

DLRmagazine

of DLR, the German Aerospace Center · No. 173 · October 2023

WINDS OF CHANGE

DLR'S WIVALDI WIND ENERGY RESEARCH FARM



OPUS 1

More topics

- ▶ **A SMALL TASTE OF THE FUTURE**
Prescreening speeds up the approval process of alternative fuels
- ▶ **SIMPLY MARVELLOUS!**
Mars Express: 20 years of the High Resolution Stereo Camera

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 Corporate Communications
Linder Höhe, 51147 Cologne, Germany
Phone +49 (0) 2203 601-2116
E-mail info-DLR@dlr.de
Web DLR.de/en
Instagram [@dlr.en](https://www.instagram.com/dlr/en)

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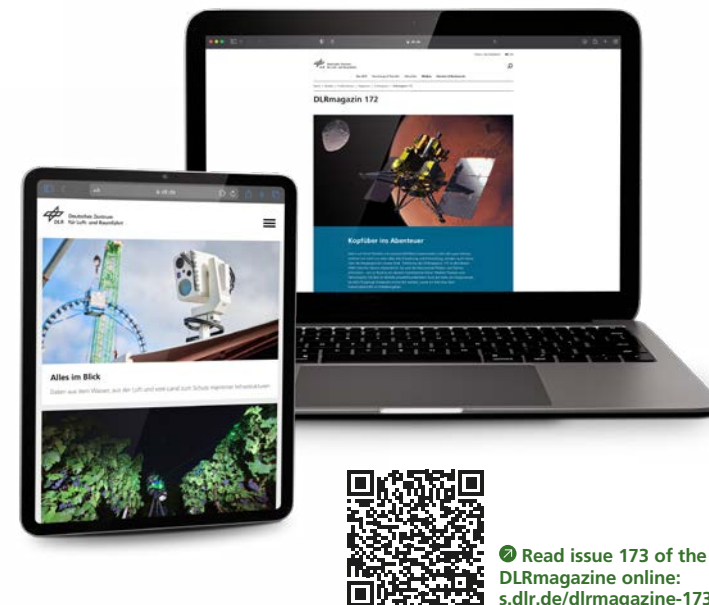


WHAT IS DLR UP TO?

If you have visited the website at DLR.de recently, you may have noticed some changes. We have introduced a new 'look and feel', which has made the website more user-friendly and at the same time added new functionality.

This also applies to the presentation of the DLRmagazine. Its revamped online presence offers a host of new options that provide added value for our readers. The individual articles that make up the issue can be easily selected from the overview page, so you no longer have to 'leaf through' the PDF. In addition to the texts and images from the print edition, the online articles also contain videos and animations for a deeper 'immersion' into the sometimes complex topics.

Of course, you can still download the DLRmagazine as a PDF or subscribe to the print edition. However, if you do not wish to receive the printed edition and would like to read the magazine exclusively online in the future, you are welcome to subscribe to the DLRmagazine newsletter at DLR.de/dlr-magazine. Whether online or in printed form – we hope you enjoy reading the latest issue of DLRmagazine.



Dear reader,

In music, the term 'opus' is used to help identify the work of an artist. The wind turbine featured on the cover of issue 173 of DLRmagazine shares this name. It is more than a conventional wind turbine – from its foundations to the tips of its blades, it is equipped with numerous specialised sensors. DLR researchers will use the data acquired using these sensors to investigate how the noise generated by future wind turbines can be reduced or eliminated, among other things. That is why OPUS 1 is not alone. This facility is part of the new DLR Wind Energy Research Farm known as WiValdi, which is short for 'Wind Validation'. Here, experts from research and industry can conduct research at full scale with an unprecedented level of detail and under real environmental conditions. The goal is to better understand wind power as a whole, with all its influencing factors.

In addition to wind energy research, the latest 'opus' of the DLRmagazine contains many other interesting articles that, among other things, highlight the extensive topic of environmental compatibility from different perspectives. The article on prescreening describes a process that DLR experts use to analyse the components of synthetic kerosene alternatives. The article on the DLR Projektträger's 'Plastic Pirates' initiative discusses the protection of bodies of water from further pollution. Across Europe, schoolchildren are collecting litter from streams, lakes and rivers. The information they gather will expand the understanding of what types of waste enter the ecosystem and how they are distributed geographically. Doing more to protect the environment is also one of the core aspects of the sustainability concept that has become increasingly important within DLR in recent years. You can find out more about this in the interview with Anke Kaysser-Pyzalla, Chair of the DLR Executive Board, and her deputy, Klaus Hamacher.

For this issue, too, we have spared no effort – a literal meaning of the Latin word 'opus' – to ensure that the following pages are once again full of enjoyment and insight.

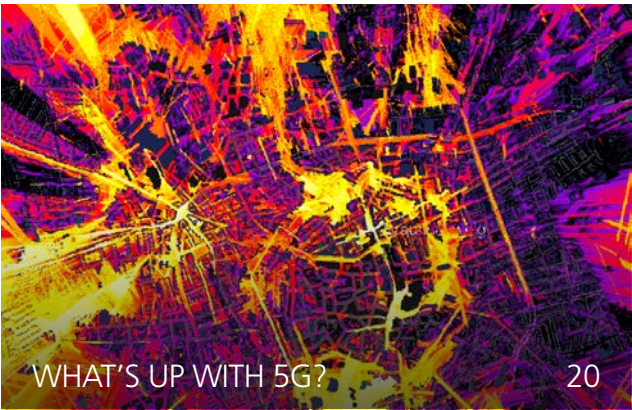
Happy reading!

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IN BRIEF



Assistance systems can also prevent collisions

SELF-DRIVING ON THE WATER

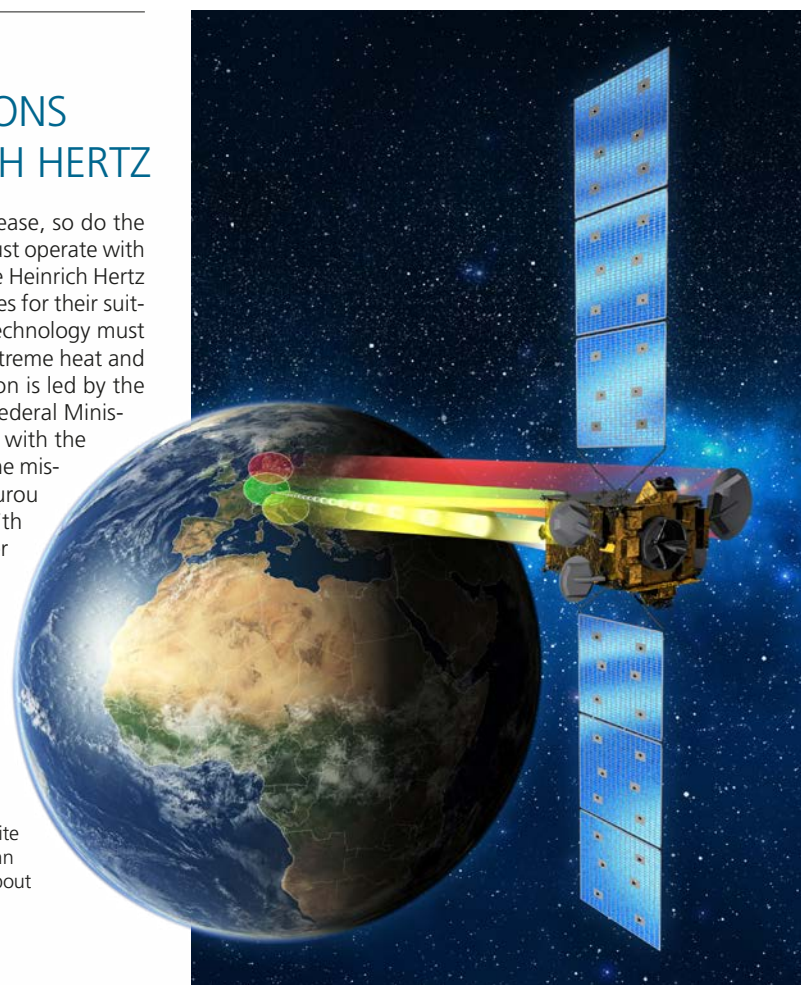
Due to the globally growing volume of maritime traffic, the importance of autonomous and automated systems is increasing. The development and research of these systems are the focus of the research conducted at the DLR Institute of Systems Engineering for Future Mobility.

One example is the e-Maritime Integrated Reference Platform (eMIR) test field. It can be used to investigate and test highly automated assistance systems. Another example is the SmartKai docking assistant. The 'parking aid' for ships has already passed numerous live tests and will be used in future in harbour areas that are difficult to navigate. DLR researchers are currently in talks with companies with the aim of establishing a spin-off company out of the project.

TESTING NEW COMMUNICATIONS TECHNOLOGIES WITH HEINRICH HERTZ

As global communications bandwidth needs rapidly increase, so do the demands on communications satellites. As a result, they must operate with much more powerful technologies. One of the goals of the Heinrich Hertz mission is to test new satellite communications technologies for their suitability for use in space. The conditions under which the technology must function in space are very demanding – it is exposed to extreme heat and cold, vacuum and microgravity. The Heinrich Hertz mission is led by the German Space Agency at DLR in Bonn on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK) and with the participation of the Federal Ministry of Defence (BMVg). The mission lifted off in July from the European Spaceport at Kourou in French Guyana on board an Ariane 5 rocket. This 117th Ariane flight was also the last of this launch vehicle. Over the past 27 years, it has become one of the most reliable and safest launchers.

The German communications satellite Heinrich Hertz will orbit Earth at an altitude of 36,000 kilometres for about 15 years



OHB System AG

REGIONAL NEWS

BERLIN: The DLR_Startup Factory supports and promotes start-up teams and accompanies them from the initial business idea to the establishment in the market. Spin-offs are closely supported and promoted in a multi-stage process.

BRAUNSCHWEIG: The research aircraft ISTAR (In-Flight Systems and Technologies Airborne Research) has already completed over 400 flight manoeuvres. In the process, new types of sensors measure how the aircraft behaves during special flight manoeuvres. DLR is using the results to further develop ISTAR's digital twin.

COTTBUS: In the HepCo test facility, the DLR Institute of Electrified Aero Engines will set up a large number of test stands. HepCo stands for Hybrid Electric Propulsion Cottbus. Pro-

pulsion components of electric and hybrid-electric aircraft, as well as entire propulsion architectures will be tested here under real conditions.

ESSEN: The hydrogen hub H₂UB networks research institutions, companies and start-ups to promote hydrogen activities. DLR, which is involved in the H₂UB, is active in many areas of hydrogen research – from production to use. With several decades of experience, researchers are working to make hydrogen comprehensively available to society and industry according to their needs.

COLOGNE: Meike Jipp has been appointed Divisional Board Member for Energy and Transport by the DLR Senate. The psychology graduate is a professor of 'Transport Demand and Impacts' at the Technische Universität Berlin and Director of DLR's Berlin Institute of Transport Research.

LEUNA: DLR has selected the Leuna Chemical Complex in Saxony-Anhalt as the site for the PtL Technology Platform (TPP). The research facility is intended to make a decisive contribution to the timely production of electricity-based fuels – also known as power-to-liquid fuels (PtL) or e-SAFs (Sustainable Aviation Fuels) – on an industrial scale. To this end, DLR will work with companies and other research institutions to develop and test the necessary large-scale technologies and processes. Construction is scheduled to begin in January 2024.

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Following conversion into a flying laboratory, the newly acquired aircraft Dornier 328-100 Model 20 will be used for research into hydrogen technologies for aircraft, among other things.

AN AIRCRAFT WILL BECOME A 'FLYING HYDROGEN LABORATORY'

The D328 Uplift research aircraft has joined the DLR fleet. The Dornier 328-100 Model 20 is being converted into a 'flying hydrogen laboratory' and will be stationed at the Braunschweig site in the future. The modular design of the aircraft, which is open to all technologies, makes it available to many potential partners – especially small and medium-sized companies and start-ups without their own facilities for flight tests. In this way, propulsion, fuel and system technologies for the decarbonisation of air transport can be tested quickly and under real flight conditions. This significantly accelerates the development of these technologies. The acquisition, conversion and use as a 'flying test laboratory' for research into hydrogen technologies in air transport are part of the Uplift project.

TERRABYTE ANALYSES GLOBAL EARTH OBSERVATION DATA

In cooperation with the Leibniz Supercomputing Centre (LRZ) of the Bavarian Academy of Sciences and Humanities, DLR put terrabyte into operation in July – one of the largest scientific platforms for analysing Earth observation data in Europe. For the first time, the platform enables researchers to efficiently analyse global data sets from Earth observation satellites at the highest resolution. The computer platform is connected to the satellite data archive of DLR's German Remote Sensing Data Center. It provides approximately 50 petabytes of storage space for current Earth observation data and data collected over five decades. The latest generation of CPU and GPU resources enable efficient operations in the cloud environment. The potential of Big Data analysis of Earth observation data is demonstrated by global products such as DLR's 'World Settlement Footprint'. This data set contains the development of the populated areas on the planet. The map was generated using many petabytes of data from the Copernicus and Landsat missions as well as the global digital elevation model created using data from the TanDEM-X mission.



Thousands of satellites orbit the blue planet. With terrabyte, global Earth observation data can be analysed in the highest resolution for the first time.

WINDS OF CHANGE

DLR's WiValdi Wind Energy Research Farm enables full-scale scientific research

by Denise Nüssle

According to the Federal Statistical Office, wind power was the second most important source of energy generation in Germany in 2022. But in order to accomplish the energy transition, wind power must be expanded even further. That means more turbines, but also improved designs. There is still much progress to be made regarding efficiency, cost-effectiveness and noise generation.

Since May 2023, DLR has been operating two wind turbines in Krummendeich – amid the idyllic fields and fruit trees along the Lower Elbe, between Cuxhaven and Stade. OPUS 1 and OPUS 2 stretch 150 metres into the sky, not far from several older wind turbines rotating in the predominantly west-southwest wind. The strong breeze enables them to consistently generate electricity from a renewable source. At first glance, the two DLR turbines do not appear significantly different from their neighbours. But up close, the differences become clear. Clusters of black measurement dots are spread out across sections of the rotor blades. They are markings for optical sensors. Then, there are the bright red measurement masts. The third wind turbine, OPUS 3, and another measurement mast are in the planning stage, while the control room is already under construction. Together they form a very special ensemble – the DLR Wind Energy Research Farm, WiValdi.

Understanding and optimising wind power

DLR planned and implemented the research farm in conjunction with the Research Alliance Wind Energy (Forschungsverbund Windenergie; FVWE) and industrial partners. 'WiValdi' stands for 'Wind Validation' and reflects the goal of the researchers – to use scientific methods to determine as precisely as possible what happens to air as it is circulated through the facilities of the research farm. To do this, the researchers are investigating a wide range of flow processes over an extended period of time. These processes range from atmospheric variations to the slightest turbulence around the rotor blades.

Field research – live, on site and at full scale

"WiValdi enables us to conduct research at full scale under real environmental conditions for the first time and thus better understand wind power as a whole with all its influencing factors," says Jan Teßmer, Head of the DLR Wind Energy Experiments Facility, which is responsible for setting up and operating the research farm. In this way, DLR can develop technologies to further increase the efficiency, cost-effectiveness and acceptance of wind energy – together with companies and other research institutions to which the test farm in Krummendeich is also open. In setting up the research farm, DLR is working closely with Enercon, one of the leading manufacturers in the

"WiValdi enables us to conduct research at full scale under real environmental conditions for the first time and thus better understand wind power as a whole with all its influencing factors."

Jan Teßmer

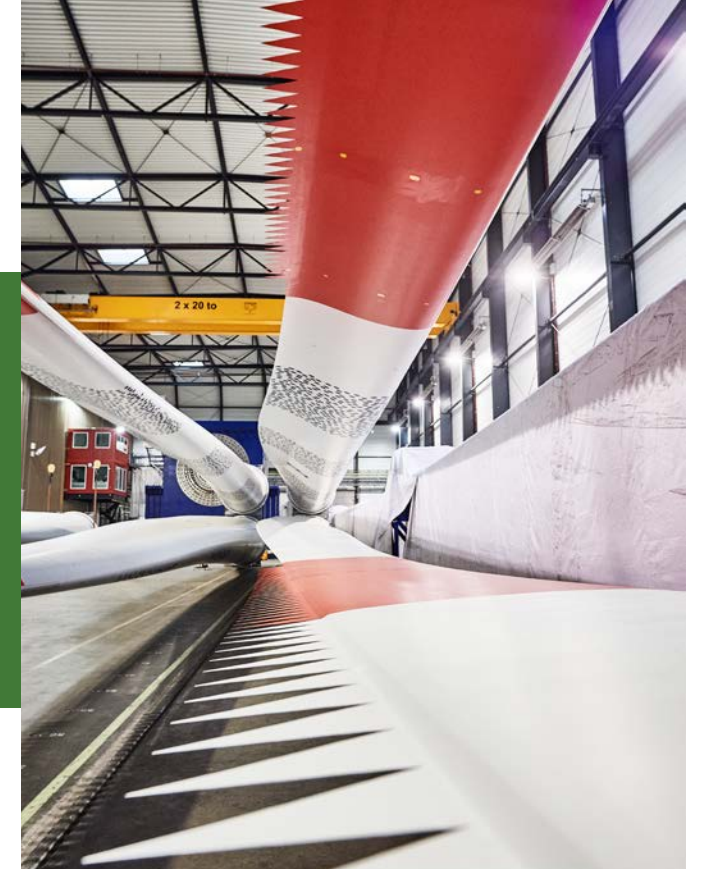
Head of DLR Wind Energy Experiments Facility

wind energy sector. The two large wind turbines, OPUS 1 and OPUS 2, each have a rated output of 4.26 megawatts.

Future wind turbines in commercial wind farms will not look fundamentally different from those that exist today. "Nevertheless, wind power is far from being entirely understood," says Michaela Herr of the DLR Institute of Aerodynamics and Flow Technology. "On the contrary, we have only just started exploring many important questions." Herr leads the newly founded Wind Energy Department at the Institute and has been working primarily in the field of aeroacoustics for many years. Aeroacoustics is the study of noise generated aerodynamically when air flows around or through components – such as the rotor blades of wind turbines.

Powerful, yet quiet

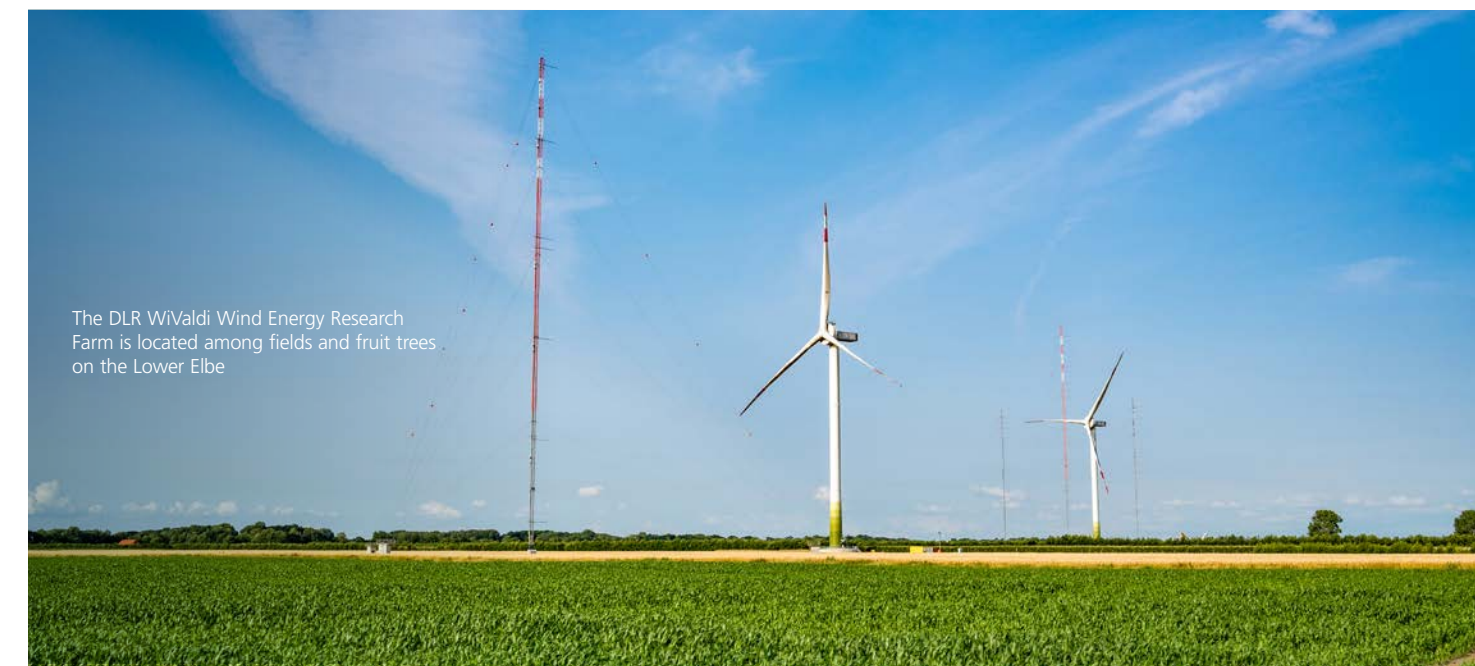
The noise generated by wind turbines is often a critical point during discussions about wind power, especially for local residents. According to a survey conducted by opinion research organisation 'forsa' in 2022, acceptance of more onshore wind power is high, at around 80 percent. It is important that it remains that way, particularly in view of the extensive expansion planned over the next few years. Germany's onshore wind turbines currently have a total output of just under 60 gigawatts. This is expected to increase to 115 gigawatts by the end of 2030.



The toothed trailing edges on the rotor blades are referred to as serrations. They reduce noise generation.



Before assembly, all six rotor blades were dynamically measured by the experts at the DLR Institute of Aeroelasticity. In addition, one blade was statically tested in collaboration with Fraunhofer IWES.



