanding of natural chemical processes will help explain how air pollution affects the atmosphere. The HALO aircraft is suitable for high-altitude and long-range scientific research atmospheric research and made 20 measurement flights over the approximately 60-day mission, which ran from December 2022 to January 2023.

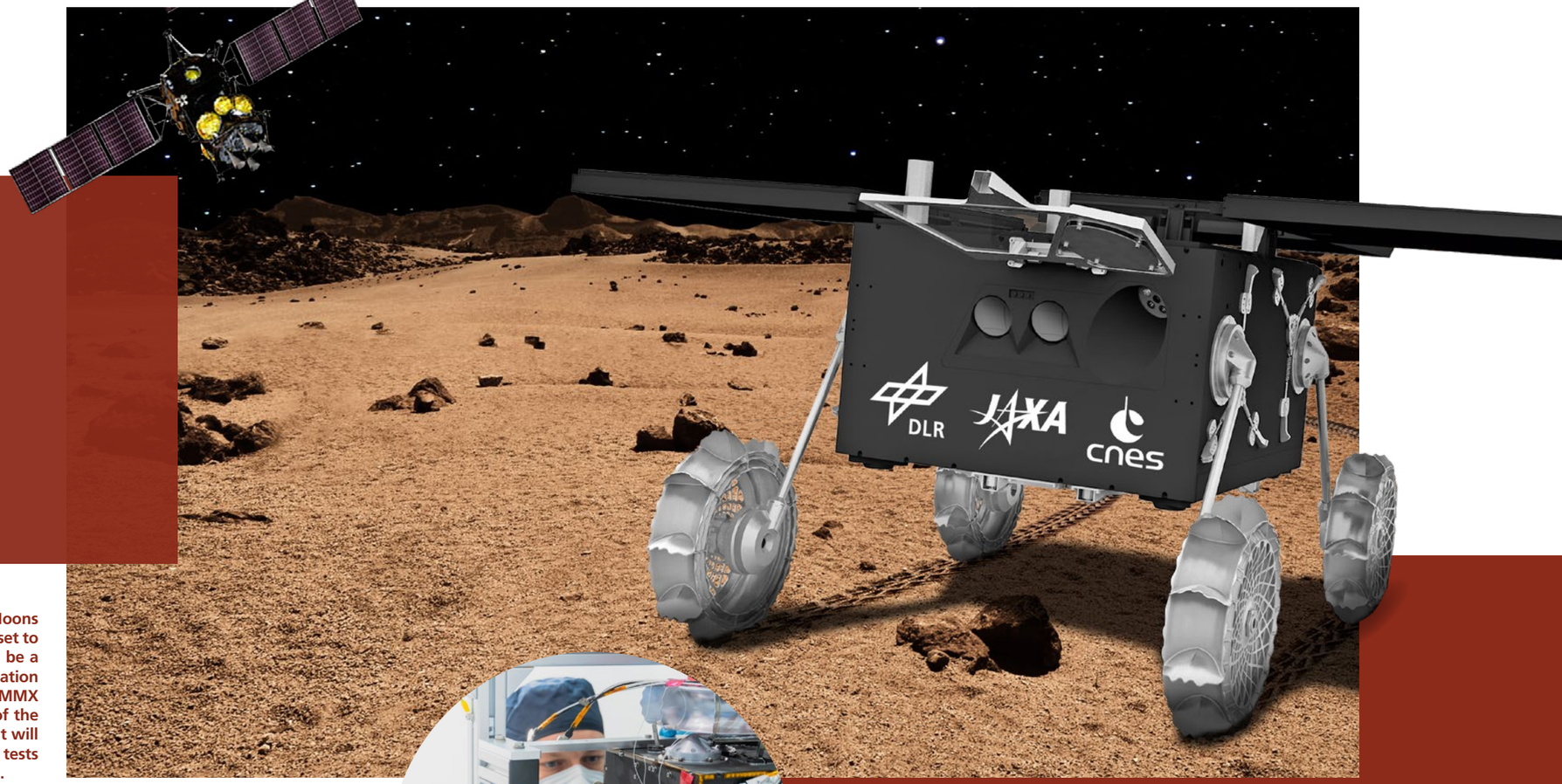
MPIC

HALO flies above the 325-metre-high Amazon Tall Tower Observatory (ATTO) research station

HEAD OVER HEELS INTO ADVENTURE

The MMX rover will explore the mysterious martian moon Phobos

by Falk Dambowsky



The MMX rover is a joint German-French project within the Japanese Martian Moons eXploration (MMX) mission. At its destination, the martian moon Phobos, it will move around under extremely low gravity.

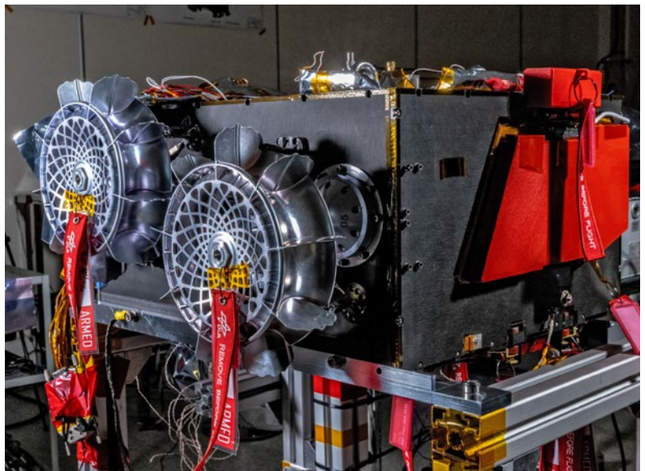
To this day, Mars' two moons Phobos and Deimos remain a mystery. The Martian Moons eXploration (MMX) mission of the Japan Aerospace Exploration Agency (JAXA) is set to explore the two moons in the second half of this decade. Accompanying MMX will be a Franco-German rover, which is being developed, built and operated in close cooperation between DLR and the French space agency, CNES. Following its separation from the MMX mothercraft and its tumbling free-fall descent and landing on Phobos – the larger of the two moons – the rover will upright itself and deploy its solar panels. Once upright, it will become the first rover to travel across a small body under extremely low gravity. The tests and preparations to make this 'first' a reality are currently underway – here on Earth.

A glass pane similar in size to a giant flat-screen TV offers a view into the clean room at CNES (Centre national d'études spatiales) in Toulouse. The 25-kilogram MMX rover lies in the middle of the room. Still without its solar panels, it is about the size of a crate. As it stretches out its four delicate legs with their – comparatively large – paddle wheels, it looked almost finished at the end of January. On the previous days, these wheels were tested for their mobility, as was the unfolding of the legs that hold them. Together they form the rover's locomotion system. Once on Phobos, this system will enable the rover to upright itself following ifs free-fall descent from a height of between 40 and 100 metres, no matter how it eventually lands. The system will also play a major role during the rest of the mission, as it will also be used to align the solar panels with the Sun and to lower the rover for scientific measurements.

Giving the rover a leg up

However, the terrestrial test of this locomotion system did not involve the rover driving along a test track or positioning itself upright from various starting positions. Instead, it was lifted off the ground in the clean room, leaving the rover's four legs and wheels floating in the air. This was to ensure that they were not put under an unnecessary load. Earth's gravity would be far too strong for the fine lightweight construction, which was conceived and designed at DLR's Robotics and Mechatronics Center for use under the extremely low gravity on Phobos, which is only one two-thousandth of that on Earth. During the tests, the wheels rotated individually in the air. The legs were then each rotated 400 degrees. The sequence of leg movements that ensures the rover can right itself from any starting position and the sequence that ensures the correct alignment of the solar panels to the Sun were also tested. The rover passed all tests: movements that had until now only been simulated functioned flawlessly in practice with the hardware involved.

CNES



The MMX rover in the clean room of the French space agency, CNES, in Toulouse. In its launch configuration, the legs and the wheels are nestled tightly against the rover's body and locked securely in place.

© DLR

A very special test was carried out in Toulouse, during which no visitors were allowed in the clean room. The engineers used special LED lights to explore the rover's various 'shutters' – hinged panes that protect the individual cameras and instruments during landing. These protective windows are supposed to open following a successful landing. Immediately after the landing, an image of the surface of Phobos will be acquired through one of these dust-covered protective windows in order to confirm the landing. Once the dust kicked up by the rover's landing has settled, the shutters will be opened.

But getting to the point at which the first image can be taken, and then the point at which the MMX rover can travel its first few centimetres on Phobos, requires surviving the landing itself. The MMX mothercraft will release the rover, which will descend in a free fall towards Phobos. The properties of the moon's surface are still not well understood, but it is likely that the rover will bounce off the ground several times and tumble before finally coming to rest. The rover is designed to autonomously upright itself with the legs of its locomotion system in the correct orientation, no matter the position in which it comes to rest. This is crucial for the deployment of its solar panels, which must then be pointed towards the Sun to begin charging the rover's battery. Once charged, the exploration of Phobos can begin.

A total of four cameras will then begin to supply us with images from the martian moon. Two navigation cameras look ahead and allow for the production of a three-dimensional representation of the terrain in front of the rover. With these images, engineers can recognise obstacles and plan the rover's route accordingly. The rover will use these data to come to a stop in front of obstacles or even drive around them entirely autonomously. The high spatial resolution of the images also makes them very well suited for geological analyses. The other two cameras, called 'wheelcams', are located underneath the rover. They monitor the contact areas beneath the two left wheels and record track depth, profile imprint and how the ground material is displaced by the rover's motion. This will help researchers draw conclusions about the properties of the moon's surface. The two wheel cameras can record short film sequences to enable the detailed analysis of the driving behaviour.

The MMX rover will spend approximately 100 days on Phobos, and centimetre by centimetre, it could explore a distance of up to 100 metres. Although it might not sound like much, it would be an enormous accomplishment for the small four-wheeled vehicle due to the impact of the moon's low gravity on its speed. There will also most probably be stones in the landing area that the rover will have to navigate around in an elaborate way. The low gravity makes any such

© DLR

The MMX rover in the DLR clean room in Bremen before delivery to Toulouse for further integration


© DLR

A conversation in the DLR clean room in Bremen. Eight DLR institutes and facilities are involved in the construction of the rover.

manoeuvre a delicate balancing act. Any motion that is too dynamic could cause the rover to lift off of the surface – with unforeseeable consequences.

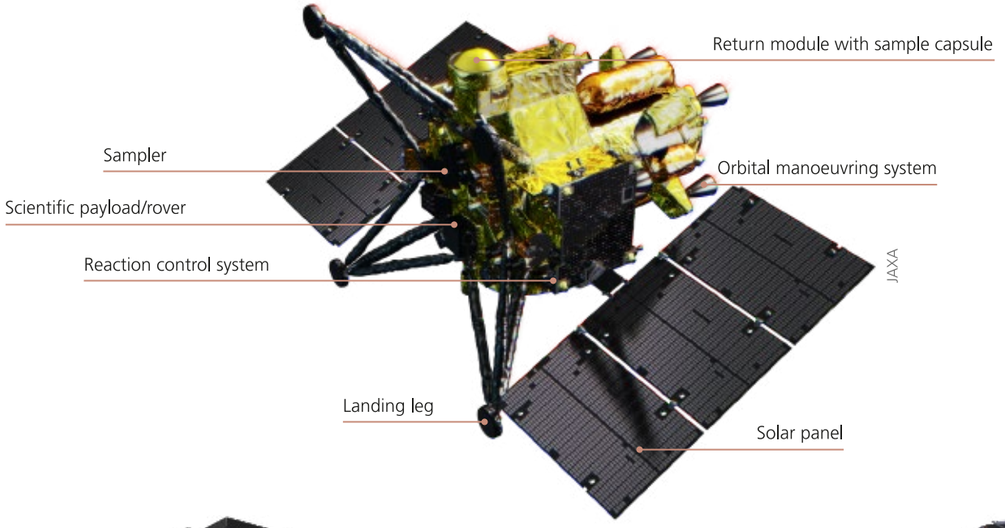
Across the martian moon in millimetres per second

The rover's speed will initially be less than one millimetre per second but it could be increased up to approximately one millimetre per second as the team's experience with the terrain grows. Possible surface properties and their impact on the rover's driving behaviour were analysed in advance at the DLR Institute of System Dynamics and Control using a physics simulation developed in-house.

The vast distance between Earth and Mars represents an additional challenge, as does the fact that data from the rover must be sent to the mothercraft before it can be transmitted to Earth. The total signal transit time from the rover to the mothercraft to Earth and back again will be approximately two days. As a result, the teams at the two rover control centres at CNES in Toulouse and at DLR's Microgravity User Support Center (MUSC) in Cologne will each have to program driving sequences that the rover can execute independently. If all goes according to plan, the MMX rover will become the first rover to explore a significant distance on the surface of a small astronomical body with low gravity. In doing so, it will face a number of challenging conditions. A 'Phobos day' lasts just under eight hours, during which the temperature on the rover will fluctuate between minus 150 and plus 50 degrees Celsius. At one third the length of an Earth day, this means the rover will experience very rapid temperature changes. Therefore, it must be designed in such a way that the temperature inside the rover is always kept within a range that ensures the electronics are protected.

Two DLR instruments to study the surface

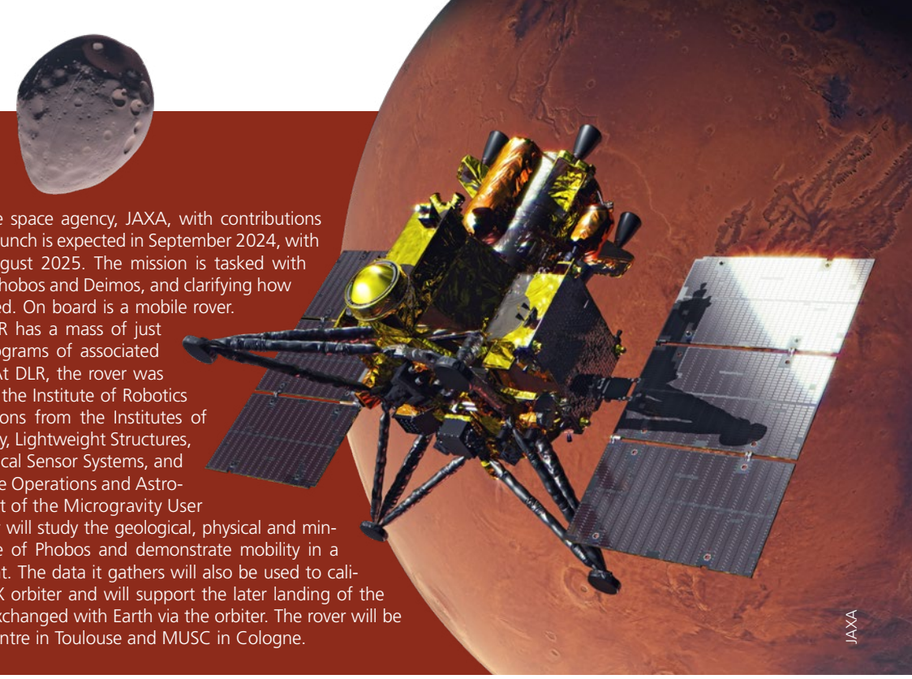
In addition to the cameras, the rover will also carry the RAX Raman spectrometer, developed at the DLR Institute of Optical Sensor Systems, and the miniRAD radiometer, developed at the DLR Institute of Planetary Research. RAX will be used to explore the mineralogical composition of the surface of Phobos, while miniRAD will collect data that will allow researchers to analyse its thermal properties. These measurement data will help to shed light on the hitherto unexplained origin of the martian moons Phobos and Deimos.



To the animation on the web

s.dlr.de/MMX-rover-animation

The rover will separate from the exploration module at a height of approximately 40 to 100 metres before falling slowly to the surface. Once there, it will likely perform several 'somersaults', remain unharmed and come to rest in an unpredictable position.


JAXA

MMX – MARTIAN MOONS EXPLORATION

MMX is a mission of the Japanese space agency, JAXA, with contributions from NASA, ESA, CNES and DLR. Launch is expected in September 2024, with arrival at Mars taking place in August 2025. The mission is tasked with characterising the martian moons Phobos and Deimos, and clarifying how and where the two satellites formed. On board is a mobile rover. This joint project of CNES and DLR has a mass of just under 25 kilograms, plus four kilograms of associated components on the mothercraft. At DLR, the rover was developed under the leadership of the Institute of Robotics and Mechatronics, with contributions from the Institutes of Space Systems, Software Technology, Lightweight Structures, System Dynamics and Control, Optical Sensor Systems, and Planetary Research, as well as Space Operations and Astronaut Training with the involvement of the Microgravity User Support Center (MUSC). The rover will study the geological, physical and mineralogical properties of the surface of Phobos and demonstrate mobility in a challenging low-gravity environment. The data it gathers will also be used to calibrate the instruments on the MMX orbiter and will support the later landing of the exploration module. Data will be exchanged with Earth via the orbiter. The rover will be operated from the CNES control centre in Toulouse and MUSC in Cologne.

The rover segment's electromagnetic compatibility test were then carried out before the MMX rover was delivered to Toulouse in November 2022.

Final assembly took place at CNES in Toulouse, including the integration of the power and communication systems as well as the scientific instruments. In Toulouse, the complete MMX rover will undergo its final tests for space qualification. The Mechanical and Electrical Connection and Support System (MECSS), which functions as the connection and separation system and which will later separate the rover from the mothercraft and send it on its journey to Phobos, is already assembled. This subsystem was also developed by DLR. The flight model is scheduled for delivery to Japan in summer 2023. It is a tight schedule that has placed enormous demands on the teams at DLR and CNES in recent months and years.

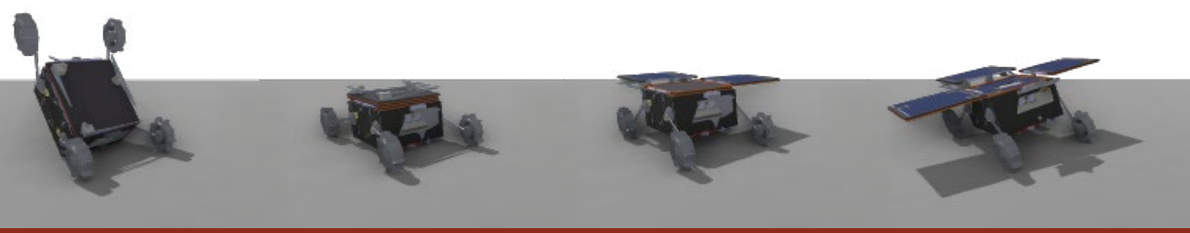
Final preparations before launch

Read more about the martian moons Phobos and Deimos and how they remain mysterious to researchers today in **Issue 171 of the DLRmagazine.**

The German-French rover will finally be integrated into the MMX mothercraft at JAXA. To be more precise, it will be integrated into the spacecraft's exploration module, which itself is equipped with various instruments and even landing legs to take samples of the martian moon close to the rover's landing site. The return module will transport the samples to Earth at the end of the mission in 2029. The MMX mission is scheduled for launch in September 2024 on board an H3 rocket from Tanegashima Space Center. This is the start of the next window in which Mars and Earth will be in a favourable position for a flight. Before that, however, the MMX spacecraft and rover must undergo final space qualification tests to test their resistance to the vibrations they will be subjected to during the launch, as well as the heat and cold and vacuum conditions in space.

As the launch to Mars and its moons draws closer, the excitement of the team is clear on days such as that Friday at the end of January in Toulouse. Following the tests, the legs and the wheels were returned to their launch configuration. Nestled tightly against the rover, they are now securely locked in place. They will now remain in this position until the adventure on Phobos begins ...

Falk Dambowsky leads the Media Relations Group in DLR's Corporate Communications Department.

