DLRmagazine

German Aerospace Center (DLR) · No. 165 · August 2020

ALL-ROUNDER IN THE STARTING BLOCKS

HYDROGEN AS AN ENERGY CARRIER

More topics:

- ANNIVERSARY IN THE ARCTIC CIRCLE
  Ten years of satellite reception in Inuvik
- A UNIQUE CLOUD COCKTAIL
  Research aircraft study the clouds, weather and climate

DLR at a glance

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 55 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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TIMES OF CHANGE

This edition of DLRmagazine is the second to be produced under the adverse conditions of the Coronavirus pandemic. While the finalisation of the spring issue – number 164 – coincided with the lockdown, this issue has been done almost exclusively from our home offices, under the conditions imposed by DLR's switch to minimum operational status and the subsequent slow relaxation of the restrictions. But we were also able to experience that a standstill does not necessarily mean a complete stall. During the production of this issue, we received impressive contributions about the ways in which research can be supported in exceptional situations, how it can be maintained with commitment and clever ideas, and how it is able to function under suddenly changed circumstances. For example, the DLR sites in Stuttgart, Bremen, Oberpfaffenhofen and Braunschweig converted their laboratories to manufacture face shields and thereby helped overcome supply bottlenecks. Research flights to study the atmosphere as well as plasma crystal experiments on the International Space Station ISS were planned and coordinated from the scientists' home offices. Transport researchers launched surveys on how a pandemic could change our mobility, and much more.

Instead of causing paralysis, the crisis has acted as a stimulant, releasing new potential and ideas. Once again, it shows how fruitful it can be when everyone pulls together to make projects possible. Public authorities, scientific and industrial partners in research, and even printers, agencies and distributors are among those who report this.

Time has obviously not stood still either and some changes that seemed to be a long way off last year 'suddenly' happened. This issue is the first with a new editor-in-chief and the last for retiring editor-in-chief Cordula Tegen, who has been in charge of this publication for the last 13 years. With professionalism, openness and passion, she made DLRmagazine what it is today, and every single issue something very special. Now, she is starting her well-deserved retirement. We wish her all the best and say:

Thank you!

EDITORIAL

Dear reader,

Some opportunities go by unused, and technologies that seem to have great potential disappear without a trace. Fortunately, others come to fruition after a long wait. For some time now, the most common element in the Universe – hydrogen – has been the focus of particular attention from scientific researchers, industry, policymakers and society . It is flexible, can be stored relatively easily and burns cleanly. Industry has been researching the use of hydrogen for a long time, and the principle of electrolysis has been known for over 200 years. Newer processes are expected to achieve higher efficiencies. Can hydrogen establish itself as the energy source that will help to mitigate climate change and finally find its calling? In any case, DLR is conducting research into this multi-talented element in many areas.

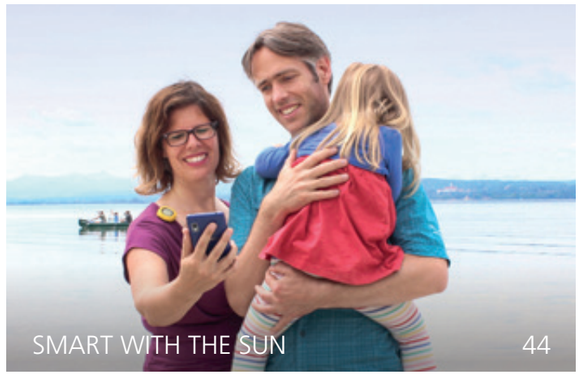
Other 'all-rounders' are also showcased in this issue. There are, for example, space technologies that are used for humanitarian assistance and flexible 'bandage' energy storage systems developed by the team around materials researcher Bilge Saruhan-Brings. You can find out why they are called 'bandages' in an interview with her. Or accompany Tobias Bellmann to the Innovation Laboratory in Oberpfaffenhofen. Here, he and his team have built up an extraordinary world of mechatronic simulations from almost all DLR departments.

Other topics covered in this issue include the new Multifocus Tower in Jülich, the tenth anniversary of the DLR ground station in Inuvik and the spin-off ajuma, which has developed a device that reliably warns against sunburn.

We hope that you enjoy reading this issue,

Your DLRmagazine editorial team

DLRmagazine **165**



NEW INSTITUTES FOR MOBILITY AND ENERGY

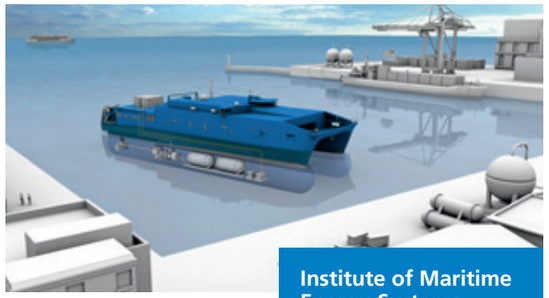
On 23 June 2020, the DLR Senate decided to establish two new institutes. The Institute of Systems Engineering for Future Mobility will be located in Oldenburg. The Institute of Maritime Energy Systems in Geesthacht will focus on reducing emissions from shipping.

SAFE AND AUTONOMOUS ON THE ROAD

The technologies used in the automated and autonomous vehicles of the future will have to be highly reliable. To this end, the new DLR Institute of Systems Engineering for Future Mobility, which emerged out of the Oldenburg-based computer science institute OFFIS e.V., will develop methods and tools for industrial processes. In collaboration with the DLR Institute of Transportation Systems, these tools will then be used in the Test Field Lower Saxony to test new system functions. In addition, the new Institute already has a world-renowned test field for automated maritime transport systems.

ENVIRONMENT-FRIENDLY ENERGY SYSTEMS FOR SHIPPING

Ships carry around 80 percent of freight. They are responsible for approximately three percent of global carbon dioxide emissions. Cruise ships also produce emissions that lead to air pollution. The new DLR Institute of Maritime Energy Systems is the first research centre in the world to systematically examine the entire energy conversion chain in shipping. Researchers at the Institute in Geesthacht will develop and test solutions for decarbonising shipping, and work with industry to bring them into use. Their development work will focus on fuel cell systems and alternative fuels. Specialists will look at the entire energy system on board, including electricity supply, heating and cooling.



Institute of Systems Engineering for Future Mobility
Oldenburg

Founding director:
Axel Hahn

Planned staff:
80

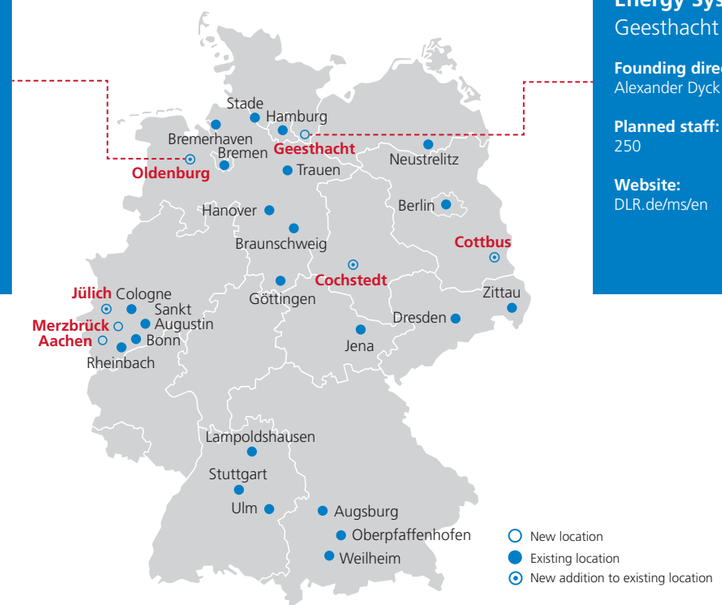
Website:
DLR.de/se/en

Institute of Maritime Energy Systems
Geesthacht

Founding director:
Alexander Dyck

Planned staff:
250

Website:
DLR.de/ms/en

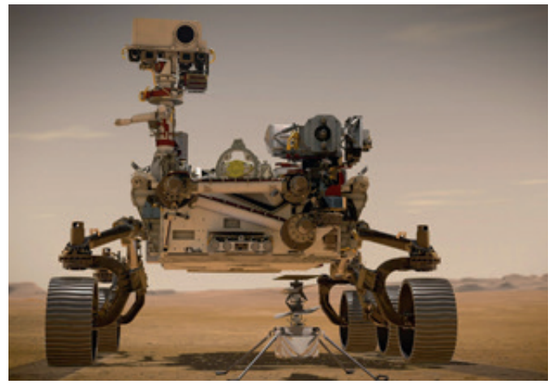


The DLR Senate also gave the green light to the **Institute of Future Fuels (Jülich)**, the **Institute of Low-Emission Aero Engines (Cottbus)** and the DLR research programme 'Electric Flight'. Two new facilities – **Small Aircraft Technologies (Aachen, Merzbrück)** and the **Unmanned Aircraft Systems Competence Center (Cochstedt)** – will be established for this purpose. The four institutes and facilities will be presented in more detail in the next issue of the DLRmagazine.

IN BRIEF

NASA'S MARS 2020 MISSION IS ON ITS WAY TO THE RED PLANET

On 30 July 2020, the Perseverance rover and Ingenuity helicopter departed for Mars. They will land near the rim of Jezero Crater in February 2021. Perseverance carries seven scientific instruments with which it will analyse the geology of the landing site, search for signs of past microbial life in rocks and sediments, and find the most promising samples for subsequent analysis on Earth. Ingenuity is a technology demonstrator; it will be the first aircraft to attempt controlled flight on another planet. Digital terrain models derived from images acquired by the DLR High Resolution Stereo Camera carried on ESA's Mars Express spacecraft were supplied to the Mars 2020 mission team and made an important contribution to the landing site selection process. The camera carried by Perseverance will acquire 3D colour images. DLR is represented on the Mars 2020 mission science team and will be involved in evaluating and interpreting the images.



© NASA/JPL-Caltech

Mars rover Perseverance and helicopter Ingenuity

© ESA/Pierre Carril

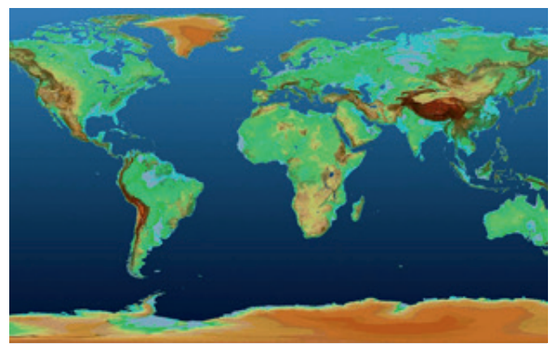
Sentinel-3 satellite in space

COPERNICUS EARTH OBSERVATION PROGRAMME EXPANDS

On 1 July 2020, following a European competition, the European Space Agency (ESA) awarded contracts for the development and construction of six further Copernicus Sentinel satellites. These will help find answers to the global challenges posed by climate change, population growth and environmental problems. Sentinel satellites are at the heart of Copernicus, Europe's largest Earth observation programme. They are already reliably and continuously providing large amounts of data on the state of the climate, vegetation and oceans. Now, six more 'Earth Guardians' are being added. The contracts are worth a total of more than 2.5 billion euro, of which approximately 800 million euro will go to space companies in Germany. Some of these new missions will measure atmospheric gas concentrations, land surface temperatures, ice mass thicknesses, and ocean ice cover and surface temperature. Others will classify land cover and determine soil moisture content, as well as performing imaging spectroscopy of the land surface.

TEN YEARS OF 3D MAPPING FROM SPACE

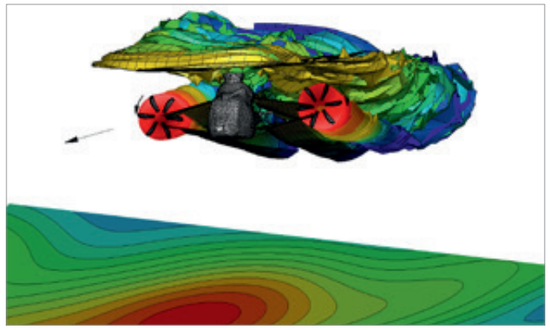
A new era in radar remote sensing began 10 years ago with the launch of the German radar satellite TanDEM-X. Since then, it has been orbiting Earth in close formation with its 'twin', TerraSAR-X, which is three years older. The distance between the satellites varies between several kilometres and sometimes only 120 metres. This enables the radars to obtain a 3D view of Earth in a single pass. This is referred to as a bistatic interferometer in space, which allows the terrain structure to be recorded in 3D in just one pass. The mission continues to be globally unique. The primary objective – the creation of a highly accurate global elevation model of Earth's entire landmass – was achieved by mid-2016. In future, further surveys are planned that will concentrate on monitoring ice sheets and permafrost areas, large-scale forest evaluations, particularly for tracking deforestation, and the observation of 2000 cities worldwide for continuous mapping of urban settlement areas.



The TanDEM-X Digital Elevation Model (DEM) covers Earth's entire land surface – a total of more than 148 million square kilometres. The absolute height accuracy is one metre.

ANALYSING HELICOPTER NOISE

DLR has investigated the acoustic properties of the Rapid And Cost-Effective Rotorcraft (RACER), a demonstrator that flies faster, farther and more efficiently than previous helicopters. Researchers at DLR Braunschweig and the French Aerospace Lab (ONERA) carried out a complete acoustic analysis in various flight modes, investigating noise from the rotor and propellers. Computational data can now be used to demonstrate that RACER will fly at over 400 kilometres per hour, making it 100 to 200 kilometres per hour faster than any conventional helicopter. In addition, it is very quiet despite having two propellers in addition to a rotor. Quiet flight behaviour is possible because RACER can be flown like an aeroplane. Low noise is an important prerequisite for the future demonstrator, as it is specifically designed for rescue missions, the provision of emergency medical assistance, and public and private delivery and transport flights. In addition to its work on acoustics, DLR is also playing a crucial role in the aerodynamic design of the wings and the tailplane.



Computational simulation of the noise contour emanating from the main rotor and propellers during RACER's flight, and a representation of the 'noise footprint'.

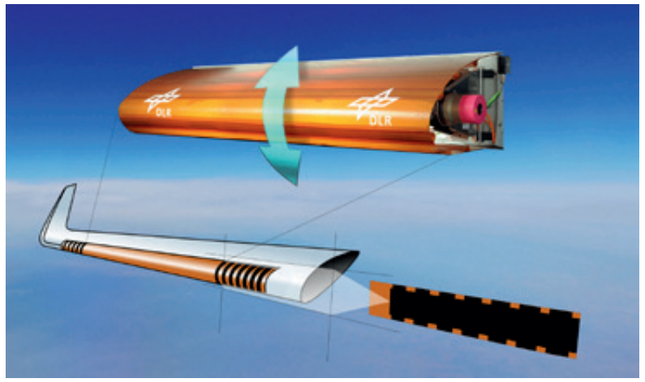
DLR and its partners developed a special LED light strip, which runs beneath the windows and flashes several times if the automated vehicle wishes to signal to a pedestrian to cross the street.

HELPING AUTOMATED VEHICLES COMMUNICATE

Whether with turn signals, hazard warning lights or flashing blue lights, vehicles often use light signals to communicate with other road users. As part of the EU project interACT, DLR researchers have worked with European industry to develop new solutions that enable automated and networked vehicles to communicate safely and reliably by means of light signals. Light is a good way of transmitting simple messages. Language and symbols, in contrast, can easily lead to misunderstandings. The project partners have developed a special LED light strip with this in mind. It runs beneath the windows and around the whole car, flashing several times if the automated vehicle wants to let a pedestrian cross the street. A small lamp is attached to the front of the windscreen at rear-view mirror level. It can only be seen by a single person, who therefore knows that the flash from the LED strip is meant for them.

REDUCING AIRCRAFT NOISE

Part of the noise from aircraft is generated by the wing. Where high-lift devices and control surfaces meet the wing, there is an abrupt transition between the airflow over these aerofoils and that flowing over the fixed part of the wing; these transitions cause some of the noise. Could a flexible surface between the wing and the moving surfaces reduce this? DLR researchers have been working with partners in academia and industry to address this question. An experimental configuration based on a one-metre span of the outboard wing section of an Airbus A320 was investigated. The slat on the leading edge was replaced with a variable-shape leading edge, referred to as a droop flap. The transition skin consists of a mix of materials – synthetic rubber and glass-fibre reinforced composites. The rubber forms the basis for the skin, into which glass-fibre plates are inserted at varying intervals. Testing revealed that the skin is very hard-wearing and highly deformable.



The leading-edge slat on the wing has been replaced by a droop flap – a variable-shape leading edge developed at DLR in 2007. The transition skin was installed as an addition.

RADAR TECHNOLOGY REVEALS WEAK POINTS IN BUILDINGS

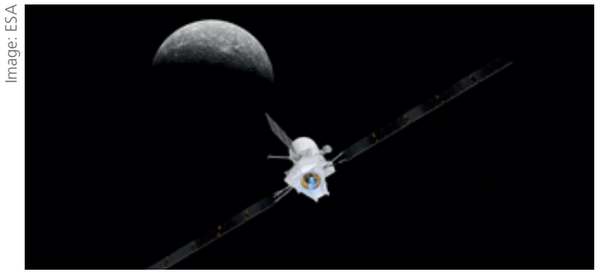
GTOM antennas examine the wall of a house

If doctors need to take a detailed look inside their patients, magnetic resonance imaging is often the method of choice. For buildings as well, looking at the inner structure or 'skeleton' is often necessary to assess their structural condition or energy efficiency.

A research team from the DLR Microwaves and Radar Institute has devised a way of using radar technology to analyse the external and internal walls, ceilings, floors and roofs of buildings in a contact-less, non-destructive manner. Radar waves penetrate non-metallic matter and are partially reflected at layer boundaries. The properties of the reflections provide information about the layers and thickness of the materials used. Researchers scan walls from the side or use drones to acquire data that they then use to create 2D and 3D radar images of the wall structure. The GTOM project was successfully completed in early August.

THE BEPICOLOMBO SPACECRAFT VISITS VENUS

Image: ESA



BepiColombo will travel a total of approximately nine billion kilometres, including a total of nine flybys of Earth, Venus and Mercury, before reaching its destination.

BepiColombo will fly past Venus on 16 October 2020. But this is not the final destination for Europe's largest ever planetary science mission. It is on its way to Mercury, the planet closest to the Sun. BepiColombo will perform two flyby manoeuvres around Venus, and use its gravitational field to decelerate before setting a course for Mercury on 11 August 2021. The amount of propellant that can be carried by a spacecraft is limited by the capabilities of the available launchers. Due to the Sun's enormous gravitational attraction, this means that visiting other planets in the Solar System can only be achieved through this kind of complex trajectory. BepiColombo is scheduled to enter orbit around Mercury on 5 December 2025. Once there, the DLR-developed MERTIS spectrometer will examine the composition and mineralogy of Mercury's surface and interior. In April 2020, MERTIS acquired images of the Moon from space. Scientists hope that it will be able to provide similarly revealing images of Venus.

DLR ACROSS GERMANY

BRAUNSCHWEIG: A flexible skin between the wing and flap system of an aircraft has been designed to reduce aircraft noise by providing improved aerodynamic properties. The DLR Institute of Composite Structures and Adaptive Systems is working with Invent GmbH and the Technical University of Munich to develop this transition skin, made of rubber and glass fibre, as part of the FlexMat project.

JENA: A high-performance data analysis cluster was inaugurated at the DLR Institute of Data Science in early July. It is intended to support scientific computing needs, especially DLR research in the fields of machine learning, visual analytics, climate informatics and citizen science.

LAMPOLDSHAUSEN: A 3D-printed combustion chamber has been successfully tested on the P8 test stand. The chamber will be used in the upper stage engine of the new European launcher Ariane 6. Such cutting-edge manufacturing processes increase the performance of space propulsion systems while simultaneously reducing production costs.

NEUSTRELITZ: DLR researchers from the German Remote Sensing Data Center have tested technology at a regional testing site in Mecklenburg-Vorpommern that will help farmers estimate crop yields and determine soil moisture. Scientists use geodata from sensors on satellites or drones for this purpose.

OBERPFAFFENHOFEN: In the eFence project, scientists from the DLR Institute of Communications and Navigation conducted research into communications and positioning technologies that can be used to detect road users who are not equipped with communications devices.

STUTTGART: Europe's largest research observatory for the detection of near-Earth satellites and space debris is currently being built on the Innovation Campus in Empfingen. The inauguration of this DLR facility is planned for spring 2021. It will use laser technology to determine the trajectory and characteristics of objects in near-Earth orbits quickly, precisely, and reliably.

