DLR

DLRmagazine

of DLR, the German Aerospace Center · No. 166 · December 2020

NEXT STOP: THE FUTURE

DLR BRINGS NEW VEHICLE CONCEPTS ONTO THE ROAD

More topics:

- A KEEN SENSE FOR WATER AND ICE
  On the trail of climate change in the Arctic
- FETCH AND CARRY
  Two new Mars exploration missions

About DLR

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

Climate, mobility and technology are changing globally. DLR uses the expertise of its 54 research institutes and facilities to develop solutions to these challenges. Our 9000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

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DLR
Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center

EDITORIAL

Dear reader,

At the German Aerospace Center, we combine cutting-edge fundamental research with the applied development of innovative ideas – right through to the creation of prototypes. With our expertise in research and knowledge transfer, we strengthen Germany's standing as a location for research and industry. Since becoming Chair of the DLR Executive Board on 1 October, I have had the pleasure of working together with our 9000 employees to address some of the greatest challenges facing society today.

While the COVID-19 pandemic currently dominates the headlines, climate change and the mobility transition continue to also demand our attention. Engineering and scientific research are crucial in our collaborative efforts here. Earth observation satellites provide us with essential data, while Big Data Science and artificial intelligence continually improve our ability to analyse them. Together with academia and industry, we are also working on a wide range of additional technologies that will help us meet these and other challenges. This includes emissions-free mobility, the development of a sustainable energy supply, secure infrastructures and the digitalisation of the factory of the future. Of course, our researchers also remain ever keen to explore new perspectives and take their research in new directions. This is what I personally find so exciting about DLR: the diversity and relevance of our research topics, and the way we work together and always think one step ahead.

The DLRmagazine offers an insight into this world. In this issue, you will learn about our Safe Light Regional Vehicle, an innovative prototype that runs on hydrogen and is powered by a combination of a fuel cell and a battery. In Oldenburg, our researchers are working on a small-scale version of the sustainable energy supply of the future. At the Institute of Aeroelasticity in Göttingen, a team is investigating how flexible wings help to reduce an aircraft's fuel consumption. Other topics include new Mars missions searching for traces of life on the Red Planet, a project to secure communication and navigation systems against cyberattacks and an overview of 40 years of Earth observation at DLR.

I hope you enjoy reading this issue!

Sincerely
Anke Kaysser-Pyzalla

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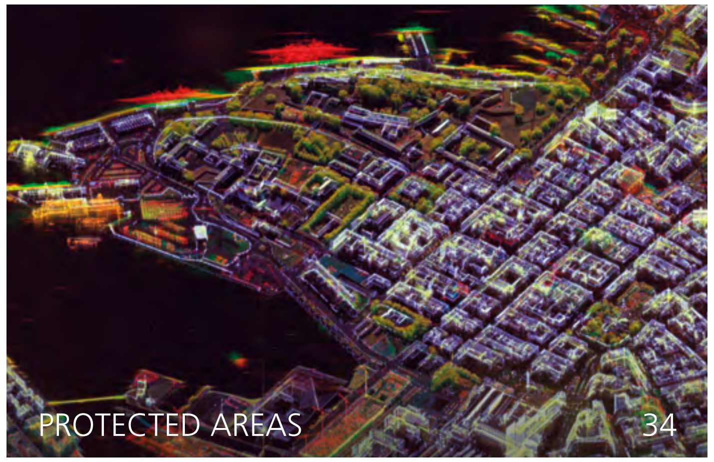

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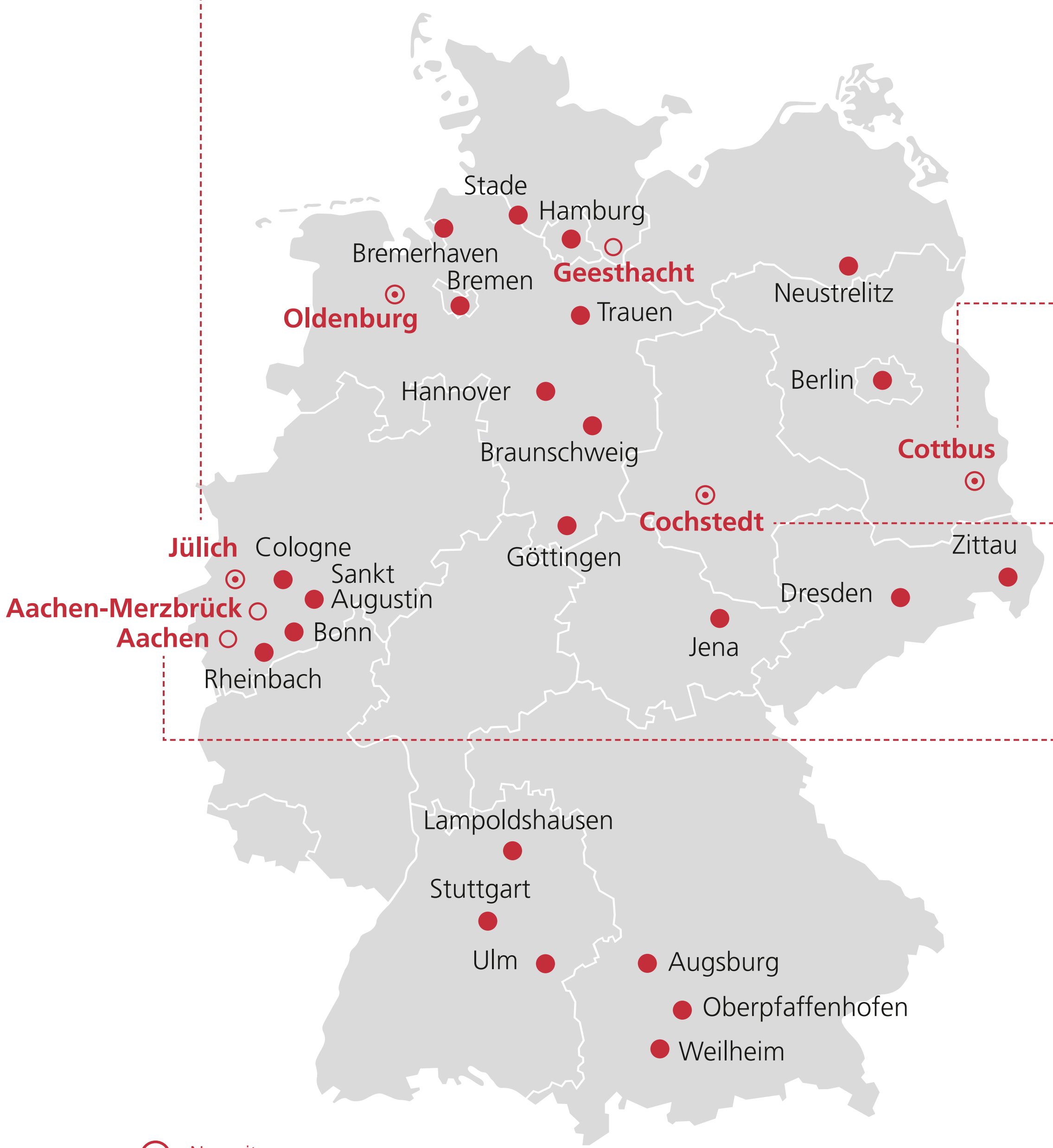
RETHINKING AVIATION AND ENERGY

DLR is establishing new research topics in the fields of aviation and energy with four additional institutes and facilities. They will focus on the energy transport chain, environmentally friendly propulsion systems for aviation and concepts for future airborne mobility. DLR is also continuing to expand the possible ways it conducts research. In addition to experiments and test flights, virtualisation and simulation will be further developed as interdisciplinary fields of expertise.



○ New site
● Existing site
⊙ New addition to existing site

The DLR Senate also gave the green light to the Institute of Systems Engineering for Future Mobility (Oldenburg) and the Institute of Maritime Energy Systems (Geesthacht). These institutes were presented in detail in DLRmagazine 165.

Institute of Future Fuels

Jülich

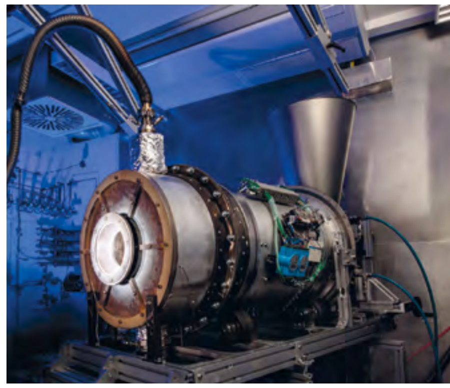
Founding director:
Christian Sattler

Planned number of employees:
120

Website:
DLR.de/ff/en

FUELS FROM RENEWABLE SOURCES

Environmentally-friendly fuels and new engines are necessary if we are to reduce the carbon dioxide emissions of the energy and transport sectors. The DLR Institute of Future Fuels is investigating how solar energy can be economically generated on an industrial scale. Solar-generated fuel should not only be cost-effective to produce, but also at least twice as efficient as present fuels. The institute is developing new and improved technologies, investigating intelligent digital networking solutions and supporting industry in their implementation. It will also assess the socio-economic aspects and logistical concepts, as well as carry out fundamental research on the relevant materials.



Institute of Low-Emission Aero Engines

Cottbus

Founding director:
Lars Enghardt

Planned number of employees:
150

Website:
DLR.de/el/en

IS SUSTAINABLE FLIGHT POSSIBLE?

This is the question that the new Institute of Low-Emission Aero Engines is addressing. At the focus of the researchers' efforts are hybrid engine designs such as the combination of a gas turbine with electrically generated propulsion and engines that run on hydrogen or other alternative fuels. Compared with current engines, these are extremely complex and place high demands on their intelligent control systems. In addition to the development of individual components and various alternative concepts for future aircraft engines, the institute will monitor and support the development of new regulations and safety measures.

Small Aircraft Technology

Aachen and Aachen-Merzbrück

Founding director:
Christian Eschmann

Planned number of employees:
80

Website:
DLR.de/kf/en

SMALL AIRCRAFT HAVE A BIG IMPACT

Electrical and unmanned flight will be important components of urban transportation in the future. That is why the Small Aircraft Technology facility is focusing on 'General Aviation' and 'Urban Air Mobility'. In addition to the overall design of new aircraft configurations and the integration of new propulsion systems, researchers are also working on new manufacturing and maintenance methods, novel infrastructures and a new air rescue service concept.

Unmanned Aircraft Systems Competence Center

Cochstedt

Founding director:
Christian Eschmann

Planned number of employees:
40

Website:
DLR.de/uc/en

ELECTRIC AND UNMANNED

This research facility is dedicated to electric-powered flight with a focus on Unmanned Aircraft Systems (UAS). Researchers will work on simulation capabilities and test flight scenarios for UAS, develop demonstrators to test the new technologies in flight and develop methods to evaluate safety-critical situations. Together with the National Experimental Test Center for Unmanned Aircraft Systems in Cochstedt, the centre will pool and further develop research activities in the field of UAS.

IN BRIEF

ASTEROID SAMPLES REACH EARTH

A capsule containing samples from the asteroid Ryugu is due to land in Australia on 6 December 2020. The capsule is part of the Hayabusa2 mission, which launched in December 2014 to study the asteroid, whose orbit crosses that of Earth. On board was the Mobile Asteroid Surface Scout (MASCOT), a lander roughly the size of a shoebox, which was developed by DLR. After arriving at its destination in June 2018, Hayabusa2 released MASCOT, which landed on the asteroid in October. The lander proceeded to gather data from the surface over a 17-hour period. Hayabusa2 later came within a few metres of Ryugu in order to collect ground samples ejected after the impact of a small projectile launched by the spacecraft itself. The data from MASCOT and Hayabusa2 have already revealed that the asteroid consists almost entirely of highly porous material. The scientists are now excited to find out what analysis of the returned samples will reveal. They are hoping to learn more about the origins and development of our Solar System, as well as the risk posed by near-Earth objects such as Ryugu. After Hayabusa2 has delivered the sample capsule back to Earth, the spacecraft will continue on its journey, and is scheduled to fly past asteroid 2001 CC21 in July 2026.


© JAXA

400,000 kilometres from Earth, Hayabusa2 will jettison the capsule containing ground samples from the asteroid and continue on its journey.

Aircraft engines emit soot particles. These act as condensation nuclei for small, supercooled water droplets, which immediately freeze into ice crystals and become visible in the sky as condensation trails.

GLOBAL AIR TRANSPORT CONTRIBUTES 3.5 PERCENT TO GLOBAL WARMING

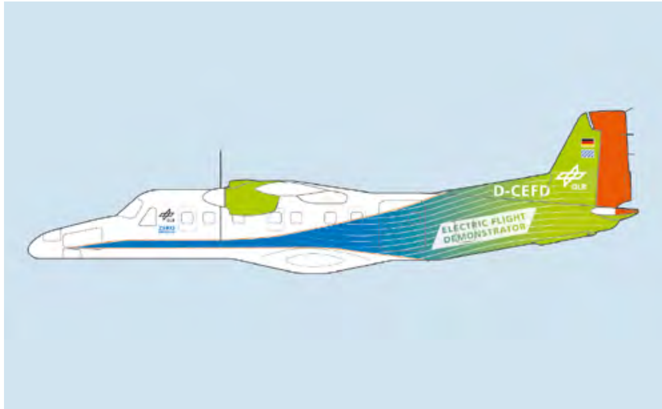
Global air transport is responsible for 3.5 percent of the anthropogenic warming of the climate. Only one third of this climate impact is due to carbon dioxide emissions, with the remaining two thirds the result of other effects. The most significant factor in this impact is contrails and the resulting cirrus clouds. These findings are the result of a comprehensive international study led by Manchester Metropolitan University and involving DLR. The study concludes that 32.6 billion tonnes of carbon dioxide have been emitted by global air transport throughout the industry's entire history – considered between 1940 and 2018. Approximately half of the total cumulative carbon dioxide emissions were generated in the last 20 years alone, primarily due to increasing numbers of flights and routes, and expanding fleet sizes, particularly in Asia. The research team estimates that the figure of 32.6 billion tonnes represents around 1.5 percent of total anthropogenic carbon dioxide emissions.

SECTOR COUPLING AND INTERNATIONAL COOPERATION AS FACTORS FOR SUCCESS

DLR is examining the potential of green hydrogen as a source of energy for a climate-neutral energy system in a two-part study. The study pinpoints two factors for the successful establishment of hydrogen as an energy source – consistent sector coupling throughout the entire supply chain, from generation and storage to use; and international cooperation on the production and distribution of this green energy carrier. Green hydrogen is sustainable and climate neutral, as it is produced from water and energy from renewable sources such as solar and wind power. However, the potential for renewable forms of energy in Germany is limited and the development of a hydrogen economy should, from the very outset, be geared towards international cooperation both inside and outside of the European Union. DLR is conducting research into solar-thermal processes that use heat to split water into hydrogen and oxygen, with the intention of reducing the cost of producing hydrogen.

This reactor uses the energy from solar radiation to generate hydrogen. It is part of the Synlight high-power spotlight system at DLR in Jülich.

NEW RESEARCH AIRCRAFT FOR ELECTRIC FLIGHT



The development of aviation towards more environmentally-friendly engines is also reflected in the special paint scheme for the new research aircraft. The green engine is to be equipped with an electric drive.

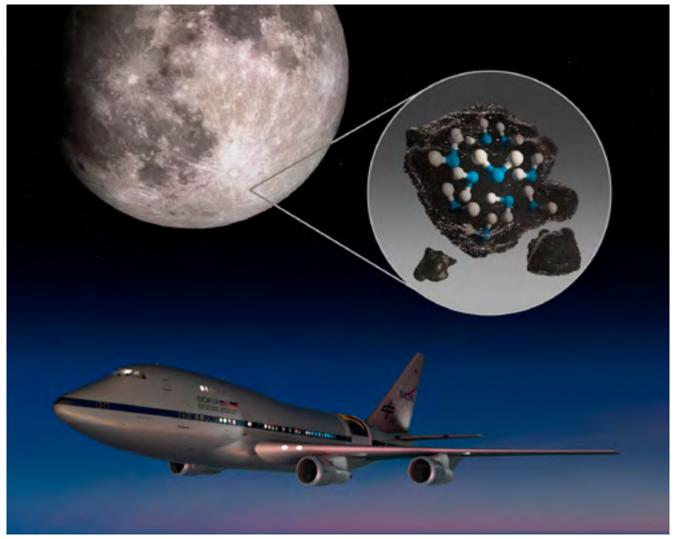
With the DO228-202k, DLR has acquired a new research aircraft to further develop electric and hybrid electric propulsion systems. In the coming years, it will work with its industrial partner MTU Aero Engines to equip and test the aircraft with a hydrogen-powered fuel cell and a single-sided electric propeller drive with over 500 kilowatts shaft output. With the exception of water vapour, fuel cells produce no emissions and are characterised by a high degree of efficiency. In the long term, the fuel cell in combination with sustainably produced hydrogen has the potential to enable virtually emissions-free air transport in regional, short and medium-haul aircraft. The aim of the joint technology project is to develop a complete drive train suitable for aviation (power line) and its cooling (cooling line). DLR is managing the flight project and providing and operating the research aircraft. It is also responsible for the integration of the powertrain. The research institute will also offer its expertise in the fields of flight testing and aircraft aerodynamics and aeroelasticity. MTU is tasked with the development of the complete powertrain powered by a hydrogen fuel cell. All work and integration processes will be carried out jointly and in close coordination. Up to 80 experts will be involved.

The fuselage of the new Do-228-202k with its new paint

SOLAR POWER FOR SUSTAINABLE PASTA

Over the next two years a pilot plant is being built close to the Barilla pasta factory in Foggia, Italy. The unique energy supply system is part of the HiFlex project with a solar tower plant as its centrepiece. Its purpose is to demonstrate the reliable and sustainable production of electricity and heat around the clock. This is possible due to the plant's high flexibility and storage arrangement. It also includes a solution for periods of less intense sunshine by alternatively using other energy sources such as wind energy. For the construction and operation of this pilot plant DLR is contributing its extensive expertise in the field of solar systems, steam generators and materials. In addition, the solar receiver, a core component of the plant, was developed and patented at DLR. The new HiFlex system has already enabled the Barilla factory to produce pasta using solar power. *Quanto sia magnifico!*

Pasta will soon be more sustainable thanks to the power of the Sun and DLR energy research



The location of Clavius Crater on the Moon. There, the SOFIA flying observatory was able to detect water molecules outside the permanent shadow at the lunar poles for the first time.

© NASA/Ames Research Center/Daniel Rutter

SOFIA DISCOVERS WATER MOLECULES ON THE MOON

The Stratospheric Observatory for Infrared Astronomy (SOFIA), jointly operated by NASA and DLR, has provided the first direct and unambiguous evidence of water molecules on the Moon outside the permanent shadow at the lunar poles. The molecules were detected near the Clavius Crater in the Moon's southern hemisphere using SOFIA's FORCAST instrument. The data from SOFIA indicate that most of the water discovered lies within the substrate covering the lunar surface. Even though the amount of water is small, it could still prove important for future crewed space missions. The European Space Agency Space Resources Strategy is currently trying to confirm whether resources such as water could enable sustainable space exploration. SOFIA will now continue to observe the Moon to investigate the water phenomenon in greater detail. Its data will complement the findings from future Moon missions.

REMOTE-CONTROLLED VEHICLES SUPPORT WORLD FOOD PROGRAMME DELIVERIES

Researchers from the DLR Institute of Robotics and Mechatronics and a consortium of additional DLR institutes and technology partners are investigating how aid supplies can be safely brought to their destinations using remote-controlled trucks. These vehicles will be used on routes that pose a great risk to human drivers, such as the impassable and flood-prone areas of South Sudan. The launch of the joint project with the United Nations World Food Programme (WFP), winner of the 2020 Nobel Peace Prize, took place in Oberpfaffenhofen on 21 October. The DLR Institute of Robotics and Mechatronics will equip the SHERP off-road vehicle used by WFP with sensors for real-time monitoring of their environment and automate them for remote control. The project, known as the Autonomous Humanitarian Emergency Aid Devices (AHEAD) project, is one of four currently being carried out at DLR as part of its Humanitarian Technologies initiative. The initiative sees technologies developed for space research utilised on Earth in cooperation with partners from humanitarian aid organisations such as WFP.

Tele-operated SHERP vehicles are being used by the WFP in the AHEAD project

ZKI damage mapping after the explosion in Beirut on 4 August 2020

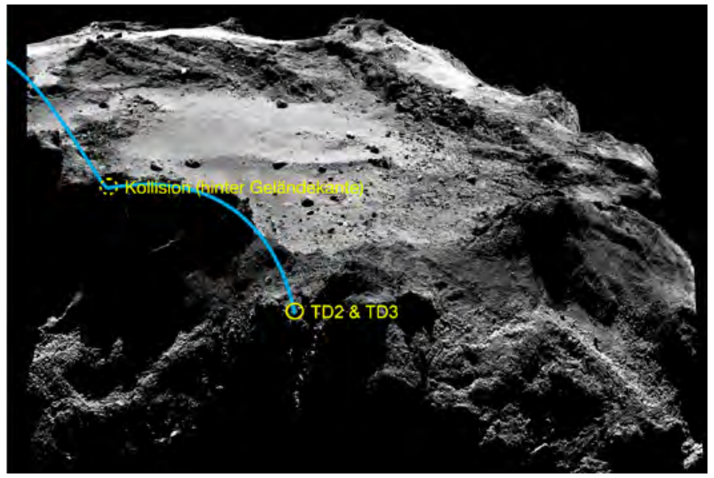
WorldView-2 © 2020 European Space Imaging

MAPPING DAMAGE FROM SPACE – DLR SUPPORTS DISASTER RELIEF IN BEIRUT

Following the devastating explosion in Beirut on 4 August 2020, a number of countries sent rescue teams and recovery experts to the Lebanese capital. On 5 August, a team from the German Federal Agency for Technical Relief (THW) set off for Lebanon on behalf of the German Federal Government to undertake a joint operation with I.S.A.R. Germany. Once there, the task force investigated and assessed the situation, searched for missing persons, evaluated building damage and supported the German embassy. The DLR Center for Satellite Based Crisis Information (ZKI) provided the team with damage maps, produced quickly using high-resolution satellite images acquired before and after the explosion. These maps could be used for orientation and to assess damage to buildings; Beirut's urban area is densely built up, making it difficult to see roofs from the ground. The ZKI maps made it possible to see where they were damaged.

4.5-BILLION-YEAR-OLD ICE ON COMET 'FLUFFIER THAN CAPPUCCINO FROTH'

Scientists working on ESA's Rosetta mission have located where the Philae lander made its second and penultimate contact with the surface of Comet 67P/Churyumov-Gerasimenko on 12 November 2014, before finally coming to a halt 30 metres away. This landing was monitored from the DLR Philae Control Center. Philae left traces behind; it pressed itself into an icy crevice in a black, rocky area covered with carbonaceous dust. As a result, the lander scratched open the comet's surface, exposing ice from when it formed that had been protected from the Sun's radiation ever since. This 4.5-billion-year-old mixture of ice and dust is extraordinarily soft – fluffier than cappuccino froth, bubble bath foam or the whitecaps of waves meeting the coast. Knowing where Philae touched down on comet 67P for the second time allows scientists to reconstruct the lander's trajectory and derive important results from the telemetry data as well as measurements from some of the instruments operating during the landing.