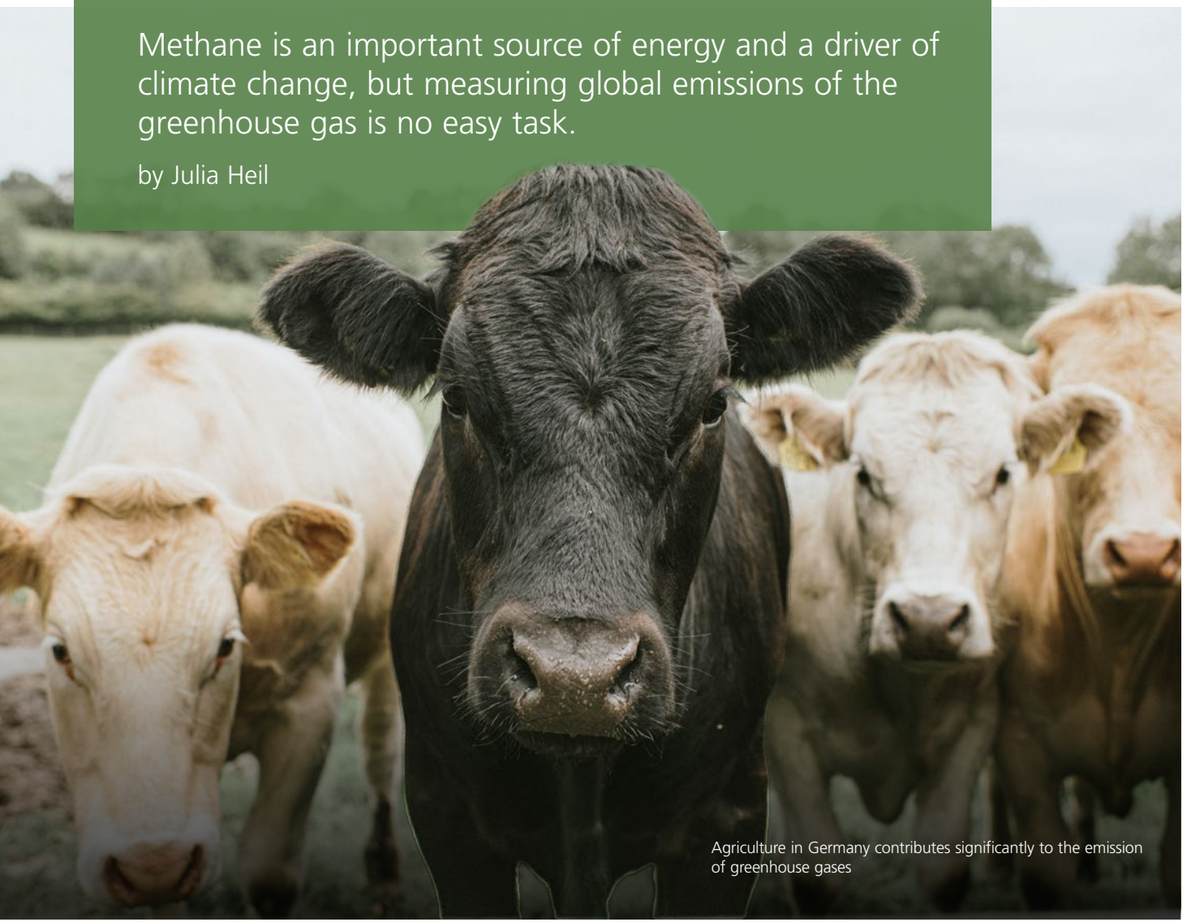


From this situation, it must autonomously upright itself with the help of its locomotion system and then deploy its solar panels. Only then will the rover be able to 'survive' and move on Phobos. Here is one possible sequence for raising and deploying the solar panels.

NO TWO CATTLE ARE ALIKE

Methane is an important source of energy and a driver of climate change, but measuring global emissions of the greenhouse gas is no easy task.

by Julia Heil

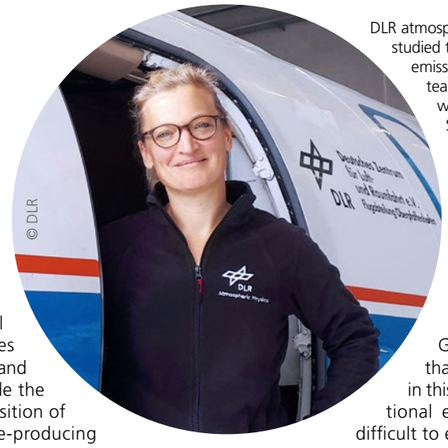


GettyImages/Catherine Falls Commercial

Agriculture in Germany contributes significantly to the emission of greenhouse gases

Methane is the main component of natural gas. It is often mentioned on the news in connection with the construction of new Liquefied Natural Gas terminals or leaks in the Nord Stream pipelines. It is also the second most impactful anthropogenic greenhouse gas after carbon dioxide and is contributing to climate change. The atmospheric concentration of this gas is now 2.6 times higher than it was at the beginning of the industrial era. By comparison, the atmospheric carbon dioxide concentration has 'only' doubled. However, methane has a lifetime of just under 10 years – at least an order of magnitude shorter than that of carbon dioxide. Overall, methane currently accounts for approximately one quarter of anthropogenic radiative forcing from long-lived greenhouse gases. The good news is that we have a true chance to slow global warming in the relatively short term by reducing methane emissions. However, the sources of methane have not yet been subject to sufficient research. Researchers at DLR are looking to change this.

The Global Methane Pledge jointly announced by the European Commission and the United States at COP 26 in Glasgow in 2021 brought the topic into political focus. The agreement aims to reduce methane emissions by at least 30 percent by 2030 compared to 2020 levels, while at the same time improving the transparency around these emissions. Over 100 nations are now supporting this commitment. "What worries us, however, is that the concentration of methane in the atmosphere increased faster in 2020 and 2021 than at any time in our records, and we don't yet have a conclusive explanation for this," says Anke Roiger, head of the Atmospheric Trace Species department at the DLR Institute of Atmospheric Physics. The concentration of the greenhouse gas has not increased in a uniform fashion over recent decades: between 1999 and 2006, the increase actually stagnated. Possible reasons for this are still the subject of heated discussion in the scientific community. However, since 2007, the atmospheric concentration of methane has been increasing again. "We are rapidly approaching the warmest scenario of the International Panel on Climate Change (IPCC), and are far from being on track for the 1.5 or 2 degrees scenario," she adds.



© DLR

DLR atmospheric researcher Anke Roiger has studied the sources and impact of methane emissions for a long time. She and her team undertake research flights to a wide variety of regions – from Upper Silesia to South Africa.

Methane is produced both naturally and as a result of human activities. Natural sources include the anaerobic processes carried out by bacteria in Earth's swamps and wetlands. Anthropogenic sources include the large amounts released by the decomposition of organic waste in landfills by methane-producing bacteria, farm animals such as cattle, which produce methane in their stomachs, and the oil, gas and coal industries. Emissions vary by region, season and level of activity. It is difficult to determine exactly how much each source releases. Scientific studies arrived at different conclusions as to which of these sources is responsible for the increasing levels seen in recent years. One of the initial hypotheses focussed on the unconventional method of gas production known as fracking, which has been increasingly practised in the United States since 2005. More recent studies, however, have indicated that emissions from biological sources such as wetlands or from livestock or landfills could be the culprit. Research focusing on the increase in 2020 and 2021 indicates that natural emissions from the Arctic were disproportionately high, driven by extreme weather.

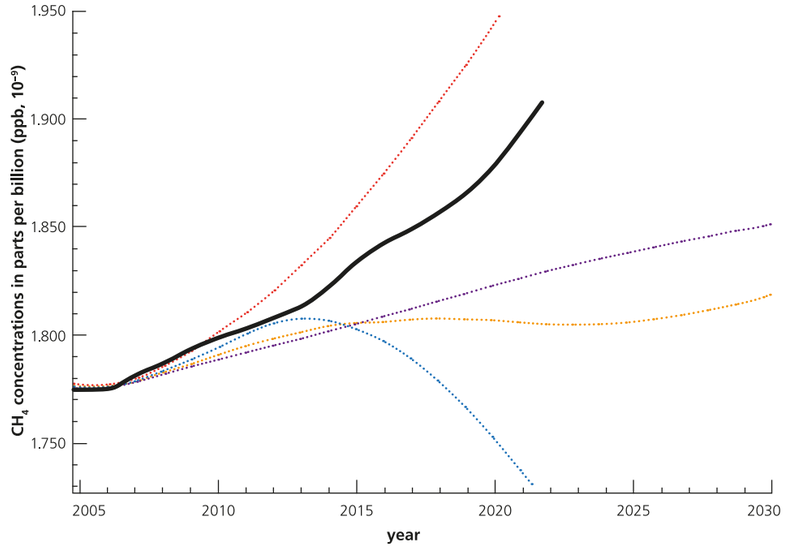
Accurate methane emission measurements are challenging

When researchers attempt to assess methane emissions, they start by making approximations based on existing data. This is called a bottom-up estimation. Methane emissions per cattle are calculated based on the number of cattle; methane emissions from waste management are approximated using the amount of organic waste; and methane emissions from natural gas flares are based on the amount of natural gas burned. While this serves as an initial estimate, no two cattle are alike, landfills differ greatly, and gas flaring efficiency is not always uniform. This was demonstrated by measurements conducted in the Gulf of Mexico in 2022. The findings suggest that larger quantities of methane are released in this region than previously assumed. Unintentional emissions such as leaks are even more difficult to estimate. Natural emissions, on the other hand, are extremely complex because they depend on precipitation, soil moisture, soil temperature, solar radiation and other meteorological parameters that vary on a daily basis. To add to the

View from the helicopter during the approach to the coal mining shafts in Upper Silesia

OBSERVED METHANE CONCENTRATIONS COMPARED TO THE IPCC FUTURE SCENARIOS

Source: The Global Methane Budget 2000–2017 (2020)



The black curve shows observed methane emissions through the years. It is clear that methane concentrations have been rising faster since 2014. The coloured curves show projections of the Intergovernmental Panel on Climate Change (IPCC), which illustrate the impact of different emission scenarios on the global rise in temperature. We are clearly approaching the warmest scenario of the IPCC. The blue curve reflects the scenario of the Paris Climate Agreement.

The DLR research aircraft Falcon takes off from the airfield in Libreville, Gabon, for the measurement flights.

Approach to Angola's capital Luanda. The country was one of the main measurement areas of the DLR campaign.

difficulty, wetlands are often located in remote regions such as the Arctic, Central Africa or the Amazon region, where measurements are only rarely carried out.

So far, Earth observation satellites have only been able to provide limited support to the pinpointing of emission sources. One reason for this is the long lifetime of greenhouse gases. This leads to the accumulation of carbon dioxide, methane and nitrous oxide in the atmosphere: a strong source of methane may only lead to a clear increase in methane concentration in the immediate vicinity. Even the most modern Earth observation satellites can often only detect sources of extremely strong emissions, such as the Upper Silesian Coal Basin in Europe. Recently, they were also able to identify very strong emissions from a landfill site near Madrid. Moderately strong sources go undetected from space. "Imagine a swimming pool full of water, and then dropping a little blue paint into it. This represents a methane source," says Roiger. "As soon as you turn on the wave generator – which represents the wind systems in our atmosphere – the colour is quickly carried away and diluted at the same time. Remember that we have a large number of anthropogenic and natural sources with emission levels that vary over time across the globe. In other words, that blue paint – the methane – gets mixed up, so it is incredibly difficult to work out where it originated."

Aircraft measurements provide a more accurate picture

Together with her team, Roiger is investigating specific regions with methane sources of interest for which there is no or insufficient data. To do this, the researchers are mainly using DLR's research aircraft. Equipped with sensitive measuring devices, the aircraft fly over methane sources and measure the waste gas plumes, which spread

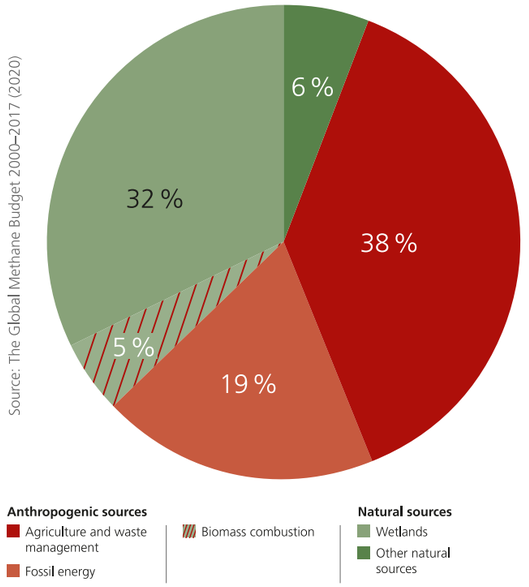
LNG terminal on the coast of Angola

NATURAL GAS – A CLEAN BRIDGE TECHNOLOGY?

Natural gas consists almost entirely of methane and has a higher energy density than other fossil fuels. Gas turbines are also relatively efficient: natural gas combustion produces less carbon dioxide per kilowatt hour than other fossil fuels. However, 'methane slip' occurs unintentionally along the entire process chain, from extraction to use. This is where unburned natural gas escapes, usually due to leaks. Scientific studies show that methane leaks occur during extraction and transport, but also in urban gas distribution networks. Methane can even escape from closed production facilities. When we take account of the methane emitted, natural gas is no more climate-friendly than burning coal and oil.

SOURCE STRENGTHS OF METHANE

(extrapolated from statistical data)



with the wind in the lowest kilometres of the atmosphere. The data they gather provide an accurate picture of the local emission levels. Some regions are home to an array of different methane sources. Here, the team uses measurements of other trace gases (or 'tracers'), such as ethane or isotope measurements, to help attribute the methane emissions to specific facilities or processes. The team is also using these research flights to test new measurement methods. The results of this campaign are helping the researchers understand both how much methane is being released and how it spreads. In 2022, DLR researchers carried out methane measurements over offshore oil production off the west coast of Central Africa. The natural gas that is generated, which does not serve any further use in Angola, Gabon and many other regions of the world, is mostly flared off. This creates carbon dioxide, which is less potent as a greenhouse gas than methane and makes the process at least a little bit more climate-friendly than releasing the methane directly into the atmosphere. In some cases, however, this combustion is incomplete, as shown by measurements: in others, methane is released directly in order to quickly regulate the pressure in the system or escapes due to leaks. "We see great potential for reducing emissions, specifically in the case of venting and leakages if the plants are inspected more regularly or if technologies for feeding gas back into the grid are installed. Industry could resell the gas obtained as a result, so the effort would be worthwhile," she adds. In the same year, Roiger and her team also studied coal emissions in Upper Silesia, the region with the largest methane emissions in Europe, and emissions from the Nord Stream leaks to better understand the impact of this extraordinary event. The first measurements of emissions from livestock farming are planned for summer 2023. The scientists will then make their way to the Netherlands with the DLR research aircraft Cessna Caravan.

These investigations are being carried out within the framework of the International Methane Emissions Observatory (IMEO). The initiative was launched as part of the Global Methane Pledge by the United Nations Environment Programme and the European Commission, with the aim of using independent measurements to better quantify anthropogenic methane emissions. IMEO researchers work closely with representatives from politics and industry. "Our task is to provide reliable data and to reveal where and how much methane is expected or unexpectedly released," says Roiger, describing the role of DLR. She adds, "In this way, we are helping to create a basis for the development of effective policy measures to reduce anthropogenic emissions." A planned EU regulation to reduce methane emissions will soon see flaring and venting permitted only in exceptional cases. This should also apply to energy imports. Although active intervention is only possible for anthropogenic emissions, Roiger believes that it is also vital to gain a better understanding of natural methane emissions. There are a many important dependencies, such as the extent to which methane emissions from tropical or Arctic wetlands increase as a result of higher temperatures or increased rainfall, which are not yet clear to researchers. Understanding them will also improve our predictions for the future.

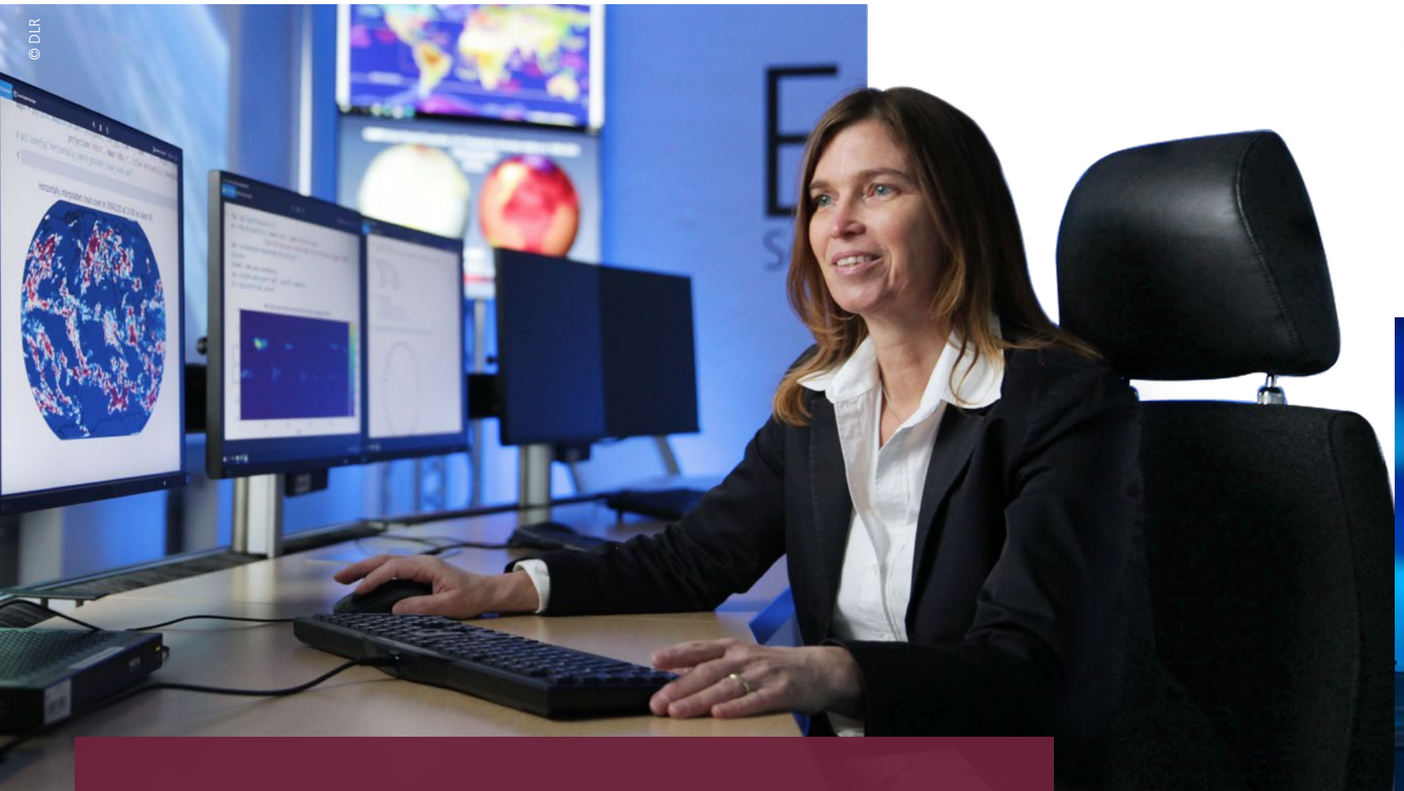
New satellites enable long-term, global monitoring of sources

"In the medium term, satellite observations will be the primary tool for monitoring emissions from space, as they can provide long-term, global datasets," says Roiger. DLR is preparing a small satellite mission for this purpose. CO2Image focuses primarily on identifying point sources of carbon dioxide, such as power plants, and is intended to measure their emissions worldwide. However, the mission will also be able to monitor methane sources. Several DLR institutes are involved, with the launch planned for 2026. From 2028, the Franco-German MERLIN mission will use lasers to measure global methane concentration gradients. Researchers will use the results to improve their models of regional methane emissions and thus our understanding of methane and its sources.

Julia Heil is an editor in DLR's Corporate Communications department.

TU Braunschweig/Falk Pätzold

View from the helicopter approaching the Nord Stream leaks, a joint project with the University of Braunschweig.



WITHOUT A DOUBT

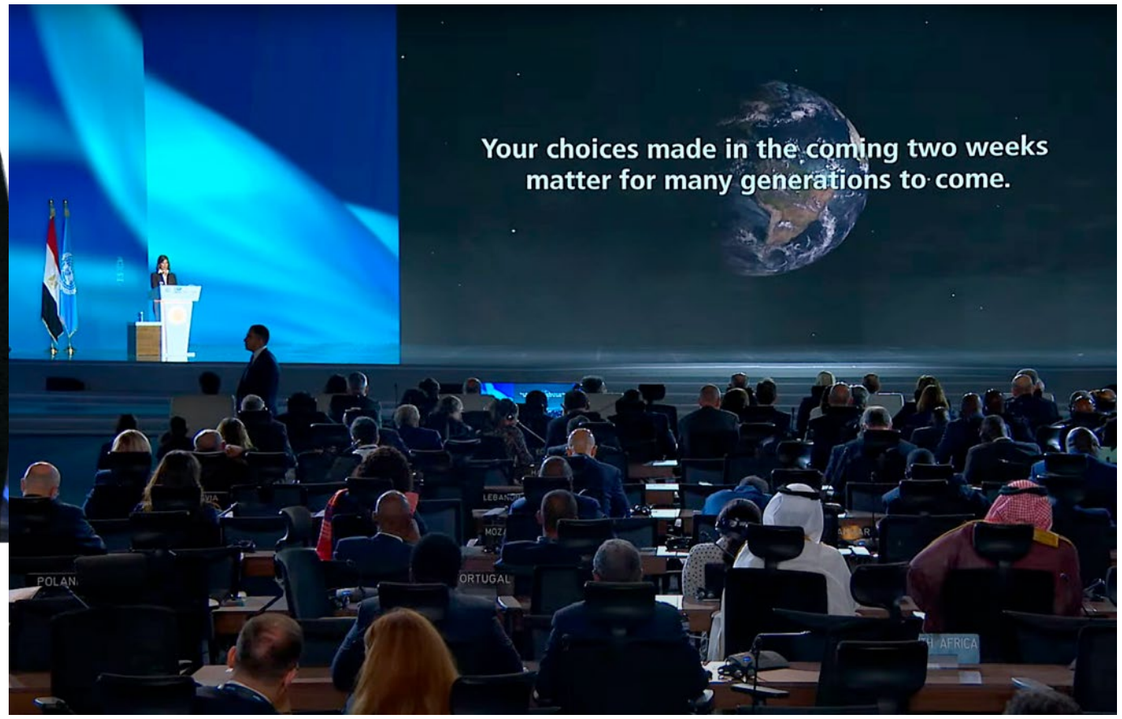
Veronika Eyring develops and evaluates models that project climate change

by Katja Lenz

"In every region of the world, we are seeing out-of-control climate impacts with extreme events becoming more frequent and more severe. Many of the recent extremes would have been highly unlikely to occur without human induced climate change."

