DLR magazine

German Aerospace Center (DLR) · No. 163 · December 2019

METROPOLITAN TRANSFORMER

THE URBAN MODULAR VEHICLE

More topics:

- GO WTH THE FLOE
- NIGHT FLIGHT AT THE END OF THE WORLD

About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. The organisation also completes research in the areas of energy, transport, security and digitalisation. Such projects are often completed as part of national and international cooperative efforts. Acting on behalf of the federal government, the DLR Space Administration designs and implements Germany's space programme, together with national and international partners. DLR is also the umbrella organisation for two project management agencies that promote research.

DLR has approximately 8600 employees at 27 locations in Germany. It also has international offices in Brussels, Paris, Tokyo and Washington D.C.

Imprint

DLR Magazine – the magazine of the German Aerospace Center

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

Editorial staff: Nils Birschmann (Legally responsible for editorial content), Cordula Tegen, Julia Heil, Elke Heinemann (Editorial management), Karin Ranero Celius (English-language editor, EJR-Quartz BV).

DLR Department of Public Affairs and Communications
Linder Höhe, D 51147 Köln
Phone +49 2203 601-2116
E-Mail info-DLR@dlr.de
Web DLR.de/EN
Twitter @DLR_en

Printing: AZ Druck und Datentechnik GmbH, 87437 Kempten
Design: B+D Agenturgruppe GmbH, Kitschburger Straße 1, 50935 Köln, www.bplusd.de

ISSN 2190-0108

Online:
DLR.de/dlr-magazine

To order:
DLR.de/magazine-sub

DLR Deutsches Zentrum für Luft- und Raumfahrt German Aerospace Center

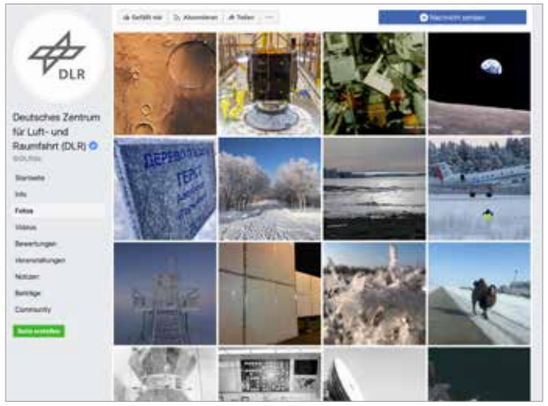
Supported by:
Federal Ministry for Economic Affairs and Energy
on the basis of a decision by the German Bundestag

DLR IN THE MEDIA

This is DLRmagazine 163 – the fourth one published in 2019. With each issue, we gain new subscribers. Whereas 10 years ago there were just under 6000 readers for the German-only edition, approximately 14,000 readers receive the DLRmagazine – in German or English – in their mailbox every three months. Particularly in Germany, the media response to DLR topics is extensive – especially in comparison with the overall national scientific research publication landscape. In the second quarter of 2019 alone, 4127 articles appeared in the press, or on radio or television, and they had a reach of 1.14 billion recipients.

The DLR_Raumfahrt_Show (DLR Space Show) attracted particular attention, as did our education and outreach programme. The establishment of seven new DLR institutes was also well received. DLR became active in social media at an early stage. Since its creation 11 years ago, the Twitter channel @DLR_de has gained approximately 98,000 followers. DLR_en was created a year later and now has over 35,000 followers.

After these, channels were created on other platforms. Today, DLR has the most widely viewed channels in German scientific research. DLR's accounts on Twitter, YouTube, Instagram, Facebook, Vimeo and Flickr have a total of 500,000 followers – and the number is rising.



With some wintery images from our Facebook page, we wish you a happy and successful 2020!

EDITORIAL

Dear reader,

Some words have a strange fate. They have a meaning that implies something 'good' but they fade due to overuse. Sustainability is such a word. It has had an amazing career, but now suffers from what we in Germany refer to as 'Schlagerkrankheit' – literally 'popular song disease'. It has been heard too frequently and everyone is tired of it. The word no longer reaches our minds, let alone our emotions. Can it be saved? Perhaps, by taking into account what we really mean when we use it.

So let's try another approach to the word sustainability – forward-thinking, compassionate, considerate. Let us look at long-term effects, rather than short-term gains. Our actions will undoubtedly affect the lives of future generations, so the question becomes – will what we create last? What impact are we having on the environment and our fellow human beings? And of course, how can we ensure that the results of our work, however beneficial they appear today, do not become a burden in the future?

Examples from DLR can be found in this issue. We explore processes in the atmosphere. We're developing power plant technologies that deliver heat and power reliably while using renewable energy sources. We're exploring improved vehicle concepts for the urban transport of the future.

A broader question is how we can do all this in a sustainable way. For example, if we fly for research, we only do so as often as necessary and with as many experiments on board as possible. There is great potential in creating knowledge together – both inside and outside DLR. For example, the Alfred Wegener Institute for Polar and Marine Research has organised a unique expedition where its Polarstern icebreaker is drifting in the arctic ice for a year with teams of researchers from 19 countries. DLR took the opportunity to install an antenna and receiving system on board to analyse disturbances to GNSS signals and improve navigation accuracy in polar regions.

Implementing such synergies, of course, requires an impetus, an idea and often perseverance, as well as openness to collaboration in the best sense of the word. There is certainly more that can be done here – both as individuals and in our work together with partners. You can call this sustainability, but you don't have to …

Your Magazine editorial team

DLRmagazine **163**

NIGHT FLIGHT AT THE END OF THE WORLD 26


JÄHN'S GREAT JOURNEY 48


GO WITH THE FLOE 36


METROPOLITAN TRANSFORMER 44


RAIN OR SHINE 34


SPACE TECHNOLOGY FOR EARTHLY SOILS 20


ON THE TRAIL OF THE WIND 14


PUSHING MATERIALS TO THE LIMIT 24

REBALANCING AT EVERY STAGE

© DLR

Jutta Graf, Head of Scientific Information, and Philipp Bergeron, Manager Sustainability at DLR.

A commentary on sustainability by Jutta Graf and Philipp Bergeron

The concept of ‘sustainability’ has become omnipresent – almost to the point of overuse. We are obliged to be sustainable in the way we live our lives, go on holiday, travel around and even do our shopping. We are meant to construct buildings and infrastructure in a sustainable manner, and presumably even sleep sustainably. Often, such ideas are reduced to a few specific details of our luxurious, first-world lives – flight shame, meat consumption, forest decline, cruise ship hysteria, the energy transition and ‘Dieselgate’, to name but a few.

So, must we do without many things to achieve sustainability?

In many cases, sustainability seems to be understood only in the ecological sense – reducing carbon dioxide emissions or preserving biodiversity. Yet sustainability is far more than that; ideally, it represents a balance between ecology, the economy and society. Achieving this balance is a challenge for each and every one of us – whether in the political arena, in our private lives, or at work. And this is precisely what brings us to DLR. If we are serious about sustainability, it goes without saying that we have to make our work sustainable. But our actions must go even further. We are analysing the root causes of things, observing the Earth, and working to develop sustainable technologies as part of a diverse portfolio. This is DLR’s societal mission. Our goal is to provide background information, explanations and solutions to lay the foundations for sustainable development.

What does this mean? All of these factors interact in a highly complex way. In order for us to be able to focus on the essentials, we follow a twin-track strategy in many of our endeavours – ‘research for sustainability’ and ‘sustainable research and work’. For example, DLR is conducting research into low-emission air transport. In addition, the increased use of video conferencing systems is intended to reduce business travel. This will help to reduce carbon dioxide emissions in line with the two strategies mentioned above. The same applies to our H_2ORIZON project. Hydrogen is produced using wind energy; this ‘green’ hydrogen serves as an alternative fuel for rocket engines and can also be used to produce electricity and heat for the Lampoldshausen site by means of combined heat and power generation. As such, the project can be considered sustainable in every respect. Our ‘DLRsustainability’ report details other areas of action and research projects of a non-ecological nature.

But we must admit that making everything 100 percent sustainable is simply not possible – because after all, sustainability is not a state of affairs, but rather a complex process that does not require sacrifice. Balancing this process time and again represents a real challenge for the future.

With this in mind, we should make it our mission to give every aspect the necessary attention, to ensure that hasty, superficial decisions do not lead to aimless action simply for the sake of doing something.

Is this possible at DLR? We certainly think so!

ENERGY RESEARCH MEETS SUPERCOMPUTING

When it comes to the energy transition – the reshaping of our energy supply to make it sustainable – energy scenarios can provide decision-makers in government, industry and society with important information, as they show potential paths of development, alternative courses of action and their consequences. For instance, these scenarios address the question of how individual cities, regions and countries can meet the demand for energy cost-effectively, securely and sustainably. As part of the BEAM-ME project, scientists from the DLR Institute of Engineering Thermodynamics in Stuttgart have been working with partner organisations to develop special algorithms. With their help, they are now able to harness the potential of high-performance computers to create energy scenarios at a high temporal and spatial resolution, as conventional computers soon come up against their limits when dealing with large amounts of data.

The new algorithms allow the experts to look at longer periods of time in their scenarios, which in turn are divided into short intervals. This means that they are able to make both generalised and highly accurate statements. Together with DLR, the project involved the Jülich Supercomputing Centre at Forschungszentrum Jülich, the High Performance Computing Center at the University of Stuttgart, the Zuse Institute Berlin, the Institute of Mathematics at the Technical University of Berlin and the company GAMS Software GmbH.

The energy transition also poses a challenge to Information Technology. With the help of supercomputers, colossal amounts of data can be used to create detailed, informative analyses of energy systems.

HOW WILL WE GET AROUND IN 2030?

The ‘Neue automobilität’ (New automobility) study reveals how automated and networked vehicles can be usefully integrated into a user-friendly, efficient and sustainable mobility system in future. Mobility hubs, car sharing and self-parking vehicles can save space and free it up for housing and living. Flexible, time-and-space-dependent prices for the use of roads and public transport (mobility pricing) will ensure more evenly distributed usage, which can prevent traffic gridlock and make driving bans unnecessary. Automated trains will be able to operate on currently decommissioned routes. Vehicles will be able to warn each other in dangerous situations. Thanks to clear mutual signalling, today’s day-to-day traffic chaos can be replaced by cooperative mixed traffic, in which road users are able to interact with and pay heed to one another to better effect.

A total of 12 ‘visions of the future’ show how automated, networked traffic could use natural resources, space, vehicles and infrastructure more effectively, thus taking the pressure off cities and local authorities. The study was presented by the German National Academy of Science and Engineering (acatech), and is led by Karsten Lemmer, a member of acatech and the DLR Executive Board Member for Energy and Transport. Science, public transport companies, town councils, the car industry and mobility service providers all contributed towards devising this concept for the transport of the future.

Local authorities play a key role in shaping better mobility systems. Intelligent, networked transport protects the environment and the climate, takes up less space and improves quality of life.

UP AND AWAY!

Otto Lilienthal has long been regarded as humankind's very first aviator, but actual proof that his designs were airworthy did not exist until now. The DLR scientist Markus Raffel has now demonstrated the flying capabilities of an authentic replica of Lilienthal's glider. Raffel built upon the scientific research carried out by DLR to mark the 125th anniversary of the first human flight in 2016, which included testing a replica of Lilienthal's monoplane glider, including in a wind tunnel. His flights on the Pacific coast, where the wind conditions are consistently favourable, lasted 10 to 14 seconds and were limited to distances of about 100 metres due to the surf. After the campaign, the biplane glider, which was constructed by the Otto Lilienthal Museum in Anklam, was handed over to the museum on permanent loan.

DLR researcher Markus Raffel on the first documented flight on a replica of the Lilienthal glider on the Pacific coast near the town of Monterey, California.

A radar sensor (Hensoldt) and an electro-optical (EO) sensor (Diehl) are attached to the top of DLR's Dornier DO228 D-CODE research aircraft. Combining both forms of technology enables the sensor system to detect other aircraft at an early stage.

SENSORS PREVENT AIRBORNE COLLISIONS

Modern sensors can process information from their surroundings in the same way as a pilot's eyes. This was confirmed by the companies Diehl and HENSOLDT together with DLR in a three-week campaign at Braunschweig research airport. The team equipped DLR's Dornier Do 228 research aircraft with a system of radar and electro-optical sensors for this purpose. During the test, another research aircraft conducted extensive manoeuvres from different directions and heights. The sensors on the Do 228 detected the other aircraft even from a considerable distance, followed its course and provided the pilot with timely warning of a potential collision course. This 'sense&avoid' sensor technology is designed to prevent collisions and ensure air traffic safety. It is particularly important for the certification and operation of unmanned aircraft.

DRIVERLESS BY RAIL

Fully automated driving will be one of the most important areas of focus for the railway over the next few decades. Yet even if trains are fully automated, there are bound to be disruptions that require human intervention. The DLR Institute of Transportation Systems is investigating the impact of automation on the performance of the train driver. To this end, the researchers are developing prototypes for the jobs that train drivers might have in future. In September 2019 future operators were invited to control simulated trains remotely, following these prototypes. For the first time at the railway line at Schlettau in Sachsen a train was driven along the tracks as though by magic. It had no driver but was instead networked with new 5G mobile technology. Vodafone's new generation of mobile communications technology drove the Thales train remotely from the Smart Rail Connectivity Campus.

The DLR scientists work with standard approaches from human factor research to assess reactions, in particular stress, situational awareness and performance. From this they are able to identify potential areas where systems could be improved. These standard approaches may take the form of questionnaires but can also make use of eye-tracking systems that capture the eye movements of train drivers.

© Vodafone GmbH

The 'driverless' train cabin during the test drive in Erzgebige, Saxony.

NOBEL PRIZE IN PHYSICS HONOURS EXOPLANET DISCOVERERS

© ESO/M. Kornmesser / N. Risinger

This artist's impression shows the extrasolar planet 51 Pegasi b, which was discovered in 1995 by the Swiss astronomers Didier Queloz and Michel Mayor approximately 50 light years from the Solar System.

The discovery of the first exoplanet almost 25 years ago changed our perception of the origin and evolution of the Universe and challenged the uniqueness of our own Solar System. This year's Nobel Prize in Physics 2019 was awarded with one half to James Peebles for his work on structure formation in the early Universe, and the other half to the two Geneva-based astronomers Michel Mayor and Didier Queloz, for their discovery of the first exoplanet orbiting a Sun-like star. In 2009, scientists from DLR, working alongside Mayor and Queloz, used the CoRoT space telescope to discover the CoRoT-7b exoplanet – the first Earth-like planet outside our Solar System. Today, scientists from DLR and other organisations are using new techniques and instruments on ESA missions such as CHEOPS and PLATO to set their sights even higher – the hunt for a second Earth.

AERIAL RECONNAISSANCE PROVIDES SUPPORT IN DISASTER SITUATIONS

© ÖRK and R. Gryc

Participants in a disaster aid exercise as part of the EU DRIVER+ project in Austria try to help the 'injured'. DLR provided real-time aerial footage and assisted with position detection and rescue logistics. The flight and mission planning for the aircraft was carried out at the UFly ground control station for unmanned aircraft, which was set up by the DLR Institute of Flight Guidance in Braunschweig.

In the event of earthquakes or other disasters, real-time aerial photography helps to assess the situation on the ground quickly and accurately. This enables aid operations to be planned in a targeted way. The use of unmanned aerial systems (UAS) has proven particularly useful, as these can be flown over areas that are difficult to access by land. The EU project Driving Innovation in Crisis Management for European Resilience (DRIVER+) helps those involved in disaster management to find the best ways of coping with disasters. The DLR Remote Sensing Technology Institute supported the project, including the contribution of a special 3K camera system. Using this camera system, DLR's D-CODE research aircraft can capture an area of 80 square kilometres in approximately 10 minutes, create geo-referenced aerial images, and quickly transmit the results to the ground control station via a datalink connection.

MEET DLR AT:

E2FLIGHT Conference 2020
20 - 21 February 2020 • Stuttgart
Radical improvements must be made to realise the vision of carbon-free aircraft technology and electric flights, as well as concept studies for the construction of airplanes, energy systems and combustion engines, aspects of certifications and systems integration. The E²Flight® conference covers all these aspects on the way to clean global aviation. Contributions made by speakers from industry and scientists from various disciplines encourage the exchange of knowledge and views. The symposium is mainly oriented towards engineers, researchers from universities as well as research centres, research groups and ministries involved with or interested in electric aircraft.

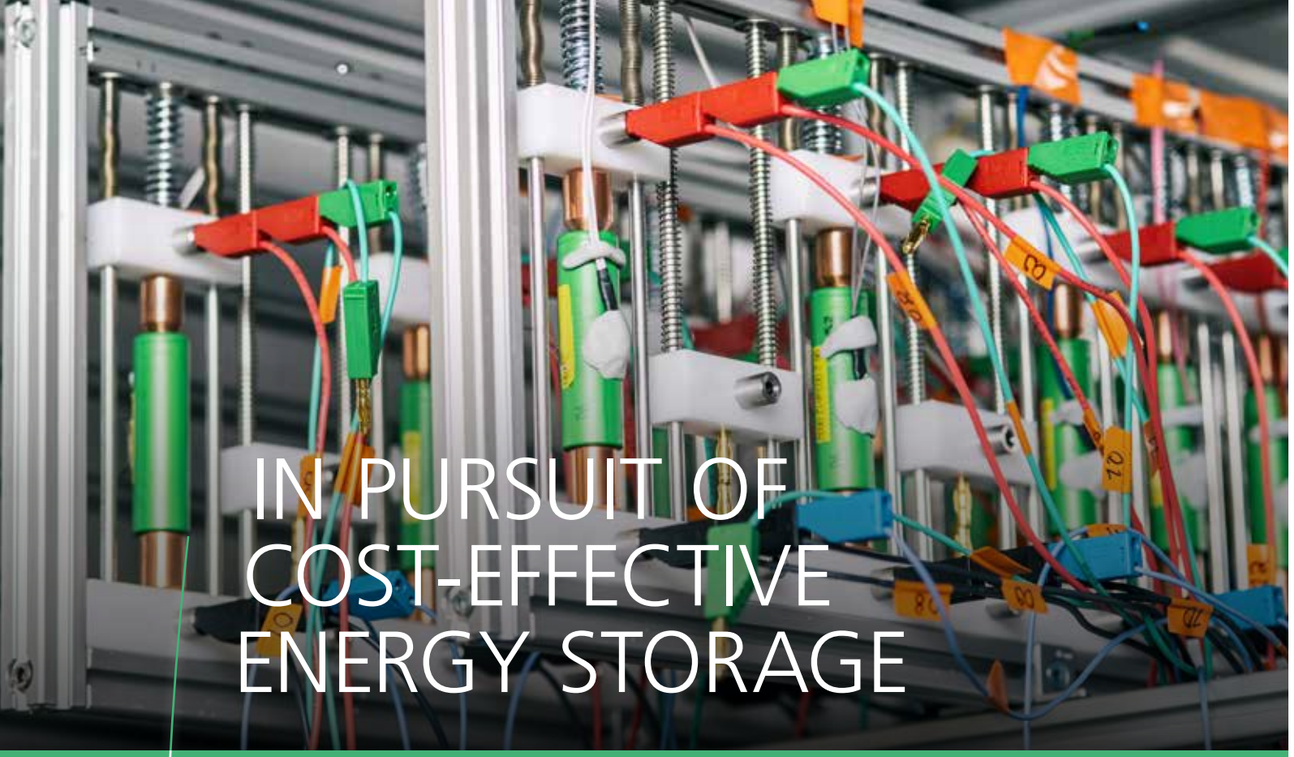
HANNOVER MESSE
20 - 24 April 2020 • Hannover, Germany
In 2020 DLR will be present at the joint stand of Hydrogen and Fuell Cells of the Hannover Messe. The DLR Institute of Engineering Thermodynamics conducts research into efficient energy storage and conversion systems that conserve natural resources. Electrochemical energy technology is a high priority, ranging from theoretical studies to basic research, and through to the development of systems and the operation of pilot plants. The joint stand will present the latest research results from these areas, together with the fuel cell group of the DLR site in Oldenburg.