The DLR WiValdi Wind Energy Research Farm is located among fields and fruit trees on the Lower Elbe



Yves Govers from the DLR Institute of Aeroelasticity checks the measurement markings on one of the rotor blades

There are already many ways to further reduce noise emissions. The use of serrations – modified trailing edges on the rotor blades – is now standard and they can be found on OPUS 1 and OPUS 2 at the WiValdi research farm. These serrations reduce the noise where it originates – directly at the trailing edges of the rotor blades. Adjustments to the turbine control system could also allow for quieter, more efficient operation. It is precisely these aspects that Michaela Herr and her team are keen to investigate. How irritating people find noise pollution depends on the volume and also on the type and characteristics of the sound. For example, the temporally fluctuating sound caused by rotating turbine blades is more disturbing than a steady noise. “With WiValdi, we can investigate directly on site and over a longer period of time how the weather and other local conditions affect the generation and propagation of the sound. At the same time, we measure the performance of the turbines and other important parameters. This allows us to develop better models and create individual analyses for new wind energy sites. In the future, it will be possible to design new farms and position their turbines in such a way that they can be operated as efficiently and quietly as possible under the given conditions and with a maximised service life.”

Welcome to the realm of sensor and measurement technologies

From their foundations to the tip of their blades, 150 metres up in the air, all of the WiValdi components are equipped with a large number of sensors. These measure temperature, humidity, wind speed, pressure and even the slightest deformation of the rotor blades. They generate a unique and growing amount of data with an unprecedented level of



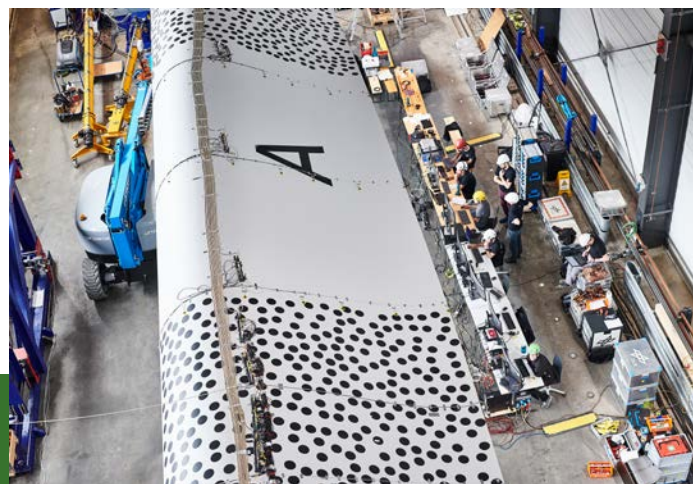
The rotor blades are each 57 metres long and weigh approximately 20 tonnes

detail. Researchers from all over the world have already expressed to colleagues at DLR their interest in gaining an insight into this unique and ever-growing collection.

Approximately 1500 sensors are installed in the six high-tech rotor blades. They make it possible to comprehensively and scientifically investigate the vibration and load behaviour, of a wind turbine on a real scale during operation for the first time. “Large, lightweight blades



For the tests, the GVT team of the Institute of Aeroelasticity suspended the rotor blades from a crane using rubber cords. This required the use of 500 cords similar to those used in bungee jumping at the front and rear ends of each blade. The blades then underwent testing using a shaker or an impact hammer. The special suspension was used for the first time on a rotor blade of this size and allowed the researchers to determine the natural vibration of the blades free from the influence of other environmental conditions.



are good for efficiency, but they are also very elastic and flexible,” says Yves Govers from the DLR Institute of Aeroelasticity. “They bend and vibrate under the loads caused by the wind, which leads to new technical challenges that we need to study in detail.” Together with the DLR Institute of Lightweight Systems and Leibniz University Hanover, which is part of ‘ForWind – the Center for Wind Energy Research of the Universities of Oldenburg, Hanover and Bremen’, his team equipped the rotor blades with sensors during their manufacture. “Imagine the sensors to be like the human nervous system,” says Lutz Beyland from the DLR Institute of Lightweight Systems. “They collect information, monitor the system and indicate where problems could arise.” The sensors enable mechanical stresses and material fatigue to be detected at an early stage and the construction methods and system control to be optimised. Before attaching the sensors, the team practiced all of the necessary steps at the DLR Center for Lightweight-Production-Technology in Stade.

The first scientific measurement campaigns started in Krummendeich before construction work began. Using a lidar measurement system, the DLR Institute of Atmospheric Physics determined information on wind speed, wind direction and turbulence at the site. This dataset serves as a comparative value against which any changes to the local airflow conditions caused by the wind turbines can be detected. Another important reference is the acoustic site assessment carried out by the DLR Institute of Aerodynamics and Flow Technology.

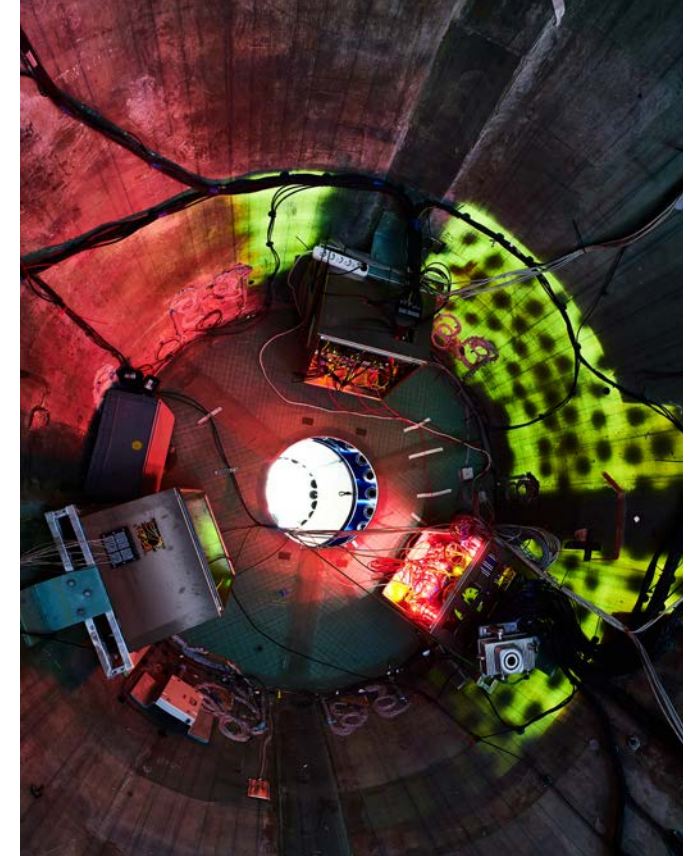
Construction begins – WiValdi takes shape

Construction began in spring 2021 and marked the advent of an exciting, yet challenging time. All aspects of the large-scale project came together in the hands of a three-strong team from the DLR Wind Experiments Facility – from planning the research wind farm and coordinating processes and contractors to communicating with the citizens of the surrounding communities.

DLR researchers Jakob Klassen and Lukas Firmhofer, and their Department Head, Jan Teßmer, had to quickly familiarise themselves with some entirely new specialist areas and understand the local conditions. The soft marshy soil, for example, which is common near the coast, requires special construction measures to protect the surrounding fruit plantations from soil erosion. “This was something very special for us. It was very different from our usual routines as researchers,”



The lidar system on the ground measures the wind at an altitude of up to 2000 metres. The microwave radiometer measures temperature and humidity up to an altitude of 10 kilometres.



Approximately 1500 measurement sensors are installed in the rotor blades of the two wind turbines.



The team tests the installation of the sensors on the rotor blades at the DLR Center for Lightweight-Production-Technology in Stade

say overall Project Manager Jakob Klassen and Lukas Firmhofer from the construction team. In addition to enthusiasm for wind power, the project also called for strong nerves as construction was delayed as a result of the COVID-19 pandemic and a shortage of skilled workers. To keep local people informed about the project and ensure that progress was visible, the team maintained an online construction site diary and organised site visits and information events.

The first measurement mast was raised in April 2022. It is located at the western entrance to the research farm, stands 150 metres tall and is equipped with over 100 sensors. The sensors allow it to measure the incoming wind from the ground to the tip of a turbine’s rotor blade. The measurement mast array followed in late 2022. This structure connects two outer 100-metre-high masts with a central 150-metre-high mast. They are equipped with sensors based on technology developed by the ForWind partners at the University of Oldenburg. These sensors determine exactly how the wind swirls after passing through the first turbine before hitting the second. “It is very

From left to right: Anke Kaysser-Pyzalla, Chair of the DLR Executive Board; Falko Mohrs, Lower Saxony State Minister for Science and Culture; Robert Habeck, German Federal Vice Chancellor and Minister for Economic Affairs and Climate Action; Karsten Lemmer, DLR Executive Board Member responsible for Innovation, Transfer and Research Infrastructure; Michaela Herr, Head of the Wind Energy Department at the Institute of Aerodynamics and Flow Technology; and Jan Teßmer, Head of the DLR Wind Energy Experiments Facility.



turbulent,” says Jan Teßmer. “It is as if the air were passing over cobblestones, so it gets shaken up significantly in the process.” Work on the foundations of the wind turbines began at the turn of the year, with further components such as the tower segments, nacelle and generator arriving in spring 2023. All of the electrical components of the wind turbine are located within the container-shaped nacelle. A lidar system is installed on the roof of the nacelle. It measures the wind arriving at and leaving the rotor.

Installation of the high-tech rotor blades

In April and May 2023, the time came to install the six rotor blades. From the DLR team to the crane operators, ground marshals and workers who received the blades in the rotor hub and fastened them with more than 50 bolts each, this last step presented a particular challenge. It was also the most exciting phase, but before it could begin, there was a lot of waiting around. The 57-metre-long, 20-tonne blades could only be lifted and installed using a large crane in good weather

and with calm wind conditions. If the wind speed was more than six kilometres per hour, as is often the case on the coast, the team had to wait. Once they made the decision to install a blade and fasten it to the structure, they had to move quickly. Once the blade was lifted by the crane, there was no turning back. The work was completed early in the afternoon of 13 May 2023 and OPUS 2 stood fully assembled in the early summer sunshine.

Lined up – a special arrangement

The WiValdi complex is not yet complete. OPUS 3, the third wind turbine, and the fifth measurement mast are expected to be completed during the course of 2024. The planning work, tenders and preparations are underway. However, the structure and composition of the research wind farm are already clearly unique. The components are positioned one behind the other, facing in the direction of the prevailing wind. Commercial wind farms would not be planned in this way today. Placing a second turbine immediately behind a first locates it within the wake. Here, the second turbine faces weaker wind and very

turbulent air. But this is exactly what the researchers intended, as they can now investigate how close together such turbines can be positioned in the future in order to make better use of available space while still achieving the highest possible level of efficiency. Simulations created using the data collected at WiValdi will help answer these questions and serve as a basis for municipalities to designate new areas for wind power. This will prove important within the context of Germany’s ‘Onshore Wind Energy Act’, which requires two percent of the land area in Germany to be allocated to wind energy generation by 2032. In addition to the construction of new wind farms, the further development of wind power is also focused on ‘repowering’ measures. This involves replacing old wind turbines with new, more powerful and more efficient systems. New research results and technologies, such as those developed at WiValdi can assist with this.

Take a deep breath and keep going

Just a few days after the assembly of OPUS 1 and OPUS 2, work continued at Krummendeich. Preparations for commissioning began in close cooperation with the turbine manufacturer, Enercon. The DLR Institute of Flight Systems makes sure that the WiValdi infrastructure is fit for research and is responsible for coordinating all the scientific contributions. Project Manager Henrik Oertel, for example, is working with his colleagues to ensure that all data generated at the farm end up in the synchronised data management system that will be available to the farm’s users. Trial operations are now underway, during which the interactions between individual systems and installations are being tested. Meanwhile, Robert Habeck, German Federal Minister for Economic Affairs and Climate Action, paid a visit to the research wind farm, which was followed by the official inauguration of WiValdi on 15 August 2023 with partners and guests from government, industry and local authorities, as well as nearby residents, in attendance. Initial research projects and the evaluation of the measurement data collected so far have also begun. Further project applications have been written and submitted, and the first requests for joint tests with industrial companies have been reviewed.

The OPUS 1 system tentatively fed its first electricity into the grid in at the beginning of August. OPUS 2 followed a few weeks later, marking another milestone for the WiValdi team

and a preview of the next 20 years, during which the research farm will make a significant contribution to improving sustainable energy supply and enable unique scientific insights.

Denise Nüssle is a Media Relations editor in the DLR Corporate Communications Department.

INTERDISCIPLINARY COOPERATION

The wind energy research area at DLR has an interdisciplinary structure, and benefits in particular from DLR’s expertise and experience in aeronautics. Like an orchestra, individual instruments may sound beautiful, but only show their full effect in concert with others. The Wind Energy Experiments Facility at DLR’s Braunschweig site operates the WiValdi Wind Energy Research Farm. It also coordinates wind energy research at DLR, to which the Institutes of Aerodynamics and Flow Technology, Aeroelasticity, Flight Systems, Atmospheric Physics and Lightweight Systems contribute.

Shared success – the WiValdi partners

DLR developed and built the research farm together with its partners in the Research Alliance Wind Energy (Forschungsverbund Windenergie; FVWE). The FVWE combines the expertise of approximately 600 researchers to drive forward the energy supply of the future. It consists of three participating institutions: DLR, ForWind – the Center for Wind Energy Research of the Universities of Oldenburg, Hanover and Bremen – and the Fraunhofer Institute for Wind Energy Systems (IWES).

WiValdi is funded by the German Federal Ministry for Economic Affairs and Climate Action and the Lower Saxony Ministry of Science and Culture. Approximately 50 million euros are being invested in its development.



The generator, the nacelle – which weighs more than 70 tonnes – and the rotor blades for the OPUS 1 wind turbine were delivered in mid-March. The journey of the three heavy-duty transporters, which were over 60 metres long, took two nights. Numerous roads had to be temporarily closed and signs, lampposts and other items of street furniture had to be removed to make way for the special vehicles. OPUS 2 was assembled in May 2023.

The installation of the turbine blades required the absence of strong winds. Once the decision to install was made, everything had to happen very quickly. The blades were mounted on OPUS 2 in almost no time at all.

A SMALL TASTE OF THE FUTURE

Prescreening speeds up the approval process of alternative fuels

by Anja Tröster



What do new aviation fuels and good wine have in common? They are both more diverse and consist of more components than most people realise – and even the smallest variation can spoil everything. For this reason, researchers at the DLR Institute of Combustion Technology in Stuttgart have developed a test method for new fuels, referred to as prescreening. Thanks to modern chemical analysis methods – similar to those used for wine – less than a millilitre is sufficient to characterise the fuel, before evaluating it in detail using modern machine learning methods.

When Hannes Lüdtke wants to examine a new fuel, he does not reach for a tap or can. Instead, the doctoral student takes a pipette and transfers the fuel into amber glass vials that measure just half the length of his little finger. These vials hold just 300 microlitres – one-sixth of a standard tube of baking flavouring. The injection volume is even smaller – one microlitre. From this tiny amount of the clear, almost odourless liquid, the chemist can determine the composition of the fuel at the molecular level. “We use two-dimensional gas chromatography for this. It is a powerful method for analysing complex liquids such as fuels using only minute samples,” says Lüdtke.

Profiling fuels

However, this step is not sufficient to determine whether the fuel is suitable for safe aircraft operations. To achieve this, the researchers must also determine the ratio of the groups of substances to one another. Only then does a profile of properties emerge – similar to the taste of a wine. Aspects such as viscosity, density, behaviour at low temperatures and high-altitude relight are key factors for approval. To determine these properties, researchers at the Institute of Combustion Technology examine the results of the gas chromatography procedure



In the ECLIF campaign, researchers from DLR and NASA investigated the exhaust plumes of aircraft. NASA's DC-8 is on the left; DLR's A320 ATRA is on the right.

using specially developed machine learning models. “These are the real key to success,” says Senior Scientist Uwe Bauder. “The models help us to reliably predict the properties that result from the composition of the fuel.”

The development of prescreening – also referred to as technical fuel assessment – marked a milestone towards making sustainable fuels market ready. The test procedure precedes the approval process. This avoids manufacturers having to invest millions of euros in setting up production for test batches of hundreds of thousands of litres, only to find that they are producing a fuel that is not ready for approval. The idea of prescreening first arose in 2017 in the EU JETSCREEN project, according to Bastian Rauch, who was a group leader for sustainable fuels at the Institute until the end of June and coordinated this project. At that time, fuel could only be evaluated using complex tests in combustion chambers, such as those conducted at the Institute of Combustion Technology. Then, however, they would have needed at least 200 litres to carry out such tests, as Rauch recalls. This requirement was already proving a major obstacle for companies intending to develop a fuel and set up production, as they might only produce a few millilitres per day or even per week.

An effective testing method from Stuttgart

As a result of these difficulties, the researchers in Stuttgart came up with the idea of developing a simple but effective test procedure – prescreening – and conducting it before the approval process. As Josh Heyne was working on this problem as part of the US National Jet Fuels Combustion Program at the same time, the

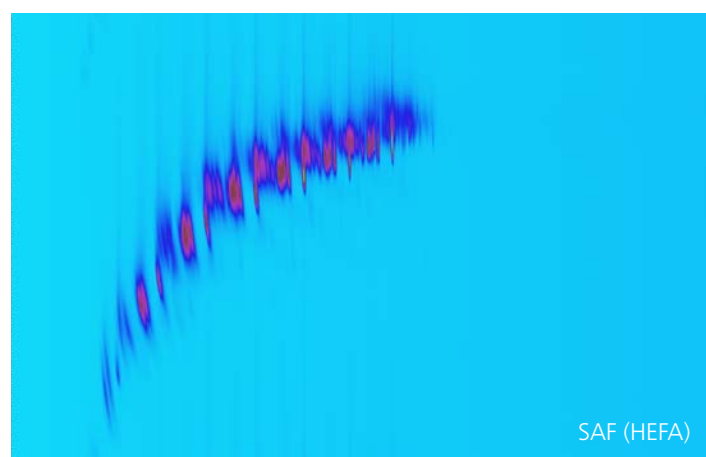
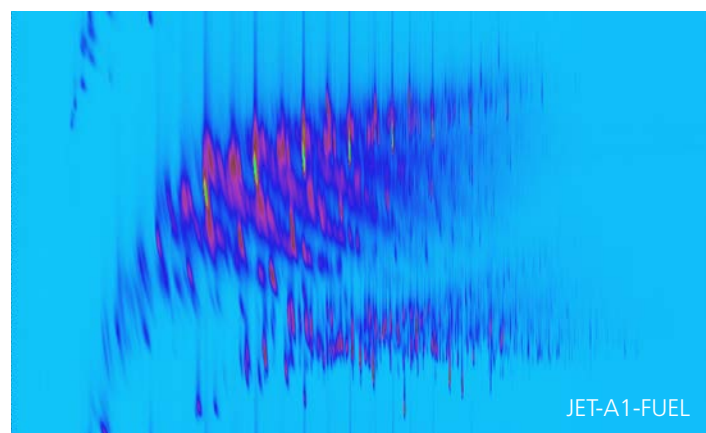
two organisations decided to collaborate. All those involved are still benefiting from the success of this cooperation today.

The SimFuel database was created in Stuttgart as an outcome of the project. It now contains data from more than 15,000 conventional jet fuels, over 450 new fuels and a vast array of analysis of the most important molecular groups in these candidates. Quite a few of these new fuels have come from research projects that made their data available. “The database is a real gem,” says Uwe Bauder, whose team works on the machine learning models. “It enables us to keep on developing the methods and models and give fuel and engine manufacturers increasingly detailed feedback.”

The experts at DLR use self-learning algorithms to couple experimental investigations in the field of chemical analytics. Bauder's team optimised a series of machine learning models to predict the most important material properties. These models are trained with data from the SimFuel database and are then used to predict the properties of new candidates based on the detailed gas chromatography results. Visualisation of the results in the form of complex, specially developed diagrams makes it possible to see what behaviours the fuel will later exhibit. Most importantly, it reveals whether these properties lie within or outside the limits specified by the certification authority.



Kathrin Großmann investigates new types of fuel in the analysis laboratory of the DLR Institute of Combustion Technology in Stuttgart



These two chromatograms show the extent to which the composition of Sustainable Aviation Fuels (SAFs; in this case Hydroprocessed Esters and Fatty Acids [HEFA]) can differ in composition from conventional Jet A-1 fuel. In the case of HEFA, the cyclic hydrocarbons (aromatics) and sulphur, which form soot during combustion, are absent. The reduction of aromatics reduces soot formation. As a result, fewer ice crystals – and thus fewer clouds – form in the atmosphere during flights with SAFs.

In recent years, the Stuttgart team has gained a lot of experience in evaluating new fuels. Many research projects have had samples of their products analysed at the Institute and were able to optimise their processes on the basis of the feedback. The evaluation of numerous new fuels, combustion chamber tests and collaboration with other DLR institutes have shown that the predictions made by the prescreening process are indeed accurate.

International demand

Four to six manufacturing companies now have their developments tested at DLR in Stuttgart each year. Their production paths vary substantially. The Institute's customers include start-ups that rely on the Fischer-Tropsch process, in which fuels can be produced with the help of electrolysis. One example is INERATEC GmbH, the most successful start-up in Germany to date. The DLR team is working on numerous projects with this spin-off

from the Karlsruhe Institute of Technology (KIT). Other start-ups use biomass as a raw material, for example XFuel, which is based in Dublin and has a production facility in Mallorca. Large corporations such as Neste and OMV also use the prescreening process to optimise their new developments. These examples show the enormous range of technical solutions that fall under the term Sustainable Aviation Fuels (SAFs).

“The prescreening process was a valuable aid for all of the manufacturing companies,” says Uwe Bauder, “because it enabled them to make corrections to the product and the production process at a very early stage.” Bauder acknowledges that the procedure does not guarantee successful certification, but notes that prescreening has significantly improved the chances of fuel candidates being successfully certified.