Veronika Eyring

Head of the Earth System Model Evaluation and Analysis department at the DLR Institute of Atmospheric Physics



Veronika Eyring at the opening event of the UN World Climate Conference (COP27) in Sharm el-Sheikh in November 2022. Eyring is the coordinating lead author of the IPCC report chapter 'Human Impact on the Climate System'.

"Recent climate change is unprecedented. We all know and feel this." There's no doubt in Veronika Eyring's words. Research findings irrefutably demonstrate how the climate is changing, and the accuracy of the projections made using climate models is always improving. Eyring's research is contributing to this. The scientist leads the Earth System Model Evaluation and Analysis department at the DLR Institute of Atmospheric Physics. There, teams use climate models to look into the past and future of Earth's climate.

In November 2022, Veronika Eyring gave an invited speech in front of heads of state and negotiators at the opening session of the UN Climate Change Conference (COP27). Using scientific data, she presented climate change, its causes and its consequences. As part of her speech, she highlighted that the concentration of greenhouse gases in the atmosphere has reached record levels; in fact, carbon dioxide has increased by 50 percent compared to pre-industrial times. "As a consequence, global warming has reached 1.1 degrees Celsius above pre-industrial levels," explained Eyring at the conference in Egypt. These numbers are worryingly close to the 1.5 degrees Celsius target agreed upon at the UN Climate Change Conference in Paris in 2015. The results come from the latest report of the Intergovernmental Panel on Climate Change (IPCC), to which researchers from around the world contribute. The report's statements are as relevant as ever: "The warming we have observed since 1850 is not caused by natural events. It is caused by human activities emitting carbon dioxide and other greenhouse gases also causing widespread, rapid and intensifying climate changes across the entire Earth system, which will increase with any additional further warming." This sentiment was reinforced by Eyring as she highlighted the findings of the scientific teams, before receiving a standing ovation from the previous speaker, Al Gore. The scientist, Nobel Peace Prize winner and former US Vice President sat next to Eyring and shook her hand as she left the stage. Did they engage in conversation? "The opportunity for direct exchange with politicians at different levels was certainly an intensive part of the COP experience," she recalls.

The time for action is now!

Veronika Eyring has been conducting research at DLR in Oberpfaffenhofen for more than 20 years and has been a Professor of Climate Modelling at the University of Bremen since 2017. Two years ago, the German Research Foundation (DFG) awarded her the Leibniz Prize for her significant contributions to improving the understanding and accuracy of climate projections. Eyring is an authority in her field, and her statements leave no room for doubt. "In every region of the world, we are seeing out-of-control climate impacts with extreme events becoming more frequent and more severe. Many of the recent extremes would have been highly unlikely to occur without human induced climate change," she said at COP27. "The time for action is now."

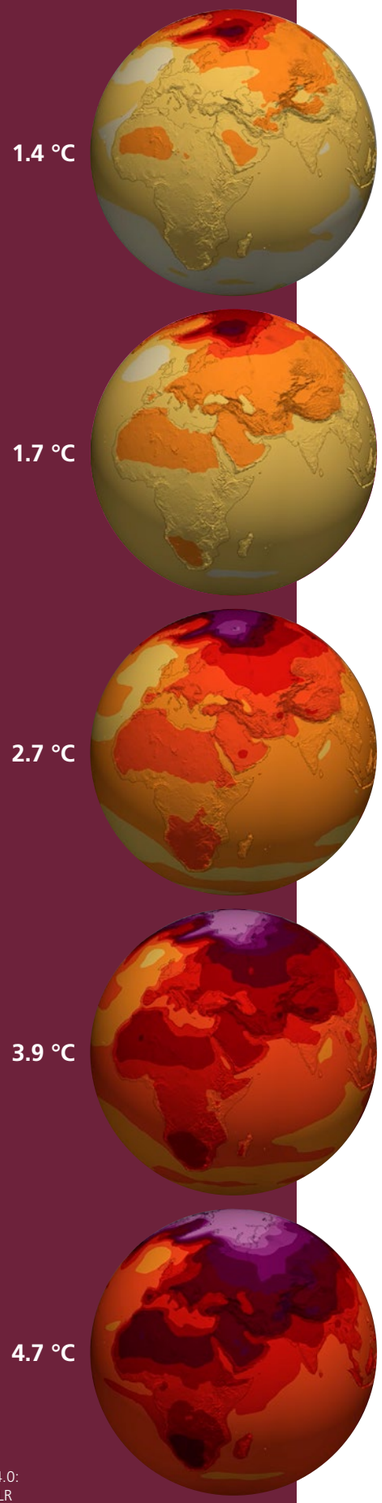
At the end of COP27, the German government announced that it found the results of the conference disappointing, particularly those related to reducing global greenhouse gas emissions. "The gap we have to close in order to limit warming to the target of 1.5 degrees Celsius is still very wide indeed, and some states have blocked any attempt to close it even a little," said Federal Minister for Foreign Affairs of Germany, Annalena Baerbock. A global shield against climate risks initiative was launched in response, with the aim of helping people affected by climate damage – primarily those in less developed and more vulnerable countries.

DLR provides essential Earth observation data

Much time has now passed since COP27, and Eyring has returned to her everyday research. "Under our current understanding, and if no additional measures are decided and implemented, global warming is projected to reach 2.8 degrees Celsius," she says. "To limit it to 1.5 degrees Celsius, we need to cut carbon dioxide emissions by approximately 45 percent by 2030. That's in seven years. And they must continue to fall to reach net zero by 2050. Carbon dioxide emissions would then have to be negative for the rest of the century." Even limiting warming to two degrees Celsius by the end of the century will require similarly drastic reductions. A diagram, scaled from blue to orange and red to purple, illustrates the warming effect: the globe is turning orange, red and even purple almost everywhere.

TEMPERATURE SCENARIOS FOR THE YEAR 2100

Projected temperature change compared to pre-industrial times



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DKRZ/DLR

Meanwhile, the computer models used to project climate change are becoming increasingly accurate. They are now capable of processing vast quantities of data, evaluating this information and linking it together to form an overall picture of the climate system. Eyring uses Earth observation data and artificial intelligence (AI) methods to obtain more reliable climate projections. DLR has the necessary experience from decades of Earth observation. And it has the infrastructure to carry out the analyses.

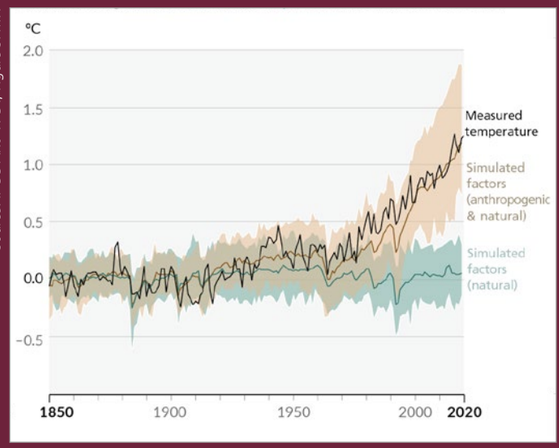
The DLR Institute of Atmospheric Physics in Oberpfaffenhofen, together with over 70 international research institutes, is in charge of developing the Earth System Model Evaluation Tool (ESMValTool), which is helping to present the results of climate model simulations. This computational tool allows a comprehensive evaluation of the climate and Earth system models in comparison with observational data. CMIP (Coupled Model Intercomparison Project), which was started more than 25 years ago, is a project in which climate models are compared with each other. CMIP sets standards for simulations, data formats and the algorithms used to evaluate them. The ESMValTool can be used to evaluate these enormous volumes of data. Eyring's team also analyses the simulations of the latest generation of CMIP6 models in comparison with Earth observation data. "This allows us to demonstrate the quality of these climate simulations," says Eyring, who led the CMIP6 project from 2014 to 2020. "Veronika Eyring and DLR have undertaken important pioneering work in model evaluation using Earth observation data. This work combines DLR's expertise in Earth observation with knowledge from climate research, thus advancing the quality of climate projections. This also puts DLR in a leading position in the fields of aeronautics and transport research to make important contributions to evaluating and reducing the impact of our modes of transport on the climate," says Markus Rapp, Director of the Institute of Atmospheric Physics.

A bridge between physics and machine learning

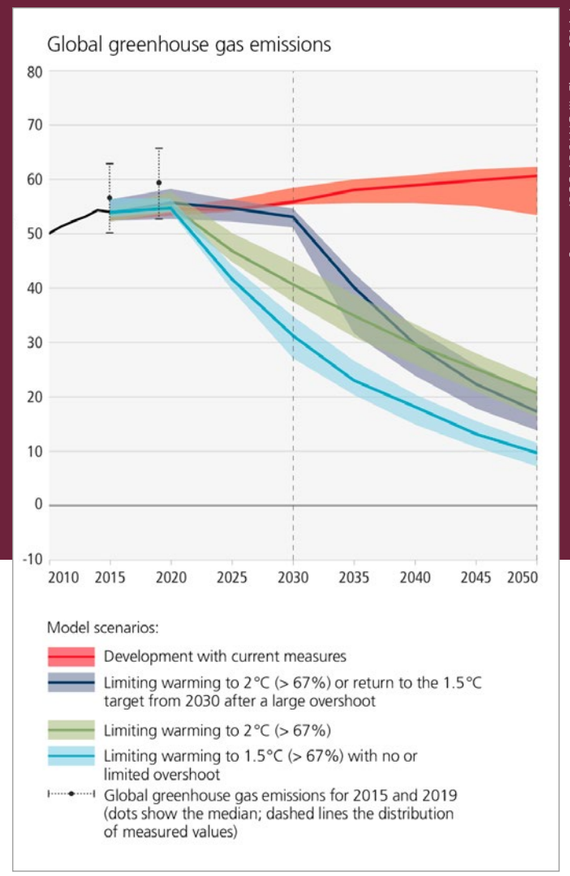
DLR is working with other research institutions to develop new machine learning methods in this field as part of the interdisciplinary Understanding and Modelling the Earth System with Machine Learning (USMILE) project, which is funded by the EU. These new methods will increase our understanding and modelling of the Earth system. Here, for example, the focus is on cloud processes. "Representations of small-scale processes such as regional cloud formation can be further refined," explains Eyring. "We are also investigating causal relationships between climate fluctuations and extreme events such as droughts using deep learning and other methods. By bridging the gap between physics and machine learning, we hope to revolutionise the modelling and analysis of the Earth system and contribute to robust long-term climate projections, also on a regional scale."

HUMAN INFLUENCE ON GLOBAL WARMING AND CLIMATE CHANGE

Source: IPCC AR6 WG I, Figure SPM.1



Development of the global surface temperature: the orange representation takes into account human and natural factors, while the green takes into account only natural factors, such as volcanic eruptions and solar activity.



Source: IPCC AR6 WG III, Figure SPM.4

This graph shows the extent to which greenhouse gas emissions must fall in order to achieve various global temperature scenarios

The Institute has now taken on a new project. The approaches first adopted for USMILE are being extended to the KLIM-QML project, an initiative that aims to improve climate models with quantum machine learning. The project began recently and is part of the DLR Quantum Computing Initiative (QCI). The aim is to develop a prototype of a climate model based on quantum machine learning.

The next generation

"Artificial intelligence is already making major contributions to climate modelling, but there is still a lot of potential," says Eyring. "This calls for a new generation of researchers who can further harness AI to address climate issues. Training them will be one of my most important tasks over the coming years." Eyring is currently supervising approximately a dozen doctoral students. In 1995, she began her doctorate at the University of Bremen, where she was able to combine her fascination for theoretical physics with climate research. Even then, researchers were warning people about climate change: they were using climate models, although they were not nearly as informative as those that exist today. Eyring became a professor at the University of Bremen in 2017. She now works as a researcher in the US and the UK and is well known in the scientific community.

Veronika Eyring from the DLR Institute of Atmospheric Physics improves climate models using Earth observation data and AI

When the organisers of COP27 asked if she would be the voice of the scientific community at the opening event, she didn't think twice. There was little time to prepare. The key messages of the speech were immediately clear to Eyring. Her department at DLR, the IPCC Secretariat and the German Climate Computing Centre assisted with her preparations and together, they produced a host of output, including an animation of the climate projections. These climate projections sent a clear signal to policymakers, businesses and society. "Every small increase in warming amplifies the effects of climate change considerably," says Veronika Eyring. "The next few years will be critical." Without a doubt.

Katja Lenz is a Media Relations editor at DLR.

WELCOME TO CANDYLAND!

That might well be the first thing that comes to mind when you see this image. But these polished metal balls have little in common with sweets. What looks like the red and white rings of peppermint swirls is actually the multiple reflection of red coil windings. The spheres lie on a grid inside the coil. As electricity from renewable sources flows through the coil, they heat up to 1000 degrees Celsius. Air flows around these spheres, absorbs the heat and transfers it. The hot air can be used, for example, for high-temperature processes in industry. This innovative power-to-heat (P2H) technology can thus be used to generate carbon-dioxide-free high-temperature heat at up to over 900 degrees Celsius from renewable electricity.

Scientists at the DLR Institute of Engineering Thermodynamics in Stuttgart are investigating such processes on a pilot scale using the P2H test bed at the large-scale HOTREG facility. At the heart of the facility is a five-metre high solid storage tank for operation with hot air generated by renewable energy at adjustable values for pressure and temperature.

A SNIFFING TOUR AT THE AIRPORT

What impact do sustainable fuels have on air quality at airports?

by Anja Tröster

Air is drawn in via the head of this device and cleaned of particulate matter that is too large

The aviation industry has high hopes for Sustainable Aviation Fuels (SAF). Research suggests that these fuels could mitigate the climate impact of aircraft – with respect to both their carbon dioxide emissions and their non-carbon effects. But how do these fuels affect the air quality at airports? A team from the DLR Institute of Combustion Technology travelled to Copenhagen to find out.

It's a cold and windy January morning on the airport apron. Planes trundle past, smelling of kerosene. In the middle of the hustle and bustle is a blue truck sporting an array of measuring instruments on its roof. Tobias Schripp, Tobias Grein and Nina Gaiser are using this mobile air measurement laboratory from the DLR Institute of Combustion Technology to study the exhaust fumes sweeping across the apron over a period of four weeks. Their study is targeting one aircraft in particular: a Scandinavian Airlines plane that commutes daily between Copenhagen and Stockholm, fuelled with a mixture of 65 percent kerosene and 35 percent SAF.

Their measurements are part of the EU's ALIGHT project to develop solutions for a smart, climate-neutral energy supply for airports. However, while plane spotters are a common sight at airports, the three researchers stand out as the only 'plane sniffers'. When the three researchers explain exactly what they are measuring, they are always met with looks of disbelief. We are used to plane spotters at airports.

But 'plane sniffers'? It is not only the airport staff who find this unusual, as project manager Tobias Schripp realises one day while trying to take measurements outside the airport grounds. Even the plane spotter he is talking to shakes his head in surprise.

But this incredulity always grows into curiosity. Once the chemist has explained in more detail how his team analyses the fine dust particles, it soon becomes clear even to the uninitiated: this research is something special. Many scientists study the effects of fuel combustion on the atmosphere using simulations. Only a handful worldwide are able to study combustion processes in real time.

How is the origin of soot particulate determined?

Not only can the lab's equipment be used to detect and identify all particulate matter between five and 1000 nanometres in number and size in real time, it can also be used to combine this information with data from the weather station on the roof of the bus, including wind direction, temperature and humidity. In addition to particulates, the researchers are also examining the concentration of carbon dioxide and other emissions. "We assume that the composition of the exhaust cloud does not change significantly over the 200 metres from the engine to us," says Schripp. "By the time we measure it, it is only a few seconds old, so the ratio of carbon dioxide and particulate matter is still the same – regardless of how the wind may have diluted it. By measuring both, we can characterise and compare the exhaust gases." The researchers can determine which particulate matter was emitted by an aircraft as the particles are much smaller than those emitted by diesel vehicles. For comparison, a human hair has a diameter of approximately 40,000 nanometres – 40 times thicker than the largest of the measured particulates.

The campaign sometimes required the three DLR researchers to start their work before sunrise

The DLR team first compared the ratio of carbon dioxide and particulate matter in the exhaust clouds of several aircraft – both those using conventional kerosene and those using partial mixtures of SAF. Then they focused on their target aircraft. Measurements of nitrogen oxides provided additional information about combustion taking place within the engines. "We look for the exhaust plume peaks in the data acquired by our measuring instruments when our target aircraft is operating on the ground. We also assign these peaks to a wind direction, which we measure directly using instruments on the vehicle," says Tobias Schripp. The experts used the target aircraft's GPS, the wind direction and the peak events to assign the exhaust gases to the aircraft. The study also proved successful for DLR's project partners. "For me, one of the most exciting moments of the ALIGHT project was when, after months of planning, the Scandinavian Airlines aircraft moved around at Copenhagen Airport powered by a 35 percent SAF blend, while DLR measured the impact on local air quality," says Sabrina Jensen, Senior Project Manager for Sustainability at Copenhagen Airport and ALIGHT Project Manager.

This is not the first time that the DLR team, based in Stuttgart, has studied the emissions of aircraft using sustainable fuels. In 2015, 2018 and 2021, the team took part in the pioneering Emission and Climate Impact of Alternative Fuels (ECLIF) campaigns. However, these studies took place under comparatively controlled conditions. "The reality of flight operations is quite different, and we want to see whether the benefits of these fuels meet expectations under these realistic conditions," emphasised Schripp. He believes that the reduction in pollutants offered by SAFs may be quite different from what was expected. Since the fuels used have fairly similar soot-forming potential, a detailed, further evaluation will probably be required.

Anja Tröster is responsible for public relations at the DLR Institute of Combustion Technology.

ALIGHT

The partners in this EU project include Copenhagen Airport, Scandinavian Airlines and BP. They are working on the implementation of climate-neutral solutions for airports. One key aspect is the supply of ground infrastructure with renewable energy, another is the introduction of sustainable aviation fuels (SAF). By 2025, an ALIGHT concept that can also be used by other airports will be developed.

ALIGHT

Jesper Jacobsen, Head of Sustainability Development at Copenhagen Airport, explains the EU ALIGHT project to Danish broadcasters.

© DLR

DLR project manager Tobias Schripp explains how his team analyses the emissions of a passing aircraft in real time

The mobile lab has often been used to investigate engine emissions during dedicated flight campaigns. Now, for the first time, it is being used for everyday flight operations.

OUT OF THE BOX

Developing aircraft quickly and cooperatively with co-development

by Björn Nagel


© DLR

Who decides on the appearance of the products that we use? Who designs them? The development of new products is not necessarily dictated from above: designers can enter into direct dialogue with users and allow them to help shape the development process. This collaborative approach is known as co-design. At DLR, researchers are keen to apply this fundamental concept to the development and production of aircraft in order to improve the joint development process – from the initial idea to production and operation.

Designers begin thinking about the appearance of a new aircraft long before the first prototype is built. This can lead to the inclusion of ideas such as large panoramic windows or a lounge area with a bar for passengers. It is also at this stage that the designers consider how the aircraft can meet the climate neutrality goals that have been set for aviation, how many passengers it should accommodate, which routes it will need to fly and how it will be powered. This requires input from a wide range of experts in fields such as aerodynamics, structural engineering, acoustics, safety and structural dynamics. They must work closely together, examine how all their requirements can be implemented efficiently and how the aircraft has to be designed so it can fly. This means that new aircraft can be brought to market more quickly.

Swift, collaborative and full of promise

"The notion of applying co-design to the entire development process was first raised by production, because they often only see a design when it is almost finished," says Jörn Biedermann of the DLR Institute of System Architectures in Aeronautics in Hamburg. Researchers at the institute are working to improve the performance, safety and efficiency of new aircraft and their components, such as the cabin.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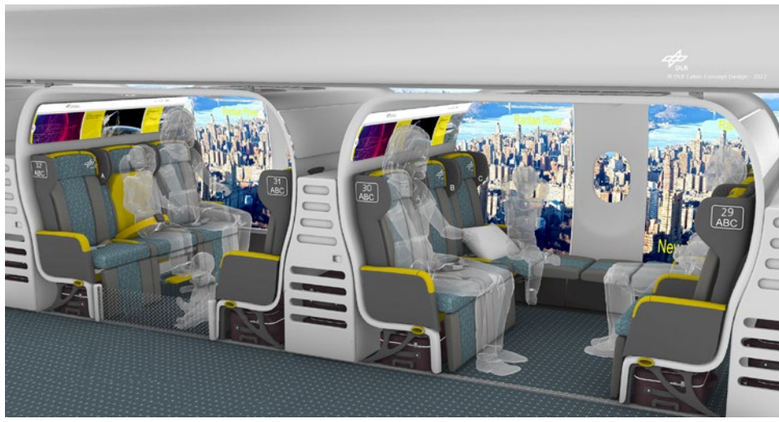
Communication and exchange are essential in co-design



This concept for an aircraft seating compartment was designed using the co-design method

Some issues are only identified once a design is submitted to production. It may become apparent that existing production technologies need to be extensively modified as they are not designed for tasks required. Sometimes systems must be upgraded or new machinery procured because the existing ones are unable to carry out the necessary work. If an aircraft is significantly longer than those manufactured previously, for example, a new production hall may have to be built from scratch to house it. Many systems are also currently optimised for just one type of aircraft. However, future aircraft will have a more modular design. Depending on the requirements, the rows of seats may be arranged differently, for example, or sleeping cabins and work areas may be incorporated into the design. These design features will naturally affect aircraft production.