ILA BERLIN AIRSHOW
13 - 17 May 2020 • Berlin, Germany
Climate protection and sustainability will be the main themes of the ILA Berlin Airshow. It is one of the focal points of aerospace worldwide and is held at the Expo-Center Airport in Schoenefeld, Berlin. This year, more than 1000 exhibitors are expected to present innovative solutions intended to contribute directly to further reducing aircraft noise and emissions. At its stand, DLR will be showcasing its current research projects in space, aeronautics, energy, transport, security and digitalisation. In the neighboring Space Pavilion, DLR will present its space activities. Moreover, several aircraft of DLR´s research fleet will be on display. Participating in the ILA Career Center, DLR recruiting staff will give advice and tips on how to successfully apply for jobs at DLR.

FOLLOW THE LATEST NEWS BY VISITING THE DLR PORTAL

All articles can be viewed online in the news archive with pictures and videos.

DLR.de/News



IN PURSUIT OF COST-EFFECTIVE ENERGY STORAGE

Eleven DLR institutes are working on energy storage systems for the power and mobility sectors within the interdisciplinary GigaStore project

By Denise Nüssle

Power and heat at the touch of a button – clean, reliable and affordable. That is the promise of the energy storage systems that will provide the foundations for tomorrow's power and transport system. These will be primarily based on electricity from renewable, yet fluctuating sources. Developing reliable storage systems that can compensate for these variations is thus regarded as a key technology for a successful energy and mobility transition. At the same time, the development of the required energy storage concepts is one of the central technological challenges faced by research and industry. To this end, DLR has initiated the GigaStore project, in which an interdisciplinary team of scientists from 11 DLR institutes are working together to develop and test high-performance, cost-effective energy storage systems.

DLR is exploring a range of possibilities. "There is no single energy storage method, no one technology, that will solve all problems. We need solutions specifically tailored to the respective application," explains André Thess, Director of the DLR Institute of Engineering Thermodynamics and GigaStore Project Coordinator. The performance requirements for a megawatt-hour system for mobile applications are extremely different to those for a gigawatt-hour, stationary storage system designed to supply a large city with power during the night or a period without sufficient sunlight. "Our aim with the GigaStore project is to adopt a whole-system approach to energy storage research," says Thess. "We examine both the technological and the economic aspects – from the processes occurring at the molecular level within a battery to the operation of entire demonstration facilities and the evaluation of their cost-effectiveness by our systems analysts. DLR researchers in the fields of aeronautics, space, energy and transport are all contributing their expertise to the project. DLR is uniquely equipped to explore this topic with such breadth and depth," Thess emphasises.

The GigaStore project is divided into three main research areas: investigating new concepts for batteries with particularly high energy storage densities, researching current power-to-heat-to-power storage systems, and designing computer simulations that will enable more rapid development and testing of new storage technologies.

High storage density batteries for Earth and space

Whether for electric mobility on road and rail, as a component in electrically powered aircraft and for on-board power supply, or as an energy supplier for satellites in space, battery systems should be as powerful, durable and inexpensive as possible. In the GigaStore project, DLR is pooling its existing expertise in battery technologies to advance new concepts with high storage densities to a stage where they are ready for practical implementation and thorough testing in demanding fields of application. The researchers are particularly interested in the use of metal-sulphur batteries. The main advantage of this type of battery is its high energy density – potentially two to three times greater than that of the currently widely used lithium-ion system. Sulphur is also readily available and inexpensive, meaning that such batteries could provide the same energy content while being lighter, more compact and less expensive to produce than those in use today. First, however, a better understanding of the electrochemical processes that take place inside these new types of sulphur-based batteries is required. Only then will it be possible to develop safe and cycle-resistant – that is, long lasting – batteries of this type for ground and aerospace applications.

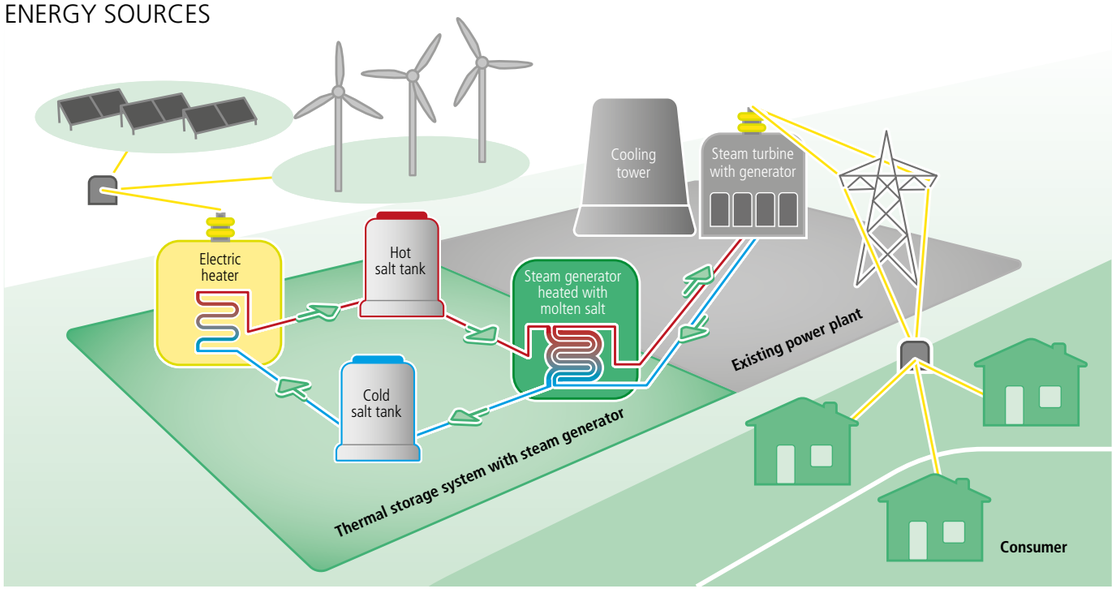
Space applications are particularly demanding of their technical components. Excellent performance and reliability are essential, as there is often no opportunity to fix problems once a mission is in progress. As such, batteries for satellite missions must meet the highest standards of safety and reliability. Satellites require large quantities of energy to power their on-board computers, control and communications systems, sensors, cameras and other scientific equipment. A satellite's power supply system has a major influence on its design, mass and cost. To ensure that batteries can withstand radiation and the vacuum of space, they are tested extensively and at great cost over the course of several years before they are used on a mission. Within GigaStore, DLR researchers are developing battery systems tailored for small satellites, qualifying them for use in space, and planning to test a prototype on a DLR satellite mission. In doing so, they are looking to reduce the costs of the battery-testing phase and allow for less expensive and faster satellite deployment. For this, they are also investigating supercapacitors – special energy storage systems that can provide large quantities of electrical energy over a very short period of time. These could be particularly useful to deal with power-demand peaks caused by attitude control systems during spacecraft manoeuvring, for example.

DLR CROSS-SECTORAL PROJECTS

- **Future Fuels**
  (DLRmagazine 158, July 2018)
- **Factory of the Future**
  (DLRmagazine 159, November 2018)
- **Big Data Platform**
  (DLRmagazine 160, March 2019)
- **Simulation-Based Certification**
  (DLRmagazine 161, July 2019)
- **Condition Monitoring for Safety Relevant Structures**
  (DLRmagazine 162, October 2019)
- **GigaStore**
  (DLRmagazine 163, December 2019)

- *Cybersecurity for autonomous and networked systems*
- *Global Connectivity*
- *Transport 5.0*
- *Digital Atlas*

THERMAL STORAGE POWER PLANT FOR CONTROLLABLE ELECTRICITY SUPPLY USING RENEWABLE ENERGY SOURCES



Carnot batteries and thermal storage power plants – taking energy conversion further

Storing energy on the scale of gigawatt-hours over several days or weeks – to bridge a period of reduced solar power production, for example – stretches conventional battery systems to their limits. To address this need, energy experts at DLR are hoping to make use of Carnot batteries. Named after French physicist and engineer Nicolas Carnot – founder of the study of thermodynamics in the early 19th century – these power-to-heat-to-power storage systems convert electricity from renewable sources into heat. This heat can be stored until energy is needed again and then converted back into electricity. In the GigaStore project, DLR researchers want to use their initial laboratory-scale demonstration units to show that Carnot batteries are an effective solution for flexible energy storage with minimal losses.

Carnot batteries in the form of thermal storage plants have the potential to be a key element of the energy transition and the structural change that will arise from phasing out fossil fuels. In thermal storage power plants, electricity is converted into thermal energy using high-temperature heat pumps and then stored in molten salt, liquid metals, rocks or ceramics. As in a conventional power plant, this heat can then be used to produce steam, which drives a turbine and generates electricity. At the same time, the stored high-temperature heat can be used for industrial processes or be converted into cold via a heat exchanger to, for example, cool data centres.

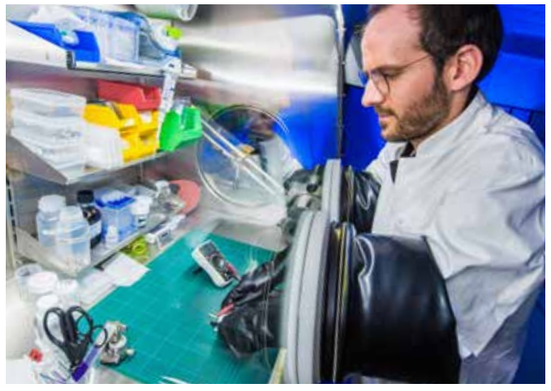
DLR is conducting research into concepts, operating procedures and storage materials for making the conversion of electricity to heat and back again as efficient as possible. The key challenge is minimising the loss of heat during the transfer to the storage medium. To address this, the recently founded DLR Institute of Low-Carbon Industrial Processes in Zittau and Görlitz is making important contributions to the development of the necessary high-temperature heat pumps. As part of a large-scale field laboratory, DLR is also planning to convert an existing coal-fired power plant into a thermal storage power plant. Much of the infrastructure that is in place will continue to be used, including the turbines and connections to the grid; only the coal storage and combustion facilities will be replaced, saving large amounts of money while retaining jobs and proven operating methods.

Energy storage simulation – a task well modelled is a task half completed

As in all areas of innovation, computer simulations and virtual design play a major role in making experimental work more targeted and hence enabling a faster and more efficient development process. Devising energy storage simulations is thus another focus of the GigaStore project. Energy researchers are gaining insights from their colleagues in aeronautics, where simulations are already being used successfully in the development of new technologies. Using computer-based modelling, DLR researchers are, for example, investigating the processes within a battery cell down to the nanoscale level – in other words, studying the most elementary processes at play inside a battery. Simulations also play a major role in the field of energy systems analysis. Here, DLR researchers use them to identify and evaluate the economic, environmental and societal impacts of different technologies, explore how new storage concepts can best be integrated into the overall energy system, and open up new areas of application for energy storage.

Denise Nüssle is an editor in the DLR Media Relations department and was responsible for communications at the Stuttgart site for many years.

View of the climate chamber at the DLR Institute of Engineering Thermodynamics in Stuttgart. Here, batteries of all kinds are tested to better understand their internal processes and continuously improve them.



© DLR

DLR researcher Dennis Kopljar investigates a lithium-ion battery. In addition to researching such conventional cell types, he is also working with his colleagues to develop future storage technologies such as lithium-sulphur or lithium-air batteries.

© DLR/Frank Eppler

André Thess
heads the DLR Institute of Engineering Thermodynamics and is Professor of Energy Storage at the University of Stuttgart. His research focuses on thermal energy storage and electromagnetic process and high-temperature measurement technology.

THREE QUESTIONS FOR GIGASTORE PROJECT COORDINATOR ANDRÉ THESS

What is the economic potential of energy storage technology?
: In the medium-term, storage technologies have the potential to create high-quality jobs and further strengthen Germany as a business location in the field of energy technology. Potential users include energy suppliers, power plant engineering companies, car manufacturers and energy-intensive industries such as steel, chemicals, glass, ceramics and cement. DLR's research makes it a scientific pioneer and is helping to maintain and expand the high level of innovation within Germany and Europe as a whole.

Will there be a mass market for energy storage systems in the future?
: A lot is currently happening in the field of battery technologies worldwide – both in industry and research – primarily in the context of electric vehicles. It is not possible to predict exactly when stationary storage systems will make their big breakthrough. The Google spin-off MALTA is currently working on a project involving Carnot batteries, and MAN Energy Solutions is focusing on thermal storage in connection with carbon dioxide cycle processes. Whether and how quickly an energy storage industry develops depends to a large extent on political and economic conditions, particularly future price developments for coal, oil and gas as well as the taxation of carbon dioxide emissions.

"In the medium-term, storage technologies have the potential to create high-quality jobs and further strengthen Germany as a business location in the field of energy technology."

Will the age of electricity follow the age of oil and gas?
: I believe that the age of electricity can only begin when adequate energy storage facilities become available. In addition to electrifying the energy supply and mobility sectors as comprehensively as possible, other paths can be taken. Synthetic fuels, which are produced from or with the help of renewable resources, are another option. Here too, DLR has extensive expertise and is investigating the development and application of regenerative fuels in another interdisciplinary project, Future Fuels.

This interview was conducted by Denise Nüssle.

ABOUT THE CROSS-SECTORAL GIGASTORE PROJECT

Participating institutes

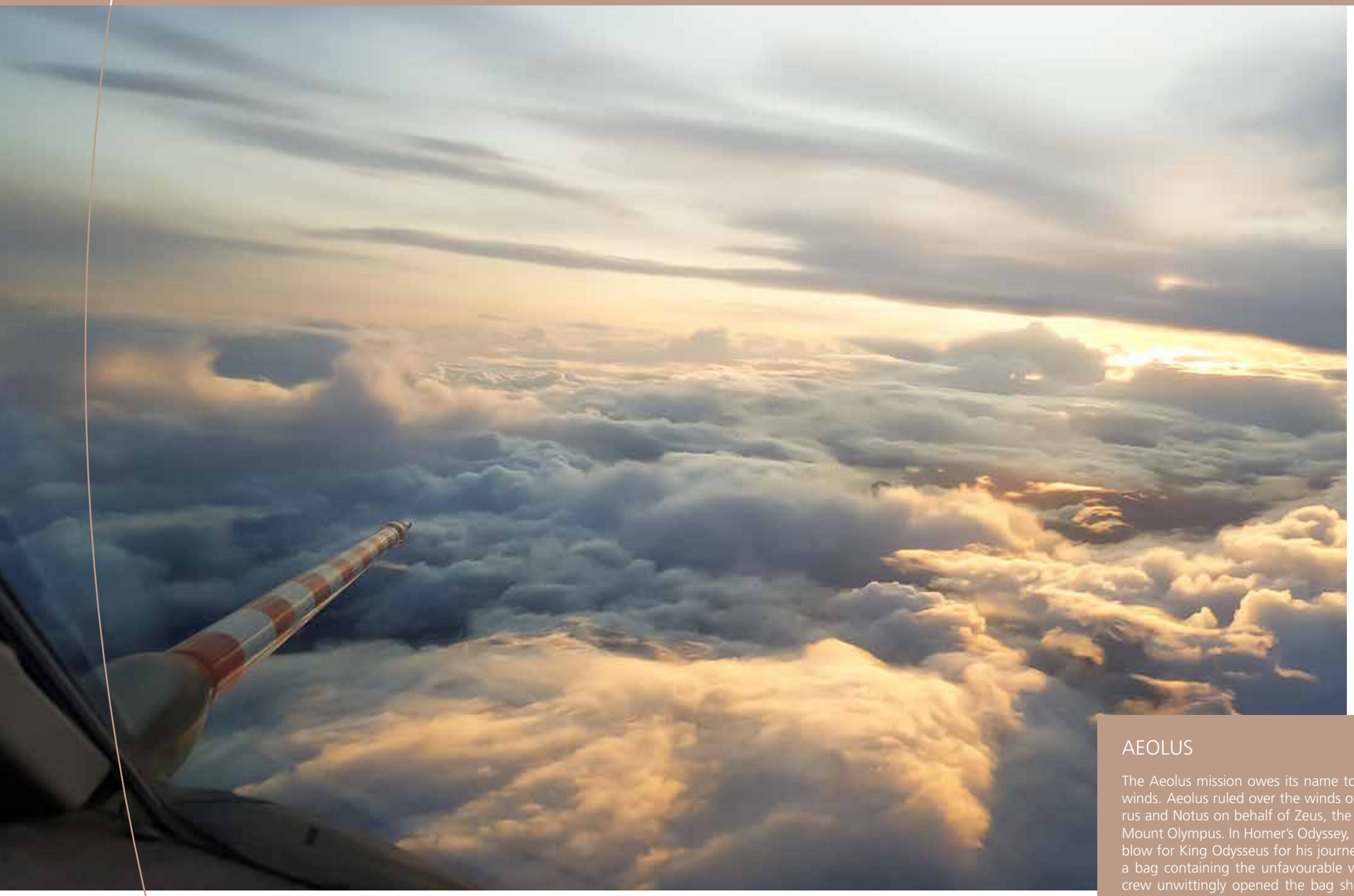
- Institute of Propulsion Technology
- Institute of Flight Systems
- Institute of Optical Sensor Systems
- Institute of Space Systems
- Institute of Software Methods for Product Virtualization
- Institute of Solar Research
- Institute of System Dynamics and Control
- Institute of Engineering Thermodynamics
- Institute of Networked Energy Systems
- Institute of Materials Research
- Institute of Composite Structures and Adaptive Systems

Duration: four years (2018–2021)
Funding volume: 13 million euro

ON THE TRAIL OF THE WIND

DLR scientists take to the skies over Iceland for the Aeolus mission

By Manuela Braun



Icelanders are said to have more words for snow than even the Inuit, and likely many more for rain and wind. A team of DLR atmospheric scientists and research pilots spent three weeks in Iceland with the DLR Falcon 20E research aircraft to measure wind speeds. Their campaign took place at the same time and, to the greatest extent possible, followed the same route as the Aeolus satellite, which has been orbiting Earth with its on-board Atmospheric Laser Doppler Instrument (Aladin) since 22 August 2018. During their stay, the team also became well acquainted with the many different types of rain and wind – horizontal rain, dreadful drizzle, and the clammy cold rising from the wet floor in the aircraft hangar at Keflavik Airport. All of these were usually accompanied by dense cloud cover over the volcanic landscape. Alternating high and low pressure areas create variable wind speeds. The jet stream – a band of constantly shifting strong winds – often flows nearby. These are ideal conditions for the Aeolus Validation Through Airborne Lidars in Iceland (AVATARI) campaign. It compares the data acquired by the first satellite-borne wind lidar with measurements from an aircraft to validate the wind profiles acquired from space and improve the retrieval algorithms.