At present, ASTM International (formerly the American Society for Testing and Materials), based in Pennsylvania, USA, is the only organisation in the world that can certify both bio-based and electricity-based alternative fuels. In this process, it involves the manufacturers of all aircraft components that come into contact with a fuel – and there are quite a number of these. Therefore, each of these companies must test a candidate fuel as part of the certification process. If each country had its own certification office, such a process would prove completely unmanageable, so it was agreed to handle all the tests at one approval centre. To date, DLR is the only research institution in Germany that can effectively implement such an approval process.

According to Bastian Rauch, however, large companies with the necessary capabilities are now seeking to establish prescreening themselves. He sees this as a positive thing: “If you think technology transfer through, this is the next logical step in the development.”

Moving away from fossil fuels

A lot has happened since the very first approval of a Fischer-Tropsch manufacturing route in 2009, not least due to the advent of prescreening. In the beginning, says Patrick Le Clercq, a Head of Department at the DLR Institute of Combustion Technology, the scientists endeavoured to imitate kerosene as closely as



In the ECLIF project, the DLR research aircraft A320 ATRA flew with different fuel mixtures.



In 2018, DLR researchers worked with a self-designed fuel for the first time in the ECLIF campaign.

possible. Any new fuel had to be measured against Jet A-1, the most common fuel for turbine engines. Nowadays, researchers and manufacturers are able to think much more freely, and the idea of what a fuel should look like is increasingly geared towards the challenges of the future instead of the fossil model of the past.

Over the course of several successful Emission and Climate Impact of Alternative Fuels (ECLIF) flight measurement campaigns, the researchers from Stuttgart demonstrated that the prescreening process can also be used creatively. During these test flights, which have been carried out since 2015, they examined the effect of synthetic fuels on the climate with colleagues from the DLR Institute of Atmospheric Physics. In 2018, for example, kerosene was mixed with a fuel made from different compositions of fats, referred to as Hydroprocessed Esters and Fatty Acids (HEFA). This was the first time that a fuel had been designed based on the ideas of the Stuttgart researchers, with a reduced proportion of aromatics. The results exceeded their expectations.

Le Clercq's team is now keen to design a fuel that burns in an almost climate-neutral way. At the same time, Uwe Bauder is working with Andreas Meurer from the DLR Institute of Networked Energy Systems to design and optimise fuels and their production as a completely digital process. In the next step, Le Clercq wants to rethink not only the fuel, but also the engines. He is expecting major progress from these efforts at co-optimisation together with engine manufacturers.

Synthetic fuels have great potential. The results of the research conducted during the ECLIF flight campaigns showed for the first time that a reduction in aromatics

results in lower soot emissions and thus fewer condensation trails. This saving could increase to up to 80 percent – a particularly significant development, given that non-carbon-dioxide effects account for the largest proportion of the climate impact of aviation. This is especially true if it takes effect in the crucial next few years, so rapid market launch is important. By developing the Technology Platform Power-to-Liquid (TPP), DLR is making an important contribution towards the introduction of this process. The facility will be set up at the Leuna Chemical Complex in Saxony-Anhalt. It is expected to produce electricity-based fuels for research purposes on a semi-industrial scale from December 2026, paving the way for industrial manufacturing companies. At the same time, scientists will be able to test completely new ideas there in the experimental production branch.

When Patrick Le Clercq uncorks a bottle of good French red wine in the evening, decants it and pours himself a glass, he often thinks about the many unanswered questions in his research projects – and is reminded that at least as much work goes into a good fuel as into a good wine.

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



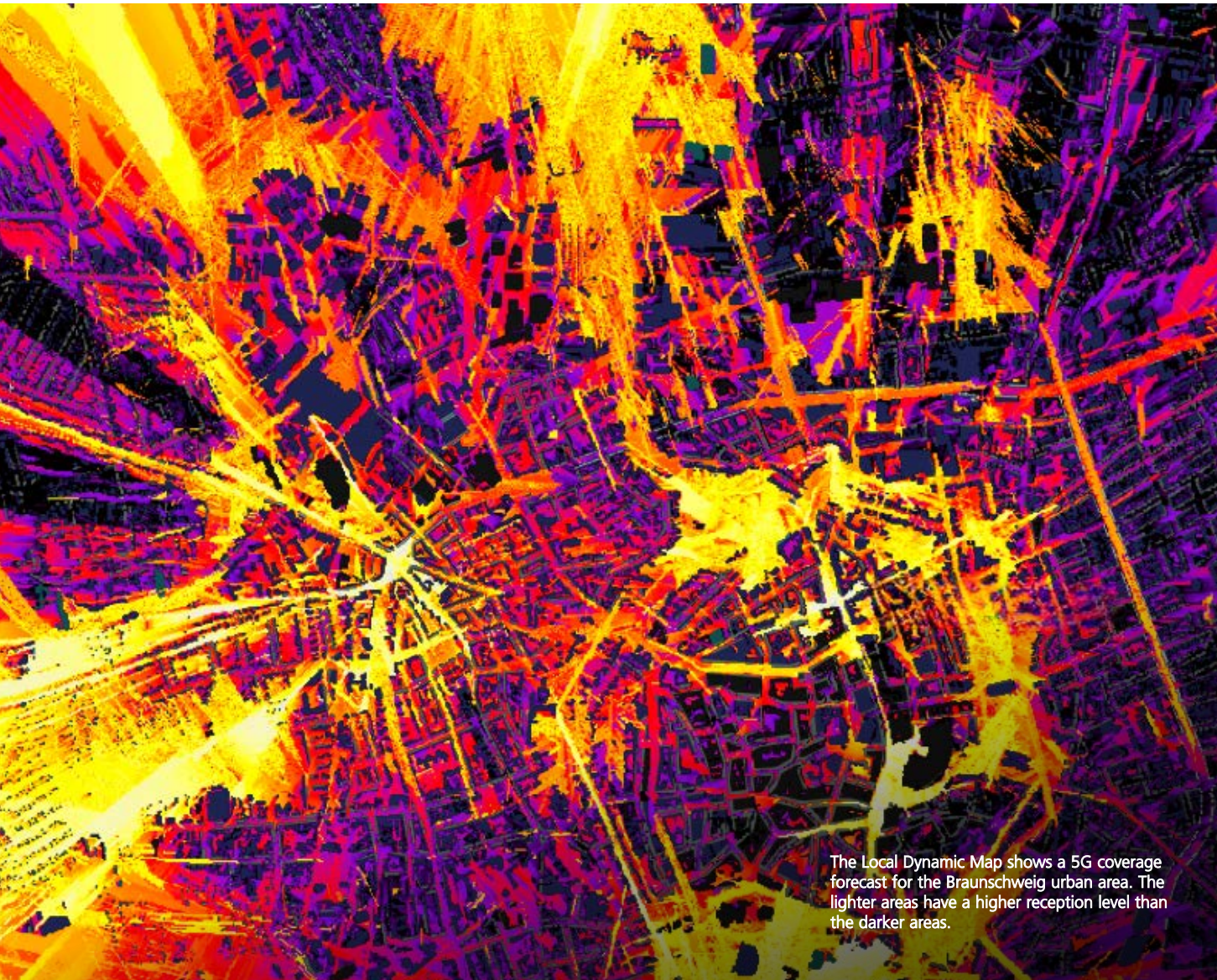
Patrick Le Clercq (left), Head of the Multi-phase Flow and Alternative Fuels Department at the DLR Institute of Combustion Technology, in conversation with Uwe Bauer, an expert in machine learning models in that department.



SUPPLE AS SNAKESKIN

What might look like a close-up straight out of the animal kingdom is actually an engine blade made of a carbon-fibre-reinforced composite. This blade is part of the Counter Rotating Integrated Shrouded Propfan (CRISP) engine compressor developed by DLR. This design combines the advantages of both open and shrouded propulsion systems – reduced fuel consumption and increased efficiency, together with similar or reduced noise levels compared to a conventional turbofan.

The most recent CRISP measurement campaign was successfully completed in early 2023. Evaluation of the structural behaviour demonstrated stable operation of the blades. In addition to the DLR Institute of Propulsion Technology and DLR Systemhaus Technik, the DLR Institutes of Structures and Design, Aeroelasticity, Aerodynamics and Flow Technology were involved in the project.



The Local Dynamic Map shows a 5G coverage forecast for the Braunschweig urban area. The lighter areas have a higher reception level than the darker areas.

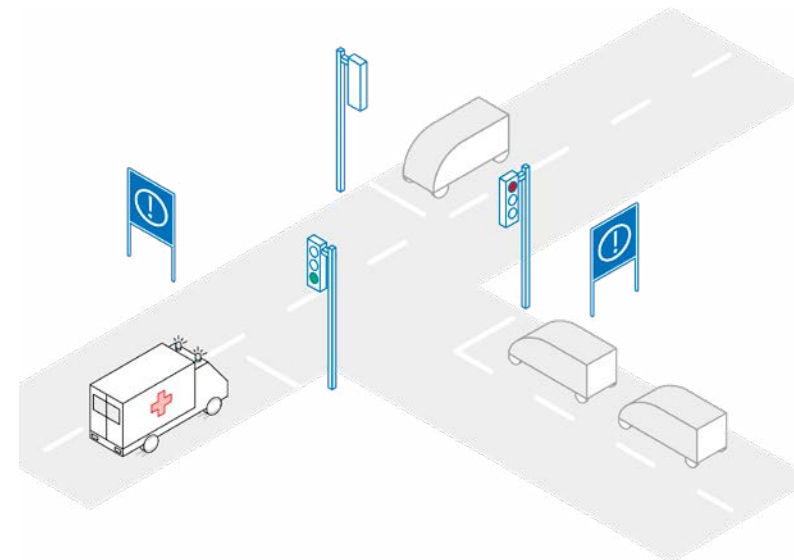
Institute for Communications Technology, TU Braunschweig

WHAT'S UP WITH 5G?

DLR tests new technologies to support emergency services based on the 5G mobile communications standard at its Living Lab

by Anna Schieben

Augmented reality, networked vehicles, telemedicine and smart homes – these are just a few of the concepts associated with the 5G mobile communications standard. The fifth generation of mobile communications enables data transmission up to 10 times faster than LTE (4G) – fast enough for real-time communication. Researchers at DLR are harnessing the power of 5G to develop technologies for networked mobility, such as intelligent ‘green waves’, drone support for emergency services and automated train operation. But before these new technologies can be rolled out, they must undergo extensive testing. The 5G Living Lab in the Braunschweig-Wolfsburg transport region is managed by DLR for this purpose.



A team of DLR researchers recently used the Living Lab to test three use cases for 5G technologies: improving the mobility of rescue vehicles, operating a drone to assist emergency responders and remotely operating a malfunctioning automated train. For all three use cases, the low latency of 5G data transmission and the ability to quickly exchange vast quantities of data were essential. The 5G Living Lab enabled these new technologies to be tested within real urban environments using the existing public 5G network.

Green wave for emergency responders

In the Emergency Services sub-project, the DLR researchers equipped various traffic lights at intersections in Braunschweig and Wolfsburg with a transmit/receive module. When emergency vehicles from the fire brigade approached the intersection, they automatically sent a signal to the traffic lights that prompted them to switch to green as soon as the

A ‘green wave’ for rescue forces – the vehicles of the Braunschweig fire brigade were connected to local traffic lights via 5G. The lights automatically switched to green as soon as they approached.



vehicle reached them. “This allows the emergency services to cross the intersection safely, which is particularly important for the safety of all road users in urban environments,” says Sten Ruppe from the DLR Institute of Transportation Systems, who is coordinating the testing of this use case. “This smart ‘green wave’ also helps emergency workers to skilfully overtake in traffic and arrive at their destination more quickly.” The researchers used the 5G Living Lab to successfully test the system in real traffic. “The fire brigade was happy to support our research, as they experience the risk to themselves and other road users associated with rapidly navigating through traffic every day,” adds Ruppe.

The researchers are now developing the technology for an app designed to inform other vehicles, pedestrians and cyclists about a fire brigade deployment near their current route. They are also exploring whether this technology could be used to instruct automated vehicles to form a rescue lane as soon as they receive notification of a nearby incident. This application is being tested in conjunction with TU Braunschweig. “During the course of the project, we used the Living Lab to conduct

THE 5G LIVING LAB PROJECT AT A GLANCE

Partner organisations:

DLR (Institute of Transportation Systems, Institute of Flight Guidance and Institute of Flight Systems), TU Braunschweig, Fraunhofer Institute for Integrated Circuits, Institute for Automation and Communication, Physikalisch-Technische Bundesanstalt and approximately 36 subcontractors

Funding:

Federal Ministry for Digital and Transport 5G Innovation Programme, 12 million euro from late 2019 to mid-2023

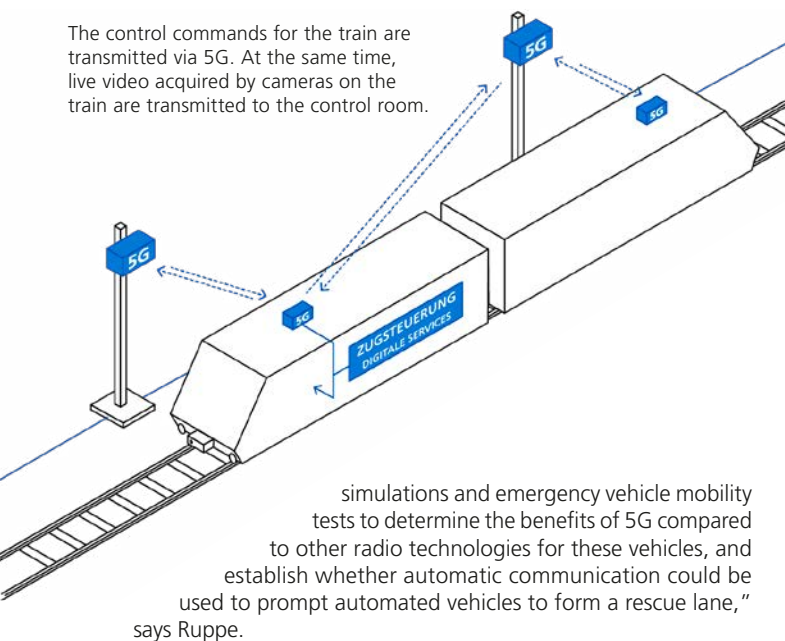
🌐 Website: 5g-reallabor.de/en





This train has no crew. It is controlled via 5G.

The control commands for the train are transmitted via 5G. At the same time, live video acquired by cameras on the train are transmitted to the control room.



Remote train operation for crisis scenarios

5G can be used to transmit large quantities of data much more quickly than previous standards such as LTE (4G). DLR researchers used this advantage to test the operation of an automated, uncrewed train in the Ore Mountains. During the tests, the train was operated by a qualified train driver located 340 kilometres away at the DLR-operated control centre in Braunschweig. "The ability to take control of an automated train remotely is essential," says Niels Brandenburger from the Institute of Transportation Systems, who played a key role in coordinating the activity. "In the case of a malfunctioning vehicle, we must be able to quickly gain remote access in order to rectify the fault or to drive it away. Our tests show that the technology works and mark a milestone for modern rail operations." During the tests, video footage acquired by cameras on the train, commands from the control centre and diagnostic messages were all transmitted in real time via the 5G network. Brandenburger and his team examined human performance from an occupational psychology perspective. "The train driver relies primarily on the video feed arriving in Braunschweig in order to operate the train remotely, so the reliable transmission of large quantities of data is essential," says Brandenburger. "In several previous studies, we examined the



The train driver in Braunschweig controlled the train in the Ore Mountains via 5G

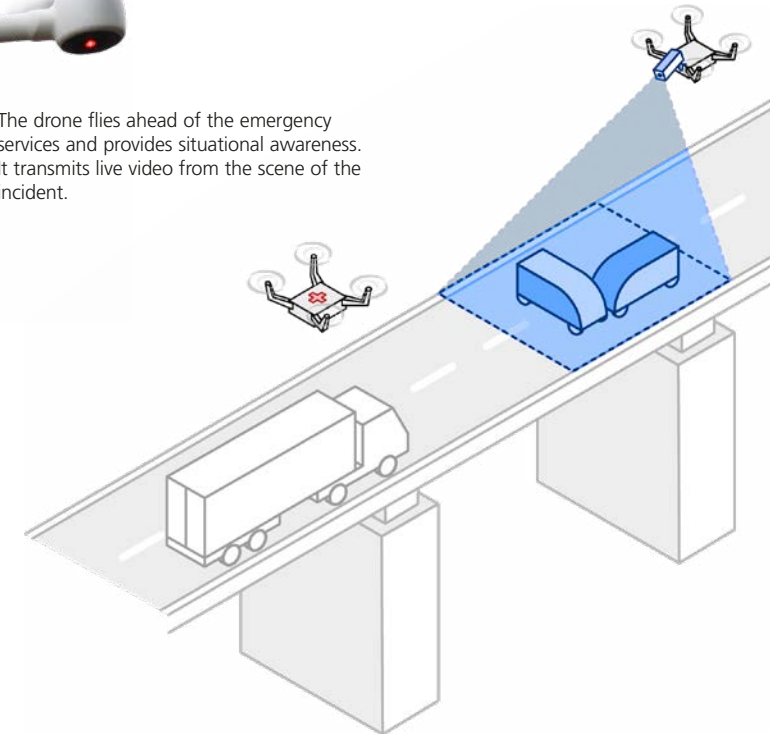
minimum quality of video necessary for a train driver to be able to reliably operate a train from a remote control room." The initial results from these studies demonstrated the need to avoid a collapsing bit rate and variable latency – particularly one that exceeds 200 milliseconds. During the tests at the Living Lab, the 5G communication technology successfully met these requirements.

Drone prepares emergency workers for deployment

The DLR team also investigated the use of a drone for specific rescue scenarios encountered by the Braunschweig fire brigade. The drone was used to transmit live video from the scene of an incident via 5G to the emergency services long before they arrived. It was operated from a control centre at the DLR site in Braunschweig and navigated automatically using references to specific waypoints. The drone was equipped with a high-resolution camera and a thermal imaging camera and used these systems to transmit a continuous stream of video from the scene of the incident to the tablet of the operations manager. "We used the drone to conduct an exciting, simulated water rescue on the Allersee in Wolfsburg," says Andreas Volkert from the DLR Institute of Flight Guidance. "The diving squad of the Wolfsburg fire brigade rehearsed a deployment while we supported them from the air. Our



The drone flies ahead of the emergency services and provides situational awareness. It transmits live video from the scene of the incident.



drone flew 30 metres above the water and provided the emergency services with sharp video imaging. This enabled them to study the lake from above and spot the person in distress much more quickly than would have been possible from the land or a boat. Even when the person – in this case, a professional diver – was at the bottom of the lake, approximately three metres below the surface, the emergency team was able to identify them clearly in the video." The operations manager controlled the drone's camera alignment using an app, which made it possible to zoom in or select different parts of the image. Artificial intelligence was also used to help analyse the images. It can, for example, identify dangerous goods signs on nearby vehicles. Emergency workers can use the system to analyse a situation before they arrive and make important decisions at a very early stage. These minutes can be crucial in an emergency. DLR researchers are currently working with the fire brigade to examine how such a system could be put into practice, how exactly the drone should be operated, and other applications for which a drone may be suitable.

Transport region enables practical research

Political and regional support was indispensable for the operation of the 5G Living Lab. During its period of active operation, the city councils of Braunschweig and Wolfsburg provided support and granted the researchers access to their transport infrastructure. The Lab benefited from close integration with the test fields that already exist in the region, such as the Test Bed Lower Saxony and the Test Field Digital Mobility. This project used data acquired at the test fields and, in turn, the project researchers made the data acquired at the 5G Living Lab available to users of the test fields. This included precise maps of the area used to test emergency vehicle mobility scenarios. Braunschweig and Wolfsburg city councils provided additional map data, including material showing active building development. "For this project, we established a software platform that stored these static data as well as dynamic data such as the variable status of the traffic lights. This platform was shared between the teams exploring the different use cases," explains Sascha Knake-Langhorst from the Institute of Transportation Systems. The software platform also stores the data acquired during the tests at the 5G Living Lab. The drone assisting the fire brigade, for example, used information about the variable

status of the traffic lights that was initially collected for use in the Emergency Services sub-project. The data on active building development within the cities were also stored on the platform and used by the drone for flight planning and by the emergency service vehicles to improve their route planning.

Although the official support for the 5G Living Lab has come to an end, the organisations involved are keen to preserve the network and the technical systems established in the region in order to continue its operation. The Lab offers a unique opportunity to capitalise on the knowledge gained here and explore further 5G use cases.

Anna Schieben works in the Cooperative Systems department at the DLR Institute of Transportation Systems and coordinated the 5G Living Lab project.



DLR researchers are currently exploring the possibility of connecting traffic lights to smartphones via 5G



SUSTAINABLE RESEARCH – RESEARCH FOR SUSTAINABILITY

Insights into an important balancing act

Interview with Anke Kaysser-Pyzalla and Klaus Hamacher

Fuel-efficient aircraft, cars that collect their own brake dust and satellites that recognise when fields need to be fertilised – the topic of sustainability plays an important role at DLR. This applies not only to its research activities, but also to DLR as an organisation. In this interview, the Chair of the DLR Executive Board, Anke Kaysser-Pyzalla, and the Deputy Chair of the Executive Board, Klaus Hamacher discuss DLR's commitment to sustainability.

Sustainability has become an important keyword for innovation. However, the question often arises as to whether everything labelled as sustainable is in fact sustainable. At DLR, we can answer this question quite clearly. Professor Kaysser-Pyzalla, what does sustainability mean for DLR?

Anke Kaysser-Pyzalla: Thinking and acting sustainably has a three-fold significance for us at DLR. Firstly, as an organisation with 55 institutes and facilities and more than 10,000 personnel across 30 locations, we prioritise sustainable actions. Secondly, our expertise in aeronautics, space, energy and transport, as well as in the cross-sectoral areas of security and digitalisation drives sustainable advancements. And thirdly, the orientation of our research topics, with which we strive to successfully achieve everything from innovation and technology through to transfer to the economy.