Adopting a co-design approach offers all parties the chance to provide input at each stage of the design process, from concept and design development to dimensioning, testing, production, operation and maintenance. Specialists from all areas are asked about their requirements and constraints from the outset. As a result, these factors are integrated into the process at an early stage and everyone works together and in parallel on the design, saving time and money. The researchers and engineers in Hamburg expect that this approach will not only improve communication, but that it will also lead to the development of more efficient processes and more innovative aircraft concepts.

Finding interfaces and making information accessible

"We are currently concentrating on co-development, which refers to the linking up of the various aspects of the design phase," says Fabian Reimer. Reimer works in the cabin design team at the DLR Institute of System Architectures in Aeronautics. "We are working together to develop ideas and define interfaces," says Mara Fuchs, DLR expert in cabin system design. "Specifically, we are gathering all the necessary information and compiling it in a way that everyone can understand." In doing so, the DLR researchers are including every development phase that an aircraft goes through during its lifetime. This is no easy task, as the various experts all work with different software programs and methods. In order to assess whether a new concept is airworthy, researchers create flow models, acoustic analyses, Finite Element Method (FEM) simulations that show whether the structures can withstand loads during flight, and more. The newly developed concepts are subject to strict safety regulations as part of their certification. Information about these requirements and much more are currently often exchanged between departments via an Excel file or PDF document. Such a document can consist of up to 1000 pages, from which every expert must pick out the information relevant to them.

"At the manufacturers, teams are responsible for a specific aspect of the aircraft, such as how the airflow in the cabin should be regulated or how to make a turbine as quiet as possible. They optimise this within the given framework conditions," says Christian Hesse, DLR cabin design expert. "This means that they may not be aware of what is happening elsewhere within the overall aircraft system," adds Fabian Reimer. This in turn leads to a situation in which supposedly effective improvements have little impact on the overall system. For example, when an advanced design was developed for the rotor blades of the

> *"We are working together to develop ideas and define interfaces. Specifically, we are gathering all the necessary information and compiling it in a way that everyone can understand."*
>
> **Mara Fuchs**
> **DLR expert for cabin system design**

New cabin concepts are being tested at the DLR Institute of System Architectures in Aeronautics using projection methods or extended reality applications

contrarotating open rotors engine type, experts assumed that this could reduce noise by 10 to 20 decibels. When considered in isolation, this was certainly the case. However, when the engines were then mounted on the fuselage structure and tested in a wind tunnel, researchers noticed that the aircraft was only approximately two to six decibels quieter, as noise is also generated by the airflow around the aircraft structure. "Only when we all sit down together do we uncover specific interfaces and interdependencies between the specialist areas. And only then can we take them into account at an early stage," says Mara Fuchs.

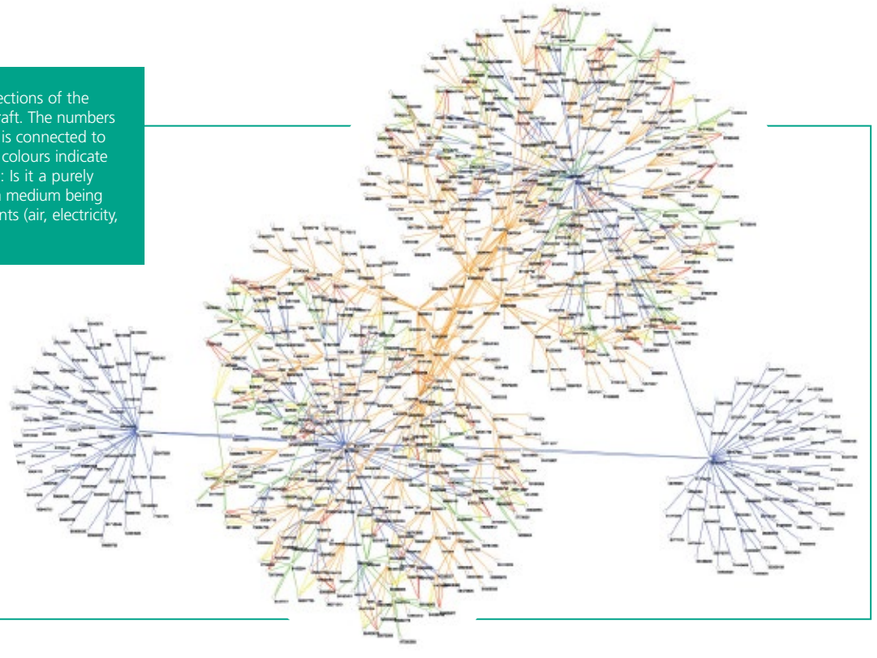
Everything is connected – the aircraft as a system

For Biedermann, co-development is a promising approach that can be used to identify previously unrecognised interfaces. "Now we see the entire aircraft as a single system in which everything is connected," he says. "With the help of co-design and co-development, we can prompt people to think outside of their own box." This approach provides an opportunity for experts to exchange ideas and gain insight into the work of others. It makes the various interactions visible and enables researchers to give each other feedback and respond to each other's needs.

Co-design and co-development at DLR ...

This approach is proving effective among the DLR institutes conducting research into aeronautics. Since 2005, DLR researchers have been developing the Common Parametric Aircraft Configuration Scheme (CPACS). This data model contains information about the design of an aircraft and its individual components. The data are issued in a format that is readable and usable by all parties. It ensures that everyone has the same overview of the aircraft at all times and is working with the latest data. It also eliminates the need to wade through a 1000-page PDF file. In DLR's Innovative Digital Cabin Design (InDiCaD) project, researchers investigated the direct exchange of cabin design data using CPACS. This process allowed experts to take the results of passenger boarding simulations into account in the design and exchange information about predicted cabin noise.

This grid shows some of the connections of the cabin components of an A320 aircraft. The numbers represent a cabin component that is connected to another component by a line. The colours indicate the different types of connections: Is it a purely mechanical connection or is there a medium being transferred between the components (air, electricity, data, oxygen).



DLR PROJECTS FROM THE FIELD OF CO-DEVELOPMENT

A TESTBED FOR COLLABORATION

The DLR Institute of System Architectures in Aeronautics has launched the Engineering Collaborative Network initiative together with the technology provider Dassault Systèmes. The initiative seeks to determine how industry can benefit from a more collaborative way of working. To do this, researchers use the 3DEXPERIENCE software platform developed by Dassault Systèmes. This integrated, cloud-based platform allows all parties involved to collaborate, communicate and track changes to the aircraft design made by others. The DLR team is working to optimise how value is added to the economic ecosystem for aeronautics, with a view to facilitating sustainable flight and meeting society's requirements for a climate-neutral future.

DEVELOPING NEW CABINS TOGETHER

The Verdika project for a networked digital cabin was part of the Federal Aviation Research Programme VI-1. Here, DLR researchers worked with partners from industry, including Airbus and Diehl Aviation, to devise a process for the automatic digital development and integration of aircraft cabins. The project focused on overhead compartment designs for different types of aircraft. All parties involved in the project came together at an early stage to investigate a modular luggage compartment design and methods for integrating it into various aircraft types. The project will end in September 2023.

DIGITAL AIRCRAFT DESIGN

Designing new aircraft can be very challenging. New designs are becoming increasingly complex, while the costs and time required are rising. The EU-funded H2020 project AGILE 4.0 aims to digitalise the design process, making it faster and more effective. AGILE 4.0 was launched in 2019 and will run until 2023. The participants are investigating new ways of modelling and optimising aircraft and evaluating these models. Their work covers the entire life cycle, including manufacture, certification and maintenance. Documents are no longer exchanged; instead, everyone involved has access to digital models that display all the relevant information.

ZENODO

In the AGILE project, this collaboration was extended to partner organisations across Europe. "We were able to show that it is possible to design an aircraft in a decentralised way in Europe, with everyone working on the same digital foundation," says Luca Boggero, DLR systems engineering expert. The many different methods and digital tools involved in the design process were linked together as part of the project. The Verdika project focused on the aircraft cabin and how it can be developed digitally in a collaborative way. In 2020, DLR launched the Exploration of Electric Aircraft Concepts and Technologies (EXACT) project, in which 20 institutes are jointly developing concepts for eco-efficient commercial aircraft. The project will run until 2024.

... and beyond

When Biedermann and his team set to work introducing co-design principles to aircraft design, they are often met with a significant challenge at the outset. "Depending on who I talk to, I may be given a different description or different requirements for the virtual and real product," says the DLR researcher. Operations may require that an entire fleet is presented as a digital product following each modification. Meanwhile, production may be more interested in depicting the current status during assembly. As a result, defining the terms can be an almost philosophical dilemma. The task of the DLR experts from Hamburg is to create a common foundation and link up the different areas of expertise. To do this, they develop knowledge-based methodologies that answer questions such as: Which information is relevant? How can I link up this knowledge? Who is connected to whom? Everything has to be consistent.

The DLR Institute of System Architectures in Aeronautics and Dassault Systèmes are looking to apply this approach in industry as part of the Engineering Collaborative Network project. Everyone involved is using Dassault's existing software platform to communicate with one another and make themselves aware of changes to the aircraft design. The DLR team will investigate remaining gaps in communication and collaboration and look at how these can be rectified – preferably together, of course.

Björn Nagel is the Founding Director of the DLR Institute of System Architectures in Aeronautics.

A MUTUAL UNDERSTANDING

How speech recognition software can improve air traffic control

by Hartmut Helmke

Fraport AG

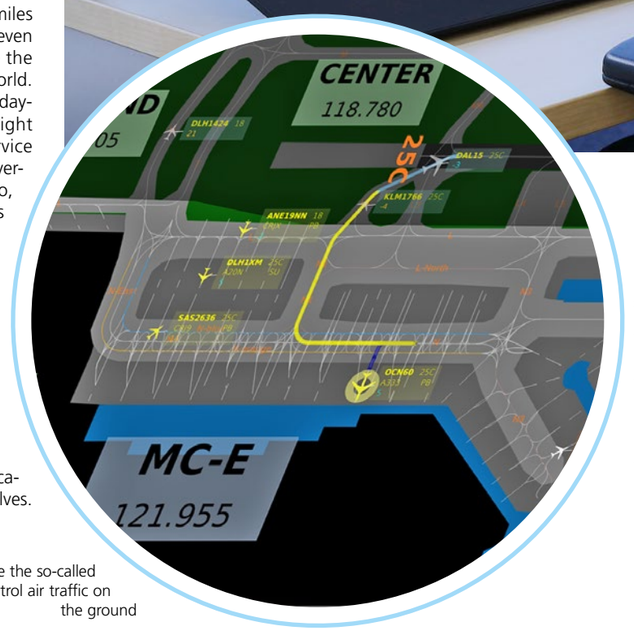
In this test, the controller was assisted by voice recognition software in directing traffic in the area around Frankfurt Airport.

Speech recognition has become a part of everyday life. Voice assistants such as Alexa, OK Google and Siri can carry out many useful functions, such as allowing us to enter a new address into our navigation system without taking our hands off the steering wheel. But speech recognition software can also be used to assist air traffic controllers communicating with aircraft in flight and on the ground. It can save them time and even reduce the aircraft's fuel consumption. For many years, the DLR Institute of Flight Guidance has been researching speech recognition software and testing it in new areas of application. But how does this software work, and what other benefits does it offer?

Air traffic controllers (ATCos) use specialised technical vocabulary when they communicate with pilots. Conventional applications such as Siri recognise just half of the words spoken in rapid, complex instructions such as "Speedbird two zero zero zero, reduce one eight zero knots until four miles final, contact tower on frequency one one eight decimal seven zero zero, bye bye!" This difficulty is compounded by the different English accents of the controllers around the world. A recognition rate of 50 percent is far from sufficient for day-to-day operation. That is why the DLR Institute of Flight Guidance has worked with various air navigation service providers and research institutions, such as Saarland University, Swiss research institute Idiap and the University of Brno, to develop speech recognition and understanding systems for air traffic control applications. To do this, the researchers evaluated and transcribed over 50 hours of spoken language. By comparison, Google has access to about 200,000 hours of transcribed speech data. The researchers used the data to train a neural network. The resulting system has now achieved a word recognition rate of over 97 percent for communication in the apron area of Frankfurt Airport.

Speech recognition versus speech understanding

In addition to the recognition rate, the quality of an application is also determined by the unrecognised words themselves.



TowerPad™/ATRiCS Advanced Traffic Solutions GmbH

Controllers use the so-called TowerPad to control air traffic on the ground

A failure to understand 'Good morning' is potentially far less fraught with danger than a mix-up with 'heading two six zero'. If the system mishears the 'two' as a 'three', the aircraft will fly north instead of west.

A communication, either from the flight deck or from the air traffic control tower, consists of various elements: a callsign, a command and possible conditions. The pilot must read back every instruction from the air traffic controller in order to confirm it. While doing so, they may alter the order of the words or use slightly different expressions. In order to ensure that the software can 'understand' these variations, in 2018, 22 partners from 15 European countries under the leadership of DLR agreed on rules for the semantic interpretation of radiotelephony communications. This is known as an ontology. DLR has now used this ontology in various speech understanding projects alongside air traffic service providers from all over Europe. These activities have proven its suitability and it is currently being further developed under the leadership of DLR.

From 2024, apron controllers at Frankfurt Airport will have to manually enter all spoken taxi clearances into a control system using a mouse or keyboard. This process will increase safety. However, it will also significantly increase their workload. In the worst-case scenario, this could reduce the number of take-offs and landings. Speech recognition software can transcribe and automatically interpret the spoken commands, leaving the air traffic controller to correct any remaining errors. A recognition rate of 90 percent would mean that they only have to manually enter every tenth clearance. This is what DLR researchers have been investigating in the Safety and Artificial Intelligence Speech Recognition (STARFiSH) project. Idiap developed the

HOW DOES AIR TRAFFIC CONTROL COMMUNICATE?

speedbird two zero zero zero
reduce one eight zero knots until four miles final
contact tower on frequency
one one eight decimal seven zero zero bye bye

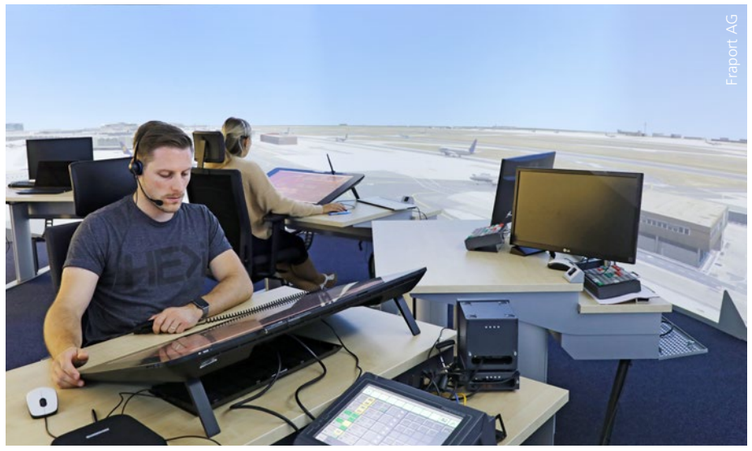
one eighty to four
tower one eighteen seven
speed bird two thousand

Callsign	BAW 2000
Instruction 1	Reduce speed to 180 knots no later than four nautical miles before landing
Instruction 2	Contact tower
Instruction 3	Switch to frequency 118.700 for the tower
Farewell	Bye bye

Above is a typical example of communication from air traffic control. It begins with the callsign – the name of the flight. This is followed by instructions to reduce the speed to 180 knots, no later than four nautical miles before landing. The pilot should then switch to the frequency of 118.700 to communicate with the tower. The pilot repeats the speed and tower frequency and finally the callsign.

speech recogniser used in STARFiSH, DLR supplied the speech understanding module, Freiburg-based company ATRiCS Advanced Traffic Solutions GmbH developed the simulator and the TowerPad, and Frankfurt Airport AG (Fraport) provided the test air traffic controllers. The system was initially tested in the Fraport AG simulator. The tests carried out in the summer of 2022 demonstrated that good speech recognition software can reduce the workload of air traffic controllers, as the input they are required to type is reduced by over 50 percent.

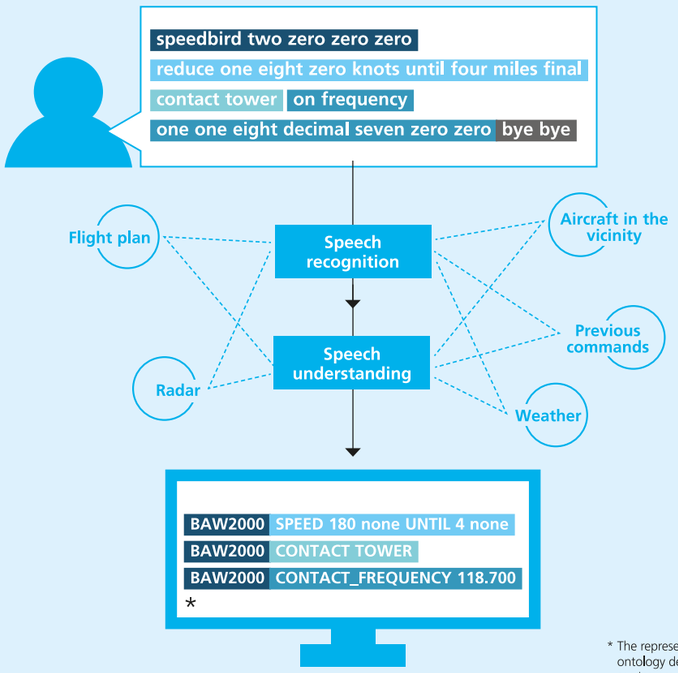
For the experiment, the pilots of several aircraft were simulated. Here, one person acts as a 'pilot', controlling up to ten simulated aircraft at the same time.



The tests of the software showed that the air traffic controllers had to enter more than 50 percent fewer commands themselves

From simulation to control room

While the STARFiSH project tested the software with voice data from simulation operations, the European HAAWAII project led by DLR is already a step further. Here, speech recognition software was used to recognise and understand instructions issued by Icelandic and British air traffic controllers resulting from live operations. HAAWAII stands for Highly Automated Air Traffic Controller Workstation with Artificial Intelligence Integration and involves Idiap, the University of Brno and the air navigation service providers of Iceland, the United Kingdom, Austria and Croatia. The software not only recognises the speech from the air traffic controllers during live operations, but also from the pilots. This is not only challenging because of the high noise level in the flight deck, but also because of the different speech accents. In addition, the air-ground voice channel is usually very noisy. The project began in 2020 with a voice recognition system that had been trained with 3000 hours of everyday English and with air traffic radio communication, but which had not yet had to contend with live speech from British or Icelandic air traffic control. As a result, word recognition rates were initially poor, with error rates of 30 to 40 percent. British and Icelandic air traffic controllers then transcribed their voice radio communications. Once the researchers had trained the neural network with these data, the word recognition rate rose to over 95 percent for the air traffic controllers and over 90 percent for the pilots. The Icelandic air navigation service provider used speech understanding to help air traffic controllers identify errors when pilots read back controller commands. British air traffic control used speech understanding to predict the workload of air traffic controllers.



* The representation of the commands is based on the ontology developed by DLR together with air navigation service providers from all over Europe.

HOW DOES SPEECH RECOGNITION SOFTWARE WORK?

The software's speech recognition algorithm transforms a spoken voice signal into a sequence of words. The speech understanding algorithm then converts the individual words into semantic units. These may be callsigns, command types or command values. The system also uses command prediction to improve speech recognition and understanding. The command prediction system uses radar, flight plan and weather data to automatically identify the callsigns of aircraft in the vicinity that could soon be addressed. It also provides potential command types and corresponding values for each callsign. Command types include changes in direction, speed or altitude. For this purpose, the command prediction system uses radar, flight plan and weather data. The results of the speech understanding process are automatically displayed on the controller's radar screen.

Saving fuel with speech recognition

In 2015, researchers at the DLR Institute of Flight Guidance demonstrated that using speech recognition software can also save fuel. Freeing air traffic controllers from the need to enter commands manually allows them to spend more time on their primary task: safe and efficient air traffic management. If a command is issued even slightly late on approach, it can result in the aircraft flying a few kilometres too far in the wrong direction. This creates more work for the controllers. Between 2015 and 2017, tests with air traffic controllers from Germany, Austria, Croatia, the Czech Republic, Denmark, Sweden and Ireland demonstrated that voice recognition software could reduce flight times by an average of approximately 77 seconds. This corresponds to a reduction in fuel consumption of 60 litres of kerosene per flight.