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DIGITAL URBAN PLANNING

Close-up of a 3D model of the city of Braunschweig showing all transport-related details

A unique database is being created in DLR's cross-sectoral 'Digital Atlas' project

By Rüdiger Ebendt

Cities are growing, and with them, so are the demands on urban planning. For transport planning in particular, the needs of many groups – citizens, city authorities, vehicle manufacturers and transport companies – must all be taken into account. They all want congested traffic areas to be as safe to use and as free of disruption as possible. Achieving this requires access to reliable information and data. Such data should, wherever possible, come from a single source, rather than numerous ones that are based on different assumptions. This is the only way of ensuring that they can be combined and evaluated in a meaningful way. In DLR's cross-sectoral 'Digital Atlas' project, researchers from 10 DLR institutes are developing a database that will enable better design and organisation of urban planning and energy supply.

The DLR research junction in Braunschweig. Various sensor systems record the traffic situation to better understand the behaviour of road users.

The project's primary focus is on geodata – digital information that can be assigned to a spatial location on Earth's surface. This includes data from moving traffic on the ground, on water and in the air. The researchers are accessing information from satellites, aircraft and ground-based sensor technologies as they collect their data. The cross-sectoral project benefits from the different fields of expertise of the DLR institutes involved, with researchers working in the fields of aeronautics, space, energy transport and security, as well as in the fields of data collection and socio-economic analysis.

Layer by layer

Each map consists of individual layers that highlight specific topics. These might be types of roads, the distribution of vegetation and trees, or the location of solar power systems. This enables urban planners to assess the necessary roads and transport connections – not only within a city, but also in the surrounding area. In addition, comparisons can be made with other cities across the globe. Metadata describe the maps in greater detail, allowing the user to quickly assess the topic in question or the spatial accuracy and resolution of the map. They are also able to perform a search using keywords.

Braunschweig in 3D

In an initial subproject, the DLR Institute of Transportation Systems generated a 3D model of Braunschweig largely automatically, using sources such as cadastral information, aerial images and survey data. Wherever possible, thematic maps derived from raw data were processed and verified in this way. This process is gradually being developed into an all-encompassing geodatabase for all modes of transport. To ensure that the 'virtual' database represents reality as closely as possible, the researchers are studying various use cases with different modes of transport. They then compare the data from these use cases and use them as the basis for the Digital Atlas.

Satellites and aircraft capture the condition of roads

The condition of the roads plays an important role in traffic safety and fuel efficiency. Cracks and potholes cause damage that continues to spread if it is not detected early enough. This is also an important issue for automated or autonomous vehicles. In order to adjust their speed and driving style appropriately, the sensors of such vehicles must not only be able to recognise infrastructure and obstacles, but also lane markings and the condition of the road surface. Until now, creating road maps has been a laborious task, requiring specialised vehicles to drive along all of the roads. This is time-consuming and expensive. Positional data in cities and narrow streets are also often only accurate to within a few metres due to the 'shadowing' effect of densely packed buildings and structures that cause signal blockages and reflections.

The Remote Sensing Technology Institute and the Microwaves and Radar Institute in Oberpfaffenhofen are now investigating new methods to acquire the necessary data using satellites and aircraft equipped with imaging radar sensors and high-resolution camera systems. These data can be recorded in a much shorter timeframe and make it possible to determine the position of objects to within 10 centimetres anywhere in the world. This requires highly accurate reference points, which are obtained from satellite data.

Neural networks can make categories such as buildings, roads and vegetation visible in an aerial image, and even extract lane markings.

WHAT IS A GEODATABASE?

Spatial data, otherwise known as geodata, are acquired and managed in a geodatabase. They are structured using a spatial data model based on a coordinate system. Such models include the following:

- geometric data such as the location and extent of building and landscape objects,
- topological data to describe the spatial relationships between the objects,
- thematic or descriptive data, such as the colour of a house, and
- nominal data – that is, purely descriptive information such as the name or location of an object.

By combining overlapping aerial images, researchers create a surface model and what is referred to as an orthomosaic – a distortion-free, true-to-scale representation of Earth's surface. All roads, lane markings, masts, buildings and vegetation are depicted and integrated into the Digital Atlas. Intelligent algorithms identify objects using machine learning and categorise them. The researchers determine the condition of the roads using black-and-white radar images. Small differences in brightness within the images provide information about the roughness and material properties. By comparing these images with ground-based reference data, it is possible to determine the roughness value in the millimetre range.

The Modular Aerial Camera System (MACS) acquired images of the harbour area in Bremerhaven for the creation of high-resolution maps

Intelligent models show traffic volume

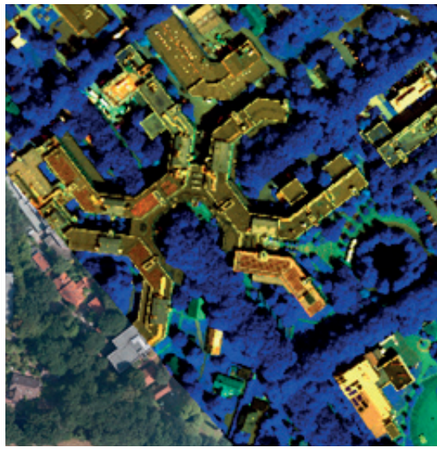
The Digital Atlas is also intended to model future developments and the consequences of implementing changes. Traffic model simulations serve this purpose and show the resulting impact on mobility. These may include the introduction of new means of transport, the expansion of infrastructure, or restrictions for certain road users. Such models require various types of data – information about the population demographics, possible travel destinations, and transport infrastructure and services. However, there is often a lack of precise knowledge about the size and spatial distribution of the population. With this in mind, the DLR Institute of Transport Research is developing new methods for determining traffic volumes. These new methods have the advantages that they require less data, and that the data that they do use can be collected worldwide using remote sensing. This makes it possible to derive traffic volume models for any region in the world.

The main sources of information for these types of models include data relating to land use, settlement patterns, as well as density and type of buildings. DLR's German Remote Sensing Data Center obtains such information from high-resolution satellite and aerial image data. These can be used to determine the distribution of the population within an area. The researchers are also using freely available data from the OpenStreetMap project, particularly those relating to road networks. This enables them to calculate how easily destinations within an area can be reached from a particular location using various means of transport. The researchers are drawing upon these and other data to develop a model of the overall traffic volume. Such models can then be used to investigate the impact of new mobility options, such as dial-a-bus services and other types of on-demand transport, on mobility behaviour.

Dynamic maps for safe and secure ports

Keeping track of people and goods in ports is particularly difficult. The DLR Institute of Optical Sensor Systems and the DLR Institute for the Protection of Maritime Infrastructures are looking into the creation of dynamic two- and three-dimensional maps in real time. Special sensor systems designed and developed by the institutes are used for this purpose. Real-time implementation is also an essential part of their work. The maps help authorities and emergency personnel with security-related tasks, and port authorities and terminal operators to quickly identify and assess critical situations, such as the danger posed by suspended loads or unauthorised access to the site. The first step is the image data acquisition by an airborne flight campaign and the production of high-resolution maps. Artificial intelligence algorithms then identify ships, road users and other objects, such as freight containers, from images acquired on the ground. Software also determines their exact position and integrates the objects into a situational picture. This results in a combined system comprised of aerial and ground images and the associated evaluation algorithms. These dynamic maps are also ideal for making autonomous traffic in ports safer.

Three-dimensional, real-time image of port area in Bremerhaven. Left: Camera image with objects that have been automatically identified by artificial intelligence and colour-coded according to their shape. Right: Preliminary 3D model of the surroundings with details of the position of an unknown or unauthorised person in the area.



The building of the Institute of Networked Energy Systems and the Wechloy campus of the University of Oldenburg. Left: optical image, right: hyperspectral image. Solar power systems are detected in the hyperspectral images using artificial intelligence techniques. This helps to predict the amount of solar power more accurately.

Predicting solar power production in cities

When is power from private solar power systems fed into the electricity grid, and how much do these contribute? Power grid operators urgently need an answer to these questions in order to be able to integrate renewables into the grid. This requires information about solar PV systems on rooftops and in open spaces, preferably collected in an automated way. The DLR Institute of Networked Energy Systems is conducting research in this field together with the German Remote Sensing Data Center. In order to identify solar power systems, researchers are analysing optical and hyperspectral high-spatial-resolution data acquired during flights over urban areas in Germany. Hyperspectral sensors perceive a continuous spectrum of electromagnetic waves, so they can identify objects more accurately on the basis of their spectral properties. The optical and hyperspectral images are used to create digital elevation models and determine building outlines.

FlexiGIS is an open-source model for the simulation of urban energy infrastructure developed at the DLR Institute of Networked Energy Systems. FlexiGIS can be used to model power generation in urban solar power systems – based on examples and use cases of the city of Oldenburg. This data help scientists to forecast solar irradiance with spatially and temporally high resolution by combining them with data from meteorological satellites. This assists network operators in grid control and thus supports the stability of the power grid.

Clear catalogue for different user groups

These four different use cases illustrate the complexity of this cross-sectoral project. In further applications, the aim is to expand the geodatabase and methods to as many modes of transport as possible, for example rail transport, and to include new types of mobility. However, the results obtained can only be used properly and to their full extent if the Digital Atlas is structured in a clear and comprehensible way. For this reason, future research will focus on the further development of a user-friendly geodata catalogue. All of the datasets will be stored there and clearly labelled. At the end the project, the Digital Atlas will be used in further research projects and, in the long term, will be made accessible to government and industry.

Rüdiger Ebendt works in the Data Management and Knowledge Discovery Department at the DLR Institute of Transportation Systems and is the scientific lead for the Digital Atlas cross-sectoral project.

For the automated detection of solar power systems, the software must be able to distinguish between different elements in order to avoid misclassifications. Roofs like this are used for test purposes; here, both solar-thermal and photovoltaic elements can be seen, but also a roof window, which must not be incorrectly labelled as a solar power system.

THE DLR DIGITAL ATLAS CROSS-SECTORAL PROJECT

Participating institutes:
Institute of Transportation Systems (Coordination)
Institute of Vehicle Concepts
German Remote Sensing Data Center
Microwaves and Radar Institute
Remote Sensing Technology Institute
Institute of Optical Sensor Systems
Institute for the Protection of Maritime Infrastructures
Institute of Space Systems
Institute of Transport Research
Institute of Networked Energy Systems

Duration: four years (2018–2021)
Budget: six million euro

A UNIQUE CLOUD COCKTAIL

Investigating the interaction between clouds, weather and climate with the HALO research aircraft.

By Silke Groß

Think of Barbados, and you will no doubt find yourself dreaming of Caribbean beaches, palm trees and sunsets. For the scientists working on the EUREC⁴A mission things are different. As far as they are concerned, Barbados is, first and foremost, the place where air masses that have been carried over the Atlantic for days meet land for the first time. Therefore, they see it as the perfect location for atmospheric research. An international team has been investigating this special mix of clouds and how it is being altered by climate change in the research project EUREC⁴A (Elucidating the role of clouds-circulation coupling in climate).

Before the air masses of the trade winds reach the Barbados mainland, low-level marine clouds form as they travel over the ocean – trade wind clouds. These clouds are an important piece of the jigsaw for scientists investigating climate change, as they are highly sensitive to their environmental conditions and thus to further global warming. However, these types of clouds and their impact on the climate are only described with great uncertainty in current climate models. This is because some of these clouds are relatively small and form over the middle of the ocean, making it difficult to examine them more closely. The EUREC⁴A research campaign is one of the biggest projects to investigate these clouds and their dependence on environmental conditions. During a four-week measuring phase in early 2020, the scientists were able to establish a comprehensive picture that will take climate research an important step forward.

EUREC⁴A – ELUCIDATING THE ROLE OF CLOUDS-CIRCULATION COUPLING IN CLIMATE

The EUREC⁴A field study is an international project with over 40 partners led by the Max Planck Institute for Meteorology in Hamburg and the French National Centre for Scientific Research (CNRS) in Paris. As part of the campaign, four research aircraft, four research ships, and ground-based measuring equipment on Barbados were coordinated for use, and the measurement results were combined with high-resolution climate models and advanced satellite-based remote sensing. The team is currently evaluating the data that they collected on the measurement flights in early 2020. The scientists involved in EUREC⁴A are focusing on four main points:

- Cloud configuration and feedback processes – investigating the impact of environmental conditions on cloud structure, the mesoscale configuration of clouds, and cloud feedback effects
- Aerosol and cloud physics – investigating the effects of aerosols on cloud formation, structure, and properties – in particular, the impact of dynamic processes on the microphysics of clouds
- Boundary layer dynamics – turbulence, mixing processes
- Atmosphere-ocean interactions – examining exchange processes

Hunting clouds at sea and in the air

Equipped with remote sensing instruments and dropsondes for meteorological measurements, the German High Altitude and Long Range Research Aircraft (HALO) was able to get a close look at the structure of the entire lower atmosphere during its overflights. Adopting a circular flight pattern at an altitude of approximately nine kilometres, the researchers examined the clouds and the humidity – and the air

HALO RESEARCH AIRCRAFT

HALO was equipped with remote sensing instruments for the research campaign. On board were a radar, a lidar (light detection and ranging), a spectrometer, radiometers and meteorological dropsondes. For the measurements over the ocean, the long flight time was particularly decisive – a unique selling point of the research aircraft. It flew the same circular flight path for nine hours. A further advantage of HALO is its flight altitude: in previous EUREC⁴A campaigns the aircraft carried out measurements up to an altitude of 15 kilometres.

During the EUREC⁴A mission in February 2020 – a 360-degree image of the pilots, Marc Puskeiler (left) and Stefan Grillenbeck (right) with atmospheric researcher Manuel Gutleben in the flight deck.

POLARISATION DIVERSITY DOPPLER RADAR (POLDIRAD)

Wavelength/frequency: 5.5 centimetres / five Gigahertz

Antenna diameter: five metres

Technical features:
transmitting and receiving with any polarisation

Field of application: measurement of precipitation (shape, phase and velocity vector)

flowing in and out of the weather system – important factors in determining the processes of cloud formation.

Below HALO, an ATR-42 – an aircraft operated by the French National Centre for Scientific Research (CNRS) – and a Twin Otter – a turboprop aircraft operated by the British Antarctic Survey – analysed the properties and structures of the clouds within the weather system. Flights made by the WP-3D from the US supplemented the observations with measurements made over the ocean further to the east. In addition to the aircraft measurements, four research ships – the German research vessels Meteor and Maria S. Merian, the US research ship Ronald H. Brown and the French research ship L'Atalante – studied the ocean and atmosphere around Barbados. The research ships served as remote sensing and in-situ platforms equipped with radiosondes, lidar and radar technology, kite balloons and uncrewed flight systems.

Approaching clouds in a controlled way and taking samples requires knowing their exact position. To that end, scientists from the DLR Institute of Atmospheric Physics brought their Polarisation Diversity Doppler radar (POLDIRAD) system to the island. With an antenna measuring five metres across, it provides information about clouds and precipitation over the ocean at great distances. These measurement data were sent to the research aircraft in real time so that the scientists and pilots could adapt their flight routes accordingly.

An obstacle course

The POLDIRAD cloud radar is usually installed on the roof of the Institute of Atmospheric Physics at the DLR site in Oberpfaffenhofen. For the EUREC⁴A mission, the system was dismantled and safely stowed in five shipping containers for the Atlantic voyage to Barbados, which took several months. Of course, it was practically inevitable that not everything would go to plan.

The team encountered numerous difficult moments in the process of getting the equipment to its destination in the Caribbean – from the complex transport logistics, to altered import and customs procedures in Barbados. Thanks to support from colleagues on the ground, customs released the containers just in time for the start of the campaign. Everyone worked hard to set up, test and put POLDIRAD into operation within a very short space of time. The potential of the radar system from Oberpfaffenhofen was evident from the very first day of measurements, when it recorded the horizontal and vertical structure of clouds up to a distance of 250 kilometres. The team worked around the clock in shifts to observe changes in the clouds over time throughout the day. The real-time measurement results enabled the pilots to head for the clouds over the Atlantic off the coast of Barbados and to coordinate the research aircraft effectively.

Round-the-clock measurements

The scientists were particularly interested in the formation and evolution of the different cloud structures. To obtain answers, they had to look at the complete lifecycle of clouds, ideally before they had even formed. Cloud systems usually form at the end of the night and change over the course of the day as they interact with incoming solar radiation. This meant that it was important to get up early. During the campaign, the HALO flights were staggered between 04:00 and 20:00 (the most active time for cloud systems). Flying multiple research aircraft made it possible to extend these observations into the night. Using the WP-3D, ATR-42 and HALO on a staggered schedule allowed the scientists to observe environmental conditions and cloud formation and development on an almost 24-hour basis.

If embarking on a night flight, for instance, the WP-3D would take off at around 20:00. The ATR-42 and HALO followed at four-hour intervals. The scientists had to arrive at the airport approximately three hours before the scheduled departure in order to prepare and calibrate the instruments for the flights. The pilots, technicians and scientists who would be flying on board came to the hangar one hour before take-off. There was plenty to do in the intervening time – reviewing the systems one last time and discussing the flight sequence were crucial tasks. Those who were not part of the crew would leave the aircraft 15 minutes before take-off, and then it would be 'all systems go'.

While HALO flew according to a fixed flight pattern, the ATR-42 focused on deliberately approaching and examining clouds and areas of precipitation – a difficult feat on a night flight. Fortunately, the POLDIRAD cloud radar was operational and able to supply the necessary information directly to the aircraft. After the flights, the aircraft landed back at Barbados Airport. The data were then saved and the team discussed the performance of the individual instruments, problems that occurred during the flight, and the achievement of the

The aerosol and water vapour lidar implemented by the DLR Institute of Atmospheric Physics

Silke Groß in the HALO research aircraft

© DLR

© Max Planck Institute for Meteorology

The Meteorological Observatory BCO (Barbados Cloud Observatory) operated by the Max Planck Institute for Meteorology Hamburg, located at Deebles Point, Barbados.

scientific objectives, before finally heading off for a well-deserved rest at the end of a long day.

In addition to the HALO measurements, the researchers had planned to use POLDIRAD to monitor the development of the clouds over the ocean over a longer period of time. Unfortunately, the team had to leave Barbados earlier than they had envisaged due to the Coronavirus pandemic. The POLDIRAD weather radar equipment is still in Barbados. It is playing an important role in weather forecasting in the Caribbean, as it is currently the only functioning weather radar on the island. The Oberpfaffenhofen team plans to head back to the Caribbean in autumn 2020 to continue its weather radar measurements.

Silke Groß works at the Lidar Department of the DLR Institute of Atmospheric Physics and leads the Radar and Lidar Synergies working group.

PREPARATIONS FOR THE EARTHCARE CLIMATE MISSION:

EarthCARE (Earth Cloud Aerosol Radiation Explorer) is a research mission devised by the European Space Agency (ESA) and the Japanese Space Agency (JAXA) to examine aerosols and clouds, as well as their interactions and climate impact. Equipped with sophisticated lidar (light detection and ranging) technology, a Doppler cloud radar (radio detection and ranging) and sensors for measuring radiation, it is one of the most complex satellites for researching aerosols and clouds.

In the EUREC⁴A campaign, the HALO research aircraft flew with an almost complete suite of EarthCARE-like instruments (radar, lidar, spectrometer and radiometer). It is one of only two research aircraft worldwide for which this is possible. Such measurements emulate future EarthCARE studies and are providing some initial insight into how the instruments interact. This is also enabling the testing and further development of algorithms to be able to assess the strengths and weaknesses of future satellite measurements – an important step in preparing for the future satellite mission.

Planned launch:
2022

Duration:
3 years, plus 1 year of reserve fuel

Orbit:
Altitude 393 kilometres , Sun-synchronous

Instruments
Doppler radar (94 GHz), high spectral resolution lidar (355 nm), multispectral imaging spectrometer, broadband radiometer

THE CLOUD COLLECTOR

In conversation with Bjorn Stevens, Director of the Max Planck Institute for Meteorology in Hamburg and Head of the EUREC⁴A research campaign.

© Max-Planck-Institut für Meteorologie, Foto: F. Batier

Professor Stevens, you have led the largest international cloud research campaign to date. What were the challenges?
: EUREC⁴A is the result of more than a decade of work, largely in close collaboration with my French colleague, Sandrine Bony, and a particularly cooperative and creative community of German scientists from DLR and various universities who have worked in recent years to establish HALO as one of the world's most outstanding research platforms. So, the study went very well. Nevertheless, we had challenges. An interesting one arose of the different cultures of scientific practice among scientific groups. In atmospheric research, we are often interested in certain

> "What you do not measure sometimes provides more information than what you measure"

phenomena and then look for exactly these phenomena. In other words, we are chasing a signal. But this gives a distorted picture of how often and how strong effects occur. For a statistical study of the kind we wanted to conduct, the biggest challenge was convincing team members again and again that what you do not measure sometimes provides more information than what you measure. To see the big picture, you also need to understand what and how often things you expect to happen are not in the picture. So, things become meaningful through their absence.