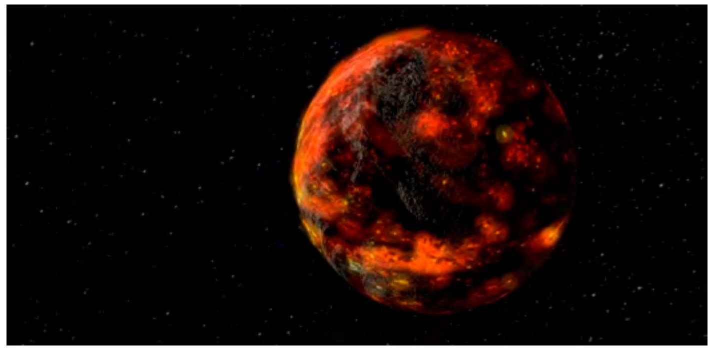


Philae's path on comet 67P

© ESA/Rosetta/MPS for OSIRIS Team

THE MOON IS YOUNGER THAN WE THOUGHT

The Moon formed a little later than previously assumed. Planetary geophysicists at DLR and University of Münster used a new numerical model to reconstruct the time at which a Mars-sized protoplanet was destroyed in a collision with the young Earth, creating a new body from the ejected debris – the Moon. They determined that this event occurred 4.425 billion years ago, making the Moon 85 million years younger than we previously thought. Early in its life, energy gained from accretion led to the formation of a magma ocean on the Moon over 1000 kilometres deep. Understanding how long it took for this ocean to cool and solidify and how the different types of rock then changed over time were the crucial steps in arriving at the Moon's new age.



The early Moon's magma ocean and first rocky crust

DLR ACROSS GERMANY

BRAUNSCHWEIG: In additive extrusion technology, plastic strands with embedded continuous filaments are created using a 3D printing head. These can be layered into any structure required. The major advantage of this technology is that it does not require elaborately shaped tools, while offering a high degree of design freedom. The DLR InnovationLab EmpowerAX works together with its partners to develop qualification measures and standards, with the aim of making this technology easily accessible to various target groups

STUTTGART: The Baden-Württemberg Technology Calendar for Structural Change in the Automotive Industry (TKBW) supports small and medium-sized companies with strategic decision-making. This study by the DLR Institute of Vehicle Concepts outlines how key automotive technology can develop under specific conditions up until 2035, and helps companies to identify future-oriented products and business areas, build up expertise in a targeted way and thus remain competitive.

OBERPFAFFENHOFEN: On 13 October, the research vessel Polarstern returned from the MOSAiC Arctic expedition after a year at sea. On board was an antenna from the DLR Institute of Communications and Navigation, which collected signals from satellite navigation systems during the expedition. A DLR team is investigating whether and how the solar wind, whose effects are felt particularly strongly in the polar regions, affect satellite navigation near the poles. The complete dataset is now available and evaluation is underway.

NEUSTRELITZ: Researchers at the DLR Institute of Communications and Navigation are developing R-Mode, a positioning system for ships that works independently of satellite signals. This should provide security in certain situations such as when GPS navigation services are disrupted. The team is currently setting up the first large-scale R-Mode test field along the coasts of Germany, Sweden and Poland.

HAMBURG: From 25 to 26 February 2021, the E2Flight conference will take place both online and in Hamburg. It will deal with the question of how environmentally friendly aircraft technologies and electric flying can be realised. The conference is aimed at international science and industry with a focus on electrified aircraft. Interested parties can register at e2flight.com

DLR.DE/EN: NEWS ON THE DLR WEBSITE
All news articles can be viewed in full and with images and videos online in the news archive.

DLR.de/en/news

THE GOLDSMITHS OF DATA

40 years of applied remote sensing at DLR

by Professor Stefan Dech and Professor Richard Bamler

How are the climate and environment changing? Where and when did it snow last winter? How quickly are settlements and cities growing? What dangers do we face? Satellite images of Germany, Europe and the entire planet can answer these questions – and many more. Every day over 21 terabytes of data are streamed from Earth observation satellites to DLR's Earth Observation Center (EOC). There, they are processed into image and information products for use in research. The 29 petabytes of data now stored at the EOC correspond to over 7 million hours of YouTube videos, or 800 years of non-stop film. This would have been completely unimaginable 40 years ago.

At that time, DLR was still the DFVLR – the Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt (German Test and Research Institute for Aviation and Spaceflight). Films were shown exclusively on one of the public service channels or at the cinema, Pink Floyd were on tour, Helmut Schmidt was the German Chancellor and the push-button telephone was the latest gadget.

Back to the beginning

The year 1980 also marked the opening of a new scientific and technological facility in Oberpfaffenhofen: the Applied Data Technology Department, a predecessor of today's German Remote Sensing Data Center (DFD). Today, the DFD and the DLR Remote Sensing Technology Institute make up the EOC. One of the first tasks of this new facility was to receive and process data from the TIROS satellites, the first spacecraft designed for monitoring and forecasting weather.

Willi Wildegger (centre), the EOC's long-standing IT manager, commissioning of a new device at the beginning of his career in 1980

In the early days, the only electrical device in the office was a telephone – and even that was one of the old rotary dial models. Drafts, documentation and calculations were all worked out by hand. The department computer was shared; it was operated via an alphanumeric terminal and was connected to a daisy wheel printer. Technologies such as 'frame synchronisers' and 'communication elements', which were intended to receive flows of data from space, generally had to be developed and constructed in-house. They were required as interfaces with the computers, which were not very powerful at the time. One highlight of 1985 was the German Spacelab Mission (D-1). The scientists at the facility, which was still in its infancy, created a 'data selection unit' (DSU) for the laboratory on board the Challenger Space Shuttle. This allowed data from the Spacelab to be specifically selected for transmission from the US to Germany; a transmission of the entire data stream via satellite was still far too expensive.

Meanwhile, in Neustrelitz, on the other side of the divided Germany, the Institute of Cosmic Research at the GDR Academy of Sciences was receiving data from the Soviet Interkosmos satellites, the first European Meteosat and the US NOAA satellites. Receiving

© EOC

North of the Arctic Circle in the Northwest Territories of Canada, DLR's Earth Observation Center operates an antenna for receiving satellite data. The ground station in Inuvik is just 2500 kilometres from the North Pole.

© EOC

Following the fall of the Berlin Wall, Neustrelitz became a DLR site. Here, data from national and international remote sensing missions are received and information is generated in real time for applications such as maritime security.

© EOC

The DLR receiving station GARS O'Higgins in Antarctica can only be supplied by ship or aircraft. However, its location close to the South Pole on the Antarctic O'Higgins Peninsula is so well-suited for satellite communication that work is carried out there all year round.

antennas had been in operation there since 1969. After the fall of the Berlin Wall, the capabilities of former East and West Germany were finally united and Neustrelitz became the site of the DFD.

Technology developed rapidly during the 1990s: the second German Spacelab was launched on the Columbia Space Shuttle; Europe launched its first Earth observation satellites into space; and the USA expanded its Landsat fleet. The European Space Agency (ESA) commissioned the DFD to serve as a data centre distributing Landsat data to users. This meant sending the data out on magnetic tapes to the few users in Germany who were able to handle this new technology or use the satellite data to create photographic prints. The DFD ran its own Earth sciences photo laboratory for that very purpose – one of the most modern of its time.

The dawn of a new age

With the launch of the first European Earth observation satellites, ERS-1 (1991) and ERS-2 (1995), a new age dawned not only for Europe, but also for the predecessor of the EOC. At that time, data acquired by the satellites' sensors could not be stored on board the satellites themselves. In order to be able to map rainforests, deserts and ice masses, scientists were reliant on strategically located ground stations in the vicinity of the observation areas for receiving data.

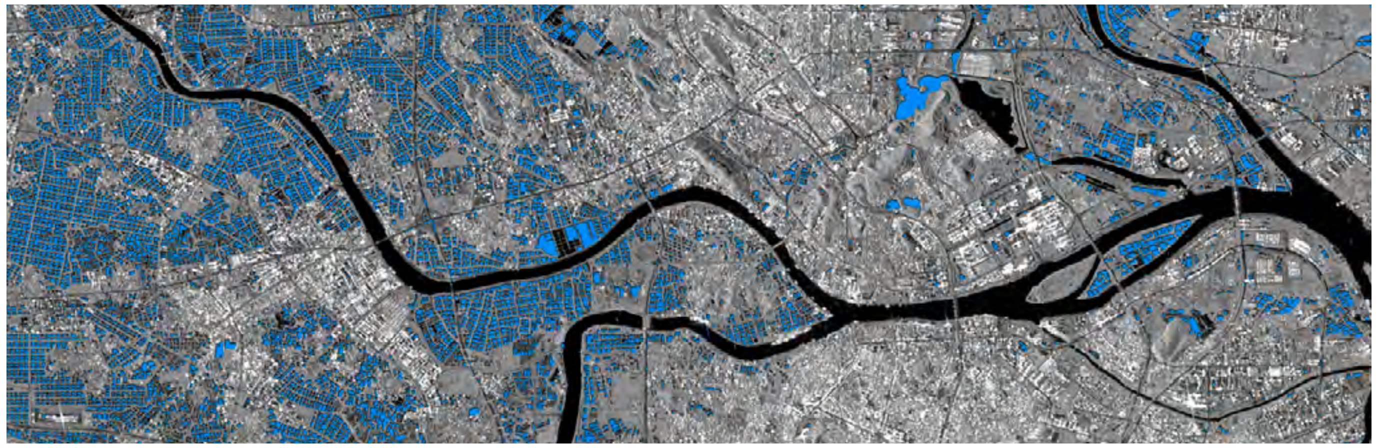
An injection of national funding enabled the first ground station for receiving satellite data in Antarctica, the German Antarctic Receiving Station (GARS), to be established near the Chilean Bernardo O'Higgins research station in 1991. GARS received data from the ERS satellites as they passed over Antarctica. Following this logistical and technical achievement, the DFD set up more temporary receiving stations in locations including Gabon, Kyrgyzstan, Mongolia and Mexico. Today, together with antennas in Oberpfaffenhofen and Neustrelitz, the receiving network includes the GARS O'Higgins station and another polar station in Inuvik, in the Canadian Arctic. Polar stations have long since proven their worth by providing a maximum yield of data thanks the frequency with which Earth observation satellites pass over the poles and can communicate with the stations there.

Big Data

Much has changed since the launch of the first European Earth observation satellites. Europe now has its own large fleet of them. The Copernicus programme's Sentinel spacecraft provide data for all – available online free of charge. Just twelve years ago, the USA initiated such 'free & open' development when it declared the images from its Landsat satellites to be an open resource. Images that had previously cost hundreds of dollars were suddenly available for free. The EU seized upon the idea, and most of its satellite data are now freely available. Only data with the highest spatial resolution – in the range of one metre or better – remain reserved for the commercial market. Yet this market is itself changing as start-ups become aware of the potential of Earth observation. There are now hundreds of small and microsatellites based on similar standard components in orbit – some as small as a shoebox. Every day, they deliver high-resolution images that, when combined, span the entire surface of Earth. Possible hardware failures are factored into the concept and image quality and geometric precision are optimised by the software at large processing centres only after the data have been received.

Out of space and into the Cloud

These days, such computer centres allow even small research groups and individuals to create new products or services using global Earth observation data. Until a few years ago, users had to download data onto their own personal computers and process it there. Today, the data often remains at the processing centre so that the algorithms are uploaded to the data instead. Companies such as Google and Amazon have discovered the potential of this service. They offer access to European Copernicus data and the necessary computing power from a single source – free of charge for research purposes in some cases, provided that they expect to benefit from the work somehow in future. The EOC today is part of this extremely dynamic Earth observation environment, which the institution and its predecessors have helped to shape for over 40 years. Parts of ESA's ground segment were designed by its teams, for example. The EOC is still responsible for receiving, processing and managing satellite data on behalf of ESA and has been able to assert its position in an increasingly commercialised market. It is currently working with the Leibniz Supercomputing Centre of the Bavarian Academy of Sciences and Humanities to develop a promising alternative to the commercial providers for processing satellite data in the Cloud. This cooperation intends to maintain the user's sovereignty when accessing and processing such data.



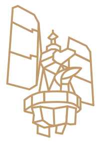
© EOC

DFD developed an algorithm which detects typical aquaculture tanks in radar images. This makes it possible to estimate the growth and production volume of aquacultures worldwide. Aquaculture is often located in sensitive coastal and mangrove regions. This image shows the Pearl River.

© EOC

In a metropolis such as Cairo, it is often difficult to provide precise data on population density. Using the World Settlement Footprint in combination with data produced by the TanDEM-X mission, DFD experts estimate building heights worldwide. This information makes it possible to more accurately determine the distribution of the population.

1971 First email sent



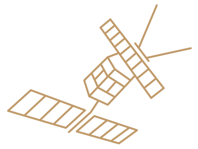
1972 Landsat-1 Earth observation satellite launched

1973 First mobile telephone prototype

1976 Apple I personal computer

1980 DLR Applied Data Technology Department founded

1983 German MOMS-01 space camera



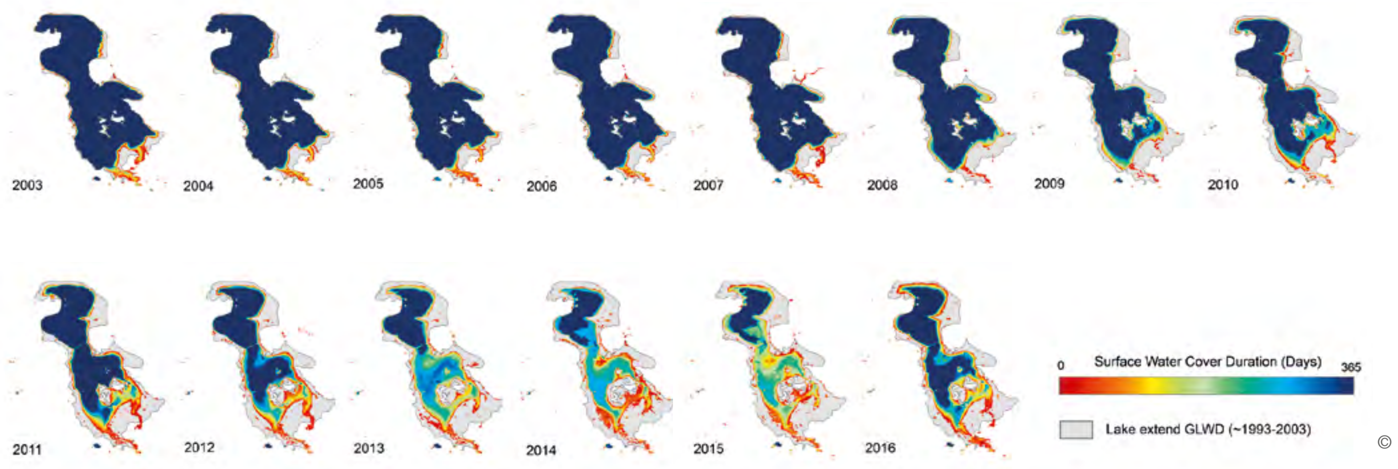
1991 The World Wide Web becomes available worldwide

1991 ESA's ERS-1 Earth observation satellite launched

1991 GARS O'Higgins commissioned

1993 Applied Data Technology Department becomes the German Remote Sensing Data Center (DFD)

1994 The SIR-C/X-SAR imaging radar orbits Earth on board Space Shuttle Endeavour



© EOC

At approximately 4,250 km², Lake Urmia was still eight times the size of Lake Constance in 2003. By 2015, however, it had shrunk to roughly 10 percent of its original area. Local, national and international initiatives and programmes have increasingly addressed the problem of desiccation and the resulting consequences. The first positive effects of the initiated measures were already apparent in 2016. In situations like this, information products created usind data acquired by Earth observation satellites, such as the Global WaterPack, can provide important information bases for future planning.

Keeping the whole picture in view

The EOC and its predecessor institutions have grown up alongside ESA and its space programme. However, the EOC has also developed particular strengths through its participation in Germany's own space programmes and radar missions. These included the world's first radar system operating in the X-band, SIR C/X-SAR, which was launched in 1994, and the first Synthetic Aperture Radar (SAR) interferometer, which made its debut in 2000 on board the SRTM remote sensing mission. This sensor made it possible to create terrain models for Earth's surface for the first time. The TerraSAR-X satellite, which carries a radar sensor with various modes of operation, was then launched in 2007. Its twin satellite, TanDEM-X, followed three years later. The two satellites fly in close formation, enabling simultaneous imaging of the Earth's surface in a process known as bistatic interferometry. No other space-faring nation had previously dared to have two satellites orbit each other in a helical path, separated by as little as a few hundred metre. The objective was to produce the first uniform, high-resolution global terrain model. The TanDEM-X mission demonstrated DLR's unique selling point better than ever before: its systems capability for satellite control, instrument development and data processing and analysis, all from a single organisation. In all of these national and ESA missions in which the EOC participated, it was able to develop the processing algorithms that took data from initial sensors all the way through to end-users. Germany became a world leader in radar remote sensing. The amount of data produced by these missions also eclipsed everything that came before them and on the basis of this experience, the EOC is now well equipped to process the far larger quantities of data produced within the European Copernicus programme.

Artificial intelligence is used to classify objects in aerial and satellite images. The algorithm recognises traffic routes, vehicles and different road markings from an altitude of approximately 500 kilometres, as shown here in a scene from Munich. © EOC

Artificial intelligence and social media for Earth observation

In order to efficiently analyse this wealth of 'Big Data', the EOC set up the 'Artificial intelligence for Earth observation' research area. Geoscientific research at the EOC has also been boosted by the large quantities of data. As one by-product of the TanDEM-X mission, for instance, the most accurate settlement map of the world ever was produced. Today, this map is being further developed using Sentinel data and supplemented with further elevation information from TanDEM-X. Using techniques from the fields of Big Data and artificial intelligence, and with help from social media, scientists at the EOC can even determine the type of individual buildings in a settlement. This allows them to determine how the population is distributed with far greater precision. This information is important for mapping at-risk areas, a process conducted by the EOC's Center for Satellite-Based Crisis Information (ZKI). Atmospheric research also benefits, as it can more accurately estimate the number of people exposed to various degrees of atmospheric health risks.

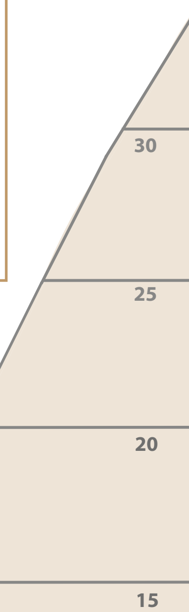
Here too, in this satellite image of a motorway junction in Braunschweig, the algorithm recognises road markings from an altitude of approximately 500 kilometres. This is valuable information for future applications such as autonomous vehicles. © EOC

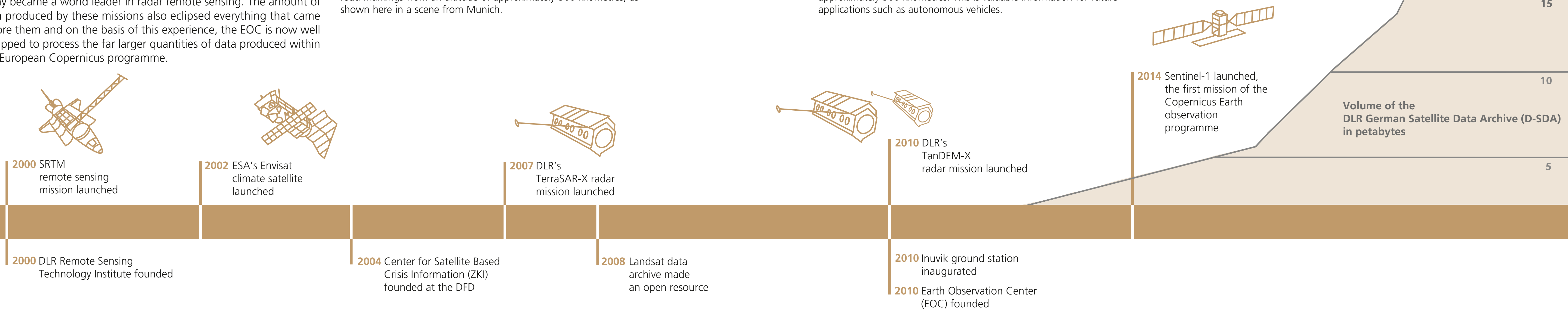
Earth observation has become an integral part of people's everyday lives. Forty years ago, no one could have dreamt of the sheer volume and diversity of data that would be accessible today or the extent of the corresponding algorithms and processing capacities. The possibilities today afforded by the internet, extensive fleets of satellites and everyday mobile applications were simply unimaginable.

Professor Stefan Dech is the Director of the DLR German Remote Sensing Data Center and **Professor Richard Bamler** is the Director of the DLR Remote Sensing Technology Institute. Together they lead DLR's Earth Observation Center.

THE EARTH OBSERVATION CENTER

The Earth Observation Center (EOC) is a DLR institute association comprising the Remote Sensing Technology Institute (IMF) and the German Remote Sensing Data Center (DFD). The DFD emerged from the Applied Data Technology Department, which was founded in 1980. The IMF was founded in 2000 following a comprehensive restructuring of DLR's Earth observation department. Since then, the two institutes, which have sites in Oberpfaffenhofen, Neustrelitz, Berlin and Bremen, have worked together as a network, initially as the Applied Remote Sensing Cluster and, since 2010, as the Earth Observation Center. Today the EOC is a leading international centre of excellence for satellite-based Earth observation.





INTO SPACE IN SEVEN DAYS

The DLR Responsive Space Cluster Competence Center pioneers a new approach

by Uli Bobinger

Dirk Zimper is the Head of the DLR Responsive Space Cluster Competence Center in Trauen.

There is a scene in the James Bond classic, 'You Only Live Twice', in which an American spaceship suddenly disappears from the radar screens. Later, the same thing happens to a Soviet space capsule. Both are suddenly deactivated and vanish. The villain Blofeld's diabolical plan to incite a war between the world powers is on the brink of success – were it not for secret agent 007.

The name's Zimper. Dirk Zimper. But whether he prefers his martini shaken or stirred is probably one of the few questions that he has not been asked in recent months. Zimper has a PhD in engineering and his time is currently in high demand. He heads the newly established Responsive Space Cluster Competence Center (RSC^3) in Trauen, Lower Saxony. Unlike James Bond, however, he and his team are not on the offensive. Their job is to replace lost or failed satellites.

The role of RSC^3 is to rapidly respond when space-based communication structures suddenly stop working. This can be done without secret agents or eliminating bad guys, despite that fact that recent space experiments from some nations certainly do seem suitable for the big screen.

China and India have already shot down some of their own satellites in orbit, not only creating a large amount of space debris, but also leading to the rest of the world asking: for what purpose? According to USA technology portal, 'The Verge', in April 2020 the Russian satellite Kosmos 2543 deployed an unidentified object in the vicinity of another Russian satellite. It is not unusual for inspection satellites such as Kosmos 2543 to approach other satellites in order to examine their condition, but the fact that another object was suddenly deployed in space after such an approach has attracted a lot of attention. The USA believes that the object launched from Kosmos 2543 – which, unusually, moved much faster than its parent satellite – could be a projectile designed to destroy other satellites.