First live application and future ambitions

In the summer of 2022, Icelandic air navigation service provider integrated the HAAWAII system into the control room in Reykjavik to display the spoken commands. The aim of this demonstration was to automatically detect read-back errors, which the system did successfully.

DLR and aircraft manufacturers are now planning to integrate the software into the flight decks to remove the need for pilots to manually enter taxiways into the system while taxiing at the airport. This brings the vision of the one-person flight deck a step closer. Frankfurt Airport is not only planning to use the system in the simulator, but from 2026 at the latest, it will also reduce the workload of air traffic controllers in the control room when entering commands.

Hartmut Helmke works in the Controller Assistance Department at the DLR Institute of Flight Guidance and is a specialist in the field of speech understanding.

Managing traffic at an airport is no easy task

SUPPORTED BY sesar JOINT UNDERTAKING

This project is funded by the SESAR Joint Undertaking within the EU's Horizon 2020 research and innovation programme under number 884287.

DLR PODCAST

This interview is an excerpt from the new podcast 'DLR-FORSCHtellungsgespräch' (DLR Research Interview). It has been shortened and edited for the DLRmagazine. Here, research pilot Jens Heider talks about his exciting work.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AN AIRBORNE ALL-ROUNDER

In conversation with a DLR research pilot

Interview with Jens Heider

Tune in to the German-language podcast at **DLR.de/podcast** and on all popular streaming platforms.

Flying in the exhaust stream of another aircraft, circling in tight loops over an airfield to measure aircraft noise, and taking off and landing again and again to test assistance systems … all this might sound like a nightmare for anyone with aerophobia, but it is Jens Heider's passion. Jens is a test pilot at DLR's Flight Experiments facility in Braunschweig and flies the research aircraft on their missions. Here he talks about how he got this extraordinary job, the challenges it involves and how much he lives up to the pilot stereotype.

How does someone become a test pilot?

There is no one path to qualification. The majority of people working as test pilots originally served in the military. But some of us have a civil aviation background, as is my case. To be honest, there is a lot of luck involved – being in the right place at the right time. But it is also about having a vision of what you want to do and the drive to go into this field. In the end, there are no guarantees of success.

And how did you end up at DLR? Was getting in here easier than the selection process to become a test pilot?

Luck was involved here, too. I finished my university studies in Bremen and my pilot training in 2003/2004. At that time, I was keen to join the regional division of a well-known German airline. But the job market was flat back then, with hiring freezes across the group. My diploma thesis supervisor put me in touch with DLR. There was a vacancy at the Institute of Flight Systems that sounded very interesting, and I thought it might be a good fit. I applied and finally joined DLR in 2004. Soon after I got there, I realised I was more drawn towards aviation, so in 2006 I applied for a post in flight operations. I was lucky enough to get the job.

Do you live up to any of the stereotypes about pilots?

Well, I wear sunglasses if it is sunny when I am flying. But that has nothing to do with the stereotype – it is just too bright otherwise.

You are a qualified flight systems engineer, so in addition to working on the flight deck, you also look after flight operations. DLR's aircraft undergo frequent modifications. The systems are also approved via DLR. What else do you do?

I have a very broad range of tasks. In addition to the assignments you mentioned, I am involved in discussions with researchers at an early stage about the expectations and requirements for their experiments. We work to establish what needs to be modified or installed on the aircraft or helicopter and how the flight tests should be planned. Most pilots and flight test engineers have several roles and also play an active part in development or testing. Our pilots need to have a degree, as they have to cover all the bases.


© DLR

What kind of degree do people need to have to work here?

A technical degree is preferred, ideally in aerospace engineering or aeronautical systems engineering. But we also have people who have studied computer science or another scientific discipline.

You have been working on the flight deck of DLR aircraft since 2006, so you have certainly experienced a lot. What has been the highlight?

That is a tough question, as there have been many great moments. One was definitely the flight measurement campaign led by the Alfred Wegener Institute, which took us to Spitsbergen for six weeks. Flying over the ice and the surrounding sea was impressive, but it also makes me sad to think how little the waters in that area freeze over now.

Let us look to the future. What are you working on right now? And is there anything that you are particularly looking forward to?

One major development is the ISTAR in Braunschweig. DLR has had this aircraft since early 2021. We have already modified it to the point where we can record the flight data immediately. We are currently installing a nose pylon – a measurement probe attached directly to the nose of the aircraft to measure the parameters of the airflow there with as little disturbance as possible. We have just installed an experimental autopilot system in our Dornier Do228 with the objective of testing the functionalities of pilotless aircraft, among other things. One overarching area that also comes into play in Oberpfaffenhofen is electric flight. DLR recently bought another Dornier 228 with the goal of replacing one of the engines with an electric motor and being able to power it via a fuel cell within the next few years. But when it comes to those sorts of long-term projects, we are talking about a time horizon of at least five years.

Thank you for giving us this insight into your day-to-day work and a glimpse of what is to come!

The interview was conducted by **Daniel Beckmann**, who works in the Corporate Communications Department at DLR and hosts DLR's FORSCHtellungsgespräch podcast.

DLR FLIGHT EXPERIMENTS FACILITY

With ten aircraft and helicopters, DLR's Flight Experiments facility operates the largest civilian fleet of research aircraft in Europe. The facility assists internal and external users with planning and conducting their experiments. These flight experiments either use the aircraft as a carrier for scientific instruments or as a subject of research in its own right.


© DLR

Jens Heider at one of his workplaces, the ISTAR flight deck.


© DLR

On location in Spitsbergen. From left: Jens Hammer, Jens Heider and Andreas Hahn (former DLR pilot) in front of the 'Polar 2', a Dornier 228 belonging to the Alfred Wegener Institute.

MULTIPLE TRACKS UNDER WAY

Alternative propulsion technologies for rail transport

Two forms of propulsion have dominated rail traffic for decades. Where overhead lines are installed, the railway is already locally emission-free. The lines supply the rolling stock via a current collector with electricity. On routes without overhead lines, trains operate using diesel engines. As in road traffic, these diesel engines cause emissions and noise that are harmful to the environment and contribute to global warming. Even in the future, there will not be overhead lines everywhere. This is why rail transport is also looking for alternatives. In a similar manner to road transport, the focus is on concepts based on batteries and fuel cells.

The first such trains are already in use, mainly in regional transport and for shunting operations. The possibilities range from converted locomotives to completely newly developed multiple units. The challenge is to find the right balance between the energy that the train takes along in the form of batteries or hydrogen and the energy supply from the infrastructure – that is, charging, refuelling or even using overhead lines.

OVERHEAD LINES

Approximately 60 percent of the German rail network is equipped with overhead lines. Further expansion is under way. However, the construction of overhead lines is not possible everywhere, for example in some existing narrow-profile tunnels. On little-used sections of track, it is simply not cost-effective.

HYDROGEN STORAGE TANKS

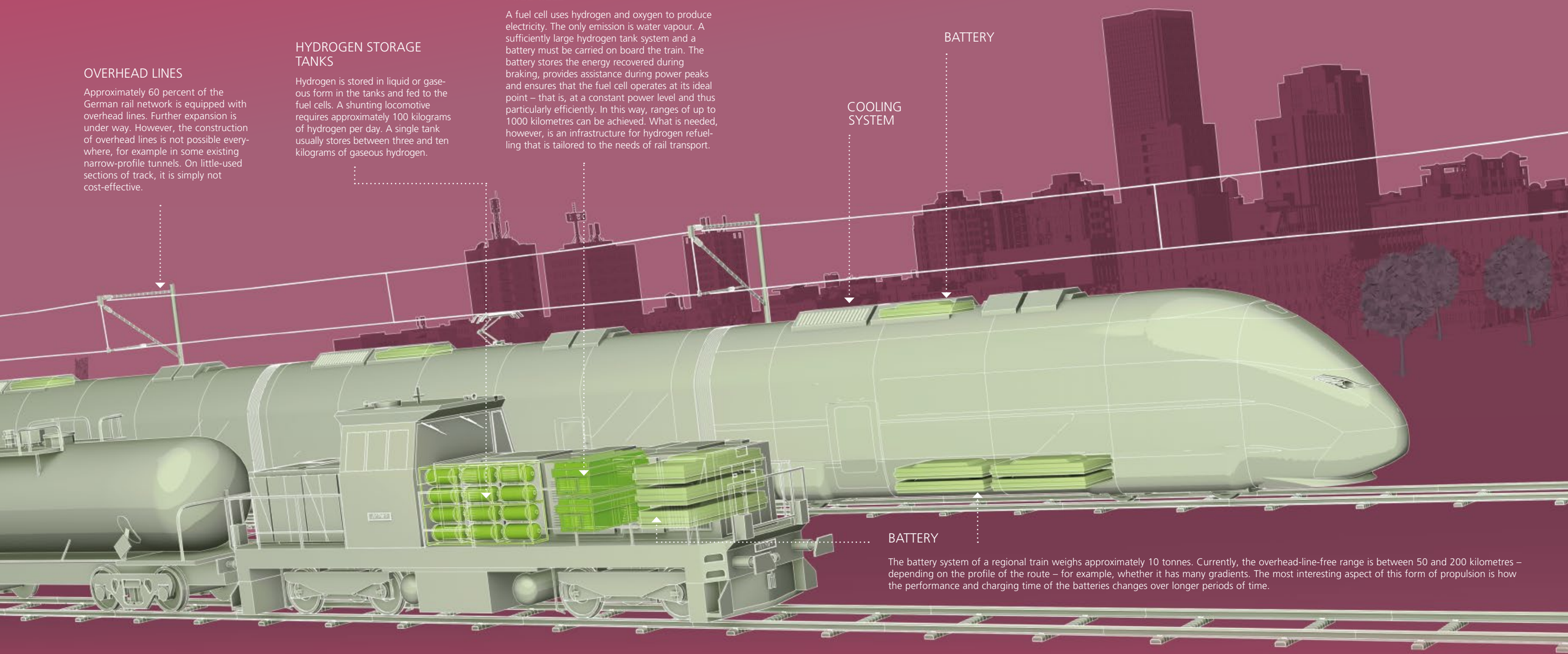
Hydrogen is stored in liquid or gaseous form in the tanks and fed to the fuel cells. A shunting locomotive requires approximately 100 kilograms of hydrogen per day. A single tank usually stores between three and ten kilograms of gaseous hydrogen.

FUEL CELL

A fuel cell uses hydrogen and oxygen to produce electricity. The only emission is water vapour. A sufficiently large hydrogen tank system and a battery must be carried on board the train. The battery stores the energy recovered during braking, provides assistance during power peaks and ensures that the fuel cell operates at its ideal point – that is, at a constant power level and thus particularly efficiently. In this way, ranges of up to 1000 kilometres can be achieved. What is needed, however, is an infrastructure for hydrogen refuelling that is tailored to the needs of rail transport.

COOLING SYSTEM

BATTERY



BATTERY

The battery system of a regional train weighs approximately 10 tonnes. Currently, the overhead-line-free range is between 50 and 200 kilometres – depending on the profile of the route – for example, whether it has many gradients. The most interesting aspect of this form of propulsion is how the performance and charging time of the batteries changes over longer periods of time.

THE RACE TO ZERO WITH ZEDU

DLR is developing the most environmentally friendly car in the world

by Denise Nüssle

Electric drive systems powered by batteries or fuel cells are an essential part of the scientific advance towards environmentally friendly road transport. However, they do not yet enable completely emission-free driving. Abrasion from brakes and tyres produces particulate matter and microplastics. DLR's ZEDU test car, a world first, aims to eliminate these pollutants using an innovative braking system and a redesigned wheel housing.

Stuttgart, the capital of Baden-Württemberg, is considered one of the birthplaces of the automobile. But for a long time, the Swabian metropolis held the rather inglorious distinction of having the highest levels of fine dust pollution of any city in Germany. Stuttgart breached the European threshold values introduced in the 2000s more frequently than anywhere else in the country. Particulate matter is invisible to the human eye. It consists of particles that float in the air for a long time before falling to the ground. The smallest of these particles can enter the lungs via the respiratory tract and, from there, enter the bloodstream. When deposited in the blood, they can pose a health risk. Traffic causes about half of the particulate matter. It is generated during combustion processes in the engine and through the abrasion of brakes and tyres. A similar situation exists for plastics: every year, road traffic generates between 133,000 and 165,000 tonnes of plastic matter that is left in the surrounding environment, primarily as a result of tyre wear. Particles smaller than five millimetres, known as microplastics, are exceptionally problematic. They have now been detected almost everywhere on Earth and can take several hundred years to decompose.

Driving without particulate matter and microplastic emissions

"In our advances towards zero-emission mobility, the focus has been on how to replace the internal combustion engine as a propulsion system in order to drastically reduce emissions of the greenhouse gas carbon dioxide. From 2035, the EU will only allow new cars to be registered that do not emit carbon dioxide when driven. Emissions such as particulate matter and microplastics generated from brake and tyre abrasion will then come into focus. In order to prevent them, we need new technologies and solutions, and we need to advocate for and develop them now," explains Project Lead Franz Philipps from the DLR Institute of Vehicle Concepts in Stuttgart. "That is the underlying motivation for the ZEDU-1 project." Philipps and his team have broken new scientific ground with their 'Zero-Emission Drive Unit – Generation 1' (ZEDU-1) and set themselves an ambitious challenge: to develop the most environmentally friendly car in the world.

From zero to prototype in two years

From early on, it was clear that the ZEDU-1 team and their industry partners wanted to install their newly developed technologies in a vehicle and demonstrate them in operation. They created a unique prototype with a distinctive design. "A car that you can sit in and drive makes a very different impression to its individual components," says Philipps. In addition to the increased attention from industry, policymakers and the public that such a prototype can generate, there was another factor behind the decision: "Working on an existing vehicle would have been difficult, as large manufacturers are reluctant to provide the kind of precise insights into vehicle design, central systems and the control mechanisms that we would need."

In parallel with the construction of ZEDU-1, the DLR team equipped this series-produced electric vehicle with instruments to measure particulate matter and microplastic emissions under real conditions.

"A car that you can sit in and drive makes a very different impression to its individual components."

Franz Philipps

Team leader at the DLR Institute of Vehicle Concepts

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ABOUT FRANZ PHILIPPS

Physicist Franz Philipps is the team leader of the Systems and Vehicle Validation division. He has worked at DLR in Stuttgart for 25 years, primarily at the Institute of Vehicle Concepts. He has overseen countless national and international projects as a project lead, contributed to over 70 scientific publications, and registered two patents and an invention disclosure. Early in his scientific career, he began looking at hydrogen as a source of energy and fuel cells as a propulsion technology. He is still deeply involved with such technology today in his research into future-oriented, environmentally responsible and climate-friendly mobility. His colleagues have dubbed him 'Master of the Roller' because he played a key role in planning, designing and building the air-conditioned all-wheel roller dynamometer. He knows this one-of-a-kind large-scale DLR facility like no other and looks after it to this day.

The team began with a specification sheet – an understatement of a term for the vital document holding all of the vehicle's requirements and planning details. The aim was to create a battery or fuel cell-powered car with no internal combustion and with a top speed of 150 kilometres per hour. Brake and tyre wear were to be either eliminated or reduced to the absolute minimum. The braking system was to be designed to recover energy from the braking process and reliably provide full braking power at all times. The entire vehicle, including its control systems, power electronics and all energy and heat flows was to be as efficient as possible. From the start, the team approached the design and assembly of each component in a way that would be

The battery, the power electronics and the DC converter for the power supply are installed in the rear of the vehicle.

A look under the bonnet reveals the supporting fans of the tyre particle extraction system

ZEDU-1 on the DLR roller dynamometer

relatively easy to scale up to series production. “No one had ever done this before. With ZEDU-1, we created a blueprint for future projects and set standards. That was both an incentive and a challenge for the whole team,” recalls Philipps. The car manufacturer HWA from Affalterbach in Swabia joined the project as the primary industry partner. With their origins in racing, high-quality, innovative braking systems and aerodynamics are part of the company’s day-to-day business.

In March 2020, the project received the green light and was granted approximately six million euros in funding from the Baden-Württemberg Ministry of Economic Affairs – just as the COVID-19 pandemic first swept through Europe. Supply chains broke down, components were not available for months and only employees who were completely indispensable were allowed to work on site with the vehicle. “For us, that meant being flexible, constantly improvising and working together digitally as effectively as possible. We would often send each other pictures showing the current status of the parts and the entire vehicle, rather than being able to see and touch the technology ourselves,” continues Philipps. In the summer of 2022, however, what had long seemed unlikely finally became a reality as the ZEDU-1 prototype was rolled out for extensive testing. It was unveiled to the public in September – a well-deserved reward for the team’s remarkable efforts.

Braking system eliminates particulate matter

The crucial new feature of the ZEDU-1 is its braking system. The researchers developed a special multi-disc brake that is integrated into the closed unit of the electric motor and gearbox rather than installed in the wheel. This reduces the size of the brake components to a minimum and enables the drive unit to be constructed in a very compact way. In conjunction with specially developed high-performance electronics, it is now possible to almost completely recover the energy used by the brakes. This recuperation is not limited to ten percent of the braking force thanks to features such as the Electronic Stability Programme (ESP) and the Anti-lock Braking System (ABS). The result is that ZEDU-1 is a highly efficient vehicle in which 75 percent of the braking energy is recuperated on the front axle and 100 percent on the rear axle even under maximum braking energy.

The brake discs consist of seven ring plates. Every second one of them is geared to the shaft of the electric motor, with the others geared to the housing. When braking, the ring plates are pressed together by an actuator and filled with oil. In doing so, the material produced by abrasion also ends up in the oil, which is continuously pumped through a filter and cleaned. The brake is activated electrically, rather than mechanically. In technical jargon, this is known as ‘brake by wire’, as an electronic signal is sent to the brake to activate it. The team also developed a hybrid induction brake for the ZEDU-1 prototype. The brake can bring the vehicle almost to a standstill entirely wear-free using magnetic forces. Generating the braking effect all the way to a standstill requires the installation of an additional friction element, which is designed to mechanically supplement the magnetic braking force automatically as it decreases. “For us, this meant redesigning not only the vehicle control system but also the entire operation of the brake and programming the corresponding software,” explains DLR researcher Franz Philipps. The induction brake has not yet been integrated into the prototype. The researchers hope to achieve this further in the next step of the project.

Redesigned wheel housing siphons off microplastics

Relocating the brakes from the wheel housing to the inside of the vehicle creates space for new technological approaches to reducing tyre abrasion. The basis for this is the enclosure of the wheels: the closed wheel housing of the ZEDU-1 is aerodynamically designed to create negative pressure during driving. As a result, tyre abrasion accumulates at a specific point. A fan unit at the front of the vehicle extracts the particles here and passes them through a filter system in a similar way to a vacuum cleaner. Only filtered air is allowed to exit the vehicle. This technology presented the team with a number of additional challenges. For instance, the housing had to allow for certain steering angles to ensure that the tyres did not touch the panelling when cornering. Regardless of the speed, the new solutions had to work steadily and reliably. The wheel housing also improves the aerodynamics and thus the efficiency of the vehicle.

Put to the test on the dynamometer

In parallel to the development of the ZEDU-1, the project team developed a concept to measure its particulate matter and microplastic emissions under real driving conditions. This required equipping the vehicle with special devices and sensors. “Until now, it has only been possible to measure brake and tyre wear to a limited extent, and it has tended to be restricted to individual components in a laboratory environment. We had to come up with some new techniques to conduct measurements on a moving car,” says Philipps.