Mr Hamacher, you are responsible for administrative and operational management at DLR. This means that you are also responsible for the sustainability of the organisation. There is certainly more to this than turning down the heating and switching off the lights, correct?

Klaus Hamacher: Naturally, this is also a matter of sustainability. But the concept of sustainability is much broader today. It ranges from sustainable organisational management to sustainable personnel and energy management to sustainable infrastructures – including, of course, scientific infrastructure. When we construct new buildings, for example, we make sure that we do so in a sustainable manner, and we apply concepts that contribute to our strategy of sustainable work.

The operation of the research infrastructure depends on the specific research activities being conducted, for example in the field of aeronautics. DLR carries out research into climate-friendly air transport; emission-free flight is an important vision for the future. What exactly is DLR doing here?

Kaysser-Pyzalla: DLR conducts extensive research on the entire air transport system, beginning with aircraft manufacturing. Our researchers develop fuel-efficient designs and optimise maintenance, repair and overhaul processes. We also focus on important aspects such as route planning, propulsion system selection and establishing the necessary airport infrastructure. Our research also investigates flight routing, with a particular focus on climate-friendly air traffic management. The consequences of climate change and also of globalisation demand consistent action – in research, in the aviation industry and in the air transport economy as a whole.

“The consequences of climate change and also of globalisation demand consistent action – in research, in the aviation industry and in the air transport economy as a whole.”

Professor Anke Kaysser-Pyzalla
Chair of the DLR Executive Board

DLR's new research aircraft, ISTAR, has successfully conducted its inaugural measurement flights. ISTAR will contribute to the advancement of aircraft, propulsion and assistance systems. It will be accompanied by a digital twin throughout its operational lifespan. How are digitalisation and sustainability connected?

Kaysser-Pyzalla: Digitalisation accelerates progress, enabling us to increase the rate at which we advance sustainable technologies. This translates into the ability to prototype new aircraft and various other modes of transport earlier, leading to faster market entry in collaboration with industry. In addition, digitalisation allows for more rapid fleet renewal and faster improvement of the quality of the corresponding aircraft or other forms of mobility. Digitalisation is a catalyst for climate protection.

Digitalisation also plays a central role at DLR. Mr Hamacher, to what extent does this make DLR more sustainable?

Hamacher: Over the past few decades, digitalisation has greatly improved process efficiency. We have witnessed remarkable transformations from the paper-based systems we used 30 years ago. It has

played a significant role in shaping new work practices, enabling virtual formats and remote working. However, it is crucial not to overlook the potential drawbacks or challenges associated with digitalisation. One notable aspect is the considerable energy consumption of IT infrastructure, particularly high-performance computers. Furthermore, we must ensure that people remain at the heart of the process.

Kaysser-Pyzalla: On the other hand, I believe digitalisation offers opportunities to certain groups that would otherwise not be able to participate in the world of work to the same extent.

The possibility of working remotely reduces the need for employees to travel.

Hamacher: Sustainable mobility involves prioritising the avoidance of carbon dioxide emissions in business operations over mitigating or compensating for them. More specifically, avoiding carbon dioxide emissions requires formats that enable collaborative virtual work. Regarding employee mobility, we are implementing a number of ini-



With the Zero Emission Drive Unit – Generation 1 (ZEDU-1) prototype, DLR and the automotive company HWA have developed a vehicle that enables mobility almost entirely without the emission of particulate matter and microplastics.

tiatives, such as installing electric charging stations at DLR sites and supporting the use of public transport. These efforts contribute to broader sustainability goals.

Sustainable mobility and energy generation are also the focus of research in the areas of transport and energy. What is the status in these fields?

Kaysser-Pyzalla: In DLR's transport programme, we have devoted extensive efforts to advancing sustainable modes of travel, transport policies and spatial planning. We have successful projects in all these areas. ZEDU stands out as the first truly emission-free vehicle; even the particulates from braking processes are almost completely captured. Climate-friendly, door-to-door mobility and the development of



The DLR In-flight Systems and Technology Airborne Research (ISTAR) aircraft is a flying simulator. Once it has been fully upgraded, it will be able to test characteristics of new aircraft designs, real or virtual, crewed or uncrewed, under real operating conditions. It will also support the development of pilot assistance systems.



At the Évora Molten Salt Platform in Portugal, DLR is working with the University of Évora to research how molten salt can be used as a heat transfer medium in solar thermal power plants. Until now, oil has been used as the heat transfer medium in such power plants.

mobility concepts have long been integral to our projects in the transport sector. We are actively exploring ways to design liveable spaces that prioritise human well-being. Together with local municipalities, we have initiated numerous regional projects that play a crucial role in transferring our expertise into practical applications.

At the Wind Energy Research Farm, DLR is investigating energy generation for urban mobility, among other things. What exactly is being researched at Krummendeich?

Kaysser-Pyzalla: At the Wind Energy Research Farm, researchers are exploring how we can harness renewable energy. In the field of solar energy research, we are already extremely successful in terms of the design concepts for power plants. This encompasses optimisation efforts in the laboratory, as well as the operation of real power plants. We have successfully inaugurated a parabolic trough power plant in Portugal, and we recently unveiled the Krummendeich wind farm. Wind energy is the second major pillar of renewable energy. At Krummendeich, we are dedicated to further improving the design of



Klaus Hamacher is Deputy Chair of the DLR Executive Board. He is responsible for DLR's administration and operational management. This includes human resources, finance, corporate control, organisational structures, quality and product assurance, internal auditing and joint venture management, major projects and appointment procedures. He is also responsible for the project management agencies. Hamacher studied business administration at the University of Cologne. He has been at DLR since 1987, with several short breaks.



Anke Kaysser-Pyzalla is the Chair of the DLR Executive Board and the leader of its 10,000 employees. She studied mechanical engineering and materials science in Bochum and Darmstadt, before completing her doctorate and qualifying as a university lecturer at Ruhr University in Bochum. Kaysser-Pyzalla has taught at various universities, served as managing director of research institutes and was President of Technische Universität Braunschweig before joining DLR in 2020.

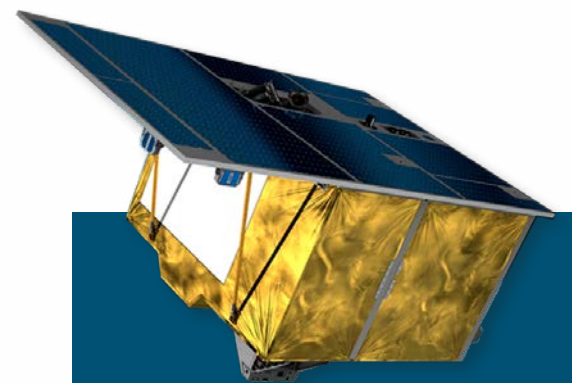
future wind farms. Here, we are researching how to swiftly adapt to changing weather conditions, minimise noise pollution, enhance efficiency and optimise the placement of wind turbines – all of this, of course, with the expertise we bring from aerospace research.

Spaceflight, in particular, has faced criticism for its perceived lack of sustainability. However, satellites play a vital role in monitoring changes on Earth. How does remote sensing of the Earth contribute to sustainable development?

Kaysser-Pyzalla: Remote sensing of the Earth has become indispensable for modern farming methods, for example. It has the potential to enable even more precise management of agricultural land in the future. This not only includes the precise application of fertilisers but also the selection of suitable crops, which depends on soil composition. These insights can be derived from satellite imagery. We also anticipate that satellite imaging will facilitate more rapid detection of plant diseases. We are currently monitoring biomass from space, and in the future, we will be capable of more accurately identifying drought conditions, specifically the lack of soil moisture down to a certain depth.

Mr Hamacher, innovative ideas and new approaches are essential for sustainable development. Research at DLR aims to address the most pressing questions concerning the future. Is that also something that motivates people to work at DLR?

Hamacher: Surveys conducted in recent years have shown that DLR is one of the most popular employers in Germany – not only among research institutions, but also when compared to companies. This applies not only to newcomers but also to personnel who have



The Environmental Mapping and Analysis Program (EnMAP) is the first German hyperspectral satellite mission. Using its two spectrometers, it analyses the radiation reflected from Earth, ranging from visible light to short-wave infrared, at a hitherto unparalleled spectral resolution. These images show the Bosphorus in Turkey. On the left is a true-colour representation; in the centre, differences in vegetation become clear in the near-infrared range; on the right, soil and rock features can be distinguished.



“We have developed a number of measures to enhance work-life balance, diversity and family friendliness that make DLR an attractive employer.”

Klaus Hamacher
Deputy Chair of the DLR Executive Board

been working at DLR for a long time. To maintain this, we have developed a number of measures to enhance work-life balance, diversity and family friendliness that make DLR an attractive employer. Their impact is

visible in published studies. However, our appeal as an employer is also based on our fascinating research – which addresses the sustainable development of society.

Kaysser-Pyzalla: All our research topics address the major economic or political challenges facing society. For us, for example, sustainability also entails security research. After all, we can only live sustainably in a social system such as ours if it can protect itself appropriately against external influences.

The interview was conducted by **Katja Lenz**, who is a Media Relations Editor at DLR.

A STRONGER FOCUS ON SUSTAINABILITY

Three questions for Professor Martin Wiedemann, Chair of DLR's Scientific-Technical Advisory Council (WTR) and Director of the DLR Institute of Lightweight Systems.

Professor Wiedemann, as Chair of the WTR, you are the voice of the DLR institutes and facilities. How are the institutes and facilities directing their research towards sustainability?



■ Our institutes and facilities have long been associated with the topic of sustainability. Our energy research focuses on the production of energy using renewable resources. In our transport research, we optimise transport routes. In aeronautics, our focus is on enhancing energy efficiency. Sustainability is also a key aspect in space research, in fields such as remote sensing of the Earth. All of these research projects consider sustainability without us explicitly labelling it sustainability research.

Does this change the role of research?

■ As new questions emerge, it becomes essential to evaluate them using a

whole-system approach. What makes an action sustainable in a broader context? Consider, for instance, the issue of handling the materials from decommissioned aircraft or wind turbines, which contributed to energy savings in the operation or to energy production. We need to analyse the entire life cycle of a product. This requires expertise and scientific methods, which are among DLR's core competencies.

Research is not possible without consuming resources, is it?

■ Our most valuable resource is knowledge. To acquire knowledge, we must use other resources. Research invariably requires the consumption of energy and materials. As researchers engaged in extensive practical testing, we are aware of the utilisation of resources in our work. However, we very carefully consider our research results and our use of resources.

THE DLR SCIENTIFIC-TECHNICAL ADVISORY COUNCIL

The Scientific-Technical Advisory Council is composed of the heads of institutes and facilities as well as personnel from DLR's research areas and its scientific and technical resources. The Council advises the Executive Board and the Senate on all scientific and technical matters.

HOT SALT

Research for the next generation of solar thermal parabolic trough power plants

SOLAR RADIATION
Falls on the parabolic mirrors and heats the molten salt to 565 degrees Celsius.

PARABOLIC TROUGH COLLECTORS

Curved mirrors with tubes running through the focus. In conventional power plants these are filled with thermal oil; in the EMSP they contain salt.

MOLTEN SALT CIRCUIT

ELECTRIC AUXILIARY HEATING

This can be switched into the circuit when the sun is not shining. It prevents the salt from cooling down and solidifying.

THERMAL STORAGE SYSTEM

Filled with molten salt. If no electricity is needed at the time, the storage tank can retain the heat at temperatures of up to 560 degrees Celsius for approximately 12 hours.

STEAM POWER STATION

STEAM CIRCUIT

CONDENSER

TURBINE AND GENERATOR

Here, electricity is generated using steam.

GRID CONNECTION

CONSTRUCTION OF AN ABSORBER TUBE

Molten salt
absorbs solar energy in the form of heat.

Solar glass
allows more solar radiation to pass through than conventional glass, and a special coating also reduces reflections.

Vacuum
between glass and steel tube for insulation.

Specially coated steel tube
absorbs solar radiation and prevents heat from escaping.

'Getter' material
absorbs the smallest quantities of gases.

In Portugal, DLR and the University of Évora are operating a parabolic trough test plant – the Évora Molten Salt Platform, or EMSP. Unlike commercial parabolic trough power plants, molten salt flows through the pipelines of the EMSP instead of thermal oil. Solar power plants using molten salt can reach particularly high temperatures and thus higher efficiencies. This increases the power yield and thus lowers the electricity production costs.

The development and construction of the plant was part of the 'High Performance Solar 2' project funded by the German Federal Ministry for Economic Affairs and Climate Action. The work was supported by the project management organisation Projektträger Jülich. This infographic shows what a future parabolic trough power plant using molten salt might look like.

A FITNESS STUDIO FOR SPACE

Testing astronaut exercise equipment

by Katja Lenz

The Astronaut Health Enhancement Integrated Countermeasure (ATHLETIC) prototype is located at the DLR Institute of Aerospace Medicine. The exoskeleton device will one day enable high-intensity strength and jump training to be carried out in microgravity against a passively generated force.



A lack of exercise quickly leads to sluggishness. And in space, the effect is quicker and even worse. This is partly due to the microgravity conditions. When you walk or raise an arm on Earth, your muscular strength has to overcome Earth's gravitational pull, but this is almost entirely absent in space. For this reason, astronauts have to make an extra effort to stay fit. That is not all: muscle atrophy in microgravity alters the body's metabolism, and the lack of muscle strength also reduces bone stability. The legs are particularly affected, as they are hardly used in space. As a countermeasure, astronauts on the International Space Station ISS undergo a daily two-hour training session on a treadmill, bicycle ergometer and weight training machine. But in smaller spacecraft, such as the kind envisioned for future missions to Mars, there is no room for this equipment. This is where NEX4EX and ATHLETIC – two concepts for an all-purpose gym for space – come in. DLR editor Andreas Ellmerer tested both prototypes under very terrestrial conditions at the DLR Institute of Aerospace Medicine.

ATHLETIC – jumping while lying down

Climbing into the exoskeleton of the Astronaut Health Enhancement Integrated Countermeasure (ATHLETIC) is easier said than done. To replicate the effects experienced in space for this test, the jump training is not performed standing up, but lying down. "This exercise equipment is designed to reduce the loss of leg muscle and bone mass," says Jonas Böcker of the DLR Institute of Aerospace Medicine, who is leading the study together with Jochen Zange. The ISS has a treadmill and dumbbells for working out: "But they don't really allow for reactive exercises that train the springing properties of the muscle-tendon complex as well as the muscles themselves," says Böcker. The ISS devices would also be too bulky for a longer space mission. However, ATHLETIC isn't exactly dainty either. "It's a prototype," explains Zange. "This is a case of outsmarting gravity." Hence the expansive, heavy support frame. Of course, the rollers beneath the equipment during the test would not be part of the set-up in space either.

In space, astronauts would float into the device, but in the Cologne laboratory, the test subjects have to climb through the frame from below. They wear cycling shoes and their feet are secured in brackets, while a standard bicycle saddle ensures sitting comfort, and a kind

of backpack holds the upper body against the backrest. This is vital to prevent the test subjects from being thrown out of the ATHLETIC device or the entire device from being thrown across the spacecraft under microgravity conditions. Andreas' position within the exoskeleton is adjusted after a few minutes. First, he does a brief warm-up to get used to the movements. Then things get serious with squats – 10 first, then 20 – and lying jumps. "The machine is now adjusted in such a way that almost 100 percent of the test participant's body weight is engaged during jumping," says Jonas Böcker. Increasing the weight further is also possible – as much as 300 kilograms would be possible for astronauts that are also advanced gym enthusiasts.

Initially unfamiliar to even those with considerable gym experience, as the footrest of the ATHLETIC prototype is pushed, the device's backrest pushes from behind. Correct flexion angles and hip positions are essential for enabling the leg, hip and back muscles to work as intended. "Coordination is easier in microgravity," says Zange. Throughout the training session, several parameters, including forces, distances and angles, electrical activity in the leg muscles and heart rate, are displayed on the monitor. The exercises are obviously having an effect. Andreas feels the strain, as the exercises that combine jumping with various forms of strength training leave him out of breath.



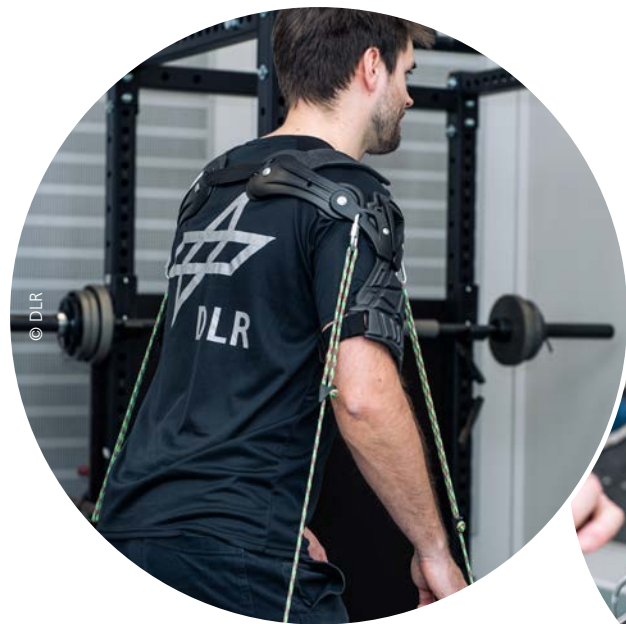
:envihab is a medical research facility of the DLR Institute of Aerospace Medicine. Here, research is conducted into the impact of various environmental conditions on humans and possible countermeasures.

DLR'S SEARCH FOR TEST PARTICIPANTS

The DLR Institute of Aerospace Medicine regularly seeks participants for various research activities. These studies investigate the effects of external conditions on human health, living standards and performance. They cover a wide range of topics. Not only are researchers investigating the effects of microgravity on humans, but also their ability to concentrate when tired and how their bodies cope with reduced oxygen levels at high altitudes.

Bed rest studies are among the best-known research conducted at :envihab, the research facility operated by the DLR Institute of Aerospace Medicine. Here, participants spend long periods of time lying down, with their bodies tilted in a six-degree head-down position to simulate the effects of microgravity on the human body.

🔗 Overview of all studies (in German) at: <https://dlr-probandensuche.de/>



Andreas is connected to NEX4EX via the cords (left). On the screen, researchers check how well he can keep his centre of gravity over the centre of the platform (right).

NEX4EX – balance, wobble and squat

Onto the next device. Compared to the ATHLETIC exoskeleton prototype, the Novel Exercise Training Hardware for Space Exploration (NEX4EX) appears easier to manage. Andreas begins by attaching a shoulder strap and standing on a base plate. Four cords are then hooked from his belt to the four corners of the base plate, which covers an area of approximately one square metre. In microgravity, the cords would be tightened to simulate the person's body weight pressing against the plate to mirror conditions on Earth. In addition to muscle training, this prototype aims to refine the spring properties of the muscle-tendon complex, offering several workout setups.

Balance training: The cords are pulled down one by one. Andreas needs to push against the resulting force with his legs slightly bent to maintain his balance. The computer randomly selects the pulling directions demanding concentration and quick reactions from Andreas, who also has the added difficulty of smiling for the camera.

Balance board: The base plate wobbles and challenges the user's stability. How does it feel? "Like riding a mountain bike. But without handlebars." So it's a little familiar.

Strength and jump training: The system is tilted horizontally, while an extra plate with shoulder pads supports the user's back. The user

then does squats and jumps, sometimes from a crouch position, sometimes hopping on the forefoot.

NEX4EX allows researchers to monitor different forces and movements, muscle activity and heart rate via monitors. "The loads on the leg structures are quite high," says Böcker. This led to sore muscles among the participants who tested the apparatus at DLR, including our editor Andreas, who felt as though he had completed an intensive gym session.

Next test on a parabolic flight

The next step is to test the equipment on a parabolic flight. To conduct such a test, a research aircraft makes a steep ascent before reducing power and descending quickly to a lower altitude, before repeating the process. This flight pattern creates intervals of approximately 20 seconds during which passengers experience microgravity that simulates the conditions experienced in space. When the time comes, DLR will again seek out volunteers to test the space gym. For more information and application details, contact 'DLR Probandensuche'.

Katja Lenz is a Media Relations editor at DLR.

THE LATEST STUDY

Ten participants tested the newly developed NEX4EX and ATHLETIC training equipment. They were selected according to the following requirements: aged between 30 and 60 years old, between 1.5 and two metres tall, weighing between 50 and 100 kilograms and physically fit.

The two training devices were developed by Space Applications Services on behalf of the European Space Agency (ESA). German company Deuter was also involved in ATHLETIC, while Novotec, AnyBody Technology and the University of Konstanz contributed to NEX4EX. The DLR Institute of Aerospace Medicine conducted medical and scientific evaluations of the equipment. The researchers also made suggestions for further development.

ESA astronaut Samantha Cristoforetti exercised regularly during her time on the ISS to prevent the loss of muscle and bone mass. Unlike ATHLETIC and NEX4EX, the ARED on the ISS uses an active force mechanism that requires external power and generates heat.



IN BRIEF

THE URBAN AIR TRANSPORT OF THE FUTURE



Design of a tiltrotor air taxi with six swivelling rotors

Drone and highly automated air taxis offer the great promise of enriching urban air transport with new capabilities. In the HorizonUAM (Urban Air Mobility) research project, DLR looked at what requirements must be met so that we can actually use urban air mobility in a few years' time, and what safety, efficiency, sustainability and affordability requirements must be met to make these concepts feasible. To this end, the researchers developed concepts for aircraft, flight corridors and stopping points ('vertidromes') that integrate into the existing infrastructure. They showed that numerous stops and affordable prices are important for the demand for air taxi transport services. The price range for a profitable operation is between four and eight euros per kilometre. Flight tests with several drones as models for air taxis took place at the National Experimental Test Center for Unmanned Aircraft Systems at DLR's Cochstedt site. Here, the researchers were able to successfully test their concepts.