Indispensable aids

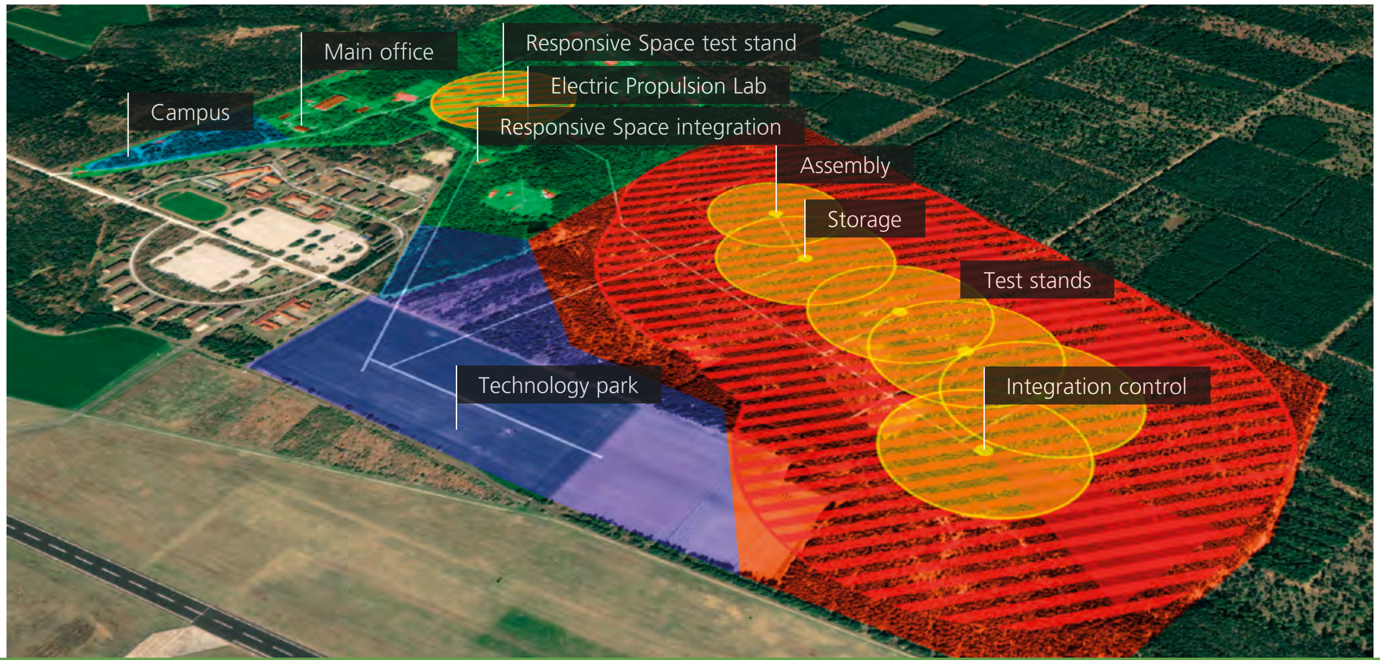
Our life on Earth is now governed by satellites. They do far more than provide weather forecasts and television shows. Without coordination from satellites, personal satellite location and navigation would be impossible, there would be no reliable data streams, no more trading on the stock exchange and computer networks would not be able to control traffic lights, train signals or power grids. So how can we respond if key satellites are disabled, be it through aggressive acts, or simply collisions with pieces of space debris?

The answer is as clear as it is challenging to implement: launch a new satellite into orbit with the necessary payload as quickly as possible to replace the disabled one. That is where Dirk Zimper comes in. The role of RSC^3 is to develop this capacity. It is a major component of 'AeroSpacePark Trauen', an innovation centre established at DLR's Trauen site at the end of summer this year.

Seven days instead of seven years

Planning a satellite mission, building the satellite, finding a suitable rocket to launch it, organising a launch campaign, getting the payload into the correct orbit, calibrating it and then operating it once it is currently a process that normally takes several years. For example, the contracts for building the European EDRS-C telecommunications satellite were signed in 2013. It was not until six years later, in August 2019, that EDRS-C was launched into space on board an Ariane 5, and the commissioning phase to prepare the satellite for operational use was only completed in July 2020. EDRS-C is now located in a geostationary orbit at an altitude of 36,000 kilometres. Even if Responsive Space initially only focuses on replacing defunct satellites in low-Earth orbits of a few hundred kilometres, doing so in seven days rather than the seven years that were needed for EDRS-C would make a James Bond film look like a documentary.

This doesn't just sound like 'New Space' – it would be a real revolution in European space travel, even if the symbolic seven days turned out to be two, three or four weeks in reality. "We have incredible expertise at our disposal across the DLR institutes," says Zimper, speaking about the challenges of such a project. "But Responsive Space is a systemic task, which means that we have to bring together all the individual disciplines in which we are strong and combine these capabilities."



AEROSPACEPARK TRAUEN

Approximately 80 kilometres south of Hamburg, Trauen is home to the most extensive DLR site in Germany – over 800,000 square metres. The newly established 'AeroSpacePark Trauen' is home not only to the Responsive Space Cluster Competence Center (RSC³) – the first research institute of its kind in Europe – but will also conduct research into electric propulsion, the demand for which is rapidly increasing in the aerospace sector. While 35 years ago only ten satellites with electric propulsion systems were in operation, today there are more than 200. However, there are still very few vacuum test facilities for such systems. The DLR Institute of Propulsion Technology in Trauen aims to remedy this and in the medium term establish Europe's largest test centre for electric propulsion. Aeronautics research will be incorporated into this cluster as well. There are also plans to establish a technology campus in Trauen that will attract space-focused companies and start-ups, and possibly also engineering service providers and companies working on technologies such as battery development. Further possible research topics that could be incorporated here include data analysis, machine learning, artificial intelligence and cybersecurity – all of which are fields of close cooperation within the aerospace sector. In the coming years, up to 60 DLR employees are expected to work and conduct research at the DLR site in Trauen.

Dirk Zimper leads Security research at DLR, an interdisciplinary research area involving collaborative projects conducted across more than two dozen DLR institutes. There are many opportunities for cooperation within DLR. New engine and fuel tank designs can be tested with help from the Institute of Space Systems in Bremen – which could also supply satellite hardware such as standardised platforms known as buses. Satellite payloads can be examined with help from the Institute of Optical Sensor Systems or the Institute of Communications and Navigation, while DLR's German Space Operations Center can assist with satellite control and data processing – the list could go on.

Space as a theatre of operations

In terms of users, Responsive Space will work in close cooperation with the German armed forces, the Bundeswehr, who are invested in the topic for obvious reasons. The overall strategy of the Ministry of Defence, published in 2018, reads: "The security and functionality of a modern information society depend on unrestricted access to space-based information and communication channels. The same applies to the capability and readiness of the Bundeswehr, which relies on space-based applications and satellite systems to fulfil its mission. Space should be regarded as a theatre of operations."

At the founding ceremony for RSC³, the Deputy Inspector of the Air Force, Lieutenant General Ansgar Rieks, was even more direct: "Defending the country and its allies," he said in Trauen, "relies on our ability to guarantee our space-based capabilities. This guarantee depends, among other factors, on Responsive Space." It is clear from the enthusiasm of the military that seven days would be a great response time – but 24 hours would be even better. The bar is set high.

All or nothing

Responsive Space encompasses the entire spectrum of space technologies: if you are not proficient in all of them, the whole system will fail. To function as intended, Responsive Space requires:

- The launch segment: the launchers and their propulsion systems, upper stages that can quickly and precisely deploy satellites, and concepts for launch and flight control
- The ground segment: flight dynamics, orbit calculations, ground stations, deployment simulations and concepts for getting payloads operational as quickly as possible and for then operating these payloads
- The space segment: the automated construction of small satellites in accordance with requirements and their rapid integration in a plug-and-play architecture on standardised platforms
- The mission segment: the development of mission strategies and deployment scenarios and their integration into the overall project architecture

DLR has proven expertise in all these areas. However, as Zimper explains: "The processes today are often still too slow, as they do not usually consider the need for a capability to quickly respond to events in space – and that is something we need to improve."

"The rockets must be there already, we cannot just start building them when we need them, and the same goes for the satellites," says Hansjörg Dittus, DLR Executive Board Member for Space Research and Technology, describing the motivation for Responsive Space. "That is the importance of the new Competence Center. We want to foster a completely new type of development here that involves establishing a community platform for the frequent exchange of ideas with industrial partners. When the situation arises, we will not have time to test systems: they must have been tested, built and designed beforehand. That is exactly what we need to do to achieve our aim of being responsive."


The ambitious vision of Responsive Space is to replace defunct satellites within 24 hours

Responsive: reacting together, immediately

With the establishment of RSC³, the aim is to create a mutually beneficial location for science, industry and users to interact. As in a football team, where the team as a whole is more than the sum of the individual players, Responsive Space will also be an interconnected network of systems. All of its components will work together, even below the famous Kármán Line at 100 kilometres altitude, which according to the Hungarian physicist Theodore von Kármán, is where space begins.

'High-altitude platforms (HAPs)' could play a particularly important role in this 'system of systems'. HAPs are uncrewed aircraft operating autonomously in the stratosphere at an altitude of around 20 kilometres. They may become important nodes in communication networks between terrestrial stations and satellites. Within the Responsive Space project, the fields of aeronautics and space are linked by DLR's cross-sectoral research on the topic of security. Even the name of the new site, 'AeroSpacePark Trauen', clearly states the importance of both research areas.

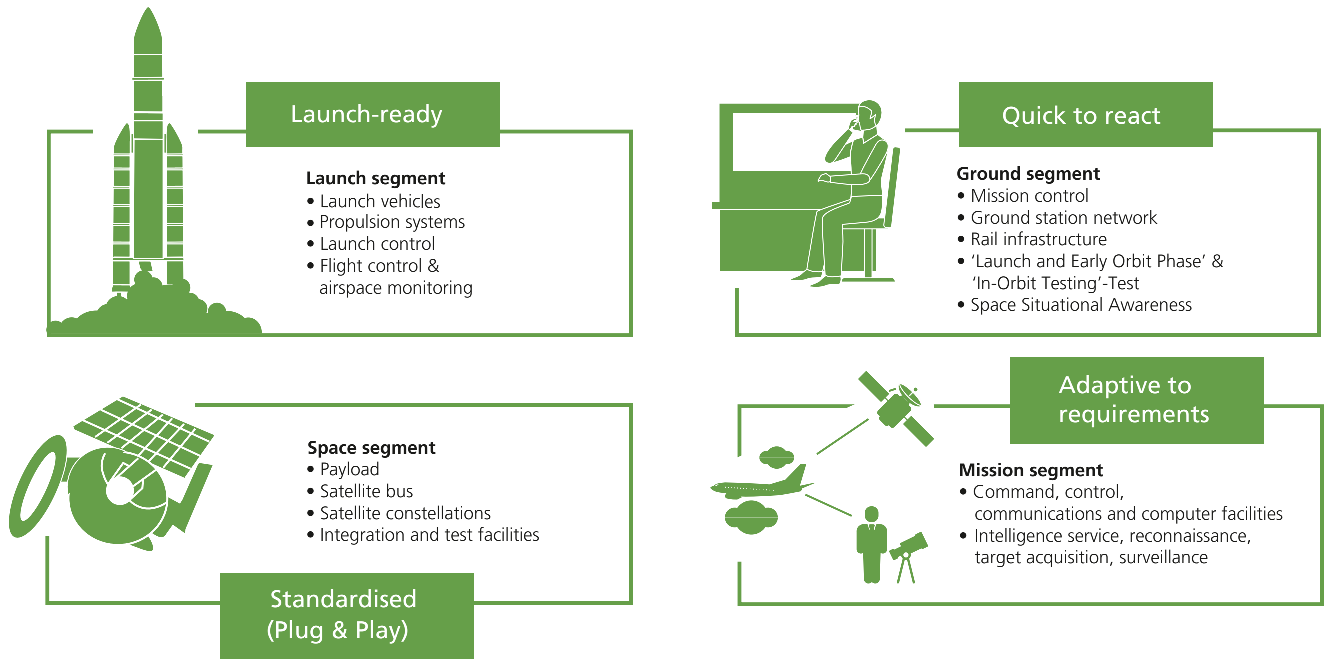
Ideal conditions

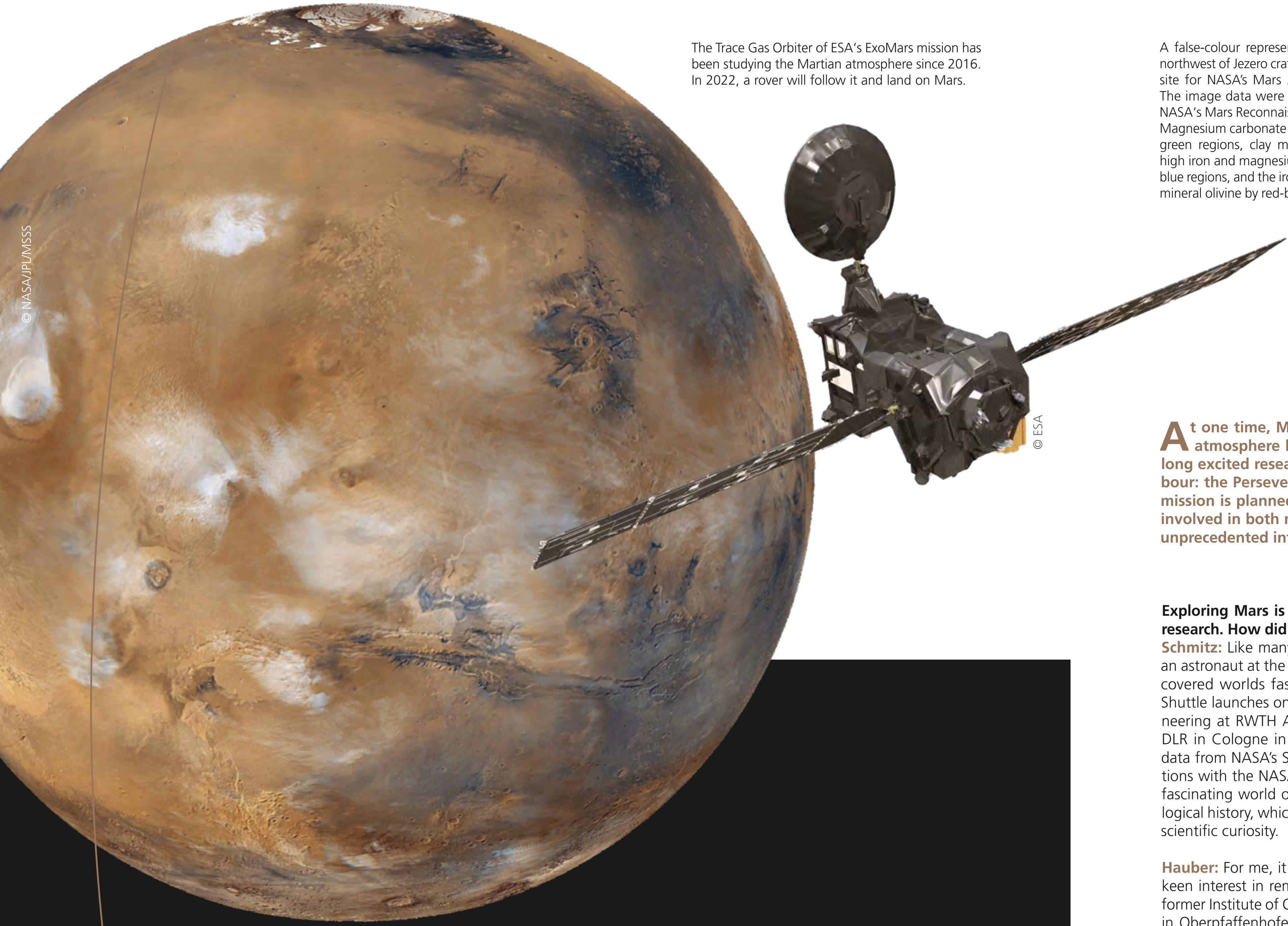
The DLR site in Trauen is perfectly suited for the development of RSC³. Testing engines and motors on the extensive site will not disturb anyone, and test benches are already operated at the site. Integration equipment for launchers and small satellite systems will be added. In its final stage, as many as 60 DLR personnel are expected to be working at the site. Under Responsive Space, the aim is for a German-made small satellite to be launched on a German-made rocket and start operating in space by 2029.

Dirk Zimper has a three-year-old son, Karl, who certainly is not yet familiar with James Bond. His favourite hero is Pippi Longstocking. This is thanks to Pippi's motto, which could also suit 007 and which his father has also taken to heart for RSC³: "I've never tried that before, so I am quite sure that I will succeed." That, in a nutshell, is the approach taken by the new Responsive Space Cluster Competence Center.

Uli Bobinger has worked as an aerospace journalist for various German television stations for many years. He is also known in the industry as a moderator of specialist congresses.

THE SEGMENTS OF THE RESPONSIVE SPACE CONCEPT





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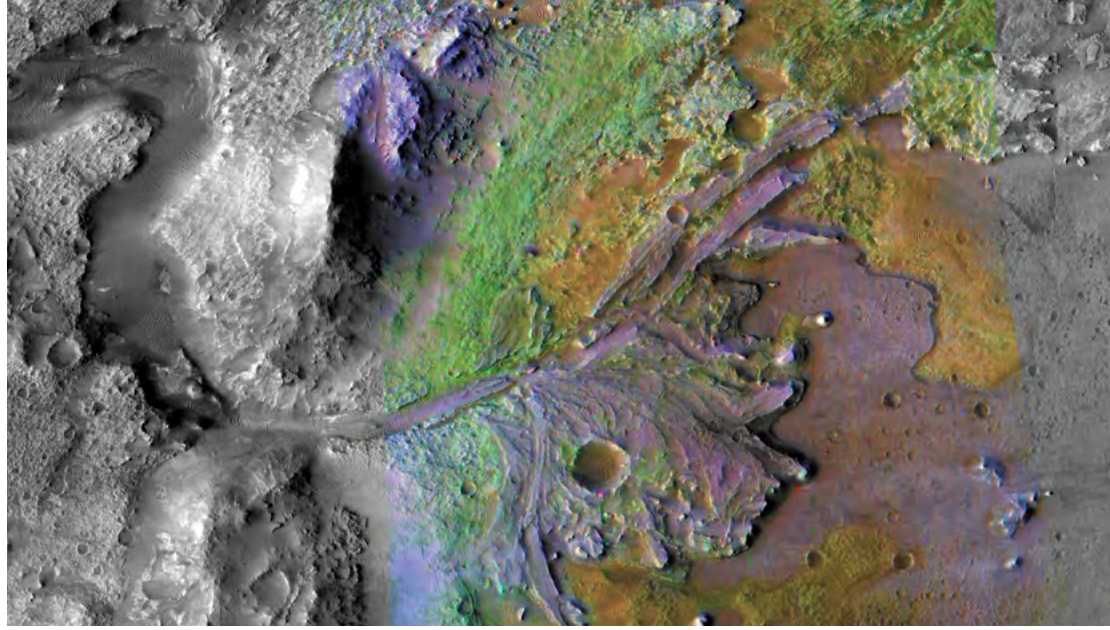
The Trace Gas Orbiter of ESA's ExoMars mission has been studying the Martian atmosphere since 2016. In 2022, a rover will follow it and land on Mars.

FETCH AND CARRY

New Mars missions and a fascinating plan to bring samples from the Red Planet back to Earth

by Falk Dambowsky



A false-colour representation of the northwest of Jezero crater, the landing site for NASA's Mars 2020 mission. The image data were acquired with NASA's Mars Reconnaissance Orbiter. Magnesium carbonate is indicated by green regions, clay minerals with a high iron and magnesium content by blue regions, and the iron-magnesium mineral olivine by red-brown regions.

© NASA/JPL-Caltech/MSSS/JHU-APL

At one time, Mars was in many ways similar to Earth. 3.5 billion years ago, water flowed through its valleys and a denser atmosphere kept its surface warm. The question of whether microbial life could have existed under these conditions has long excited researchers. In the early 2020s, two Mars missions will begin their searches for traces of life on our celestial neighbour: the Perseverance rover of NASA's Mars 2020 mission is already on its way, while the rover component of ESA's ExoMars mission is planned for launch in autumn 2022. Nicole Schmitz and Ernst Hauber of the DLR Institute of Planetary Research are involved in both missions. In an interview with DLRmagazine, they discuss the coming decade of Mars research – including the unprecedented interplanetary feat of bringing Martian rock samples back to Earth.

Exploring Mars is among the most exciting topics in planetary research. How did you become so enthusiastic about it?

Schmitz: Like many other children, I started to dream about being an astronaut at the age of three. The night sky, adventure and undiscovered worlds fascinated me, and I also followed all the Space Shuttle launches on television. So I decided to study aerospace engineering at RWTH Aachen University, which led to an internship at DLR in Cologne in 2004. There, I got the chance to help analyse data from NASA's Spirit and Opportunity rovers. In my daily interactions with the NASA team I gained more and more insight into the fascinating world of our neighbouring planet and its complex geological history, which still offers more than enough riddles to fuel our scientific curiosity.

Hauber: For me, it was a combination of my geology studies and a keen interest in remote sensing. That was what brought me to the former Institute of Optoelectronics, which was located at the DLR site in Oberpfaffenhofen. After only a few projects I was captivated by Mars, with its varied landscape, carved by wind, water and ice. Even after decades of research, Mars still gives us surprises – the latest of which is the possibility of subglacial lakes currently being discussed by researchers.

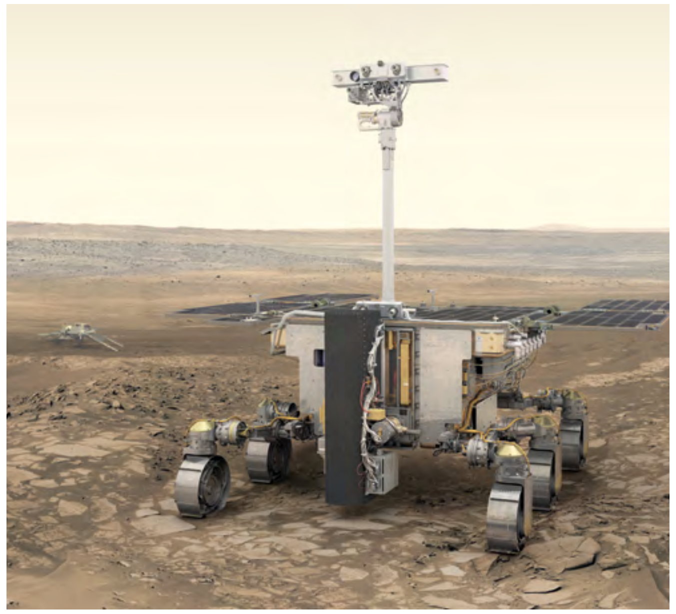
On 18 February 2021, the NASA rover Perseverance will land in Jezero crater. What will it do there?

Schmitz: Jezero is located on the inner edge of one of the largest and oldest impact basins on Mars. It is a fascinating spot that has been shaped by a variety of geological processes. More than 3.5 billion years ago, there was water flowing into Jezero crater, and a river delta formed near the western rim. For the first time in the history of Mars research, Perseverance has sample collection containers on board, which will hold rock and soil samples taken from a depth of several centimetres. The rover is about the size of a small car and has a mass of around 1000 kilograms. It has room for seven scientific zinstruments that will allow it to analyse the geology of the landing site and to search for traces of past microbial life in rocks and sediment. The most promising of these will be transported back to Earth for detailed analysis in the future.

Hauber: And then comes the really exciting part! For decades now, scientists have been discussing how to get samples from Mars to Earth, and now it has become a top priority for both NASA and ESA. Things have finally got moving, and Perseverance marks the beginning!

What is different about ESA's ExoMars rover, which is planned for launch in 2022?

Hauber: The main difference is the drilling depth. ESA's ExoMars rover, named Rosalind Franklin, will be the first to be able to drill down as far as two metres into the Martian surface. It will then also be able to immediately analyse the extracted material – via gas chromatography and mass spectrometry, for example – with its various instruments. There is a chance that cosmic rays have not penetrated that far beneath the surface. This increases the possibility that we will be able to detect traces of past microbial life there.