The situation is complicated. Nobody can anticipate how fast the low-pressure system will advance in the next few days or whether it might even act unpredictably. "If conditions here develop more quickly, the situation will change completely," says Andreas Schäfler of the DLR Institute of Atmospheric Physics. Oliver Reitebuch and Christian Lemmerz, who also work at the Institute, carefully study maps showing wind directions and speeds, as well as cloud cover for the next few days. The trio have converted the hostel's lounge into a conference room, in which they are planning the Falcon's next measurement flights. The room – with its cosy and somewhat worn armchairs, a coffee table, a floor lamp and a small bookshelf in the corner – is the meeting point for everyone at the end of the day.

Located 40 kilometres from Iceland's capital city of Reykjavik, the hostel is usually occupied by holidaymakers who either have a very early flight home from Keflavik airport or who arrived in the country late at night. In the past, US military personnel lived and worked here when it was part of the former NATO base, Ásbrú. Nowadays, the area is accessible to the public and some of the residential buildings have been transformed into simple, practical hotels with rooms looking out over the airport's perimeter fence. For the researchers, pilots and technicians of the Aeolus team, this is ideal as it takes just a few minutes by car to reach the hangar where the Falcon is parked. The hostel has therefore become the 'base camp' for DLR's three-week measurement campaign.

Under the track of the satellite

The first week went so well that the campaign team could hardly believe it. Already during the transfer flight from Oberpfaffenhofen, near Munich, to Iceland on 9 September 2019, the scientists switched on the instruments on board Falcon and followed the ground track of the Aeolus satellite north of Scotland. The 'A2D' lidar instrument has the same

AEOLUS

The Aeolus mission owes its name to the Greek god of the winds. Aeolus ruled over the winds of Boreas, Eurus, Zephyrus and Notus on behalf of Zeus, the most powerful god on Mount Olympus. In Homer's Odyssey, he let favourable winds blow for King Odysseus for his journey by sea and gave him a bag containing the unfavourable winds. When the ship's crew unwittingly opened the bag shortly before arriving at their home port, the winds escaped and drove them back to their point of departure.

system architecture and receiving optics as Aladin on Aeolus, and was used alongside the 'two-micron wind lidar', a well-proven system that provides more accurate wind speed measurements. Thus, the first AVATARI dataset was stored even before the team arrived in Iceland. Over the following days, the Falcon took off almost daily to measure the wind as synchronously as possible with the satellite. Wind speeds of up to 60 metres per second, mixed cloud coverage – and then a flight on 17 September through the jet stream's strong winds. "A dream," says Oliver Reitebuch, Scientific Lead for the Aeolus Data Innovation and Science Cluster (Aeolus-DISC) at DLR.

Hoping for ideal conditions

Now, in the second week of the AVATARI campaign, the dream is crumbling a little. During the calibration flight over the Greenland ice, a safety mechanism on the wind lidar caused problems, and not all measurements could be carried out as planned. Troubleshooting will be conducted upon return to the hangar. At the same time, the weather around Iceland is becoming much more unstable. Twice a day, meteorologist Andreas Schäfler retrieves forecasts from the European Centre for Medium-Range Weather Forecasts (ECMWF).

An ideal measurement flight must meet certain conditions. The cloud coverage below the predicted satellite track should not be too high or too dense, as the laser pulses from space cannot penetrate dense cloud cover. "However, some clouds on the measurement path are also quite good for observing the reaction of the Aeolus instrument to them," Schäfler adds. Since the satellite orbits the Earth from pole to pole and only takes measurements transverse to the flight direction, east-west winds are easiest to capture. High wind speeds that vary at different altitudes above the ground are particularly suitable to calculate detailed wind profiles. The jet stream with its strong winds is therefore particularly interesting for atmospheric researchers. "We want sophisticated scenarios that are challenging for the satellite wind mesaurements," emphasises Campaign Coordinator Christian Lemmerz. Falcon's flight route may not extend south of Iceland into the North Atlantic flight corridor, in which a large proportion of air traffic from Europe to America takes place. If the Falcon comes too close to this area, Air Traffic Control will give a command via radio to turn back. When planning the measurement flights, the rest periods between flights required for the crew as well as the pilots Roland Welser and Thomas van Marwick must also be taken into account.


© DLR

Briefing in the breakfast room. From left to right: Christian Lemmerz, Frank Probst, Oliver Reitebuch and Andreas Schäfler decide when and over which route the next measurement flight should be conducted.

THE ALADIN INSTRUMENT

Aladin, the Atmospheric Laser Doppler Instrument, is the first lidar (light detection and ranging) system carried by a satellite for distance-resolved measurement of wind speeds. It fires laser pulses towards the atmosphere. The light scattered back from the atmosphere is used to determine the wavelength shift with spectrometers. The Doppler effect is proportional to the wind speed in the direction of the laser beam.

- Laser wavelength: 355 nanometres
- Laser pulse energy: 60 millijoules
- Pulse repetition rate: 50 Hertz
- Telescope diameter: 1.5 metres
- Vertical resolution: 500 metres to 2 kilometres
- Horizontal resolution: 10 to 90 kilometres
- Specified measurement accuracy:
  2 to 3 metres per second random error, 0.7 metres per second systematic error

LASER INSTRUMENT WITH EXPERTISE FROM GERMAN INDUSTRY AND RESEARCH

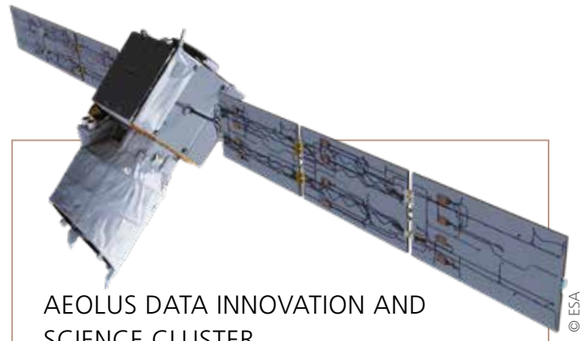
The Aeolus satellite was launched on 22 August 2018 from Europe's spaceport in Kourou, French Guiana, and orbits the Earth at an altitude of 320 kilometres. The mission is part of ESA's 'Living Planet' programme, in which Germany is the primary partner and contributor. The DLR Space Administration in Bonn manages Germany's contributions to ESA on behalf of the German federal government. Aeolus, and the Aladin laser system in particular, can improve medium-range weather forecasts. German industry and academia were involved in the development of the laser instrument. OHB System AG in Munich developed the transmit-receive optics for the ultraviolet laser. Tesat-Spacecom GmbH in Backnang built the communications system and the reference laser for the Aladin instrument. Airbus in Friedrichshafen was responsible for the electrical systems on the satellite platform. A number of small and medium-sized enterprises and research institutions achieved a technical breakthrough with the qualification of the laser optics for operation in vacuum. The companies Layertec GmbH (Mellingen) and Laseroptik GmbH (Garbsen) supplied optics and coatings, the Laser-Laboratorium Göttingen eV, the Laser Zentrum Hannover eV and the DLR Institute of Technical Physics in Stuttgart carried out the optical qualification and test measurements. These facilities contributed significantly to the integration of an optical system into the instrument that, despite the high laser power, will operate reliably for the planned three-year service life of the satellite.

More information: t1p.de/j1s4

Filling in the gaps in weather forecasting

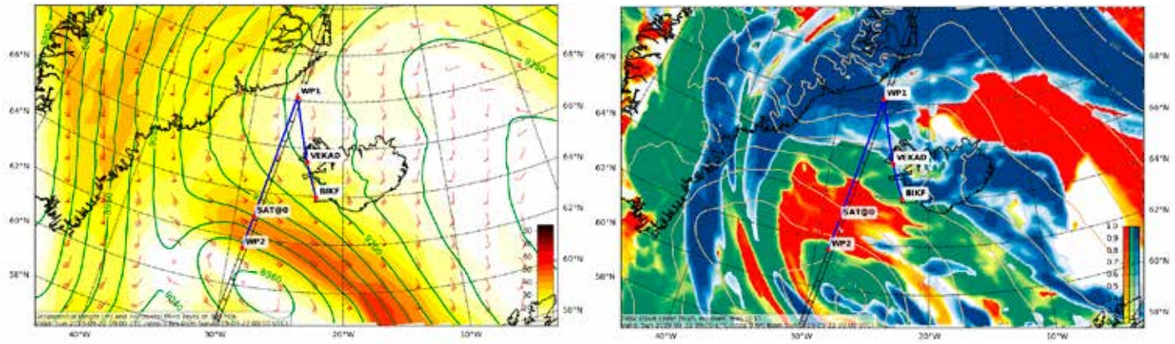
Aeolus is a European Space Agency (ESA) satellite mission aimed at filling the gaps in medium-range weather forecasting. Such a mission has long been at the top of the wish list of the World Meteorological Organization (WMO), a part of the United Nations to which the German Weather Service also belongs. "We only have a few wind measurements in the upper layers of the atmosphere," says Reitebuch, referring to localised measurements performed over land with balloons or radiosondes. But what happens worldwide in the various layers of the atmosphere has not been sufficiently measured. "We are lacking data for the southern hemisphere, the tropics and over the oceans." The wind, however, is crucial for circulation in the atmosphere. Given that the data is sparse, weather forecasts for events such as tropical cyclones or for wind speeds in the jet stream – needed by aircraft operators for optimal route selection – are not very accurate, especially for more than three days ahead.

The first wind lidar workshop took place in the late 1980s, with the aim of determining the requirements for such a unique mission. The development of the Doppler lidar Aladin broke new ground. To reduce the risk and support the development, it was decided to build a prototype of the instrument for tests on board an aircraft. The first flight campaign finally was in 2009 with a demonstrator of the satellite instrument on board the Falcon. Now that the satellite is in operation, the airborne demonstrator collects comparative signals to validate the satellite data acquired from an altitude of 320 kilometres. Reitebuch has been working on the Aeolus mission for two decades – "Actually, most of my professional life". DLR's main task is to develop the algorithms and processors that convert the detector signals transmitted to Earth by the satellite into final products.


© ESA

AEOLUS DATA INNOVATION AND SCIENCE CLUSTER

DLR coordinates the ESA-funded Aeolus Data Innovation and Science Cluster (Aeolus-DISC). Together with 10 international partners, including ECMWF, Météo-France or KNMI, the cluster has the task of monitoring and improving the performance of the Aladin instrument on board the Aeolus satellite and the quality of the resulting data. Another important task is the further development of algorithms and processors to convert the detector signals from the lidar into final wind and aerosol products. The cluster also conducts experiments with numerical weather forecasting models to investigate the influence of Aeolus data on medium-range weather forecasts.



The predictions by the European Centre for Medium-Range Weather Forecasts (ECMWF) for wind (left) and cloud cover (right) on 22 September 2019 show high wind speeds and relatively little high cloud cover along track. The Aeolus satellite – the probable track of which DLR scientists have marked with a black line on the weather maps – passes over a low-pressure area south of Iceland. The left image is colour-coded to show the wind speeds at an altitude of approximately 10 kilometres. The blue line indicates the Falcon's route from Keflavik, its flight under the satellite (WP1 to WP2) and its return to Keflavik. The image on the right shows the cloud cover as seen from the satellite. High clouds are shown in blue, medium-level clouds in green, and low-level clouds in red.

Rendezvous with Aeolus

The decision is made in the hostel lounge; the conditions for a measurement flight look favourable on Sunday morning. A band of south-easterly winds is within range and the point at which the Falcon can turn onto the predicted satellite track seems to be in a region with higher wind speeds. Even though the satellite travels at an altitude of 320 kilometres and a speed of 7.5 kilometres per second, and the Falcon 'only' flies at 200 metres per second and an altitude of approximately 10 kilometres, the instruments have the same field of view. The DLR flight operations staff can now take over. The pilots receive the data needed for their flight planning, and their coordinator, Frank Probst, registers the flight and route with Air Traffic Control. The Falcon is due to take off at approximately 07:00 local time and the rendezvous with the satellite will take place at 08:28.

The first team is already in the hangar by 04:10. The instruments are sensitive and need to be switched on before the flight, to achieve the correct temperature. It was cold in the hangar during the night. Christian Lemmerz squeezes between instrument racks and equipment to reach the laser instrument's control console. One more piece of equipment in the Falcon and there would be no room for the scientists. It took several days before the flight campaign to install and test everything for correct functioning and safety in Oberpfaffenhofen. Lemmerz knows the instruments inside out. Switches are flipped, the cooling for the laser is started, and computer programs are activated. Gradually, A2D and the two-micron lidar come to life. Technician Christoph Grad checks the Falcon's nose boom, in which sensors acquire information on wind direction and speed, as well as on temperature and humidity during the flight. For the scientists, this provides additional information with which they can classify their wind measurements in the direction of the ground over the course of the flight.

At 05:00, the rest of the team arrives at the hangar with the pilots and the scientist who will be operating the two-micron instrument during the flight. It is still dark outside the big metal doors and rain is falling steadily. Pilot Thomas van Marwick puts his bag in the aircraft and unpacks his sandwiches as he prepares for the three-and-a-half-hour flight. This campaign does not require any demanding flight manoeuvres. Roland Welser has been at the controls of the Falcon for decades and Thomas van Marwick joined DLR as a pilot six years ago. "This is not an exciting flight for us," he says. "There is plenty of time to eat breakfast, but flying over Iceland and Greenland always offers an incomparable view." The final preparations are carried out in a calm and focused manner. Everyone knows the schedule. Postponements are not possible, because the research aircraft has to fit with the departures of the big commercial airliners. The Falcon is rolled out of the hangar and takes off at 06:58.

After landing at 10:30 it is clear that the decision to conduct the flight was the right one. On the satellite track, the unwanted high clouds were only present over the northern part of the route. Elsewhere, the instruments encountered some clouds in the lower levels of the atmosphere. The wind speed ranged from moderate to higher speeds of about 50 metres per second. A hard drive with the data is transferred from the Falcon into the hands of Stefan Rahm. He has constructed a mission 'ground segment' in his hostel room with which the fresh data can be processed and examined to gain a first impression. Each flight yields 200 gigabytes of new data to be compared with that acquired by the satellite and for optimising the retrieval algorithms. "My colleagues like to fly the Falcon until it almost falls from the sky," jokes Rahm and disappears to his computer with the data.

© DLR

The pilots Roland Welser (left) and Thomas van Marwick go through the final procedures before the Falcon takes off with the instruments and scientists on board.

© DLR

Christoph Grad is responsible for ensuring that the Falcon is able to record parameters such as temperature, humidity and wind direction during flight using its on-board instruments.

Successful results for AVATARI

"There are several reasons why we need such DLR campaigns," explains Thorsten Fehr from ESA. "Firstly, they helped prepare the mission for launch. Now, they are also improving the mission by calibrating and validating the satellite data." A possible follow-up mission can only be defined if the weak points, successes and requirements have been carefully analysed. In addition to DLR and the DISC consortium, only a select group of international lidar teams and weather services currently have access to the Aeolus data from space. The global wind profiles can only be incorporated into existing weather forecasting models when the quality of the data is guaranteed and its processing is optimal. It is anticipated that the data will be made available to the broader scientific community from the beginning of 2020.

At the end of the AVATARI campaign, the Falcon will have followed the Aeolus satellite's track a total of 10 times. Additionally, the scientists were able to calibrate their instruments twice during flights over Greenland's ice. "This is more than in any of the earlier campaigns conducted for the Aeolus mission," says Oliver Reitebuch, summing up the missions. And also, more than would have been expected, judging from the weather situation during the campaign. This is a further step towards more accurate medium-range weather forecasting. The wind profiles recorded by Aeolus in the tropics, for example, will improve forecasts globally. "When it comes to the weather, everything is ultimately intertwined," says Reitebuch.

Manuela Braun is responsible for communications strategy at DLR's Space Research and Technology division.

© DLR

The measurement instruments are sensitive – any failure during flight can lead to the loss of research data. Before the flight, Oliver Reitebuch makes sure all the instruments are ready for take-off.

© DLR

In the Falcon's very confined cabin, Campaign Coordinator Christian Lemmerz (right) and Uwe Marksteiner prepare the instruments for the upcoming measurement flight.

Weather and wind were not always favourable, but in the end the scientists were able to obtain extensive datasets during a record number of measurement flights. This will enable them to put the data acquired by the satellite to the test and develop new evaluation algorithms.

© Stockfoto Getty Images

SPACE TECHNOLOGY FOR EARTHLY SOILS

The C.R.O.P. biofilter turns biological waste into fertiliser

An interview by Manuela Braun

It was not the first warning. On 25 July 2019, the European Commission once again requested Germany to comply with the 1991 Nitrates Directive of the Court of Justice of the European Union. In particular, fertilisation with manure and slurry contribute to excessive levels of nitrates in groundwater. As such, measures should be taken to significantly reduce the contamination of water by nitrates from agriculture. The Court denounced the fact that German regulations – for example with regard to the spreading of fertilisers – continue to be insufficient, and threatened to impose substantial fines. Of course, manure is a natural by-product of livestock farming. But storing it and using it in a timely manner as plant fertiliser is difficult. If too much fertiliser is applied, the nitrate content cannot be completely absorbed and utilised by the plants. The excess nitrate is then washed out into groundwater, lakes and rivers.

One method for converting agricultural animal waste products into a more easily dispensable fertiliser solution is derived from space technology. Jens Hauslage of the DLR Institute of Aerospace Medicine has been developing and testing the Combined Regenerative Organic food Production (C.R.O.P.) biofilter since 2011. One example of this biofilter is currently travelling through space on board the Eu:CROPIS satellite. It could one day be used to produce a nutrient solution for plants during missions to the Moon or Mars by recycling astronauts' urine, and has potential applications on Earth. In this interview, the DLR scientist explains how volcanic rock and microorganisms could also be used to reduce nitrate concentrations in soils and groundwater here on Earth.

Jens Hauslage
works in the Gravitational Biology Department at the DLR Institute of Aerospace Medicine and leads the C.R.O.P. and Eu:CROPIS projects. He and his team simulate and test greenhouses that could one day form part of future habitats on the Moon or Mars. He envisages a hybrid life-support system, comprising physicochemical systems connected to biological life support systems. The physicochemical system would provide stability and security of supply, while the biological system would ensure a continuous and long-lasting operation.

© DLR

A C.R.O.P. filter is currently on board the Eu:CROPIS satellite, orbiting Earth at an altitude of approximately 560 kilometres. How does the filter work and what are its potential applications in space travel?

: Using human waste as fertiliser to, for example, grow tomatoes, is not possible on a space station or in an extraterrestrial habitat. Doing so would be far too unhygienic. If we were to use the microorganisms that actually do the work within Earth's soil in these environments, then they would need a habitat. That is why we take solid but porous volcanic rocks and 'trickle' water and urine over them in our C.R.O.P. biofilter. The small pores and cavities in this type of rock provide an ideal environment for the types of organisms that convert ammonia from urine or liquid manure into nitrates here on Earth. This community within the lava rocks thus takes on the function played by the soil in agricultural fields.

How can a biofilter that may eventually be used to turn human waste products into a nutrient solution help to reduce high nitrate levels on Earth?

: Our soils play an important role in converting liquid manure into fertiliser. The problem is that there is far too much manure for the number of plants actually using the fertiliser. Due to this surplus, we have to store it to avoid the risk of contaminating our drinking water. It goes without saying that no one wants to have a 'lake of manure' on their doorstep, and storing and transporting it are not economical. But the C.R.O.P. filter is capable of using natural means – without the need for chemicals and high-energy inputs – to produce a detoxified fertiliser solution that is no longer foul smelling and is easy to store in a concentrated form. This new fertiliser can be used in a much more controlled way, without contaminating the soil or groundwater. In addition, the filter uses bacteria that can also break down substances such as drug residues, which pose a very serious problem during the treatment of drinking water.