What do you remember most about the campaign? And what did you learn about cloud formation and its effect on the climate?
: It is too early to say exactly how clouds influence the pace of global warming. However, we are very confident that we have collected the data required to answer this question. What struck me most about the campaign was that changing circumstances help us see each other in a different light – be it that young scientists took on responsibility or that we received local support to carry out our measurements. In terms of nature, I also have indelible memories of the campaign – the impact of the winds on water as a layer of air over the ocean cooled by evaporating rain, or the way the clouds flowed into the colours of the setting sun.

Where would you like to travel next for research and why?
: In August 2023 or 2024 I hope to find myself near 35 degrees west and 10 degrees north, in the North Atlantic Ocean between Venezuela and Guinea. There, in the deep tropics, air masses from the southern and northern hemispheres meet and create violent rain bands, the formation of which releases enormous amounts of energy that influence the climate worldwide.

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

© Max Planck Institute for Meteorology


© DLR

Measurement instruments are prepared for use in the HALO research aircraft

TAKING TO THE SKIES IN TIMES OF A PANDEMIC

The BLUESKY project investigates the atmosphere during the Coronavirus lockdown

By Falk Dambowsky and Valerian Hahn

DLR's Falcon research aircraft has seen a lot in its time – it has been used for scientific purposes for over four decades. Ten years ago, it was deployed as a 'volcanic ash hunter' when air traffic over Europe largely came to a standstill following the eruption of the Icelandic volcano Eyjafjallajökull. In the aftermath, the Falcon conducted measurement flights through the ash cloud, acquiring data that would prove important in assessing the situation and determining the right moment for European air traffic to resume operations. In May 2020, it embarked on another very special mission – to examine the sky during the COVID-19 lockdown, while most aircraft remained on the ground.

The Falcon was not alone as it performed these remarkable flights. It was accompanied by the High Altitude and Long Range Research Aircraft (HALO), which is also stationed at DLR's site in Oberpfaffenhofen. The German research team, which included many scientists from the DLR Institute of Atmospheric Physics, aimed to study the atmosphere during the lockdown resulting from the Coronavirus pandemic – a time of less air traffic and, as such, reduced air pollution.

Overseeing the mission while working remotely

Before the two research aircraft could take off, they had to be prepared at the DLR Flight Experiments Facility in Oberpfaffenhofen. Numerous instruments were installed and adapted as the aircraft were prepared for the upcoming mission under challenging conditions. This task was made somewhat easier for the team because the measures to equip the aircraft for other, previously planned, flight campaigns were still in place. Preparatory work for these missions had been suddenly halted due to the introduction of COVID-19 precautionary measures, and their planned flights postponed indefinitely. This meant that many important instruments had already been installed on HALO and Falcon, and only a few had to be newly installed and prepared. The COVID-19 precautionary measures forced experts across DLR to find ground-breaking solutions. Campaign organisation and certification activities for the aircraft and their instruments now had to be conducted from the scientists' desks at home. In order to get the aircraft flying as quickly as possible despite the restrictions, while also protecting the people involved, the on-site staff worked in daily shifts with minimal personnel. Wherever possible, instruments were prepared to allow monitoring and control from the scientists' home offices during the preparations and the research flights themselves.

Despite its ramifications, the pandemic represents the opportunity of a century for scientists to measure trace gases and aerosols in the air above European cities and at cruising altitude on flight paths. What impact do emissions from industry and air transport have on the atmosphere, and how much have these emissions been reduced by the restrictions put in place in response to the pandemic? How does air traffic affect the upper troposphere? These are the central questions being addressed by the BLUESKY project, which was launched at short notice during spring 2020 under the leadership of DLR and the Max Planck Institute for Chemistry. Prior to the campaign, a decrease in concentrations of nitrogen dioxide in industrial hubs and a marked reduction in contrails over Europe had already been demonstrated by satellite measurements evaluated by DLR. This gave rise to the assumption that the emissions of other trace gases and aerosols – microscopic particles that form when fossil fuels are burned, among other causes, and which have a bearing on cloud formation – had also been reduced. Unlike satellite images, which are taken from a considerable distance, measurements made on board research aircraft can deliver data with much greater precision and higher resolution, thus providing a more complete picture of the situation.

A bright blue sky

Following the initial measurement flights over Germany – from Oberpfaffenhofen to the Ruhr region and over Berlin and Hamburg – the two research aircraft flew to Milan. This region in the Po Valley is an important industrial and business location in Northern Italy. Due to the far-reaching pandemic measures introduced by the Italian government, the chances of measuring a corona-induced reduction of air pollutants in the boundary layer were particularly good there, similar to those above the Ruhr area. After a temporary, significant drop in road traffic in the weeks of the lockdown, cars were already visible on the roads again with the loosening of the restrictions, and factories gradually increased their production. However, one could not yet speak of 'normality'.

The BLUESKY team was particularly interested in the emissions from urban agglomerations. On this day, the exhaust plume from Milan drifted westward, spreading across the surrounding area and accumulating in the foothills of the Alps. Directly above the city and in the surrounding region, the Falcon's instruments recorded high aerosol and particulate matter levels in the boundary layer at an altitude of one to two kilometres. In contrast to these boundary layer measurements, the two DLR research aircraft flew at cruising altitudes between 10 and 12 kilometres above the Atlantic off the Irish coast in two flights. There, the team carried out measurements on the few remaining emissions from the 80 percent reduction in air traffic.

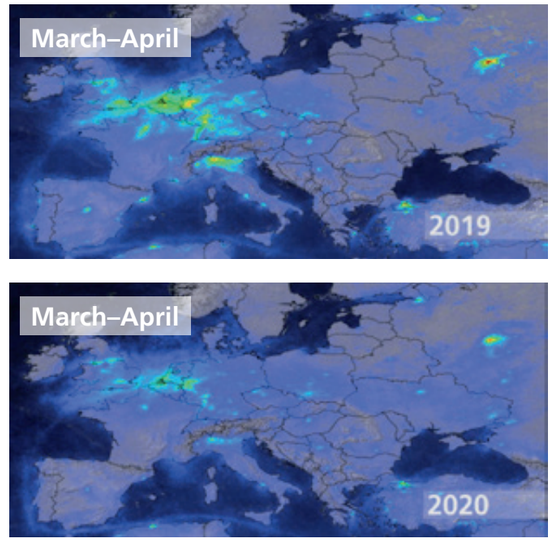
The airspace over western Ireland is flown through by passenger and cargo aircraft at the beginning of their North Atlantic routes on their way to America. The influences of air traffic are particularly easy to measure in the clean air over the ocean. HALO and Falcon's measurements focused particularly on nitrogen oxides and aerosols from passenger flights. The first results of the Falcon showed a slight decrease of aerosols in the upper troposphere. Among other influences, such lower aerosol concentrations in the air make the sky appear bluer.

Situation is comprehensively documented

Falcon and HALO took off for BLUESKY a total of 20 times from their Bavarian home airport in May and June 2020. The data acquired during these missions will be evaluated by the end of the year. The analyses will include comparative data from previous HALO research flight campaigns on air traffic emissions and emissions from conurbations. The coming year will also be interesting. There will be further measurement flights that the researchers hope will document the situation after the pandemic.

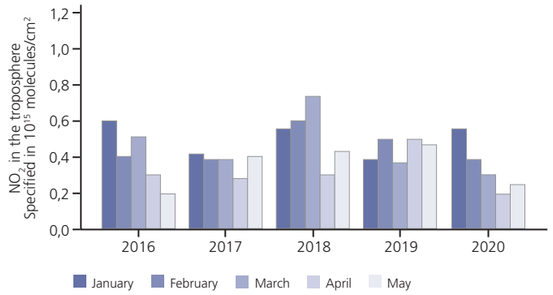
Falk Dambowsky is an editor in DLR Media Relations.

Valerian Hahn is a doctoral student working in the field of Cloud Physics at the DLR Institute of Atmospheric Physics.



Even before the BLUESKY flights, DLR's Earth Observation Center (EOC) detected a sharp drop in nitrogen dioxide over Europe compared to the previous year. The data originate from the TROPOMI sensor on board the European Copernicus Sentinel-5P satellite. Nitrogen dioxide is an indicator of air pollution from industrial activities and road traffic.

CONCENTRATION OF NITROGEN DIOXIDE IN THE ITALIAN PO VALLEY



Development of tropospheric nitrogen dioxide over the Italian Po Valley from 2016 to 2020, measured with the GOME-2 sensor on board the European weather satellite MetOp. The values from March to April 2020 are significantly reduced compared to previous years, while the values in May 2020 increased again after the lifting of the lockdown measures.

Measurements in the clouds above the Po valley

ALL-ROUNDER IN THE STARTING BLOCKS

Hydrogen has enormous potential as an energy carrier. DLR is working on making it as widely usable as possible.

By Denise Nüssle

This hydrogen supply system is located at the DLR site in Cologne. The Institute of Propulsion Technology uses it to develop and test new, efficient, powerful gas turbines for aviation and the energy sector.

Hydrogen already enjoys pole position in the periodic table. With the atomic number one, it is found right at the top. Will it soon become the hero of the energy and mobility transition, too? It certainly has what it takes. Hydrogen carries a lot of energy, burns cleanly, is easy to transport, and can be stored reliably over long periods of time. DLR is involved in all areas of hydrogen research and across the entire process chain. Its scientists are able to draw upon several decades of experience when it comes to harnessing the potential of this all-round talent of an energy carrier.

Hydrogen is an incredibly versatile energy source. It can address a wide range of applications for clean mobility, the efficient supply of electricity and heat, as storage to offset fluctuating renewable energy sources, as a basis for alternative fuels, or as a process gas in industry. Sustainable and cost-effective production of hydrogen is thus crucial for efforts to combat climate change through the massive reduction of harmful greenhouse gas emissions, particularly carbon dioxide, in the energy, industrial and transport sectors. At the same time, the establishment of a cross-sectoral and, if possible, global hydrogen economy will open up enormous opportunities for new technologies and business models.

Colour theory 101 – grey, blue and green hydrogen

On Earth, hydrogen occurs almost entirely in a chemically bound form, for example in water, methane or biomass. For it to be used as a source of energy, the hydrogen must first be extracted from these compounds. This is achieved using energy in the form of electricity or intense heat. ‘Grey’ hydrogen is mainly obtained from natural gas and currently accounts for around 95 percent of global production. However, this also results in considerable carbon dioxide emissions. ‘Blue’ hydrogen is obtained by separating it from these greenhouse gases and storing them, or produced using electrolysis, which relies on electricity from nuclear power. Only ‘green’ hydrogen is sustainable and climate neutral. Water and energy from solar, wind, hydropower or biomass are used in its production. Until now, producing it in significant quantities has been considered too expensive. Karsten Lemmer, DLR Executive Board Member for Energy and Transport, is confident that this is set to change in future. “First of all, the expansion of renewable energies must continue. In addition, large electrolysis systems should be installed in Germany as soon as possible. This is the first step towards making green hydrogen competitive.”

THE NATIONAL HYDROGEN COUNCIL

The council consists of 26 high-ranking experts from science, business and society. The members were appointed by the German Federal Cabinet in June 2020 and have expertise in the fields of hydrogen production, research and innovation, decarbonisation of industry, transport and buildings/heat, infrastructure, international partnerships, and climate and sustainability. The council advises and supports the German State Secretary Committee for Hydrogen by making proposals and recommending actions for the implementation of the National Hydrogen Strategy. Karsten Lemmer, DLR Executive Board member for Energy and Transport, is a member of the Hydrogen Council.

HYDROGEN RESEARCH AT DLR

INSTITUTES:

Institute of Propulsion Technology

Institute of Low-Carbon Industrial Processes

Institute of Vehicle Concepts

Institute of Composite Structures and Adaptive Systems

Institute of Air Transport and Airport Research

Institute of Future Fuels

Institute of Low-Emission Aero Engines

Institute of Maritime Energy Systems

Institute of Atmospheric Physics

Institute of Space Propulsion

Institute of Space Systems

Institute of Solar Research

Institute of System Architectures in Aeronautics

Institute of Engineering Thermodynamics

Institute of Combustion Technology

Institute of Transport Research

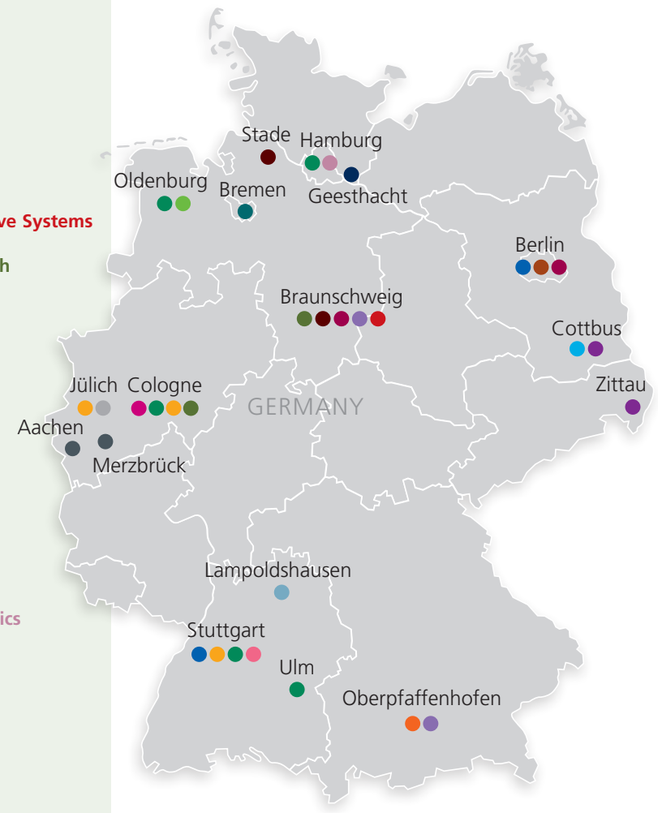
Institute of Transportation Systems

Institute of Networked Energy Systems

Flight Experiments Facility

Small Aircraft Technology Facility

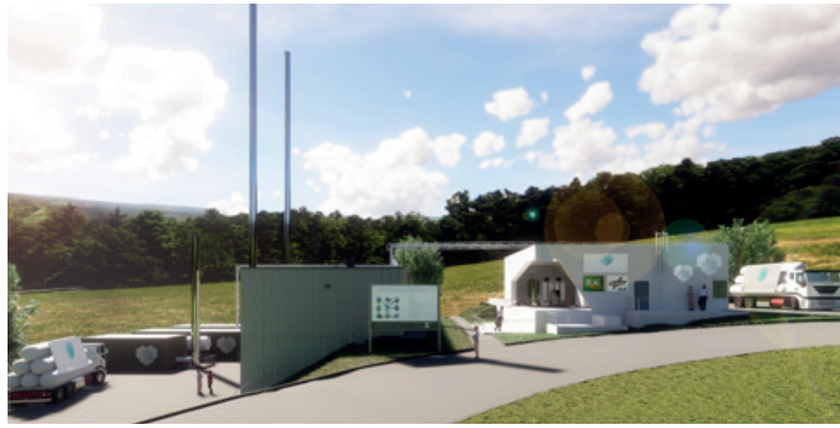
Center for Lightweight-Production-Technology



Towards green hydrogen – electrolysis and solar processes

DLR is focusing on two methods for the production of hydrogen on an industrial scale – electrolysis and solar thermal processes. Electrolysis is the most advanced form of this technology, and it is already commercially available. The principle, whereby water is split into hydrogen and oxygen molecules using electricity, has been known for over 200 years. At present, scientists are particularly interested in three technological implementations of electrolysis – alkaline, proton-exchange membrane, and high temperature electrolysis. DLR is involved in the development of all three. Germany currently has a total electrolysis capacity of 30 megawatts in place, powered by electricity from renewable sources. This capacity would have to be massively expanded in order to make the transition to a hydrogen economy. A study by the German National Organisation for Hydrogen and Fuel Cell Technology (Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie; NOW) envisages an increase in this capacity to 137–275 gigawatts by 2050. This will require both smaller, decentralised electrolysis systems – at filling stations, for example – and centralised, large-scale electrolysers with particularly high levels of efficiency.

Solar thermal processes for producing hydrogen promise higher efficiency, but they require lots of space. In this process, solar thermal power plants use solar energy to produce heat for thermochemical water splitting. DLR is continuing to develop components and systems that will allow these plants to be made as efficient, durable and suitable for industrial use as possible. The new DLR Institute of Future Fuels will play an important part in this endeavour. The first pilot plants are already in operation, but it will take several more years before the solar hydrogen production processes are ready for the market.



DLR's H_2ORIZON plant in Lampoldshausen is to produce 'green' hydrogen by means of electrolysis. The energy for this comes from the nearby wind farm, which is operated by the project partner ZEAG Energie. The hydrogen produced is then used in the site's combined heat and power plant, for fuel cell vehicles, or for rocket engine tests on the site's test stands.

Major hydrogen demand requires national production and imports

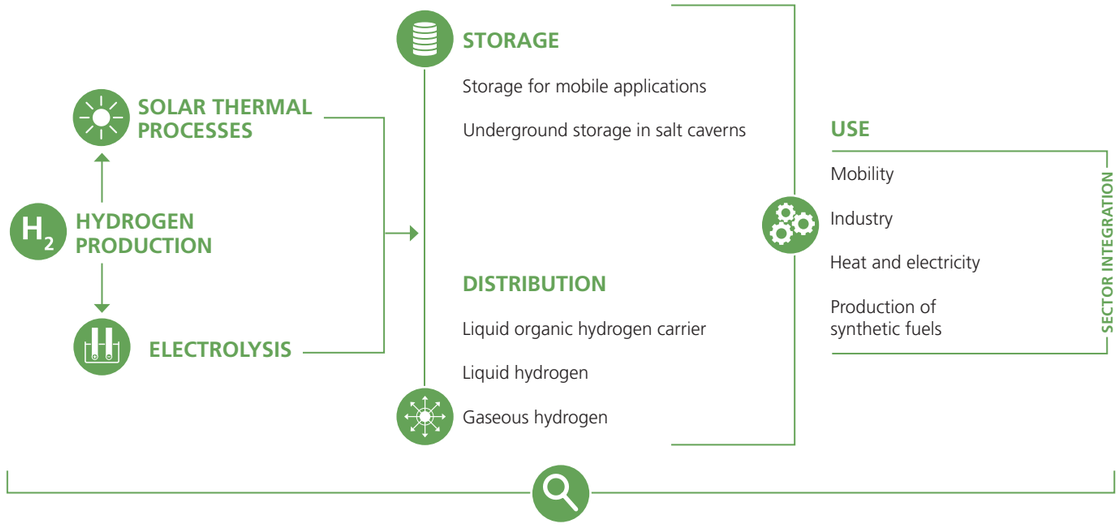
In order to meet the rapidly increasing demand for green hydrogen, it will be essential to significantly increase the power supply capacity from renewable energy sources. Germany's potential and available land area for this are somewhat limited. There are also issues with acceptance, such as those currently being experienced with wind power. "We will not manage to produce the amount of green hydrogen needed for the energy economy, industry and mobility in Germany. International solutions are needed. Large-scale hydrogen production should be established in sunny countries. Solar thermal processes have the highest potential to drastically reduce production costs. Global hydrogen logistics must then be devised for distribution," says Lemmer.

Within Europe, such hydrogen production is mainly suited for regions of Spain, Greece, and southern Italy. The production and export of hydrogen could be factored into a European 'green deal' and help to stimulate national economies following the Coronavirus pandemic. Countries in North Africa and the Middle East are also attracting interest from Germany and Europe for their potential in this area.

Transport, storage, and distribution – building and modifying infrastructure

In addition to production, cost-effective and reliable hydrogen transportation is essential for a future hydrogen economy. This involves both the transport routes from global production sites to nodes within the customer countries and local distribution to the end consumer. There are a number of possible approaches for this. The hydrogen could be transported in liquid form, or converted into ammonia, methane, or other liquid organic carriers. For now, it remains unclear which of these approaches will prove the most economically attractive. If hydrogen needs to be transported to an end consumer, it will probably be transported by lorry as a liquid or compressed gas. Another means of transporting and distributing hydrogen is to gradually convert the existing natural gas network into a hydrogen network. The German gas network consists of a

HYDROGEN PROCESS CHAIN – FROM PRODUCTION TO USE



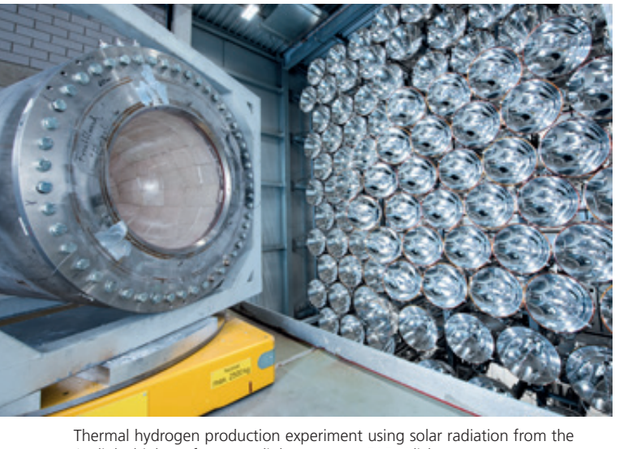
transport network that extends 40,000 kilometres, with a distribution network covering 470,000 kilometres. To a certain extent, it is already suitable for distributing hydrogen. However, the introduction of a larger proportion of hydrogen would require careful investigation and optimisation of the various materials, components, operating methods and user requirements.