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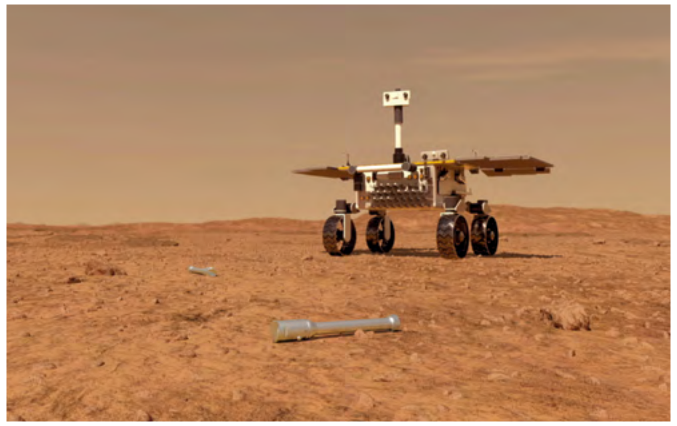
The Rosalind Franklin rover of ESA's ExoMars mission

Rosalind Franklin will not prepare any samples for later transportation to Earth. What are the advantages of laboratory analysis compared with examinations carried out on board rovers on Mars?
Schmitz: The possibilities for analysis on board rovers are limited in size and complexity. So it is helpful to have access to the more extensive arsenal of analytical equipment available on Earth. Unfortunately, some of the equipment from these laboratories cannot yet be reduced in size enough to make them suitable for space travel. It is also very advantageous to collect samples today that can then be examined on Earth in decades time using more advanced future technologies.


The Mars 2020 rover Perseverance takes drill samples of Martian rocks with its arm, seals them and places them on the ground.


The Sample Fetch Rover, which could launch in 2026, will collect the samples and transport them to the Mars Ascent Vehicle (MAV).


The MAV delivers the sample capsules into orbit around Mars, where they are collected by a spacecraft and brought to Earth.

What exactly are the traces of life that we are looking for?
Schmitz: At its landing site, Perseverance will search for what are known as 'biosignatures'. These are objects, substances or structures that can only have been left by living organisms, such as patterns in the rock or chemical isotopes. Unlike previous Mars rovers, Perseverance has the tools required to detect these 'fingerprints' of life, to map the signatures and to understand their formation and origins. These fingerprints come in many different forms. In order to confirm any findings, we would have to find several independent signs, and to be certain, we would then bring samples of these potential biosignatures to Earth to be analysed in highly-specialised laboratories.

Hauber: Even on Earth, identifying billion-year-old biosignatures in rocks is anything but simple. Biosignatures can be morphological, physical or chemical in nature. Like Perseverance, Rosalind Franklin can also perform analyses that are able to identify these fingerprints. However, because the ExoMars mission won't be sending examples back to Earth, it's particularly important to find several independent biosignatures to be really certain.

How will the samples from Mars actually get to Earth?
Schmitz: First, Perseverance will leave capsules (caches) containing rock and sediment samples at the places they were collected. A planned second component to the mission will pick these samples up in the future. This Sample Fetch Rover is expected to be provided by ESA. The next step will be the launch vehicle, the Mars Ascent Vehicle (MAV) supplied by NASA. The samples will be packed into the MAV and launched on a small spacecraft into orbit around Mars. The Sample Fetch Rover and the MAV could be launched together in 2026.

Hauber: Then comes the most difficult part of the mission, unprecedented in its complexity. Another spacecraft, that ESA is also expected to provide, will arrive in Mars orbit towards the end of the decade and collect the sample container while in orbit. From there, it will return to Earth in the early 2030s with the samples on board. Due to the great distance between Earth and Mars, remote steering of the spacecraft will not always be possible, therefore a high degree of automation will be required. The top priority throughout all stages of the mission will be to protect the samples.

How are scientists preparing for the arrival of the samples from Mars?
Hauber: The landing capsule with the samples inside is planned to land at a military site in Utah, USA. From there, it will be recovered by a specialist team and taken to a high-security laboratory for preliminary analysis. Preparing this laboratory will be a complex operation, as there will be numerous safety and security requirements to consider and all of the necessary equipment will have to be prepared well in advance.

Schmitz: One question that is particularly relevant is how the initial analysis laboratory and subsequent laboratories can be designed to ensure maximum biological safety. Until now, we have designed our secure laboratories to prevent anything from unintentionally getting out. For samples from other planets, we will have to design the research environment in such a way that they cannot be contaminated from outside, to preserve their integrity.

How are you involved in this very logistically, technically and scientifically complex process?
Hauber: The ideas and proposals behind these missions are developed by many international research groups. Since summer 2020, I have been a part of the joint NASA-ESA Mars Sample Return Science Planning Group 2, where approximately 20 experts from the USA and Europe across various fields of expertise meet regularly. Together, we are drawing up a plan for the examination of future Martian samples. We discuss things such as how large the first sample laboratory should be and what equipment it should have. Distribution is another key consideration. Where and how should the Martian samples be stored? How will they be distributed among scientists around the world and according to which criteria? Then there is the question of whether and how any of the samples should be sterilised for non-biological investigations.


The sample capsules of the Perseverance rover

Schmitz: We are also directly involved in the first mission of the Mars Sample Return programme. I am a Co-Investigator for the Perseverance rover's Mastcam-Z camera instrument. In the international mission team, we are already planning what type of rock and soil samples we would like to collect with Perseverance, based on various scientific criteria. This means that during the mission, we will be involved in the day-to-day decision making regarding where the rover should take samples. I was also previously on international committees dealing with the scientific, technical and software aspects of the Mars Sample Return programme.

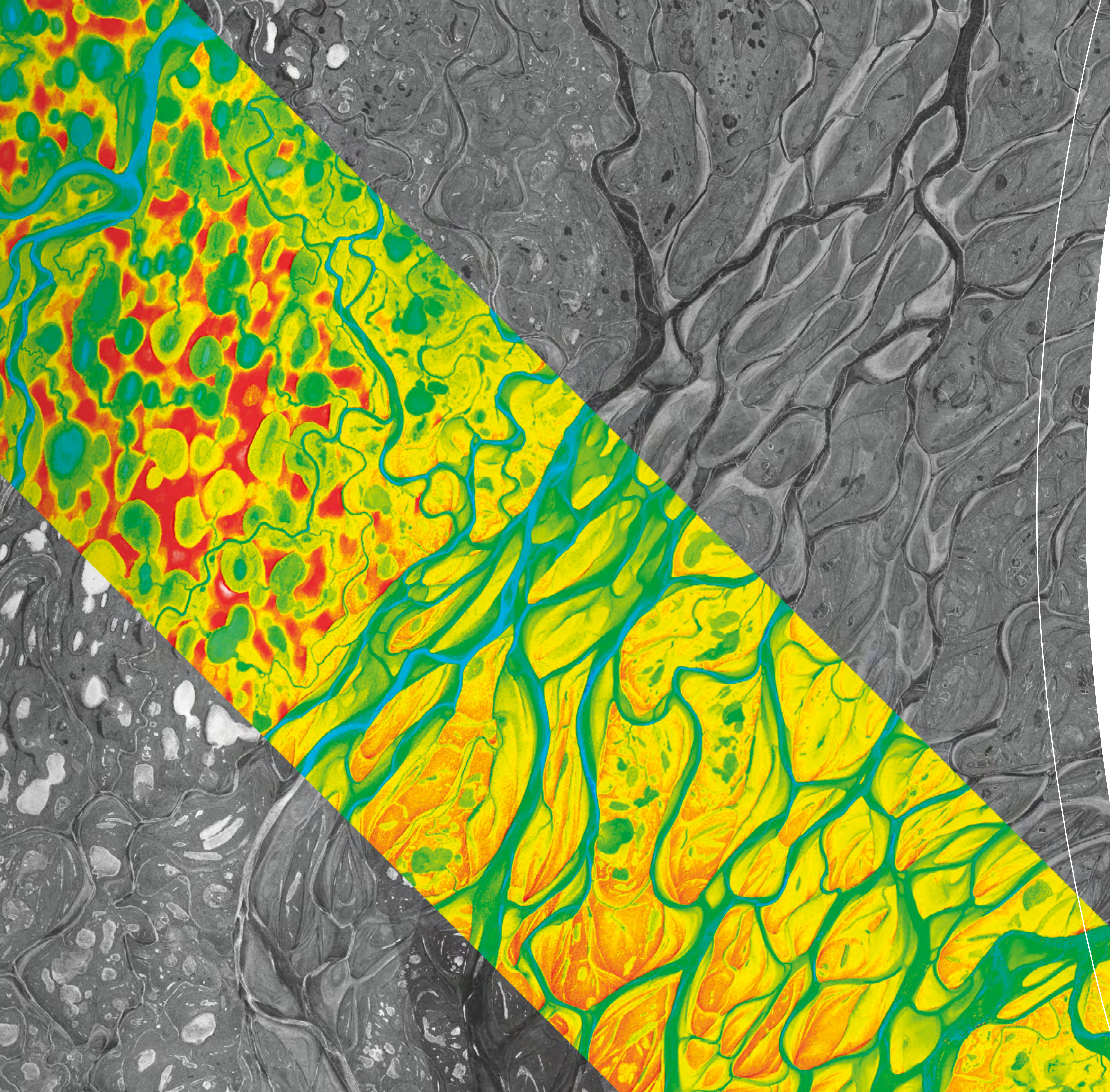
What new findings from Mars do you hope to see from ExoMars and Mars 2020 by the end of the decade?
Schmitz: We are hoping to get closer to answering one of the most exciting questions in Mars exploration: was it once home to simple life? For this, we need even better data to help us understand how geological, physical and chemical processes have impacted the planet's habitability – its viability for life – over time. We are very hopeful for the examination of the samples collected by Perseverance and for the analyses carried out by the ExoMars mission.

Hauber: We also hope that improved data will allow us to more precisely model the internal evolution of Mars, to better understand its formation and geological history in comparison with the other Earth-like planets in the Solar System.

The interview was conducted by **Falk Dambowsky**, editor at DLR Media Relations.

Ernst Hauber is a geologist and a member of the team that chose the landing site of the ExoMars rover. The team relied on data from the ESA Mars Express probe's High Resolution Stereo Camera, whose image recording Hauber has coordinated since 2005. He's also acting project research manager of the ExoMars rover's PanCam instrument, preparing mission operations. And, Hauber is a member of the ESA Working Group on Planetary Protection, which works to prevent space probes from contaminating the Earth and other planets, and to help coordinate international regulation in this regard.

Nicole Schmitz is a research associate and engineer in planetary geology at the DLR Institute of Planetary Research, She has been involved with DLR since her student days, when she helped to evaluate data from NASA's Spirit and Opportunity Mars rovers. As co-project leader of PanCam instruments on the ESA ExoMars rover and co-investigator on the Mastcam-Z team on NASA's Perseverance rover, Schmitz is involved in technical and research activities on the next two Mars rover missions. She has also been a member of the international ESA and NASA teams working on the research, technical and programming preparation of the Mars Sample Return programme.



REACHING NEW HEIGHTS

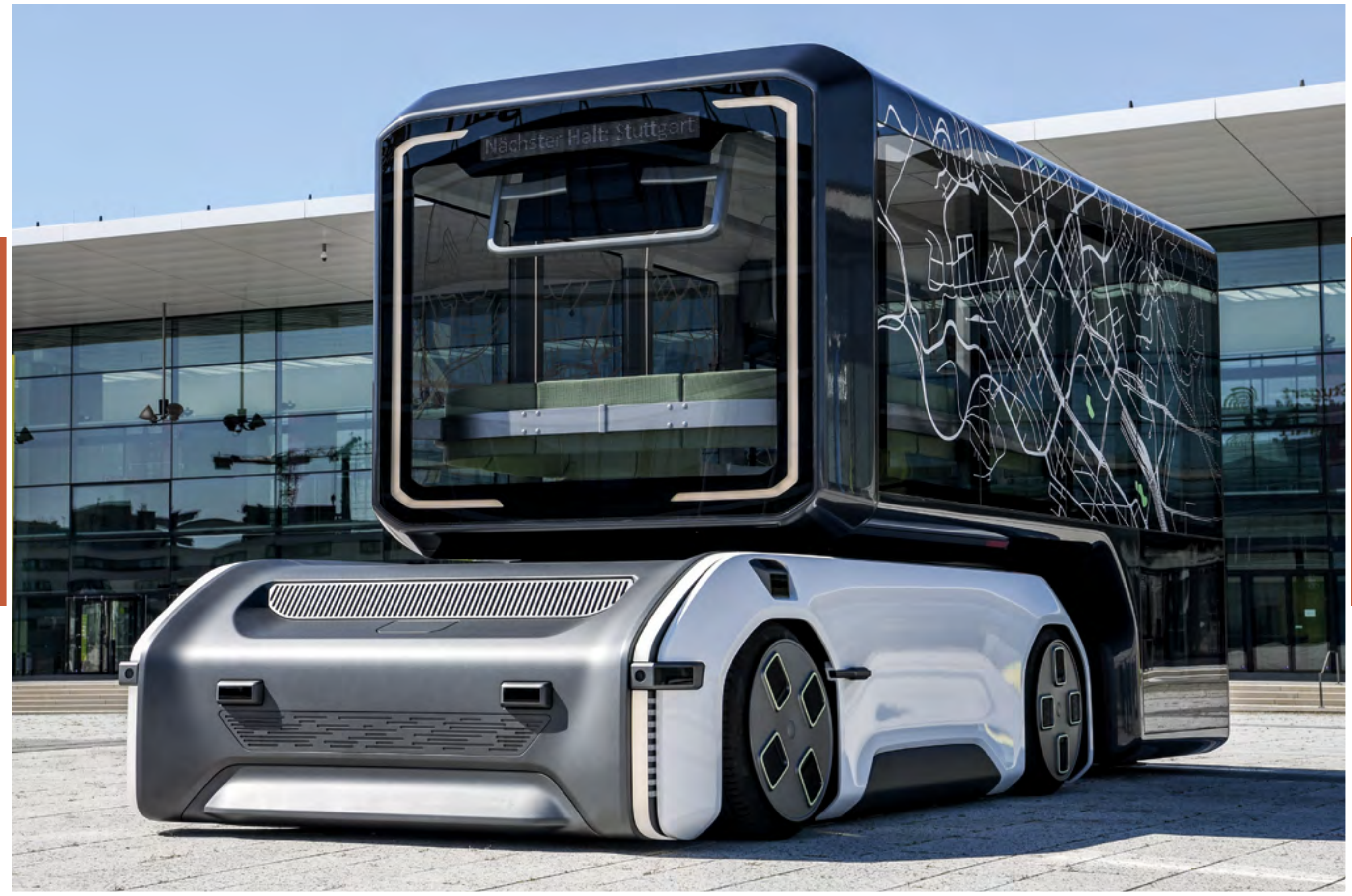
10 years of TanDEM-X

Orbiting Earth in close formation, the 'twin' satellites TerraSAR-X and TanDEM-X have worked together as a unique radar interferometer since December 2010. With the addition of TanDEM-X, a view of Earth that could only be captured in two dimensions prior to 2010 (as shown here in black and white) gained a new dimension. This image shows the Lena Delta in Russia. Here, after 4294 kilometres, the river flows into the Laptev Sea, a marginal sea of the Arctic Ocean. The 1500 small islands in the delta are constantly changing shape as new sediment is deposited which alters the flow of the water. In an atlas, the variations are so small that this entire area is depicted at a single, constant elevation. TanDEM-X can visualise these elevation differences in much greater detail, with a vertical accuracy of better than two metres. By mid-2016, scientists at DLR had created a precise three-dimensional elevation model of the entirety of Earth's landmass using data acquired by the TanDEM-X mission. Since then, the twin satellites have been gathering data for a second global elevation model. This model, known as the 'Change DEM' (Digital Elevation Model), will document changes to Earth's surface in three dimensions. Initial analyses have already revealed dramatic developments such as the melting of glaciers and ice sheets and the unrestrained deforestation of tropical rainforests.

NEXT STOP: THE FUTURE

The U-shift concept will make urban mobility and logistics more efficient and the Safe Light Regional Vehicle is lightweight, safe and low-emission

by Denise Nüssle



The DLR Institute of Vehicle Concepts is developing the future of urban and regional transport. Two of its vehicles – a futuristic, U-shaped driveboard with interchangeable capsules designed to carry passengers or goods, and a small, lightweight vehicle powered by a fuel cell and capable of reaching speeds of up to 120 kilometres per hour – have already been tested on the road.

MODULAR, MOBILE AND FIT FOR THE FUTURE

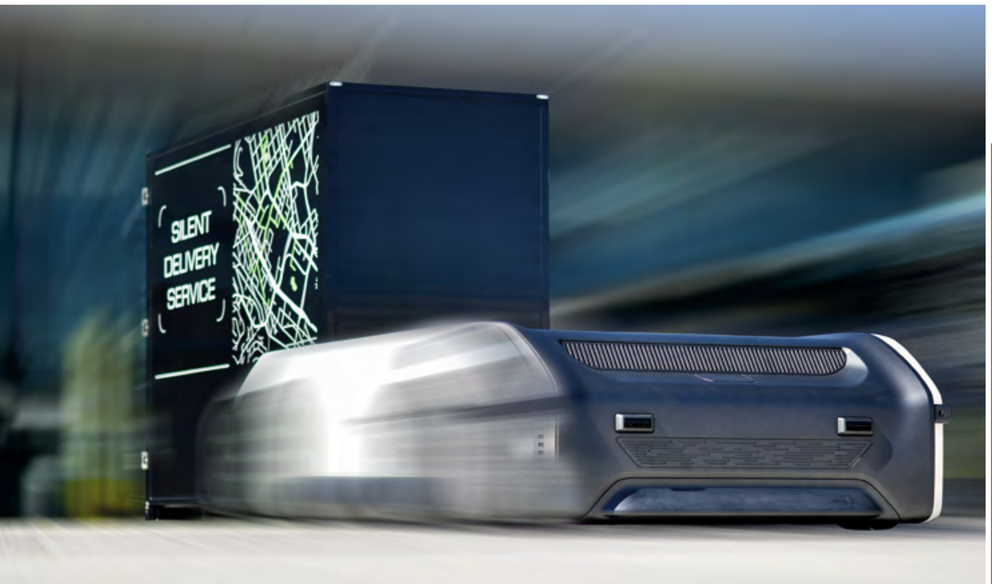
With its futuristic design and coloured in white, black and matt grey, the new U-Shift vehicle concept is a real head-turner. Wherever it goes, all eyes are drawn towards the vehicle, which is the size of a large van, as if by magic. What they see is a completely novel approach to the concept of urban mobility for transporting passengers and goods. In its shape and underlying technology, U-Shift differs fundamentally from anything on the road today – and the same goes for the business and service possibilities it enables.

"What makes U-Shift so special is that we have separated the drive unit from the capsule-like structures, which can be used to transport either passengers or goods," says Project Manager Marco Münster of the DLR Institute of Vehicle Concepts in Stuttgart. The U-shaped drive unit, known as the driveboard, houses all the technical components and systems needed for autonomous and environmentally friendly electric travel. The capsules can be designed for a wide variety of tasks. "This ‚on-the-road' modularisation enables many new business models, some of which we probably cannot even imagine today," says Münster. As the capsules have uniform dimensions and connections, they can be easily transferred to different modes of transport – in future, these could include air taxis or cable cars.

U-Shift can support local public transit and increase its appeal. It can be used as a flexible on-demand bus in urban areas with few regular bus services, provide door-to-door services in inner cities, or act as a supplement to public transport at peak times. The capsules could also be used as mobile offices, as event venues or as an alternative to mobile homes. For commercial goods, U-Shift could be used for delivery or parcel services that can operate through the night, such as a mobile parcel station or for supplying shops. DLR researchers have also suggested mobile pop-up shops, workshops for craftsmen and women or a mobile citizens' advice bureaux. In the field of waste disposal, U-Shift could be configured for refuse collection, as a road sweeper or even a mobile recycling collection point.

A disruptive concept for an industry in flux

The world of transport is undergoing a fundamental transformation, with technology trends and social developments reinforcing one another. The technology for automatic and networked driving is leaping ahead, together with the associated legislation. By the middle of the century two-thirds of the world's population will be living in urban areas. The challenges and demands for future-oriented transportation are particularly high. Pollution, noise and space limitations mean that, even today, many cities are trying to restrict the use of individual motor vehicles. Meanwhile there are growing opportunities for offering transportation as a service. "This is where our U-Shift concept comes in. It allows us to combine an endless variety of vehicle variants, break open new business models and to make a huge contribution to change in the automotive and logistics industries," explains Professor Tjark Siefkes, Director of the Institute of Vehicle Concepts.



DLR's partners in the U-Shift project

The DLR Institute of Vehicle Concepts is developing U-Shift with several partners. The Stuttgart Institute of Automotive Engineering and Vehicle Engines (FKFS) is responsible for developing the drivetrain. The Institute of Vehicle System Technology (FAST) and the Institute for Information Processing Technologies (ITIV) of the Karlsruhe Institute of Technology (KIT) are helping to develop the chassis and electrical and electronic architecture respectively. The Institute of Measurement, Control and Microtechnology (MRM) of the University of Ulm is responsible for the automation.

"Private cars spend about 95 percent of the time parked and doing nothing," Siefkes continues. "With U-Shift, the driveboard can be in operation almost 24 hours a day, carrying out a variety of transportation tasks assigned by a control centre." DLR researchers have calculated that there will be a need for approximately five to ten times as many capsules as driveboards. That is why, economically, it makes sense to integrate all cost-intensive, high-tech components into the driveboard. In addition to the lifting device and the autonomous driving components, driveboards will carry the wheel hub motors, battery modules and control electronics.

A prototype to test, discuss and optimise

Prototypes such as U-Shift are extremely important when developing novel vehicle concepts, as engineers can physically interact with them and try them out. "They are also a bit of an adventure," says Münster. "Between the computer model and the first physical vehicle, there is a lot of testing to do, and decisions have to be made about how futuristic you dare to be."

In addition to the driveboard, the U-Shift team has built two capsules. The passenger capsule is equipped with seven ergonomic seats, a wheelchair or pram seat and a folding seat. A large door with an integrated ramp ensures barrier-free access. The cargo version offers space for several pallets or trolleys.

Currently, the driveboard is remote-controlled, but the DLR team is planning to automate it during the next stage of development. "With U-Shift, safety is our top priority," explains Münster. "This is ensured by a network of sensors made up of laser scanners, video cameras and radar systems. Powerful computerised control centres will enhance operational safety." Exchanging capsules will also be fully automated, a challenge requiring a high degree of precision from the sensors and the driveboard controls. The prototype is giving researchers experience with the system for raising, manoeuvring and lowering the capsules, as they take gradual steps towards the goal of full automation. The next big step is the construction of a second driveboard that will have an increased powertrain output, incorporate hardware and sensors for automated and networked driving, test a new battery system and fine-tune the chassis and the lifting device.

Technology meets people

For a futuristic vehicle concept such as this to be successful, it needs a combination of advanced technology and human creativity. It is also just as important to win people over to the idea. They should want to use U-Shift because they are excited by it, because it can meet their mobility requirements quickly and efficiently, and because they feel they are in safe hands. With the help of the prototype, the researchers want to record people's needs and wishes. To this end, they have launched a survey to collect opinions and ideas about U-Shift and its many applications. Workshops with interested citizens are also planned to jointly develop ideas on how U-Shift can be further developed. The focus is on testing and optimising the interfaces between people and vehicles. This includes the mechanism for opening the doors, for example, the regulations on how and through which medium users can obtain all the necessary information for their journey and who is allowed to enter the capsule and when.

New products and business models for Germany's automotive industry

The U-Shift team is planning a second prototype for 2024 that will be fully automated and have a maximum speed of approximately 60 kilometres per hour. This next phase will bring the project's potential to foster innovative mobility services into sharper focus. "U-Shift makes integrated and comprehensive transport solutions possible for the first time," explains Siefkes. "This is because we bring together passenger and logistics transport, which were previously always separated. This will allow companies to operate as both passenger and freight transport providers at the same time." So far, the feedback from relevant stakeholders – within the automotive, delivery and logistics sectors – has been consistently positive and encouraging for the project team. New business models will be further analysed for technical and economic potential at workshops with industry associations, and through pilot trials. For all interested parties – whether they are potential manufacturers of driveboards and capsules, driveboard fleet operators, transport service or maintenance providers, or control centre operators – what matters most is the collaborative effort to identify opportunities for the future. "We have the chance to establish Germany as the market leader for new products and services for businesses and suppliers in the automotive industry and far beyond," says Siefkes.