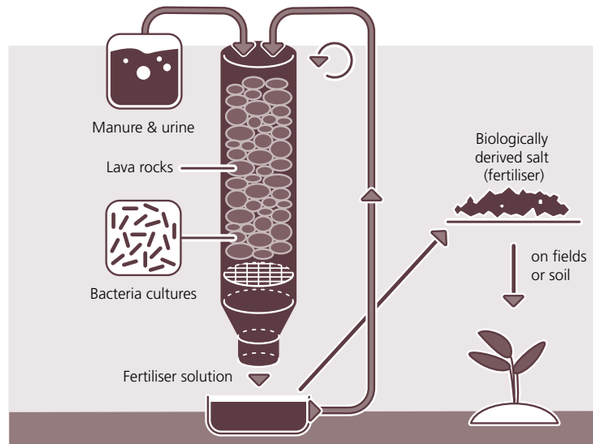
How much liquid manure is produced in Germany?

: I estimate the amount to be approximately 250 million tonnes per year. In addition, another 30 to 60 million tonnes from the Netherlands and Denmark are transported to Germany, where they are spread.

Why is storing manure and spreading it on agricultural land in line with demand such a problem?

: Liquid manure is actually a hazardous substance. It contains high concentrations of ammonia, which can be a potent toxin for humans. In addition, ammonia plays a key role in the formation of particulate matter. As I said, millions of tonnes of manure are produced every year. It can be stored in open ponds or in closed silos – although nobody wants to finance them. The C.R.O.P. filter produces a biologically derived solution that takes up far less space and is also more stable when stored. Safety is a real problem in storing large quantities of liquid. Imagine if a lake of liquid manure were to leak. Hundreds of thousands of litres of liquid waste would immediately flow into the ground. This does not happen with a dry substance.

The interview was conducted by **Manuela Braun**, who is responsible for communications strategy at DLR's Space Research and Technology division.



The filter consists of a vertical tube filled with lava rocks. Beneath it is a container of water. Water is continually pumped upwards from the reservoir and trickled back down over the lava rocks.

The rocks contain bacterial cultures such as Nitrosomonas or Nitrobacter that are able to convert biological waste (liquid manure, urine or fermentation residues) into a fertiliser solution for plants. They also remove toxins.

ESA/DLR/FU Berlin (G. Neukum)

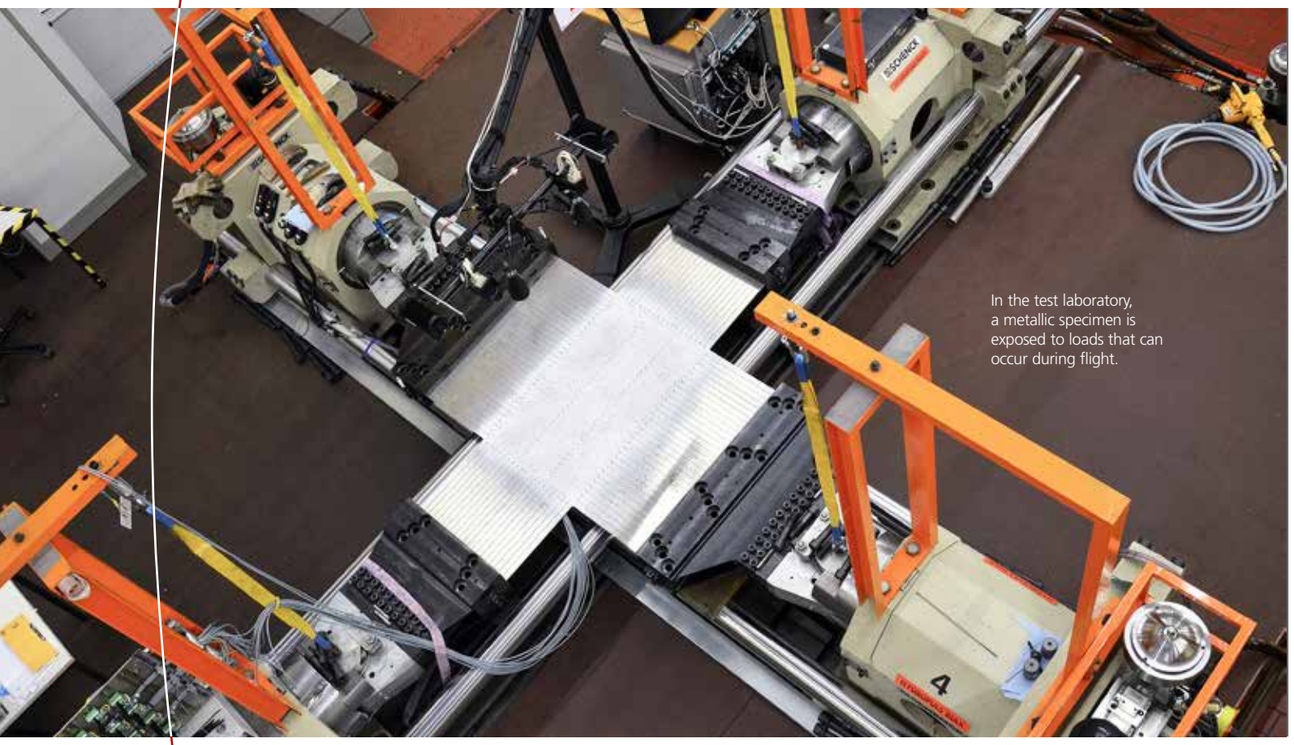
20,000 ORBITS AROUND MARS

During the night of 24 to 25 December 2003, the European Space Agency's (ESA) control centre reported that its first planetary mission – Mars Express – had successfully entered orbit around the Red Planet. On board was the High Resolution Stereo Camera (HRSC) developed by DLR. Originally intended to operate for just two Earth years, the mission has been repeatedly extended by ESA, most recently until the end of 2022. On 26 October 2019 this marathon runner among spacecraft – only NASA's '2001 Mars Odyssey' mission has been in orbit for longer – completed its 20,000th orbit around Mars. During the mission, HRSC has acquired terabytes of high-resolution image data in stereo and colour. While very useful for scientific purposes, the images are frequently also aesthetically pleasing. This image shows the Promethei Planum region near the South Pole. The carbon dioxide ice formed during winter gradually sublimates in the Martian summer, once again revealing the underlying landscape. Liais Crater, which can be seen in the upper right of the image, has a diameter of approximately 120 kilometres.

PUSHING AEROSPACE MATERIALS TO THE LIMIT

Artificial intelligence detects cracks in aircraft fuselages

By Frank Seidler



In the test laboratory, a metallic specimen is exposed to loads that can occur during flight.

Metallic materials are an integral part of the structure of modern aircraft. Their safety and efficiency depend on an expert understanding of how such materials behave during daily flight operations, where they are subject to the highest loads, and when parts need to be replaced.

DLR materials researchers are conducting extensive tests on aircraft materials – from entire components up to their microstructures. They subject these specimens to mechanical forces occurring during flight and observe how they perform using special camera systems. This provides them with a deeper insight into the behaviour of the materials and their limits. "We want to exploit the materials' properties to their maximum. Knowing those limits enables us to determine when an aircraft needs maintenance and to estimate the overhaul intervals more accurately," says Eric Breitbarth, who works in the Metallic Structures and Hybrid Material Systems Department at the Institute, and adds, "This saves time and money." It also protects natural resources as it allows the use of heavy, durable metals only where they are really needed. This makes the aircraft lighter and reduces its fuel consumption while preserving its safety and ability to withstand loads caused by wind gusts or cabin pressurisation.

Algorithms detect cracks

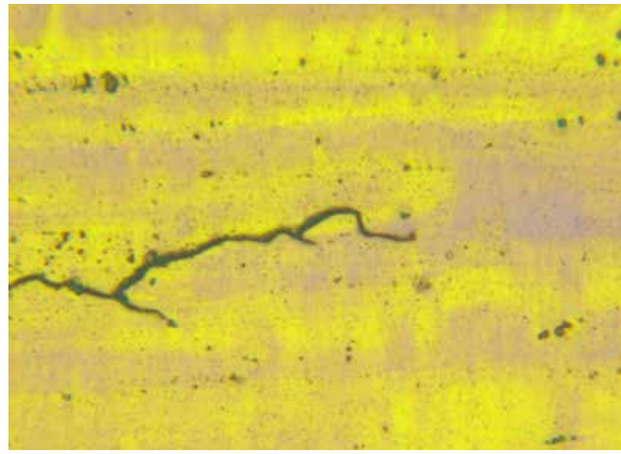
The team in the Department of Metallic Structures and Hybrid Material Systems is assisted by artificial intelligence (AI) methods that allow them to develop precise material-characteristics and predictive models more quickly. Two examples are Digital Image Correlation (DIC) and Deep Learning. During post-processing of DIC data a virtual image is overlaid on a component to reveal areas of higher and lower strains. Cracks will arise in the metal where the stresses are highest. Fatigue of materials is a normal phenomenon during the operational life of an aircraft. If the cracks become too large, the affected component has to be replaced during routine maintenance. AI algorithms used in the evaluation of the DIC data identify these cracks and can compute their local crack tip loadings. Once the software has detected such a crack, it is imaged by automated tracking microscopes to observe the local crack tip field. This technique is used to investigate the interaction of the mechanical loading conditions with the local microstructure of the materials. The experts can use this new technology to create new lifetime models of materials.

In order to include the influence of the microstructure, the scientists need more than surface data generated by DIC. For this purpose, they use 3D computer tomography to create a virtual model of the internal structure of the material in which the individual constituents are clearly visible. Previously, DLR scientists had to analyse these highly detailed images manually – a time-consuming process. But the first generation of trained deep-learning algorithms is now taking on this work. The software determines and evaluates the composition of the material in a fraction of the time that it would take a human to complete the same task. Machine learning processes, particularly Convolutional Neural Networks (CNN), are now being used very successfully for pattern recognition and semantic image segmentation at the DLR Institute of Materials Research. These techniques help to evaluate large amounts of computed tomography data quickly and accurately, providing insights into areas such as the damage process within aircraft components to an extent that is not possible using conventional methods.

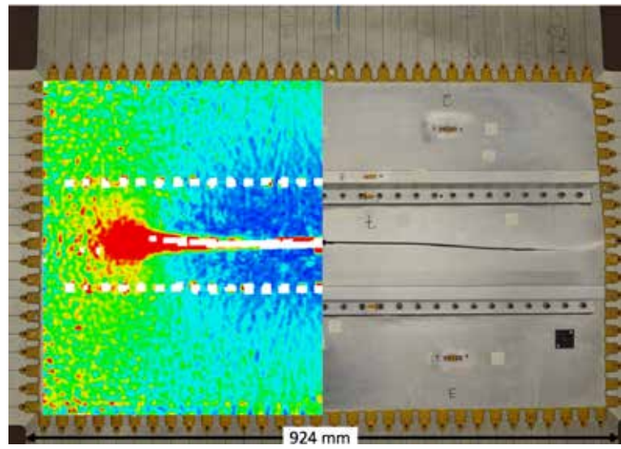
Tested to the max

The materials are tested using the biaxial testing facility at the Institute of Materials Research in Cologne. Specimens are subjected to non-constant loads in two directions using four hydraulic cylinders until they fail. This experiment makes it possible, for example, to reproduce the loads of a fuselage accumulated over a service life of several decades within just a few hours. "The system has been in operation for some time, but AI has opened up completely new possibilities for us," says Breitbarth. In addition to AI, robotics will be used in combination to automate the entire testing sequence up to the evaluation of the results.

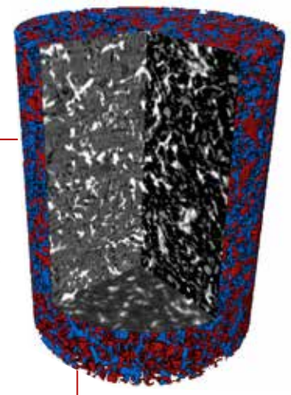
Frank Seidler is responsible for marketing and communications at the DLR Institute of Materials Research.



Material fatigue can cause fine cracks to arise in an aircraft fuselage. If these remain undetected for a long time, they can continue to spread, which could have severe consequences.



The intelligent camera system and digital image correlation automatically show where the mechanical loads within the sample are greatest.



MAKING THE INVISIBLE VISIBLE

3D computed tomography reveals the internal structure of a cast aluminium-silicon alloy (grey). Such materials are used in the automotive industry – for pistons, for example. The AI system identifies the individual constituents of the alloy and assigns them different colours; silicon is blue, while what is known as the intermetallic phase (aluminium mixed with other metals such as copper or iron) is shown in red. Aluminium is transparent in this representation. This provides the researchers precise information about the composition of the material and how it will behave. When will it break? How strong is it? After a week of training, a neural network can supply this information within a few minutes. Without this technology, it would take researchers six months to one year to produce similar results with this level of detail.

NIGHT FLIGHT AT THE END OF THE WORLD

DLR's HALO research aircraft is on a mission to investigate atmospheric gravity waves

By Falk Dambowsky

Antarctica is one of the most remote and least-explored regions on Earth. At first sight, what is happening there seems very distant, yet it has a great impact on the global climate and, therefore, on all of humankind. The behaviour of the global population, in turn, affects events in these distant polar regions. And although the ozone hole over Antarctica is now slowly shrinking again, the chemistry and physics of the atmosphere above Antarctica, and hence the processes relating to global warming at play there, will influence the global climate for decades to come. Only a few people – scientists, engineers, research pilots – travel deep into the southern sub-polar region to measure, explore and understand these interrelationships and processes. In 2019, a team from Germany joined them, on a mission with the High Altitude and Long Range (HALO) research aircraft.

On this occasion, HALO is staying in a rather worn old military hangar that has rarely been used since the now long past Falklands War. Behind it, an extensive landscape – endless grassland, dotted with grazing sheep. The town of Río Grande lies on the other side of the airfield. At night, all that can be seen above this town of 66,000 inhabitants on the Atlantic coast are lights. Besides the two scheduled flights from Buenos Aires that land here every day at 03:30 and 08:00, the airspace over Tierra del Fuego, at Argentina's southernmost tip, is very quiet.

The SOUTHTRAC (Transport and Composition of the Southern Hemisphere Upper Troposphere and Lower Stratosphere) campaign team comprises researchers from the DLR Institute of Atmospheric Physics, the Karlsruhe Institute of Technology, the Forschungszentrum Jülich, the universities of Mainz, Frankfurt, Wuppertal and Heidelberg, and DLR Flight Operations. They have set up a make-shift control room in a run-down, wood-panelled office adjacent to the hangar. This is where everything comes together – weather forecasts are analysed, flights are planned, and contact is maintained with air traffic control. As many of the HALO flights take place at night, the team works in shifts and the instruments are calibrated and serviced during the day. An average of 50 people work on the ground in Argentina over the entire campaign, with almost 150 experts involved in the SOUTHTRAC mission overall.

THE HALO RESEARCH AIRCRAFT

The High Altitude and Long Range (HALO) research aircraft has been in service for more than 10 years. It is a joint initiative of German environmental and climate research institutions. The operation of HALO is funded by a consortium consisting of the German Research Foundation, the Max Planck Society, the Karlsruhe Institute of Technology, the Forschungszentrum Jülich, the Leibniz Institute for Tropospheric Research and the German Aerospace Center (DLR).

Into the waves

In the event of a night flight, the crew arrives at the hangar in the early evening. Take-off is scheduled for 20:00, while the last twilight remains over the mountains. The cabin and flight deck offer room for 13 instruments, five scientists, two pilots and one on-board engineer, which means that each scientist has to work with several instruments simultaneously. In addition, various teams on the ground monitor the flight. After take-off this evening, HALO will first fly across the Chilean Andes to the Pacific Ocean. There, it will come into direct contact with mountain waves. This type of gravity wave is one of the subjects of the current research programme. Mountain waves are formed by the interaction of uplift and gravity in the atmosphere and

are also referred to as lee waves, because they are generated on the sheltered (lee) side of mountains. "We notice that we are passing through the waves due to changes in airspeed," explains DLR test pilot Marc Puskeiler. "When this happens, the autopilot gently oscillates back and forth between higher and lower thrust in order to maintain altitude and speed."

Once over the open Pacific, HALO will make a 90-degree turn so that it is flying parallel to the Andes, until it is some 100 kilometres from Santiago de Chile. Then, the research aircraft can really show its capabilities, ascending to a maximum altitude of approximately 14 kilometres. During the nocturnal flight, only the Moon and stars can be seen from the flight deck windows, together with the laser that scans the skies above HALO for gravity waves up to just below the boundary of space, at an altitude of 100 kilometres.

ALIMA shines through the atmosphere

"HALO has an additional optical window at the top of the fuselage for the new Airborne Lidar for Middle Atmosphere research (ALIMA) experiment. The laser beam is directed upwards through this window and the instrument captures the backscattered return signals," explains Bernd Kaifler of the DLR Institute of Atmospheric Physics. "To be more precise, we record periodic fluctuations in temperature, pressure and wind that extend up to 90 kilometres into the middle atmosphere – the stratosphere and mesosphere." These are triggered when strong wind systems from the Pacific meet high mountains such as the Andes. In the tropopause region – the transition from the troposphere to the stratosphere – the research team on board is investigating the chemical and dynamic processes that influence the climate-relevant trace gases ozone and water vapour.

Following another 90-degree turn over the Pacific, HALO will embark on a course across the South American continent until it is 200 kilometres from Buenos Aires. Here the pilots will turn and fly a similar course back to the starting point. After approximately nine hours and a few cups of coffee on board, the crew will be back in remote Río Grande.

The most important atmospheric conditions for the formation of the ozone hole over Antarctica are low temperatures and a reduced exchange with mid-latitude air masses. The latter is ensured by a stable atmospheric system – the Antarctic polar vortex. But this can be weakened by strong wave activity. Until now, this effect has not been sufficiently taken into consideration in climate and weather models. SOUTHTRAC is now providing the data needed to supplement existing climate models with this crucial piece of the puzzle.

Other flights conducted as part of the mission flew out over the Atlantic, above the Andes and across the Antarctic Ocean all the way to the Antarctic Peninsula, which HALO overflew for the first time. In September and November, the team collected a wealth of data on the climate and climate change in the southern subpolar region. After travelling to the southernmost tip of the world for a total of eight weeks, the researchers have returned to Germany satisfied and confident that they have taken a major step towards understanding past and future climate changes on the basis of the data collected. At home, extensive analysis of the data will begin, while HALO is prepared for future missions to Barbados, Brazil and Iceland.

Falk Dambowsky is an editor at DLR's Media Relations department.

The Andes is the longest mountain range on Earth and the world's strongest source of gravity waves

The HALO research aircraft on the apron of the airport in Río Grande. Inlets can be seen on the upper edge of the fuselage. Air is drawn through these into the interior of the cabin for analysis.

Launch of a radiosonde near El Calafate airport. The launches were carried out by Ludwig-Maximilians-Universität München, also a project partner in SOUTHTRAC. From here, gravity wave measurements were also performed using a glider piloted by Klaus Ohlmann.

WHAT ARE GRAVITY WAVES?