Large storage facilities will be an essential part of the overall hydrogen infrastructure. They will be necessary to reliably cover seasonal peaks in demand, such as during colder and darker months. In Germany, underground salt caverns are considered to be particularly suitable for this purpose. DLR is examining the safety of such storage facilities, the durability of the materials used there, and how the quality of the stored hydrogen changes over time. It is also conducting research into possible business models for production and storage, and analysing the potential of different locations, particularly in northern Germany. For geological reasons, these areas are particularly suitable for the type of infrastructure required.

Sustainable hydrogen mobility for roads, rail, air and sea

Green hydrogen represents a sustainable alternative for many applications powered today by petrol, diesel, kerosene or heavy oil. At the same time, it preserves the conveniences to which we have become accustomed, allowing for long range travel and fast refuelling. Hydrogen fuel cells are characterised by high levels of efficiency and, unlike the direct combustion of hydrogen in engines and turbines, produce only water vapour as emissions. DLR is developing special fuel cells and new types of hydrogen tanks for mobile use and integrating them into the propulsion systems of cars, buses, lorries, trains, aircraft and ships. Hydrogen-based propulsion solutions have significant advantages over battery concepts when it comes to transporting heavy loads over long distances.

Private transport vehicles powered by hydrogen fuel cells are already available on the market. DLR experts are analysing their market share and adoption. The DLR Safe Light Regional Vehicle (SLRV), a concept vehicle, will have a highly efficient hydrogen drive and is scheduled to make its first trips in autumn 2020. Trains powered by fuel cells provide an emissions-free alternative to diesel locomotives or multiple unit trains on stretches of track without overhead lines. DLR conducted a study in which it examined the market for trains with hybrid drive concepts and, together with the rail vehicle manufacturer Alstom, developed and tested the world's first fuel-cell-powered multiple unit train. Additional trains and test regions are set to follow. The first buses with fuel cells are already on the streets as part of pilot projects, while several manufacturers are developing lorries with this type of drive.



Thermal hydrogen production experiment using solar radiation from the Synlight high-performance light source at DLR Jülich

How a future aircraft powered by hydrogen might look

A car powered by a hydrogen fuel cell as service vehicle at DLR Oldenburg

One focus of the new DLR Institute of Maritime Energy Systems is the use of hydrogen to power ships. The scientists are conducting research into aspects such as service life, suitability for everyday use, and the efficient integration of such systems. One example of such integration could be the simultaneous use of electricity produced using hydrogen to drive the ship's propulsion and refrigerate its cargo. DLR is also working with companies and research institutions to launch the world's first sea-going ferry to be powered with hydrogen fuel cells.

In aviation, hydrogen can be used as a fuel in modified gas turbines. This is of particular interest for large classes of aircraft, but requires the development of hydrogen storage systems that are compatible with aircraft and new combustion chambers. Powering flight with hydrogen fuel cells and electric propulsion systems has so far posed a highly complex technical challenge, but promises to be remarkably quiet, efficient, and emissions-free if successful. The use of liquid synthetic fuels based on hydrogen could also improve the sustainability of flight. In future, they could be deployed not only in aviation, but also anywhere that conventional drive systems cannot easily be replaced with climate-friendly alternatives such as batteries or hydrogen fuel cells. These fuels would require only minor adjustments to drivetrain components and infrastructure. In the DLR cross-sectoral project 'Future Fuels', 11 institutes are investigating the chemical and physical properties of such climate-neutral fuels and their performance, composition and cost-effective production methods.

Green hydrogen for power and heat

The energy sector is also set to benefit from this versatile source of energy. Hydrogen fuel cells and gas turbines can be used to generate a controllable supply of power and heat. The energy system of tomorrow will be based on renewable energy sources with fluctuating power outputs, and so a source such as hydrogen is needed to offset peaks in demand or reductions in supply. The aim is to achieve the highest possible levels of efficiency.

Only minor adjustments are required to convert current efficient gas-fuelled power plants to hydrogen usage. DLR is currently working with turbine and power plant manufacturers to investigate fuel cell versatility and devise concepts for making the combustion of natural gas and hydrogen mixtures as stable and low in emissions as possible.

Sector integration – networking as a key to success

Coupling of the mobility, energy, and industrial sectors will play a key role in this process. The more technologies and applications that are integrated into the system, the more flexible and stable it will become as a whole. Green hydrogen is crucial for sustainability here. At the same time, it is important not to limit considerations of the environmental impact of the necessary components to just their manufacturing phase. Given the limited nature of resources, it is important to find sustainable solutions for replacing or recycling them. Despite the myriad challenges, Karsten Lemmer is hopeful about the future: "The transition towards a sustainable hydrogen economy can only succeed if we think of networks, consider the power, heat, mobility and industry sectors together and find whole-system solutions."

Denise Nüssle is a Media Relations editor at DLR.

ARE WE ON THE BRINK OF THE HYDROGEN ECONOMY?

How? Why now? And why us? Using hydrogen to tackle the climate crisis.

An interview with Karsten Lemmer, DLR Executive Board Member for Energy and Transport.

© DLR

Hydrogen is not a new discovery, so why would it make its breakthrough right now?

: Sustainably produced hydrogen has the potential to be the central building block for an energy and transport system with massively reduced greenhouse gas emissions. In contrast to the past, we now have the technologies and global networks – and, due to climate change, the urgent need – to drive the use of green hydrogen forward. Hydrogen can be directly used and stored, and can form the basis for the production of sustainable liquid fuels. Although it has long been successfully researched, bold approaches to use hydrogen on a large scale are now required. The German Federal Government has provided a good impetus for this with its National Hydrogen Strategy. Germany can take on a pioneering role for a global hydrogen economy. This is an important step both for the climate and for Germany as an industrial and scientific location.

What do researchers and companies need to build a hydrogen economy?

: Massive investment is currently required in technology and demonstrations, as is further investment in basic research and the establishment of the conditions for widespread market introduction. It is also important to understand that this is an international issue. We will not be able to produce the amount of green hydrogen needed for the energy sector, industry, and mobility in Germany alone. International solutions are needed. In addition, to exploit our own generation potential and further research the technologies, the expansion of existing renewable energies must continue. In the short term, large electrolysis systems should be established in Germany. This will help to build up technological leadership and expand the distribution infrastructure. Large-scale hydrogen production should also be established in sun-rich countries. Solar thermal processes have the highest potential to drastically reduce production costs. Global hydrogen logistics must then be created for distribution. Establishing hydrogen-based propulsion systems in mobility is not only a consideration of cost, improvements to infrastructure and product range are necessary. And last but not least, legislators must also take action. Only effective measures for market introduction and incentive systems can ensure that green hydrogen makes its contribution to the energy and mobility transition.

How can DLR support the establishment of a hydrogen economy?

: In order to exploit the potential of hydrogen, the energy system must be considered in its entirety and with all its interactions. Here, DLR has built up unique expertise over many years through its synergistic activities across the fields of space, aeronautics, energy and transport. Nevertheless, there are still plenty of research questions surrounding hydrogen, These concern future synthetic fuels, new technologies for transport and storage, production technologies using wind and solar power, system integration at all levels of the energy system, hydrogen-based sector integration, hydrogen-based electricity regeneration processes, analytical technology assessment and transformation strategies, to name but a few. DLR therefore conducts research along the entire system chain, starting with the production of green hydrogen by electrolysis or solar generation, through to its use in the transport, industrial and energy sectors. Hydrogen offers solutions to the problems of our time – from a green electricity supply to carbon-dioxide-free transportation.

This interview was conducted by **Denise Nüssle.**

A POWERFUL DUO

DLR Jülich is increasing the potential for solar research with its Multifocus Tower

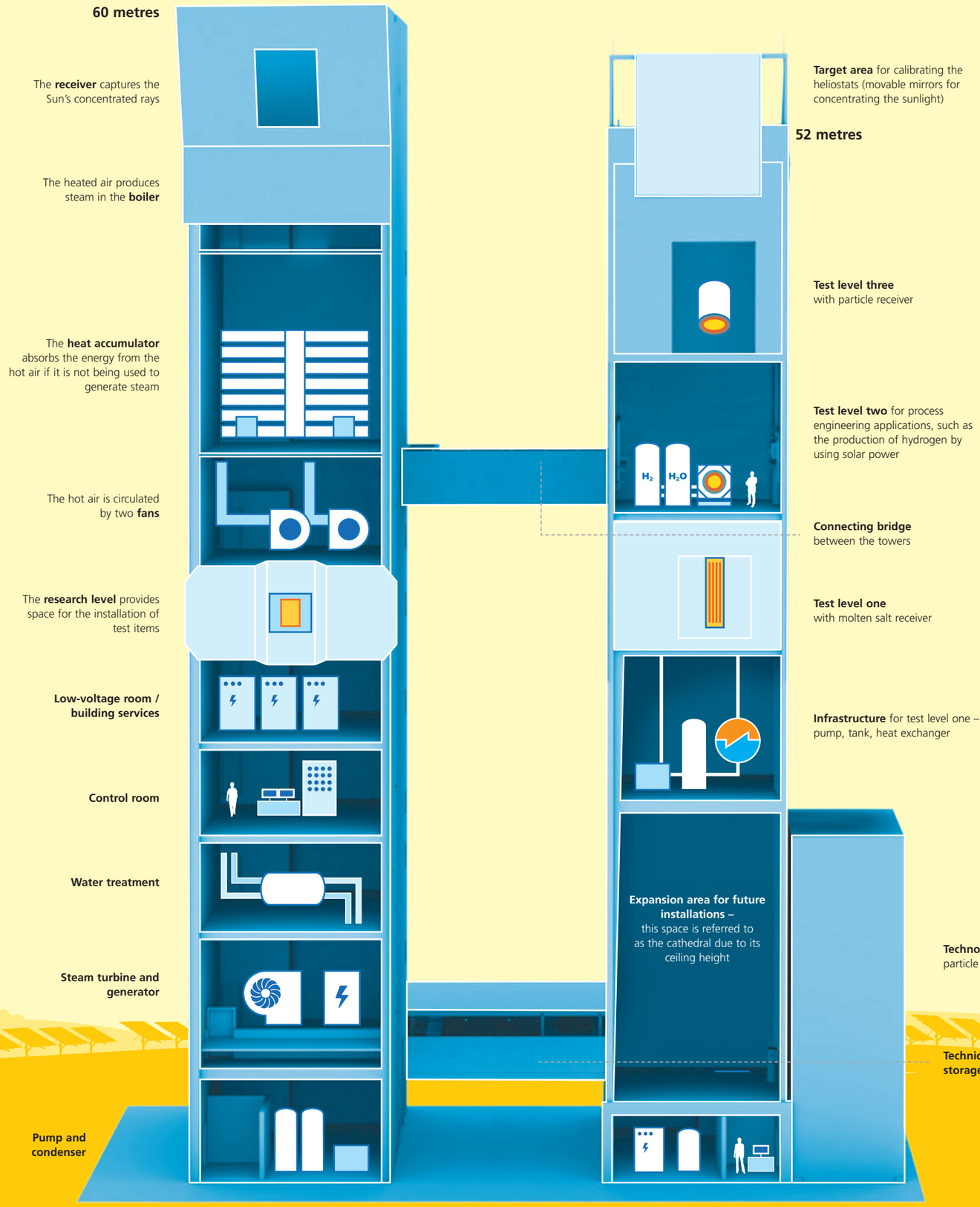
THE SOLAR TOWER

The Jülich Solar Tower is the only solar thermal tower power plant in Germany. It is used exclusively for scientific purposes. Here, DLR is investigating new solar tower technologies, production processes for solar fuels, and the use of solar process heat in industry.

Concentrated solar radiation is directed onto the receiver. There, the ambient air is heated up to 700 degrees Celsius and is transferred to a steam generator. The steam drives a turbine and a generator produces electricity.

The ceramic heat accumulator integrated into the plant ensures that electricity can be generated even when it is cloudy.

At the research level, experiments are currently being conducted to further develop air receiver technology.



THE MULTIFOCUS TOWER

The new Multifocus Tower has three experimental levels, where different forms of technology can be tested at the same time. The initial experiments on these levels are:

- The HEHTRES particle receiver – a thermal receiver that uses millimetre-sized ceramic spheres to absorb, store and transport heat,
- High-temperature process for the solar production of hydrogen,
- The HPMS-II molten salt receiver – here, salt is tested as a transport medium for high-temperature heat.

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Bilge Saruhan-Brings
Bilge Saruhan-Brings works at the DLR Institute of Materials Research in Cologne. She is Head of the Functional Coatings group in the Department of High-Temperature and Functional Coatings and is in charge of the H2020 project BAT4EVER, which deals with the development of self-healing batteries. In the image, she can be seen with her team members Delale Korkut, Jenny Roth and Apurba Ray (from left) in the electrochemistry laboratory.

POWERED BANDAGES

A DLR team is developing a special energy storage device

By Julia Heil

Rechargeable lithium-ion batteries have long proven their worth in our everyday lives. Unfortunately, they also have their drawbacks. In addition to insufficient charging and discharging speeds, their energy storage capacity is reduced following several charging and discharging cycles. They overheat quickly and can even ignite. In other words, they can be highly susceptible to failure. If this kind of battery is damaged, there is the risk that it will release electrolyte components that are hazardous to the environment and health. This also applies to other power storage devices that use liquid electrolytes. A team from the DLR Institute of Materials Research is working on a production process for a flexible, environment-friendly energy storage system that can overcome these disadvantages. Named 'polycap', it can absorb and release electrical current very quickly, and is also bendable and lightweight, similar to a bandage. The DLRmagazine editorial team spoke to Bilge Saruhan-Brings to find out what it is all about.

Lithium-ion batteries have drawbacks and can pose hazards when bent, curved or deformed in their everyday use. What makes your innovation special?
: We call these new power storage systems 'polycaps'. They cannot ignite, are environment-friendly, and are so thin and flexible that they can be attached to a base material similarly to bandages. They can even be integrated into components and textiles, such as fabrics on passenger seats, vehicle doors and aircraft wings. We can even produce them directly on various surfaces. They can also be installed in difficult-to-reach places, such as wind turbines and satellites or on mobile devices such as laptops or smartphones. Our polycaps have a lower energy density than batteries, but can go through more than 30,000 charging cycles. A conventional lithium-ion battery can only manage a couple thousand charging and discharging cycles.

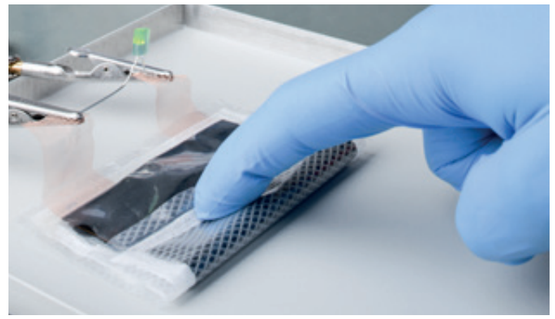
How did the name come about?
: Polycaps comes from the term supercaps, which is short for supercapacitors. Supercaps are hybrids between a battery and capacitor. Batteries can be charged with a given amount of energy over a long period of time – several hours. Capacitors, on the other hand, absorb far smaller amounts of energy over a very short time – within a few seconds to a minute – and release it immediately. Supercaps in turn are able to absorb and release moderate amounts of energy within minutes or even seconds and to store it for a short time. They are often used as a bridge between energy source and battery, for instance as electricity storage in intermediate gates. This can apply well to solar power plants, where they transfer energy from the collectors to the battery. Polycaps are essentially supercapacitors but they have a polymer electrolyte instead of a liquid electrolyte. We would like to transfer this technology to batteries in the near future.

You will need a new name …
: Yes, definitely! We will call them PolyBats.

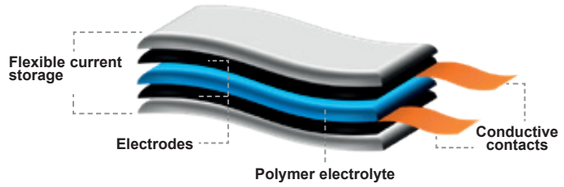
What are polycaps made of? How can you prevent the leakage of harmful electrolytes that can occur with supercaps and batteries and is damaging to health and the environment?
: The electrodes consist of carbon compounds to which a polymer has been mixed. These are much more environmentally friendly than the electrodes of lithium-ion batteries, which consist of lithium compounds. The conductive polymers of our polycaps also serve as binding agents for our electrodes. Currently, a combination of organic chemicals is used as binding agent in the lithium-ion batteries. These are mechanically weak and toxic and are difficult to dispose of. Our polymers not only bind, but also increase the conductivity of the electrodes and thus the storage capacitance. Instead of a liquid electrolyte, we use a polymer gel. These are carbon-based macromolecule chains with integrated ions for charge transfer. This gives our electrolyte more the character of a solid and prevents leakage. In addition, our current collectors are made of polymers instead of the conventional aluminium foils, which make them lighter and more flexible. I find the polycaps easy to bend, roll and fold, and they will still work perfectly. They can also withstand thermal shocks, endure exposure to radiation and are vacuum-resistant.

How do you actually manufacture the polycaps?
: When developing our products, we are guided by the known mechanisms of lithium-ion batteries. Our goal has been to produce a new electricity storage system that is as environmentally friendly, cost effective and efficient as possible. We use a combination of carbon nanotubes and conductive graphene particles for the electrodes. Embedded in the polymers, they form layers that are highly flexible yet extremely mechanically stable.

What applications are on the horizon?
: We can imagine many areas where the polycaps might be used, including the space, security and mobility sectors: any application in which every gram matters and high levels of power are needed for a short period of time. Another special feature is that we can use the polymers to give the polycaps additional properties. They can then be used like piezoelectric sensors, for example. These release energy when pressed; react as sensors whenever an external force is exerted on them, and vice versa.



Rolling, buckling or folding does not affect this new bandage type of energy storage cell. The diagram below shows the structure of the polycap.



Could this energy storage system also be used on aircraft?
: Sure, we considered this closely: the polycaps could be integrated into passenger seats on aircraft with thermoelectric generators (TEGs) that generate electrical current using the temperature difference between the ambient air and the passenger's body. This is fed into the polycaps and can contribute to the power supply of the on-board electronics. In addition, the polycaps could be installed with energy converters at decentralised locations where power supply is needed.

Given that you are likening the new energy storage system to a bandage (Band-Aid), do you also have healthcare applications in mind?
: Yes, absolutely, they open up new possibilities in this sector. The bandage batteries can be equipped with various power generators and sensors, enabling them to record and transmit information about patients' health in everyday settings or in hospital. If integrated into clothing, they can be used to store data in a similar way to current smartwatches. Sensors can also be embedded into battery cells to monitor battery life. Battery cells can be designed to act as low-load sensors at the same time. In our recently approved H2020 project BAT4EVER we will be conducting research to introduce self-healing polymers into battery components. These polymers are composed in such a way that the functional side chains of the molecules always come together, like magnets. This allows them to survive dents, holes and even cuts, and can be charged and discharged several times over longer periods of time, while retaining their high levels of performance.

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

WHAT ARE POLYMERS?

Polymers are chemical compounds. They are composed of large molecule chains. In the case of polycaps electrolytes, the polymers form a matrix in which the electrolyte material is embedded. This gives the electrolyte the properties of a flexible solid.

ANNIVERSARY IN THE ARCTIC CIRCLE

A decade of satellite data reception in Inuvik

By Bernadette Jung

Since June 2019, the satellite ground stations that make up the Inuvik Satellite Station Facility have been decorated with artworks by local indigenous artists. They symbolise important aspects of the traditional way of life of Inuvik's indigenous people. The image on the DLR antenna was created by Ronnie Simon of the Gwich'in people. Right: Station construction in 2009.