EUCLID EXPLORES THE DARK UNIVERSE

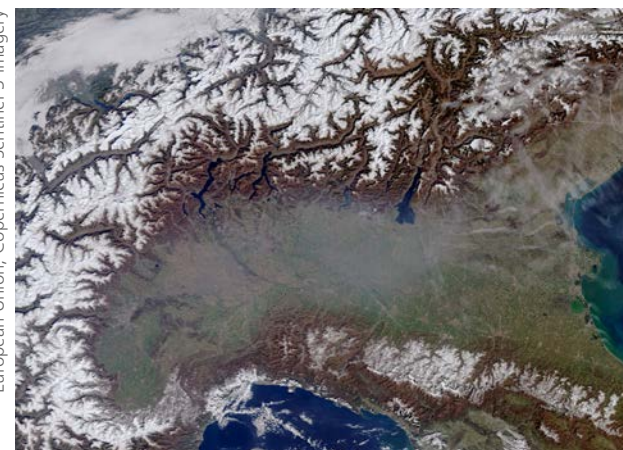
Since the end of July 2023, the Euclid space telescope has been on the trail of the two great unknowns of the Universe – dark matter and dark energy. Together, these components make up 95 percent of the Universe. Nevertheless, they still hold many secrets. The telescope is intended to help unravel them. To do this, it will observe about one-third of the entire Universe within the next six years. The telescope, which weighs about two tonnes, orbits the second Lagrange point (L2), which is 1.5 million kilometres from Earth. Euclid is a mission of the European Space Agency (ESA). It was launched on 1 July 2023 on board a Falcon 9 rocket from the US company SpaceX. Germany is the largest contributor to the ESA science programme, funding around 21 percent of the mission. The German Space Agency at DLR is responsible for coordinating Germany's contributions to ESA on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK).



The telescope is mounted on the SpaceX Falcon 9 launcher adapter

25 YEARS OF THE COPERNICUS EARTH OBSERVATION SYSTEM

What began in 1998 under the name 'Global Monitoring for Environment and Security' (GMES) is today Europe's largest and most successful Earth observation programme. Copernicus is a joint programme of the European Union (EU) and the European Space Agency (ESA). The information from the programme's current seven Sentinel satellites is used to research and monitor climate change, as well as for applications in modern agriculture and disaster management. The data also serve as the basis for important international environmental and climate protection agreements, for example, within the framework of the United Nations (UN) climate conferences and the UN Sustainable Development Goals (SDGs). The Sentinel data and Copernicus services are free of charge – whether for government users, the scientific community, businesses, start-ups or non-profit organisations and citizens.



This image was acquired in March 2023 by one of the Copernicus Sentinel 3 satellites. It shows the low level of snow cover in the Italian and Swiss regions of the Alps. In this area, the daily snowmelt equivalent was significantly below the previous record value of 2021/2022.



SIMPLY MARVELLOUS!

DLR's High Resolution Stereo Camera has been in orbit around Mars for 20 years

by Ulrich Köhler

The European Space Agency's (ESA) Mars Express spacecraft was only intended to orbit Earth's planetary neighbour for two years. But, as of December 2023, it will have been operating there for 20 years. One of the seven experiments on board is the High Resolution Stereo Camera (HRSC), which was built by DLR in cooperation with German industry. To this day, the image data acquired by this instrument continues to provide important scientific insights – from the traces left by water and ice on the Red Planet, some of which date back billions of years, to deciphering the planet's puzzling climate history and the current changes in the martian landscape caused by wind and weather.

Images: ESA/DLR/FU Berlin, CC BY-SA 3.0 IGO



When the seasons paint pictures on Mars: The onset of spring sublimates the icy cover of the high southern latitudes and conjures this almost impressionist effect on the landscape.

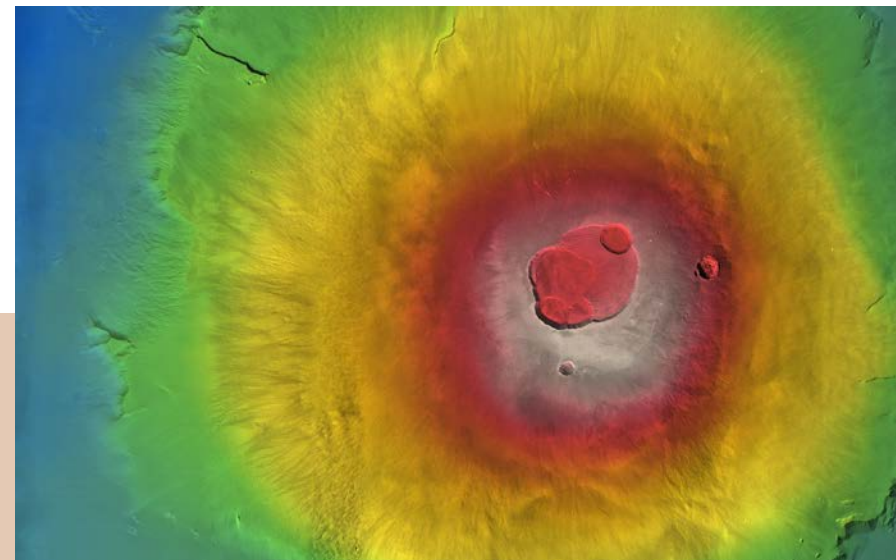
This mosaic of a hemisphere of Mars shows the striking 4000-kilometre-long rift valley system of Valles Marineris in the centre and the huge volcanoes of the Tharsis rise with the highest volcano in the Solar System, Olympus Mons, at the upper left edge of the image. Simply exquisite, Mars, which is also called the Red Planet due to its oxidised iron-containing minerals.



The Hydraotes Chaos region, first imaged during the 18th orbit of Mars Express, was unveiled to the public in January 2004. Since then, the maze of mesas over 2000 metres tall has been repeatedly observed using DLR's HRSC.



This iconic Mars Express image shows water ice at the bottom of a crater near the north pole of Mars. The unnamed impact crater has a diameter of about 35 kilometres and lies in the northern lowlands of Vastitas Borealis.



Digital terrain model of Olympus Mons, the highest mountain in the Solar System (the colours indicate increasing elevation from blue to grey). At its base, the giant volcano has a diameter of about 600 kilometres. The volcanic giant rises more than 22 kilometres above the blue-coloured lowlands of Amazonis Planitia in the west.



Find out more about the Mars Express mission: [DLR.de/mars_en](https://www.dlr.de/mars_en)

Twenty years ago, on 2 June 2003, during a fine summer's day in Berlin, some 200 pairs of eyes from the fields of scientific research, technology, space administration and the media witnessed the launch of Europe's first mission to another planet on large screens in Berlin-Adlershof. The launch of Mars Express from the distant Kazakh spaceport of Baikonur went perfectly. The sense of relief was enormous, yet the celebrations remained muted. The disappointment over the loss of two DLR camera systems during the ill-fated Russian Mars 96 mission, which crashed into the Pacific Ocean a few hours after launch in November 1996, was still too fresh.

On arrival on 25 December 2003, once again with a DLR camera on board, (almost) everything went as expected. This time, the Mars Express orbiter, referred to as 'MEX' by everyone involved, slowed down to enter an orbit around Earth's outer neighbouring planet. The previously detached British lander, Beagle 2, arrived on Mars but transmitted no data. However, all seven of the orbiter's experiments

worked perfectly. Today, after years and 25,000 orbits later, in a small technological miracle, they continue to do so – with minor limitations.

ESA had originally planned the mission to last only one Mars year, or just under two Earth years. But like the famous VW 'Beetle', MEX is indestructible. And so is the HRSC instrument developed at DLR, which is still unparalleled in planetary research. Over the past two decades, HRSC has recorded Mars globally in high-resolution, colour and in 3D, using technology that, despite being completely outdated from today's perspective, is absolutely reliable.

The DLR Institute of Planetary Research in Berlin plans the HRSC image acquisitions, manages their usage and, together with the Freie Universität Berlin, processes the image data of the martian surface acquired by nine sensors into high-quality data products. For the first time, these products have allowed geological processes to be quantified and morphological features to be studied spatially. The topographic

data have also been used by NASA to select landing sites for other missions – an extremely valuable dataset for scientific research and space exploration. In addition, Mars Express has served as an orbiting radio relay station connecting NASA and Chinese landers with Earth when needed. This will continue for the foreseeable future. ESA has just extended the mission until the end of 2026, with the possibility of further extension until the end of 2028. Not every 'Beetle' has lasted that long!

Ulrich Köhler is responsible for public relations at the DLR Institute of Planetary Research and, as a planetary geologist, has been 'on board' the DLR science team from the very beginning of the Mars Express mission. Over the 20 years of MEX, he has given hundreds of talks on the mission, described around 250 landscapes and commented on approximately 2000 images.

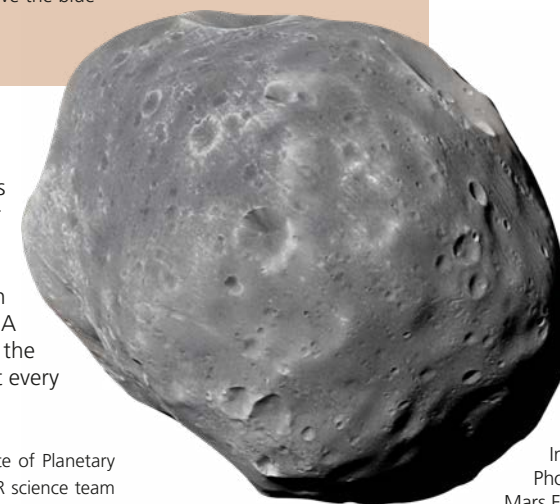
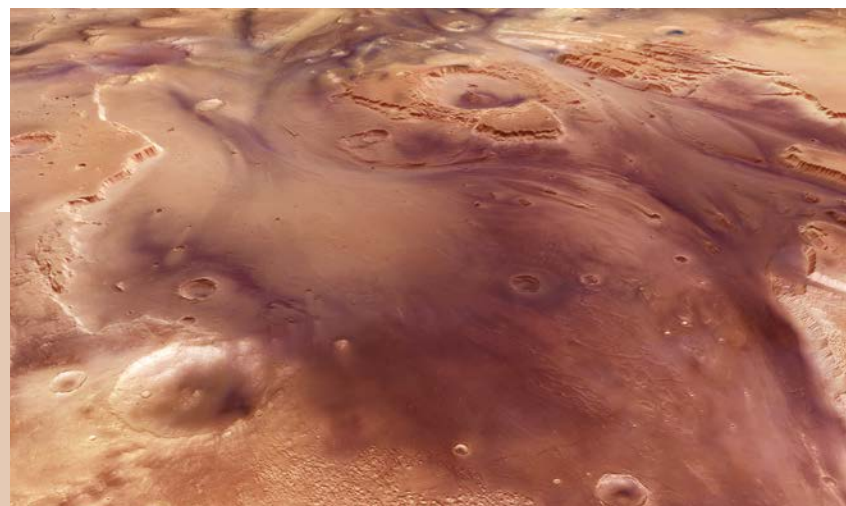


Image of the martian moon Phobos. The HRSC uses the Mars Express flybys to study this moon more closely. But the origin of the martian moons Phobos and Deimos has not yet been conclusively explained. The Martian Moons eXploration mission (MMX), which is scheduled to launch in September 2024, has the task of exploring the two moons more closely.



River valleys eroded by flowing water were first observed by the Viking missions of the late 1970s. The high-resolution digital terrain models of the HRSC not only enable better geological interpretations, but also allow quantitative statements to be made about water quantity and erosion rates, like here in the Kasei Valles.



A dark dune field covers the floor of the Rabe impact crater, whose floor is pierced by pits and cavities. On the slopes of the pits, thin dark lines reveal the volcanic ash layers from which the dune material originates. In this contrast-enhanced image, the volcanic sands that are in reality grey-black appear bluish.



Tune in to the German-language podcast at [DLR.de/Podcast](https://www.dlr.de/Podcast) and on all popular streaming platforms.



THE MARTIAN

In conversation with a planetary scientist

Interview with Daniela Tirsch

Only six people in the world have the privilege of naming surface features on Mars – and Daniela Tirsch is one of them. Now a planetary geologist at the DLR Institute of Planetary Research, she never dreamed of such a career as a child in Berlin – she wanted to be a dancer. The researcher tells us about her passion for the black dunes on Mars and explains why the most beautiful sand is on Earth – and why it is green.

In addition to images, audio recordings from Earth's neighbouring planet have been available for some years. In February 2021, for example, the Perseverance rover recorded the wind blowing across Mars. What goes through your mind when you hear something like that?

This sort of thing is very close to my heart – the dunes of Mars are my favourite topic and were the subject of my doctoral thesis. They are particularly beautiful and dark. Dunes are formed by the wind. I got goosebumps when I first heard the sound of that wind recorded on Mars itself. At the same time, I wondered why someone hadn't thought of sending a microphone to Mars sooner.

You've always had a soft spot for sand: you've been collecting sand from all over the world for many years. But what do you find so special about the dark dunes on Mars?

Most of them are found in impact craters. Some of the material was carried there by the wind, but it mainly originates from the dark layers exposed on the crater walls. The dunes look beautiful and consist of greyish-black volcanic material. If you want to study such dunes on Earth, you have to go to areas where volcanism and a relatively dry

climate coincide. Some of these are very beautiful places – another great aspect of my research. For example, I have been lucky enough to go to Hawaii twice to study dunes in the Ka'ū-Desert, which are similar to those on Mars. That was amazing.

What is your favourite sample of sand, and why?

Oh, that is an easy question. It is from Hawaii, and I love it because the sand is green. It consists primarily of the volcanic mineral olivine. The sand is found at Green Sand Beach, a well-known place on the Big Island. This beach is quite difficult to get to. We walked through the heat for almost two hours and suffered many blisters. But then this cliff opened up before us, revealing a picture-perfect beach made of green sand. I had never seen anything like it before.

How did you become a planetary scientist? Planetary research was not originally on your wish list.

To be honest, I never dreamt of planetary research as a child. I actually wanted to be a dancer, but I had to give up on that dream for health reasons. So, I went to university and studied what was then my favourite subject at school – geography with a minor in geology and ecology. I loved it! During my job search, I came across a doctoral position at DLR. I was offered the job during the interview and thought: "So, now I am a planetary scientist!" On my first day at work, I was given a book about Mars... and that is how it all began.

Now you are involved in the Mars Express mission. The High Resolution Stereo Camera (HRSC) instrument used on the mission was developed at DLR and regularly delivers images of the Red Planet.

Yes, I really enjoy this aspect of my work. HRSC allows us to create digital terrain models and images of the surface of Mars, so we can

show Mars in colour and three dimensions. I think our images of Mars are very aesthetically pleasing, too.

You are also a member of an International Astronomical Union (IAU) working group on naming surface features on Mars. Have you been responsible for any particular names?

Well, I should start by saying that I'm extremely proud to be one of only six people in the world who get to name surface features on Mars. That said, we do not think up names, we just receive suggestions. I particularly like naming impact craters that are less than 50 kilometres in diameter. These are given the names of villages or smaller towns – those with a population under 100,000. Before I

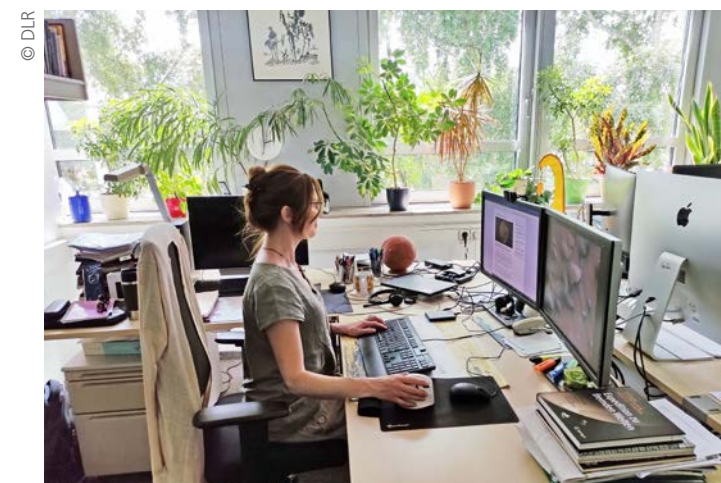
became part of the committee, I suggested naming a crater 'Jena'. At that time, though, Jena had an official population of 109,000 people, so my suggestion was rejected. So I proposed the name of my favourite village in Thailand – Pai. So now there is a crater on Mars called Pai. I still think that it is nice that you can bring Earth to Mars by immortalising the names there.

Thank you very much for such an interesting interview and a fascinating insight into the Red Planet.

The DLR-FORSCHtellinggespräch podcast is produced by Daniel Beckmann, Andreas Ellmerer and Antje Gersberg from DLR's Corporate Communications Department.



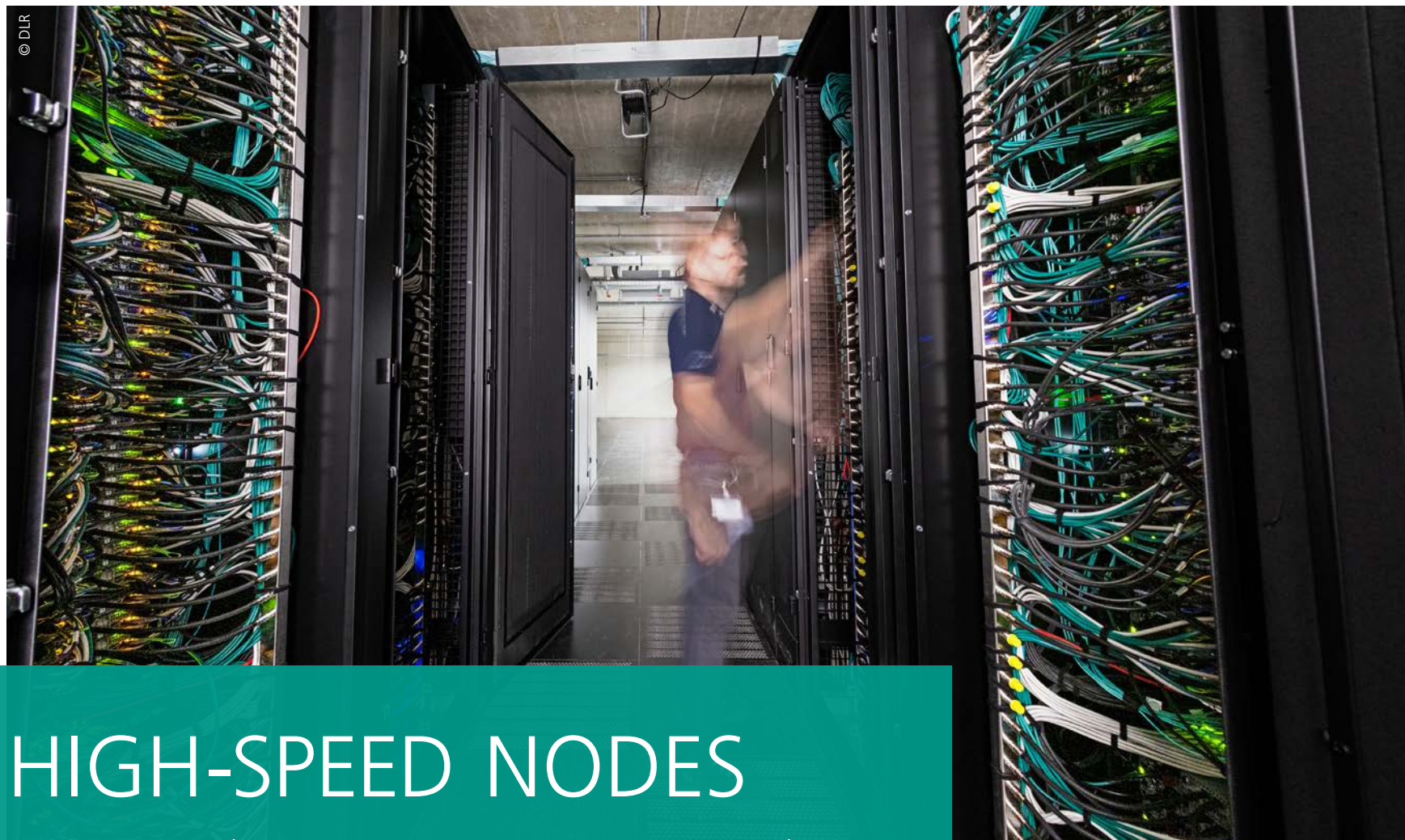
Daniela Tirsch (centre) during field work on a large dark dune in Hawaii. Here, sand samples are being taken from different depths of the dune so that the depositional conditions over time can be deciphered.



The day-to-day work of a planetary geologist involves a great deal of office work. But thankfully this is often combined with looking at and analysing beautiful images

THE DLR INSTITUTE OF PLANETARY RESEARCH

At the DLR Institute of Planetary Research in Berlin-Adlershof, scientists conduct research into the Solar System, particularly with regard to the origin, formation and development of planets, their moons and small planetary bodies such as asteroids and comets. Among other things, they are concerned with the question of whether life exists only on Earth or is also possible on other celestial bodies – such as extrasolar planets orbiting other stars. For this purpose, they develop cameras, spectrometers, laser altimeters and radiometers, which are used on missions to the planets, moons and small bodies found in the Solar System.



HIGH-SPEED NODES

DLR's CARA and CARO supercomputers support research projects with their exceptional computing power

by Anja Philipp

In 1937, Konrad Zuse developed the world's first fully programmable computer. Powered by the electric motor from a vacuum cleaner, and with a clock speed of approximately one hertz, it went down in history as the first digital computer. The era of vacuum cleaner motors has long since faded into history; motherboards, central processing units, graphics processors and disc drives have become vital components. Nowadays, computers can perform several billion calculations per second, but even these modern systems are frequently pushed to their limits by scientific researchers. Simulating phenomena such as the airflow around aircraft wings or the behaviour of the propellants inside rocket engines demands computers with much higher performance. DLR operates two such supercomputers at its sites in Dresden and Göttingen.