U-Shift currently operates by remote control, but the DLR project team is planning a highly automated prototype for 2024.

The U-shape of the driveboard allows the capsules to be exchanged relatively easily. The integrated lifting device plays a central role in this: it allows fast, ground-level access to the capsule for people and for loading.

PREMIERE OF A SPEEDSTER

In early October 2020, an unusual vehicle completed its first circuits of the driver training centre at Kirchheim unter Teck, 25 kilometres southeast of Stuttgart. Whizzing around in the autumn sunshine through the hilly route that typically leaves learner drivers with sweaty palms was the prototype of the DLR Safe Light Regional Vehicle (SLRV). The vehicle is compact, light and agile, but also particularly safe. This combination of traits is not often seen in vehicles of its class. The key technology is its sandwich panel chassis, which weighs just 90 kilograms. DLR has combined this novel lightweight construction approach with an efficient fuel cell engine, demonstrating that safe and environmentally-friendly mobility is possible even with light vehicles. Such small, light and electrically-powered vehicles will become a major feature of inner city and regional commuter traffic in the future.

At the wheel of the SLRV prototype is DLR employee Sebastian Scheibe. He is a member of the development team led by Project Manager Michael Kriescher. Both have been investing their expertise and passion into the project at the DLR Institute of Vehicle Concepts in Stuttgart for several years. Before the prototype could be built, the team had to conduct material testing, followed by the construction and testing of components and several crash tests using the Institute's own facilities. For many of the researchers, the project is a dream come true. In addition to calculations and computer simulations, they were often able to help in the workshop and see the car take shape piece by piece.

The many advantages of sandwich design

The team's creation consists largely of sandwich panels with an outer layer of metal and an internal layer of plastic foam. "The front and rear of the vehicle are constructed out of these panels, which are glued together," says Kriescher. "Both sections serve as crumple zones and house much of the vehicle technology. The passenger compartment consists of a shell topped with a ring structure that absorbs the forces that act on the car while driving and protects the occupants in a crash." The two-seater weighs approximately 450 kilograms. This sandwich design has not yet been used in any cars in series production. "Our aim is to use projects such as the SLRV to highlight the potential of this construction and to further develop the technologies required to manufacture them."

The interlocking and glued sandwich panels are unique and make SLRV light and stable

SLRV may look like a sports car, but it is built to save resources and features a highly efficient hybrid powertrain. As a result of its low weight, it can manage with a relatively small fuel cell. This is coupled with a battery that provides additional power when needed, such as when accelerating. This combination is lighter than current battery systems and gives the car a range of 400 kilometres and a maximum speed of 120 kilometres per hour. The hydrogen tank is located between the two seats, and the waste heat from the fuel cell is used to warm the passenger compartment. The sandwich panel chassis provides good heat insulation in winter, reducing the energy consumption of the car's climate control system.

Commuting, car sharing and shuttle service

To date there are only a few models in the light electrical vehicle (L7e) class, with the best-known being the Renault Twizy. "Our SLRV demonstrates that we can produce a full-size vehicle in this category," says Tjark Siefkes, Director of the DLR Institute of Vehicle Concepts. "It offers a high level of passive safety, a respectable range and speed and a stylish design." The SLRV is particularly suited for suburban or out-of-town areas. As a shuttle, it could complement public transport in suburban or rural areas or be used as a resource-friendly commuter vehicle. As it can be refuelled in approximately only five minutes, it is also suitable for car sharing services.

Technical specifications:

- Length: 3.9 metres
- Body weight: 90 kilograms
- Total weight: 450 kilograms
- Power: max 25 kilowatts
- Fuel cell: 8.5 kilowatts, Weight: 28 kilograms
- Battery: 1.5 kilowatt hours, Weight: 25 kilograms
- Range: 400 kilometres
- Hydrogen tank: 39-litre pressurised tank containing 1.6 kilograms of hydrogen at 700 bar.
- Price: 15,000 euros
- Expected life: 300,000 kilometres
- Price per kilometre: 10 cents (for an expected service life of 10 years)

Love at first sight: the prototype is an instant hit

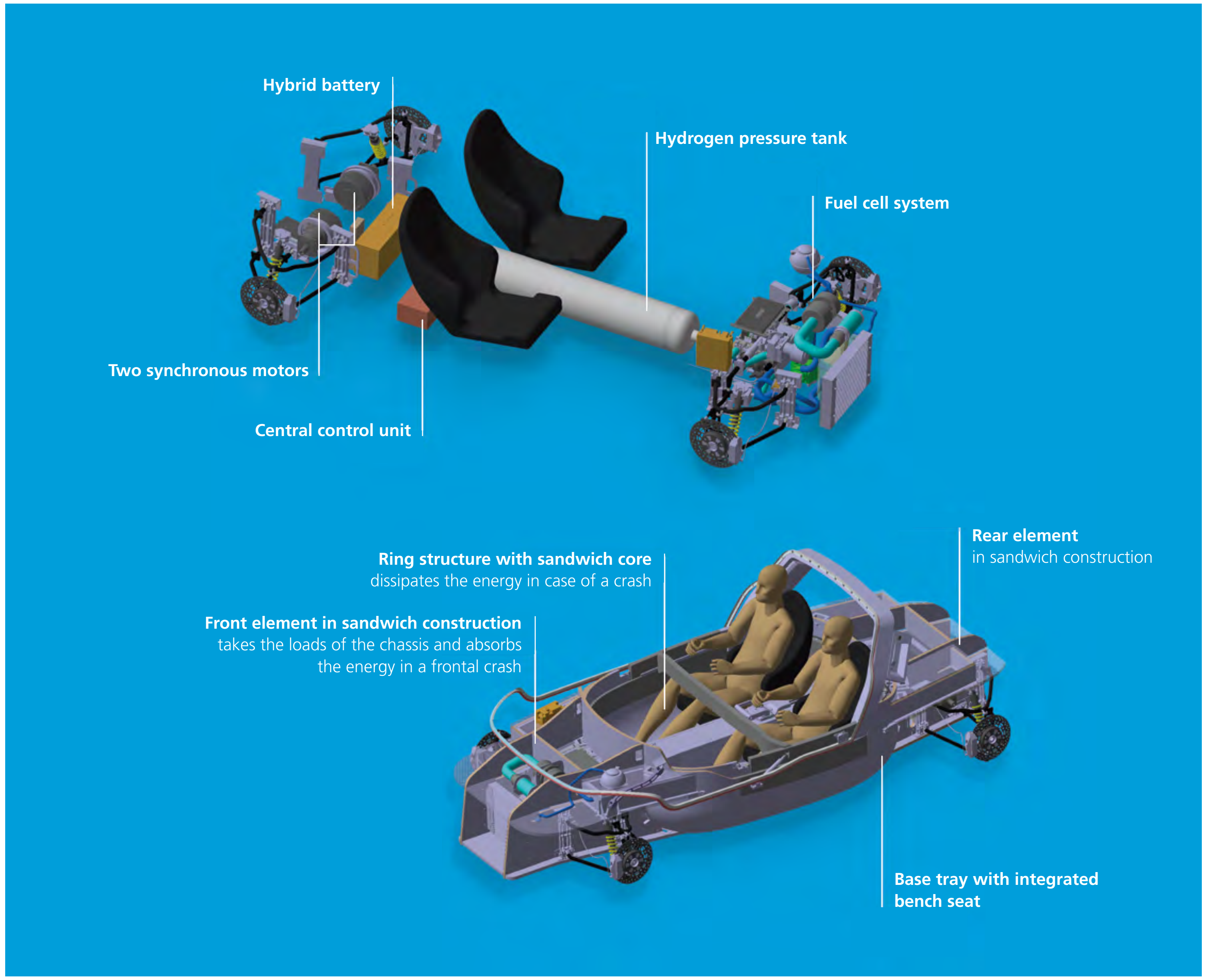
The first public trials of the SLRV were followed by a wave of positive feedback for the DLR team, both from prospective partners in industry and research and from private individuals. "Many people asked us when the SLRV would be on sale, whether it could be pre-ordered or whether we are looking for test drivers," says Kriescher. "This positive feedback was very encouraging. The concept and the underlying technology have definitely struck a chord with people."

Whether the SLRV will ever go into series production depends on interest from industrial partners. But that is not the deciding factor for the SLRV team. "We see the SLRV as more of a technology platform," says Siefkes. "We want to use the prototype to test the incorporated technologies and components, and further develop them in cooperation with manufacturers. That is our contribution to making future transport resource-efficient, safe and affordable. It is very likely that at least parts of the SLRV will make it on board the next generation of cars – and on the future generations that follow."

Denise Nüssle is a Media Relations editor at DLR.

NEXT GENERATION CAR

In the Next Generation Car (NGC) project, a total of 20 DLR institutes are collaborating on technologies for cars of the future. In addition to the SLRV, there are two other car concepts which are addressing the megatrend of urbanisation: the Urban Modular Vehicle (UMV), which is an urban vehicle for private or commercial users, and the Inter Urban Vehicle (IUV) (see DLRmagazine issue 163) for longer journeys between metropolitan areas.



PROTECTED AREAS

DLR experts are conducting research into how autonomous and networked systems can be protected against cyberattacks

by Hannes Bartz and Okuary Osechas

Aircraft without pilots, control towers without air traffic controllers and interconnected ships: welcome to the age of networking. But each ground-breaking development also brings with it new threats. In July 2019, for instance, the navigation systems of several ships in the port of Shanghai were fooled into communicating the wrong coordinates and seemed to other ships to appear and disappear again in different locations, like ghosts. Cybersecurity threats also arise in very different areas. In a number of instances, unknown persons have been able to send unauthorised instructions to aircraft by radio. While the increasing automation of systems improves their reliability, their dependence on IT technologies leaves them vulnerable to cyberattacks. Dynamic developments invariably give rise to new weaknesses and threats. In the DLR cross-sectoral project 'Cybersecurity for Autonomous and Networked Systems', experts from four DLR institutes in the fields of security and aerospace are developing technology and methods for preventing such attacks.

What is cybersecurity?

In the modern world, vast quantities of data are constantly exchanged via global networks. This exchange of information is a clear target for unauthorised interference. Both worldwide networks and what are known as cyber-physical systems such as airports, in which different components interact and communicate with one another, are at risk. Cybersecurity is the set of active measures taken to protect such systems against malicious attacks. Particularly in aerospace, traditionally there has been a focus on safety more than security. Safety tends to refer to the protection of systems against random faults, while security usually refers to protection against deliberate tampering.

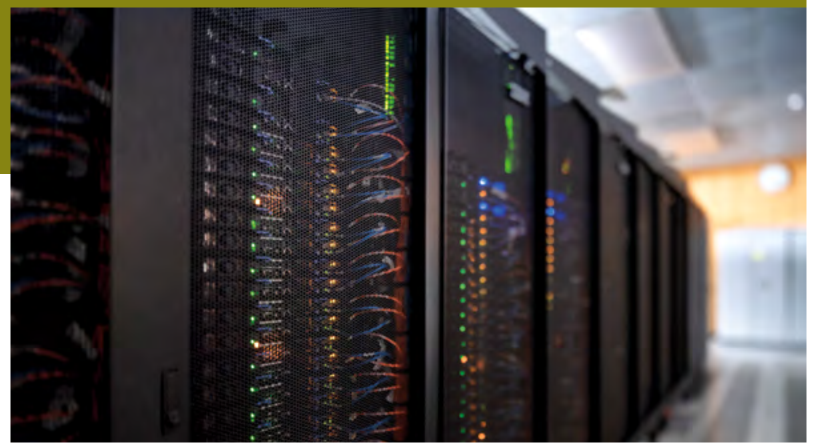
RADAR IMAGE OF OSLO HARBOUR

Radar images are used for many purposes. One example is the production of dynamic situation pictures for monitoring maritime infrastructures. For this, it is vital that the data used are reliable and trustworthy at all times. DLR's Microwaves and Radar Institute is researching methods for detecting and reducing interference in radar images.

Even though cyber threats are diverse in their approaches and their targeted systems and applications, they share a number of fundamental characteristics, such as the corruption of information or signals. Experts refer to 'jamming' or 'spoofing' if signals are disrupted or altered. A jammer intentionally disrupts a system for so long and with such severity that it can no longer function. Spoofing refers to the deliberate, targeted deception of an unsuspecting user. DLR researchers are developing techniques for reducing the impact of jamming and spoofing. These may include special encryption procedures to ensure that data cannot be manipulated, or processing techniques that allow for the rapid location of disrupters in radar images. To do this, the DLR teams have been analysing previous known attacks and developing appropriate countermeasures.

Protecting information

One current issue in the aviation sector is that communications remain largely analogue and unencrypted. As such, the system is vulnerable to malicious external interference. Air traffic management, which ensures safe, efficient air transport, is currently in the process of switching over from analogue to digital data transmission.



Computing cluster at the DLR Institute of Aerodynamics and Flow Technology

The new digital communication standards that allow aircraft to communicate with each other and with air traffic control must be secure. DLR has played a leading role in developing the L-band and C-band digital aeronautical communications systems (LDACS and CDACS) which can transmit data in real time and secure it against attacks and distortions by means of encryption.

Current encryption methods, such as those used for secure internet connections (HTTPS), will become ineffective in preventing attacks once quantum computers become a reality. Such computers are able to perform operations that would be extremely difficult for conventional computers and thus pose additional risks. Although only a few prototypes have been developed across the world so far, powerful quantum computers may become more widely available in the coming years.

The objective of post-quantum cryptography is to design new types of encryption methods that can enable systems to withstand attacks by quantum computers. As part of this cross-sectoral project, a DLR team is devising encryption methods that are suitably robust to these new challenges. Through such research, the communication systems used by aircraft and satellites are being made resistant to incidents such as unauthorised radio transmissions and secure from future threats.

Protecting signals

Aircraft are particularly vulnerable on their landing approach. Satellite-based approach systems are a window for both jammers and spoofers, posing security risks that cannot be eliminated using current technology. On a test flight in February 2020, DLR demonstrated how jammers could disrupt the onboard electronics of a commercial airliner, paralysing its entire satellite navigation system. Faced with such an attack, the pilot would have to continue flying by using legacy technology that is reliable, but less efficient. The DLR Institute of Communications and Navigation is developing antennas and satellite receivers that can help landing systems to withstand such attacks. The antennas recognise the direction from which a signal is coming – whether from above, as it would if it is coming from a satellite as it should, or below, if it is instead being emitted by a spoofer on the ground – and asses its credibility. This technique minimises the effect of jamming and spoofing and prevents ships from showing up in the wrong locations.

In the last five years, Synthetic Aperture Radar (SAR) systems have become more widespread. SAR belongs to the class of imaging radars and is used for remote sensing. However, both the unintentional and intentional disruption of SAR sensor systems is increasing. For some time now, the DLR Microwaves and Radar Institute has been investigating how such interference signals affect imaging and how the disruption that they cause might be eliminated. Researchers are developing methods that allow the original, unimpaired radar images to be reconstructed and evaluated without altering the sending or receiving devices. They are also designing future systems that are less prone to interference.

THE DLR CROSS-SECTORAL PROJECT CYBERSECURITY FOR AUTONOMOUS AND NETWORKED SYSTEMS

Institutes involved:

- Institute of Flight Guidance
- Microwaves and Radar Institute
- Institute of Communications and Navigation
- Institute for the Protection of Maritime Infrastructures

Duration: 2019–2021

Budget: approximately 7 million euros

Satellite navigation is vulnerable to interference and deceptive external attacks. This is particularly critical for satellite-based landing approach systems. DLR experts are working on procedures to make them more robust. Next year, the technology will be tested using the DLR research fleet.

Protecting systems

Critical infrastructure such as offshore wind farms, traffic control centres, ships and harbours require particularly robust protection against cyberattacks, as our society depends on their ability to function reliably. As part of the project, researchers are defining evaluation criteria to assess the security situation and its threats, and using them to devise appropriate protective measures. These include measures to ensure the continued reliable interactions between systems such as the communication between ship and harbour, and assistance and advisory systems to warn of attacks.

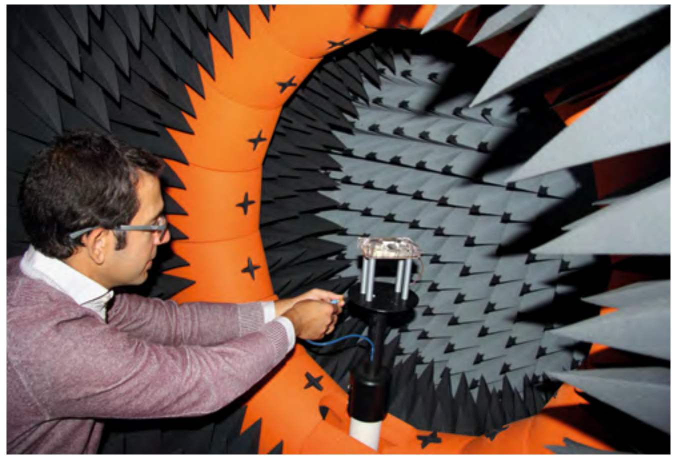
Digitalised harbours or airports comprise countless individual interfaces. This makes them particularly susceptible to attack and in need of specialised protection. As the landscape of the digital world is constantly changing, these security requirements must be continuously adapted. As part of the cross-sector project, a team from DLR is creating a demonstrative, comprehensive security management system and reviewing it in a special laboratory set up to represent an air traffic control tower.

Pooling expertise

The cross-sectoral project's work to protect information, signals and systems has now converged in a jointly developed landing approach system and a dynamic infrastructure mapping system. The broad range of expertise across the participating institutes is ensuring that the security of the new designs is evaluated from all perspectives and correctly implemented.

A secure landing approach system for aircraft

The jointly developed secure landing approach system will ensure the safe autonomous landing of future aircraft. Satellite-based systems such as the Ground-Based Augmentation System (GBAS) – developed in collaboration with DLR – are particularly vulnerable to cyberattacks. To remedy this, DLR has designed a data encryption process that is also robust against attacks by quantum computers and has integrated it into both the GBAS system and the digital protocols that aircraft exchange with ground stations. The experts also improved the resistance of the onboard satellite navigation receiver to jamming and spoofing. They are currently preparing for test flights in 2021.



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Stefano Caizzone from the DLR Institute of Communications and Navigation in Oberpfaffenhofen tests a '3+1 antenna'. This antenna is specially designed for receiving satellite navigation signals on board civil aircraft and is robust against both jamming and spoofing.

© DLR

Measurements made on board a container ship have revealed that satellite signals are particularly distorted at ports. This antenna can target an eliminate the effects of jamming transmitters.

During landing approaches, critical data are transmitted between the airport and the aircraft. DLR's LDACS communication system protects against the falsification of such data and, in the event of satellite signals being disrupted, can guide the aircraft safely to their destination.

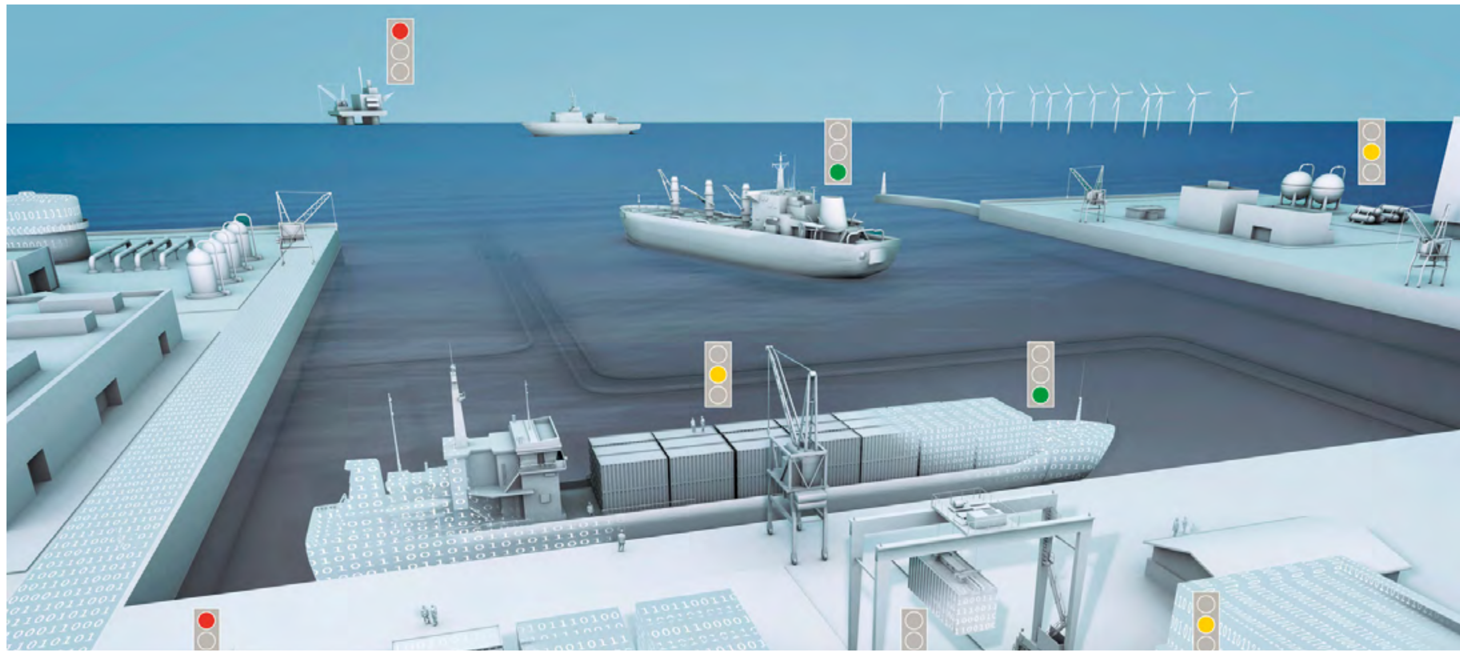
A dynamic map highlights potential hazards

In addition to the secure approach and landing system, the researchers developed a dynamic situation map with an integrated traffic light system. The map depicts the status of the entire infrastructure, such as a harbour or airport, in real time. It acquires its information from the different areas of expertise in the cross-sectoral project: shipping, aviation and radar reconnaissance. A green light means that a component in the system is in no danger, while yellow indicates that it is potentially vulnerable and needs to be inspected and red signifies that it is currently under attack. This system allows authorised personnel to respond quickly and initiate countermeasures to protect the infrastructure's other components. Bremerhaven harbour has already implemented such a map, and the team is currently working on creating a similar map for airports. In the ongoing bid to neutralise the threats of false radio transmissions and ghost ships, the secure landing approach system and dynamic map are promising beginnings.

Okuary Osechas works in the DLR Institute of Communications and Navigation and coordinates the DLR cross-sectoral project Cybersecurity for Autonomous and Networked Systems together with his colleague **Hannes Bartz.**

DISTRIBUTING QUANTUM KEYS SECURELY

Modern encryption systems use randomly generated keys to ensure the security of communications. Only users with the key can access the information, so it is vital that the key is known only to the two intended parties and does not fall into the hands of spies. Quantum key distribution ensures the secure distribution of these keys and guarantees long-term protection against any type of cyberattack. A team from the DLR Institute of Communications and Navigation is working with national and international partners to develop systems for satellite-based quantum key distribution. In this process, quantum states are transmitted via a free-space optical chanel. While current fibre-based systems are limited to several hundred kilometres, this technology allows for transmission over large distances and thus makes satellites suitable for global quantum key distribution. Experts at DLR are working on a system that is robust enough for world- wide quantum communication, and quantum key distribution in particular.



Simulation of an interactive map with a traffic light system indicating the current risk of cyberattack for individual maritime systems

During the static tests, forces representing the aerodynamic lift experienced in the wind tunnel pull the wing upwards.