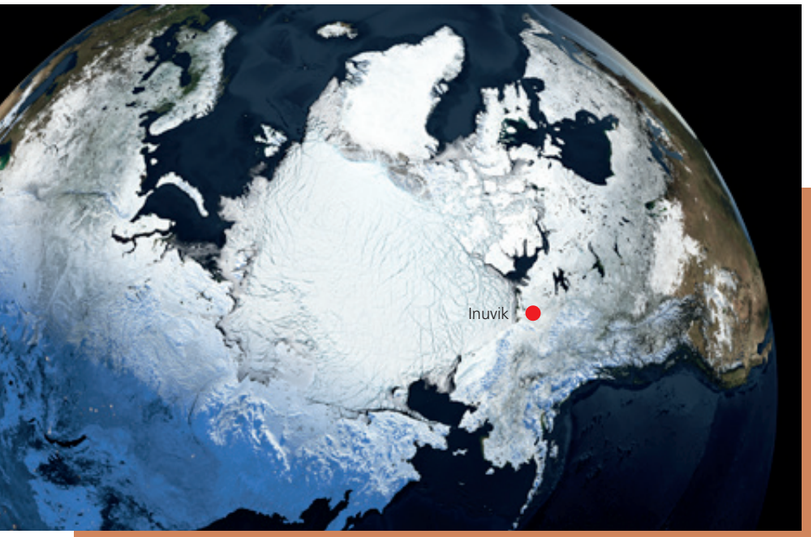
When the Sun is shining and there is no wind, Inuvik's annual average temperature of minus 10 degrees Celsius does not seem so bad. But when the weather turns, the Arctic reveals its true nature. Storm clouds gather in the infinite blue sky, gusts of wind blow a gale, and buildings and vegetation vanish into the white vastness within minutes. In winter, the temperature can drop to as low as minus 45 degrees Celsius. During the short summer, clouds of mosquitoes billow from the countless puddles, ponds and lakes. With temperatures rising up to 30 degrees Celsius, the permafrost is transformed into a slushy morass. Why on Earth would anyone want to set up a ground station here?

Inuvik lies within the Arctic Circle, in the Northwest Territories of Canada. It is located just 150 kilometres south of the Arctic Ocean, and less than 2500 kilometres from the North Pole. DLR's Earth Observation Center (EOC) has been operating an antenna for receiving satellite data in this inhospitable region for 10 years. The facility is DLR's second ground station in a polar region, following the German Antarctic Receiving Station GARS O'Higgins. Ground stations inside the polar circles make it possible to establish contact with the same satellite several times a day, as the orbit of most Earth observation satellites takes them near the poles roughly every 45 minutes. Inuvik can receive data from a satellite for up to two-and-a-half hours per day. This makes it indispensable for data-intensive operations such as those of the German TanDEM-X mission, which is used for three-dimensional mapping of Earth's surface. Since 2018, the antenna has also been used for the European Copernicus Earth Observation Programme and receives data from the Sentinel-5P environmental satellite.

At the time of its anniversary in June 2020 the antenna was not alone. While its inauguration was witnessed merely by trees and a few onlookers, the DLR ground station is now accompanied by other antennas. They are part of what has become the Inuvik Satellite Station Facility (ISSF). The ISSF currently comprises five antennas and is managed by the Canada Centre for Mapping and Earth Observation (CCMEO).

At home – indigenous art and chatting while shopping

The fact that the site is located on permafrost places special demands on antenna construction. Sixteen supporting pillars driven 14 metres into the permafrost ground keep the 31-tonne structure stable even during Arctic storms and thaws. This is the only method of ensuring that the 13-metre reflector can point accurately at the target satellites and maintain reliable contact with them as they fly overhead – even during extreme weather



A special place in the Arctic

Inuvik is located in Canada, at approximately 68 degrees north and 133 degrees west, and is accessible year-round by road via the Dempster Highway or by regional airlines. Inuvik means 'Place of Man' in Inuvialuktun. The city was founded in 1953 as a logistics centre in the Northwest Territories and was initially named New Aklavik. In 1958, it was renamed Inuvik. As of 2018, 60 percent of its inhabitants are of European origin, 25 percent are Inuit and 15 percent Métis. In addition to English, the local languages are Inuvialuktun and Gwich'in.

conditions. To date, the DLR antenna has recorded more than 30,000 passes by the TanDEM-X satellites alone. Up to 350 gigabytes of data are received every day and transferred to the EOC in Oberpfaffenhofen.

Yet its foundation is not the only thing that makes this ground station unique. As of last year, instead of the usual white paint, the Inuvik antennas boast an array of brightly coloured artworks. The DLR antenna is adorned by a typical Inuit ice fishing scene created by local indigenous artist Ronnie Simon, which is part of the 'Antenna as Canvas' project. The art installation transforms the Earth observation technological masterpieces into a remarkable symbol of the bond between the indigenous population and the station operators in Inuvik. Representatives of the Gwich'in, Inuvialuit and Métis people were involved in the construction of the station from the very beginning and blessed the facility during its inauguration in 2010.

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Erhard Diedrich, Head of the International Ground Segment Department at the EOC, has been involved from the very beginning – in Inuvik and at the GARS O'Higgins Antarctic Station, which was established 30 years ago.

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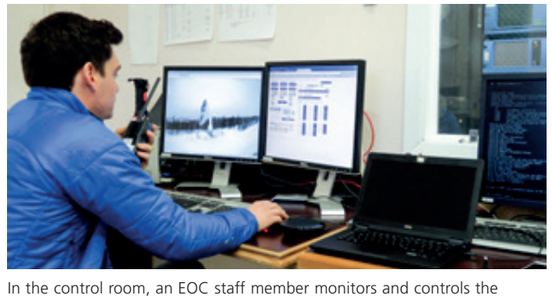

In the control room, an EOC staff member monitors and controls the mechanical work on the antenna.

Each of the approximately 3500 inhabitants is familiar with the satellite ground station, which sits on a hill overlooking the road between the settlement and Inuvik Airport, the lifeline for local supply and infrastructure. Thanks to the Dempster Highway and regional airlines, it is now accessible all year round. 'The Germans' are also familiar faces, as Erhard Diedrich of the EOC is well aware. Although the system is now largely automated and can be operated from Germany, it is visited by DLR employees two or three times a year to perform maintenance work. Diedrich is responsible for the DLR antenna and therefore a regular visitor to Inuvik. He frequently hears: 'Ah, you're from the ground station …'. "When I go shopping in town wearing my DLR jacket, people often approach me and strike up a conversation. It feels great to be greeted so warmly." This development is a particular source of pride for the remote sensing expert, as he had a lot of explaining to do in the beginning. "Back in those days, my explanations of what I was doing in Inuvik were met with incredulous astonishment and a certain amount of head-shaking," he recalls. After more than 10 years of activity by the EOC team, it is as though the receiving facility has always been there; it is simply part of the local scenery.

Sustainability – research instead of mining

The construction and operation of the Arctic antenna was considered hugely important – not just among German researchers. Canadian government authorities and research partners have supported the scientists' ambitious project since they first made contact, and remain the driving force behind remote sensing activities in Inuvik to this day. Like the local Aurora College, the ISSF satellite ground station with its DLR antenna is an example of the sustainable facilities that are urgently needed in Inuvik. For decades, northern Canada has been dominated by mining. This is putting increasing pressure on the highly sensitive Arctic ecosystem and is affecting the regional economy due to fluctuating yields.

Discussions between DLR, CCMEO and the government of the Northwest Territories led to a special expansion of the ground station, which included the Herculean feat of laying a fibre-optic connection to Inuvik. The Mackenzie Valley Fibre Link traverses more than 1115 kilometres of Arctic permafrost and was completed in 2017, within two years. Previously, Inuvik's telecommunications with the outside world relied on microwave relay stations along the Dempster Highway. The new fibre optic link is used not only to operate the ISSF, but also provides Inuvik's inhabitants with a fast internet connection, which they can use to access training and telemedical care, for example.

The Earth observation data received by the DLR ground station provide information about the condition of Earth's surface, ice, vegetation, oceans and atmosphere. Permafrost regions around the globe are currently experiencing massive changes as a result of global warming. The permafrost is thawing. Parts of the Canadian coast and infrastructure are already being lost due to the onset of erosion. Yet the real danger lies within the ice itself. The frozen ground stores enormous quantities of greenhouse gases, which are released when it thaws. Monitoring such changes over vast expanses of land is only possible with space-based Earth observation. Satellites can make a real contribution to understanding the Earth system and supporting international measures to combat climate change.

Due to its permafrost, Inuvik is also a focal point for environmental and climate researchers from all over the world, who come here to investigate the changes directly on site. They receive support from the Aurora Research Institute, which puts offices, laboratories and technical equipment at their disposal. In cooperation with their counterparts from the EOC, data services may soon be added to the list, including information about the current state of the ice derived from radar data. The DLR Earth Observation Center has initiated sustainable development with its first receiving facility in northern Canada. The remote sensing experts from Oberpfaffenhofen look back on 10 years of successful data reception operations. They also look forward to the advancement of research over the coming decades. Its close proximity to the pole, good supply routes, rapid internet connection and, most importantly, the warm welcome on the ground, make Inuvik the ideal place to receive data from international satellite missions. The EOC is quite at home in the Arctic.

Bernadette Jung is an editor at the DLR site in Oberpfaffenhofen.

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INUVIK SATELLITE STATION FACILITY

The DLR ground station in the Arctic is run by the German Remote Sensing Data Center, part of the Earth Observation Center. It is located on the site of the Inuvik Satellite Station Facility (ISSF), which is managed by the Canada Centre for Mapping and Earth Observation (CCMEO). The ISSF has four more antenna systems, which are operated by the Swedish Space Corporation (SSC), Natural Resources Canada and the French space agency CNES (Centre National d'Etudes Spatiales).

© Maxar DigitalGlobe, processed by DLR

Automatic damage assessment of Beira, Mozambique, following the tropical cyclone Idai in March 2019: In DLR's Data4Human project, damage to buildings in settlement areas is recorded using intelligent data processing methods from the field of remote sensing. This data is then made available to humanitarian aid organisations.

HIGH-TECH HELPING HAND

A DLR initiative is developing new technologies for humanitarian aid

By Bernadette Jung

Every night, one in nine people go to bed with an empty stomach. The consequences of climate change, natural disasters and armed conflicts threaten the livelihood of many. However, the number of people receiving little to no help is constantly on the rise. Germany is one of the world's largest providers of humanitarian aid and is renowned for its dedicated, professional work. These qualities are in urgent demand within the global community, as the need for humanitarian aid has been growing for years. Aid organisations are now increasingly turning to technological support in order to make their measures more effective and sustainable. DLR has long served as a partner in this field and is now intensifying its commitment.

In May 2019, DLR's Space Research and Technology Directorate launched an initiative that places humanitarian technology needs at the heart of its research. The Humanitarian Technologies initiative draws upon DLR's expertise for humanitarian purposes. In this project, cutting-edge technologies are being further developed and deployed for humanitarian purposes.

The initiative connects DLR experts, both internally across different disciplines and institutes, and externally with humanitarian aid organisations, political decisionmakers and other stakeholders. Achieving successful outcomes requires interdisciplinary and international cooperation between those involved with humanitarian aid, stakeholders within the affected countries and the research sector. The network partners exchange experiences and identify needs. These range from logistical support for people and relief supplies, to monitoring of the humanitarian situation and the status on the ground, dealing with the causes and consequences of climate change, avoiding the root causes of migration, and providing a decentralised energy supply in disaster-stricken regions. The results of this close dialogue are used to develop tailor-made technologies.

"It is good to see that the humanitarian community is so open to technological innovation," says Stefan Voigt, Coordinator of the Humanitarian Technologies initiative. "Since the launch of the initiative, new non-governmental organisations and stakeholders have been approaching us with questions and requests. We have already come up with lots of good ideas for new projects as a result." The first two projects of the initiative – the mobile greenhouse 'MEPA' (see info box) and the data service 'Data4Human' – were launched at the beginning of this year.

Innovation from adversity

In acute crisis situations, reliable data and information are important for assessing the overall situation and initiating appropriate actions and measures. Often, however, this information is simply not available to aid organisations. Telecommunication networks within the crisis-stricken regions may be damaged or even fully destroyed. In addition, it is sometimes difficult or impossible for humanitarian NGOs to use large information mechanisms, such as the International Charter 'Space and Major Disasters', which provides rapid satellite data for emergency management free of charge in the event of a disaster. This means that they need to find other ways of assessing the situation.

With that in mind, the Data4Human project team is developing a data service for humanitarian aid. Data4Human combines conventional remote sensing data from satellites, aircraft and drones with web-based information. Social media, news portals and other freely available web services can serve as up-to-date data sources. By combining these different data sources, stakeholders can get a sense of the overall situation quickly, reliably and with insights at a local, regional and even global level. DLR is combining Earth observation and web technologies for this purpose. The individual tools and functionalities of the data service are being developed by scientists from DLR's Earth Observation Center (EOC) and the DLR Institute of Data Science together with the United Nations World Food Programme (WFP), the German Red Cross, the Humanitarian OpenStreetMap Team and Human Rights Watch.

© DLR-ZKI

In the event of a disaster, DLR provides fast and reliable situation assessment based on up-to-date satellite data. In future, Earth observation data will be increasingly combined with information from the Internet.

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In the Data4Human project, DLR scientists are working with users to develop a data service that is tailored to the needs of humanitarian aid organisations.

WHAT IS HUMANITARIAN AID?

The overarching goal of humanitarian aid is to provide needs-based assistance to people in emergency situations or at risk of finding themselves in acute hardship due to crises, conflicts, natural disasters and other causes. The aim is to enable those affected to survive with dignity and security, to alleviate the suffering of those who are unable to overcome their acute emergency on their own, and to provide these people with future prospects. This work is often conducted in difficult political circumstances, in poor security situations, and often under huge time pressure. Maintaining the humanitarian principles of humanity, impartiality, neutrality and independence is therefore a key prerequisite for humanitarian aid. As the number of humanitarian emergencies increases, and with them their duration, the need for humanitarian aid continues to grow. Today, more people than ever depend on humanitarian aid.

Humanitarian mission in the Dominican Republic: In July 2018, the DLR Institute of Flight Systems conducted flight tests to transport relief supplies to hard-to-reach areas with the unmanned helicopter superARTIS. The flights were planned and monitored from the mobile ground control station.

The small unmanned helicopter superARTIS (Autonomous Rotorcraft Testbed for Intelligent Systems) is operated as an experimental carrier by the DLR Institute of Flight Systems. Its range, robustness and payload capacity make it well suited for humanitarian missions.

© DLR

With each flight, the unmanned helicopter transported up to 25 kilograms of food, water and medicine, six kilometres over the Enriquillo salt lake, safely dropping the payload boxes on the other side.

The combination of Earth observation data from space and analysis from the Internet is new and is driving research at DLR. Although the field of humanitarian technology is still relatively young, it offers huge potential for innovation, and DLR is one of its pioneers. Approximately 20 years ago, EOC experts began processing satellite data for disaster management purposes. Today this expertise is in high demand and is being further developed for humanitarian applications. The WFP has already used it to create its Spatial Risk Calendar, which is intended to more accurately assess and predict the spatial patterns of recurring natural disasters to ensure global food supply. Since 2019, the world's largest humanitarian organisation and DLR have been working together to develop and implement technologies to assist the United Nations in achieving the 'Zero Hunger' sustainability goal.

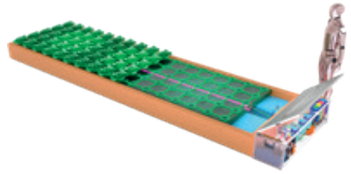
Earth observation data for emergency aid

The Data4Humanproject includes the development of automated mapping of damage to infrastructure and buildings in the wake of natural disasters. The EOC uses and continues to develop its own data processing methods from the fields of big data and machine learning. Rapid, interactive maps of disaster areas are also being generated in cooperation with the Humanitarian OpenStreetMap Team. As part of the project, the scientists are also working on the possibility of using remote sensing data to detect and document human rights violations such as the displacement of the Rohingya people in Myanmar. Knowing when particular villagers were forced to leave their homes is important to Human Rights Watch and their ability to present a well-founded documentation and research accordingly. Other possible applications include monitoring migration or the support of transitional development assistance, such as by observing how quickly reconstruction progresses following a disaster. The humanitarian partners should be able to use these operational data services from late 2021 onwards.

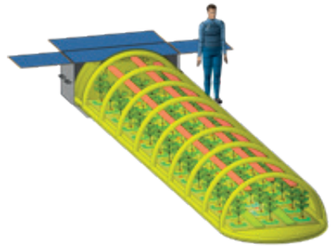
An important part of the current innovation is driven by technology transfer from DLR space research, but is not limited to this field. One example is the use of unmanned aerial vehicles to drop relief supplies in disaster-stricken regions that are difficult to access. DLR tested this technology successfully with an unmanned helicopter in the Dominican Republic in 2018. Other successful DLR research projects with a humanitarian focus include the treatment of drinking water using solar power, the development of warning systems and the detection of land mines by radar. In future, technological developments for humanitarian search and rescue operations or robotics applications could also be used in life-saving missions.

MEPA – MOBILE GREENHOUSES

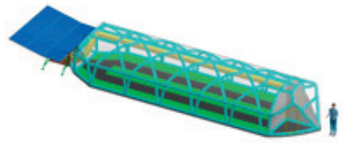
MEPA offers the possibility of cultivating fresh food in disaster-stricken regions. It is one of the first projects of the Humanitarian Technologies initiative. Experts from the DLR Institute of Space Systems and the Institute of Aerospace Medicine have developed three concepts for this purpose. All plant cultivation units have a few things in common: they do not require any soil, are reusable, can be used individually and easily, allowing fast plant production, with the first harvest after just four to six weeks.



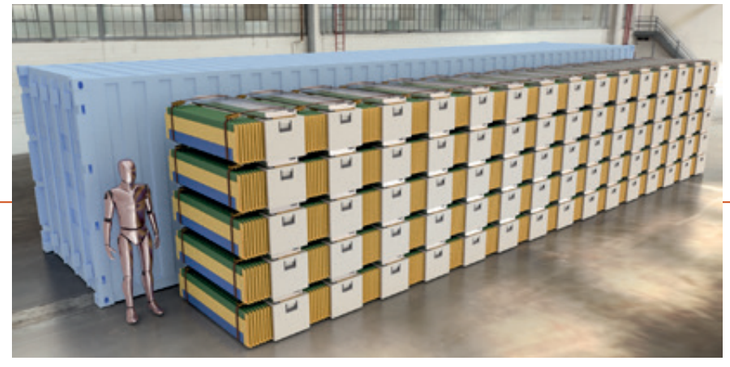
The **'basic system'** is based on hydroponics in open water tanks. The cultivation area is seven square metres and can yield 85 heads of lettuce, weighing around 42 kilograms in total, in each harvesting cycle. The system is equipped with an automated solar-powered support unit.



The **'hybrid system'** has an area of approximately 20 square metres and is suitable for growing small plants. The inflatable greenhouse is just under one metre tall and houses a seed-cultivation mat that can be illuminated with LED strips. The semi-closed system allows water to be recovered and is powered with solar energy.



A **'closed-loop system'** has been devised for tall-growing or larger varieties of vegetables such as tomatoes and cucumbers. The walk-in greenhouse is three metres wide and 17 metres long. It offers a cultivation area of roughly 30 to 40 square metres. Irrigation, ventilation, temperature control and energy supply create a closed circulation system and are controlled by support modules. Up to 21 units can be transported in a freight container, providing a total harvest area of 350 square metres.



When folded, up to 75 MEPA basic system units can be transported in one container.

Bridges to a better future

"We are involved in an exciting field of research and are just starting to harness the true potential of applying DLR technology to humanitarian tasks," says Voigt. "It is fascinating to see the level of motivation and commitment that the scientists and humanitarian organisations are bringing to the initiative. Being able to support humanitarian aid with our research and thus providing relief to people in need is very rewarding. It makes our work more meaningful."

When DLR satellite experts created the first emergency maps 20 years ago, few people had a laptop and only one in seven people owned a mobile phone. There are now more mobile phone connections than people on Earth, and on average almost every other household in developing countries has internet access. Technological progress has also improved the scope for humanitarian aid in such regions. Yet as the growing demand shows, the situation is not improving fast enough. Plans are currently underway for the next batch of DLR Humanitarian Technologies projects, due to begin in autumn 2020, so that help can be provided where there is the greatest need.

Bernadette Jung is an editor at the DLR site in Oberpfaffenhofen.

Two questions for Thomas Zahneisen, Director for Humanitarian Assistance, German Federal Foreign Office

NEW TECHNOLOGIES FOR EFFECTIVE ASSISTANCE

In recent years, Germany has increased its funding for humanitarian aid and has become one of the biggest donors worldwide. Why?

Thomas Zahneisen: The need for humanitarian aid has increased in recent years, and more people are dependent on humanitarian aid than ever before. Germany has reacted to this and has continuously increased its humanitarian aid support for several years now: in 2019 1.64 billion euros were provided for humanitarian aid. In 2008, the figure was 59.6 million. Despite all the solidary commitment of donor countries such as Germany, the gap between demand and available resources has not yet been closed. In 2019 the German Federal Foreign Office, which is responsible for this task, published its new Strategy for Humanitarian Assistance Abroad 2019 - 2023, which sets the course for the future and gives special attention to innovation.