Gravity waves are waves in the atmosphere or ocean caused by gravity acting on a stable, layered medium (that is, by uplift in air or water). They should not be confused with gravitational waves, which are waves in space-time. Gravity waves occur if, for example, air masses encounter mountains, are lifted by the pressure of the wind and then descend again on the other side of the mountain. This vertical displacement of air masses generates waves that propagate vertically and horizontally through the atmosphere. The world's strongest single source of atmospheric gravity waves is the southern Andes. In the region of the Antarctic peninsula and South America, the wind comes predominantly from the west, and the Andes – which run north to south – present an enormous obstacle; they thus form a powerful gravity wave generator. If there are high wind speeds at ground level. in the stratosphere and mesosphere, these waves can spread high into the atmosphere, up to an altitude of 90 kilometres. This happens at the southern tip of South America when the polar night jet reaches the Andes during winter. This creates a perfect waveguide upwards through the atmosphere. The SOUTHTRAC mission is investigating the effect of gravity waves on the climate.

© DLR

Bernd Kaifler (right) and Thomas Gulde of KIT in the HALO research aircraft

Bernd Kaifler
works at the Lidar Department of the DLR Institute of Atmospheric Physics and is responsible for all projects dealing with lidar-based exploration of the middle atmosphere. Over the past seven years, he has developed systems that have been deployed in the most remote regions of the world – from New Zealand to northern Scandinavia – and for the last two years in Tierra del Fuego. Last year, he and his team flew the world's first balloon lidar for the middle atmosphere on a NASA balloon.

SCIENTIFIC WAVE SURFING

Numerous miles, great volumes of data and – most importantly – plenty of coffee. In this interview, DLR atmospheric physicist Bernd Kaifler explains the SOUTHTRAC mission in Argentina, where a team of scientists is investigating the impact of gravity waves on the climate and the transport of air masses in the atmosphere.

Dr Kaifler, in September 2019 you spent several weeks in Río Grande, Argentina, at the southernmost tip of South America. What impressed you most during your time there?
: I would have to say the weather. I had already been to Río Grande twice in the last two years, for the purpose of setting up and maintaining a ground-based lidar system there to investigate atmospheric gravity waves. It is always quite stormy at that time of year. Río Grande lies on the east coast, on the wide plain of Tierra del Fuego, and is completely exposed to the wind. Cape Horn and the Drake Passage, which are both feared by sailors because of their storms, are not far away. We soon became accustomed to battling with the wind on the walk from the hotel to the aircraft hangar every day. However, on this occasion there were two days when the air was completely still, which is far from typical. In addition, seeing the desert-like expanses, due to the low amount of precipitation, with a backdrop of snow-covered mountains, certainly makes a striking impression.

The southern Atlantic, the Pacific, the Andes and Antarctica are all far from Europe. Why do you need to fly there in a research aircraft? Could you not just obtain the information you need from space, using satellites?
: These gravity waves can be detected from space using suitable instruments on board satellites. However, from that distance the resolution of the measurements is not high enough to capture their complete spectrum. In addition, the orbits of the satellites mean that they only pass over any given location once or twice a day. In contrast, measurements conducted using an aircraft offer enormous advantages. For example, we can choose to fly a course that follows the direction of propagation of the waves over the Andes and thus record an accurate wave spectrum. In addition, we can fly the aircraft over a specific location several times in one day and record changes over time.

Measuring temperature profiles up to an altitude of 90 kilometres sounds very impressive indeed when you consider that during its mission HALO 'only' flew at a maximum altitude of 14 kilometres. What does the new laser-based ALIMA lidar do? What makes it special?
: ALIMA is a truly unique instrument and we reached the limits of what is technologically possible during its development. The laser has a power of 15 watts, the receiving telescope has a very small field of view to minimise sources of optical interference, we have extremely narrow-band optical filters in the receiver to filter out as much daylight as possible, and we use optics with very high transmissivity and detectors with high quantum efficiency. These devices have been used in ground-based instruments for some years. What is different is that we have made the lidar instrument sufficiently compact and stable to fit into and work inside an aircraft. ALIMA delivered unique and scientifically very interesting data during its first measurement flights. For example,

© DLR

Meteorological ground station in El Calafate, operated by Ludwig-Maximilians-Universität München.

we were able to conduct temperature measurements at altitudes of up to 90 kilometres, despite turbulence and vibrations within the aircraft. During the next measurement campaign in two years time, we want

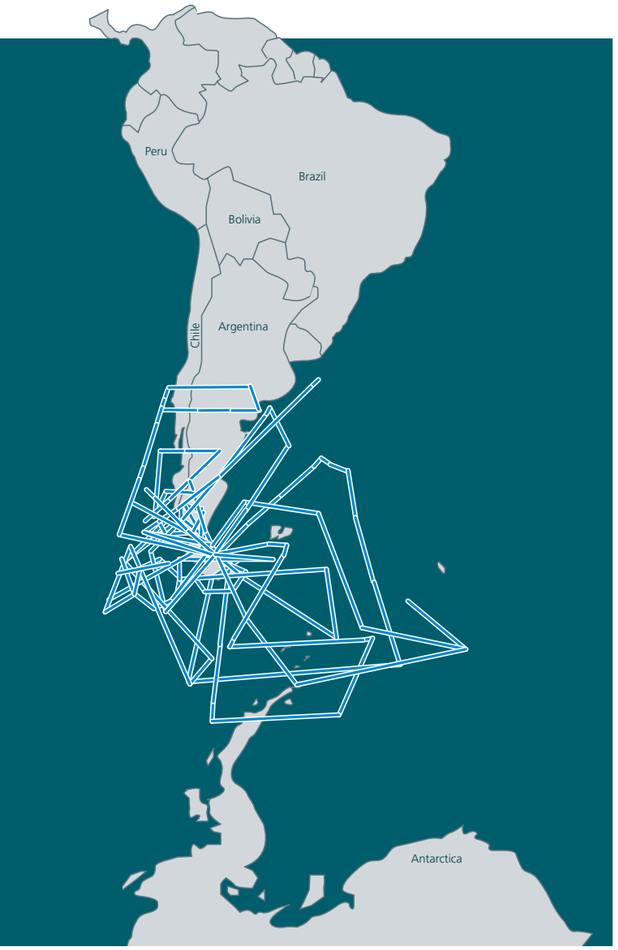
> "ALIMA delivered unique and scientifically very interesting data during its first measurement flights."

to go a step further and measure wind profiles in the direction of the laser beam, high above the aircraft. Wind measurement is the hardest discipline when using lidar instruments. We have done pretty much everything we can to prepare ALIMA; all that remains is to improve the laser's stability.

Space must be a bit tight inside HALO, with all the instruments. Who else is on board for this mission? How does it feel for the five of you to be responsible for so many measurement devices simultaneously, sometimes for 10 hours at a time?
: On board HALO there are two pilots, a flight engineer and five scientists, who look after the 13 scientific experiments. One of the scientists is appointed as mission scientist; this is a special role. The mission scientist is in constant contact with the pilots and the other scientists for matters such as adapting flight routes, turns and changes in altitude to the scientific requirements during the flight. But cooperation is always a must. Preparing and dropping probes is always a joint effort. The task of operating the inlet valves for the trace gas measurement devices is generally assigned to whoever is within reach of them, regardless of which experiments are officially their responsibility. We receive support from scientists and technicians on the ground, some in Río Grande itself and others back in Germany. We can communicate and get advice from people on the ground using a chat program connected via a satellite link. This comes in useful if a device is causing problems, the software crashes or simply if we see something interesting come up on the live instrument displays, which means that we might have to change the measurement device settings. The people who spend hours preparing and calibrating the instruments before every flight, and then switch them off under controlled conditions and service them afterwards, also play a vital role. It goes without saying that the crew on a 10-hour flight cannot manage everything on their own. Not only does this exceed the usual working hours, but nine to 10 hours of flying time is also physically and emotionally draining. The instruments require constant attention, which in most cases means checking a seemingly endless scroll of numbers, graphs and controls. Nowadays, this is mainly done electronically, on a laptop screen. The need to check everything constantly means that you even have to think twice about taking a bathroom break.

There is no lunch break; you cannot take your eyes off the screen as you eat. That said, you are willing to put up with a certain amount of

Aircraft and instrument maintenance in the hangar in Río Grande on a day of ground operations



Routes of the measurement flights performed by the HALO research aircraft during the SOUTHTRAC mission in September and October 2019

hardship for the sake of good measurement data, especially when you know that people on the ground are counting on your success. In addition to the scientists and technicians for the instruments, there is also the ground crew for operating the aircraft, the flight planning team, the weather forecasting team, the management team and many others. As part of the crew, you are essentially the visible tip of a huge pyramid of over 100 people who are all necessary to make the mission a success.

Can you describe a typical day during the campaign in Río Grande, at the end of the world? Did you have some free time alongside your routine tasks?

: On a flight day, everything runs according to a schedule that is determined by the departure time. For our night flights, for instance, this was 20:00 local time. That does not leave much room for leisure. Work in the hangar generally begins five to seven hours beforehand, with the preparations for the experiments. A colleague comes to collect me at 17:00 and takes me to the hangar. At that point, the decision is made as to whether or not the flight will take place. At the hangar, the team and I perform a functionality test on ALIMA. In the meantime, Sonja from the weather forecasting and flight planning team calls in and we go over the flight plan together, running through a few key issues. What is the weather like? Will the gravity waves in the latest forecast still be in the same place? Is there a chance that we might have to land at a different airport because the landing strip in Río Grande is icy?

The aircraft technicians tow HALO out of the hangar two hours before take-off. This is a dramatic event for the experiments, as taking the aircraft outside means interrupting the power supply. This is problematic, as heated detectors cool down and vacuum pumps come to a standstill. To keep the interruption to a minimum, all of the experiments have to be shut down as quickly as possible and, most importantly, at the same time, in a coordinated action. Once HALO has been rolled out of the hangar and the experiments have been powered up again, there is just one hour to get them into their flight configuration. All those who will not be flying exit the aircraft 15 minutes before take-off. We begin a ground test for the lidar, and the green laser beam is visible over the aircraft for two minutes. All those who have gathered to wave off the aircraft pull out their camera to take photographs of HALO and the green beam. No sooner has the laser been turned off than we start taxiing. HALO takes off at exactly 20:00, heading into the dark towards the Andes. And we begin our measurements.

Approximately nine hours later, just before 05:00, we land back at the airport in Río Grande. The ground team is already waiting for us at the hangar. They help us to shut down the experiments and secure the data. This takes about 45 minutes. There is a short debrief at about 06:00 and we finally make it back to the hotel at 07:30, just in time for breakfast. No one opts for the coffee, and shortly after we fall into bed, tired but happy. Once again, the measurement flight has been a success and tomorrow will be spent on the ground.

What will we learn about Earth's changing climate from the wealth of data acquired by the SOUTHTRAC HALO mission?

: We still know very little about the impact of climate change on the middle atmosphere. This is largely due to the fact that the current climate models do not incorporate gravity waves, and their effects are only taken into consideration in a very approximate way. In order for us to be able to better characterise the effects of gravity waves, we must first understand where the waves originate and how they propagate. One specific question, for instance, is whether a strong source is necessary for gravity waves to reach an altitude of 90 kilometres. Or do these waves become unstable along the way, breaking up and failing to reach high altitudes precisely because of their large initial amplitude? In that case, it would instead be the weak waves that could reach high altitudes under good propagation conditions. Acquiring data is essential to answer these and other questions. We can then use this information to detect wave packets in the atmosphere. This is one of the objectives of SOUTHTRAC – so these are process studies. In the medium term, we hope to be able to contribute our results to help achieve a more realistic incorporation of gravity waves into climate models.

Where would you like your next research destination to be, and why?

: I would like to return here, to Río Grande, and repeat the flights in the southern winter, perhaps in July. Shortly before our arrival in Río Grande there was an occurrence of stratospheric warming, which contributed in part towards the collapse of the polar vortex and had a massive effect on the propagation conditions for gravity waves. This happens extremely rarely in the southern hemisphere; the last time was in 2002. So, on the one hand, the campaign was fortunate enough to be able to study the effects of stratospheric warming. On the other, however, it could also be seen as rather bad luck, as it meant that studying the undisturbed propagation of gravity waves was no longer possible. That is why I am keen to repeat the measurements, and South America is still the perfect place to do this.

The interview was conducted by Falk Dambowsky

THE ALIMA INSTRUMENT

This airborne instrument for remote sensing in the middle atmosphere measures high-resolution air density and temperature profiles above the aircraft up to an altitude of 90 kilometres. It provides data within a range that would otherwise only be reached by sounding rockets. The Airborne LIdar for Middle Atmosphere research (ALIMA) instrument has been developed and constructed over the last six years at the DLR Institute of Atmospheric Physics and is now being used for the first time as part of the SOUTHTRAC campaign. The measurement principle is based on lidar technology. Five-nanosecond-long pulses of light generated by a powerful laser are beamed through a window at the top of the aircraft fuselage. As the light travels through the atmosphere, air molecules scatter part of the laser radiation back to the aircraft, where it is captured by a telescope and directed onto detectors. The length of time between the emission of a light pulse and the detection of the scattered light determines the altitude at which the scattering has taken place. The strength of the received signal makes it possible to determine the air density at this altitude.

Before take-off, the ALIMA instrument is tested one last time and the green laser beam, which is directed upwards through a window in the aircraft fuselage, is briefly visible.

© DLR

Svetlana Cvetkova and Valentin Lauther from the University of Wuppertal keep an eye on the data. A total of five scientists are in charge of all the experiments on board HALO during the flight.

© swb AG

When the power plant's 15-megawatt battery storage system is fully charged, surplus power is used for heating.

RAIN OR SHINE

DLR is creating a digital replica of a unique hybrid power plant

By Heinke Meinen

A simple stroll along the East Frisian coast is enough to see why northwestern Germany is pioneering the energy transition. A fresh gust of wind blows where just a minute ago the Sun was shining. Both on land and far out in the North Sea, countless wind turbines now produce energy on the scale of several coal-fired power plants. Each year, 70 percent more electrical power is produced from renewable sources than is consumed in the region.

The influence of the weather on the energy system has become a serious economic factor. The situation demands complex technological innovations, but also opens up new opportunities for industry and environmental conservation. Since 2009, the Bremen-based company swb AG has been focusing on integrating the power and heat sectors with the operation of a hybrid regulating power plant. This innovative power plant concept combines a large stationary battery system with a thermal storage system and an electric boiler. The advantage of this system is that the battery can compensate for fluctuations in the grid extremely quickly by absorbing and releasing energy (positive or negative frequency containment reserve). When the battery is fully charged, excess renewable energy, for example caused by strong winds from the North Sea, is converted into heat and can be fed into the district-heating network.

Compensating for fluctuations

Although the Bremen power plant is already in operation, the hybrid concept offers plenty of potential for optimisation. To this end, swb AG is working in cooperation with AEG Power Solutions and DLR in the 'HyReK 2.0' research project funded by the German Federal Ministry for Economic Affairs and Energy. The DLR scientists participating in this project are focusing on analysis, evaluation and optimisation of the processes involved in the Bremen plant. "The growing use of renewable energies is giving way to increasing fluctuations in the supply of power," explains Theys Diekmann, HyReK Project Manager at the DLR Institute of Networked Energy Systems. "So far, these fluctuations have primarily been offset by fossil-fuel burning power plants. We would like to demonstrate ways in which this and other services can be provided by a flexible hybrid power plant in a decarbonised energy system."

At the moment, Diekmann and his team are developing a simulation model based on real data from the plant to help optimise the power plant concept for future applications. The aim is to use a high-performance computer to conduct detailed analyses of the behaviour of the grid and to observe how the plant positively influences this. The model will also simulate the constituent devices of the power plant such as the inverter, which serves as the interface between the battery and the power grid. "We want to use this as a basis for developing the technology in such a way that the activities of individual power plant components are not viewed separately, and are instead aligned towards the overall system behaviour," says Diekmann. "This will enable us to optimise the efficiency and durability of the system and the individual components, thereby making it possible to derive an economically viable operator concept."

Power plant technology put to the test

How valid the simulation is will become clear as the project progresses through the transition into simulated practice. At this point, the simulation data will be implemented in a real laboratory equipped with the power plant technology together with the power plant operator. However, Diekmann adds that the simulation has scientific merit of its own. "This model can be used to simulate energy scenarios that we expect to occur in the future. From this, we can determine possible future commercial applications," he explains. "In addition, the model enables us to identify potential further options for flexibility around the hybrid concept. We want to develop strategies to shape the future energy system without having to expand the grid."

While Diekmann's team is working on the technological aspects of the project, a second HyReK working group at the Institute is focusing on analysis and evaluation. What potential is there for implementing the hybrid concept in Germany? What do the lifecycle assessments look like? Which business models could emerge? "On the basis of such questions, we are analysing the hybrid concept and conducting a multi-criteria evaluation. At the end, we will be able to make specific recommendations for action," says Henning Wigger, leader of this part of the project. This roadmap is intended to provide recommendations about regulatory incentives and identify key players in the implementation of such hybrid concepts.

In order to assess the power plant's contribution to climate protection, Wigger also takes a whole-system view at the plant as part of the lifecycle assessment. "We look at each of the installed components over their entire lifecycle – from cradle to grave as it were. In some cases, this goes all the way back to the extraction of the ore itself and examines the conditions under which a component was manufactured, as well as the emissions produced as a result."

Keeping an eye on new developments

In addition to numerous other parameters, such as energy payback time (EPBT) or recycling concepts, the scientists take a range of scenarios into consideration as part of their assessments. These may relate, for example, to possible future developments in carbon dioxide pricing. Wigger is still unsure about whether the standard computer program designed to process the plant's operational data will be able to incorporate these complex requirements. "We are still considering whether it would be easier to develop our own program." Whatever the choice, the Bremen-based hybrid concept will have to directly compete with other technologies – from hydrogen production to the delivery of surplus power to cold storage facilities.

Insights into how close Bremen's hybrid power plant will come to its ideal future condition with its current technology will be available at the end of the project in Autumn 2021. In the meantime, those setting out on a walk along the stormy North Sea coast will see why a more flexible energy system could provide the energy transition with the decisive tailwind that it needs.

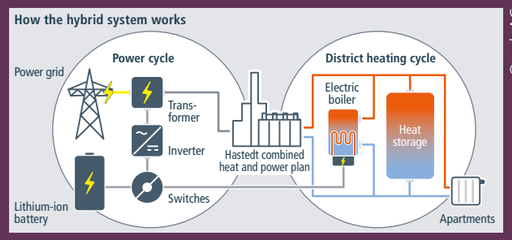
Heinke Meinen is responsible for communications at the DLR Institute of Networked Energy Systems in Oldenburg.

© DLR

At the Institute of Networked Energy Systems, the team led by HyReK Project Manager Theys Diekmann (rear) is creating a model that simulates the operation of the hybrid regulating power plant run by Bremen-based swb AG on a high-performance computer. In this way, it is possible to conduct a detailed examination of how the power plant interacts with the power grid. The model can already be used to simulate future energy scenarios, for example those with significantly higher proportions of renewable energies.

© swb AG

The electric boiler of the Hastedt hybrid power plant works like an oversized immersion heater and converts surplus electricity into heat. When required, this is delivered to the Bremen district heating network.



© swb AG

The hybrid concept integrates the power and heat sectors. The combination of battery storage and a power-to-heat system with a conventional power plant makes it possible to use fluctuating renewable energy sources more efficiently.

GO WITH THE FLOE

An international research team is drifting across the northern Arctic Ocean, frozen in the sea ice, on a mission to improve our understanding of the Arctic and climate change.