BENDING INSTEAD OF SNAPPING

Researchers at the DLR Institute of Aeroelasticity are investigating just how flexible an aircraft wing can be

by Christine Unger

Aircraft wings bend while in flight. To see this for yourself, all you have to do is look out of the window during a flight. Beyond a certain limit, these wing deflections become known as 'large deformations'. Professor Wolf Krüger of the DLR Institute of Aeroelasticity explains whether these deformations are dangerous, the conditions in which they occur and why modern wings are becoming increasingly elastic.

Is it normal for a wing to bend in flight?

: Absolutely! The majority of an aircraft's mass is concentrated in the fuselage, which is pulled downwards by gravity. This is counteracted by lift, which forces the wings upwards and allows the aircraft to fly. These opposing forces require that the wings bend. If they did not, they would have to be very rigid, and that would make them very heavy. So this deflection is factored into the design of the wing and is part of its normal behaviour.

At what point does it become a 'large' deflection?

: That depends on the size of the plane and its wingspan, the materials used and the construction of the wings. Whether a deflection is regarded as 'large' or not depends on the dimensions of the plane. As an example, consider the deflection at the wingtip of an Airbus A340. During a flight, its wingtip deflects at least two metres when compared to its shape on the ground. This might seem a lot at first, but it is actually normal for a commercial aircraft. The wingspan of an A340 is 60 metres. So the ratio of the deflection to the length of the wing is seven percent. During extreme manoeuvres, the deflection can be more than twice this amount. Some cargo aircraft have even greater wing deflections. The wings of the Boeing 787, which are made of carbon fibre-reinforced polymers (CFRP), have around the same span but have a deflection of three metres during flight. Under maximum load, during gusts of wind or manoeuvres, the deflection can be as much as 8.5 metres. This is a deflection of 28 percent and is well within the territory of 'large' deflections. As a general rule: if the deflection at the wingtip is more than 10–15 percent of the length of the wing, it is considered a 'large deformation'.

Do these deformations occur for all types of aircraft? Why do they become so large?

: You can see the effects best in gliders. Wings with a large span but a short depth – also known as the wing's chord – produce less drag. That is why the wings of all high-performance gliders are particularly slim and, as a result, flexible. However, this trend is now spreading to commercial aircraft, which is leading to increased wing deflection. The advantage of the reduced drag for commercial aircraft

> "This trend is now spreading to commercial aircraft, which is leading to increased wing deflection."

is a corresponding reduction in fuel consumption. Whereas previously, greater wingspans automatically entailed more weight, which would become unsustainable beyond a certain point, new construction techniques and materials such as CFRPs make these so-called 'high aspect ratio' wings possible. With the right materials and optimal design, we can even use the deformation to reduce the forces acting on the wings. Ideally, this would also reduce the weight of the wings. This method is known as 'aeroelastic tailoring'. Passenger comfort is also improved as it allows the vibrations of the aircraft structure to be reduced in a controllable way. Large deformations also occur outside of aviation, for example in the blades of wind turbines, where a slim design is also beneficial.

What are the consequences of a deformation being 'small' or 'large'?

: Even the way they are considered in our calculations is very different, and this is at the centre of our work at the DLR Institute of Aeroelasticity. When a wing bends, its centre of gravity shifts, and it appears to get shorter. This deformation also causes the directions of the local lift forces acting on the wing to rotate. If the deflection of the wing remains small, these effects can be neglected in any calculations.

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Professor Wolf Krüger is the Head of the Loads Analysis and Aeroelastic Design Department at the DLR Institute of Aeroelasticity and leads the Multibody Systems in Aeronautics and Astronautics department at Technische Universität Berlin. He is involved in international youth exchange programmes and strongly supports the atmosphere of international cooperation at DLR. What does he enjoy most about his work in aeroelasticity? "The wide range of disciplines, the interplay between simulation and experimentation and the great working atmosphere at the Institute."

It is common and very helpful to use assumptions like this that simplify the process of calculating the forces acting on an aircraft and adapting its structure accordingly. Such simplifications also keep the required calculation times for the analyses relatively short.

The Institute of Aeroelasticity is developing ways to more accurately model wings experiencing large deformations. What exactly are you working on at the moment?

: In order to model large deformations, we need to use appropriately comprehensive mathematical approaches. We can no longer rely on simplifications. In aerodynamics, these techniques include 'computational fluid dynamics' and 'non-linear vortex lattice' methods. To model the structure, we use 'finite element' or 'multibody simulation' software. We approach the problem from two angles of complexity – speed and detail. On the one hand, a method was developed at the institute, within the scope of a doctorate, which can represent non-linear structural deformations using fast analysis methods. On the other, we also use complex finite element models which depict aircraft structures with a high degree of detail.

That sounds like a lot of time in front of a computer...

: … That may be true, but we also conduct experimental tests of our methods. Since flight tests requiring the use of a commercial aircraft are very costly, we start off with laboratory and wind tunnel testing. In Göttingen, we carried out a series of wind tunnel tests with specially designed wings where we tested our design and simulation methods as well as new measuring techniques. For example, we tested a forward-swept wing whose tip almost touched the top of the wind tunnel without reaching its own structural limits. It was made of layers of a fibre composite material. These layers are arranged so that the angle of attack does not increase if the wing bends, as is normally the case with forward-swept wings. Using this approach, we optimised both the design and the construction materials. Structural optimisation of this kind, achieved using an unconventional arrangement of laminates, is an example of aeroelastic tailoring for which our institute has been developing a variety of approaches for many years.

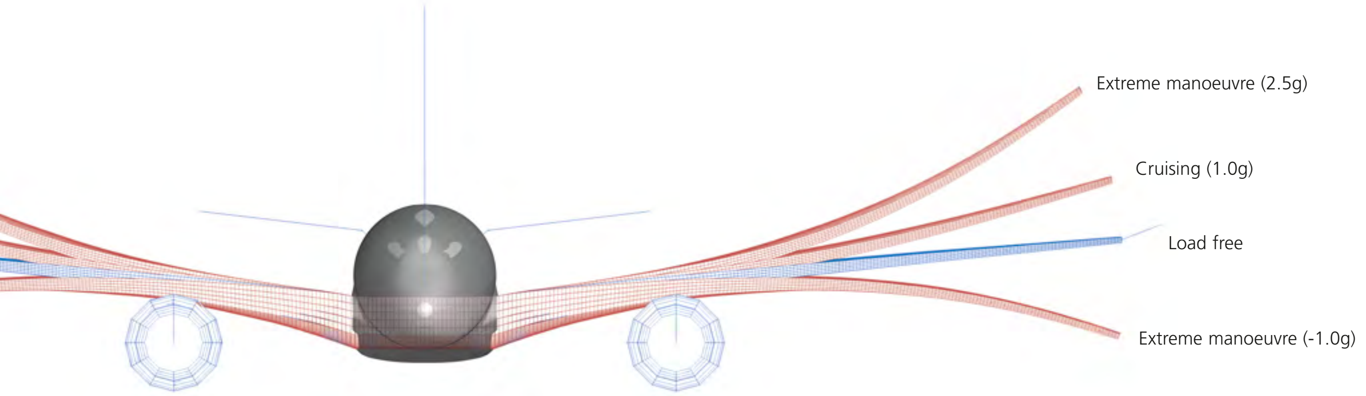
Do you work with project partners from within Germany as well as abroad?

: Correct. This is a field of both high academic and industrial importance. Aircraft manufacturers are very interested because as aircraft wings are made progressively more lightweight – such as through the use of fibre composites – they will experience increasingly large deformations and will require new structural designs. One important area of research currently on the agenda is the use of new materials with unconventional properties. We develop new approaches within internal projects across multiple DLR institutes, within the aviation research programme in collaboration with Airbus, and in national and international cooperation with research institutes and universities such as Technische Universität Braunschweig (TU Braunschweig), ONERA (France), Delft University of Technology (TU Delft, Netherlands) and the University of Michigan (USA).

The interview was conducted by **Christine Unger**, editor at the DLR Institute of Aeroelasticity.

© Carlos Cesnik, University of Michigan

The X-HALE light aircraft was developed and tested at the University of Michigan and tested in collaboration with the DLR Institute of Aeroelasticity using new simulation methods.



This simulation shows how an aircraft wing deforms during flight. 'g' represents the force relative to the strength of gravity.

DLR INSTITUTE OF AEROELASTICITY:

The DLR Institute of Aeroelasticity deals with physical phenomena that occur in nature and engineering, particularly in aircraft. Researchers study the interaction between aerodynamic forces and elastic structures such as aircraft wings, which deform and vibrate when forces act upon them. These effects impact the design and operation of aircraft. Researchers at the Institute calculate aeroelastic behaviour using numeric analysis methods and then carry out wind tunnel and flight tests to validate their calculations, all in order to improve the safety and performance of new aircraft designs.

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The wing flex of the Concordia glider is clearly visible in flight

GLOSSARY:

Aeroelastic Tailoring: A method for designing wing structures where specific features of the material, such as directional stiffness, are specifically exploited to reduce the loads that act on an aircraft in gusts of wind and when manoeuvring. This method is extensively used for fibre composites.

Carbon fibre-reinforced polymers (CFRP): Composite carbon fibre materials contained in a resin. The direction in which the carbon fibres are laid determines the stiffness of the material and can be adapted to different load directions.

Finite element software: Computer software for structural analysis and investigating the aeroelastic properties of aircraft. The model of the structure being investigated is divided up into many simple objects, such as small beams, sheets, cuboids or tetrahedrons, which are known as 'finite elements'.

Multibody simulation software: Computer software used in vehicle development and the design of wind turbines. It represents dynamic systems as a combination of individual bodies that are flexibly joined by springs or other forces. This method is particularly suitable for analysing large rotations.

Non-linear structural deformations: In linear deformations, the deflection is proportional to the force applied – if the force is doubled, the deflection also doubles. This is a good approximation when the force applied is small. With greater force, the ratio of the force applied to the deflection is no longer proportional, and the direction in which the structure deforms may also change under greater forces.

Forward-swept wing: To allow high-speed flight, aircraft wings are not positioned at right angles to the body but are 'swept' backward or forward. In conventional commercial aircraft, the wing points, or is 'swept', backward. Forward-swept wings are unusual, but they have many advantages and are therefore studied in many DLR projects.

A KEEN SENSE FOR WATER AND ICE

A DLR team is on the trail of climate change in the Arctic

by Jörg Brauchle and Manuel Moser

The Polar 6 research aircraft in flight over the Arctic Ocean

DLR's MACS always records triplets of a colour image visible to the human eye (centre), a thermal image (top) and a near-infrared image (bottom). Each of the images contains different image information. The thermal image, for example, reveals a heat swirl in the water and the near-infrared image makes it easier to automatically detect water.

From left: Valerian Hahn, Manuel Moser and Jörg Brauchle.

The Arctic is one of the world's most sensitive ecosystems and the place where global climate change has become most apparent in recent years. The latest measurements show that the sea ice has retreated extremely far to the north again this summer. Only once since records began has the extent of the Arctic sea ice shrunk to less than four million square kilometres. That was in 2012. But in 2020, things are looking very similar. A DLR team was here this year as part of a major international polar expedition sent to investigate ice and cloud cover.

The two converted Basler BT-67s belonging to the Alfred Wegener Institute (AWI), the Helmholtz Centre for Polar and Marine Research, stood out dramatically as they made their final approach to Longyearbyen in Spitzbergen. But the two research aircraft – named Polar 5 and Polar 6 – are actually regular guests at the 'Cold Coast'. Their latest visit, however, was different. Restrictions put in place as a result of the COVID-19 pandemic had left lingering uncertainty about whether their latest research campaign would go ahead at all. The winter expedition planned for early 2020 had been called off abruptly, so upon hearing that the research flights for the summer expedition could take place as usual in September, the crew was more than pleased.

Against all odds

Even the crew of the Polarstern – the German polar research vessel that has been drifting with an Arctic ice floe for a year – had to face the consequences of the pandemic. With adapted procedures, it was able to continue its journey, but had to leave its prematurely thawing ice floe much earlier than expected. The Polarstern's journey was part of the Multidisciplinary drifting Observatory for the Study of Arctic Climate Expedition (MOSAiC), whose aim is to better describe and understand the changing state of the Arctic system. In July 2020, Polarstern quickly passed through an area of relatively loose drift ice and reached the North Pole. Sea ice physicists believe that even with a very cold winter, the ice will not be able to return to its original extent. The water now exposed to the sky absorbs, rather than reflects, additional solar radiation, thawing the ice from below as well as above.

The MOSAiC Expedition is coordinated by the AWI and is the largest polar expedition ever undertaken. Over 70 institutions and hundreds of contributors from 19 countries are conducting field measurements at the ice floe, acquiring images using satellites, and overcoming some enormous logistical hurdles. Polar 5 and Polar 6 were essential for the aerial measurement campaigns. The two DLR institutes represented on board

Preparations on Polar 6 for a sea ice flight. Large quantities of orange survival equipment are carried for emergency situations.

© Thomas Krumpen/AWI

Jörg Brauchle operates the MACS camera during a measurement flight

© Esther Horvath/AWI

Manuel Moser and Valerian Hahn prepare the Cloud Combination Probe, an instrument for measuring water droplets and ice crystals present in clouds.

the two aircraft made use of very different sets of measuring instruments. The high-resolution Modular Aerial Camera System (MACS) of the DLR Institute of Optical Sensor Systems took aerial photographs of the sea ice, while the probes of the DLR Institute of Atmospheric Physics gathered information about the structure of the Arctic clouds.

Waiting for a clear view

With the exception of a handful of isolated research stations, Longyearbyen is the most northerly human settlement in the world, with a population of just 2500. This year, it is the only option as a base for flights over the sea ice, as the pandemic has resulted in the temporary closure of the research stations in northern Greenland and Canada. Longyearbyen is approximately 1300 kilometres away from the North Pole and researchers here in August are met with temperatures reaching two degrees centigrade, and sleet.

As breakfast began, all eyes were already on the sky. Thick cloud cover extended all the way to the horizon. The mountain peaks on the other side of the fjord had vanished into the dark grey base of the clouds. The rugged slopes of the high plateaus surrounding Longyearbyen were equally hidden. There was almost no wind. Consulting weather apps on laptops and smartphones gave no cause for joy either. The forecast: a light south-west breeze with light rain and broken clouds at 2000 feet for the next 24 hours. Any cautious hopes for suitable flight conditions began to fade away. But the weather briefing with local meteorologists who advise pilots and researchers about flight conditions was scheduled for 08:00. A final glimmer of hope remained.

But in the hanger too, there was no good news for the teams of the two research aircraft. The current conditions ruled out any flights for now, and the next weather briefing was not planned for until around noon. Suddenly, however, there was a flurry of activity. Backpacks were stowed away, laptops closed and the last of the coffee hurriedly gulped down. The sky had cleared unexpectedly, and the first few people were already running around in their bright orange high-visibility survival suits. Firearms – a last resort in case of polar bear attacks – were also at the ready. You never know when and where it might be necessary to make an emergency landing. On board each aircraft were two pilots and up to four crew in the cabin to operate the research equipment. The aircraft were already fuelled, and once all the final preparations have been completed, they were ready for take-off.

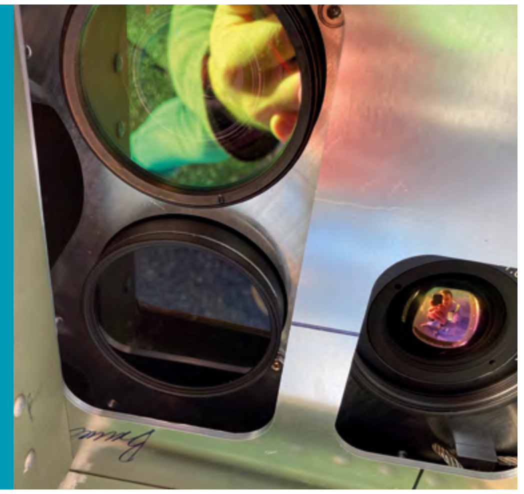
Spotting the smallest of fissures

Polar 6 is equipped with a variety of remote sensing equipment, among which is DLR's MACS. In 2014, an earlier version of the camera was used to photograph the highest glacier on Earth in the Himalayas ambient temperatures of down to 35 degrees below freezing. Now it was heading for its first flight over sea ice. The sensor system of MACS is made up of three different cameras. It is very small and fits into a hatch in the hull of the aircraft that is half the size of a sheet of A4 paper. Nevertheless, its sensors are extremely capable. They are able to record images simultaneously and at high frequency at various wavelengths: in the visible, near-infrared and thermal infrared spectrum. This combination allows researchers to obtain insights they otherwise could not. For example, it is important for sea ice physicists to find out more about fissures in the ice. Under which circumstances do they occur? How do they freeze over? What is the role of melting pools? The aerial images obtained using MACS will help to answer these questions. Specialists use these images to accurately determine and model the state of the ice and the roughness of the ice and snow. The images show the area photographed at a resolution of better than four centimetres per pixel.

First, the aircraft flew towards Greenland. After almost two hours in the air, the first sea ice came into view. Greenland became clearly recognisable. Here, researchers could see the remnants of the ice that

DLR'S MODULAR AERIAL CAMERA SYSTEM

- The Modular Aerial Camera System (MACS) is a family of aerial camera systems developed at DLR in Berlin.
- The sensors and software are modular and can be configured individually.
- Image classification data and 2D maps can be transferred to the ground in real time, where 3D models can then be derived.
- The system is adapted to the carrier and environmental conditions, from small drones for disaster missions to fast flying aircraft.
- The real-time image processing already provides important information in flight.



The sensor of the MACS camera is so small that it fits through a hatch in the bottom of the aircraft fuselage.

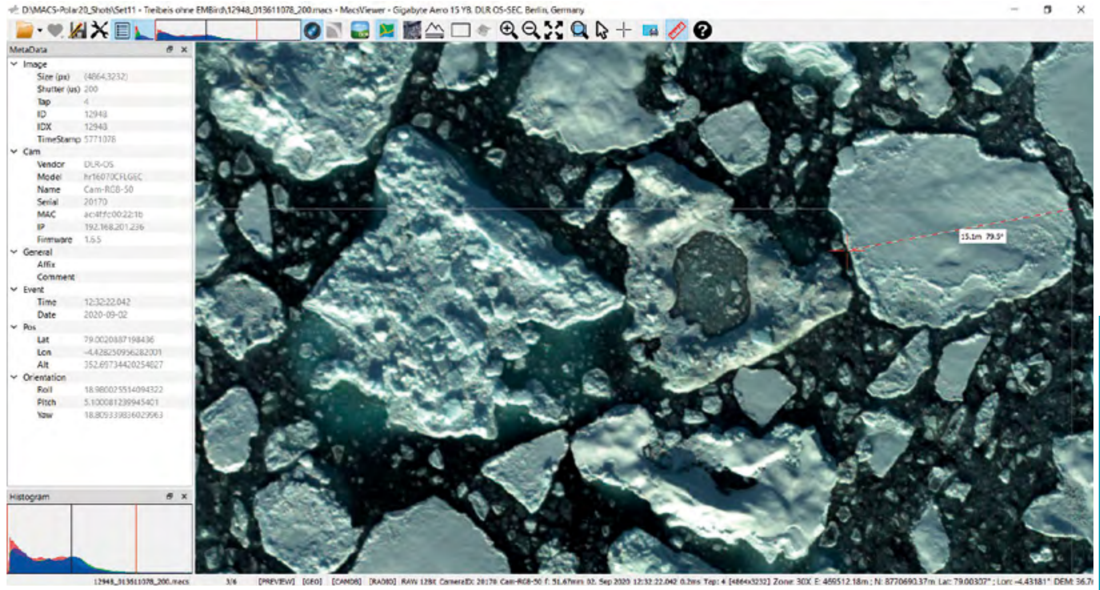
months ago and far to the north had surrounded Polarstern. From an altitude of 100 metres, the AWI's EM-Bird instrument was lowered on a rope. From a height of 15 metres, the torpedo-shaped device measures the thickness of the ice using electromagnetic sensors.

Whenever an interesting feature has to be recorded, MACS is activated using a switch referred to as 'Yeti, now!' – a throwback to the original camera system's time in the Himalayas. The three sensors record their data at a rate of four images per second. This rate is chosen to avoid any gaps between the images when acquired at an altitude of 100 metres. The measurements are carried out in parallel to those of EM-Bird. Later, the two sets of data will be combined, allowing the researchers to confirm the plausibility of their ice thickness measurements. Later flights in the campaign flew even further north. Even with a comparatively large aircraft such as Polar 6, the edge of the ice sheet could only just be reached this year. The view from the window was thought provoking: the drift ice was surprisingly loose, even at 84 degrees north, less than 700 kilometres from the North Pole.

Diving into the Arctic clouds

Meanwhile, the crew of Polar 5 was concentrating on the atmosphere and the cloud cover over the Arctic Ocean. Previous investigations have revealed that clouds play an important role in the rapid warming of the Arctic. Alongside the AWI and the universities of Leipzig,

The view of the drift ice to the left of the aircraft as it flies at an altitude of 100 metres, 700 kilometres from the North Pole.



Drift measurement

Already during the flight, the image data acquired by MACS are displayed on the computer – in this image, the data from the colour camera. The researchers use this to check that all the settings are correct. As this is a calibrated system, initial measurements such as determining the size and orientation of objects of interest can be carried out directly.

Cologne, Mainz and Clermont-Ferrant, a team from the Cloud Physics Department at the DLR Institute of Atmospheric Physics used special cloud probes to measure microphysical properties such as droplet size distribution, ice and liquid water content and ice crystal shape, as well as to study mixed-phase clouds. These measurements complement the observations made using remote sensors. Seasonal effects are particularly important for the researchers, as their influence is not yet fully understood. When Polar 5 entered an area of particular interest within the clouds, the researchers prepared the dropsondes, which measure the vertical temperature and relative humidity profiles in different cloud layers. The ice floes of the drift ice could be seen far below the aircraft. The probes recorded series upon series of data, each revealing more information about the structure of the clouds. The main cloud layers differ greatly, with the lowest clouds being at temperatures significantly above freezing and diffused with low droplet concentrations. Above them are mixed-phase clouds containing both water droplets and ice crystals of various shapes and sizes. The researchers are hopeful that these data will help improve the accuracy of future weather forecasting models at these latitudes.

After several hours of conducting measurements, the aircraft returned to Spitzbergen, passing the research settlement of Ny Alesund, where as many as 130 researchers carry out meteorological investigations and permafrost examinations in summer. Polar 5 was joined by fellow research aircraft Polar 6 as the two landed almost simultaneously back at the airport.

120,000 new insights

Upon completing their campaign, the teams shared a collecting sigh of relief. Not just because they could finally remove their bulky survival suits, but also because, while they shared memories of the expedition and its years of planning, 120,000 images recorded using MACS – a combined size of almost two terabytes – were being copied and pre-processed. By the next morning, the images had been successfully pre-processed and the camera's storage module was ready for its next mission. Now, when a flight is grounded due to bad weather, the team has thousands of exciting images to go through. The thermal images in particular are an important source of new information, as they show things that the naked eye or images taken with the other cameras cannot see.

During the two-week campaign, many hundreds of thousands of images were taken. They will be used to train artificial intelligence systems and to evaluate the information provided by these systems. This kind of machine learning will be necessary in future to interpret the ever-increasing volume of scientific image data and to derive relevant results from them. The entire dataset obtained during this campaign will be made available to interested institutions for research purposes. The MACS-Polar camera system will continue to be developed and prepared for future expeditions. As these measurements are integrated into other polar research disciplines, the data will provide an increasingly accurate and more comprehensive understanding of the state and development of the sensitive Arctic system. The team also hopes to revisit the Arctic region again – together with Polar 5 and 6 – to further increase our understanding of water and ice.

Jörg Brauchle works at the DLR Institute of Optical Sensor Systems and is the project manager for the Modular Aerial Camera System (MACS). **Manuel Moser** is completing a PhD in cloud physics at the DLR Institute of Atmospheric Physics. Both were involved in the MOSAiC polar expedition.