High Performance Computing (HPC) surpasses the power of conventional personal computers by leveraging a network of individual computers referred to as nodes. This interconnected system is commonly referred to as a cluster, in which the computers work together seamlessly and function as a single, powerful supercomputer, processing vast quantities of data at impressive speeds. A typical cluster processes data approximately 10,000 times faster than a standard laptop. DLR's two HPC supercomputers are named CARA and CARO after their official title – 'Computer for Advanced Research in Aerospace'. CARA is located in Dresden and CARO in Göttingen. They are operated by the DLR Institute of Software Methods for Product Virtualization, which functions as DLR's HPC competence centre. "Not everyone who would benefit from DLR's HPC clusters is familiar with them yet. The competence centre supports DLR's institutes by providing advice to new users who are interested in accessing the

systems," says Daniel Molka from the Institute of Software Methods for Product Virtualization. The competence centre is run by the High-Performance Computing Department. The operation of the cluster is carried out in cooperation with the Center for Information Services and High Performance Computing (Zentrum für Informationsdienste und Hochleistungsrechnen; ZIH) at TU Dresden and the Society for Scientific Data Processing (Gesellschaft für wissenschaftliche Datenverarbeitung Göttingen; GWDG).

CARA and CARO by the numbers

The CARA supercomputer is equipped with almost 150,000 processor cores. CARO in Göttingen has approximately 175,000 cores. In the course of an upgrade, some nodes were equipped with graphics cards (GPUs). When it entered operation in July 2022, CARO secured a place



CARA is located in the Lehmann Center Data Center at the Dresden University of Technology

among the top 150 fastest computer systems in the world. This cluster achieves a computing speed of 3.46 petaflops, meaning it can execute 3460 trillion floating point operations per second.

Formidable computing power at DLR

Researchers use the computational power of CARA and CARO to carry out complex simulations or work with artificial intelligence methods. Currently, approximately 25 DLR institutes are utilising the capabilities of the two supercomputers and others have shown interest. In particular, institutes specialising in aeronautics – such as the Institute of Aerodynamics and

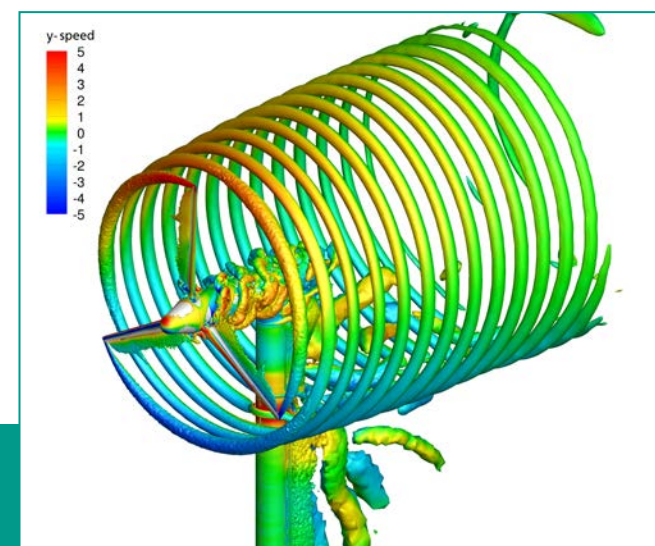
Flow Technology and the Institute of Aeroelasticity – make extensive use of these supercomputers.

CARA and CARO often come into play to conduct elaborate simulations. By employing physical and mathematical models, various components of aircraft or wind turbines, for example, can be translated into the virtual world. To gain a better understanding

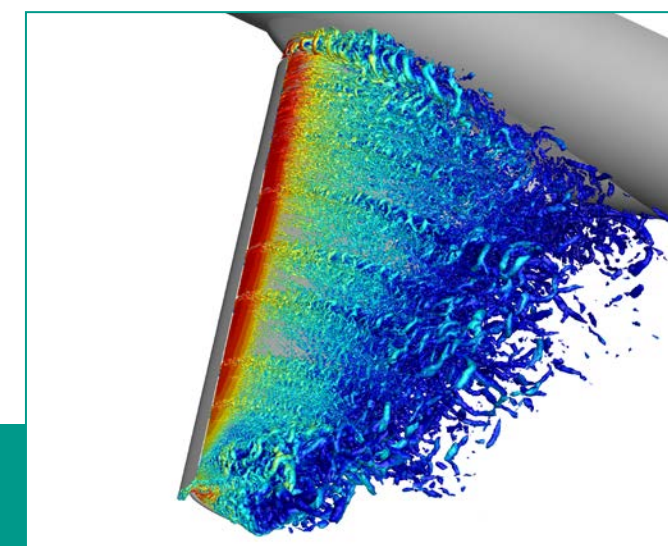
of flow physics as a basis for technology development, these simulations can become exceptionally complex. "When we model a wind turbine, we go into the smallest details," explains Cornelia Grabe from the Institute of Aerodynamics and Flow Technology. This approach enables the researchers to conduct virtual tests on flow behaviour or structural mechanics and to investigate and evaluate important performance parameters such as efficiency, durability or sound generation. As the level of detail increases and additional phenomena are taken into consideration, the demand for computing power rises. "The advantage is that we can use such simulations to test physical experiments in advance – in the past we had to build prototypes and carry out tests. Today, much of this is done virtually," says Dirk Schneider from the Institute of Space Propulsion. However, despite the significant advancements in simulations, experiments remain essential, as, ultimately, the results of the simulations must be confirmed in the real world.

Wide range of research areas

Flow simulations take up the largest share of CARA's and CARO's computing time. In one application, researchers at the DLR Institute



CARO and CARA are used to simulate the aerodynamics and flow behaviour around wind turbines



This flow simulation illustrates the behaviour of air flowing over an aircraft wing. The flow pattern changes depending on the aircraft's velocity and angle of attack.



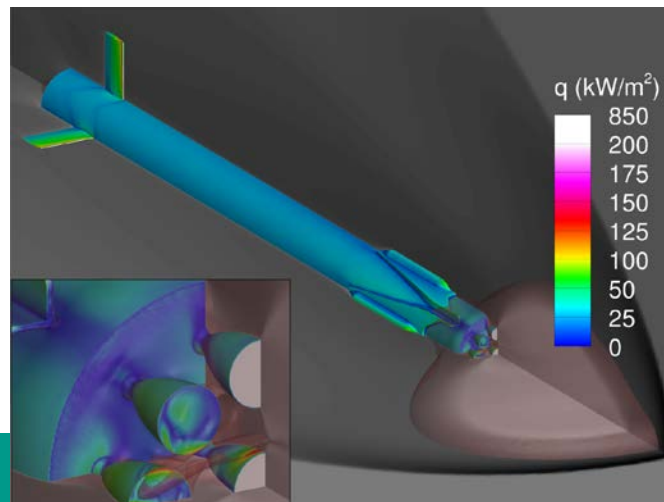
The CARO high-performance computer is located in Göttingen. Among other things, it is used for the numerical simulation of aircraft and wind turbines.

The combustion and heat transfer processes in liquid-propellant rocket engines are being modelled at the DLR Institute of Space Propulsion in Lampoldshausen. When these engines are being developed, it is important to be able to predict the thermodynamic states in the combustion chamber as well as the cooling processes. For these simulations, the researchers take up considerable resources at the CARO HPC cluster in Göttingen. "The simulations are becoming increasingly complex," says Sabine Roller, Director of the Institute of Software Methods for Product Virtualization, adding: "This is because with increasing computing capacity, more detailed representations are possible in the simulations." In addition, institutes with a focus on artificial intelligence are increasingly using the computing

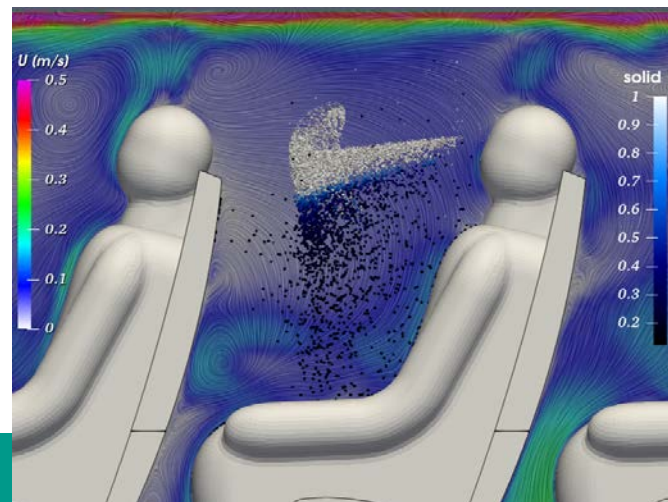
power of supercomputers. Research areas that work with Big Data are also turning to CARO and CARA. This is especially the case when extensive statistical models that incorporate large amounts of data are being created.

Software options for applications

Certain computer software is required for a simulation to run on CARA or CARO. This software is typically developed by researchers from the various DLR departments. Another option is to access open-source software. Here, the source code is freely accessible, so that changes can be made to suit the project and the research. Commercial software typically allows for individual parameter adjustments, but otherwise often has limited flexibility. For this reason, DLR scientists typically use software that they have written themselves or that can be adapted. They are supported in this by experts from the Institute of Software Methods for Product Virtualization. These specialists possess in-depth expertise in computer science and programming and have a comprehensive understanding of the computers themselves.



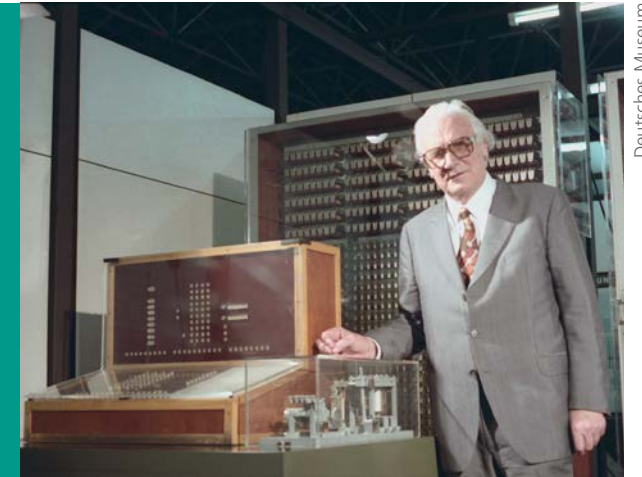
The Spacecraft Department in Göttingen is conducting research into the aerodynamics of reusable launch vehicles. This image shows the thermal load on a rocket's exterior during a braking manoeuvre in reverse flight, when three of its nine engines are running. Normally, the rocket would heat up considerably during re-entry into Earth's atmosphere. The exhaust plume created by the three central engines shields the underside of the rocket from the hot air flow and prevents this.



This HPC simulation shows a cabin in which thermally representative mannequins are sitting. It has been used, for example, to investigate various ventilation concepts. Among other things, the researchers investigated how exhaled particles are distributed in the surrounding environment.

THE FIRST COMPUTERS

The use of computers in aeronautical research dates back to the 1940s. Konrad Zuse (1910–1995) developed his first electronic calculating machines during the 1930s. In 1939, Zuse introduced the experimental Z2 computer to experts at the German Aviation Research Institute (Deutsche Versuchsanstalt für Luftfahrt; DVL) in Berlin-Adlershof – one of DLR's predecessor organisations. Recognising the potential of this innovative computing machine, the DVL provided support for Zuse's work. By 1941, Zuse had unveiled the Z3, the world's first operational, programmable and fully automatic calculating machine. This could be used for the analysis of flutter phenomena in aircraft – a difficult and time-consuming task to carry out manually. In early 1945, Zuse successfully transported the improved Z4 to the Aerodynamic Research Institute (Aerodynamische Versuchsanstalt; AVA) in Göttingen, another of DLR's predecessors, where it was temporarily stored. The Institute's directors were astounded by the machine's performance during a demonstration.



Konrad Zuse next to the Z3

© DLR



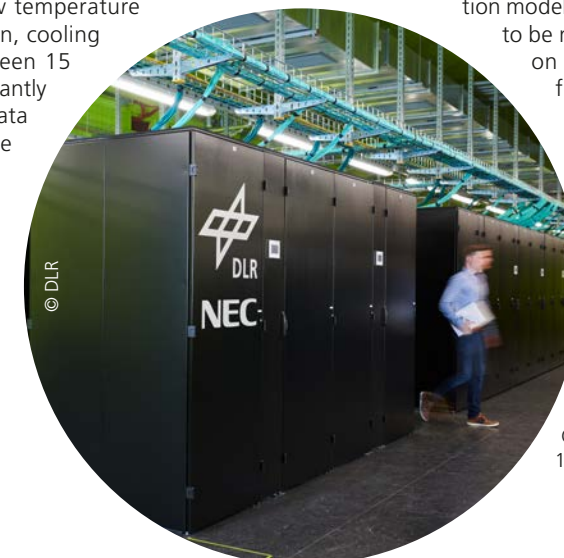
Developing aircraft and their engines is extremely complex. Simulations accelerate and facilitate this process.

Typically, the simulations are executed concurrently on the supercomputers. By doing so, the DLR experts aim for a continuous and high utilisation of the computers. Most of the calculations only use a small part of the machines, while a few take up a quarter or half of their current capacities. In addition to the varying number of nodes used, the calculations performed by the users also differ greatly in their runtimes. These range from a few minutes to several days. The resources must be distributed as fairly as possible among the participating institutes and their users. Keeping the utilisation high requires good planning.

Upgrades are inevitable

When we purchase a new laptop, it is certain that this model will soon become obsolete due to further technological developments. Supercomputers are no different. Keeping the high-performance computers up to date with the latest technologies is vital for research work with increasingly complex simulation requirements. Therefore, DLR intends to operate each supercomputer for a service life of approximately five to six years before they receive the hardware upgrades necessary to meet the demand for increasingly complex simulations. "At present, there is no better alternative to high-performance computers. We anticipate that people will still be working with them in 30 years' time," says Daniel Molka. The increasing complexity of aircraft simulation models means that the HPC clusters will continue to be needed in the future. The current emphasis on climate-friendly air transport may lead to future aircraft designs that differ significantly from those that are in use today. However, before these new designs can be built and tested, numerous simulations will have to be run on DLR's supercomputers.

Anja Philipp works in the Corporate Communications Department for DLR's Eastern Region.



CARA in Dresden has almost 150,000 processor cores

High energy consumption put to good use

The computing power of CARA and CARO requires a lot of energy. With a power consumption of up to 1200 kilowatts (CARA) and 800 kilowatts (CARO), the high-performance computers are among the major power consumers at DLR. The two computers use a hot-water cooling system with a flow temperature of 35 degrees Celsius – for comparison, cooling water temperatures are usually between 15 and 18 degrees Celsius and are significantly more energy-intensive. The Dresden data centre uses the waste heat from the water cooling to heat the surrounding buildings. There are also plans to integrate the data centre into Dresden's district heating network. At CARO in Göttingen, the surplus heat is used to warm the greenhouses operated by the Faculty of Agricultural Sciences.

THE FIRST OF ITS KIND

The DLR Quantum Computing Initiative is focusing on real-life applications for quantum computers

by Felix Knoke



XQ1i is the first quantum computer manufactured for the DLR Quantum Computing Initiative. It was delivered to the DLR Innovation Center in Ulm during May 2023.

eifertfotodesign.de

Quantum computers are designed to solve problems that conventional supercomputers are unable to address, whether this is devising new materials, establishing improved routings, cracking complex optimisation problems or facilitating ultra-efficient machine learning. As a universal quantum-mechanical tool, they offer enormous potential for research, industry and business. However, this exciting technology has not yet made the leap from basic research to practical applications. The DLR Quantum Computing Initiative is set to change that. Together with partners from industry, business, start-ups and research, it is developing prototype quantum computers and the necessary technologies and applications. The first projects have already started.



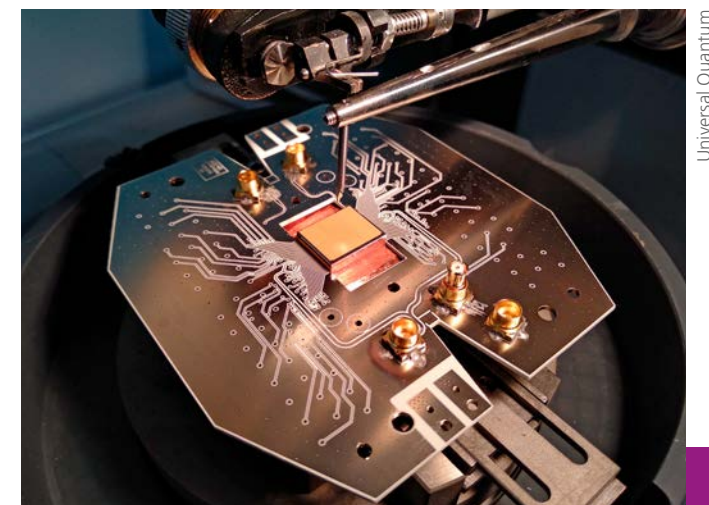
Diamonds are a promising candidate material for quantum processors. The electronic state of nitrogen vacancy sites (NV centers) is revealed when they are excited with green light. The system responds with a red fluorescence.

THE TREMENDOUS POTENTIAL OF QUANTUM COMPUTERS

There are particularly complex computing problems that only quantum computers can solve efficiently – with enormous positive consequences for research, business and society. Due to their special way of performing calculations, quantum computers enable, for example, breakthroughs in the optimisation of difficult logistics tasks, in the development of novel materials and the simulation of chemical processes and physical systems. As a universal quantum-mechanical tool, they support the development of innovative quantum technologies such as extremely sensitive sensors and absolutely interception-proof communications. But before society can benefit from the tremendous potential of quantum computers, research and development on the hardware foundations and possible applications must be continued, and an ecosystem for industrial use must be established.

When an inconspicuous van pulls up in front of the DLR Innovation Center in Ulm, there is little to indicate that history is being made. The doors open to reveal a sparsely loaded flatbed – a pallet and pallet lifter, some odds and ends, and a foil-wrapped crate the size of a refrigerator.

But this refrigerator-shaped package contains something important – a quantum computer. Leipzig-based start-up XeedQ has built it for the DLR Quantum Computing Initiative (DLR QCI). The small, four-qubit system has a somewhat awkward name – XQ1i – and is the first device of its kind. Admittedly, the XQ1i cannot solve any serious problems just yet. Instead, it will give the DLR research teams their first experience with real quantum computing hardware, which will provide them with a head start as soon as larger, more complex machines become available.



Universal Quantum

To date, DLR has commissioned nine quantum computer projects and two supporting technologies from start-up companies. Researchers in Hamburg have mainly been working on quantum computers based on ion trap technology, while their counterparts in Ulm have concentrated on technologies based on neutral atoms, photons and NV centers. An analogue computer serves as a complementary platform for hybrid computing. This image shows an ion trap quantum processor from Universal Quantum, manufactured as part of the DLR QCI project Toccata.

“As the DLR Quantum Computing Initiative, we have set out to pave the way for quantum computers, from basic research to industrial applications,” says Robert Axmann, Head of the DLR QCI. “This will not happen overnight. There are many challenges involved in developing the necessary technologies and putting the structural necessities in place so that quantum computers can be used commercially on a large scale.”

Technology transfer at two sites

To aid effective technology transfer, DLR has established two innovation centres, one at its Ulm site and one in Hamburg. There, contracted companies and research teams have access to clean rooms, offices, workshops and laboratories. DLR research projects, industry, the start-up scene and future users of quantum computing come together here. By combining infrastructure and expertise, DLR enables deep-tech start-ups without their own laboratories and production facilities to develop and manufacture their own hardware and technologies at an industrial level. Ultimately, the quantum computers created as part of the DLR QCI will be made available to DLR institutes and interested partners via a quantum computing platform. By fostering the close connection between research, science, industry and business, DLR is supporting the German government's goal of putting Germany and Europe in a prime international position and consolidate their status at the forefront of this technology. DLR commissions complete systems that it can use itself, while at the same time enabling start-ups to develop their ideas to market maturity. The resulting intellectual property will remain with DLR to enable the strategic development of these technologies in Europe without the risk of expertise moving abroad.



© DLR

It might look like a refrigerator, but XQ1i is a quantum computer, and the first of its kind. Here it is being moved into the DLR Innovation Center in Ulm.

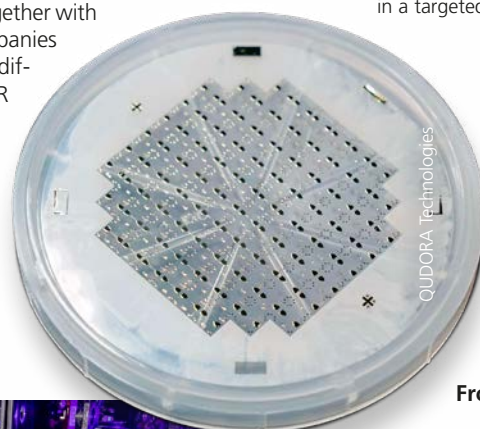


Qubits are selectively produced through the implantation of nitrogen into very small diamond wafers



The Ummendorf-based start-up Diatope vapour-deposits precisely defined diamond layers onto a high-purity diamond wafer in a clean room

An ion trap chip from the Braunschweig start-up Qudora. Individual ions are placed on these structures in a targeted manner to be used as qubits.