By Philipp Burtscheidt

© Alfred Wegener Institute / Stefan Hendricks

A vast white expanse, the endless night of the Arctic winter, a distant outpost of humanity, cut off from civilisation – almost as remote as the International Space Station. On 20 September 2019, the Polarstern was waved off from Tromsø harbour in northern Norway. The German research icebreaker, which belongs to the Alfred Wegener Institute (AWI), embarked on its journey to the Arctic Ocean, where it would become frozen in the sea ice for one year. The largest Arctic research expedition of all time has been given the name 'Multidisciplinary drifting Observatory for the Study of Arctic Climate' – or MOSAiC.

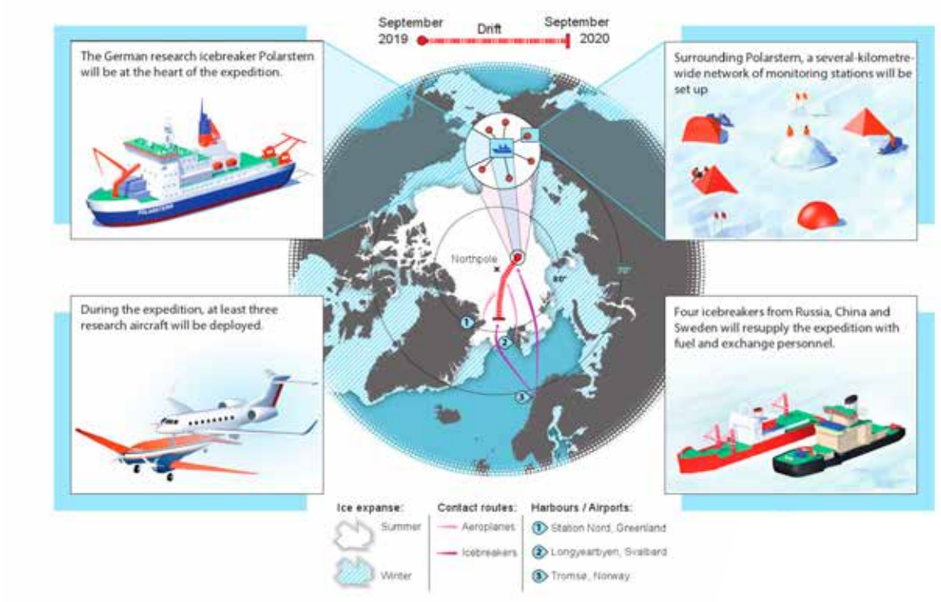
The crew reached their destination in October. Shortly after, they identified a suitable ice floe for drifting and moored to it. As the Arctic winter set in and temperatures dropped, the sea ice thickened and the Polarstern froze fast. It has since been drifting across the Arctic Ocean, carried along by the forces of nature alone. This will be the first mission to conduct extensive and highly accurate measurements and experiments in the Arctic over four seasons. For more than two months, the Polarstern will be less than 200 kilometres from the geographic North Pole. MOSAiC will focus on climate and environmental research. The researchers are hoping to obtain fundamental data and insights into climate change. A better understanding of the physical and chemical interactions of ice, snow, atmosphere and ocean in the Arctic will enable the development of more accurate climate models. Over the course of the mission, the research vessel will travel approximately 2500 kilometres.

Exploring the epicentre of climate change

Teams of scientists from 19 countries and over 70 institutions are participating in the MOSAiC project, under the leadership of the AWI, the Helmholtz Centre for Polar and Marine Research. The researchers will carry out numerous experiments above, on, in and under the polar ice with the aim of cracking the 'Arctic puzzle'. They want to find out how the atmosphere, sea ice, ocean, ecosystem and biogeochemical processes interact with one another. Like the pieces of a mosaic, when viewed together, the results of the different MOSAiC research projects should provide an accurate picture of the Arctic system as a whole.

The Arctic reacts much more strongly to climate change than regions at lower latitudes, and it has an enormous impact on the global climate. The atmosphere here is warming faster than anywhere else. The 'eternal ice' is becoming ever thinner as the years go by. The increasing reduction in the ice surface is constantly changing the face of the Arctic and its ecosystems. In August 2008, the Arctic's Northeast and Northwest passages were both simultaneously free of ice for the very first time. What was once eternal is threatening to become temporary as time goes by.

PIECES OF THE MOSAIC EXPEDITION



© Alfred Wegener Institute / Martin Kuenstling

An expedition of extremes

MOSAiC is a mammoth undertaking – both scientifically and logistically. Four icebreakers from China, Russia and Sweden will supply the Polarstern with fuel and provisions over the course of its mission. The crew will be rotated at regular intervals, with a total of 600 international experts working on site throughout the mission – from researchers, to the ship crew, and through to polar bear guards. Three research aircraft will require a landing strip of their own on the ice. A network of diverse research stations will be set up around the Polarstern, with the vessel as the base station. The various measuring stations will investigate the Arctic ecosystem as comprehensively as possible.

A single expedition day costs 200,000 euro, with the budget for the entire expedition amounting to 140 million euro. Some 50 percent is financed by Germany, mainly with funds from the Federal Ministry of Education and Research. The remaining amount is borne by international partners.

© Alfred Wegener Institute / Stefan Hendricks

The Alfred Wegener Institute's research icebreaker Polarstern made its maiden voyage in 1982 and has travelled over 1.7 million nautical miles since. Today, it remains the most modern and versatile polar research vessel in the world.

© Alfred Wegener Institute / Stefan Hendricks

AWI sea ice physicists work on the sea ice amidst bracing winds and ever-growing snow drifts

THE MOSAIC TEAM RESEARCH AREAS AT A GLANCE

ATMOSPHERE
Only a thin layer of ice separates the atmosphere from the Arctic Ocean. At an outdoor temperature of down to minus 45 degrees Celsius, the water, at a temperature of 1.5 degrees, acts like a heater. Cracks are increasingly appearing in the ice, allowing heat to escape into the atmosphere and forming clouds. MOSAiC atmospheric researchers are now investigating the properties of these clouds and their effect on global temperature.

SEA ICE
Climate change has significantly altered the Arctic Ocean. The sea ice has become thinner and more mobile. MOSAiC provides scientists with an opportunity to observe and measure how sea ice and snow cover change over the seasons. The Sea Ice Team is examining the thickness of the ice, its composition, the snow cover and the amount of light that penetrates into the ocean under different conditions.

OCEAN
For the very first time, the MOSAiC mission is giving oceanographers the opportunity to investigate temperatures and currents at different depths of the Arctic Ocean over the course of an entire year. The scientists are concentrating on circulation in the upper levels of the gigantic ocean currents that carry vast quantities of water into and out of the Arctic. The temperature here affects the ice cover, and thus the atmosphere.

BIOGEOCHEMISTRY
A constant exchange of gases between the atmosphere, ice and sea water takes place in the Arctic. These include carbon dioxide, nitrogen oxides, methane and other trace gases – all of which have an impact on the climate. Both the freezing and melting of ice as well as microorganisms and algae influence their interactions. These processes are not sufficiently understood. As part of MOSAiC, researchers are examining the dynamics of gases and other chemical compounds.

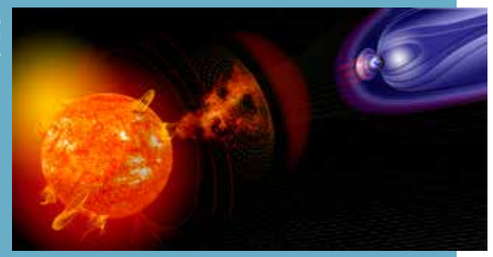
ECOSYSTEM
Despite the harsh environmental conditions, a myriad of animals and plants live on and in the sea ice, in the Arctic Ocean and on the seabed. Biologists will take samples and conduct an array of experiments during the MOSAiC mission. They are hoping to gain a better insight into the species that live in this region, their habitats, the way in which they interact, and their response to the changing seasons and environmental influences.

Up-to-date news, straight from the Arctic, are published regularly on the MOSAiC Twitter and Instagram feeds under the hashtags #MOSAiCexpedition, #Arctic and #icedrift. More information about the expedition is available at:

- www.mosaic-expedition.org
- follow.mosaic-expedition.org

© Alfred Wegener Institute

Polar lights make the interaction of the solar wind and the atmosphere visible. Although a beautiful sight, they can disrupt satellite navigation.



© NASA

Solar activity affects Earth's atmosphere. The effect is particularly noticeable in the polar regions.

© DLR

Simon Plass and satellite navigation expert in the DLR MOSAiC team, Friederike Fohlmeister, mount the receiving antenna on the sounding deck. They were responsible for water- and cold-proofing the installation.

© DLR

During his free hour and from the Fjellheisen mountain station, DLR project leader Simon Plass collects ship signals, known as AIS (Automatic Identification System) signals, from the waters off Tromsø.

DLR's scintillation recorder – the heart of the measuring on board the Polarstern.

YOU'VE GOT MAIL … FROM THE ICE

Satellite signals are particularly susceptible to interference at the poles. The DLR Institute of Communications and Navigation is investigating a robust positioning system.

Several teams of DLR experts support the MOSAiC mission. The German Remote Sensing Data Center (DFD) is providing sea ice maps for the Polarstern. DLR's Maritime Safety and Security Lab in Bremen is developing new methods for differentiating between different types of ice using samples collected over the course of the mission. The DLR Institute of Communications and Navigation is conducting research into improved positioning in areas close to the poles. To this end, a team of researchers installed a receiving station for satellite navigation signals on board the icebreaker. For the first time, this mission will establish an extensive base for these signals close to a pole. As the facility is self-sufficient, it requires no on-board presence from the DLR team.

Philipp Burtscheidt spoke to Simon Plass, DLR's MOSAiC project manager in Tromsø, Norway, about the research conducted by DLR on the Polarstern. Plass and his team installed the facility just days before the icebreaker set sail on 20 September 2019.

Why is DLR involved in the MOSAiC mission, an expedition focusing on polar climate research?

: Broadly speaking, the MOSAiC expedition has the overarching goal of better understanding the Arctic system as a whole. In addition to measurements and experiments on the Arctic Ocean, the ice and the lower atmospheric layers, research questions also include phenomena in the upper layers of the atmosphere.

The solar wind exerts a particularly strong effect within the ionosphere in the regions around the North and South Poles, most famously manifested in the Aurora Borealis and Aurora Australis. These polar lights make the interaction between the Sun and Earth visible to the naked eye, but they can also interfere with satellite signals. When it comes to navigation signals, this can lead to incorrect positioning data being picked up by the receivers. Improving safety in polar regions is another of MOSAiC's aims.

Are you measuring atmospheric interference?

: This interference is a natural phenomenon known as scintillation, which takes place in the ionosphere. The effects are stronger in the polar regions, where the Earth's magnetic field is weaker than at mid-latitudes. Here, the energetic particles of the solar wind can penetrate into the atmosphere more easily. Our devices do not measure disturbances in the ionosphere itself, but rather the satellite signals. With our monitoring equipment, we can detect changes in the signals caused by scintillations. In the event of a disturbance in the atmosphere, the device records the raw signals from the Galileo, GPS and GLONASS systems until the scintillation is over. We need the raw data from the satellites to recognise patterns and develop more robust navigation receivers.

Before MOSAiC, the necessary data from polar regions were not yet available in sufficient quantities. We hope that the scintillations that occur during this year in the Arctic are enough to yield a wealth of data for analysis upon the return of the Polarstern.

What happens if you detect a distinctive pattern in the disrupted satellite signals?

: Together with the DLR Institute for Solar-Terrestrial Physics, we will evaluate the collected data and develop algorithms to devise countermeasures for addressing atmospheric interference on the receiver side. Modern standard navigation receivers do not 'notice' whether they are receiving a disrupted signal; they simply analyse every signal and calculate a position. If the signal is disrupted, the receiver issues incorrect position information or no position whatsoever. These errors can be considerable during a scintillation. In the event of adverse conditions at the poles, it is particularly important to know exactly where you are. This is especially critical in the case of rescue missions, as safety must be ensured during maritime operations. In future, navigation receivers will be 'smarter' in this regard, or more resilient. They will be able to compensate for signal interference and display reliable and precise positions, even in polar regions. Looking ahead, within two to three years we will have tangible results and will have developed algorithms capable of coping with scintillations. But we are still a long way from the finished product.

What could go wrong on the long journey?

: Our on-board technology consists of an external unit – the antenna on the top deck – and the core system inside the Polarstern. The computing unit receives, processes and stores the incoming raw signals. The devices have to work self-sufficiently, as no one from our team will be on board.

The hardware is vulnerable, particularly the antenna and the cable in the exterior. They will be directly exposed to temperatures of up to minus 45 degrees Celsius, ice, salt and storms with high waves. The cable attached to the antenna could give in or fray during a storm. The hardware inside the vessel is firmly tied down and the temperature is constant. That said, the ship's vibrations could cause the plug connections or solder joints to come loose. Surfaces could become rusty. During big swells, one of the crew could grab out to try to keep their balance and snap the mooring. Of course, these are all worst-case scenarios, but they could happen. We could also encounter errors with our software, as we programmed it ourselves. Although it was thoroughly tested for three months in Germany, you never know.

You are not on board. How can you tell if there is a problem?

: We have written a software routine that regularly checks all of the components. All of the data are stored locally on our hard drives, as well as on the Polarstern's on-board server. Our system automatically sends us a weekly email with the status of the device. Are data being received? Is the power supply working? In the event of a problem, we can contact the Polarstern. However, the data volume is very low: we can only send 50 kilobytes per week from the Polarstern. Basic communication is possible, but it goes without saying that we cannot have a livestream or issue detailed instructions over the telephone on how to rectify errors. Communication coverage is simply very poor in the Arctic Circle.

How do you intend to respond to problems?

: We have given a lot of thought to how we can react from a distance. It is very difficult. That is why the system must be maintained by all those on board, and the whole crew has to be able to repair it, should the need arise. We have provided a detailed manual for addressing software or hardware failures, and attached spare cables for all of the installed cables next to the assemblies.

How did DLR become involved with the Polarstern?

: As often happens in life, it was a matter of chance and being in the right place at the right time. As part of my work on the Arctic Council, I became the communications engineering expert for the German delegation of the Federal Foreign Office in 2015. In 2016, we presented Germany's Arctic research work at the Arctic Circle Assembly, which is held every year in Reykjavik. Representatives from the AWI also attended. Among them was Markus Rex, the MOSAiC expedition coordinator. We really hit it off. The following year, we met again at a network event for the Helmholtz Association of German Research Centres. On that occasion, I told him "I heard that you are working on the amazing MOSAiC project. Is there any chance that we could participate?" As we did not intend to put any members of staff on the vessel and our system is small, can run self-sufficiently, and can be operated at an on-board voltage of 230 Volts, he did not see a problem, and replied, "Yes, of course!"

For DLR, MOSAiC goes far beyond scientific research. What else has driven you?

: MOSAiC is a wonderful example of the interface between research, policy, industry and diplomacy. For instance, government representatives must be able to understand what we are doing, and appreciate why it is necessary. DLR can make a significant contribution towards climate research and environmental monitoring in this regard, by providing the expertise, tools and data required – not just for Germany, but worldwide.

The Arctic Council is all about diplomacy at an international level. It addresses cross-border cooperation. Given the geography of the Arctic, it is vitally important to think in a 'pan-Arctic' manner by working out comprehensive solutions across the sovereign territories of the neighbouring states. This is far from easy at times. Ensuring smooth operation across these interfaces is one of my tasks at DLR. I support these different areas and maintain contact with all parties. This allows for close and direct exchange, and is a fantastic part of my work. Every interface has an aspect of its own, and its own requirements. Of course, that is very diverse and a lot of fun.

How did it feel to install the technology in Tromsø and then disembark?

: I left the Polarstern happy yet somewhat exhausted. We worked intensively for several days. I came away from Tromsø having had a marvellous experience and took lots of wonderful memories home with me.

I envy the crew for this unique opportunity to be part of such an expedition, especially given that they will be conducting measurements and taking samples on site. That said, during that time they will be completely isolated in a highly inhospitable environment – almost like being on the International Space Station. Although in the Arctic you are much more likely to come face-to-face with a polar bear than you are with aliens during a spacewalk!

Philipp Burtscheidt is an editor at DLR's Media Relations department.

Simon Plass
is an electrical engineer and works at the DLR Institute of Communications and Navigation in Oberpfaffenhofen. In addition to managing the Department of Institute Project Management and Institute Administration, he coordinates the Institute's maritime activities. In 2015 he was invited to join one of the Task Forces of the Arctic Council as an expert. The previous year, he was appointed to the DLR Scientific-Technical Advisory Council, an advisory body for the DLR Executive Board. He has chaired the Council since 2019.

Plass' work now covers a fascinating spectrum of research, project management, departmental management, execution of measuring campaigns and implementation of the technology transfer of the results into industry – at the interface of research, industry, government and diplomacy. Plass is 42 years old and the father of two children.

© DLR

© Adobe Stock/sdecoret

THE FUTURE OF HEALTHCARE

Sustainability at the DLR Project Management Agency

By Stefanie Huland, Corporate Communications, DLR Project Management Agency

Sustainablity – this buzzword has been on everyone's lips ever since the 'Fridays for Future' movement, led by the Swedish climate activist Greta Thunberg. Sustainable behaviour is now a goal to strive towards in every area of life. Here, the DLR Project Management Agency (DLR Projektträger) presents the first in a series on its efforts on sustainability, and shows just how diverse the topic is. This first issue in this series discusses the digitalisation of the healthcare system.

© DLR-PT

Rainer Girgenrath
is Head of the Clinical Research, University Medicine and Digital Health Department at DLR's Project Management Agency. Previously, he worked as a neuroscientist and university lecturer for psychology in Düsseldorf, Regensburg and Leicester, UK.

Artificial intelligence, Big Data, telemedicine – digitalisation has long been part of the healthcare sector. The foundations for tomorrow's networked medical world, in which doctors and researchers alike have access to anonymous patient data, are being laid today. The aim is to achieve better and faster provision of care that can save lives in case of an uncertain diagnosis. At present, the flood of digital data is akin to having the internet without a search engine. Rainer Girgenrath, Head of the Department of Clinical Research, University Medicine and Digital Health at the DLR Project Management Agency, explains how we can improve the current state of affairs.

Medicine is facing major challenges. Digitalisation is affecting medical research and treatment alike. What do you expect over the coming years?
: In the near future, we will see players in healthcare – General Practitioners (GP), university hospitals, pharmaceutical companies, as well as researchers – increasingly working together in networks, even across national borders. The ultimate goal is to integrate data and knowledge. Imagine a patient in Munich who goes to see his GP and is found to have a rare disease, such as a specific kind of tumour. Almost at the touch of a button, the GP will find similar cases in other cities, and see the drugs that were used to treat the condition successfully. In addition, the doctor will also be able to access the latest research results from Germany. This will directly benefit the patient. That is precisely where we are heading.

How can we make that happen?
: All of Germany's university hospitals are currently busy building data integration centres. In doing so, they are laying the groundwork for the exchange of data. This large-scale project is being realised thanks to a funding initiative that will make it possible to control how we, as a society, can achieve specific research goals over the medium and long term. This is exactly where our work as the DLR Project Management Agency begins. The creation and expansion of overarching data centres is part of the Medical Informatics Initiative, which we have been instrumental in developing over the past three years on behalf of the German Federal Ministry of Education and Research. That said, it will be another two years before data exchange is available to and utilised by all university hospitals, and it will probably take a few more years before its use is widely spread among GPs.