NEWS

The GESTRA space radar will monitor the space debris situation in low-Earth orbit to help prevent collisions with satellites.

GESTRA SPACE RADAR READY FOR OPERATION

The German Experimental Space Surveillance and Tracking Radar (GESTRA) will monitor objects in low-Earth orbit around the clock. There, several thousand satellites, spacecraft and other objects move in their orbits, but also hundreds of thousands of pieces of space debris. These represent a collision hazard due to their high velocities. GESTRA was developed and built by the Fraunhofer Institute for High Frequency Physics and Radar Techniques on behalf of the DLR Space Adminis-tration. The system is unique in its complexity: with an antenna system comprising 256 individually electronically controllable transmitter/receiver modules and a mobile structure with two separate containers for the transmitter and receiver. The final tests are currently underway, and the first German space radar is scheduled to go into regular operation in early 2021 at the Bundeswehr site at Schmidtenhöhe, near Koblenz.

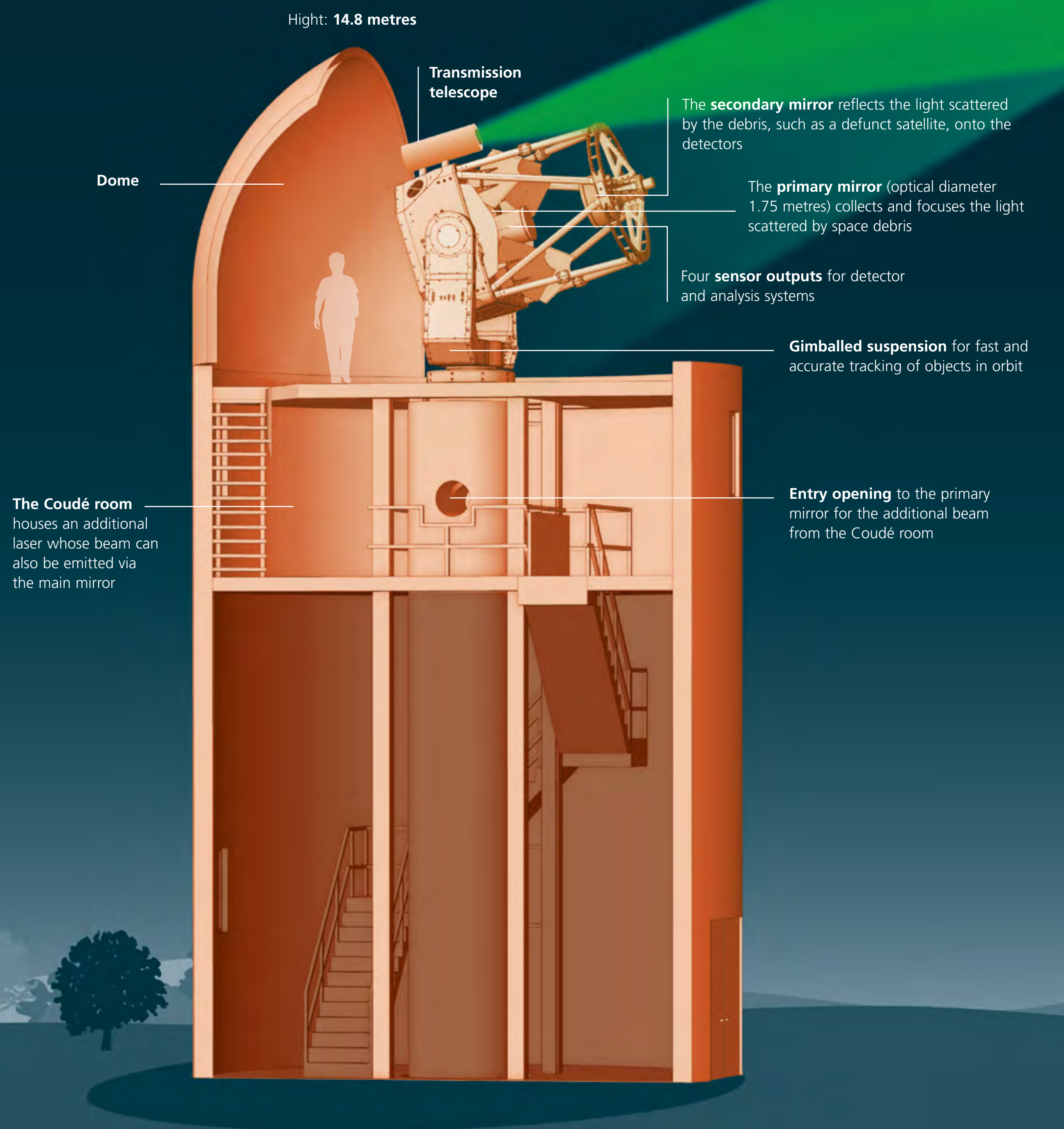
The test dummy sits in the test room filled with very small bubbles during experiments exploring the effectiveness of non-medical face masks in preventing the spread of COVID-19.

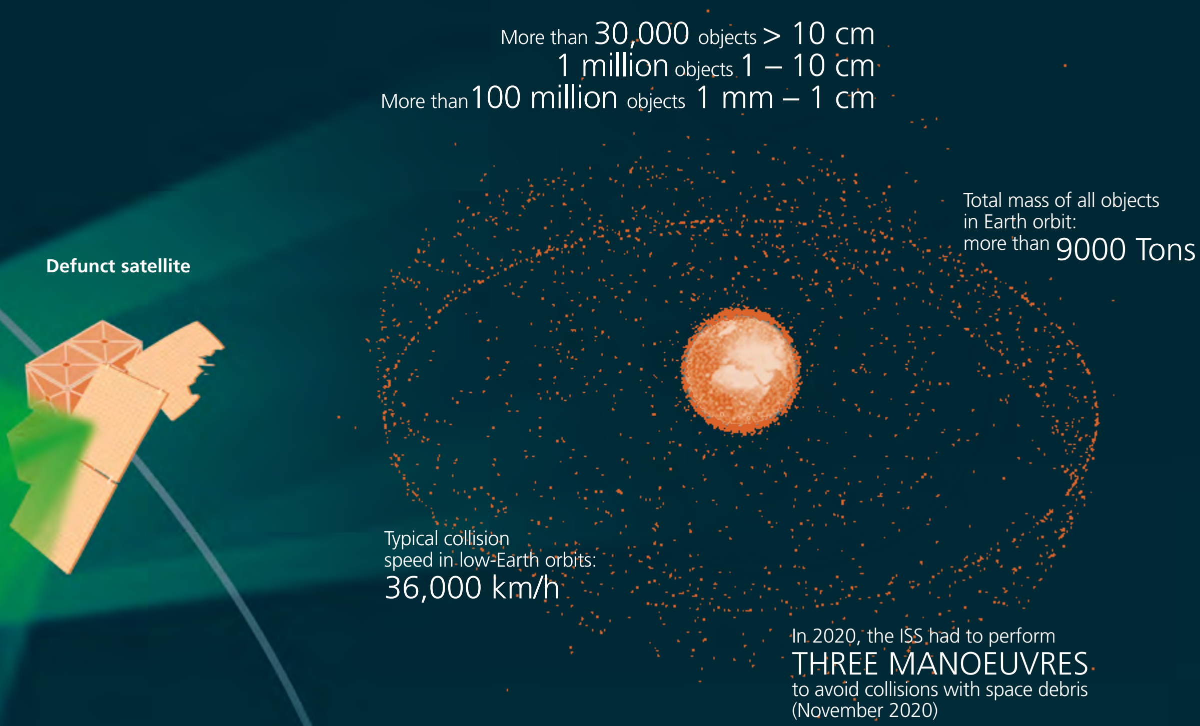
HOW EFFECTIVE ARE NON-MEDICAL MASKS?

Non-medical masks are an important part of the fight against the COVID-19 pandemic. Several DLR institutes came together in an interdisciplinary, collaborative project to investigate the functioning and effectiveness of non-medical fabric masks. In the first phase of the project, the flow of exhaled breath and ambient air and the influence of different masks was investigated. For this purpose, an experimental space measuring 12 cubic metres was flooded with very small soap bubbles the size of sugar grains (diameter approximately 350 micrometres). Filled with a mix of helium and air, the bubbles remained suspended for long periods and followed the complex flow field in the test room. A seated test dummy breathed in the test room. Its artificial lung created a cyclic air flow that replicated that of a human being. A built-in heater simulated body warmth and induced the associated thermal currents in the surrounding air. Using technology that is normally used to examine airflows in the aerospace industry, the experiments clearly showed how wearing a non-medical mask influences the distribution of exhaled aerosols and how this contributes to preventing the spread of infection.

I SPY WITH MY LITTLE EYE…

DLR's new observatory will allow for the analysis of space debris





THE SPACE DEBRIS LASER RANGING GROUND STATION

One of the largest telescopes in Europe to observe space debris is currently under construction in the north of the Black Forest. The DLR Institute of Technical Physics will use it to determine the nature and trajectories of space debris objects. The researchers also want to explore ways in which lasers can be used to redirect space debris objects in such a way that they burn up in Earth's atmosphere.

The new observatory will locate defunct satellites and debris objects as small as approximately ten centimetres in size. To do so, the objects are illuminated by a pulsed infrared laser. The backscattered light is captured by the telescope and the distance of the object from the telescope is determined to within one metre using the elapsed travel time of the laser pulse.

The large diameter of the telescope – just under two metres – allows DLR researchers to measure the spectra and polarisation of sunlight reflected by the debris particles. The material of space debris can be determined from the distribution of wavelengths that it reflects across the visible spectrum and into the infrared. Ageing processes caused by high-energy radiation can also be studied. The new DLR research observatory is planned to enter operations in spring 2021.

A HEAVYWEIGHT FROM OUTER SPACE

A stony meteorite found in the Swabian Jura reveals secrets of the Solar System

by Ulrich Köhler

The heaviest stony meteorite ever found in Germany, 'Blaubeuren', was dug up in a front garden in 1989, but its true nature was not identified until this year. For planetary researchers, finding such a meteorite is a stroke of luck as it provides rare insights into the period of planetary formation, four and a half billion years ago. The discovery of meteorites by laypersons is also one of the most exciting, unexpected and inexpensive forms of Citizen Science.

Coincidence still writes the best stories. In 1989, Hansjörg Bayer discovered an abnormally heavy boulder in his front garden in Blaubeuren, a picturesque village west of Ulm that is also famous for its incredibly deep Blautopf spring and karst landscape. Bayer loaded the rock onto a trailer in 2015 and was preparing to dispose of it, but suddenly had a flash of what he refers to as 'divine inspiration'. "I decided to keep it!" he says. Five years later, he was struck by another idea, "I bet DLR could help me figure out what this thing really is!"

The DLR Institute of Planetary Research received the call in January. "I've got an enormous and strangely heavy rock here," said Bayer. "I found it in 1989 when I was digging a cable trench in my garden. We don't see many heavy, dark brown rocks like this here in the Upper Swabian Jura. Could it possibly be a meteorite?"

The planetary researchers in Berlin receive similar enquiries on a regular basis. They follow up on all of them, but in most cases the finders are left disappointed. The rocks in question almost always turn out to be blast furnace slag, chunks of asphalt or waste material from ore mines – rocks of terrestrial origin, rather than meteorites. More than 2000 enquiries over the last 15 years have identified just three meteorites. In case of doubt, the researchers call upon Dieter Heinlein, a scientist who has helped supervise the fireball cameras that contribute to the European Fireball Network at DLR for decades. On clear nights, DLR cameras record the trails of light produced by meteors over Central Europe. These can be used to determine the regions where possible meteoroids – chunks of rock or metal from the asteroid belt between Mars and Jupiter that enter Earth's upper atmosphere – will land. In the case of bolides – the largest, brightest fireballs which explode after just a few seconds – the possible landing sites of any remaining meteorites can be reconstructed geometrically. Then the hunt begins for the latest cosmic intruder.

Germany's largest stony meteorite

Heinlein examines potential meteorites in the basement laboratory of his home in Augsburg. He began by sawing through a 23.4-gram fragment that had sheared off of 'Blaubeuren'. His reaction when he looked through a hand-held magnifying glass was one of amazement and complete certainty: metal particles glistened in the light among a matrix of millimetre-sized chondrules – crystallised silicate melt droplets with rounded outlines that are a typical feature of the chondrite class of meteorites. What Hansjörg Bayer had tenderly lifted from the protective clay loam in the village of Blaubeuren in 1989 was undoubtedly a meteorite. It weighed 30.67 kilograms, measured 29 by 25 by 20 centimetres and had a density of 3.34 grams per cubic centimetre. Heinlein can recall all 52 of the meteorites found in Germany in detail, and he knew this one was special. "This is sensational," he thought. "This find from Blaubeuren has almost twice the mass of the previous record holder, the 'Benthullen' meteorite discovered near Oldenburg!"

Ten thousand years in the Jura soil

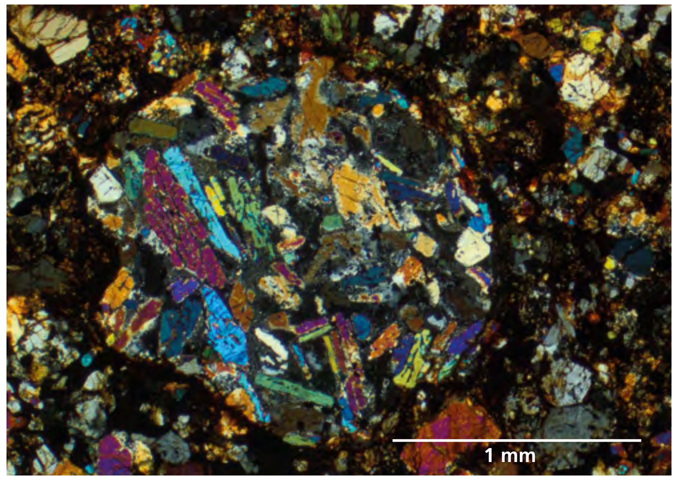
Further examinations were carefully carried out at specialised laboratories. First, a stonemason from Mindelheim sawed off a small corner of the meteorite. Addi Bischoff of the University of Münster then prepared thin sections for examination under a polarisation microscope and classified the find as an H4-5 chondritic breccia of shock stage S2. This means that the stony meteorite did not suffer any severe collisions in space and has a high metal content. This metal is an alloy of iron with 10 percent nickel.

Timothy Jull of the University of Arizona and Silke Merchel of the Helmholtz Centre in Dresden-Rossendorf determined the meteorite's concentrations of long-lived radionuclides, such as carbon-14 and beryllium-10. These give an indication of how long the meteorite has been on Earth. The heavy degree of weathering suggests that the meteorite entered the atmosphere around ten thousand years ago, during the early Mesolithic, as a meteoroid weighing several tonnes. It lost most of its mass through ablation as it plummeted through the atmosphere, before finally falling onto the Swabian Jura.

For planetary researchers, meteorite finds always offer welcome additions to the insights into the celestial bodies of the Solar System acquired using technically and financially demanding dedicated spacecraft missions. The 19,000 meteorites found on Earth to date are divided into many different classes. This variation refutes the theory that they are all fragments of a single planetary body that broke up between Mars and Jupiter. Instead, the process of planetary formation appears to have come to a standstill in this region after the formation of the countless distinct planetesimals that continue to deliver us meteoroids and meteorites today. Every new find adds to our knowledge about the origins of the Solar System and subsequently the asteroid belt. Rare, chance discoveries of meteorites and targeted searches based on the observation of fireballs are highly productive examples of Citizen Science. With the nice anecdote behind its discovery, 'Blaubeuren' is a brilliant example of a find that demonstrates how the involvement of laypersons can expand the pool of available data that supports scientific research.

Ulrich Köhler is a planetary geologist at the DLR Institute of Planetary Research. As a planetary geologist with Swabian roots, the discovery of the 'Blaubeuren' meteorite is dear to his heart and one of the most exciting events of his career.

Dieter Heinlein studied physics and astronomy at the University of Erlangen-Nuremberg in his native Franconia. After a period at the university's Institute for Theoretical Physics, he decided to become self-employed. 'Hands-on' astronomy held greater fascination for him than the theoretical modelling of cosmic phenomena. From then on, he devoted himself to his love of meteorites, which he had already began to collect as a teenager. At the time, this hobby was limited to a rather small number of enthusiasts and it was not easy to find meteorites as there was no professional market for them yet. Instead, acquisitions had to be bartered with museums. With his collection of originals and the 1:1 casts of important finds that he made himself, Heinlein is internationally renowned for his extensive scientific knowledge. His wife Gabriele shares his enthusiasm, and his knowledge is in high demand for talks and expert appearances at the internationally renowned Munich Show, a fair for minerals and gemstones. He has carried out valuable work for DLR for many years, including looking after fireball cameras and as the go-to expert for special meteorites such as 'Blaubeuren'.



Under a polarisation microscope, thin sections of the 'Blaubeuren' meteorite revealed countless crystallised melt droplets with rounded outlines. Known as chondrules, these formations give the chondrite class of meteorites its name.

The DLR Institute of Planetary Research in Berlin operates a portal for reporting meteorite finds, identifying meteorites and providing access to DLR's European Fireball Network.

DLR.de/Feuerkugelnetz (German language)

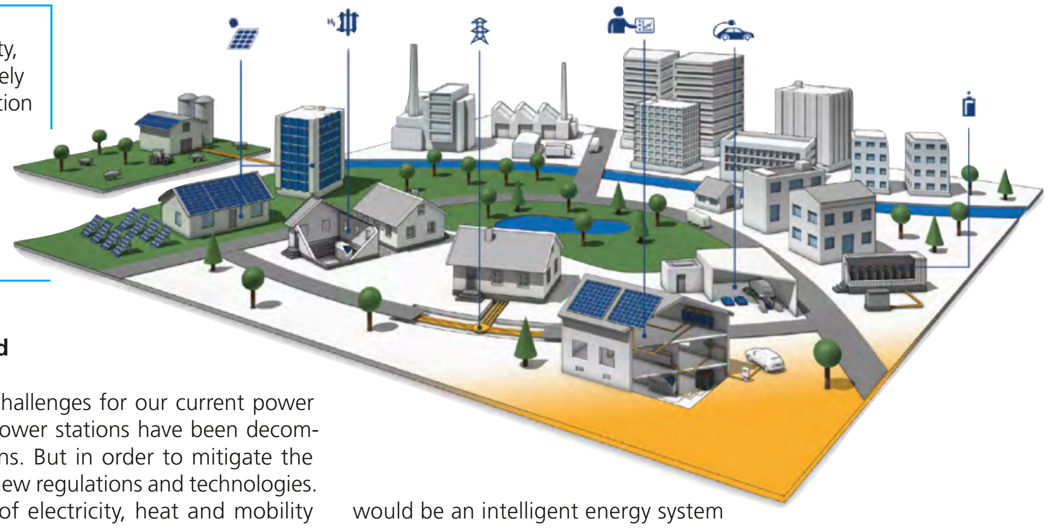
AN ENTIRE CITY IN A LABORATORY

At NESTEC, DLR trials the energy supply of the future

by Jana Hoidis

Power grids, sine waves and all kinds of scientific measurements are displayed on eight large monitors, all watched intently by two researchers. "That is the network control room at our NESTEC laboratory," says DLR engineer Jan Petznik. "Here, we are monitoring power generation and consumption down to the individual households." Petznik is the laboratory manager at the Networked Energy Systems Emulation Centre (NESTEC), which opened in 2019 at DLR's Oldenburg site. The power network inside the laboratory is a self-contained system in which the voltage and frequency of the electricity supply can be freely adjusted. In addition to general power grid simulations, the electronic systems at NESTEC can be used to replicate the operation of energy systems such as wind turbines or entire households. This process is known as emulation. Physical hardware such as the electric vehicle charging points at DLR's Oldenburg site can also be integrated into the experiments. This is made possible by the real-time computer system. Miniaturised urban districts composed of buildings, electrical grid and charging points are mapped virtually and examined in the laboratory. In doing so, researchers can explore new methods for regulating future energy supply systems or test new components under realistic conditions.

In the future Smart City, the electricity, heating and mobility sectors are closely linked. By exchanging more information between producers and consumers, the available resources, such as solar energy, will be more efficiently exploited.



Transformation of the power grid

The energy transition poses major challenges for our current power grid. As of 2020, many coal-fired power stations have been decommissioned for environmental reasons. But in order to mitigate the effects of climate change, we need new regulations and technologies. Sector coupling – the interlinking of electricity, heat and mobility sectors – is changing the nature of power consumption. Additional energy is needed to charge electric cars or operate heat pumps. Renewable sources of energy such as solar or wind power depend on the weather. Whether the sun is shining, or the wind is blowing will increasingly influence when and how much energy is fed into the supply network in future. However, neither the Sun nor the wind are governed by human needs. Whatever the conditions, people will still want to take hot showers in the morning, they will want to cook at lunchtime, and they will want to switch on their washing machines, dryers and televisions in the afternoons. New approaches are therefore needed to keep the grid stable and make the energy supply more intelligent. With the NESTEC laboratory, new solutions can be explored in a safe environment.

In the past, electricity flowed through the network in one direction: from the power station to the consumer – i.e. buildings or factories. In the future, new districts will be designed in line with the 'Smart City' concept. One project in which DLR is involved is the 'Energetic Neighbourhood' in the old air base district of Oldenburg. Here, energy providers and energy users are located close to one another and form a network to distribute power amongst themselves. Solar panels on houses, electric heating systems and electric vehicles are just a few examples of the power, heat and transport systems involved. This concept requires a very flexible network which allows power to flow in all directions. "The mix of simulation and emulated hardware here allows us to visualise effects on local and regional power grids very precisely and determine events such as crucial peak loads," says Jan Petznik, explaining the benefits of investigating such neighbourhood concepts at NESTEC. "We can represent a neighbourhood in the laboratory using the hardware, while at the same time modelling the connected distribution network at a higher voltage level on the computer." Smart City concepts such as this could then be transposed onto existing urban regions to transform them into smart districts.

Today a charging station, tomorrow a wind farm, the next day a Smart City

The laboratory complex, which covers an area of approximately 180 square metres, has its own power supply which is provided by a 800 kilovolt-ampere (kVA) substation. NESTEC can emulate up to 18 network participants, including houses, energy storage facilities, electric cars or wind turbines. There are also nine photovoltaic inverters from various manufacturers and a 30 kVA synchronous generator. Power lines up to two kilometres in length can be realistically represented in NESTEC's experiments. These are the components that will be found in the energy system of a typical Smart City by 2050. By directly integrating cogeneration plants and heat pumps at two of the institute's test stands into NESTEC's closed network, components from the heating sector can also be taken into account.

How can a future power grid with variable renewable energy still remain stable, and become more efficient at the same time? One approach would be an intelligent energy system that communicates with all individual components and automatically prioritises how the energy will be distributed. The demand on the grid varies; power demand is very high at times of the day when many people are simultaneously using their cookers, washing machines, dishwashers, televisions and computers. If several electric cars are also plugged into charging points at this time, parts of the network could be brought to its limit, or even exceed it. The vision of the researchers working at NESTEC is for the cars to communicate with the charging points using artificial intelligence systems. A self-learning computer system recognises the charging behaviour of the cars' owners and allocates the services or postpones the charging process according to by what time they actually need to be fully charged again. At the same time, algorithms use short-term weather forecasts to determine the future energy available from local producers such as the nearby solar power generation system. This relieves the electrical networks and expands the share of renewable energies in the transport sector. NESTEC is an ideal environment for developing and testing such systems.

Jan Petznik is particularly fascinated by the flexibility of his laboratory: "Today we are testing rapid charging points, tomorrow an entire Smart City district and a few days later the digitalisation of power grids and new market models for electricity trading. Having access to these possibilities is unique and is what makes my everyday work so exciting and challenging."