Where do you see a need for innovation?

Thomas Zahneisen: Humanitarian assistance must reach people in need more effectively and quickly and the gap in unmet needs must be reduced. It is not only about innovation steps in the technological field, it is also about improving processes and procedures, or even completely new ways of thinking. For example, digital technologies make cash and voucher solutions more secure, and they also make it easier to involve local stakeholders and aid recipients. Since the Federal Foreign Office does not implement aid projects itself, but relies on partnership-based cooperation with United Nations humanitarian organisations, the Red Cross and Red Crescent Movement and humanitarian NGOs, we address concrete innovation needs primarily through direct contact with these organisations. We also support lighthouse projects such as the WFP Innovation Accelerator in Munich.

Two questions for Bernhard Kowatsch of the United Nations World Food Programme (WFP). He heads the Innovation Accelerator of the World Food Programme.

INNOVATIONS SUPPORT PEOPLE IN NEED

How is the World Food Programme using cutting-edge technology in the fight against hunger?

Bernhard Kowatsch: Innovation has been part of the World Food Programme's DNA since it organised its first humanitarian airlifts in 1962. Today we use cutting-edge technology such as artificial intelligence and satellite observation. Our 'Skai' application, which uses artificial intelligence to analyse satellite images of natural disasters, and 'HungerMapLive', a global hunger monitoring system, help us assess hunger, predict emerging crises and plan humanitarian response. In WFP's food assistance, we make increasing use of cash-based transfers, vouchers and electronic means of payment, enabling people to buy the food they need in local shops while supporting the local economy. Blockchain technology is used to do this – in 2019 it provided over US$2.1 billion to 28 million people in 64 countries.

What opportunities does the Humanitarian Technologies initiative offer WFP and other humanitarian agencies?

Bernhard Kowatsch: It provides support through cutting-edge innovations and technologies. Research on self-driving cars is now helping us develop remote-operated all-terrain amphibious vehicles for food delivery, and remote sensing technologies support the assessment of food crises or natural disasters. It is about the adaptation of technology to real problems that we face and providing the best possible support to those most in need. Together we can achieve much more. The initiative is also a mutual collaboration, where, for example, our experience in hydroponic agriculture may inform food sustainability in the future of space travel. We are thrilled that this dialogue exists between DLR and WFP, which can fertilise the seeds of new ideas for humanitarian response in the future.

↗ WFP's global hunger monitoring system: **hungermap.wfp.org**

IN BRIEF

MOBILE MEASUREMENT VEHICLE EXAMINES AIR POLLUTANTS

DLR researchers are using a converted van as a mobile laboratory for measuring soot, nitrogen oxides and carbon dioxide concentrations in the air. The vehicle was equipped with instruments and sensors at the DLR Institute of Combustion Technology in Stuttgart. These are intended to identify pollutant hotspots such as traffic junctions, and locate emissions sources. They are mainly focusing on ultra-fine particles less than 100 nanometres in diameter. These are so small that they can penetrate deep into the human respiratory tract and remain there. Conventional environmental measurement technology and simple sensor solutions do not usually detect these tiny particles. The measurement vehicle is currently travelling around and conducting air quality investigations in places such as cities or in the vicinity of airports. However, it can also be used to conduct investigations into road traffic and shipping, or to perform waste gas analysis for industrial combustion processes.

The mobile measurement vehicle being used on the Marienplatz in Stuttgart

Image: Pixabay

Passenger transport services continue to increase

GLOBAL ROAD TRAFFIC IS GROWING WITH PROSPERITY AND POPULATION

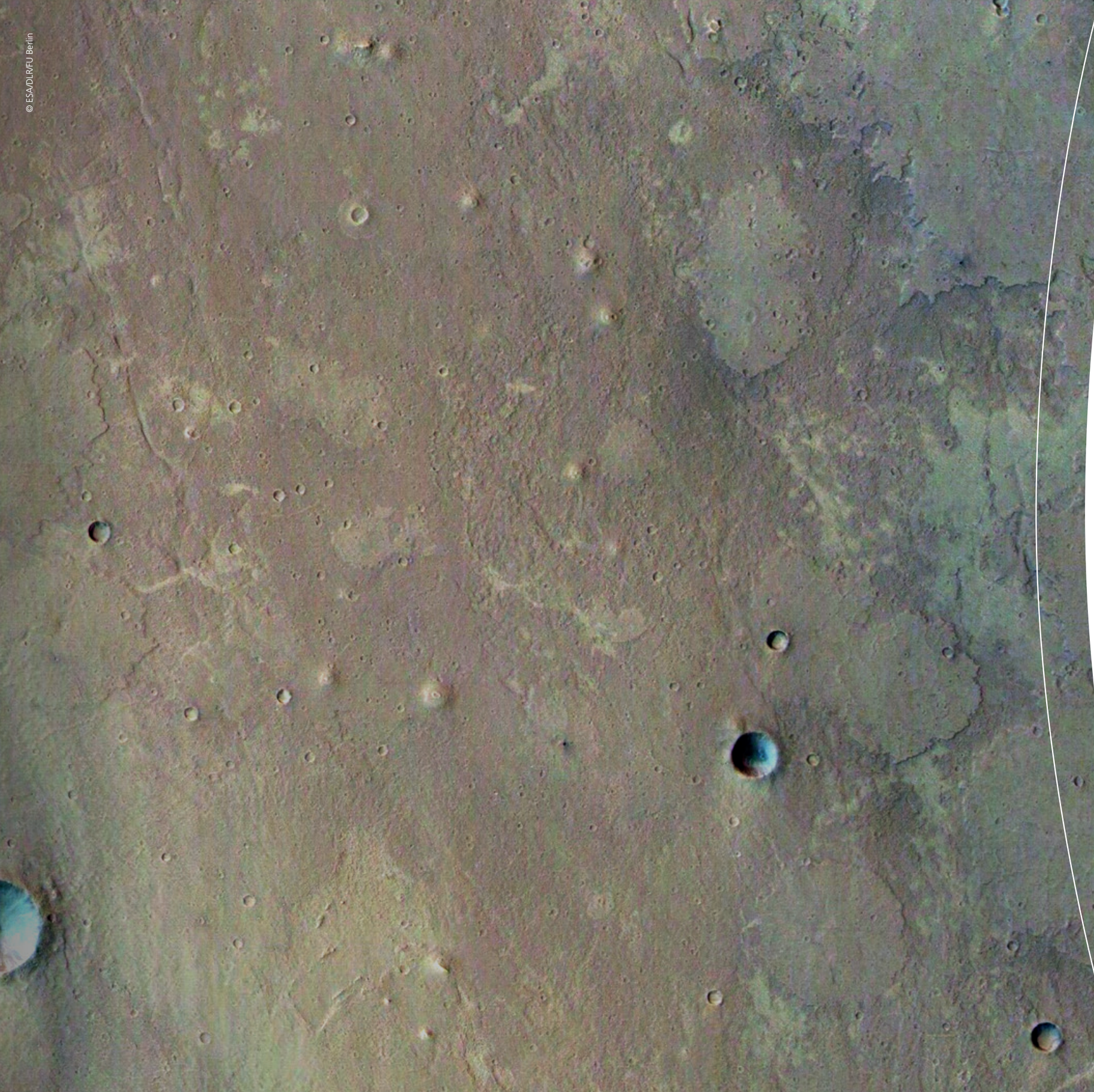
Currently, approximately two billion people worldwide have access to 1.2 billion passenger vehicles. In the view of transport researchers, this number will continue to rise significantly, because the growing population and increasing prosperity in many countries until the 2070s will lead to increased vehicle ownership and higher vehicle mileages. In the Transport and Climate Project (TraK), led by the DLR Institute of Transport Research, a consortium of eight institutes is working to estimate the effects of increasing traffic volumes on the global climate. Based on the results, they are seeking sustainable technological developments and alternative mobility options. To this end, the team from the Institute of Transport Research simulated worldwide vehicle numbers and global mileage up to the year 2100 and found that the global number of passenger vehicles could grow to 3.1 billion by 2050 and to 4.4 billion by 2100. However, if rail passenger transport were to be significantly expanded in parallel with road transport, it would be possible to restrict the growth in the number of cars to less than 3.4 billion by 2100.

IMPROVING LEARNING

Climate models are currently being honed in over 40 research centres as part of the Coupled Model Intercomparison Project Phase 6 (CMIP6) under the Global Climate Research Programme, which is led by the DLR Institute of Atmospheric Physics. The models are being used to calculate the impact of climate change on the global increase in temperatures and regional trends such as intensity of precipitation. As such, they are important tools in supporting the work of decision-makers in government, national planning and business. In a study, a team of climate researchers from Imperial College London and DLR's Atmospheric Research and Data Science divisions was able to demonstrate how new data-based machine learning methods can be used to evaluate climate models and improve our understanding of climate change.

High-performance computers are at the heart of research into simulations in many areas of research

© DLR/Thomas Ernsting



© ESA/DLR/FU Berlin

MUD VOLCANOES ON MARS

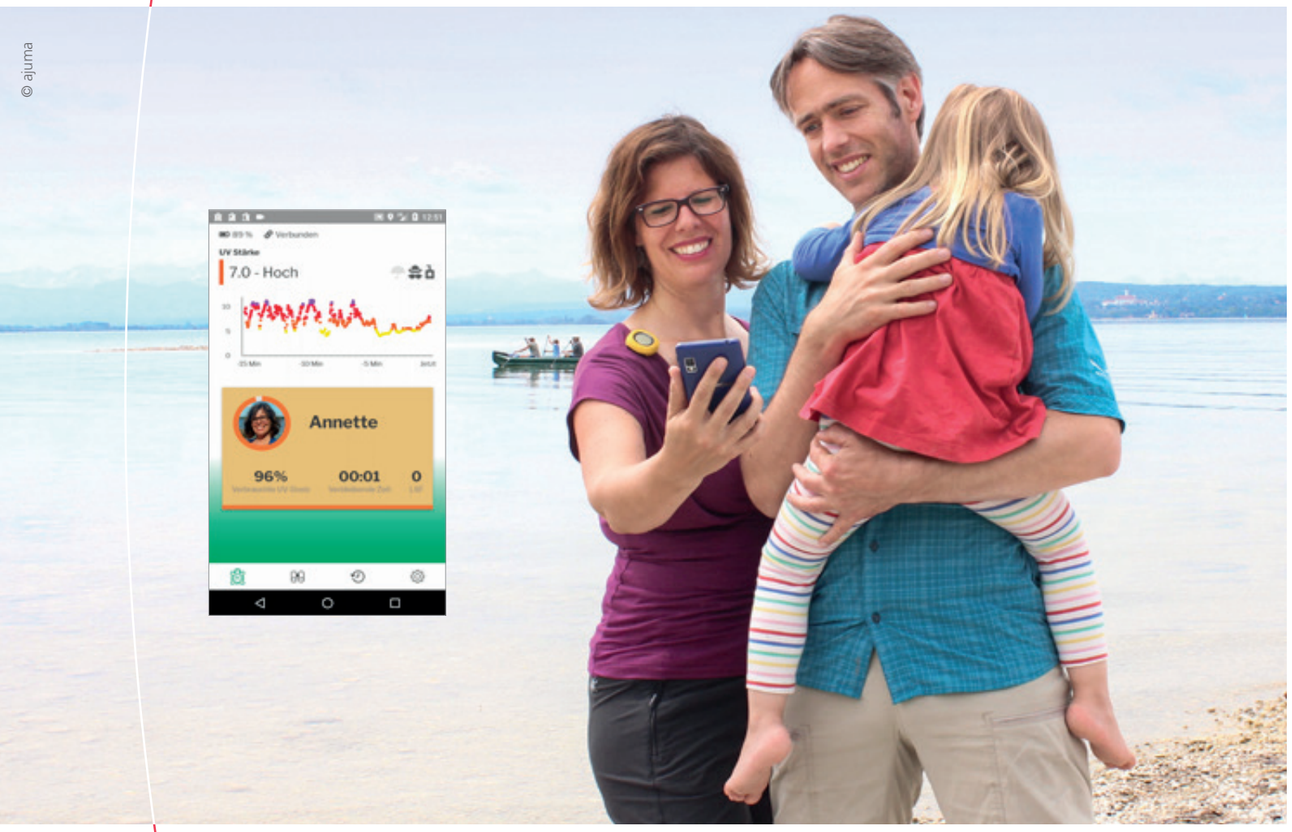
Planetary scientists have long debated whether Mars is home not only to ‘fire-breathing’ – that is, magma-fed – volcanoes, but also mud volcanoes. The DLR Institute of Planetary Research has been involved in laboratory experiments that show that mud on Mars behaves similarly to molten lava on Earth. Dozens of small hills with a central crater have been discovered in the Chryse Planitia lowland area of Mars; an example can be seen to the left of centre in this image. These may be the result of mud volcanism. The flat, bright areas on the right, which resemble pancakes or cow pats, may have been formed by flowing mud. For comparison, the crater that is partially visible at the bottom left of the image has a diameter of approximately 2.9 kilometres. Research into the behaviour of water-containing mud on the surface of bodies with thin or no atmospheres is also relevant for some asteroids (such as Ceres) and icy moons in the outer Solar System. Geologists have identified approximately 1800 mud volcanoes on Earth, many of them on the sea floor.

The Chryse Planitia region was imaged by DLR’s High Resolution Stereo Camera (HRSC) on board ESA’s Mars Express spacecraft. These and other images of Mars can be downloaded at a printable resolution at: **DLR.de/hrsc-mars-images-flickr**

SMART WITH THE SUN

The UV-Bodyguard early warning system from DLR's spin-off 'ajuma' protects users from excessive levels of solar radiation

By Verena Müller



© ajuma

Sunlight is crucial for maintaining healthy vitamin D levels. But too much UV radiation can be very unhealthy, causing sunburn or, in extreme cases, leading to skin cancer. As always, the right amount is key. But how does one know what the correct level for a particular skin type is? A small device is here to help – UV-Bodyguard from the DLR spin-off 'ajuma' is a UV measurement assistant developed based on DLR know-how.

The UV-Bodyguard sensor is connected to a smartphone app and continuously measures UV radiation in real time. It sends the data to the smartphone and warns the user about high radiation levels and the risk of sunburn. At the same time, it also indicates how long the user should stay in the sun to top up their vitamin D levels. In this interview, ajuma founders Annette Barth and Julian Meyer-Arnek explain how the device works.

Annette Barth is a business psychologist and holds an MBA. She has worked as an innovation and product manager in industry for many years. **Julian Meyer-Arnek** has a doctorate in physics and is an atmospheric researcher at the German Remote Sensing Data Center (DFD), where he works in areas including UV observation and forecast (UV-Check). They founded ajuma in June 2019. They are also partners outside their work and have a daughter who inspired the idea for UV-Bodyguard.

How did you come up with the idea for UV-Bodyguard?
Barth: I have very sensitive skin and have often suffered from sunburn. When our daughter was born three years ago, we became particularly concerned about the dangers of ultraviolet (UV) radiation and particularly its effect on children. Young children are particularly at risk if they are exposed to sunlight for too long. Without solar protection, they can only stay in bright sunlight on the beach at midday for 10 minutes. Even with sunscreen the time that they should be spending in the sun is very limited. We thought it was important to protect our daughter against too much UV radiation, no matter what the situation.

Meyer-Arnek: I have been working on the UV-Check project of the Association of German Dermatologists since I joined DLR in 2004, so I have been heavily involved in UV research. As UV is highly dependent on local conditions, it makes sense to measure radiation directly on the body itself. The type of UV sensor that we had in mind did not yet exist, so we decided to develop UV-Bodyguard and then start our own company.

How does UV-Bodyguard work?
Barth: UV-Bodyguard is a wearable device equipped with special UV-measurement technology. The user can connect it to a smartphone app via Bluetooth, select the appropriate profile for their skin type and the protection factor of the sunscreen that they are using, and then initiate the measurement process. The built-in sensor continuously monitors local UV radiation in real time and transmits these data to the smartphone. Local UV measurement is important because numerous factors such as the ground surface – snow, sand or water – and cloud cover, the time of day or year, and altitude all have an influence on the intensity of the UV that actually reaches the user's body. The app shows the length of time that a person can stay out in the sun and warns the user when their skin is at 50 percent of its protection capacity. This is the recommended dose for vitamin D synthesis. Once 95 percent has been reached, the device issues a second warning ahead of the body being exposed to too much sunlight and there is a risk of sunburn. An important point with regard to privacy is that all of the data are stored locally on the smartphone, not in the cloud.

"Knowledge is the best sunscreen."

Meyer-Arnek: The app also provides a UV forecast for the user's location, allowing them to plan their outdoor activities accordingly. The system combines satellite data from the European Union Copernicus Programme with UV data from UV-Bodyguard. This is a very important advantage of our innovation, as it measures the actual radiation experienced by the wearer while also using information from Earth observation satellites to generate an accurate radiation forecast. Knowledge is the best sunscreen.

You were awarded the DLR Copernicus Masters prize at the end of 2019. What does that mean for you?
Meyer-Arnek: We were delighted to have been selected by an independent jury of experts as the best application idea in the field of Earth observation. It is a prestigious prize for us and an important confirmation that we are not the only ones who believe in this approach. It was deemed scientifically sound by the jury as well. It has been one of our greatest successes so far and has given us a real lift, especially during project phases when things have not gone quite so smoothly.

What has happened since then, and where do you plan to take things in future?
Barth: At first we thought that our UV-Bodyguard would be of more interest to families with children, so we designed the casing in the shape of a turtle. During our Kickstarter crowdfunding campaign, we received many enquiries from adults, athletes and people who spend a lot of time outdoors, so we are now also offering a watch-style design for adults. We are currently in the final stages of producing the casing, so UV-Bodyguard should be on the market in the summer. In addition, we are planning more product lines and working on other exciting Sun-related projects.

Verena Müller is a coordinator at DLR Technology Marketing.

© ajuma

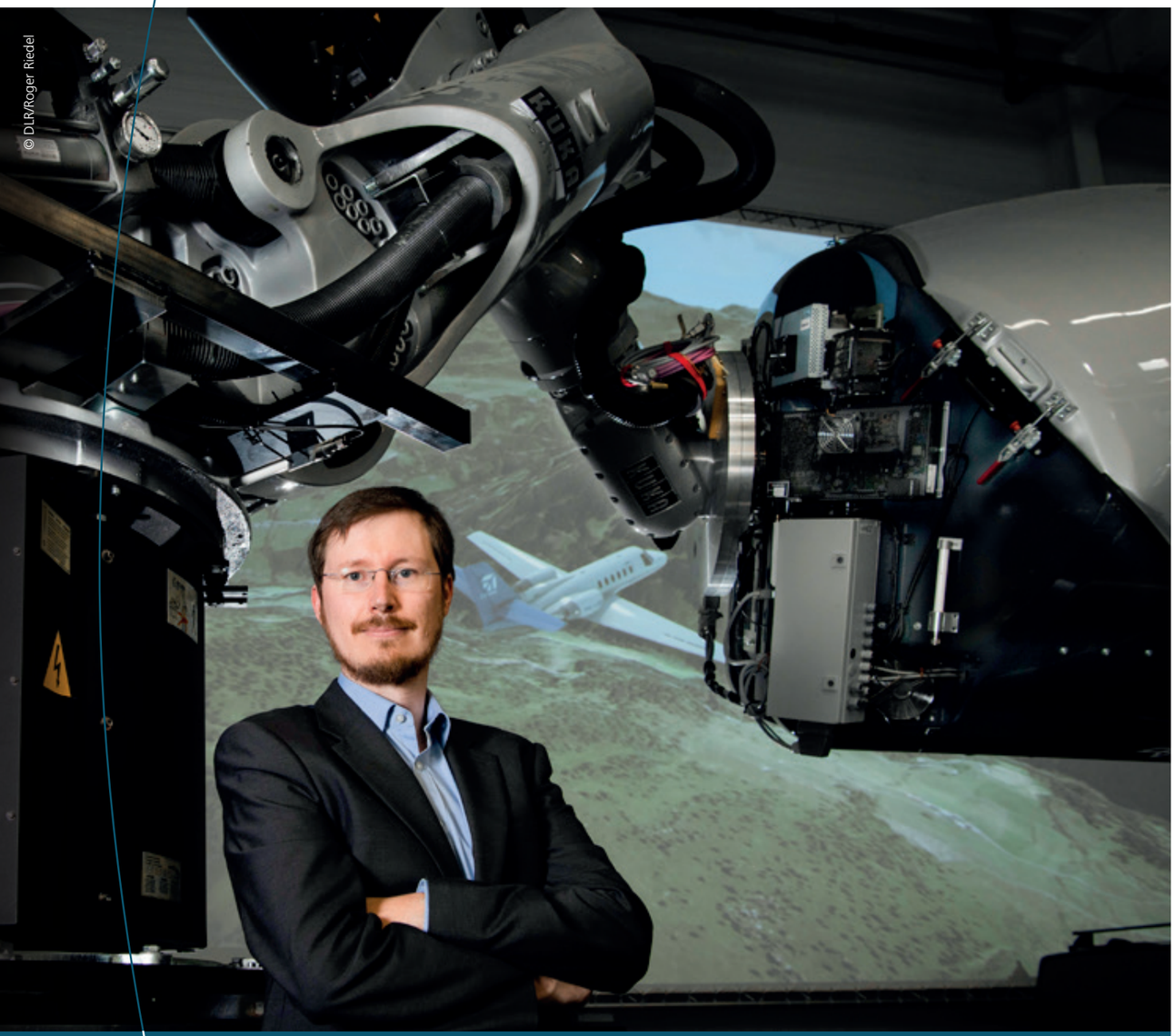
The sensor measures the incident solar radiation and the matching app shows the remaining time until a healthy dose of sunlight is reached. UV-Bodyguard can be attached to clothing with a clip or Velcro strap.