The DLR researchers first generated a baseline dataset for a standard electric vehicle and determined the emissions from the brakes and tyres separately to provide a reference. To do this, they used one of the institute’s standard electric vehicles, equipped it with measuring instruments and carried out initial tests on the on-site roller dynamometer and on the road. “Test routes and normal roads already have a lot of dust on them. You can’t tell exactly what was produced by the

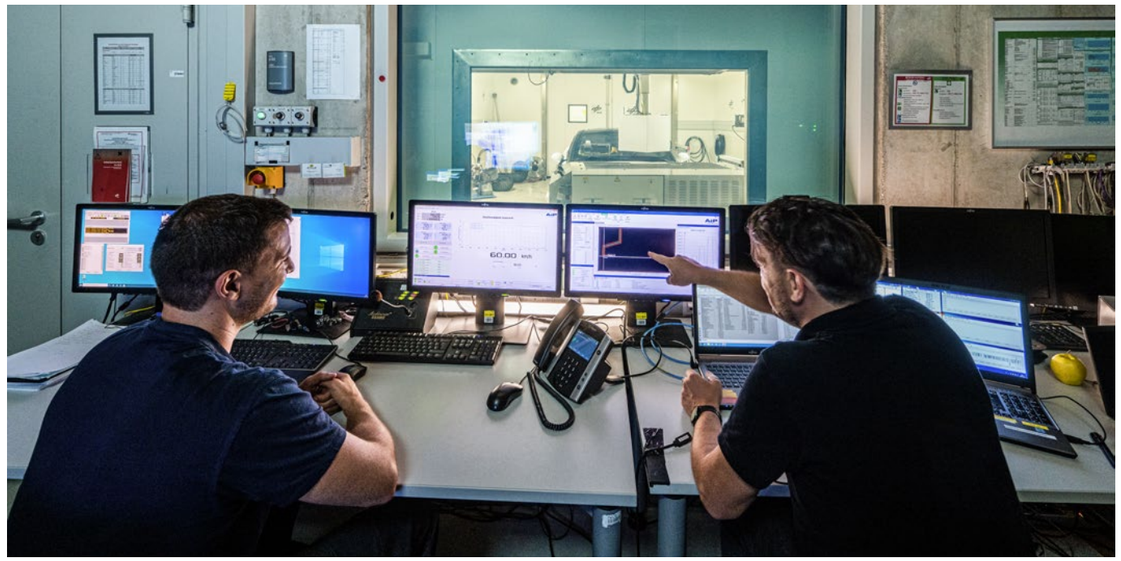
ALL-WHEEL ROLLER DYNAMOMETER WITH CLIMATE CHAMBER

The ‘roller’ is one of the DLR’s unique large-scale research facilities and is located at the Institute of Vehicle Concepts in Stuttgart. Future vehicle drives are developed and tested here using the latest equipment and techniques. For this purpose, test vehicles are permanently mounted on the roller test bench and, for example, road travel is simulated. When driving, the wheels turn on rollers in the floor of the facility. This replicates specific driving cycles and route profiles under controlled conditions and allows energy consumption and emissions to be measured. The dynamometer is housed in a climate chamber which can maintain temperatures from negative 40 to positive 60 degrees Celsius and humidity between zero and 80 percent. The maximum speed at which vehicles can be tested is 200 kilometres per hour. The facility can be air-conditioned and is also suitable for testing hydrogen vehicles. It is used both for research projects and for tests by industrial companies.

Fabius Epple and Sven Reiland from the DLR Institute of Vehicle Concepts, both members of the ZEDU team, mount the fairing on the measuring wheel

Sven Reiland at ZEDU testing on the roller dynamometer

© DLR



Fabius Epple from the DLR Institute of Vehicle Concepts and Tobias Grein from the DLR Institute of Combustion Technology in the control room of the roller dynamometer. From there, they observe the driving cycle of a test drive.

test vehicle and what was already there. That's why tests under controlled conditions on the roller dynamometer are so important," says Philipps.

The researchers then began to explore other questions, including the behaviour of the air flowing around the car – around the tyres and brakes in particular – the strength of these air currents, the distribution of the abrasion particles and how temperature affects the measurements. They moved systematically, evaluating the collected data after each round of tests and honing the measurement concepts and technology. The ZEDU-1 team received support from the DLR Institute of Combustion Technology, also based in Stuttgart, which is equipped with state-of-the-art measuring devices and sensors and staff with plenty of experience measuring particle concentrations, emissions and ambient air. With this equipment and expertise, the institute can detect and gauge particulate matter down to an ultrafine level. Together, the researchers determined the total particulate matter emissions and the size distribution of the particles.

An important aspect of this measurement work was that it built upon the worldwide harmonised light vehicle test cycles (WLTC), an internationally standardised process for measuring vehicle emissions. The DLR team also defined its own standard-compliant real drive emission (RDE) test cycle using city, interurban and motorway route sections in the Stuttgart region. They also carried out special braking manoeuvres at different speeds and temperatures and recorded the resulting emissions.

Boxberg test route – a debut excursion on tarmac

For the team, the big moment finally arrived at the beginning of August 2022 when they were able to watch their creation put through its paces for a week at the Boxberg test centre. The centre is usually a facility used by car manufactures for vehicle testing, driver safety training courses or thrill-seeking amateur racers. This was where ZEDU-1 completed its first tests away from home. Although all of the team members were itching to be in the driving seat, only two were lucky enough to get behind the wheel. This is because drivers required a special training to use the test site in north-eastern Baden-Württemberg and an extra briefing specific to ZEDU-1, as the DLR prototype differs significantly from the standard vehicle. This covered topics such as how the steering reacts to certain manoeuvres, the meanings of the various warning lights and how the vehicle behaves at higher speeds. It was an exciting, adrenaline-fuelled experience.

"Our main focus was on making the best possible use of the opportunity to carry out extensive measurements and come away with a treasure trove of data for evaluation, but of course, that didn't stop us enjoying the driving itself."

Franz Philipps

From left to right: Hybrid test vehicle of the DLR Institute of Vehicle Concepts, ZEDU-1 prototype, mobile laboratory for measuring air pollutants of the DLR Institute of Combustion Technology.

© DLR

"Our main focus was on making the best possible use of the opportunity to carry out extensive measurements and come away with a treasure trove of data for evaluation," recalls Philipps. "But of course, that didn't stop us enjoying the driving itself." As on the roller dynamometer, ZEDU-1 tackled different driving profiles and cycles, and repeatedly carried out specific braking manoeuvres. Unlike in the laboratory, however, the vehicle could now test its cornering. Researchers from the DLR Institute of Combustion Technology also attended the event. With their mobile measuring vehicle on site, they were able to evaluate the initial data from the test drives in real time.

No brake wear and significantly less tyre wear

Having evaluated the data, the ZEDU-1 team is convinced of their findings. "Our figures show that our approach can avoid brake wear altogether. As predicted by our simulations, the tyres expelled virtually no abrasion emissions into the environment up to a speed of 60 kilometres per hour. Even at higher speeds of up to 120 kilometres per hour, we were able to reduce them by 80 to 90 percent," summarises project manager Franz Philipps.

The team also generated a large amount of data during the measurement campaigns and developed new measurement concepts. Both have the potential to drive major advances in research and industry-related development toward climate-friendly mobility, whether in terms of tyre compounds, new brake systems or filter concepts. The media coverage of ZEDU-1 reached far beyond Germany and

The ZEDU-1 also stood out at the Hockenheimring during the ADAC GT Masters season finale from 21 to 23 October 2022 and drew many onlookers

demonstrates that the project has struck a chord. Companies in the supply industry and brake and tyre manufacturers have also expressed an interest. The introduction of the Euro 7 standard for passenger cars and light commercial vehicles planned for 2025 will address the entire size spectrum of ultrafine dust and define threshold values for emissions from brakes and tyres. The issue of particulate matter and microplastic emissions isn't likely to disappear from the political agenda any time soon.

Denise Nüssle is a press officer at DLR.

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Jörg Brauchle (left) and Matthias Geßner with the Vector drone after a successful deployment

AN EXTRAORDINARY MISSION

DLR supports rescue efforts in Turkey with novel real-time situational awareness imagery

Interview with Matthias Geßner

The recent earthquakes in the border region between Turkey and Syria were among the worst natural disasters of the last century. Aerial images can help rescue workers get their bearings and assess the extent of local damage. Since 2016, DLR has been cooperating with the aid organisation International Search and Rescue (I.S.A.R.) Germany. Matthias Geßner and his colleague Jörg Brauchle, both from the DLR Institute of Optical Sensor Systems in Berlin, were on site in Turkey as part of this cooperation. Their most important piece of luggage: the MACS-Nano aerial camera system.

Matthias, in early February you both stood on a mountain in the city of Kırıkhan. Tell us about your experience.

That was a very emotional moment. The city that lay below us had been completely destroyed. People were living on the streets and we could see an incredible amount of suffering. We had been on site for three days and had already carried out some mapping flights with our Modular Aerial Camera System (MACS). However, after the first flight with the drone, it was clear that our system would not be enough to map the entire city in time. We usually use a larger drone system for precisely such purposes – but it was at the manufacturer Quantum Systems in Gilching for modifications at the time of the quakes. So, our DLR colleagues in Berlin and the manufacturer's team did everything they could to get the drone ready for use literally overnight. The support of the German Federal Agency for Technical Relief (THW) was also essential in order to secure a cargo slot on the first scheduled relief transport from Germany. With this support, a ready-to-use flight system was set up and equipped within a few hours – just in time for the early morning take-off of the transport aircraft flying to Turkey. It was a real team effort. After a 12-hour drive to the arrival airport – which was different from the one initially planned – we finally had the drone in our hands. We were able to fly our system for the first time the next day – from atop the mountain in Kırıkhan. The effort paid off: within an hour, we had mapped 3.5 square kilometres of the city with our camera – three times as much as we had managed in the previous flights. But that was not all: telecommunications were mostly idle, but thankfully, at that moment, we had a stable Internet connection. So, we were able to transmit our map data directly to the United Nations' (UN) operations command system.

You were part of the I.S.A.R. Germany team for this mission. In addition to flying the drones, what other tasks did you carry out?

The members of I.S.A.R. specialise in different areas of operation: management, search, rescue and medical care. We went through various training sessions beforehand, which gave us additional skills to assist as part of the rescue team. On the day we arrived, when it was already too dark to fly the drone, we were able to accompany a team and help where needed.

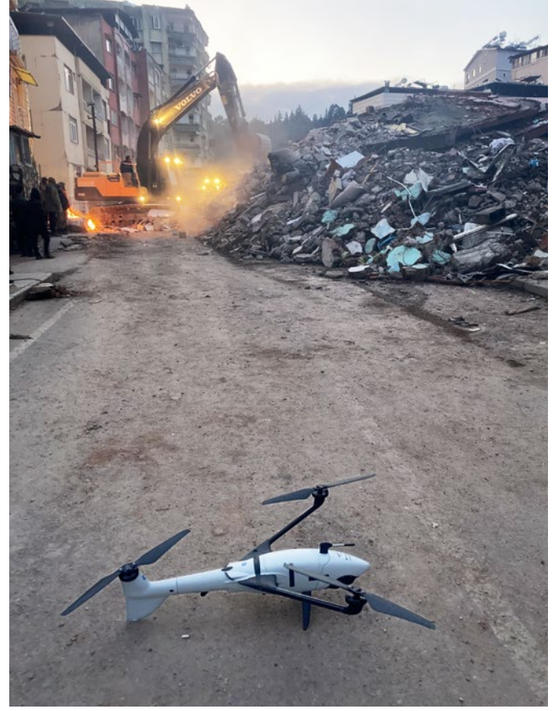
So, you found yourselves amid the rubble immediately upon arrival. That cannot have been easy.

Indeed. There were situations for which I was prepared during exercises, but which took on a completely different dimension when I was confronted with them in real life. Rescuing people from the rubble is sometimes extremely difficult and can take a very long time. Relief workers have to make very quick decisions about whether or not a rescue is possible. There were cases where people were rescued from the rubble but then died shortly after. Sometimes the relatives were standing right next to them. But we also experienced successful moments in which people were rescued alive. Seeing the professionalism and commitment of the I.S.A.R. team working in this disaster situation made a lasting impression on me.

> *"There were situations for which I was prepared during exercises, but which took on a completely different dimension when I was confronted with them in real life."*
>
> **Matthias Geßner**
> **DLR Institute of Optical Sensor Systems, Berlin**

How can aerial photography assist rescue operations?

Aerial images made available as soon as possible are enormously helpful for the effective coordination of emergency responders on site. With them, teams can get their bearings: Where is the extent of the destruction greatest? Which roads are passable? What is the fastest way for teams to get to the scene? The MACS camera has extremely high resolution. We generated a photo-realistic aerial map using its images in real time, which could then be transmitted directly to the mobile devices of the I.S.A.R. team or the THW. Our department is in close contact with the International Search and Rescue Advisory Group (INSARAG) of the UN. As a result, we can also transmit our situational awareness images in real time to their operations command system, the INSARAG Coordination and Management System (ICMS). In doing so, we are providing all relief organisations involved with access to the same maps.



First, the team mapped the city of Kırıkhan with a smaller drone system.

What did you take away from the mission?

Such a mission can only be accomplished as a team. Jörg and I used the drones to take the photos on site. We were assisted by our colleagues in Berlin around the clock to ensure that together we achieved the best possible result. In four days, we took more than 15,000 aerial photos, which allowed us to identify details on the scale of two centimetres. With this mission, we were also able to demonstrate what this new technology is capable of. One of our next goals is to establish a system developed by DLR consisting of the MACS camera and the drone as a permanent element of mission support at I.S.A.R. Germany. From my point of view, this could substantially improve disaster response.

This interview was conducted by **Antje Gersberg** and **Julia Heil**, both part of the DLR Corporate Communications team.

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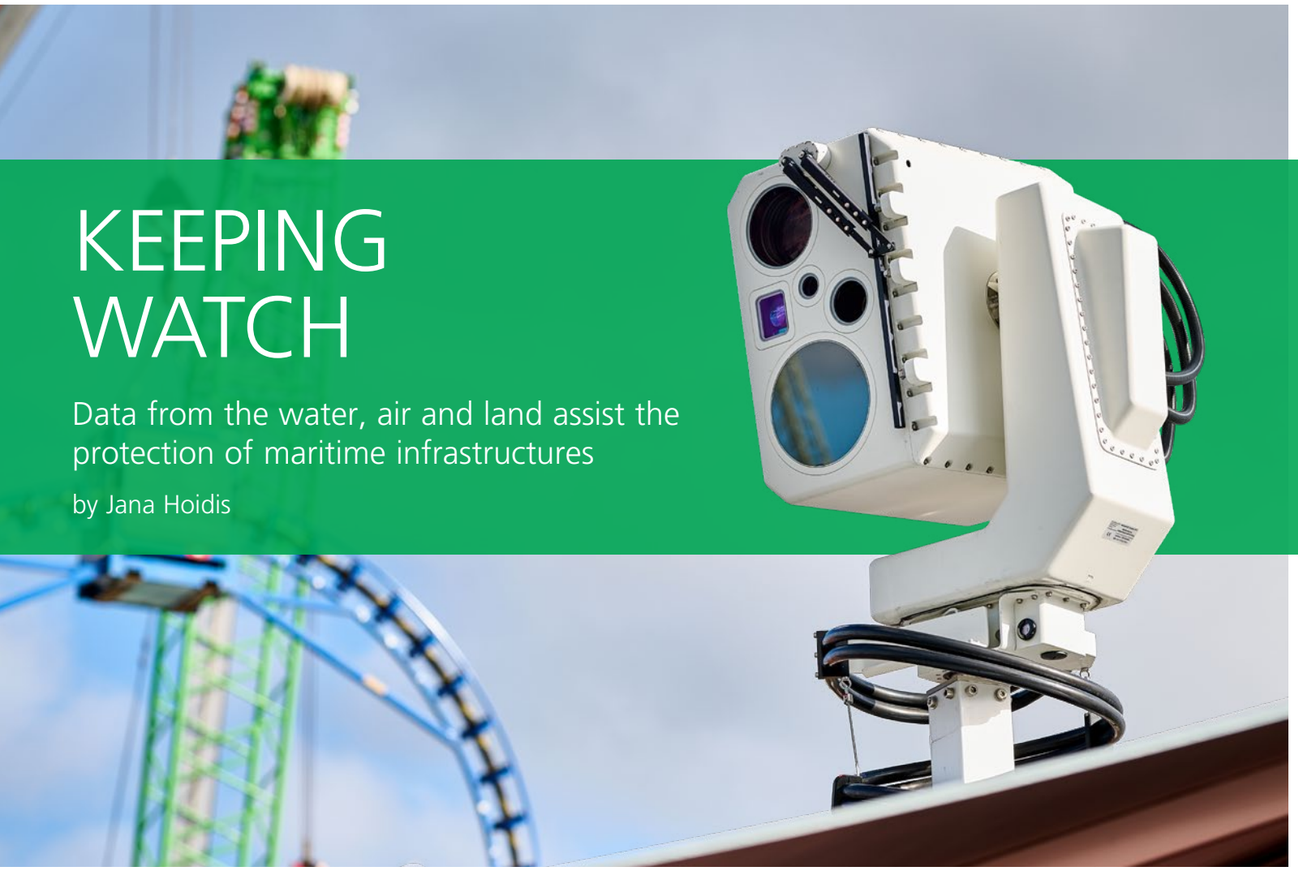
Mapping the local disaster area in real time. On the right, the image flight plan of the Vector drone.



KEEPING WATCH

Data from the water, air and land assist the protection of maritime infrastructures

by Jana Hoidis

The sabotage of the Baltic Sea pipelines and Europe's dependence on global energy supply chains highlight the importance of protecting maritime infrastructures. Information acquired using sensors from the water, in the air and on land helps to provide an overview of hazardous situations. In Bremerhaven, researchers at the DLR Institute for the Protection of Maritime Infrastructures develop situational pictures based on these sensor data to protect ports and offshore wind farms from accidents and attacks or to inspect sunken objects.

In the Maritime Awareness Realtime Instrumentation Network (MARLIN) project, DLR is developing a situational awareness system that displays security-relevant data in real time. It is intended to help authorities and port operators keep an eye on the situation at all times and to be able to intervene proactively in the event of an incident. The situational awareness system includes information acquired from the water, in the air and on land. Various cameras are installed at the port, or on drones, and autonomous submersibles record the situation underwater using sonar. Together, the individual systems provide a comprehensive overview of the situation. The researchers have already tested the system in two use cases. In the process, they were also able to demonstrate the effectiveness of the interaction between the individual sensors.

Man overboard

The first test took place in Bremerhaven's Fishery Harbor in 2019. Smoke flares simulated a fire on an inflatable boat while several crates were thrown overboard – some floated on the water while others sank to the bottom. One crew member, in this case a sea rescue training mannequin, also fell into the water. Fixed cameras installed in the harbour area as well as mobile cameras on emergency vehicles and drones – all part of the MARLIN system – observed the situation and provided an overview of the danger zone as well as the surrounding area. Thermal imaging cameras can be used to detect people even in poor visibility, as long as their body temperature has not yet dropped too much. Cameras with active laser illumination, known as range-gated systems, are able to measure the distance to objects through the fog, making it possible to easily locate the training mannequin and the flotsam.

Smoke flares simulate a fire on the inflatable boat. The sea rescue training mannequin takes on the role of a stranded person.

MARLIN combined this incoming information and displayed it in real time in a situational awareness system. Rescue and security teams can use this to obtain valuable information and optimise their operations. The DLR SeaCat, an autonomous underwater vehicle, was then used to survey the harbour basin to identify lost cargo and detect damages in the harbour basin. Detailed images of conspicuous areas were acquired using a smaller, remote-controlled diving robot.

Interfering with a docking ship

IIn October 2022, MARLIN was put to the test a second time – this time in Nordenham harbour. The researchers were divided into two teams. The first team had the task of preventing the cargo of a fictitious dangerous goods transport from being brought ashore in the port. To do this, they first scouted the situation with a drone. This was registered by the system and repelled by the second team, which took on the role of security forces. The intruders then approached simultaneously in a boat and from land. The team approaching from land lit a smoke grenade as a distraction while the other team attempted to enter the harbour unnoticed in an inflatable boat. MARLIN pooled the information gathered by the various sensors in the harbour and analysed the situation. It then alerted the security team. The emergency forces successfully repelled this attempted intrusion, turned away the inflatable boat, averting all danger. "The demonstration was very successful. Our team had to combine many different technologies into a common situational awareness system in a very short time," says Maurice Stephan, head of the Department of Maritime Security Technologies at the DLR Institute for the Protection of Maritime Infrastructures.

A modular toolbox

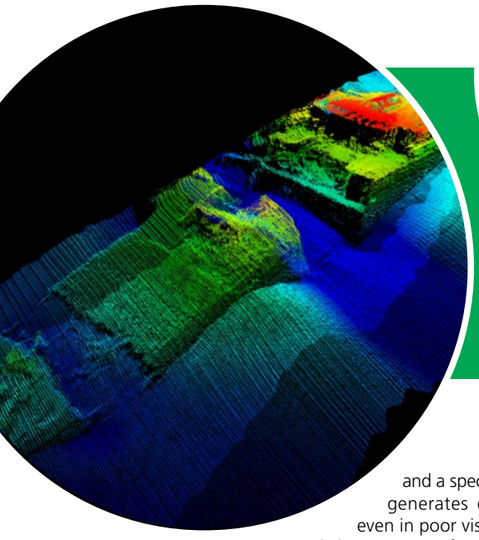
MARLIN uses technologies specially developed by DLR. These include the range-gated camera system developed by the DLR Institute for the Protection of Maritime Infrastructures, which combines a very short laser pulse

The data from the various sensors of the MARLIN system converge in the situation awareness room. If hazards are detected, the system informs the emergency services.