Jana Hoidis is responsible for communications at DLR sites in northern Germany (Hamburg, Bremen, Bremerhaven and Oldenburg).

One of the charging points at the DLR site in Oldenburg involved in an experiment. Jan Petznik monitors the most important data of the charging process.

CHANGING THE WORLD THROUGH EDUCATION

The path towards a sustainable, just and inclusive future

by Stefanie Huland

Ever since the Fridays For Future movement, 'sustainability' has been the buzzword on everyone's lips. Sustainable behaviour has now become a goal to strive towards in every area of life. The DLR Project Management Agency (DLR-PT) has created a short series presenting examples of its efforts towards sustainability, which reveals the sheer diversity of its work in this area. This article, the fourth in the series, addresses how sustainability can be incorporated into the education system.

Sustainability starts with education. You can only shape a more environmentally friendly and so-cially cohesive society if you understand the interactions and mechanisms at play in a globalised world. The United Nations supports efforts to achieve this aim through the interlinked UNESCO Education for Sustainable Development (ESD) programmes, the 'Global Action Programme on ESD' and 'ESD for 2030', both of which are being implemented in Germany. Astrid Fischer, Head of the 'Cultural and Civic Education, Education for Sustainability' Department at DLR-PT, and her colleague Kathrin Walz collaborate with various partners to implement ESD in the relevant frameworks and create a sustainable and just world for future generations.

Astrid Fischer is the Head of the 'Cultural and Civic Education, Education for Sustainability' Department at the DLR Project Management Agency and has worked on various educational topics and programmes there since 2001.

Kathrin Walz has been a Scientific Officer at the DLR Project Management Agency since 2018 and leads the Coordination Unit for Education for Sustainable Development. She has worked for non-governmental organisations in this field since 2011. She works in the Education, Gender Division at DLR-PT.

What is the idea behind the project?

Fischer: Education for Sustainable Development, or ESD, is key for the achievement of the UN's Sustainable Development Goals as it empowers people to think and act in a more future-oriented, sustainable way. As humans, we have to be aware of how our decisions affect others and how they impact the world of our children and grandchildren as well as current generations. For example, what are the consequences if I buy throwaway fashion items every month – and what would the difference be if I bought sustainable products or second-hand clothes instead? What type of energy am I using? What modes of transport do I use? All these decisions have a long-lasting impact on the climate and the planet. People should be empowered to see and understand the consequences of their actions, and hopefully to adapt their behaviour. The aim is to help everybody acquire the knowledge, capability, values and mindset to fulfil their role in contributing to a peaceful and sustainable society.

How is this being implemented in Germany?

Walz: Together with 300 actors at the federal, state and local authority levels, as well as from business, academia and civil society, the German Federal Government has developed and adopted objectives and measures for various areas of education in the form of a national ESD action plan. The aim is to embed ESD structurally at all levels, from early childhood and school education through to employment – in other words, for life. DLR-PT has been working on this with the Federal Ministry of Education and Research (BMBF) since 2016. We are in contact with all stakeholders and support the work being carried out by numerous committees by contributing ideas and offering expertise. We are also the responsible contact for funding projects such as a project monitoring the implementation of ESD in Germany at Freie Universität Berlin. That means we are at the confluence of numerous streams of information and activities, which we use as a basis for advising and supporting the BMBF and other institutions.

How can we incorporate sustainability into education? Can you provide an example?

Walz: ESD means taking a 'whole institution approach'. Sustainability should be strongly represented in all learning environments. At a day-care centre for children, it might include involving all, especially the children in the design of outside areas, i.e. the creation of an insect-friendly area and a vegetable garden. Vegetables from the garden could then be included in the lunch menu. Sustainability, fair trade and local origin would be considered when purchasing toys. ESD is also integral to personnel management, pedagogical design, mission statements and further vocational training. As part of the local community, day-care centres can collaborate with sports clubs and local care homes or with local authorities on the topic of mobility. Joint projects are also carried out with schools or migrant organisations. In order to make all this possible, it is essential for ESD to be incorporated in all educational structures within Germany, and that is what we are working towards.

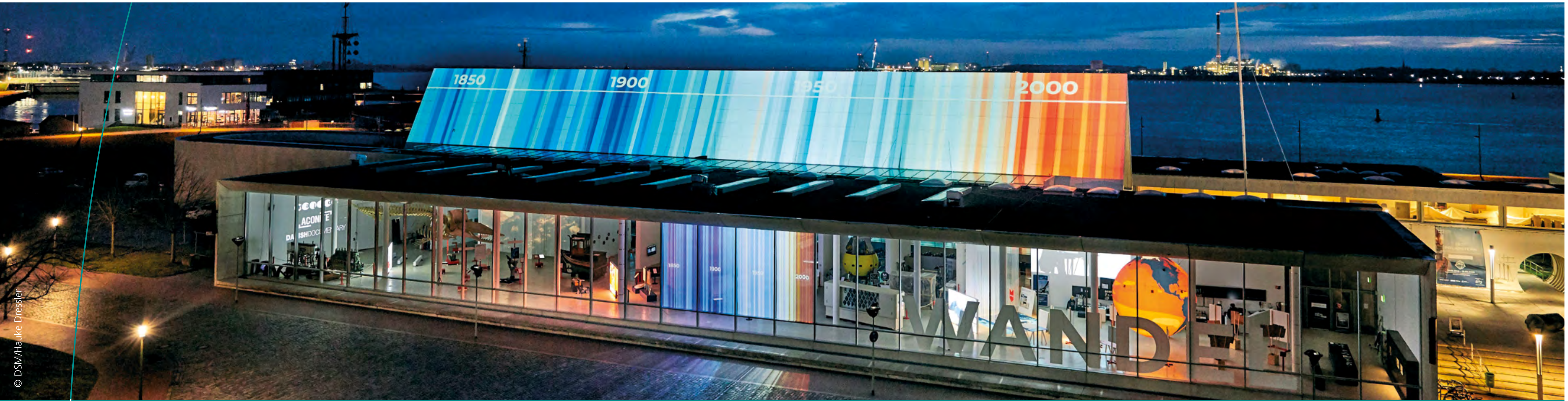
Would you say that the COVID-19 pandemic has once again placed sustainability and the centre of public awareness?

Fischer: The pandemic has increased the public focus on and awareness of key issues. Sometimes a crisis acts as a magnifying glass, forcing us to examine our situation in greater detail. We have experienced first-hand what it is like to have fewer cars on the road and a clearer sky. We have become more aware of new ways to interact with each other – particularly virtual ones – which we should explore and consolidate for the future. This is just a snapshot of course, but it is a great opportunity to use these experiences as starting points and make constructive use of the new awareness about sustainability that we hope people have developed.

The interview was conducted by **Stefanie Huland**, Corporate Communications, DLR Project Management Agency.

A particular focus of the ESD action plan is the inclusion of the younger generations

The next article in this series will examine how fostering the next generation of scientists can play a role in social transformation towards a sustainable future.



© DSM/Hauke Dressler

THE SEA, THE SHIP AND THE SAILOR

A visit to the German Maritime Museum

by Peter Zarth

The German Maritime Museum (Deutsches Schifffahrtsmuseum; DSM) in Bremerhaven is one of eight German research museums of the Leibniz Association. Over 80 percent of its budget is allocated to scientific projects. This national institution showcases the importance of the oceans, shipping and humanity's relationship with the sea over the centuries. Visitors gain an insight into the research being carried out at this architectural jewel, designed by Hans Scharoun. The building is flooded with light and structured according to clever lines of sight. with an extension to the main building designed by Dietrich Bangert. The author was moved by a story that is hard to believe.

The Seefalke

We are sitting in the crew mess on board the deep-sea salvage tug Seefalke (Sea Hawk). Certain traces left in the thickly lacquered, solid oak table remind us that people ate here during strong wind and storms as the ship pitched and rolled. The table has been fixed to the floor so that it cannot move, and the top divided into sections with screwed-in fiddle rails to prevent things sliding off in rough seas. Deep-sea salvage tugs are equipped to assist ships in distress: to recover them in severe weather, tow them back to shore or put out fires. The 14-millimetre-thick steel plates forming an outer skin of the ship's hull gave the Seefalke its stability. Mighty hawse pipes prevented the heavy tow ropes from getting caught on the ship's structures and fittings. Yet none of this could prevent the ship from being sunk twice itself during its wartime service. Having been raised again both times, it has been out of service and part of the museum harbour since 1970. With its remarkable history, it has all the typical attributes of the German Maritime Museum fleet: it stayed true to its course but did not hesitate to chart a new one when the need arose. The aim is to transform a technical museum into a place that "asks the big cultural and historical questions," says Sunhild Kleingärtner, Professor of Maritime Archaeology and Shipping History and Managing Director of the DSM.

The egg

The Seefalke saw use all over the world. The crew were paid only if they were successful: "It was a case of no cure, no pay," says Sabrina Nisius, who originally studied Christian archaeology and history of Byzantine art and now leads tours of the harbour and museum. Nisius points to the place on the bow that once held a chicken coop, complete with hens that provided fresh eggs for the sailors on board. She tells us about the amateur radio enthusiasts who have now found a home on the Seefalke. Such stories capture the imagination not just of the children, who have long had the run of the museum ship. These vessels tell an extraordinary tale of how seafaring can shape people, and how people in turn can shape the sea.

The myth

We have now moved on from the museum harbour to the Scharoun Building and are leaning on a railing that allows us to marvel at the genesis of this institution, as though looking over the rail of a ship. Below us, in a room specially created to display it, lies the Bremen cog. It enjoys "an almost mythical reputation in scientific circles," writes Amandine Colson, archaeologist, art historian and conservator, in one of the DSM's accompanying booklets. The cog is the best-preserved medieval merchant ship in the world, and a truly sensational exhibit – "there's nothing else quite like it". It was discovered by chance in the Weser in 1962. Wet-wood preservation techniques for ships were perfected for this vessel. After 38 years – many of which were required for the salvage operation and more than 18 for conservation work – the ship was presented to the public in its preserved form in 2000. Speaking with a mixture of scientific objectivity, enthusiasm, respect and adoration, Nisius describes this oaken vessel as a contemporary witness to the human activity and skills at the time in which it was built.

The water

How was something created in the Middle Ages able to withstand the ravages of time for so long? This might seem a simple question for researchers, but the answers are complex and the museum offers many. One oft-repeated platitude is that laziness and boredom lie at the roots of

© DSM/Mareike Heger

Visitors to the DSM should allow themselves plenty of time. You could spend a day poring over the outdoor areas alone, which feature a vast array of exhibits, from a harpoon cannon to the Seefalke, a deep-sea salvage tug. The museum's model ship collection is legendary and has recently been expanded with top-quality digital models.

human progress. In actual fact, it is often sparked by necessity and the struggle for resources. In the past, great expanses of water were insurmountable, so people started to build ships. To meet the daunting challenge of mastering the sea, they embarked on a long history of research, trial and error, in order to learn to build better ships. Ships were used for all kinds of purposes, including military campaigns, trade, tourism, exploration and research. Ships connect people with the sea, and in doing so they change the world. For centuries, many discoveries have been made aboard ships. This is the focus of the exhibition 'Planet Sea'. The United Nations Convention on the Law of the Sea, one of the most important of all international agreements, demonstrates how vital oceans and shipping are to this very day. The Convention regulates almost all areas of maritime law and sets out rules for the seas and oceans, which cover over 70 percent of the planet. Creating a set of rules that bind people all over the globe requires a familiarity and profound understanding of the subject.

The ocean

Frederic Theis, an archaeologist, historian and expert in early modern shipping and navigation, currently works on the joint research project 'Maps – Oceans. For a History of Globalisation from the Water'. Theis attributes the emergence of the systematic scientific exploration of oceans and coasts from the early 19th century, especially by Great Britain, to a universal human characteristic: "Boredom definitely had a part to play in it," he says. Following the end of the Napoleonic wars in the early 19th century, the Royal Navy was suddenly without a fitting challenge, so it went looking for new assignments. For economic reasons, during the 19th century Great Britain also had a far greater interest than mainland European nations in the sea and in discovering new markets. This led to the first cartographic campaign to be conducted for purely scientific ends, orchestrated by a navy that was 'bored stiff'. The result was impressive: the systematic mapping of coasts and oceans. Theis points out an often-overlooked and thus underestimated outcome of the project: "Nautical charts make the world tangible and foster an understanding of global interrelationships." The current exhibition bears the fitting title of 'Maps, Knowledge, Sea – globalisation from the water' and runs until March 2021.

The land

Professor Kleingärtner is fascinated with the connection between ships and seas, and the land where people live. In the early 1970s, Germany did not yet have a national museum specifically devoted to seafaring. The shipbuilding industry itself was on its deathbed but needed to be preserved. Key players in the maritime industry called for a national museum. Substantial contributions were made to it, including the largest collection of maritime art in Germany and a barque, the Seute Deern, a wooden boat primarily intended to be co-financed as a restaurant ship. The contract for the architectural design was awarded to Scharoun. He envisioned ideas that would shape the present and future of the museum – ensuring that the building "is in harmony with the environment, climate and landscape".

Thanks to the impressive work of the salvage crew, restoration experts and many others, these planks have been preserved for posterity. In 1380, they were used to create a ship that was then discovered in the Weser in 1962. Following several years of salvage work and 18 years of restoration, the Bremen cog now has its own room at the DSM.


© DSM


© DSM/Nadiia Khatymlianska

The German Maritime Museum puts a big emphasis on its younger visitors. Under expert guidance, a 'helmsman' and 'first officer' set the deep-sea salvage tug Seefalke on a course for the museum.


© DSM

The German Maritime Museum is situated the ideal location: practically 'in' the mouth of the Weser, the open sea within sight and one of Germany's major port cities behind. The 'Harbour Worlds' of the maritime city of Bremerhaven are seen here from above. In the foreground, the extension of the DSM, and behind it the building designed by Hans Scharoun – cubic from the air, a spatial marvel inside.

The ship

Anyone who has ever seen ships lying in the German Bight, many of them far longer than 300 metres and wider than 50 metres – dubbed 'shoeboxes' by the locals – will know that the time of romantic seafaring is long past. Indeed, it probably only ever really existed in the cinema. However, to Kleingärtner this development raises a number of questions: How do we want to live in a modern world served by such massive ships? How do we get from a museum devoted purely to technology to a place that asks questions about the interaction and networking of maritime and land-based systems? True to its motto of 'Human and Sea', the DSM seeks to create new approaches that allow objects to tell their stories. "We want to look beyond our own standard frame of reference," she says, "but we also want to see things from our visitors' perspectives and conduct intensive visitor research." The participatory element of the museum incorporates contemporary witnesses and the involvement of local citizens. Multiple perspectives enhance the way in which people view the exhibits. They are inevitably the focus of dissemination and research, but as Kleingärtner says: "we address them from other angles, weaving in bigger themes." This feeds into projects and research themselves, as well as a sophisticated communication approach that makes explicit references to research. Research is currently underway on provenance, historical trends such as colonialism – from colonial assets to the slave trade – and putting into context issues such as the dumping of munitions at sea. A separate project is devoted to goods that were taken from Jewish citizens and shipped via ports such as Trieste, Antwerp and Bremerhaven.

The horizon

Professor Kleingärtner is not sparing in her criticism: "In many cases, the sea is a kind of blind spot; it is not an area of focus for politicians or the general public. Yet it is an essential part of all of our lives." There is little in the way of debate about it. As a research museum, the DSM does not proffer solutions, but rather basic information that can inform active decisions. "Essentially, we are trying to expand upon our existing knowledge by weaving in new perspectives. This can be done through new presentation techniques and design, coupled with the holistic approach that is the sole preserve of museums."

'Human and Sea' is all about representing interactions in a comprehensible and illuminating way. The line of the horizon – sometimes narrow, sometimes broader – was incorporated into every version of the museum logo. A visit to the DSM makes it clear just who is capable of crossing those horizons.

The human

Let us return to the Seefalke, and to the year 2019. Relatives of a contemporary witness of the ship's service years support him around his visit to the museum. He was once a sailor aboard the deep-sea salvage tug. Now, age catches up with him, he is frail and his mind is clouded. After a few preparations, he approaches 'his Seefalke' – slowly, on crutches. He cannot make it over the high side of the ship alone. On deck, he takes a few shaky steps, looking and shuffling from one part of the ship to another. As he carefully lays down his sticks beneath one of the many 'No smoking' signs, he begins to reminisce, a twinkle in his eye: "We used to smoke like chimneys here, round the clock..." He proceeds to describe the ship to his companions and recount what it was like during tough missions, how they braved the sea in a storm, how they saved people and ships. Finally, he disembarks without need of his crutches, his thoughts now alive as the sea.

Peter Zarth works in DLR's Public Affairs and Communications department.

German Maritime Museum –
Leibniz Institute for Maritime History

Hans-Scharoun-Platz 1
27568 Bremerhaven
Telephone: +49 (0) 471 482 07 0
info@dsm.museum

Opening hours

Museum building:
Daily 10:00–18:00

Admission

Adults: 6 euro
Concessions: 3 euro

Web: dsm.museum

REVIEWS

LESS ABOUT SPACE, MORE ABOUT HUMANS

Away depicts the journey of astronaut and commander Emma Green (two-time Oscar-winner Hilary Swank) and her international crew on the first manned mission to Mars. While the series does revolve around the crew's efforts to complete their arduous mission, the focus lies on the relationships between the crew members and their ties to loved ones on Earth. This includes commander Green´s husband and daughter and the daughter and granddaughters of cosmonaut Misha Popou, to name a few. While the portrayal of hyperemotional and surprisingly unprepared astronauts is unrealistic, the crew's ability to band together is enjoyable to watch. The show, created by Andrew Hinderaker and run by Jessica Goldberg, not to mention an impressive list of producers, is truly a testament to how far television has come in terms of special effects. The impressive visual portrayal of life in outer space is arguably the shows best feature. Even so, Away is more family-drama than Sci-Fi, referring not just to the crew's families on Earth but also the family the crew ultimately becomes. If you enjoy character-driven narratives against the backdrop of space exploration, give it a watch. The show aired on 4 September 2020 and is available on Netflix.

Sara Kehrer

TRAVEL BACK IN TIME TO THE COUNTDOWN OF THE CENTURY

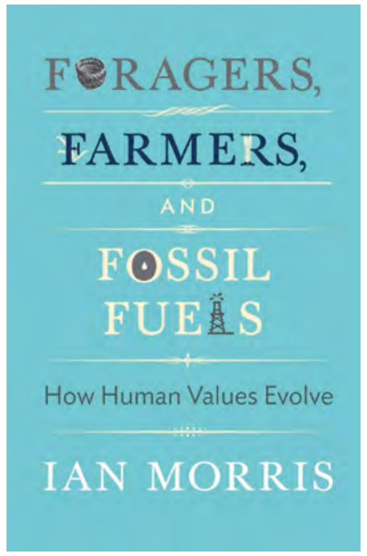
bbc.co.uk/programmes/w13xttx2

Lunar Module Eagle floated in space for 13 minutes after it detached itself from the Columbia command module and ignited its engines. Then it landed on the lunar surface. These historic minutes of communication between Houston, Columbia and Eagle are a compelling introduction to the BBC podcast **13 Minutes to the Moon**. But the series, produced to mark the 50th anniversary of the American moon landing, doesn't just cover these thirteen minutes: it tells the story of the whole moon landing adventure, which lasted for over a decade and culminated in humans stepping on the Moon for the first time.

The podcast includes 12 episodes and a lot of additional material, including many less well known details of the Apollo missions that led up to the first Moon landing of Apollo 11. A second season includes the Apollo 13 mission. BBC presenter Kevin Fong leads us through the individual episodes. Interviews with participants and numerous original audio recordings from NASA give the series an authentic character. If you want to experience the journey to the Moon up close, this podcast will give you goose bumps.

Melisa Seyrek Intas

A WAKE-UP CALL TO COMMON SENSE



"First the food, then the morals" is a phrase freely taken from Berthold Brecht. According to Ian Morris it should instead read: "As the food, so the morals". In his book **Foragers, Farmers, and Fossil Fuels**, published by Princeton University Press, Morris argues that every age has its own moral values, and that the way energy sources shape societies is the way they are formed. Human values and societies depend on how we generate our energy. In three parts, Foragers, Farmers, and Fossil Fuels presents a scientific discourse between archaeologists, historians and philosophers on the origin of our basic values.

Morris sketches a macro-history of humanity from the hunter-gatherers and their settling as farmers to the globalised industrial society. He compares social structures, division of labour, gender differences and the propensity to violence, and even uses this approach to derive possible values we will have in the future. His future scenarios range from a world dominated by Chinese culture, to a science-fiction-like bio-technologisation in which mankind forms a global superorganism. Two historians, a philosopher and the Canadian novelist Margaret Atwood give the discourse a philosophical perspective.

The book comes across as credible, conclusive and excellently structured, even if the macro-history may seem a little long-winded. The scholarly debate is scientifically rational and yet lively, at times quite smug and exhilarating. Morris rethinks, refines and expands his point of view. All in all, provocative, philosophical and stimulating, this is what makes this book worth reading. Not necessarily a read suitable for by the swimming pool or at bedtime, but a work that tempts the reader to use their 'common sense'.

Jens Mende

RECOMMENDED LINKS

VISIT RYUGU IN VIRTUAL REALITY
trek.nasa.gov/ryugu
Developed by members of the NASA Ames Research Center & JPL, this site allows you to interactively explore the asteroid Ryugu from your browser. Whether you want to know how many Golden Gate Bridges wide the asteroid is, or visit landing site of the DLR/CNES Mascot lander in virtual reality, this is the perfect place to learn about the distant celestial body - just in time for samples from the asteroid obtained by the Japanese spacecraft Hayabusa2 to arrive at Earth in December!

THE WORLD AT YOUR FINGERTIPS
nasa.gov/connect/ebooks
NASA's free e-book collection is a goldmine for space enthusiats. Learn about the history and science behind everything from human spaceflight to environmentally friendly aviation and X-ray astronomy. There is even a whole series on all you need to know to conduct your own experiments on board the International Space Station.

ON THE HUNT FOR THE NORTHERN LIGHTS
gi.alaska.edu/monitors/aurora-forecast
The aurora borealis has inspired many legends and myths. They were considered messengers of imminent disaster or the shining armour of the Valkyries. The dancing lights are actually caused by sunspots and solar flares. This website from the University of Alaska Fairbanks provides a prediction of when and where the next aurorae will appear. Maps for different regions can be selected. It also answers general questions about optimal conditions for the observation of or research on the phenomenon.

THE BEAUTY OF RESEARCH
DLR.de/flickr
Whether the view from a research aircraft of the clouds over the ocean near South America, the endless cratered landscapes of Mars, or the robots that children and young people have made during the COVID-19 lockdown, on DLR's Flickr account, our various research areas show their best side.

PHILOSOPHY THROUGH THE AGES
historyofphilosophy.net
This philosophy podcast already has almost 500 episodes. Beginning with the Presocratics, Peter Adamson, Professor of Philosophy in Late Antiquity and the Middle Ages at King's College London, works his way through the history of Western philosophy. Each episode lasts between 15 and 20 minutes. Adamson describes his podcast as a complete history of philosophy because, in addition to the classics such as Socrates, Plato, Descartes or Kant, he also covers philosophers who often receive little attention in textbooks.

Cover image

Light, manoeuvrable and safe: this is DLR's new Safe Light Regional Vehicle (SLRV). Its potential uses include daily commuting from the outskirts to the city centre, shuttle services to public transport, or even as a car-sharing vehicle. Its range is 400 kilometres and its maximum speed is 120 kilometres per hour. The lightweight vehicle is powered by a resource-efficient combination of a fuel cell and a battery. The SLRV is one of the new vehicle concepts currently being developed at DLR that could shape the future of transportation. Using prototypes of these concepts, DLR experts want to not only test new technologies on the road, but also gauge the public opinion and determine whether people are enthusiastic to use similar vehicles in the future.

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