AJUMA GMBH

ajuma stands for Annette, Julian and Maya. The company, a spin-off from DLR in Oberpfaffenhofen, was founded by Annette Barth and Julian Meyer-Arnek in 2019 on the basis of long-term research into UV radiation conducted at DLR. The couple has developed a wearable device that comes in various designs. It indicates what a healthy dose of sunlight is and informs the user of the time that remains before it is reached. It also gives a timely warning of the risk of sunburn. UV-Bodyguard is particularly suitable for children but is also helpful for people who spend a lot of time outdoors. ajuma has been based at the ESA Business Incubation Centre since November 2019. This is a start-up incubator at the Application Center Oberpfaffenhofen (Anwendungszentrum Oberpfaffenhofen; AZO), which receives funding from the European Space Agency (ESA).

More information: **uv-bodyguard.de**

IN THE LABORATORY OF A THOUSAND POSSIBILITIES


© DLR/Roger Riedel

Robots come to life in the computers at DLR's Systems and Control Innovation Lab

By Julia Heil

Collaborative research over 750 square metres. Aeronautics, space and transport meet digitalisation in the hall of the DLR Institute of System Dynamics and Control in Oberpfaffenhofen.

Tobias Bellmann stands in the 12-metre-high hall and cranes his neck. "Pure programming was never really my thing. I like it when things actually move." Right beside him, a three-metre-long robotic arm rotates like a metallic stem, with a cockpit gondola hanging like a flower at its end. This is the 'Robotic Motion Simulator' for driving and flight simulations. A little further along is DLR's RObоMObil, a futuristic white-and-blue electric vehicle that can drive autonomously, both diagonally and sideways. Next to it is a glass box containing an aircraft control surface awaiting its next test. A few metres ahead, behind a plexiglass screen, an orange-and-black industrial robot lifts its short gripping arm into the air. Designed for experimental purposes, it can carry a load of 200 kilograms. "This is essentially a showcase for DLR – we work in the fields of aeronautics, space and transport. However, all that can be seen here are the outer workings of the technical systems; the really exciting stuff is hidden away inside the control cabinets."

Tobias Bellmann, who holds a doctorate degree in electrical engineering, is Head of the Systems and Control Innovation Lab (SCIL) and is in charge of the laboratory hall that houses this extraordinary world of mechatronic systems. He and his team are interested in the software that brings technology to life. They develop models and simulations to control and operate these types of complex systems. "If you simulate a robot exactly and know precisely how it works, then you can control it more effectively," says Bellmann. To illustrate this, he plays a video featuring a manufacturing robot. The arm moves on a pre-programmed trajectory, swinging back and forth a bit. The researchers created a virtual model of the robot that detects any vibrations and automatically adjusts and balances the motor outputs. As soon as the new software is installed on the robot, the arm travels evenly along the trajectory, without jerking as it moves. As its name suggests, the DLR Institute of System Dynamics and Control has always specialised in precision control systems. To that end, the Institute works with entities such as Kuka AG, which manufactured the industrial robots in the laboratory hall. Numerous algorithms that are used by today's Kuka robots were developed at DLR.

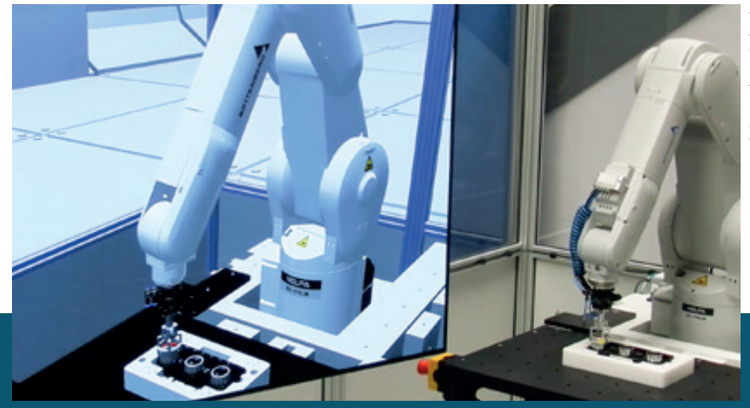
Bringing ideas to life

The researchers' desire to make their knowledge available to small and medium-sized enterprises (SMEs) has grown over time. "I had just finished my doctoral thesis and the relocation to this hall had just taken place when the call for tender from the Helmholtz Association of German Research Centres to set up the Science Innovation Labs was announced," says the project leader. "This was the perfect opportunity for us to bring impetus to the new laboratory." The Helmholtz Innovation Labs were devised with the aim of bringing partners from science and industry together to investigate new technologies and ideas. In 2016, the SCIL was selected for the first group of innovation laboratories, alongside six other labs from various other research institutions. Another nine laboratories joined in 2019. The laboratories have engaged in regular exchanges since they were first founded. "We are all pioneers and encounter the same kinds of issues," says Bellmann. These tend to be of an organisational nature. Many of the laboratories have expanded thanks to the Helmholtz funding, and there is a great deal of enthusiasm. Although the funding will come to an end in October 2021, this does not worry Bellmann. The SCIL is now largely able to support itself through third-party projects and funding, and its network is continuously growing. The most challenging matter is partner acquisition. Once companies have decided to work with DLR, they rarely confine themselves to a single contract. In order to best support such companies, SCIL assists with the selection of suitable funding programmes. Following the initial contact, the company sends the researchers their product information. The researchers then develop a computer model, bringing the product into the virtual world. To give some examples, this might


© Futurium

Architecture in the wind

This dynamic, 15-metre-tall artwork stands in front of the Futurium in Berlin. The SCIL calculated the load that would be borne by the individual elements in windy weather. Before the artwork was constructed, DLR researchers used a computer model to determine its feasibility. "We didn't want the top discs of the artwork suddenly ending up in the Chancellor's office," jokes Bellmann.



© Battenberg Robotic

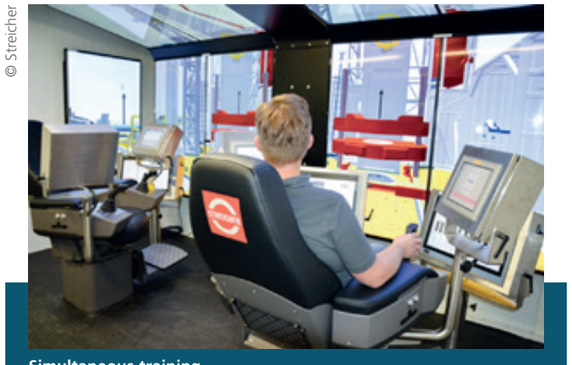
Push button to test

This robot pushes every button on an automotive control panel. It measures whether they have the correct pressure point and thus checks whether all the controls, even those from different manufacturers, feel the same throughout the entire production period of a vehicle model. The SCIL, together with the company Battenberg Robotic, developed a digital prototype of this test robot, which behaves exactly like its real counterpart. The advantage – with the digital twin, the robot's programming can be tested on the computer without having to build a real prototype beforehand. For use, the program is then uploaded to the real robot, ideally, requiring almost no changes.

"The digital twin of our measurement robot, developed in cooperation with DLR, enables fast programming and safe trialling of test sequences. We can then run the processes on the real test bench with almost no changes, which is significantly less time-consuming than manual set-ups."

Jan Thiede, Battenberg Robotic

© Streicher



Simultaneous training

The real-life version of this extraordinary training room is on the Heimdal drilling platform in the North Sea. Every training session at the original facility costs approximately 10,000 euro per person per hour. The SCIL team therefore teamed up with DrillTec to develop this training simulator. It shows every motor, sensor and drive component. The simulator is linked to the original system controls and uses the same input devices. The driller that operates the drill pipe sits on the right. To his left is the assistant driller, who transfers the new pipe sections from the storage area so that the drill pipe can be assembled.

come in the form of digital twins for systems, enhanced control technology, virtual commissioning, or optimised simulator technology. This approach saves time and resources – a physical prototype does not have to be constructed for every idea. The simulations will often provide an advance indication of whether or not a project is likely to succeed. "We use the very latest methods to connect a wide variety of simulations with one another. These can include anything from structural and propulsion simulations to aerodynamic and fluid dynamic computations, and all the way through to thermal simulation," says Bellmann.

A crane serves as a model

The concept of digital twins and virtual products may seem very abstract. That is why there is a two-metre-tall, yellow crane next to the foyer. The researchers have recreated the real construction crane digitally – doing so required 76,000 differential equations and took three months. It responds in the same way as its physical equivalent on a construction site, but can be conveniently controlled using a screen. It is displayed using 3D visualisation software developed by computer scientists at the Institute. The example of a crane was chosen because DLR does not conduct specific research in this field, so use of shared data was not a concern. In workshops, the SCIL team shows how the digital crane is assembled and how such a simulation works. "A representative from a large crane manufacturer attended one of the seminars. He confirmed that our training simulation is highly realistic." Bellmann smiles and straightens his narrow-framed glasses. The equations and models that the researchers developed for the crane are collected and stored in model libraries, just like the models used for other projects. These can then be used for other projects. The usage rights for these libraries are renegotiated for each collaboration. The information that may or may not be used for research is clearly defined. This is a win-win situation for the DLR researchers, as every model and contribution from a collaborative partner broadens their knowledge and allows them to explore new subject areas. In return, the companies benefit from the latest scientific expertise in digital model development and receive support in setting up their own simulation departments.

Back to the future

Returning to the laboratory hall, Bellmann casts an eye over the technical equipment. "There really is something here for every possible requirement, whether you want to test industrial applications or assistance systems, try out flight controllers or wing surfaces, or conduct

Centrifugal force test for safety

For fairground rides, the researchers simulated the forces that occur while they are in motion. During the rollovers, the system experiences increased mechanical excitation and starts to oscillate. The simulation showed that this load decreases when the seats are mounted closer to the axis of rotation. This also saves material. In addition, the researchers supported the manufacturer in developing software that determines the load condition of the ride by means of a measurement run and adjusts the trajectory so that it remains the same even if fewer or more people are sitting in the gondola.

driving simulations." Depending on the application, the researchers can connect the hardware in the laboratory hall to virtual vehicles, aircraft or spacecraft in a very short period of time. In recent years, the SCIL team has simulated a drilling platform, a measuring robot and a fairground ride, to name but a few examples. The SCIL researchers learn something new with every project. While previously the focus was on individual robots, they are now increasingly devoting their attention to overall systems. Bellman is considering a number of approaches for the future. "We are currently seeing the impact from global events such as the Coronavirus pandemic." There is a demand for better simulations

"Thanks to our collaboration with DLR, we were able to build up expertise in the field of simulation and digital twinning quickly and effectively. By using virtual prototypes, we were able to save both time and costs in our development processes."

Rupert Köckeis, Streicher Gruppe

in many sectors. A higher degree of automation can heighten the appeal of production locations in Germany and make Europe more independent.

With this in mind, the SCIL is also supporting the DLR cross-sectoral research project 'Factory of the Future'. This project involves several DLR institutes working on robot-assisted production processes within the context of Industry 4.0. In addition, Bellmann is also examining new developments and ideas for the Innovation Laboratory. "Every factory I visit gives me new ideas about how concepts such as 'digital twins' could be further developed. The only real problem I am facing at the moment is that there are not enough hours in the day."

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

THE INNOVATION LABS – 2016 GROUP

KIT Innovation HUB at the Karlsruhe Institute of Technology – technologies, services, and products for innovative infrastructure components and their construction

SCIL (Systems and Control Innovation Lab) at the DLR site in Oberpfaffenhofen – provides SMEs with fast access to digital engineering and support in building simulation competence

MicroTCA Technology Lab at the German Electron Synchrotron (DESY) – versatile and precise communications electronics, for example for industrial automation or particle accelerators

MIL (Miro Innovation Lab) at DLR in Oberpfaffenhofen – research infrastructure and expertise in the field of medical robotics

MiBioLab (Microbial Bioprocess Lab) at the Jülich Research Centre (Forschungszentrum Jülich) – develops production processes based on microorganisms

MDCell (Max-Delbrück Center Cell Engineering Lab) at the Max Delbrück Center for Molecular Medicine – new gene therapy technologies

HySPRINT (Hybrid Silicon Perovskite Research, Integration & Novel Technologies) at the Helmholtz Center for Materials and Energy in Berlin (HZB) – new materials and process technologies for solar energy conversion or sensor systems

THE INNOVATION LABS – 2019 GROUP

BaoBab (Brain antibody-omics and B-cell Lab) at the German Center for Neurodegenerative Diseases (DZNE) – new methods for the study of autoantibodies that cause brain diseases

ZAIT (Centre for Aerogels in Industry and Technology) at DLR in Cologne – research into aerogels and aerogel composites

OPTSAL (Optical Technologies for Situational Awareness) at DLR in Berlin – optical technologies from aerospace for security applications

SuFIDA (Disruptive Digital Diagnostics) at the Jülich Research Centre (Forschungszentrum Jülich) – counting marker molecules for detecting diseases that are difficult to diagnose

3D-US Lab (3D Underground Seismic Laboratory), at the German Research Centre for Geosciences (GFZ) – tunnel and borehole seismology for the 3D exploration of underground structures

FERN.Lab (Remote Sensing for Sustainable Use of Resources) at GFZ – application-oriented, transdisciplinary methods to make remote sensing data usable

Ultratherm at the Helmholtz Centre in Dresden-Rossendorf (HZDR) – dedicated to flash lamp and laser healing, in which materials are exposed to high temperatures for a very short time

CLEWATEC (CLean WAter TEChnology Lab) at HZDR – technologies for flexible and resource-saving wastewater treatment

FlexiSens at HZDR – novel magnetic field sensors in miniature format on thin, flexible substrates

© DLR

ELECTRIC MOBILITY IN SWAHILI

A DLR project investigates the potential of electric motorcycle taxis in Tanzania

By Denise Nüssle

Motorcycle taxis are widely used in developing countries. DLR transport and energy researchers investigated whether these universal vehicles, often three-wheelers, could be powered by electricity. In doing so, they embarked upon a rather unique scientific expedition.

Dar es Salaam roars. Lying on the shores of the Indian Ocean and home to over five million inhabitants, the largest city in Tanzania rumbles and roars in the humid tropical heat. A small group of DLR researchers is hard at work amidst the hustle and bustle of traffic, which is a law unto itself. For most tourists, Dar es Salaam is merely a stopover on the way to Mount Kilimanjaro or the Serengeti National Park – the DLR team's itinerary, however, is quite different. The researchers want to find out whether small motorcycle taxis, over a million of which whizz along the country's roads and dirt tracks, could be powered electrically. They consider this to be a potential solution for making the rapidly increasing demand for mobility and transport more sustainable.

Motorcycle taxis play a major role in the city's public transport. These two- and three-wheeled vehicles represent a flexible and inexpensive way for the majority of the population to reach public bus routes or quickly travel to areas that lack public transport. But such vehicles make a substantial contribution towards noise and air pollution. At the same time, the mobility business is an important part of the economy in Africa's rapidly growing major cities and is often the sole means of livelihood for the numerous small and micro enterprises. The self-employed drivers generally rent the vehicle. Their entire families, averaging five people, are dependent on the subsequent earnings.

At the heart of the action – use and acceptance of electric motorcycle taxis

First, the DLR team had to become acquainted with the local market and people. "Sticking to your desk won't get you very far if you are looking to develop a concept that really works and is adopted by the locals. Over the course of two stays, we carefully observed the situation in Dar es Salaam, examined the condition of the infrastructure and, most importantly, talked to the motorcycle taxi drivers," explains Daniel Ehebrecht from the DLR Institute of Transport Research in Berlin. He brought his valuable experience and connections from previous projects in Tanzania to the project. Discussions with local authorities, research institutions and companies from the energy and recycling sectors, as well as vehicle traders and the managers and owners of motorcycle taxi firms were important elements of the on-site visits.

During these group discussions, the reseachers and motorcycle taxi drivers exchanged views on potential benefits and challenges, and aired any concerns about electrification. Here, the emphasis was on three-wheeled vehicles, known as bajaj, which can transport several people at once. A local assistant helped the DLR team with the necessary arrangements and connections, and translated the information required into Swahili. By conducting a survey of more than 100 drivers, the scientists were able to acquire information about the vehicles, their maintenance and operating costs, the ownership structure, the number of daily journeys and the working hours. Over the same period, the research team equipped a total of 70 vehicles at four motorcycle taxi ranks with GPS devices for one week each and prepared driver logbooks. This made it possible to track and record the various journeys, distances, speeds and areas covered. In addition, the drivers also collected information on the number of passengers, luggage and fuel costs. DLR's know-how and technology in this area originates from its MovingLab. Here, a survey and analysis method was established that makes it possible to draw conclusions about mobility behaviour that can be used to support traffic modelling and forecasting (article in DLRmagazine 162).


© DLR

Driver of a two-wheeled motorcycle taxi in Dar es Salaam: There are over one million of these vehicles in the country.


© DLR

Peter Makundi, field assistant, and Mirko Goletz, a resercher at the Institute of Transport Research, discuss the results of the GPS measurements.

"The drivers have a close-knit network and were generally very open to electrically powered motorcycle taxis. They considered less noise and air pollution to be particular benefits of electrification, but also identified the improved acceleration, greater comfort as a result of reduced vibrations and gear changes, and potentially higher income made possible by modern vehicles," says Ehebrecht, summing up the team's findings. However, it is absolutely necessary that the battery charging is as reliable as possible, and that the vehicle has sufficient range and a maximum speed of around 80 kilometres per hour. They would also like to maintain the purchase and maintenance costs of such vehicles roughly the same as those of existing combustion vehicles.

Electric drive concept – what is technically feasible and reasonable?

With these user requirements in mind and the extensive data from the survey and the on-board GPS tracking device, Christian Wachter and department head Frank Rinderknecht of the DLR Institute of Vehicle Concepts in Stuttgart, set about designing an appropriate electric powertrain. Their main focus was on the needs of the users and the specific application scenario.

MOBILITY IN AFRICA – AN ELECTRIC FUTURE?

Whether in Rwanda, Kenya or Tanzania, the seeds of electric mobility have already been sown in Africa, particularly in its cities. In 2018, the VW Group opened a plant in Kigali, the capital of Rwanda. Electric vehicles should begin rolling off the assembly line there in the not-too-distant future. There is also an array of ideas and initiatives from small African start-ups, global companies, international development programmes and non-governmental organisations for electrically powered cars, motorcycles, trucks and buses, and app-based mobility services. Sustainability is becoming an increasingly important factor in future development and is also gaining a foothold in policy. Electromobility has the potential to become a key technology for social progress in Africa. The potential is vast, but so are the challenges. With widespread access to sunshine, water and wind, the continent has lots of renewable resources for generating power. Often, however, it lacks storage facilities and the necessary infrastructure. Hundreds of millions of people are still suffering from power shortages. Large areas, especially in the Sub-Saharan countries, are not connected to a power grid. As the population grows, so does the need for mobility and transport opportunities. Young people are particularly receptive to new technologies, with between 800 and 900 million Africans currently using smartphones.

Calculating the energy consumption of an electric vehicle and thus determining its range or the necessary battery capacity requires a driving cycle that represents the operating conditions as realistically as possible. "Using the data from over 7000 journeys, we have developed a driving cycle that replicates a standard motorcycle taxi trip in Dar es Salaam," explains Wachter. The system also maps different route profiles and road conditions. "This allowed us to perform simulations to calculate the energy consumption according to the number of passengers and luggage weight, and thus determine the necessary battery capacity." The battery should be as robust, inexpensive and safe as possible. Since the drivers have to do a lot of repairs themselves on the spot, this calls for a low-voltage battery rather than one with a higher voltage.