A bird's eye view provides an excellent overview

A team of DLR researchers mimics the seaward entry into Nordenham harbour using an inflatable boat

The DLR underwater vehicle SeaCat dives to scan Bremerhaven's Fishery Harbor for sunken cargo



The SeaCat and an autonomous diving robot (right) were used to create detailed images of sunken warships. On the left is a 3D scan of the barrage breaker Friesland, which sank off the coast of Heligoland in 1944. Next to it is an image of sunken sea mines. The rusting wrecks and munitions leak toxins that pollute marine animals and plants. The toxic munitions should therefore be salvaged.

and a specialised camera. It generates detailed images even in poor visibility, such as in darkness, snow or fog. Another in-house development is the Modular Aerial Camera System (MACS) from the DLR Institute of Optical Sensor Systems, which can be used to quickly create digital maps of small-scale areas. MARLIN combines its own developments with commercial systems such as the Automatic Identification System (AIS) used in maritime navigation, 3D laser scanners and various sonar technologies. This enables it to provide comprehensive positional information. For data analysis, the system uses machine learning methods from the field of artificial intelligence. This makes it possible to automatically detect and classify relevant objects as well as conspicuous events in the scenes being monitored. "MARLIN is intended to form a basis for a variety of different situational awareness systems. From this modular system, different user groups can then select the hardware, such as cameras, underwater sensors or software modules, best suited for their specific purposes," explains Maurice Stephan.

Visibility to the depths

DLR also used the SeaCat and the diving robot to support the North Sea Wrecks project led by the German Maritime Museum. During the project, DLR sensor technology was used to provide detailed images, scans and videos of sunken ships. The deployment on the high seas helped the DLR researchers to improve the calibration of the instruments on the underwater vehicle for specialised situational awareness systems. Hundreds of ship and aircraft wrecks lie at the bottom of the North Sea, not least as a result of the two world wars. They are accompanied by thousands of tons of conventional and chemical munitions. The wrecks, their cargo, fuel tanks and ammunition are all obstacles to navigation and sources of toxins, not to mention often still explosive. They thus pose a threat to people and the environment. In 2021 and 2022, the Heincke, a research vessel of the Alfred Wegener Institute for Polar and Marine Research (AWI), travelled to the sea around Heligoland. DLR was on board and created underwater images of the World War I cruisers SMS Mainz, SMS Ariadne and SMS Hela, as well as the World War II barrage breaker Friesland. "Operating on the high seas has allowed us to further develop our sensor technology and our diving robot. High-resolution image data provide us with an even more precise overview of the situation underwater," reports David Heuskin, head of the Technology Testing Systems Group at the DLR Institute for the Protection of Maritime Infrastructures. "This experience will help us to use our underwater sensor technology for wider-area situational awareness at sea in the future."

Protecting wind farms

Crucial infrastructures for which improved situational awareness could prove critical include offshore wind farms. As their importance to a reliable energy supply continues to grow, so does the potential impact on society from related security threats. Possible hazards include severe weather or drifting ships, but also human threats such as sabotage or attack. In the Applied Research on Resilience-driven Offshore Wind Farm Safety and Security (ARROWS) project, DLR is exploring possible hazard scenarios for these wind farms. The researchers are developing recommendations for action for wind farm operators, energy suppliers and security forces in the event of such a scenario. An interesting factor here is that both the Coast Guard authorities and the potential attackers can only move much more slowly on the water than on the road or in the air. "As the distance of the wind farm from the coast increases, so does the response time of intervention forces like the Federal Maritime Police," says Frank Sill Torres, acting director of the DLR Institute for the Protection of Maritime Infrastructures. "In the event of a hazardous situation, it is important to take targeted countermeasures and inform energy providers at an early stage so that supply remains secure."

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The DLR team discusses the sequence of events in a mock scenario in which the MARLIN system is tested

© DLR

Observational instruments are installed on a van so that they can be deployed quickly and flexibly at the site of operation

Identifying potential hazards, but how?

Situational awareness requires the assessment of a large number of parameters. These include information from camera, radar and sonar systems as well as AIS, weather and marine data. One possible hazard scenario could be an attack on a submarine cable that carries electricity from the wind farm to shore. Information on the location of buried power cables and where they are vulnerable to attacks can be obtained from freely accessible maps. Cables buried less deeply can be manipulated more easily. Thus, a ship approaching such a spot or following the route of a cable represents conspicuous behaviour. The ship's AIS signal sends information such as the voyage route, the type of ship and the national flag of the country under which the ship is sailing. This data can be used to check whether the ship has already attracted similar attention in the past. However, it is possible that the AIS data transmission has failed due to technical problems or that the ship's conspicuous route is due to defective steering. In this case, contacting the vessel directly can provide clarity. "A hazardous scenario cannot always be clearly distinguished from a harmless one. It often comes down to nuance," adds Frank Sill Torres.

From the situation overview to the recommendation for action

In the future, recommendations for action will be incorporated into situational awareness systems as part of efforts to make them 'smarter'. Critical objects and situations could be displayed graphically on a nautical chart or on a digital plan of a wind farm. A future system will map a comprehensive model of the wind farm and provide reliable and timely support to the security forces and operators making decisions in hazardous situations. "We are pleased to contribute to the security of supply of renewable energies," says engineer Sill Torres, referring to the work in the ARROWS project. "A constant exchange with wind farm operators, security authorities and energy suppliers is very important to us and enables us to support them in the best possible way using solutions developed by DLR."

Jana Hoidis is responsible for communications at the DLR sites in Northern Germany.

istockphoto/Riccardo_Mojana

"In the event of a hazardous situation, it is important to take targeted countermeasures and inform energy providers at an early stage so that supply remains secure."

Frank Sill Torres
Acting Director of the DLR Institute for the Protection of Maritime Infrastructures

FINDING FUNGI

Detecting fungal pathogens in vineyards

by Verena Müller

DLR/Kölbl

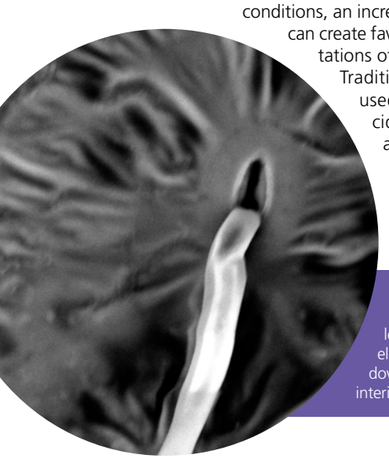
DLR/Geiß

"Our work is practical and makes an important contribution towards integrated crop management, best practice approaches and environmental protection. The proximity of DLR Lampoldshausen to the historical wine region of Württemberg means that regional vintners and cooperatives will be able to benefit more from the monitoring system in the future."

Christoph Kölbl
Project Lead vinoLAS

Fungal pathogens in viticulture are a major challenge for wine-growers. In addition to the laborious task of picking out the affected vines during the grape harvest, it can impact the quality of the wine and the grower's financial return. To address this, researchers at the DLR Institute of Technical Physics in Lampoldshausen have developed the vinoLAS detection system, a small box that can detect fungal infestation at an early stage.

The effects of climate change have increased significantly in recent years. In addition to the wider dangers posed by extreme weather conditions, an increase in heavy rain in summer can create favourable conditions for infestations of harmful fungi in vineyards. Traditionally, wine-growers have used large quantities of fungicides to combat these fungi and avoid major financial losses. One of their primary enemy is downy mildew. When this pest attacks the vine, it results in limp, brown clumps where there should be plump, green fruit. "If fungal pathogens are detected at an early stage, we can take countermeasures to limit the spread locally," explains vinoLAS Project Lead Christoph Kölbl. "This reduces the use of fungicides and the associated cost, protects the environment and ultimately increases the quality of the wine. Our new system is designed to detect and classify fungal infestations as early as possible, without having contact with the plant and over a large area of the vine's leaf surface."



Downy mildew loves moisture. Its spores are spread by the wind and rain. They can penetrate deep into the leaf tissue and spread out from there. This scanning electron microscope image shows a vine leaf affected by downy mildew. The fungal hyphae penetrate the leaf interior through the pores.

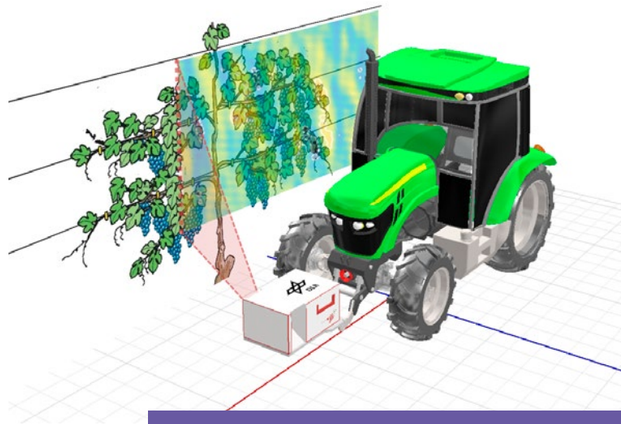
Detecting fungal pathogens with laser-induced fluorescence

The team of researchers uses fluorescence detection for this. A specially optimised laser system emits light with a wavelength in the ultraviolet and visible spectral ranges. When these beams hit the vines, the molecules of both the plants and the fungi are excited and emit so-called fluorescent light. This fluorescent light cannot be seen by the human eye. The vinoLAS system has two spectrometers specially designed to detect this fluorescent light, which the researchers then use to analyse the spectrum of the emitted light. Characteristic patterns in the spectrum indicate that the plant or part of the plant is infected by a fungus. The researchers first tested this system in the laboratory using potted vines of the Müller-Thurgau and Riesling varieties, which they infected with downy mildew. Using the emission spectra, they were able to identify the fungal infestation on the plants and monitor the changes in the plant structure over a period of several weeks. These tests demonstrated that the system is capable of detecting fungal infestation no later than eight days after the plant comes into contact with the pathogen. The researchers are currently working on shortening this period to enable even more reliable early detection. Thanks to its active laser illumination, vinoLAS can be used regardless of weather conditions and daylight, including after dusk.

Monitoring large areas of cultivation in vineyards

The vinoLAS team is currently testing the monitoring system at a dedicated test vineyard near Heilbronn. In doing so, they always keep the requirements of the vintners in mind. Although there is still work to be done, both the wine-growers and their industrial partners have already expressed an interest in the system, as there is nothing else like it on the market. "Our work is practical and makes an important contribution towards integrated crop management, best practice approaches and environmental protection. The proximity of DLR Lampoldshausen to the historical wine region of Württemberg means that regional vintners and cooperatives will be able to benefit more from the monitoring system in the future," says Kölbl.

The DLR team will start by installing their system on a narrow vineyard tractor, so that viticultural tasks and fungal infestation monitoring can be carried out in parallel. As it travels through the vineyard, the system systematically measures large areas of foliage without touching the plants. The latest data are transmitted to the wine-growers immediately, allowing them to localise any infestation right away. They can respond by cutting back the affected areas or treating them with fungicides as quickly as possible. "A later application involving drones is envisaged for use on steep slopes. But the ground-based system covers the greatest need," says Kölbl, who works at the Department of Atmospheric Propagation and Effect at the DLR Institute of Technical Physics. This is something of a passion project for Kölbl, who originally comes from the region of Allgäu, which is famous for its livestock farming, and is excited to work with the vineyards around Heilbronn. "I have always loved looking for alternative applications, which is how we progressed from our research on bacteria to the topic of fungal pathogens in vineyards. I believe it is important to consider transfer from research to application right from the start of a project."



The DLR-developed system is housed in a box slightly smaller than a Eurobox – approximately 30 by 40 centimetres. The box can be attached to the front mounting of a narrow vineyard tractor using a special mount.

DLR team work towards market launch

Looking ahead, the researchers plan to carry out further measurement campaigns in the vineyards under real conditions. The vinoLAS system will be tested on other grape varieties and use the results to improve their analysis models. The team is also in close contact with companies developing sensor systems in the agricultural sector, specialising in digital data modelling for agriculture, focusing on spraying applications or producing plant protection products, and wine-growers and cooperatives. The positive response they have received makes Kölbl and his team confident that vinoLAS could soon see active use in real vineyards.

Verena Müller works for Innovation and Transfer Marketing at DLR.

THE IMPACT OF SCIENCE

How the DLR Projektträger drives knowledge and technology transfer

by Stefanie Huland

istockphoto/Dilok Klaisataporn

Progress begins in the mind. But how does an idea become a scientific finding, and then go on to become a service or a product? The DLR Projektträger plays a major role in making this transition possible. Two examples demonstrate how this works.

Ralf Heyder
Network of University Medicine Coordination Office, Charité Berlin

"During consultations with the German government in March 2020, it soon became clear that we could only address the Covid-19 pandemic if we effectively pooled our research findings and clinical knowledge and quickly made them available for patient care. This meant connecting all 36 university hospitals in Germany as part of a single network. For us at the Coordination Office, the first challenge was to bring all stakeholders together. After that, we needed to provide cross-site data infrastructure that allowed patient data to be collected, stored and shared in a standardised way, in compliance with data protection regulations. During this phase, the DLR Projektträger supported us with its many years of experience, including supervising the Medical Informatics Initiative of the Federal Ministry of Education and Research (BMBF). The legal and administrative requirements for funding could not have been implemented so quickly without the advice of DLR Projektträger. The special challenge about the funding was that we had to get started with the implementation right away, without the usual preliminary planning phase. Today, long- and post-Covid patients also benefit from the shared database and the treatment concepts that have been developed. Should a similar situation arise in the future, we have the structure to deal with it."

THE NETWORK OF UNIVERSITY MEDICINE

The Network of University Medicine, which is funded by the BMBF, was founded in April 2020 as part of the crisis management efforts to combat the Covid-19 pandemic. Its purpose is to coordinate university-based research into Covid-19, jointly collect and evaluate data, and improve the level of preparedness for pandemics in Germany. It also seeks to collate and evaluate action plans and diagnostic and treatment strategies from as many German university hospitals as possible.

Steffen Raach
sowento GmbH

"The Eurostars CROWN project centred around optimising floating offshore wind turbines. We implemented it together with a German-Spanish research team. As part of the project, sowento GmbH researched how to make the platforms more stable. We developed the Real-time Observer software application for this purpose. It measures and models the stress on the anchor lines that attach the platforms to the seabed. This allows for better planning and implementation of maintenance work, so that floating offshore wind turbines can be operated more safely overall. We are currently working on bringing the Real-time Observer to market as hardware. The research funding made this possible. The funding for the project was handled by the DLR Projektträger. The project was partially funded, so we also had to contribute our own capital. For companies as young as ours – sowento was founded in 2016 at the University of Stuttgart and has been a limited company since 2018 – this is often the sticking point, as you have to demonstrate how you can make this contribution. This could have quickly become mired in red tape, but the DLR Projektträger demonstrated a lot of openness and trust. Both sides acted very transparently, which is what made the collaboration so successful and enjoyable."

EUROSTARS

Eurostars is a cross-border funding programme aimed at innovative small and medium-sized enterprises (SMEs). It provides funding to SMEs that research and develop innovative products, processes or services in bilateral and multilateral cooperation. Eurostars is part of the European Partnership on Innovative SMEs. The partnership is co-funded by the European Union through Horizon Europe. The BMBF supports the German partners of the selected projects.

GREATER FREEDOM – MORE TRANSFER

Interview with Martin Wegner, Head of the Society, Innovation and Technology Division at the DLR Projektträger.

© DLR

When discussing research, people often talk about the transfer of findings. What does 'transfer' actually mean in this context?

We usually make a distinction between conventional technology transfer and knowledge transfer. Technology transfer is seen as a process for identifying promising ideas and scientific findings, developing them and feeding them into commercial or industrial applications. This can lead to new products and services. Knowledge transfer provides vital impetus for harnessing research findings to the benefit of society and initiating new developments, decision-making and knowledge growth in civil society, politics and business. Ultimately, both technology transfer and knowledge transfer have the common goal of generating economic and societal benefits.

Why is simply conducting the research not enough?

Society is currently facing a number of profound challenges in terms of geopolitics, security, climate change and environmental protection, so there is a constant need for new technological and social developments. This can only be achieved if we get better at harnessing potential, open up spaces for research and innovation and foster a bold approach to new ideas, findings and concepts. This requires optimal interaction between all stakeholders from the fields of science, business, policy and civil society. The development of the mRNA vaccine against the Covid-19 virus is an example of just how effective it can be when the players involved in research and development combine their forces and focus on a specific goal. The vaccine could only come to market so quickly and assist in the fight against the pandemic because its development had already been funded for many years. Incidentally, the DLR Projektträger played a key role in this and in the subsequent rapid transfer of scientific knowledge to develop a Covid-19 vaccine.

Looking at the entire innovation system, how can transfer be improved? What does the DLR Projektträger think needs to change?

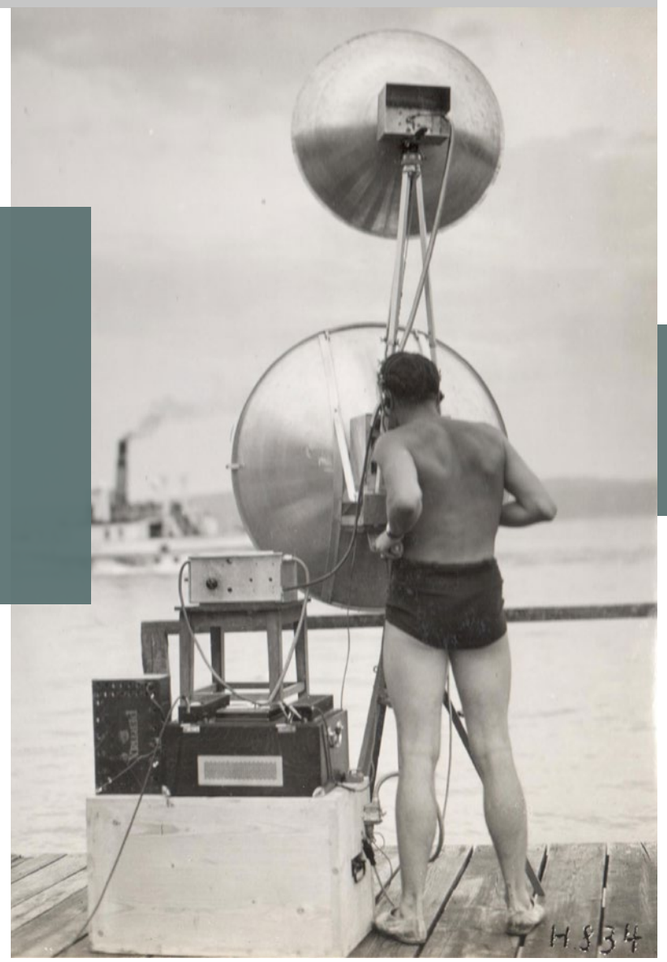
One crucial step will be to manage the many interlocking public programmes and initiatives that strengthen the research and innovation system. The DLR Projektträger will play a central role in this. We need to take more risks while ensuring that taxpayers' money is used responsibly. This requires funding programmes that are planned and implemented in a targeted manner, and where progress is transparent in terms of implementation and the effects achieved. We also need new and more flexible funding formats that are capable of challenging existing systems, processes and technologies. This means seizing the opportunities presented by digitalisation and simplifying and accelerating funding. In specific terms, the principle of annuity in the Federal Budget Code should be abolished and credit checks on smaller innovative companies and start-ups should be simplified to allow for greater freedom and more flexibility for increased research transfer and impact.

More on the area of Society, Innovation and Technology at:
s.dlr.de/PT-D-SIT

Stefanie Huland works in the Corporate Communications Department at the DLR Projektträger

FROM THE ARCHIVE

DLR's Central Archive is home to over 50,000 documents, with some real treasures buried among them. This series of articles searches for clues amid the wealth of images, documents, records and articles to root out such gems. In this issue, we delve into the history of the Gräfelfing Wireless Telegraphic and Air Electricity Test Station (DVG) – one of DLR's predecessor organisations.



Testing of a radar device developed by the DVG on Lake Ammer in 1937

COME IN, GRÄFELFING

How radio and television technology from Bavaria made history

by Jessika Wichner

Ever heard of Gräfelfing? A train from Munich to Lake Starnberg will take you through the unassuming town, where making a stop is definitely worth your while. The rural idyll may appear much like any other, but everything changed here in 1908 when radiofrequency technician Max Dieckmann (1882–1960) set up the Gräfelfing Wireless Telegraphic and Air Electricity Test Station (Drahtlostelegraphische und Luftelektrische Versuchsstation Gräfelfing; DVG).

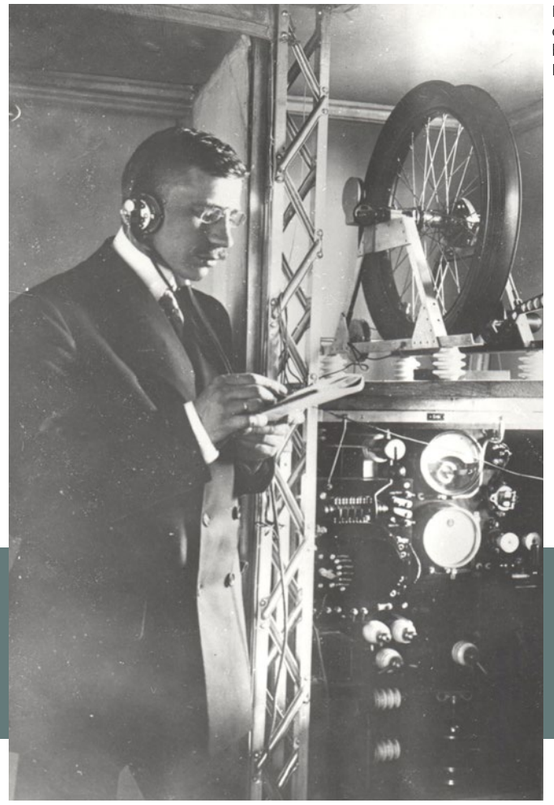
Dieckmann, who in 1907 took up an assistant position in the department run by experimental physicist Hermann Ebert (1861–1913) at the Technical University of Munich, was involved in investigations into atmospheric electricity. A year later, he rented a meadowed area with a wooden hut in Gräfelfing for his students to use to carry out practical experiments. He called this newly acquired field the DVG. Soon, the first transmission masts sprouted, experiments began and the students were joined by the first official DVG staff.