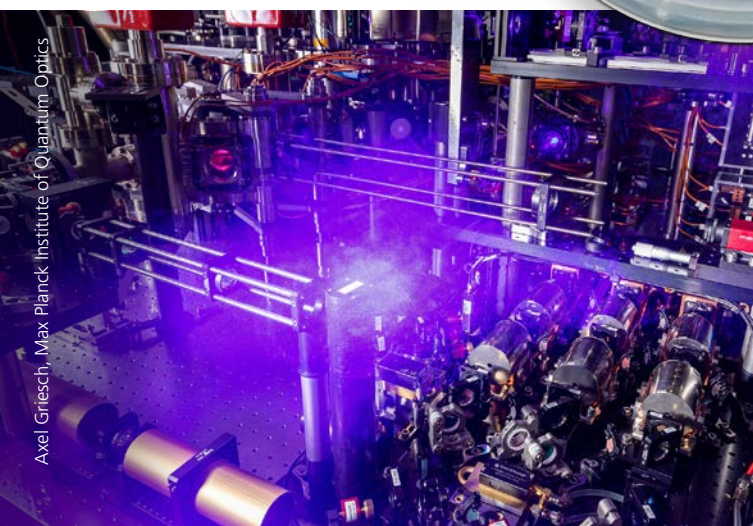
chain from suppliers to applications, the DLR QCI is strengthening the entire spectrum of expertise in the German quantum computing ecosystem."

In Hamburg, for example, researchers are focusing on the industrial production and use of quantum computers based on ion traps. In Ulm, meanwhile, the focus is on qubits created using Nitrogen-Vacancy (NV) centers, neutral atoms and photonic systems.

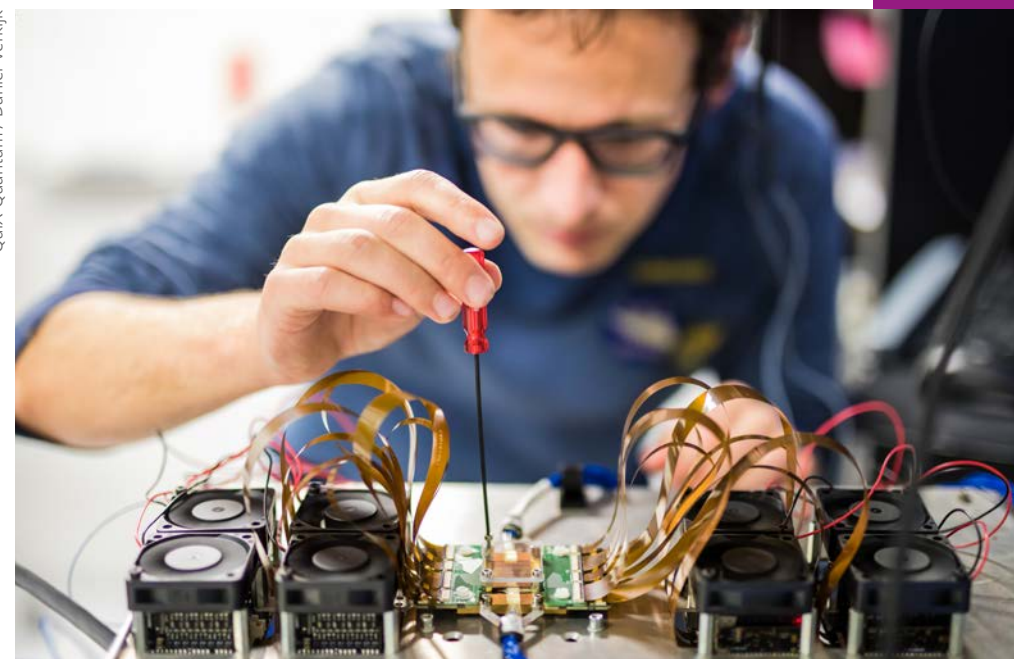
From the laboratory to the outside world

There were a number of obstacles in getting the XQ1i from the van to the lab at the DLR Innovation Center. XeedQ founder Gopi Balasubramanian and the DLR QCI hardware team combined forces to manoeuvre the heavy computer into a passenger lift. The XQ1i is a robust system, so it works at room temperature and can withstand a bumpy ride. This distinguishes it from other approaches to quantum computing, which may require extensive cooling systems or complex control and measurement units.

The XeedQ team has already moved into an office on the second floor of the DLR Innovation Center in Ulm. From there, XeedQ will work with two companies at the Ulm site that provide enabling technologies – tools necessary for developing the quantum computing ecosystem. Diatope, a start-up based in Ummendorf, near Ulm, produces special diamonds for NV-center-based quantum computers. As part of the DLR QCI, meanwhile, Advanced Quantum is developing an analysis platform for the quality assurance of such diamond qubits. Using the expertise of both companies, XeedQ aims to expand its NV-center platform to an industrial



The start-up Planqc, from Garching, near Munich, is developing an advanced quantum computer for the DLR QCI using neutral atoms.



A lot of manual work is still required in the development of this photonic quantum computer, constructed using optically integrated circuits.

scale. For companies like XeedQ and SaxonQ, which is also developing a mobile NV-center quantum computer for the DLR QCI – this means technological advancement and greater independence at the same time. Quantum technologies are still so new that some components are only available from a single supplier. This dependency can stand in the way of sovereign hardware access for the German high-tech sector.

Advancing the quantum computing ecosystem together

Germany offers excellent conditions for a breakthrough in quantum computing, with strong academic quantum research, high-tech medium-sized suppliers, large-scale industry in research-intensive sectors and a deep-tech start-up scene that is driving technology transfer from cutting-edge research to applications. Policymakers also take the issue seriously. The DLR QCI, which was launched in May 2021, will receive 740 million euros in funding from the German Federal Ministry for Economic Affairs and Climate Action over a period of four years. Some 80 percent of the money will flow directly to industry. DLR will use 20 percent of the funds for its own research and development work. For quantum computing to be a success in Germany, all of this needs to be brought together in a thriving ecosystem. An innovative start-up scene that turns great ideas from research into products is one thing, but use cases in industry and business are also needed to turn good ideas into sound business models. Building this bridge is the task of the innovation centres. "That is why direct interaction on site is so important to us," says Kathrin Höppner, Manager of the Innovation Center Ulm. "By fostering close cooperation between research, development, the supplier industries and applications, we not only support innovation, but also create the necessary structures for the sustainable development of competitive quantum computers, while the expertise and value chains remain in Germany."

It is still unclear which approach – or combination of approaches – will one day win the quantum computer race. It may not be the gigantic, dazzling quantum computer that comes out on top, but a small system that started out as a good idea and looked like a refrigerator in the back of a van.

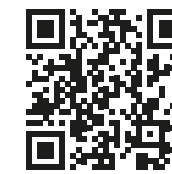
Felix Knoke is responsible for communications at the DLR Quantum Computing Initiative.



The KLIM-QML project will improve climate models with the help of quantum machine learning and will investigate, among other things, how ship emissions contribute to cloud formation.



View of the Columbus Control Centre. The QMPC project is researching how to solve complex logistics tasks with the DLR QCI's quantum computers. This applies to spaceflight operations just as much as to the optimisation of container terminal operations or public transport timetables.



See all QCI projects at qci.dlr.de/en/projects



A SOLUTION TO POLLUTION

The Plastic Pirates initiative gets to the bottom of water pollution

by Nina Wünsche and Stefanie Hulan

Torn plastic bags and disposable bottles on the banks of the Rhine, cigarette butts on the beach, a yoghurt pot floating in the sea – the amount of plastic waste in oceans, seas, rivers and streams is increasing worldwide. How much waste is there, what exactly is it made of and where does it all come from? These questions are being addressed by Plastic Pirates – a German initiative spread across Europe by the DLR Projektträger.

Although humans and all life on Earth depend on water, the pollution of our oceans, seas, rivers and streams continues to increase. In particular, the steadily rising level of micro- and macroplastics is altering our highly complex water systems. But we still know far too little about this plastic waste: Where does it come from and where does it go? What types of waste are found on and in our waters? Where is pollution of rivers and oceans particularly high? And how much microplastic is already in the water?

The Plastic Pirates clean up

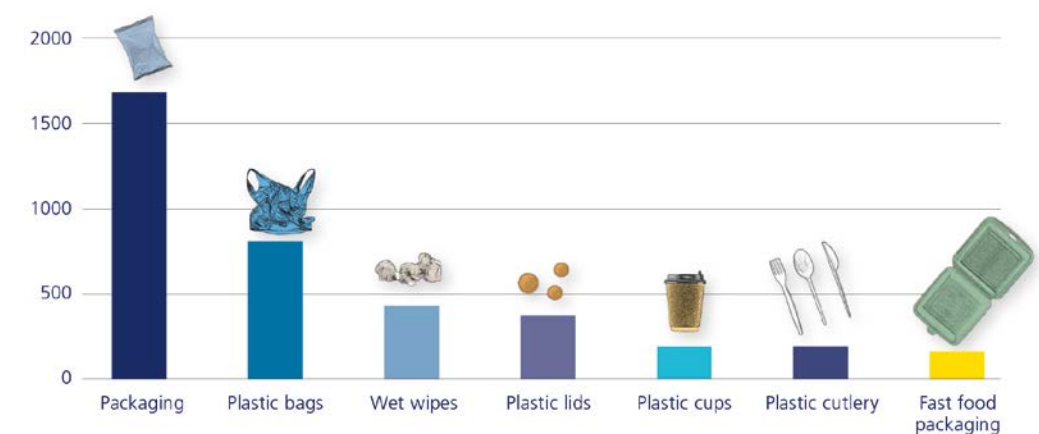
The Plastic Pirates aim to get to the bottom of these questions. The initiative sees young people collect litter in and around waterways as part of a school class or youth group. The special aspect of this activity is that they do so according to scientific principles and document their results. The information they gather is made available on an online map, creating a vast treasure trove of data that benefits researchers all over the world.

The DLR Projektträger spreads the Plastic Pirates across Europe

The 'Plastic Pirates – Go Europe!' project was initiated by the German Federal Ministry of Education and Research following the recommendation of the DLR Projektträger. The European Commission is now providing funding to enable more European countries to participate. The DLR Projektträger is responsible for the Europe-wide implementation of what was originally a German initiative on behalf of the Commission. After starting the Europe-wide roll-out in summer 2022, the Plastic Pirates are now active in 12 countries and contribute to the EU mission 'Restore our Oceans and Waters by 2030'. Roughly 5000

Henry, 14 years old, Plastic Pirate from Albert-Schweitzer-Gymnasium in Hamburg

» Plastic waste is really everywhere in the environment, even as invisible microplastic in the water. And this litter harms all living creatures – both humans and animals. Thanks to the Plastic Pirates, I now know how researchers work. Everyone can make a contribution to scientific research and therefore to protecting the environment. What I particularly enjoyed is getting to learn more about the rivers in my neighbourhood.



Number of disposable items found during sampling in autumn 2019 and spring 2020

young Plastic Pirates have now taken part in the initiative across nearly 300 coordinated sampling events, from Portugal to Bulgaria. This initiative is now a flagship citizen science project of the European Commission and shows great potential to be extended further into the world. "The biggest challenge at the beginning was to get more European countries interested in the project within just a few months and – in line with the European Year of Youth 2022 – to set up sampling campaigns across Europe," explains Philip Ackermann,

coordinator of the initiative at the DLR Projektträger. "At the DLR Projektträger, we are proud that by spreading the Plastic Pirates initiative to Europe, we are helping to inspire Europe's youth for science, while at the same time collecting data on the extent and origin of pollution in our rivers and seas."

Nina Wünsche works in European and International Cooperation at the DLR Projektträger, **Stefanie Hulan** in Corporate Communications.

Janne, 14 years old, Plastic Pirate from Albert-Schweitzer-Gymnasium in Hamburg

» I was surprised by how much waste we found and how many people throw their litter away instead of putting it in the bin. To reduce the use of plastic, I want to choose plastic-free options such as buying honey in a glass jar instead of a plastic container at the supermarket. Another option is to buy fruit and vegetables at the market instead of wrapped in plastic. The best way is to avoid waste and reduce plastic. If more people take care to produce less waste, they can make a big difference to the environment.



MACROPLASTICS: Macroplastics are pieces of plastic larger than five millimetres. Examples include fishing nets, water bottle caps, lighters and flip-flops. Floating macroplastics are a danger to marine life because these can easily be mistaken for food and ingested. Turtles, seals, whales and other animals can also become entangled and injured in broken and abandoned nets, known as ghost nets.

MICROPLASTICS: Microplastics are pieces of plastic smaller than five millimetres. They are formed when macroplastics in the ocean break down into smaller and smaller pieces due to solar radiation, salinity and wave action, for example. Many microplastic particles are also created by the abrasion of car tyres on roads. These particles then enter the ocean through sewage and rivers. Microplastics are also mistaken for food by animals and end up in their bodies: when these marine animals are eaten, they end up in the human body.

Source: Federal Ministry of Education and Research

THE LATEST PLASTIC PIRATES CAMPAIGN



Students from the Albert-Schweitzer-Gymnasium carried out a Plastic Pirates sampling campaign on Hamburg's Elbe beach in April

EXPLORING THE WORLD OF COMPUTER SCIENCE

A visit to the Heinz Nixdorf MuseumsForum in Paderborn

by Michael Müller and chatGPT



The Thomas Arithmometer. This sophisticated version of the calculator was a gift to the King of Portugal.

What fascinates most people about computer technology is probably not just the hardware, but particularly the latest applications. Both are the subject of the large permanent exhibition at the Heinz Nixdorf MuseumsForum in Paderborn. Here, visitors can immerse themselves in the wide world of information technology. This DLRmagazine article was written by a special team of authors. One part was written by ChatGPT, and the other by DLR editor Michael Müller. Can you guess which is which?

The history of computing brought to life

The Heinz Nixdorf MuseumsForum will fascinate technology enthusiasts, history fans and anyone with a curious mind. Located in the charming city of Paderborn, this museum offers visitors an exciting journey through the history of computer technology – from its humble beginnings to the cutting-edge technologies of today.

The collection covers a wide range of computer artefacts, including ancient calculating machines, early computers and vintage hardware. Visitors can also admire the incredible advances that have taken place over the years, from the large mainframe computers of the past to the sleek, powerful machines in use today. The attention to detail in the presentation of these artefacts, as well as the informative descriptions, bring the history of computing to life.

The museum also excels in conveying the importance of computer technology beyond its technical aspects. It places great emphasis on the social impact of technology, showing how it has revolutionised various industries and changed the way we live, work and communicate. The thought-provoking exhibits highlight the ethical and social implications of computing and encourage reflection about the responsible use of technology in a rapidly evolving world.

With its well-curated exhibits, interactive experiences and insightful commentary, the Heinz Nixdorf MuseumsForum offers an engaging and educational journey into the world of technology. Whether for technology fans or people simply curious about the impact of computing, this museum inspires, informs and conveys a deep appreciation for the ever-changing digital landscape.

On the trail of the bits

It is a round trip in the truest sense of the word. On two floors, visitors move in ever-tighter circles past hundreds of exhibits until they eventually reach the core of the exhibition. The entrance to the first floor transports them back to ancient times. They can follow a rich historical timeline – from the invention of writing to the first ratchet-wheel calculating machines of the Middle Ages pioneered by Tübingen professor Wilhelm Schickard (1592–1635), the start of series production of the French arithmometer, widely adopted by the insurance industry in the mid-19th century, and the comptometer. This device replaced clerks in the USA who specialised in the lightning-fast addition of long columns of numbers at the beginning of the 20th century. Even today, the comptometer can outperform modern pocket calculators when it comes to rapid addition.

The exhibits also reconstruct important breakthroughs in computer technology that occurred in the USA, England and Germany in the 1930s. They include the first machines that could perform complex

calculations automatically, as well as electrical components such as relays and vacuum tubes that overcame mechanical barriers. An interesting side note – no patent has ever been granted for 'the computer'.

Heinz Nixdorf was formerly the Head of the MuseumsForum, which is located in the Nixdorf company's headquarters. He was one of Germany's greatest computer pioneers alongside Konrad Zuse. His life and work are, of course, part of the Hall of Fame, the core of the first floor. Alan Turing is also represented here, with a Turing machine on display. In the 1940s, Turing, a British mathematician, developed a test procedure to differentiate between human and artificial intelligence – a concept ahead of its time that is increasingly relevant today.

One floor up, the exhibition covers the widespread adoption of home computers for personal use. The influence of space exploration shaped this development significantly, particularly NASA's Mercury, Gemini, and Apollo programmes, which led to the historic Moon landing in 1969. The production of computers for the Apollo mission is especially striking. In a very time-consuming and error-prone process, the programmes of the control computer (capacity: 600,000 bits) were woven around magnetic ferrite cores. A wire that went through a core represented '1'; past the core represented '0'. This is just one of many remarkable stories from the early days of information technology that will leave a lasting impression.

The inner part of the second floor explores significant contemporary advancements, although it lacks any mention of quantum computing. Instead, it emphasises the potential of artificial intelligence. This article covers just a fraction of what awaits visitors to the museum. Allow ample time to make the most of a trip to Paderborn.

ChatGPT (Chat Generative Pre-trained Transformer) is a chat program that uses artificial intelligence to communicate with human users via text-based messages. **Michael Müller** is an Editor in the DLR Corporate Communications Department.

HEINZ NIXDORF MUSEUMSFORUM

Fürstenallee 7, 33102 Paderborn
Germany
Phone +49 5251 306-600

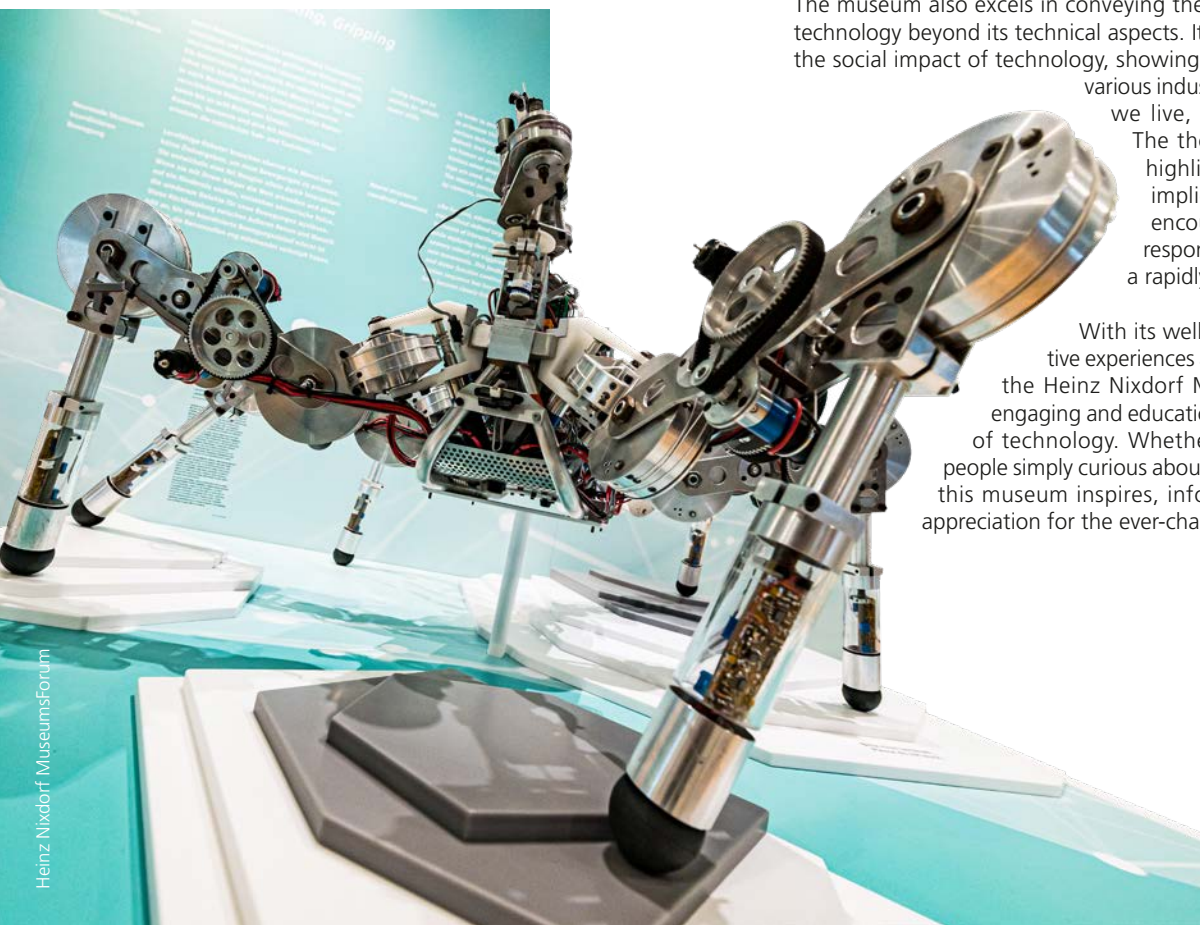
Opening hours:
Tue to Fri 09:00–18:00,
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Admission:
Adults: 8 euros,
Reduced entry/groups of 10
or more: 5 euros

hmf.de/en



Artificial intelligence on four legs. LAURON derives its name from the German for 'walking robot, neuronally controlled'.



FROM THE ARCHIVE

More than 50,000 documents are stored in the DLR Central Archive, with some real treasures buried amongst them. This series of articles searches for clues amid the wealth of images, documents, records and articles to unearth such gems. In this issue of the DLRmagazine, we feature the AVA test car, which remains the subject of numerous myths today.



GETTING THE 'GÖTTINGEN EGG' ROLLING

The AVA experimental car, also referred to as the Schlörwagen, was the most streamlined car in history.

by Jessika Wichner

Even if the name does not necessarily suggest it, transport research at the German Aerospace Center (DLR) has a long history. The Aerodynamics Research Institute (AVA) in Göttingen and the German Institute for Aviation Research (DVL) in Berlin-Adlershof were both testing cars in wind tunnels during the 1920s and 30s. But what happened when aircraft manufacturers started building motor vehicles?

Following the entry into force of the Versailles Peace Treaty in 1919, aeronautical research, flights with powerful engines, and the construction of aircraft engines were prohibited in Germany. As a result, aeronautics research institutions and aircraft designers had to seek alternative sources of income. Consequently, several aircraft manufacturers, including Edmund Rumpler (1872–1940), switched to automobile construction. They benefited from their aerodynamic knowledge, which could also be transferred to motor vehicles.