Electric motorcycle taxis that are already on the market – mostly from Indian or Chinese manufacturers – mainly use lead-acid batteries. These can be found all over and are relatively easy to recycle. The visiting DLR team learned about the recycling options used by two local companies. The drawback of such batteries is that they are very heavy and provide a short range compared to lithium-ion batteries. This is why the researchers favour robust, low-cost lithium-ion technologies, which are expected to become more widely available in the coming years. However, it is not yet clear how these will be recycled. "Which technology is used will essentially depend on the constraints on local and global development in the areas of society and mobility. We are always mindful of this as we go about our work," says Rinderknecht.

Another important consideration is that electric motorcycle taxis should be manufactured in Tanzania wherever possible. Most manufacturers of conventional models import their vehicles in components. They are then easy to assemble by hand with simple tools. "This represents a challenge, but also makes us think about how, given the local situation, high-tech can be used specifically where it makes sense and works," says Rinderknecht, describing the challenging task.

Snapshots of Dar es Salaam. Places like the one on the lower image are well suited for the development of an infrastructure for charging electric vehicles.

© DLR

Motorcycle taxi driver from the MAPIMAMATA drivers' association, DLR researcher Daniel Ehebrecht (third from left) and field assistant Peter Makundi (first from right), who also acted as an interpreter, during a meeting. The logging devices of the DLRMovingLab, which were used during the field phase, can be seen on the table.

Making charging possible: where will the electricity come from?

Only about a third of the Tanzanian population is connected to the power grid. The supply is generally fairly good in large cities, but the overall network stability is highly variable. "Being able to charge motorcycle taxis securely and reliably is key to the success of such a concept," says Meike Kühnel of the DLR Institute of Networked Energy Systems. "For this reason, we have been looking particularly closely at Tanzania's electricity system. We have used existing datasets to determine locations at which taxi drivers wait for customers, take a break, or park their vehicles overnight. We are currently developing a network of charging points based on these data." Knowing what things are like on site was also hugely beneficial. Without it, the scientists could have overlooked important details, such as the fact that, for regulatorly reasons, charging points are only permitted on private premises. As two thirds of drivers keep their motorcycle taxis in guarded car parks overnight, it makes sense to charge batteries then, with supplementary charging available during the day at central locations that are frequently visited by drivers.

The exchange with the motorcycle taxi drivers was a particularly exciting and interesting experience for the team. "We were greeted warmly and openly by the drivers. Often, they gave us a very personal insight into their day-to-day lives," recalls Ehebrecht. Kühnel and Wachter add the sentiment that, "Everday life here may be completely different to ours, but it functions well, contrary to some prejudices or concerns." The project is close to the hearts of all of those involved, partly because of their shared experiences and the close collaboration of three DLR institutes from the fields of transport and energy, but also because, as Rinderknecht explains, "much of the mobility sector is in its earliest stages in developing countries like Tanzania. New and sustainable ideas and technology can have a massive impact here." The team and the project are set to continue as soon as possible, with funding applications for a pilot test with the first electric vehicles in Dar es Salaam already underway.

Denise Nüssle is an editor at DLR's Media Relations Department.

PARTICIPATING INSTITUTES

DLR Institute of Transport Research:
The Berlin-based institute is currently working across several disciplines to investigate developments in passenger and commercial transport. The aim is to achieve an efficient, modern and forward-looking transport system that will prove sustainable for people and the environment. For this purpose, the scientists are examining the mobility behaviour of individuals and companies and incorporating them into models that show their various impacts and prospects. In doing so, their focus is on digitalisation and automation.

DLR Institute of Vehicle Concepts:
Whether for road or rail, innovative vehicle concepts and the technology they require are at the heart of the research being conducted by this DLR institute in Stuttgart. The topics investigated include lightweight and hybrid construction methods, alternative propulsion systems, innovative energy converters and storage systems for cars, as well as the analysis and evaluation of technical systems.

DLR Institute of Networked Energy Systems:
Researchers at the DLR site in Oldenburg are developing technology and concepts for future energy supply based on renewable resources. They are studying how the power, heat and transport sectors can be intelligently and efficiently connected within the energy system of tomorrow. The scientists hope to ensure a stable, efficient energy system despite the often weather-dependent and decentralised generation of renewable electricity and heat.

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FULL SPEED AHEAD FOR THE MOBILITY TRANSITION

On the road to autonomous driving

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 third in the series, addresses the future of mobility.

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Peter Wüstnienhaus
is Head of the Energy and Mobility Department at the DLR Project Management Agency (DLR-PT). He is particularly interested in projects that relate to the energy and mobility transitions. Before joining DLR-PT, he was responsible for IT projects as a service provider in the automotive industry.

Imagine electronically operated shuttle services that drive autonomously through the inner city, transporting people and delivering medical supplies as required – all monitored from a control station that only intervenes if the vehicle cannot figure out where to go next. Does that sound like science fiction? Far from it, says Peter Wüstnienhaus, Head of the Energy and Mobility Department at the DLR Project Management Agency. He is confident that the mobility of the future will be here sooner than we think.

How independent are today's cars?

: The cars that we see on the road today are partially automated and networked. This means that such vehicles are capable, for example, of keeping to their lane or observing the speed limit. One example that will probably be familiar to everyone is what is referred to as parking space detection. Whereas in the past it was only possible to count how often car park barriers opened and closed, today sensors at junctions and on lampposts can reliably detect the actual number of free parking spaces. Communication between vehicles and with the existing infrastructure generates huge quantities of data. It is therefore essential to establish who is responsible for these data, and what will happen if a vehicle is suddenly no longer being supplied with data during its journey.

How and where do you test something like this?

: One possibility is a roughly three-kilometre test route in Düsseldorf. Here, an entire stretch of road is equipped with upgraded sensors, which transmit information to a vehicle that allows it to drive independently, without a person in control. It is clear from such work that if the information ceases to be supplied from the surrounding environment, the car must be able to come to a halt, at the very least. The initiative is a cooperative project launched by the state capital, Düsseldorf. It is currently funded and supported by the German Federal Ministry of Transport and Digital Infrastructure (BMVI). Questions relating to artificial intelligence and automation will continue to play an important role in research over the coming years. As a project management agency, our task is to look four to five years into the future when designing the appropriate funding programmes, and also when assessing submitted ideas and arranging the subsequent funding of projects.

What remains to be done to realise the often-cited mobility transition?

: Another aspect of the project, which we are pursuing through a funding initiative from the German Federal Ministry for Economic Affairs and Energy (BMWi), is traffic reduction. The solution cannot be that everyone owns an autonomous vehicle 20 years from now. Imagine your vehicle driving you into town and having to go back home on its own because it cannot find a parking space. This would lead to twice as much traffic and is far from the desired mobility transition, regardless of what propulsion method the cars use. The fact is that vehicles will have to be used by several people.

How can that be achieved?

: In cities, people only start leaving their cars at home when the shortage of parking spaces becomes too great or fuel prices are very high. Therefore, switching to another type of transport must be as convenient as possible. What we need is an app that combines the different modes of transport while allowing users to directly book

> "The future of mobility will arrive sooner than you think!"

their entire journey. I am confident that everyone would be happy to roll their transport needs into one monthly subscription of, perhaps, 100 euro. That way, they are paying for a service that covers the use of bus, rail, bicycles and e-scooters. Car-sharing or taxi and shuttle services would be an extra 50 euro. That is the vision. And we are not far from that point. I imagine it will be another six or seven years.

In the countryside, people often rely on their own car to get from A to B. Are there any specific solutions for such areas?

: In these areas, what is referred to as the 'last mile' is an important factor – the journey from the station to the person's front door. We will have made significant progress when we are able to cover this journey with shuttles that can pick us up from home or the train station on demand. If you then consider that these shuttles will not require a driver, but will instead be fully automated, electrically powered, and monitored by a control centre, the whole thing may become more economically viable. We are already overseeing such research projects. The future of mobility began a long time ago.

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

The next article in this series will examine the role that education plays in ensuring that we continue to act sustainably in the future.

A STUNNING GEM

For energy, but against power plants? An enlightening visit to Berlin's Energy Museum

By Peter Zarth

© EMB – Harald Janz

In the past, the world's largest battery storage facility – today, a vibrant museum in Berlin-Lankwitz

This museum makes virtue out of adversity. It is largely unknown, especially among those who consider the Mitte area to be the entire extent of Berlin. In comparative terms, it is out in the sticks, in Lankwitz. To make matters worse, it is only open by prior appointment. Its exhibition guides are veritable masters of their art. During the visit, we learn about a different kind of energy transition, get to know Berlin as an 'electropolis' and, above all, discover what happens behind the sockets. We also cross paths with young visitors who cannot get enough of this large former battery storage facility. The Berlin Energy Museum is absolutely stunning, not least in terms of its architecture.

Showcasing the Berlin electropolis

Let us start simply, by looking at how the museum, a marvellous educational institution, presents itself: "The aim of the museum is to show how energy supply technologies developed, and illustrate their links to Berlin's 'electropolis'. It is particularly important to explain energy supply technology to young people. The Energy Museum is divided into themed sections: Power Plant Technology; Grid Technology/Operation; New Technology; Measurement Technology; Protective Technology; Communications Technology; Workplace Safety; Applications Engineering; and the Archive. Evidently, there is a heavy emphasis on electrical engineering and technology. More than 5000 exhibits are on display, their stories entwined and charged with energy.

Stories from the past

The story of the electrotechnical revolution is just as exciting as that of its industrial counterpart: both transformed life as people knew it. What is more, it is inextricably interwoven with the history of Berlin. Werner von Siemens paved the way when he discovered the dynamoelectric principle in 1866. The establishment of the first German electrotechnical association in 1879 provided a boost for the scientific integration of electrotechnology and the development of applications engineering, allowing it to tap into potential markets. As such, Berlin became a global forerunner in the field, evolving into an electropolis. During World War II and the subsequent Berlin Blockade, the energy supply could only be maintained to a limited extent. In 1952 all connections between the West Berlin grid and the overarching networks were severed for political reasons, and West Berlin became an 'electricity island'. "Discussions between the GDR and the FRG were kept to a minimum and were distinctly frosty, limited to the factual and technical essentials," says Horst D. Kreye, Chairman of the museum's Coordinating Committee.

Berlin Diagonale and the world's largest battery storage facility

The island-like status of West Berlin inspired some creative and complex solutions. As the political situation made it impossible to supply the city from a peripheral high-voltage overhead power line, a new approach was required. This led to the creation of the world's first large 380-kilovolt cable connection in 1978, which was further developed after the 'electrical reunification' – a different kind of energy transition – using the latest XLPE cable technology to create the Berlin Diagonale, or diagonal power link. The newfound restriction of spontaneous power station outages led to the construction of the world's largest battery storage system at the Steglitz thermal power station, the premises of which are now home to the Berlin Energy Museum.

A living museum

The development of Berlin's electropolis is also outlined in the equally massive Lankwitz complex. The visitor is granted an insight into important innovations since the discovery of the dynamoelectric principle. Crucial to this phenomenon was the cooperation between electrotechnical industry, energy suppliers, energy users and science. Hans-Heinrich Müller, Deputy Chairman of the Committee, explains high voltage systems to us, tells us why we talk about 'an electrical smell' (it is actually the insulating material), delights in the fact that 'physics is unchangeable' and covers everything up to cogeneration. Before starting a tour, he tells the group what they can expect: "We want to be a living museum where people can keep on discovering new things," he says. Today, the problem is that "everyone wants energy, but not everyone wants power plants."

There are three guides for a maximum of 30 guests. They currently work, or have previously worked, in the field of electrical engineering and now volunteer their time. "We want to talk to every visitor at least once and give them the chance to ask questions," says Ferdinand Menke-Zumbrägel, a former teacher. He sometimes reconstructs basic versions of the exhibits for demonstration purposes. This is a hands-on, interactive museum. Here, FAQ means frequently answered questions.

© EMB – Harald Janz

For decades, all major cable manufacturers were based in Berlin. The Energy Museum showcases a variety of cable models and fittings of all voltage levels. Almost all of these cables were used in Berlin.

Powering the modern world

We often take things that are commonplace within our world for granted. Yet these are often the result of generations of laborious work. In Lankwitz, this sentiment is conveyed to young visitors in particular. "Young people value technology," says Menke-Zumbrägel, "but not all of them are inclined to make a real effort or put up with any sort of struggle in dealing with it." Today, electrotechnology shapes our lives in an almost imperceptible way. At the Berlin Energy Museum, representatives of the generation that came of age in the 1960s pass on their knowledge about energy and electrotechnology in a fascinating way. It is worth noting that Tuesday is dedicated to (team)work. The volunteers potter about and there is a lively hum about the place.

According to Horst D. Kreye, "the work of the volunteers means that the Berlin Energy Museum is constantly in a dynamic state of flux and thus keeps everything fresh and exciting." The museum makes no fuss even about its greatest advantage: the building itself (architect: Hans Heinrich Müller). After all, we are not in a museum building, but exactly where 'electricity came from'. You can smell, taste, feel and see that everywhere, right up to the offices. It might be out in the sticks, but it packs quite a punch.

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

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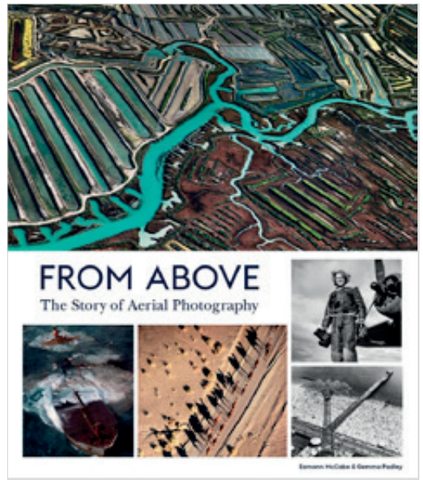
Admission: free of charge
Visits by reservation only

energie-museum.de

REVIEWS



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INVENTIVENESS PROVIDES NEW PERSPECTIVES AND INSIGHTS

The desire to see what is happening down on Earth from a bird's eye view is as old as humankind. The illustrated book **From Above: The Story of Aerial Photography** by Eamonn McCabe, published by Laurence King, fulfils this wish. In the 21st century, when it is easy to fly up to high altitudes on an aircraft, even experienced travellers cannot resist the allure of looking out of the window. The chance of catching a glimpse of one's own house, the bustling city, or the landscape in all its forms never ceases to fascinate, not least because this snapshot from the air forges a more direct connection with our earthly environment than, for example, images acquired by a satellite.

It was precisely this fascination that made photographers take to the skies – or, at the very least, send their cameras up into the air, sometimes displaying impressive inventiveness while doing so. From 1846, unmanned kites were fitted with early photographic technology so that they could take pictures of the world below. A decade later, the Frenchman Nadar (a pseudonym) took the first aerial photograph from a tethered balloon. His images showed Paris and the Arc de Triomphe as they had never been seen before. Over time, all kinds of cameras were carried by mini airships and even birds, along with the aircraft, gliders and drones that are commonplace today. Constant efforts have been made to develop more areas of application for aerial photography, driven by the excitement of looking at Earth from above. After the devastating earthquake that laid waste to San Francisco in 1906, George R. Lawrence's panoramic images helped to assess the damage and coordinate rescue operations. During the wars in the years that followed, aerial views often gave one side a decisive tactical advantage, but also showed the incredible extent of the destruction.

Today, aerial images remain an indispensable tool for protecting against and coping with disasters. In addition, the serious changes wrought on the landscape by humans sometimes only become visible and understandable from the air. Images that tend towards the picturesque and artistic can deceive the viewer about the destruction and exploitation of nature that is actually occurring. Yet not all images have to reveal a deeper message on closer inspection; expansive, richly detailed panoramas and almost surreal perspectives invite one to simply enjoy and admire them. Like a carefully curated museum, this portfolio of 200 photographs not only holds a mirror up to the viewer and expresses a subtle critique of society, but also delights with a fascinating journey back into the history of aerial photography and the world it captured. From Above shows the creativity and adaptability of humankind, its unscrupulousness and greed, and at the same time its regard and appreciation for nature. In many places, it prompts us to change our way of looking at things and see how beautiful the world in which we live really is, and how much it deserves to be preserved.

Daniel Beckmann

TURNING HISTORY UPSIDE DOWN

The Soviet Union is the first nation to land on the Moon, while the US watches it happen on TV. The NASA astronaut corps, led by Neil Armstrong, look on as a Russian cosmonaut hoists the flag of the US's great rival on Earth's satellite. Yet their sense of defeat is short-lived, as the competition to conquer space reignites. The US drama **For All Mankind** is a clever and playful take on the 'What if …?' genre and presents an alternative history of the space race between the two superpowers.

After the initial shock, the US embarks upon the Apollo program, builds a lunar station and discovers water on the Moon. An all-female astronaut class adds weight to the story as the series takes an expansive look at the society and gender relations of the 1960s and 70s. Initially conceived as a publicity stunt by the US president, the female astronauts soon become more than equal counterparts to their male colleagues.

At the outset, good and evil seem to be pitted against each other in the competition between the two superpowers. Most of the action shows the US side and has the viewer rooting for the NASA heroes. But is US engagement in space really on behalf of all humanity, as the title of the series proclaims? The protagonists begin to have their doubts.

For All Mankind combines an original idea with exciting characters and plenty of action, all accompanied by a suitable soundtrack for truly cinematic entertainment. The first season, comprising ten episodes, is now available on Apple TV+. A second season has already been announced.

Denise Nüssle

HOW TO GROW A ROBOT

It's hard to imagine the future without considering the role artificial intelligence will play in it. **How to Grow A Robot – Developing Human-Friendly, Social AI**, by Mark Lee, provides a great overview of the history and current state of AI and robotics. Rather than focusing on the areas where they have excelled, the book discusses the failure of 'task-based' AI techniques so far to replicate general human intelligence and social interaction. The consequences of this are especially apparent in robotics, where AI-based robots are outclassing humans in many straightforward tasks, but where any attempt to replicate multiple human behaviours usually fails miserably. Lee offers a look into a new approach: developmental robotics. Within this paradigm, robots are taught like we teach humans. Behaviours and concepts are learned gradually as the robot develops its motor and sensory systems, paving the way for a greater understanding of the human experience by AI agents through embodiment in the real world.

Lee provides a sober, comprehensible and well-sourced overview of the state of robotics and artificial general intelligence, dispelling many of the common doom scenarios along the way, but without shying away from the words 'we don't know'. A must-read for anyone interested in these dynamic and rapidly advancing fields.

Ruben Walen

RECOMMENDED LINKS

RETRO CHIC
mustardchannel.com
Flying aircraft carriers, a daring Airbus take-off and jet-powered trains are just some of the many topics that make Mustard something to relish. In video retrospectives, historical images and elegant 3D models are used to present incredible flights of fancy and ultimately unrealised visions from the world of transport technology.

CLASSROOM AT HOME
esa.int/kids/en/home
Currently homeschooling or on vacation and looking for fun space activities? Then the ESA kids website is for you! In it you will find plenty to keep children entertained and educated, from videos on life in space or on distant exoplanets, to competitions and games that the whole family can enjoy from home.

A VAST CULTURAL COSMOS
artsandculture.google.com
Fancy an audience with Nefertiti or an online exhibition all about why zebras have stripes? No problem! The Google Arts & Culture app and website bring together numerous virtual tours of exhibitions at over 2000 museums and archives all over the world, including the Berlin Museum of Natural History, the German Maritime Museum and the Senckenberg Research Institute. But beware – once you have entered this cultural cosmos, you will find it very difficult to leave.

PERSEVERANCE AND INGENUITY
twitter.com/NASAPersevere
NASA's Perseverance rover and Ingenuity helicopter en route to Mars and ready to explore its surface. Follow them on twitter for updates on the latest mission to search for evidence of ancient life on Mars. The journey to the Red Planet began on 30 July 2020, with landing in Jezero crater scheduled for 18 February 2021. Rock samples collected by the rover will hopefully one day be brought back to Earth by future missions.

STATE OF THE CLIMATE
climate.copernicus.eu/european-state-of-the-climate
The European State of the Climate is a yearly report and assessment of the climate in the European region. Compiled by the Copernicus Climate Change Services, the 2019 report uses both satellite and in-situ measurements to examine how 2019 compared to previous years on aspects such as temperature, precipitation and conditions in the European Arctic.

GLIMPSES OF DLR
DLR.de/youtube
From astronauts on the ISS explaining the experiments they perform, to news about Solar System exploration missions and fascinating robotics and aerodynamics research – DLR's YouTube channel has it all.

Cover image

Hydrogen is easy to transport and relatively simple to store. And the all-rounder has a wide range of applications: It is the basis for alternative fuels as well as storage for surplus wind or solar energy. It is also used in transport or energy technology. The tanks shown here supply hydrogen to the gas turbine test rig at the DLR Institute of Propulsion Technology in Cologne. This is where the researchers are developing new, economical and powerful gas turbines.

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