Why is it so difficult to get digitalisation moving faster?
: First of all, all those involved must agree on a standard procedure to follow. This happens in the concept phase of a project. In the case of the Medical Informatics Initiative, university hospitals were asked to submit their own ideas for a central data centre. Ultimately, only the best concepts received funding, but university hospitals that did not submit a winning proposal were given the possibility to adopt one of the approved concepts. Despite this competitive situation, we succeeded in getting everyone on board. In my opinion, this shows how important the topic is for the health care system.

There seem to be increasing reports about leaks of patient data, most recently in September, when MRI images of millions of patients worldwide became freely available on the internet. German patients were among those affected. How can you ensure that the data in the centres are secure?
: Data protection and security are incredibly important. These are concerns that we and the Federal Government need to take care of ourselves; we cannot leave it to commercially driven companies. It is our responsibility to protect people. Personally, however, I would argue that Germany's standards of data protection are higher than that of any other country. This is clear from the process that we are going through as part of our initiative. Data privacy specialists, researchers and hospital representatives all sit down with us to reach an agreement on a joint data standard. This takes time, but I am certain that in the end, if the process continues to be adhered to, all data will be stored securely. Indeed, there is no other alternative. We cannot just say that we will reject digitalisation because we are scared of data leaks. If we do that, people will ultimately die from diseases in cases where they could have been helped.

Sustainability begins with a business idea. In the next issue, the DLR Project Management Agency will show how this works.

THE DLR PROJECT MANAGEMENT AGENCY

For over four decades, the DLR Project Management Agency has been committed to making Germany a strong location for research, education and innovation. As one of the largest project management agencies in Germany, highly qualified employees currently manage approximately 10,000 projects and over 1 billion euro of research funding. They work on behalf of German federal ministries, federal states and the European Commission, as well as scientific organisations, foundations and associations. They advise on strategies and programmes, provide specialist and administrative support for research funding projects, and assist with knowledge transfer and the evaluation of research findings. The agency covers a range of topics – from education, health, society, innovation, technology, environment and sustainability all the way through to European and international collaboration.

MEDICAL INFORMATICS INITIATIVE

The Medical Informatics Initiative is overseen by the DLR Project Management Agency on behalf of the Federal Ministry of Education and Research (BMBF). It is aimed at strengthening medical research and improving patient care. The first step is the establishment and networking of data integration centres at university hospitals and partner institutions. This is the prerequisite for connecting research and healthcare data across different locations. The initiative will run for four years and receive 160 million euro of funding from the BMBF.

METROPOLITAN TRANSFORMER

DLR's Urban Modular Vehicle research platform combines numerous applications in one vehicle

By Julia Heil

A car slowly rounds the corner, gliding by almost silently. It has four seats, but possesses neither an accelerator pedal nor a steering wheel. Developed by researchers at the DLR Institute of Vehicle Concepts in Stuttgart, this car is a design for tomorrow's urban vehicle.

Both people and goods need to be transported in a city, and in varying numbers and quantities. Together with transport researchers in Berlin, the DLR team investigated how many people the vehicle should accommodate, from a user's perspective. The team also investigated the range that electric vehicles need to have in order to be attractive, as well as under what conditions people would prefer to use a shuttle rather than their own car.

Their results revealed the diverse expectations regarding vehicles. "We need different solutions for transporting cargo and moving people safely, quickly and comfortably from A to B. So we have to think in a modular way," says DLR Project Manager Marco Münster. The answer is the Urban Modular Vehicle, or 'UMV', a versatile urban vehicle. It is a concept for an electrically powered, largely automated road vehicle that is truly multipurpose – a modular body construction combines different vehicle types in a single platform.

The basic version of the UMV has four seats and a light metal chassis structure. The body design, powertrain and level of automation can be adapted to satisfy the respective requirements. The DLR researchers designed a total of nine different models – from urban cars to vans. The length (3.7 to 4.1 metres) and height (1.6 to 2.3 metres) of the central module can be adjusted. The front and rear modules remain common to all variants but can also be modified as required, and the vehicle body can be adapted according to its intended use. Thanks to the lightweight construction, the vehicle's basic structure weighs just 182 kilograms. "The basic idea behind the vehicle is that of a modular system, with which a large number of variants can be produced cost-effectively while retaining as many common components as possible," says the DLR researcher.

From cargo vehicle to 'skateboard'

The variable UMV design allows researchers to investigate a concept for the development of conventional cars with human drivers, before progressing to fully autonomous vehicles. In the 'Cargo' variant, the user still does the driving. But the researchers are also simulating autonomous variants. In one scenario, a mobile delivery service drives independently through residential areas between 21:00 and 23:00, so that parcels can be delivered or collected when people are at home.

The Stuttgart team are also working on a 'skateboard' variant of the UMV. They are designing a substructure to which different, interchangeable body units can be attached. "This is already the case with cargo vehicles that can accommodate different bodies. We would like to develop something similar for transporting people," Münster explains. For now, however, the Skateboard UMV only exists in the virtual world.

Peoplemover as a first prototype

Münster and his project team have created the UMV Peoplemover 2+2 as the first prototype. In contrast to the Cargo variant, this concept has been exclusively designed to transport people and would complement public regional transport by acting as a shuttle. Its interior has a simple design and the large surfaces are easy to clean. Passengers can charge their electronic devices via USB ports. At the moment, the prototype has a demonstration powertrain. In the future, it should be able to achieve a range of 400 kilometres with a 400-volt battery. The battery will be located in the double floor of the vehicle.

Vehicle summoned using an App

In contrast to conventional cars, the Peoplemover does not park near the door of the user's home, but is summoned using an App when needed. "Most cars stand around for 90 percent of the day and occupy already scarce space in the city. Our UMV would also spare people the tedious search for a parking place," adds Münster. The researchers' aim is for the concept to provide assistance in areas where, for example, public transport connections are poor or where passengers would otherwise only be able to reach a destination by following a circuitous route. Additionally, the Peoplemover could also alleviate the burden of rush hour traffic. To this end, the vehicle could be integrated into local public transport and be able to display route options in combination with subways, suburban trains, buses, cycle paths or footpaths. A display on the vehicle ceiling shows travel information such as route, arrival time and weather data. In addition, it also displays possible stops where other people can get on or off. Through this link, the scientists hope to reduce individual traffic in cities and offer passengers the optimal route to their destination.

The UMV is part of DLR's 'Next Generation Car' (NGC) project, in which transport researchers from 22 DLR institutes are jointly developing technologies and concepts for future road vehicles. In addition, in the overall NGC project they are looking into the powertrain, energy management, vehicle structure, chassis and vehicle intelligence. They are also cooperating with colleagues from the research specialities of transport systems and railways. The next-generation vehicles will have alternative powertrains, provide optimised safety components for passengers and road users, and be able to drive autonomously. Their body structures are all lightweight, and it will be possible for them to be fully integrated into the transport environment.

In addition to the UMV, the Stuttgart team have produced vehicle designs for commuter transport and long-distance journeys. Marco Münster and his project team have more plans: "The Peoplemover offers a versatile development platform for many DLR researchers over the coming years and can be used in inter-institute and interdisciplinary projects. Examples include the design of the interior, the development of climate control concepts, the upgrading of the vehicle with sensors and computers and much more."

Julia Heil is an editor at DLR's Public Affairs and Communications Department.

DLR researcher Marco Münster, who is seen here travelling with his colleague Kristiane Schuster, controls the Peoplemover using a joystick. In the future, the vehicle will be able to drive autonomously.

Sensors for the autonomous driving functions and identification of the surroundings will in future be installed on the vehicle's exterior. Devices for communicating with other vehicles and with the infrastructure, as well as antennas for receiving satellite signals, are integrated into the roof. Radar systems are located in the bumpers and optical sensors are installed in the front and rear windows. Eighteen ultrasonic sensors around the vehicle will support proximity detection in the future.

The vehicle is summoned using an App. Passengers also use this to authenticate themselves by means of a display in the Peoplemover's side window.

After successful authentication, the sliding doors open. The journey can begin once the seat belts have been fastened.

THE URBAN MODULAR VEHICLE

With the Urban Modular Vehicle, DLR transport researchers have completely rethought tomorrow's urban car. An intelligent and safe electric vehicle, the special feature of the UMV is that all vehicle variants are based on the same basic module, making its design extremely versatile. The modular design also enables researchers to investigate different technologies and concepts using a single platform.

The **UMV Basic** is the standard version of the Urban Modular Vehicle with 2 + 2 seats and a length of 3.7 metres. It is designed to achieve automation levels between three – assisted driving – and five – fully autonomous. This vehicle's structure forms the basis of all UMV derivatives.

The two-seater **UMV Cargo** is a small delivery van, ideal for smaller businesses that need to flexibly move their materials and products across an urban setting. The standard version is 3.7 metres long, while the extended version is 4.1 metres long.

In contrast to the cars with a driver's seat, the **UMV Cargo-Mover** is completely autonomous. It can deliver parcels independently and has a cargo volume of 3800 litres.

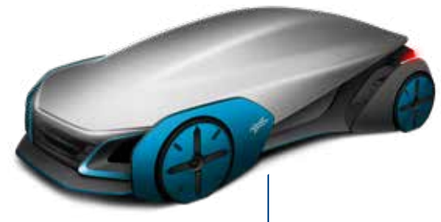
A special feature is the **'skateboard' variant**, in which a variety of body designs can be attached to the substructure. This has the advantage that this vehicle can be used for transporting either people or cargo.

NEXT GENERATION CAR

As part of the Next Generation Car project, DLR is working on several concepts for the car of the future. The vehicles need to be energy-efficient, emission-free, safe and cost-effective.

Perfect for commuters:

The Safe Light Regional Vehicle (SLRV) is the most lightweight member of the NGC family. At just 400 kilograms, it weighs the same as a golf buggy. Its body is made from a light aluminium foam sandwich with an inner ring structure. This economical two-seater is ideal for commuters and can be used in areas with insufficient train or bus connections. For this design, the DLR researchers used selected safety standards for a conventional car on a vehicle in this size class (L7E) for the first time. The Stuttgart team want to make lightweight vehicles more attractive. The DLR specialists are currently integrating the powertrain – based around a fuel cell – into the test vehicle. With one tank of hydrogen, the SLRV will be able to travel approximately 100 kilometres during test operations. With the finished test vehicle, the researchers want to assess how the vehicle components interact in real situations.



For long distances

The Interurban Vehicle also comprises a fuel-cell-based powertrain and will be able to achieve a range of up to 1000 kilometres – perfect for journeys between cities. Thanks to the alternative powertrain, the vehicle is completely emission free. It will accommodate up to five people with their luggage. It is designed for an automation level of up to SAE four. This means that the car can take over the driving task in certain situations. As the 'latest' development, it currently exists only as a bodywork demonstrator, without a powertrain. Researchers at the DLR site in Stuttgart want to use it to investigate how different electrical functions can be integrated into the structure.

SIGMUND JÄHN'S GREAT JOURNEY

A contemporary of the first German in space remembers the cosmonaut, who passed away on 21 September 2019.

By Gerhard Kowalski

© DLR/Archiv

When Sigmund Jähn was born in 1937, there was certainly nothing to indicate that he would one day travel into space. His father was a sawmill worker, his mother a housewife, and his birthplace, Morgenröthe-Rautenkranz, a village with a population of just a few hundred – inauspicious circumstances for the birth of a space explorer. Neither was there any sign that Jähn's journey would one day help draw East and West Germany a little closer together. Space journalist Gerhard Kowalski remembers.

My first journalistic involvement with Sigmund Jähn's great adventure began in late May 1978, a few months before the first spaceflight by a German. I was the only newspaper journalist commissioned by the East German Ministry of Defence to compile material about Sigmund Jähn and his backup, Eberhard Köllner – all in the strictest secrecy. Two press officers took me to their offices and introduced me to their former instructors, teachers and families. As a result, I drafted 20 typewritten pages of material on each of the candidates. I was also tasked with submitting a launch report six weeks before the actual event took place. Fortunately, I was able to draw upon my experiences at the launch of the US-USSR Apollo-Soyuz Test Project in 1975 and the first flight of the East German MKF 6 multispectral camera in 1976.

I was then lucky enough to be chosen to accompany Jähn's launch from the Baikonur Cosmodrome, on the Kazakh steppe. Before meeting him in person, I feared that the East German leadership had selected a brisk, dyed-in-the-wool 'Red Prussian', who would no doubt spout party slogans all day long. Instead, I met a friendly yet extremely modest and rather measured Saxon, who almost had to be persuaded to talk. Indeed, it was precisely his quiet and thoughtful manner that helped Jähn achieve an almost pop-star-like status in East Germany following the flight. The party and state leadership were happy to bask in his reflected glory and took their cosmonaut hero all over the country.

For his part, Jähn never made any secret of his commitment to East Germany, but big statements were never his style. Instead, whenever he could, he set the speeches that had been prepared for him aside and spoke to the people in his own words. When faced with western journalists who sought to provoke him into making critical statements about East Germany, he resorted to the formulaic phrase that he was 'there of his own free will'. And his commitment to German unity was clear from his Solomon-like statement: 'The last thing we need is a fratricidal war'. This was not enough for many journalists and politicians, but little effort was made at getting better acquainted with, or indeed understanding the man who became the first German and 90th human being to go into space. Sigmund Jähn brought this pioneering achievement to a united Germany.

By sheer coincidence, the second German to travel into space, Ulf Merbold, was also from the Vogtland region. It is a peculiar irony of this dual German history that Merbold left East Germany before the wall went up and flew into space as a Payload Specialist on the STS-9 Space Shuttle mission. It is to his credit that he helped Major General Jähn, who had been discharged from the National People's Army, start afresh in the west and recommended him to DLR and the European Space Agency (ESA) as a consultant. That is how Jähn ended up in Cologne, while also making recurrent trips to Baikonur and Star City, near Moscow. He assisted five German astronauts from the former West Germany, including Merbold, with preparations for their spaceflights with the Russians – first to the Mir space station and later to the ISS. He helped the youngest of them, Alexander Gerst, even after he had officially retired.

On 26 August 2018, to commemorate the 40th anniversary of Jähn's spaceflight, the German astronaut corps' celebrated with their friend and longest serving representative in Morgenröthe-Rautenkranz. Alexander Gerst called in from the ISS. Gerhard Thiele summed up everyone's thoughts in his address: "I am glad you were the first." The cosmonauts Aleksandr Ivanchenkov and Pavel Vinogradov were there on behalf of Jähn's former spaceship commander Valery Bykovsky, who passed away in March 2018, and also conveyed warm wishes from Star City's director, Pavel Vlasov. Jähn, who had pushed so many boundaries on his travels, was moved to tears by these tributes.

Gerhard Kowalski, who was born in 1942, is a space journalist, author and technical translator. In the former East Germany he worked as a correspondent for the state news agency ADN, before becoming a freelancer. Sigmund Jähn and him were friends for over four decades.

© DLR

Sigmund Jähn with cosmonaut Pavel Vinogradov in June 2018 during his last visit to Baikonur Cosmodrome

"Sigmund's life revolved around space travel, his family and his friendships, which transcended international borders that are not visible from space. We German astronauts have flown and will continue to fly to space on his shoulders. Despite being over 80 at the time, Sigmund never missed a chance to travel to the remote Baikonur Cosmodrome for either of my launches. On the day before my first launch, I was in the completely isolated quarantine area, and I remember him standing outside my window with a mischievous grin on his face, asking whether I wanted to go for a walk."

Alexander Gerst, Astronaut

"With the death of Sigmund Jähn, the German space community has lost a world-renowned cosmonaut, scientist and engineer. The first German to go into space always saw himself as a bridge builder between East and West and an advocate for the peaceful use of space. We will preserve and perpetuate this message, for Earth and space, in his memory."

Pascale Ehrenfreund,
Chair of the DLR Executive Board

"On 9 November 1989 we were in Riyadh; it was the eve of the conference of the Association of Space Explorers (ASE). We stood around European astronaut Sigmund Jähn as we witnessed the fall of the Berlin wall live on television – arguably the hardest day of Sigmund's life. Many years later, as Head of the European Astronaut Centre from 2000, I benefited greatly from his early involvement in our astronaut training, which Ulf Merbold had helped arrange. Sigmund's generous advice allowed us to benefit from his Russian experience on many occasions."

Ernst Messerschmidt, Astronaut

"My greatest memory of Sigmund Jähn is the transfer of two cars to Star City in December 1990. The purpose of this adventure was to keep our two German cosmonaut candidates, Klaus-Dietrich Flade and Reinhold Ewald, mobile on Earth as well. Sigmund guided us through Poland and the then still existing Soviet Union. He showed his 'Propusk', which identified him as a Hero of the Soviet Union, to the amazed officials at the Soviet border. It was a matter of course for him to lead us safely to Star City."

Rolf-Dieter Fischer, Former astronaut trainer

"My most vivid memories of Sigmund Jähn are from his early days as a consultant for DLR. He was simply irreplaceable in the negotiations with the Russian team during preparations for the first flight by a German astronaut to the Russian space station Mir. With his calm, friendly and reserved demeanor, Sigmund helped us all to understand the situation in Moscow at that time – the uncomfortable feeling when handing one's passport to immigration control, the minders in the hotel, the menus … He also gave me tips on how to survive the mandatory vodka toasts. However, I am not sure that the plants behind my chair fared quite so well."

Beate Fischer, Head of the Astronaut Training Department at DLR Space Operations

IN HUMBOLDT'S COSMOS

Researching, dreaming and bringing worlds together

Peter Zarth interviews author Andrea Wulf on behalf of the DLRmagazine

The 250th anniversary of Alexander von Humboldt's birth has prompted publishing houses, the media and various other organisations to pay tribute to him. He is praised as a tireless explorer, environmentalist, communicator and advocate of equality for all. To gain a closer insight into the life of this polymath and natural scientist, the DLRmagazine spoke with Humboldt's renowned biographer, Andrea Wulf, experienced his adventures as a graphic novel, and pored over the multi-award-winning book The Invention of Nature: Alexander von Humboldt's New World.

Wulf is a storyteller. As such, she writes and loves immersing herself in thought. She brings together worlds – worlds of science and of beauty, of young and old, of poetry, knowledge and art. She connects 'dry numbers' with 'the magic of nature'. Wulf prizes words like 'pure' and 'clear'. Born in India and raised in Germany, we now find her sitting in London, looking out of the window and sipping coffee. A 19th-century invention – the telephone – connects us. As the story goes, the first sentences spoken via telephone in 1861 were: 'The horse does not eat cucumber salad' and 'the Sun is made of copper'. Scientists and engineers clearly had a sense of humour even back then.

Humboldt and climate change

Andrea Wulf wrote the international bestseller 'The Invention of Nature: Alexander von Humboldt's New World'. She 'still cannot believe' its success. The effect of her book, especially on young people, makes her happy. Andrea Wulf loves conversation. "Through conversation, even the most contrasting scientific disciplines can come together." She loves speaking to anyone, anywhere, and is often invited to give lectures across the world – and she listens, too. Questions concerning climate change are "the most important topics." It was these that led her to Humboldt. "My listeners are often interested in climate change. Young people are rightly very concerned." The environment could do with more "heroes and role models like Humboldt." Yes, the historian Andrea Wulf really did say 'heroes', as Humboldt warned early on about the destruction of the environment. In 1832, he predicted that man would change the climate in three ways: "… by destroying the forests, by artificial irrigation and by producing large amounts of steam and gas from industrial hubs."