Rumpler designed the Rumpler-Tropfenwagen (Rumpler raindrop car), which had a droplet shape when viewed from above, enabling it to achieve a low drag coefficient (C_d value). A model of Rumpler's car was tested in the AVA wind tunnel around 1920. In the years that followed, companies such as Daimler approached AVA to have racing car models systematically analysed in the wind tunnel. In this way, AVA developed a new field of research. In 1935, it received an order from the German Ministry of Transport (RVM) to develop a so-called semi-streamlined car – a vehicle with a streamlined tail.

Once the model had been tested in detail in the wind tunnel in Göttingen, AVA received a follow-up order from the RVM to design and construct the prototype of a fully streamlined vehicle. Such vehicles were characterised by streamlined features at both the front and rear. Engineer Karl Schlör (1910–1997) was entrusted with this task. Initial experiments with a model in the wind tunnel showed that the new body shape had a significantly lower drag coefficient compared to the conventional, box-type vans that were common at that time.

Forever streamlined

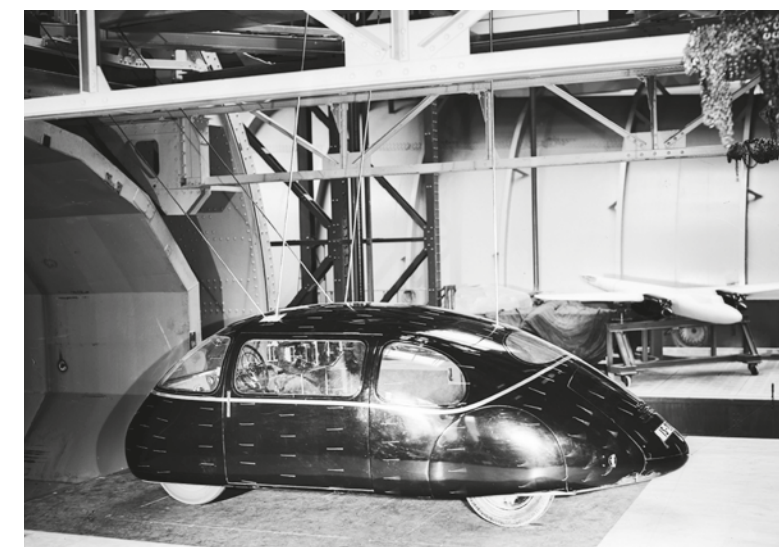
The next step was to build the model at full scale. In order to keep the drag coefficient as low as possible, Schlör made sure that the wheels of the car were surrounded by the bodywork and that all protruding components, such as door handles, indicators and headlights, were recessed into the body. Since commercially available chassis were too small for this streamlined body, Schlör disassembled the chassis of a Mercedes-Benz vehicle with a 1.7-litre rear engine and welded the individual parts back together in a modified arrangement. This resulted in a steering column located in the centre of the car. At the rear, there was space for up to six passengers across two rows of seats, arranged one behind the other.



Engineer Karl Schlör developed the AVA experimental car in 1938. In 1942, he brought a captured Russian propeller to AVA and mounted it on the car for test purposes.

Since the AVA had no experience with vehicle body construction, they commissioned the Ludewig Brothers company in Essen to build the 'AVA test car'. It was later dubbed the Schlörwagen or the 'Göttingen Egg' due to its distinctive shape. Schlör transferred the car from Essen to Göttingen at the end of 1938.

There, the car was analysed in the wind tunnel. Its average drag coefficient was just 0.186. For comparison, in modern cars, this value is between 0.22 and 0.35 (up to 0.4 in SUVs). Initial measurements of the



The Schlörwagen in the AVA wind tunnel in 1938. It could accommodate a total of seven people.

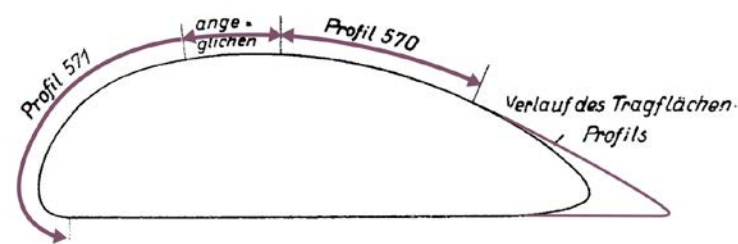
drag coefficient during test drives on the motorway between Göttingen and Kassel resulted in values of around 0.189, which did not particularly surprise the experts given the car's systematically streamlined design.

Desire and reality – top speed

However, the maximum speed of 146 kilometres per hour, as measured and stated by Schlör in his report, sparked controversy. In particular, renowned motor vehicle researcher Wunibald Kamm (1893–1966) cast doubt on Schlör's statement. He also criticised the AVA test car's susceptibility to crosswinds due to its aerodynamic shape. Schlör was unable to dispel the doubts about his vehicle's top speed. On a test drive on the AVUS motor racing circuit in Berlin, for example, the car only reached 110 kilometres per hour.

The AVA experimental car was exhibited at the Berlin Motor Show in February 1939 – but only outside the gates of the show grounds. A model of the car that was showcased inside the exhibition site had to be declared as merely a test vehicle with no intentions for series production. The Volkswagen Beetle made its public debut at the same 1939 Berlin Motor Show. The RVM wanted to prevent the AVA test car from being perceived as competition. In contrast to the Beetle, the Göttingen experimental car offered significantly more passenger space, higher speed and lower fuel consumption.

With the outbreak of the Second World War, motor vehicle research at the AVA was discontinued. Schlör was subsequently transferred to the AVA branch office in Finse, Norway, and later appointed head of



Based on the model of a semi-streamlined car, Schlör selected a body shape composed of Göttingen wing profiles 570 and 571.

The Schlörwagen's last trips took place in 1942



the AVA outpost in Riga. The AVA test car was used for the last time in 1942, when Schlör returned home to Göttingen on leave.

During the final years of the war, the car was dismantled into its individual parts. In 1948, Schlör, now working at the Bavarian State Ministry of Transport, attempted to transfer the car – or what was left of it – from the AVA to Bavaria. However, this failed due to a decision by the British military government, which refused to release the test car. The fate of the AVA test vehicle remains unclear. It can be assumed that it was scrapped at some point, as the body had been badly damaged in 1942, rendering it unusable for further test purposes. Due to its unexplained fate, numerous myths have sprung up around it. Some stories suggest that the Schlörwagen was transported to England after the war, while others propose that it was destroyed during the offensive on Riga. Both accounts,

however, have been ruled out since the car was still in Göttingen in 1948. In any case, the vehicle continues to fascinate to this day.

Jessika Wichner is Head of the DLR Central Archive in Göttingen.

MAKING RECENT HISTORY TANGIBLE

Three questions for Horst-Dieter Görg, a member of the Mobile Welten e.V. association.

Mr Görg, you and other members of Mobile Welten are building a replica of the Schlörwagen. How did you come up with the idea?

■ We have been investigating the field of aerodynamics for many years. The Schlörwagen was a particularly interesting project, as its drag coefficient (C_d) remains unparalleled to this day. Fortunately, we were able to find partners quickly and establish contact with DLR, within one of whose predecessor organisations the Schlörwagen was developed. And then there is the local connection – our association is based in Hanover, where some of the test drives took place. That makes it doubly exciting for us. Saving energy and streamlining are



“Saving energy and streamlining are more important today than ever, and I think we can learn a great deal from the past.”

Horst-Dieter Görg

Member of the Mobile Welten e.V. association

more important today than ever, and I think we can learn a great deal from the past. We hope that this project will make recent history tangible.

You have already built a full-scale model. What comes next?

■ The model will be on display at the August Horch Museum in Zwickau until the end of October 2023. You cannot drive it, though. In 2019, we discovered three original, albeit dilapidated Mercedes 170 H cars in the Westerwald mountains, which had served as the foundations for the Schlörwagen. We are currently using the parts to build two Schlörwagens in cooperation with the Central Garage in Bad Homburg. The educational value of the model is important to us, so we are keen to make its inner workings visible, perhaps using

acrylic plastics or other innovative designs. The frames were rebuilt in 2020 and 2021, and recently our coachbuilder has attached a lattice construction – as a sort of guide for the wooden framework that is yet to be manufactured. Now, you can guess the shape of the outer shell. First, however, we need to raise money for the wooden structure, as everything is funded with donations and personal contributions. The wooden structure will certainly be a challenge for our carpenters, as everything about the Schlörwagen is round and none of the standard profiles are suitable. At the same time, we want to bring the engine back to life; at the moment it is just a collection of parts.

Where will you go first to debut the Schlörwagen?

■ I would actually like to begin showing it off next year, at a streamlining-themed event in Dessau. The Schlörwagen would fit right in, even if it is only half-finished.

REVIEWS

HELGOLAND

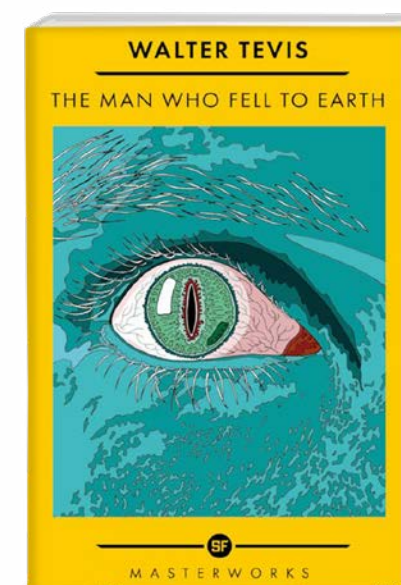
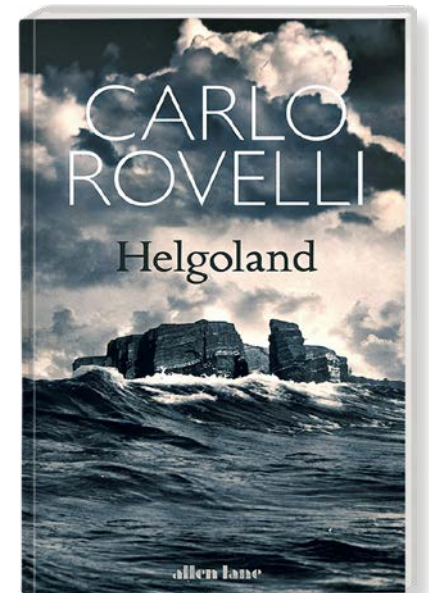
This review is less of a spoiler alert and more of a warning: quantum mechanics is not for the faint of heart, even in Rovelli's gentle hands. The setting: a small, rocky island in the North Sea called Helgoland. The main character: German theoretical physicist Werner Heisenberg. The plot: Hoping to recover and think on **Helgoland**, Heisenberg ends up calculating for the peculiar behavior of the quantum atom in a new way. The results have a dizzying effect on the world of physics.

Consider the science of matter and energy to be, say, a two-dimensional drawing: what you see is what you get. Action triggers reaction; simple and complete. Quantum mechanics' deeper dive into what's happening on the scale of particles and atoms renders this 2D understanding of the natural world 3D: what you see in the newly visible angles of this quantum world is seemingly unexpected and a little bizarre.

Carlo Rovelli fleshes out all the above with historical context, including conversations and debates among key physicists of the day; breakdowns of the scientific complexities in question, with illustrations especially welcome for the uninitiated; and philosophical correlations on what it means to experience a lived moment, on the micro and macro scale. He's leading us, in the end, to a conclusion far simpler than the science involved in taking us there: a humanist consideration of the quantum world. If this sounds like a lot, it's because it is, certainly if you're new to or rusty in physics. The scientific explanations might require some backtracking and re-reading. But the historical context is illuminating, not least for shining a light on the struggles and doubts of the greatest scientific minds of the 20th century.

You can't go wrong with a Rovelli read; for a theoretical physicist, his prose is artful and stays with you, even if the finer scientific points don't.

Laylan Saadaldin

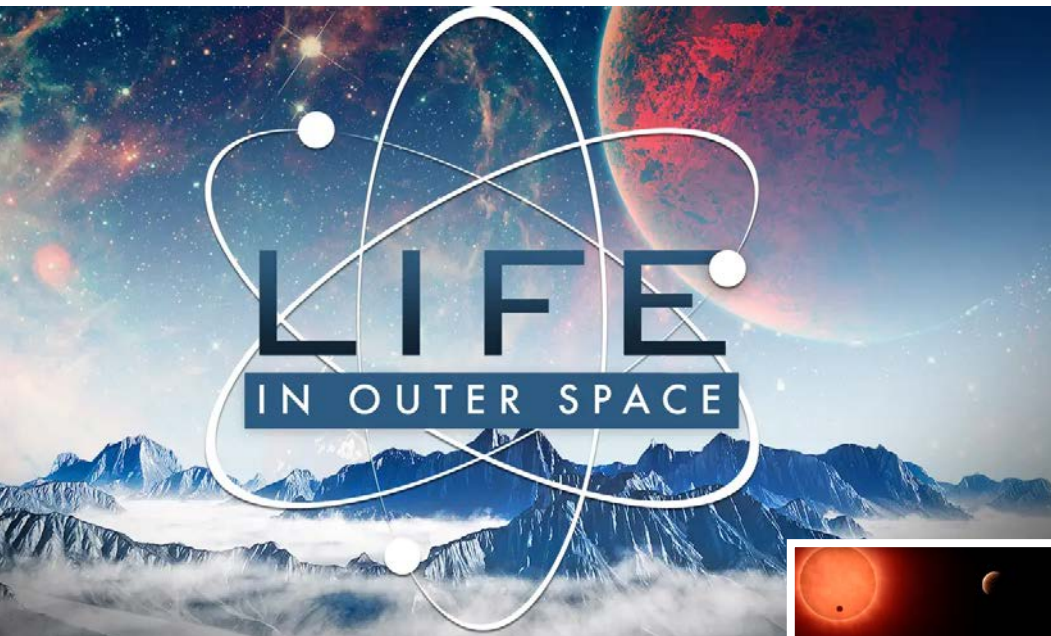


THE WEEPING ALIEN

The Anthean stumbles more than he walks. The unfamiliar terrestrial gravity bears down on him. He is driven by an iron will. He must save his people. From his native celestial home, which has become a wasteland, he must get to Earth. Hyper-intelligent and in a quest to understand the inhabitants of this promising planet, he builds an empire to construct a spaceship. But loneliness, heat and, increasingly, the stupidity of human actions get to him. Only a brilliant, hard-working engineer and a drinking welfare recipient are allowed into the life of the tall, fine-boned alien. But he is soon seized by doubts, which he drowns in gin. For even the ultra-modern technologies of his people and money – a lot of money – are apparently not enough to make Earth the new, redemptive home.

The US author Walter Tevis (1928–1984) wrote **The Man Who Fell to Earth** in 1963, and the book was adapted into a film starring David Bowie in 1976. **Diogenes Verlag** has now republished this little masterpiece in a new edition to save it from oblivion – thankfully. Tevis' straightforward depiction of life on Earth is thought-provoking. Not only because he describes society so clearly and accurately, but also because we have to admit that even today, 60 years (!) after the book was published, people still do not adequately appreciate and protect the unique life on Earth. In the end, the question that the novel's hero asks himself gets under your skin – are the ignorant people living on Earth worth saving?

Cordula Tegen



EXPLORING THE FINAL FRONTIER

The possibility of finding life on other planets has long fascinated scientists and the public alike. Over the years, numerous space missions have been launched to explore this mystery, fuelling the creation of several documentaries on the subject. Among these, the series **Life in Outer Space** offers a fascinating look into the latest research and theories on the existence of life beyond Earth.

The documentary presents the basics of the science behind this search in an accessible way. In the episode 'Exoplanets', it provides viewers with a crash course on extrasolar planets. This episode highlights the cutting-edge instruments and methods used by researchers to detect these celestial bodies and determine their habitability.

'Life in Outer Space' adeptly navigates through a heap of intriguing topics, from the discovery of the first exoplanets to the remarkable achievements of NASA's Kepler telescope, which unveiled a few Earth-like planets, such as Kepler 62e and 62f. It also discusses the vital contributions of missions like James Webb Space Telescope and ESA's CHEOPS in furthering our understanding of exoplanets.

As the documentary shifts from exoplanets to the broader realm of intelligent extraterrestrial life, it does so somewhat abruptly. Although the inclusion of discussions on SETI and the hunt for radio signals are still interesting, it leaves viewers with some unanswered questions.

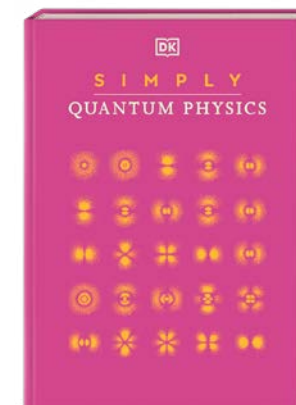


The visuals and narration are absolutely striking and exquisite. However, the film does suffer from occasional repetition and redundancy, which could have been trimmed to improve the overall viewing experience.

Nevertheless, for those intrigued by the prospect of alien life in the Universe, this series offers a comprehensive overview of the ever-evolving frontier of the search for life in the Universe. Whether you seek to expand your knowledge or introduce someone to this subject, I recommend giving it a watch.

Yasmin Tosta

CONCENTRATED KNOWLEDGE, ELEGANTLY PRESENTED



Quantum physics – these words float through society like mosquitoes on a warm summer night. When the pink book from the SIMPLY series published by **Dorling Kindersley** was in front of me, I was initially reluctant to open it. I was afraid of the amount of knowledge it might contain. But once I got over my inhibitions, I flew through this book. Quotations, pictures, comparisons, simple language – all of this makes it an easy read. The most important concepts are presented in a nutshell. The publisher advertises with the slogan 'Are you short of time but hungry for knowledge?' Well, you do need to have a bit of time and some leisure moments, but opening the book is the first step. Vivid graphics provide an introduction to the world at the very

smallest scale – a visual reference work on more than 100 core topics in quantum physics. It is definitely worthwhile and even a bit of fun.

Also published in this series is **Astronomy**, a journey of discovery through the unending Universe. From the Big Bang to planets, galaxies and constellations – almost 100 topics are explained on a double-page spread in this well-structured book. The many images and graphics as well as the easy-to-understand explanations make you want to keep turning the pages. For those who want to delve further, the SIMPLY series offers a wide selection of fascinating topics, from the brain to climate change, and psychology to mathematics.

Miriam Poetter and Noemi Bödecker

AN UNCONVENTIONAL TRIP TO MARS



In their wonderful comic strip **Little Spaceoneers**, published in English by **Design & Data GmbH**, author Carlo Palazzari and illustrator Tristan Wilder show how to combine words and illustrations in such a way that the reader is sucked into the story as if they were passing through a wormhole. Five friends, aged between 001 (Laika, the robot dog – favourite band Kraftwerk) and 12, set themselves the goal

of flying to Mars. To do so, they establish a space start-up. The finely developed characters are strikingly different from one another. At the beginning, one gets the impression that their successful collaboration is completely unrealistic. But as the story progresses, this is shown not to be the case. The diversity of the group and their interactions are a magical and incredibly entertaining combination. They go through all the phases of setting up a business and bring very individual qualities into play so that the goal of landing on Mars can be achieved – whether it is raising money through a self-built lemonade machine and a musical performance, team building around the campfire or motivating each other during identity crises. The group sticks together and perseveres – giving up is not an option. This comic strip is a journey into the unconventional and imaginative minds of young, space-loving people, convincingly demonstrating that the journey is the destination. With a fabulous sense of understatement and well-placed fun facts, Palazzari and Wilder manage to ensure that adults can also find great enjoyment in this read. It will probably not be the last adventure for this extraordinary team.

Antje Gersberg

RECOMMENDED LINKS

HOW MUCH WATER DO I DRINK?

everylastdrop.co.uk

Water is becoming scarcer all over the world. We drink it, wash ourselves and cook with it every day. The interactive website Every Last Drop shows how much water a person in the UK uses every day. This includes water consumption that is not necessarily visible to us as consumers. A short video shows how we can easily save water in everyday life without giving up anything.

SMALL BUT MIGHTY

planetary.org/defend-earth/asteroid-close-calls

An asteroid of just 20 metres in diameter could do a lot of damage if it hit the Earth. Many asteroids pass the planet at a smaller distance than the Moon, yet they cannot be seen with the naked eye due to their small size. If you want to know which asteroids have flown past Earth in the past and which will do so in the future, take a look at this graphic from The Planetary Society.

BEAUTIFUL CODE

s.dlr.de/codestories

Software has become indispensable, especially in research. It enables the simulation of weather and climate data, helps in the evaluation of medical research data or in satellite operation. In this podcast from the DLR Institute for Software Technology, scientists talk about the wide range of topics they research and are passionate about (in German).

TRAVELLING IN THE SOLAR SYSTEM

solarsystemscope.com

What is Mars actually like? And how many martian moons are there? Answers to these and other questions about the Solar System can be found on this website. Here you can travel among planets, stars and astronomical objects and find information in the encyclopedia about their composition, origins and much more. In addition you can look up at the night sky from Earth.

IDEFIX, THE MARTIAN MOON EXPLORER

Instagram: @mmx_rover

Somethin' is brewin' about to begin: IDEFIX, the Martian Moons Eploration (MMX) rover's official Instagram account, is coming soon. The German-French rover is part of JAXA's MMX mission, which is set to launch in 2024. Follow the account for exclusive updates on the mission – from launch preparations to the journey to Phobos – and enjoy a front-row seat to the exploration of the martian system (in German).

Cover image

On the Lower Elbe between Cuxhaven and Stade, in Krummendeich to be precise, the OPUS 1 wind turbine towers 150 metres into the air. It is part of the DLR Wind Energy Research Farm WiValdi (Wind Validation), which was officially opened in mid-August 2023. In addition to OPUS 1, the research facility comprises another wind turbine called OPUS 2 and several measurement masts. A third turbine is in the planning stage. The DLR experts involved come from a wide variety of fields and work in an interdisciplinary manner. They all have a common goal – to better understand wind power as a whole, with all its influencing factors. On this basis, DLR will work with companies to develop technologies that will further increase the efficiency, cost-effectiveness and acceptance of wind energy.



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