Early tests on airships

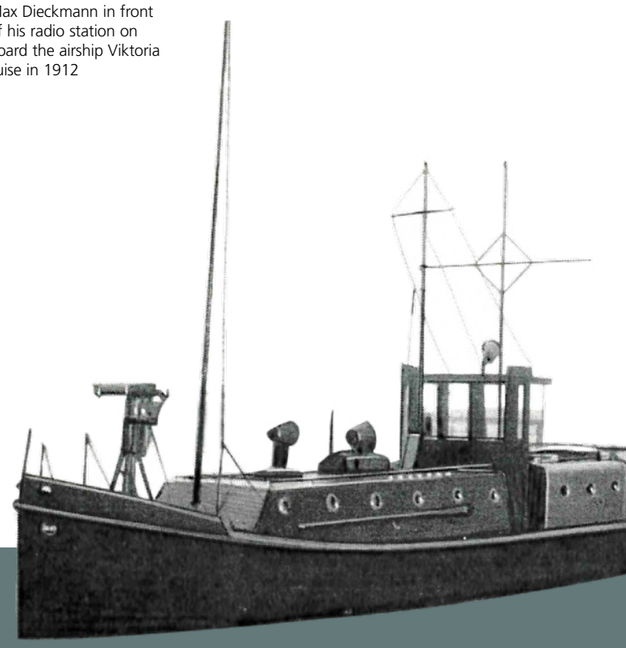
In 1909, Count Ferdinand von Zeppelin (1838–1917) became aware of the DVG and asked Dieckmann to investigate whether radiotelegraphic transmitters could be used on airships. Initial experiments in Gräfelfing proved promising, so Dieckmann took the transmitters with him to Lake Constance – the home of the Count – to test them on board his airships. These tests were successful, and the Count gradually began to equip his airships with radiotelegraphic transmitters. In May 1912, for the first time in history, passengers on LZ 11 Viktoria Luise not only had the thrill of travelling on an airship, but were also able to send private telegrams to people on the ground during the flight. Whether the novelty of air travel or the possibility of communicating with acquaintances and relatives while en route was the greater attraction is hard to say. What is certain is that radio technology revolutionised aviation. It was now possible for airships and aeroplanes to communicate with each other and receive information from the ground. Now, nothing stood in the way of orderly air traffic control.

The development of the first aircraft autopilot functions at the DVG marked another major contribution to the modernisation of aviation. This development began on Lake Ammer. Before venturing into automatic flight control, Dieckmann had already developed a remote control system for motorboats. He intended the system to demonstrate the possibility of automating steering manoeuvres. In 1929, the DVG team demonstrated such a remote-controlled motorboat to the Hungarian Navy on Lake Balaton. Using a remote control and command transmission system, the team started the motorboat's engine, carried out various control manoeuvres, and even activated a machine gun to fire single shots and burst rounds. From then, it was only a matter of time before aeroplanes were equipped with autopilot functions.

Images: DLR Archive



Max Dieckmann in front of his radio station on board the airship Viktoria Luise in 1912



The motorboat remotely controlled by the DVG on Lake Balaton in 1929

The Gräfelfing Wireless Telegraphic and Air Electricity Test Station (DVG) was founded in 1905. Back then, Max Dieckmann was working as an assistant to the physicist Ferdinand Braun (1850–1918), who taught in Strasbourg. In 1897, Braun had developed a cathode ray tube, which later also became known as the Braun tube. Dieckmann used this tube in 1906 to reproduce silhouettes in a format of three by three centimetres. He pursued this idea further in 1925, when he used a Braun tube to construct a device that can be found in almost every household today: the television. This was exhibited that same year at the German Transport Exhibition in Munich.

Radio research continued to grow in importance throughout the 1930s. The Oberpfaffenhofen Aeronautical Radio Research Institute (Flugfunk-Forschungsinstitut Oberpfaffenhofen; FFO) was founded in 1937, and Dieckmann was entrusted with its management. The DVG existed parallel to the FFO during this period. In 1942, the government of the German Reich bought the DVG from Dieckmann and incorporated it as a branch of the FFO. After the end of World War II, the FFO was initially closed, but was able to resume its work in 1954. After a short interim phase in Munich-Riem, it was transferred back to Oberpfaffenhofen in 1956.

Now, how about that trip to Gräfelfing?

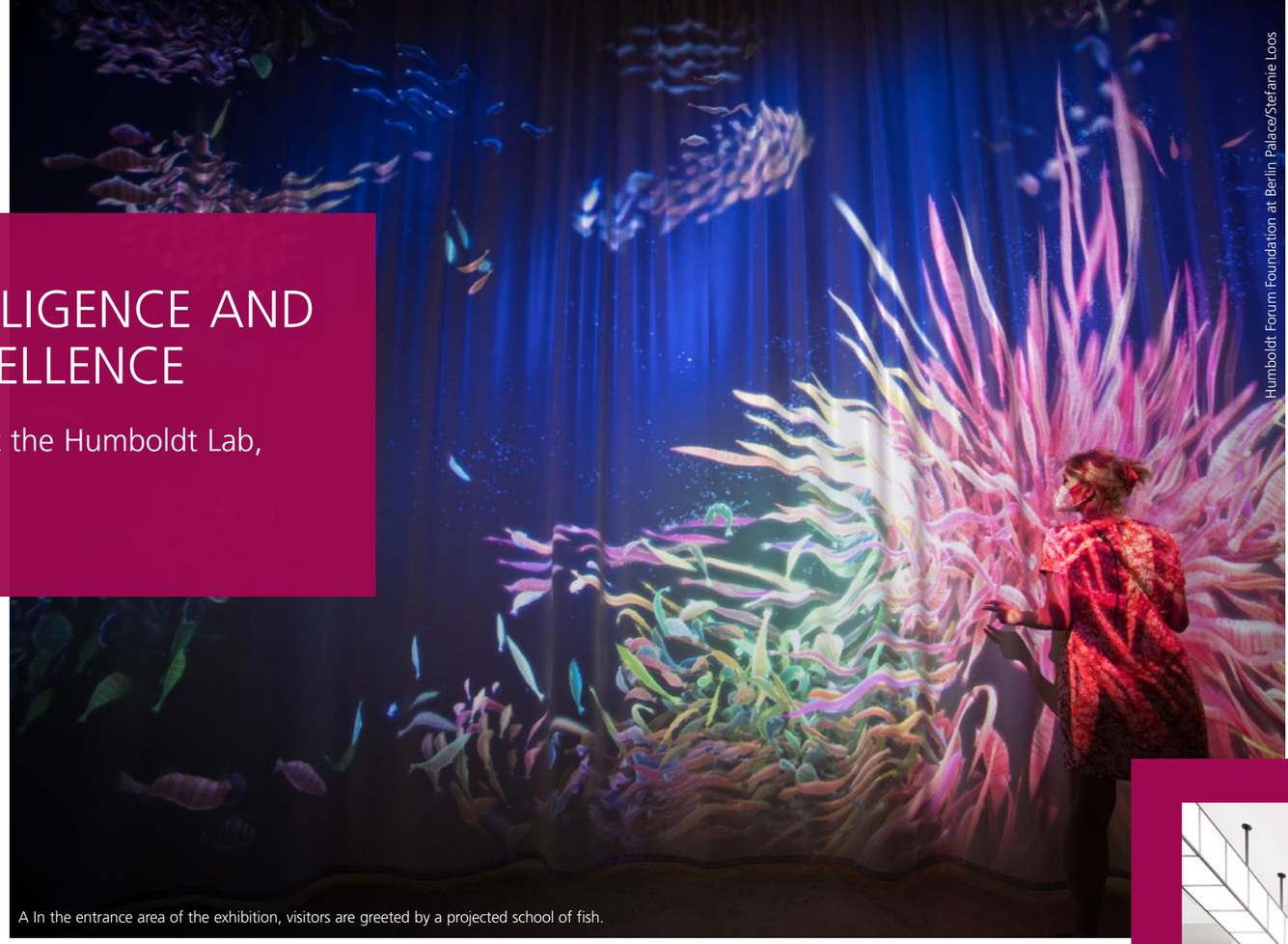
Jessika Wichner is responsible for the DLR Central Archive in Göttingen.

The DVG in the 1910s

COLLECTIVE INTELLIGENCE AND CLUSTERS OF EXCELLENCE

The ‘After Nature’ exhibition at the Humboldt Lab, Berlin

by Michael Müller



Humboldt Forum Foundation at Berlin Palace/Stefanie Loos

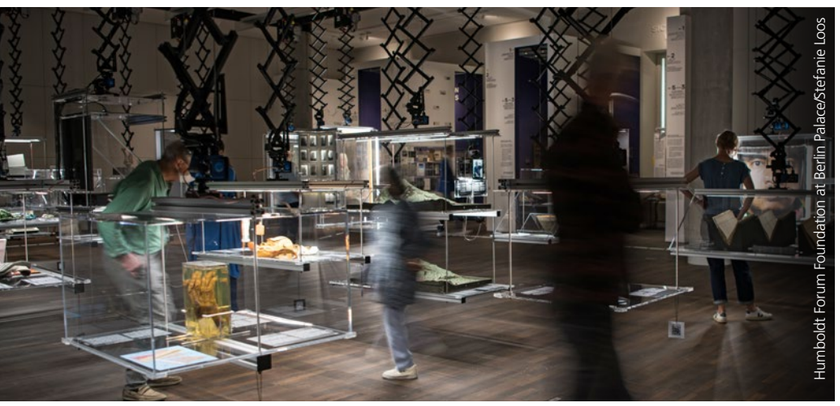
A In the entrance area of the exhibition, visitors are greeted by a projected school of fish.

What does a school of ornamental fish have to do with modern science? You might find yourself wondering, upon entering the ‘After Nature’ exhibition at the Humboldt Lab, inside the new Berlin Palace. Guppies are displayed on the huge projection screen that diagonally divides the entrance hall. If danger threatens, they rearrange themselves in an instant and simultaneously change their swimming direction. This ability to act like a complex single organism is a powerful image for modern research, which turns to interconnectedness across disciplines in its efforts to address the most pressing challenges of the modern age.

The Humboldt Lab is a part of the Humboldt Forum, alongside the collections of the Ethnological Museum and the Museum of Asian Art. It was recently built on the site of the former Palace of the Republic. Exhibits on human medicine, climate research, information technology and sociology are displayed across an area of approximately 500 square metres. They address several fundamental questions: How have humans shaped the world since the beginning of the industrial age? What problems has this caused? And how can science contribute towards solving them? The Lab focuses on research projects by scientists from the Humboldt University of Berlin and the clusters of excellence across the capital in which they are embedded.

From Humboldt to brain research

The exhibition begins with several screen exhibits that connect pioneering eighteenth-century researchers Alexander and Wilhelm von Humboldt to present-day projects involving current researchers from Humboldt University. They cover subjects including the detection and treatment of neurological diseases using a new kind of miniaturised magnetic resonance imaging (MRI) machine. Unlike a classic MRI, this device allows patients to make various movements, such as with their hands, during a brain scan. When a patient is unable to carry out a movement as instructed, the area of the brain that should have activated but instead remained passive can be pinpointed. If surgery is required, a highly accurate projection onto the exposed brain can be used to highlight this area. The similarities between a neural network and a school of fish are clear.



Humboldt Forum Foundation at Berlin Palace/Stefanie Loos

Exhibits hang from the ceiling and seem to float in space

Is the ‘liberal script’ finished?

By the time you enter the second room of the exhibition, you’re well and truly hooked. Exhibits suspended from the ceiling appear to float within the space. A 20-metre projection screen displays concise scientific facts about the Anthropocene – the age in which humankind has irrevocably left its mark on nature.

One of the discourses on the big screen deals with the ‘liberal script’ – the 19th-century principle according to which societies organise themselves as nation-states and grant their citizens varying degrees of security and freedom. The world has become a global village. We are increasingly experiencing how fundamental problems such as climate change, energy insecurity, racism, and social tension between rich and poor transcend national borders and can only be resolved with collective intelligence.

Academics studying this phenomenon have indicated that the hope that humankind had reached the ‘end of history’ after the end of the Cold War has not been fulfilled. The balance between security and freedom has been shaken to its core. Researchers point out that in response to the Covid-19 pandemic, freedom was restricted in the interest of safety, albeit temporarily, even in liberal societies. Given the challenges of our time, has the ‘liberal script’ run its course? The discourse breaks off abruptly, leaving plenty of food for thought.

Interactive and participative

While conceptualising the exhibition, the organisers were keen to gather feedback: Visitors may react to the ongoing discourse and express their thoughts in real-time via Twitter. Selected posts are projected onto the constantly rearranging screen segments that appear alongside the video statements made by the researchers, infographics and musical intermezzi. This digital feature is a fascinating way of conveying information and a highlight in itself.

Two minor points of criticism: Firstly, the exhibition almost exclusively showcases research projects conducted at Humboldt University. The work of other institutions such as the Helmholtz Association, Fraunhofer Society or Max Planck Society, which also work on collective intelligence and have connections with Humboldt University, is omitted here. Secondly, Alexander von Humboldt’s archival research into foreign peoples and local dialects, which occupies a small corner and is rather text-heavy, can seem incongruous in an otherwise very modern exhibition.

Finally, a recommendation: it is best to avoid peak times and visit the exhibition in the evening in order to take in the space and the discourses, each as long as 30 minutes, undisturbed. There are regular public tours in various languages, group tours for families and workshops – perfect for those who want to experience the exhibition collectively.

Michael Müller is an editor in DLR’s Corporate Communications department.

Stiftung Humboldt Forum im Berliner Schloss/Alexander Schippel

THE HUMBOLDT LAB

Humboldt Forum, Schloßplatz, 10178 Berlin

Opening hours:
Wed-Mon: 10:30–18:30
closed Tuesdays

Admission to the Humboldt Lab is typically free.
Special events may carry an entrance fee.

www.humboldt-labor.de/en

POWERED UP

Talk shows flicker on an old-fashioned television, boy bands sing on the kitchen radio and power plants emit smoke on the outskirts of the city. Everything is running, everything is expanding, and everything is consuming electricity. It is the 1990s. Computers, mobile phones and stereos are in almost every household and every room. Industry and society's hunger for energy is steadily increasing. In windy areas of Europe, wind turbines are growing taller, and protests against the pollution caused by coal-fired power plants are rising outside the cities. Some markets are increasingly turning to renewable energy sources instead of fossil fuels. Can they reliably meet the growing demand?

The rather artistic map on **Gigawatt'**s game board (Play for the Future, Amsterdam) reveals the strengths of various European regions. The wind blows over the North Sea, the Sun shines on a Mediterranean beach, water flows in the mountains and nuclear reactors power Eastern Europe. Up to six players each take responsibility for the energy supply in one of these regions. They all start with several coal and gas-fired power plants – as reliable but environmentally damaging legacy plants – and the same electricity demand and production output, which are represented by game pieces of different colours and shapes. With each round, the demand increases, and the player must make sure to satisfy it. This is done in five phases. You buy technology cards; build and improve power plants, energy storage or power lines; roll the dice for demand, income and energy balance; trade what is left over or missing; and finally try to buy shutdown rights for fossil power plants at auction – if your budget allows. The aim is to satisfy demand sustainably with the help of various technologies and a strategically favourable electricity mix, and to cooperate as sensibly as possible in an international energy market. The game ends as soon as all coal and gas-fired power plants are switched off in a region and more electricity is generated there than is consumed.

It quickly becomes clear how challenging and dynamic a widely interconnected and sustainable electricity market is. If you rely too much on wind or solar energy, the next sudden downturn will force you to buy electricity from other regions. If, on the other hand, you leave coal and gas-fired power plants connected to the grid for too long, you risk ever higher carbon dioxide penalties and, in the worst case, bankruptcy. While the game is in its first edition after a successful crowdfunding campaign, there is still room for improvement in the rules and gameplay. However, these weaknesses are not significant, thanks to the game's logical interconnections and its extremely attractive design. Again and again, parallels are drawn with the real world and the game conveys a somewhat superficial but comprehensible, sometimes even instructive, impression of how the European energy market works. This is not the only reason why Gigawatt is exciting – the challenges behind it are currently 'electrifying' the world more than ever.

Daniel Beckmann

DO ROVERS DREAM OF ELECTRIC SHEEP?

The launch and monitoring of the rovers Spirit and Opportunity on their Mars exploration mission has shown the extent of human ingenuity. In search of signs of water that might have existed there, the two robots faced adverse weather conditions but made several discoveries about the Red Planet. What no one expected, nor had predicted, was that Oppy, initially on a 90-day mission, would work at total capacity for another 15 years. Now, we can relive this journey and see what went on behind the scenes in **Goodnight Oppy**, a stunning documentary directed by Ryan White.

From the start, the film shows how the twin rovers were humanised by the team of scientists and engineers, resulting in an emotional and genuine bond between them. The spectacular realistic images and special effects are perhaps the most impressive feature, and the narration of Golden Globe winner Angela Basset as the voice of Oppy's diaries is the icing on the cake. Another strong suit is the focus on the soundtrack used to wake up Oppy and Spirit, which would always cleverly match the circumstances on Mars.

Despite the fascinating narrative and images, the film omits significant milestones in the history of scientific space development in an effort to be accessible and engaging. Viking, NASA's first-ever programme that sent two probes to Mars in the 1970s, was mentioned but major events such as the Mars Pathfinder mission in 1996 and the arrival of Curiosity to the planet in 2012 were overlooked. The latter even occurred while Opportunity was still active.

Either way, with a collection of moments that will both move you and keep you on the edge of your seat, the documentary is an entertaining watch that leaves you wondering what the future of space exploration has in store for us all. This original Amazon Studios production has been available on Prime Video since 23 November 2022.

Yasmin Tosta

ROAD TO SUCCESS

For many young adults, finding the right path to their future careers can be daunting, especially when family expectations come into play. The pressure to choose a profession can be overwhelming, and the lack of real-world experience can make the decision-making process feel like a shot in the dark. In **The Self-Improver: A Pilot's Journey,** Nick Eades takes the readers on his personal growth journey from struggling student to successful pilot, which will surely resonate with those who are or were at some point pursuing their way in life.

The book is well-structured, with each chapter focusing on a specific period in the author's life. It covers a range of topics related to aviation and self-development, including the challenges of flight training, the importance of preparation and planning, and the role of perseverance and discipline in achieving success. Eades chronicles his experiences with a good balance between personal anecdotes and more technical information about the aviation industry, offering valuable lessons and advice for aspiring pilots.

Overall, this insightful memoir is an easy read that will captivate even someone who knows almost nothing about aviation. Eades' engaging and candid writing style makes the book somehow relatable and hard to put down. As the world's most experienced Boeing 747 pilot, his journey is an inspiring reminder that it's never too late to work towards your goals.

Yasmin Tosta

RECOMMENDED LINKS

THE POWER OF ARTIFICIAL INTELLIGENCE
s.dlr.de/dhMiR

Did you know that your daily meals might have been produced with the help of AI? This weekly podcast created by the MIT Technology Review will enlighten you. From farming to wildfires to satellites, this podcast will show you how artificial intelligence is much more embedded in our daily lives than you would have thought.

FOR THE CURIOUS MINDS
youtube.com/c/OddAnimalSpecimens

If you are interested in natural history, this YouTube channel is for you. The videos showcase all types of preserved animals from museum collections across the USA, with a set of intriguing and unusual facts behind each specimen.

ENERGY TRANSITION
s.dlr.de/MvaiT

This podcast is a must-listen for energy enthusiasts. In each episode, different experts join the host to discuss the most recent news on the energy transition, renewables, and current events in the industry.

3, 2, 1 … LIFT OFF!
countdown.dlr.de/en/

Just like the iconic countdown before the ignition of rocket engines, the COUNTDOWN magazine by the German Space Agency at DLR will surely spark your enthusiasm for space exploration. This publication offers an international perspective on Germany's rapidly growing space industry and a sneak peek into the latest technologies.

FOLLOW JUICE ON ITS WAY TO JUPITER!
s.dlr.de/RlRsx

ESA's JUICE mission recently launched on an eight-year journey to the Jupiter system. Follow JUICE's winding journey to its distant destination via Earth, the Moon and Venus live at using this link, or sign up for monthly progress updates by following @ESAJuiceBar on Twitter.

GETTING OLDER, WITHOUT GETTING OLD?
youtu.be/lkEHvSWeMzU

Does getting older necessarily mean getting weak, frail and ultimately, dying? In this podcast, a researcher and a doctor describe how scientists are narrowing in on the biological processes that cause us to age and how they could possibly be slowed, stopped or even reversed.