The magic of nature

Andrea Wulf has conducted brilliant research and travelled to many of the significant places related to Humboldt's life, so she knows exactly what she is talking about. Very much a 21st-century historian, she has a wonderfully wry sense of humour. "Sometimes it is as if I am Humboldt's spokesperson," she says. Her enthusiasm is obvious, even over the phone. It is clear that this is much more than public relations work for her. Wulf has researched Alexander von Humboldt and wants the present to build on his work. "History helps us to understand, to think, and to know how to think," she stresses. Humboldt brought art and science together, and within this pairing lies the magic of nature. "Basically, science and art are the same – they are driven by curiosity. The human imagination – essential for both science and art – was formed in nature." This should not be forgotten. Wulf then follows up with one of the most compelling sentences of our quiet conversation: "We will only protect that which we love."

"Nature needs to be experienced"

'Beauty' is a term that comes to Andrea frequently, and in surprising places. It is apparent that Humboldt and Andrea Wulf both see beauty as a characteristic of nature, and a facet of humans, art and science. "Humboldt could speak about the beauty of nature, about tropical plants or deep mountain gorges. He approached scientific language poetically," she says. "Humboldt wanted to draw his readers into nature, he wanted comprehensibility. It is precisely that emotion that appeals to children like those of the 'Fridays for Future' movement, and indeed people of all ages. "Nature must be experienced," says Humboldt.


© Antonina Gern

Author Andrea Wulf enjoys talking with people from all over the world and values life's quiet moments

"I see 'my' Humboldt with the historian's gaze, including the ambiguity of his person," says Wulf. "My new, illustrated book is almost like an homage, as I consider Alexander von Humboldt to be an artist, too."

Close your eyes, and what you see then belongs to you

It is 26 July 2013 and Andrea Wulf and her best friend Julia Niharika-Sen are climbing Chimborazo. "Above the clouds, at an altitude of more than 5000 metres, the air is clean." It is a clear day.

Some 211 years earlier, on 23 June 1802, shortly before reaching the summit of this mountain – which at the time was considered to be the highest on Earth – Alexander von Humboldt seems to have been lost in a nebulous land, spellbound by an empty, almost uncanny space. Suddenly the fog clears, and he sees the snow-white peak of Chimborazo towering against the blue sky …

The friends take out their copies of Alexander von Humboldt's diary and begin to read:

"… On 23 June (…) we climbed Chimborazo. (…) Since the day was very dark and foggy, the summit was only visible from time to time. A lot of snow had fallen during the previous night …"

The stillness of the surroundings envelops Andrea Wulf and Julia Niharika-Sen. They see the world from above. Silence.

"Sometimes, when I write, I close my eyes," says Andrea Wulf, as our conversation comes to a close. "I have a vivid imagination." Imagination is the sister of art, of beauty, of science. It would be wonderful to listen to this connector of worlds forever, and thus learn about ourselves along the way.

Peter Zarth, DLR Public Affairs and Communications

REINVENTING THE MOMENT

This book is a risk. A 272-page adventure, it is illustrated in great detail but contains a lot of text for a graphic novel. Mind you, it is still a novel. The adventures of a 19th-century researcher and explorer, it is longer than many modern novels. Is it unwieldy? Or perfectly readable? How will it be received in these days of swiping and scrolling?

Adventures take time. They are inherently chaotic, even conceptually. When recounted and illustrated between the covers of a book, they require structure and rigour – far more than just talent. Finding a balance between text and images, and creating a good guide for people who want to feast their eyes and read at the same time is vital.

Lillian Melcher and Andrea Wulf have largely succeeded in this. While it might seem overly pedantic to add 'largely', when the result is so impressive, we fear only a lack of patience on the part of the reader. In this coming year, before busy work and school schedules begin, readers should have plenty of time for birds and plants, for the page on the Orinoco, for the white-water rapids and Havana, for electric eels and for Chimborazo – and also for all the other little wonders in the book.

After the worldwide success of Wulf's Humboldt biography, his diaries inspired the author to create a book that would show Humboldt's artistic side and, as she says, "the incredible ease with which he unites science and art." The Adventures of Alexander von Humboldt follows Humboldt's South American journey.

To a certain extent, this complements Wulf's 'The Invention of Nature: Alexander von Humboldt's New World', but this graphic novel also goes beyond that. It is emotive and full of surprises, and a young genius has put the 'adventures' into images. Lillian Melcher, just 23 years old and fresh out of university at the time of the book's creation, is truly gifted. As Wulf states in her introduction to the themes and text, Melcher combines the visible with the invisible using her paintbrush, with naivety in its original sense – conveying open-mindedness and authenticity. Our only question is what prompted the publisher to change the colour gradient of Melcher's original image for the front and back covers so radically that they no longer have much in common with the style of the novel itself. The intense colour and the golden print of the title raise expectations of something quite different.

The visual aspect conveys a message – immerse yourself in every page and experience pure exoticism. Even the ordinary is portrayed extraordinarily, leaving plenty of room for the reader's imagination. Wulf particularly admires the invisible element, as we might refer to it, of Melcher's work. Melcher certainly did more than just her homework. How did Humboldt hold his measuring instruments? What exactly did the body painting of the Orinoco Indigenous population look like – did it resemble the hut on the Antisana? Melcher's meticulous approach saw her delving into a kind of archaeoastronomy in researching Humboldt's 1803 journey from Guayaquil to Mexico, on which the 'Southern Cross' moved ever closer towards the horizon. Wulf questioned astronomers in order to find out exactly how this constellation changed on this route at that time, and Melcher drew accordingly. But she not only drew. Humboldt's fellow traveller, Bonpland, often had trouble drying plants and notes in the humidity of the tropics, and as a result they became mouldy. In order to faithfully depict this, the illustrator sprinkled paper and plant samples with milk, orange juice, coffee and tea, placed them in her damp shed and let them become mouldy. We, the readers, can rely on the detail of Lillian Melcher's detailed visual presentation of the content.

"Really, really great," says Andrea Wulf about her collaboration with Lillian Melcher. Her enthusiasm stands out all the more in the otherwise more reserved interview presented on the previous pages). Melcher has a commendably calm eye. Her pictures and ideas are captivating. The choice of unexpected imagery, by turns bold, cheeky and joyous, dispels any exaggerated belief in the authority of science – all with ease, humour and wit. She does not draw in an overly elaborate style, as has often been said, and as might be expected from the odd, albeit intriguing cover image. Lillian Melcher reinvents the moment. What an adventure!

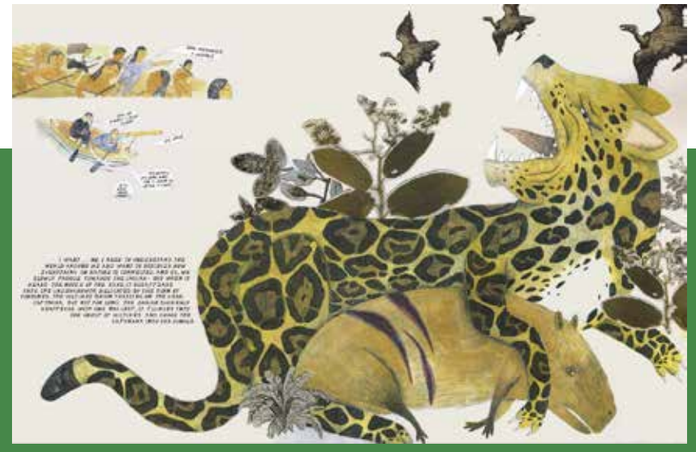
za

NEAR AND FAR

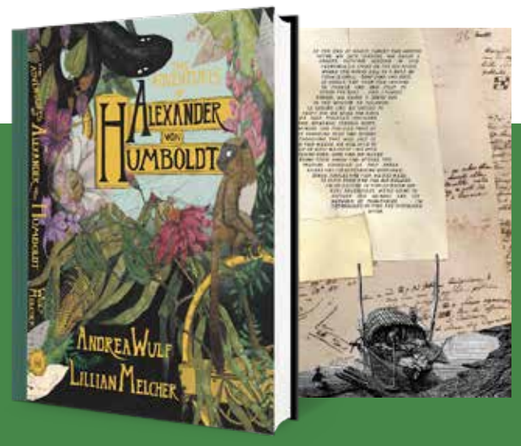
In the 1970s, the terms 'nature' and 'the environment' went their separate ways. While they are somewhat vague even today, they had been associated with each other until then. This would not have mattered had it not involved a shift in perspective – the human being in nature was brushed aside. The environment, and with it nature, especially its endangerment, were increasingly seen from the perspective of and for humankind, with a strongly emphasised ecological component. This has led to the alienation of humanity from nature. Nature conservation, which considered people to be part of nature, became environmental protection, which regards nature as being looked upon from a human perspective.

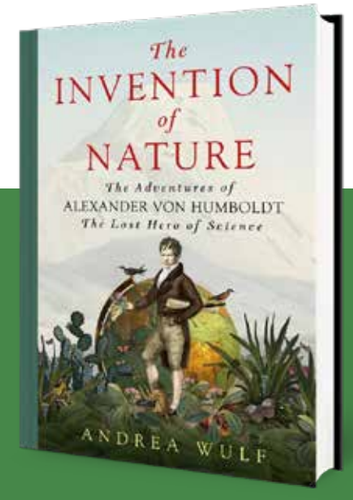
Andrea Wulf manages to capture this paradox in the very title of her book 'The Invention of Nature: Alexander von Humboldt's New World'. For Humboldt, the early 19th-century science superstar, there was neither separation between humans and nature, nor between nature, science, art, poetry and music. Wulf's award-winning work needs no introduction, but it is worth recommending, especially to young people who are as yet unfamiliar with Humboldt's life and impact. The author writes easy-to-read scientific prose from the heart, although one could wish for better copy-editing (for example, talking about the 'western' world in the 19th century can lead to some incorrect associations). It takes a stand, even takes sides – and it brings to life a time, a way of thinking and a type of person that today might seem to distant, but which, at least in terms of Humboldt's thinking and work, are still surprisingly modern.

za



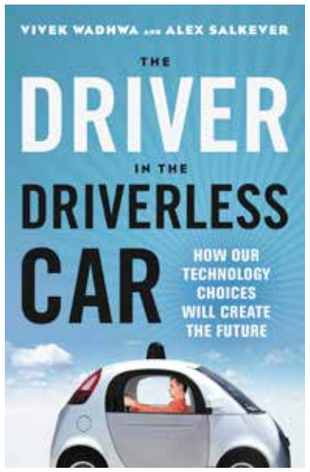
Lillian Melcher traces Alexander von Humboldt's adventures with dreamlike certainty. The illustrations and text here show what drove von Humboldt to paddle towards the jaguar on the right: "I want ... no, I need to understand the world around me and want to discover how everything in nature is interconnected ..."





REVIEWS

THE DRIVER IN THE DRIVERLESS CAR



"Will the future look like Star Trek or Mad Max?"

With this question, the reader of **The Driver in the Driverless Car** is enticed into a realm of possibilities and given a tantalising and terrifying glimpse into the future of technology. We are alerted to numerous technological advances that are arriving thick and fast – from computers composing classical music to the creation of life forms from synthetic DNA – and encouraged to question the implications of such progress.

Technologist Vivek Wadhwa opens our eyes to how shockingly different life is likely to be in the next 50, 20, even 10 years. In just a couple of decades, our children could receive a one-on-one education from robots, we could be artificially augmenting our bodies and minds with personalised medicines, and with the arrival of self-driving cars, we could consider the concept of owning and driving our own cars preposterous.

Wadhwa focuses on three broad questions that he suggests we should consider for every emerging technology:
- Does it have the potential to benefit everyone equally?
- What are its risks and rewards?
- Does it promote autonomy or independence?

This book may not tell us how our technology choices will create the future, as the cover suggests, but it does present us with an impressive overview of technologies and encourages us to decide on the ethics ourselves. Although Wadhwa doesn't have space to delve into the details of each technology, he does raise awareness, painting both a bright and scary future and giving readers a starting point to find out more.

Although quite US-centric, and written with an occasionally awkward writing style, this book is filled with fascinating stories and thought experiments that effectively drive home the author's points. He looks at technological advances from a distance, emphasising that the future is up to us to create: "even if our hands are not on the wheel, we will decide the driverless car's destination".

All in all, the author is optimistic about how we will use technology to create a more equal, productive and almost utopian future. But how will you feel after reading this book?

Nicole Shearer

INSIDE THE INTERNET: 50 YEARS OF LIFE ONLINE

A National Geographic documentary
Published June 2019

Some 50 years after its inception, the internet is ubiquitous, and many can't imagine living without it. I should know, I'm one of them! To me, the internet and the world are inseparable. But did you know there was a time when there was no internet as we know it, and the world was not connected within mere seconds? This short National Geographic special explores the rise of the internet and in particular how it has changed the world forever.

With a mere 50 minutes of playtime, we can't expect them to cover every aspect of a subject as big as the internet, but I think this special does a good job at covering a variety of topics relating to it. At first, the focus is on the history of the internet, from its early days in the dungeons of the US Department of Defense, to global pervasiveness in modern times. It gradually transitions to exploring different applications and aspects of the internet that no one could have imagined 50 years ago. We often don't really think about the possibilities and cultural shifts that the internet has induced. Nowadays, we can find dates, talk, entertain ourselves, learn and much more in a few swipes while never even leaving the sofa. But even though the growth of the internet was explosive, these concepts were introduced quite gradually over the course of the internet revolution. The chronological order and personal interviews in this special nicely illustrate these developments and the sense of wonder and discovery that came with them. Conversely though, it would have been interesting to see the perspective of younger people who have never lived without the internet, which is something this special lacks. Some of the topics also feel a bit rushed, such as the part on cybersecurity.

We can't have everything in 50 minutes though, and **Inside the Internet** still offers an easily accessible flashback into the history of the internet and its associated cultural shifts. Although it currently cannot be seen everywhere, I truly hope it will soon be available worldwide.

Ruben Walen

OUR PAST FROM SPACE

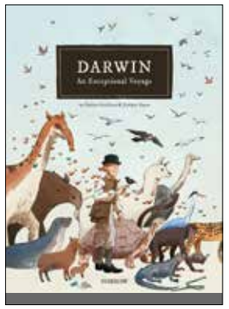
For more than 30,000 years our ancestors have roamed the Earth: surviving, thriving, creating and destroying. Archaeologists attempt to reconstruct how they lived by studying the artefacts and buildings they left behind. And today they have an impressive array of research tools at their disposal, including high-resolution satellite images which have revolutionised the field.

In her book **Archaeology from Space**, Sarah Parcak takes the reader on a meandering journey throughout the history of archaeology, with a particular focus on the significance of contributions from aerial photography and satellite imagery. This book is not a technical exposition of the mechanical workings of satellites or data processing. Parcak's focus is on the opportunities that increasingly high-resolution satellite imagery provide, and the challenges of interpreting the data translating it to the dig sites on the ground.

The rest of the book is a mix of her personal experiences as an archaeologist, storytelling (meet Meryt from Old Kingdom Egypt), and an exploration of the various challenges (political conflict, looting, funding, a goat eating your excavation maps) and opportunities in her field (using satellite imagery to protect heritage sites, involving the general public). It holds a bit of everything, but above all it is an engaging exploration of a fascinating profession by an archaeologist with great passion for her profession.

Merel Groentjes

HERE BE DRAGONS



The name Charles Darwin likely conjures up an iconic visage of a bearded, grey-haired scholar; an unchanging character frozen in time. But throughout the graphic novel, **Darwin: An Exceptional Voyage**, French author Fabian Grolleau and illustrator Jérémie Royer reveal a younger Darwin, his opinions and theories still in motion; a man in his early twenties full of uncertainty, inexperience, and facing the pressures and expectations of his family and society.

The book is a narrative retelling of Darwin's personal account of his 1831–1836 voyage aboard H.M.S Beagle, focused on his time in South America and the Pacific. Its story-within-a-story format, as an older Darwin recounts tales from his travels to his children, works as a neat disclaimer that this is a work of both fact and fiction meant to entertain and inspire. It's not a textbook, it's lighter on the science and serves more as an introductory text, but encapsulates the intoxicating awe and wonder the young man himself must have felt as he sailed around the world. That isn't to say it avoids darker topics. Of the monsters Darwin encounters, it's Man, not giant lizard, that is the most terrifying. Grolleau does a good job of presenting Darwin's encounters with brutal colonialism and his anti-slavery views, uncharacteristic of the time and putting him at odds with the Beagle's captain, whilst not ignoring his conflicted thoughts on the 'savagery' of various native peoples and their need for civilisation. Royer illustrates these difficult scenes in a thought-provoking way without over-the-top depictions of violence.

In fact, the illustrations throughout are great. In a style reminiscent of Tintin, the close-ups of flora and fauna encountered on the journey are a fitting tribute to the sketches Darwin and colleagues peppered throughout later editions of his writings. Accompanying them are more emotive double-page spreads of thunderous storms and migrating monarch butterflies, towering mountains, colossal glaciers and the sweeping constellations of the southern hemisphere's night sky.

Above all, **Darwin: An Exceptional Voyage** is a story about the power and scale of time. From Darwin's own coming of age and the origins of the theory that would one day change scientific understanding, to the fluidity of civilisations, the geological history of the Earth itself, and the eon-spanning development of the life that calls it home. And it's definitely worth taking the time to read.

Joshua Tapley

RECOMMENDED LINKS

THE BURN
t1p.de/95f3
From Hollywood to Darmstadt. Catch an authentic glimpse of ESA's European Space Operations Centre in action with this 10-minute film set inside the main control room. A challenging spacecraft manoeuvre tasks Operations Managers, spacecraft engineers, flight dynamics experts and software and systems specialists to 'work the problem', while fighting against time, the inexorable pull of gravity and a capricious Solar System. Many of the actors appearing in video are in fact engineers currently flying missions at ESA.

DLR SCIENCE IN ONE PLACE
DLR.de/Dossiers
Missions to other planets, electric flight, automated driving or a new life for coal-fired power plants – anyone interested in science will find what they are looking for here: the new dossier format of the DLR web portal, compiles information about specific research topics. In addition to background texts, there are numerous links to previous and subsequent article publications as well as videos, images, documents, blog posts and posts from social networks.

BYTES TO BASES
dna.unicef.no/en
Cassettes, floppy disks, and even CDs are evidence of just how quickly information storage media can become outdated. But one has stood the test of time. The UN Convention on the Rights of the Child – the most widely ratified UN Human Rights Treaty – has been encoded in nature's oldest information storage method, DNA. The convention, recorded in molecules of synthetic DNA, will be held at the Arctic World Archive in Svalbard, Norway.

FOLLOW CHEOPS
twitter.com/ESA_CHEOPS
The 2019 Nobel Prize in Physics was awarded in part to the discoverers of the first exoplanet orbiting a Sun-like star. As the exploration of alien worlds continues, be sure to follow ESA's CHEOPS mission on Twitter. Planned for launch in December 2019, CHEOPS is primarily tasked with studying previously identified exoplanets orbiting bright, nearby stars to strengthen our understanding of planetary formation and evolution.

RIVAL HUBBLE FROM YOUR BACKYARD
t1p.de/e8im
Time for a new hobby for the new year? If you're awed by deep-sky images of faraway galaxies or vistas of the night sky taken from the planet's surface, you might be interested to know that getting started in astrophotography is easier than you'd think. Just remember, even the best astronomers can't control the weather!

Cover image

Urban vehicles should bring people and goods from A to B safely, comfortably and in an environment-friendly manner. In the Urban Modular Vehicle, DLR combines various vehicle types on a single platform. The 'Peoplemover' variant can be used as a shuttle to supplement the local public transport system and saves individual parking spaces.

DLR
Deutsches Zentrum für Luft- und Raumfahrt
German Aerospace Center